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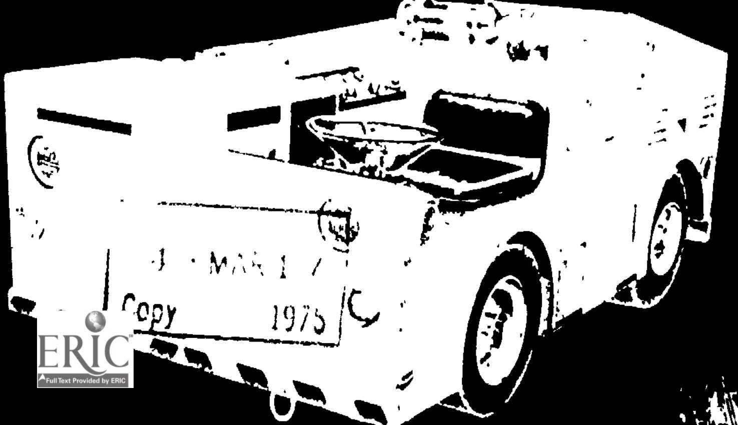
ABSTRACT

The training manual is designed as a self study text for use by Navy and Naval Reserve personnel preparing to meet the professional qualifications for advancement to Petty Officer Third Class and Petty Officer Second Class in the rating of Aviation Support Equipment (ASE) Technician E (Electrical). The first chapter provides information on the enlisted rating structure, the ASE rating, and requirements and procedures for advancement and includes references that will help in advancement and in the performance of ASE duties. Chapters 2 through 16 consist of materials on: maintenance forms and records; publications; elementary physics; tools and materials; drawings, diagrams, and identification markings; ground support equipment; servicing and maintenance; test equipment; automotive electrical systems; automotive accessories; power generating equipment; power generating systems; gas turbine engines; air conditioning systems; and corrosion prevention and control. The document is illustrated throughout with numerous photographs and diagrams. Two appendixes cover electrical formulas and electrical and electronic symbols and are followed by a subject index. (Author/BP)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PREFACE

This Rate Training Manual is one of a series of training manuals prepared for enlisted personnel of the Navy and Naval Reserve who are studying for advancement in the Aviation Support Equipment Technician rating. As indicated by the title, the manual is based on the professional qualifications for the rates ASE3 and ASE2 as set forth in the Manual of Qualifications for Advancement, NavPers 18068 (Series).

Combined with the necessary practical experience, the completion of this manual will greatly assist personnel in preparing for advancement to ASE3 and ASE2. This manual should also be valuable as a review source for the more senior rates.

This training manual was prepared by the Naval Education and Training Program Development Center, Pensacola, Florida, for the Chief of Naval Education and Training. Technical review of the manuscript was provided by personnel of the Aviation Support Equipment Technician School, NATTC, NAS Memphis, Millington, Tennessee, and the Naval Aviation Integrated Logistic Support Center, Patuxent River, Maryland. Technical assistance was also provided by the Naval Air Systems Command.

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THE UNITED STATES NAVY

GUARDIAN OF OUR COUNTRY

The United States Navy is responsible for maintaining control of the sea and is a ready force on watch at home and overseas, capable of strong action to preserve the peace or of instant offensive action to win in war.

It is upon the maintenance of this control that our country's glorious future depends, the United States Navy exists to make it so.

WE SERVE WITH HONOR

Tradition, valor, and victory are the Navy's heritage from the past. To these may be added dedication, discipline, and vigilance as the watchwords of the present and the future.

At home or on distant stations we serve with pride, confident in the respect of our country, our shipmates, and our families.

Our responsibilities sober us, our adversities strengthen us.

Service to God and Country is our special privilege. We serve with honor.

THE FUTURE OF THE NAVY

The Navy will always employ new weapons, new techniques, and greater power to protect and defend the United States on the sea, under the sea, and in the air.

Now and in the future, control of the sea gives the United States her greatest advantage for the maintenance of peace and for victory in war.

Mobility, surprise, dispersal, and offensive power are the keynotes of the new Navy The roots of the Navy lie in a strong belief in the future, in continued dedication to our tasks, and in reflection on our heritage from the past.

Never have our opportunities and our responsibilities been greater.

CONTENTS

CHAPTER 1

AVIATION SUPPORT EQUIPMENT TECHNICIAN E RATING

This training manual is designed as a self study text for use by those personnel of the Navy and Naval Reserve who are preparing to meet the professional (technical) qualifications for advancement to Petty Officer Third Class and Petty Officer Second Class in the rating of Aviation Support Equipment Technician E (Electrical). Minimum professional qualifications for advancement in all ratings are listed in the Manual of Qualifications for Advancement, NavPers 18068 (Series). The qualifications list which was used as a guide in the preparation of this manual was current as of the August 1972 revision. Therefore, changes in the qualifications occurring after the 1972 revision may not be reflected in the information presented here.

This manual does not contain coverage on all "quals" listed in the "Quals" Manual. Some of the "quals" listed are wholly or partially covered by the following basic Rate Training Manuals:

Basic Electricity, NavPers 10086-B, chapters 1-5, 7-19, 20, and appendixes 3 and 4.

Basic Electronics, Vol. 1, NavPers 10087-C, chapters 4, 5, 7, and 8.

Tools and Their Uses, NavPers 10085-B, all chapters.

Blueprint Reading and Sketching, NavPers 10077-C, chapters 1-5.

Basic Machines, NavPers 10624-A, chapters 1-12.

Military Requirements for PO 3 & 2 NavPers 10056-C, chapter 14.

It is important that personnel studying for advancement be familiar with the content of these chapters; advancement examinations will be based on this material as well as the material covered in this Rate Training Manual.

This chapter provides information on the enlisted rating structure, the ASE rating, requirements and procedures for advancement, and references that will help you in working toward advancement and in performing your duties as an ASE. Also included is information on how to make the best use of Rate Training Manuals. It is therefore strongly recommended that you study this chapter carefully before beginning intensive study of the remainder of the manual.

ENLISTED RATING STRUCTURE

The present enlisted rating structure consists of general ratings and service ratings.

General ratings identify broad occupational fields of related duties and functions and may be held by both Regular Navy and Naval Reserve personnel. This type rating provides the primary means of identifying billet requirements and personnel qualifications; it is established or disestablished by the Secretary of the Navy, and is provided a distinctive rating badge.

Service ratings identify subdivisions or specialties, within a general rating which require related patterns of aptitudes and qualifications and which provide paths of advancement for career development. (Not all general ratings have service ratings—only some of them.) Service ratings may also be held by both Regular Navy and Naval Reserve personnel and can exist at any petty officer level; however, they are most common at the PO3 and PO2 levels.

NOTE: The term "rate" identifies personnel occupationally by pay grade; "rating" refers to the occupational field.

AVIATION SUPPORT EQUIPMENT TECHNICIAN (AS) RATING

The AS rating is divided into three service ratings at pay grades E-4 and E-5. The service ratings are ASE (Electrical), ASH (Hydraulics and Structures), and ASM (Mechanical). The general rating, AS, applies at pay grades E-6 through E-9.

Figure 1-1 illustrates all paths of advancement for an Airman Recruit to Master Chief Aviation Support Equipment Technician, Chief Warrant Officer (W-4), and to Limited Duty Officer. Shaded areas indicate career stages where qualified enlisted personnel may advance to Warrant Officer (W-1), and where selected Warrant Officers may advance to Limited Duty Officer. Personnel in enlisted rates and warrant ranks not in shaded areas may advance only as indicated by the arrows.

Aviation Support Equipment Technicians E service, test, and perform organizational and intermediate level maintenance and repair of automotive electrical systems in mobile and self-propelled ground support equipment; aviation armament handling equipment, including generating, starting, lighting, and ignition systems, electrical components and wiring in auxiliary electrical power units used in servicing aircraft; electrical control systems in gas turbine compressor units and air-conditioning systems; and electrical and electronic circuits and components in general aircraft servicing equipment. They also service and maintain storage batteries, and perform periodic maintenance inspections of ground support equipment.

As an ASE3 or an ASE2, your assignment possibilities cover a wide range of duties and responsibilities. Your specific duties will depend to a great extent upon the type of organization to which you are attached. A greater number of ASE's are assigned to activities which perform intermediate level maintenance. These billets exist aboard aircraft carriers and naval air stations. In each instance, the ASE will most likely be attached to the support equipment division of the Aircraft Intermediate Maintenance Department (AIMD).

The ASE may also be assigned to a unit that performs organizational maintenance. The unit may be permanently attached to a particular naval air station, or may use a certain naval air station as a home port and alternate between the station and a ship or between the home port and another land base or bases.

Instructor duty is available to the ASE2, and in special instances may be available to the ASE3. Instructor billets are available in the AS school at NAS Memphis, Millington, Tennessee, in the Naval Air Maintenance Training Group (NAMTG) with headquarters at Memphis, and with the Chief of Naval Education and Training Support in Pensacola, Florida.

Instructor billets are normally filled on a voluntary basis. Detailed information concerning assignment to instructor duty is contained in the Enlisted Transfer Manual, NavPers 15909 (Series).

LEADERSHIP

One does not have to be a member of the Armed Forces very long before realizing that more leadership is required of the higher rates. Advancement not only entails the acquisition of superior knowledge, but also the demonstrated ability to handle people. This ability increases in importance as one advances through the petty officer rates.

In General Order No. 21, the Secretary of the Navy outlined some of the most important aspects of naval leadership. By naval leadership is meant the art of accomplishing the Navy's mission through people. It is the sum of those qualities of intellect, of human understanding, and of moral character that enable a person to inspire and to manage a group of people successfully. Effective leadership therefore is based on personal example, good management practices, and moral responsibility. The term leadership includes all three of these elements.

The current Navy Leadership Program is designed to keep the spirit of General Order No. 21 ever before Navy personnel. If the threefold objective is carried out effectively in every command, the program will develop better leaders. As one advances up the leadership ladder, more and more of his worth to the Navy will be judged on the basis of the amount of efficient work obtained from subordinates rather than how much of the actual work he performs.

For further information on the practical application of leadership and supervision, the latest edition of Military Requirements for Petty

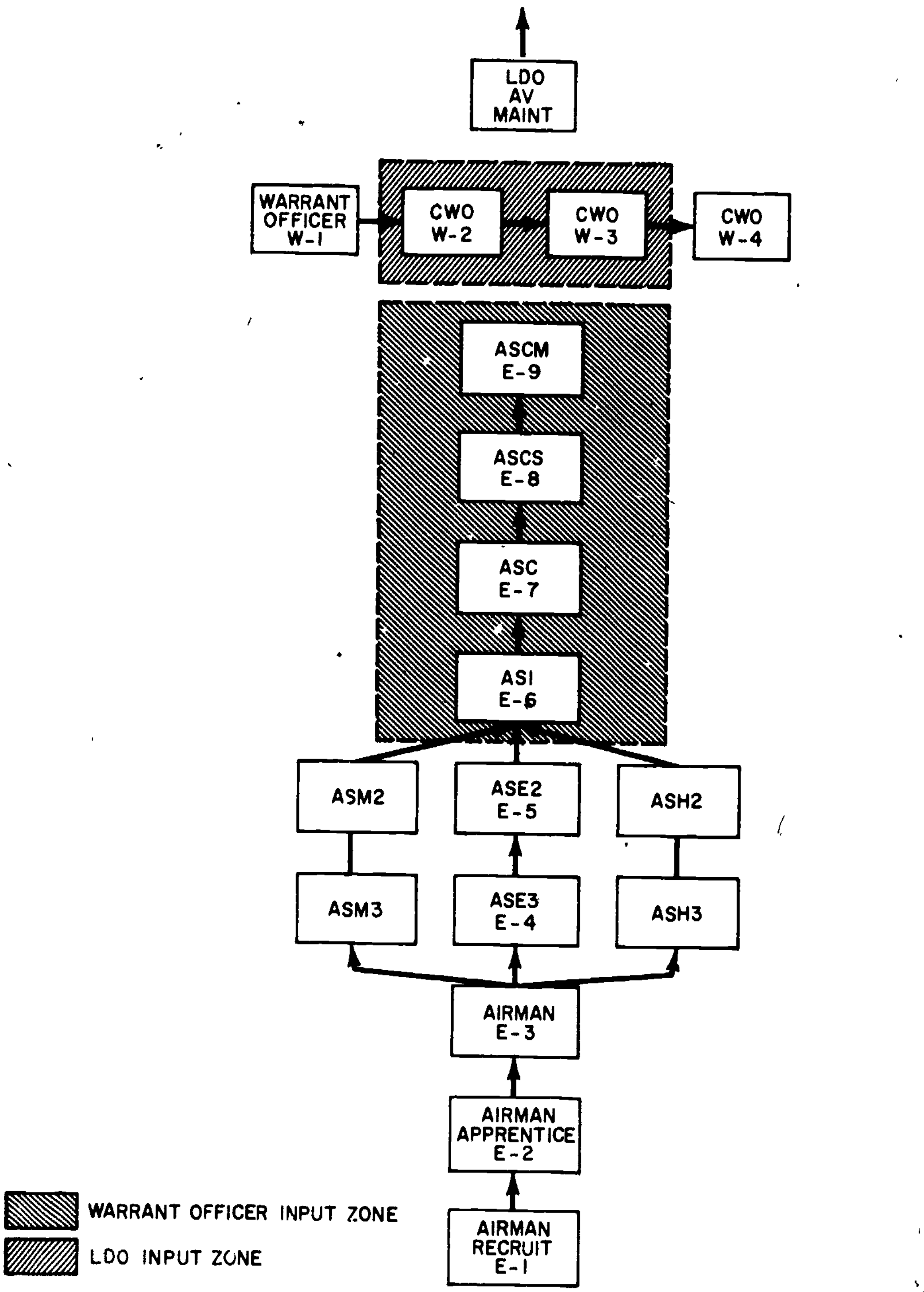


Figure 1-1.—Paths of advancement.

Officer 3 & 2, NavPers 10056 (Series), should be studied.

ADVANCEMENT

Some of the rewards of advancement are easy to see. You get more pay. Your job assignments become more interesting and more challenging. You are regarded with greater respect by officers and enlisted personnel. You enjoy the satisfaction of getting ahead in your chosen Navy career

The advantages of advancement are not yours alone. The Navy also profits. Highly trained personnel are essential to the functioning of the Navy. By advancement, you increase your value to the Navy in two ways first, you become more valuable as a technical specialist in your own rating; and second, you become more valuable as a person who can train others, and thus make far-reaching contributions to the entire Navy.

HOW TO QUALIFY FOR ADVANCEMENT

What must you do to qualify for advancement? The requirements may change from time to time, but usually you must:

1. Have a certain amount of time in your present grade
2. Complete the required Rate Training Manuals by either demonstrating a knowledge of the material in the manuals by passing a locally prepared and administered test, or by passing the Nonresident Career Course based on the Rate Training Manual and the appropriate Military Requirements Manual.
3. Demonstrate your ability to perform all the practical requirements for advancement by completing the Record of Practical Factors, NavEdTra 1414/1.
4. Be recommended by your commanding officer, after the petty officers and officers supervising your work have indicated that they consider you capable of performing the duties of the next higher rate.
5. Successfully complete the applicable military/leadership examination which is required prior to participating in the advancement (professional) examination.

Remember that the requirements for advancement can change. Check with your educational services office to be sure that you know the most recent requirements.

Advancement is not automatic; after you have met all the requirements, you are only eligible for advancement. You will actually be advanced only if you meet all the requirements (including making a high enough score on the written examination) and if quotas permit.

HOW TO PREPARE FOR ADVANCEMENT

What must you do to prepare for advancement? You must study the qualifications for advancement, work on the practical factors, study the required Rate Training Manuals, and study other material that is required. You will need to be familiar with the following:

1. Manual of Qualifications for Advancement, NavPers 18068 (Series).
2. Record of Practical Factors, NavEdTra 1414/1.
3. Bibliography for Advancement Study, NavEdTra 10052 (Series).
4. Applicable Rate Training Manuals and their companion Nonresident Career Courses.

Collectively, these documents make up an integrated training package tied together by the qualifications. The following paragraphs describe these materials and give some information on how each one is related to the others.

"Quals" Manual

The Manual of Qualifications for Advancement, NavPers 18068 (Series), gives the minimum requirements for advancement. This manual is usually called the "Quals" Manual, and the qualifications themselves are often called "quals." The qualifications are of two general types - military requirements, and professional (or technical) qualifications.

Military requirements apply to all ratings rather than to any one particular rating. Military requirements for advancement to third class and second class petty officer rates deal with military conduct, naval organization, military justice, security, watch standing, and other subjects which are required of petty officers in all other ratings.

Professional qualifications are technical or professional requirements that are directly related to the work of each rating.

Both the military requirements and the professional qualifications are divided into subject matter groups; then, within each subject matter group, they are divided into practical factors and knowledge factors. Practical factors are things you must be able to DO. Knowledge factors are things you must KNOW in order to perform the duties of your rate.

The qualifications for advancement and a bibliography of study materials are available in your educational services office. Study these qualifications and the military requirements carefully. The written examination for advancement will contain questions relating to the knowledge factors and the knowledge aspects of the practical factors of the professional qualifications. If you are working for advancement to second class, remember that you may be examined on third class qualifications as well as on second class qualifications.

It is essential that the "quals" reflect current requirements of fleet and shore operations, and that new fleetwide technical, operational, and procedural developments be included. For these reasons, the qualifications are continually under evaluation. Although there is an established schedule for revisions to the "quals" for each rating, urgent changes to the "quals" may be made at any time. These revisions are issued in the form of changes to the "Quals" Manual. Therefore, never trust any set of "quals" until you have checked the change number against an up-to-date copy of the "Quals" Manual. Be sure you have the latest revision.

Personnel Qualification Standards

Personnel Qualification Standards (PQS) (OpNav Instruction 3500.34) are presently being utilized to provide guidelines in preparing for advancement and qualification to operate specific equipment and systems. They are designed to support the advancement requirements as stated in the "Quals" Manual.

While the "Quals" and Record of Practical Factors are stated in broad terms, each PQS is much more specific in its questions that lead to qualification. It provides an analysis of specific equipment and duties, assignments, or responsibilities which an individual or group of individuals (within the same rating) may be called upon to carry out. In other words, each PQS provides an analysis of the complete knowledge and skills required of that rating tied to a specific weapon system (aircraft and/or individual systems or components).

Each qualification standard has four main subdivisions in addition to an introduction and a glossary of PQS terms. They are as follows:

100 Series—Theory
200 Series—Systems
300 Series—Watchstations (duties, assignments, or responsibilities)
400 Series—Qualification cards

The introduction explains the complete use of the qualification standard in terms of what it will mean to the user as well as ho o use it.

The Theory (100 Series) sectic. specifies the theory background required as a prerequisite to the commencement of study in the specific equipment or system for which the PQS was written. These fundamentals are normally taught in the formal schools (Preparatory, Fundamentals, and Class A) phase of an individual's training. However, if the individual has not been to school, the requirements are outlined and referenced to provide guidelines for a self-study program.

The Systems (200 Series) section breaks down the equipment or systems being studied into functional sections. PQS items are essentially questions asked in clear, concise statement (question) form and arranged in a standard format. The answers to the questions must be extracted from the various maintenance manuals covering the equipment or systems for which the PQS was written. This section asks the user to explain the function of the system, to draw a simplified version of the system from memory, and to use this drawn schematic or the schematic provided in the maintenance manual while studying the system or equipment. Emphasis is given to such areas as maintenance management procedures, components, component parts, principles of operation, system interrelations, numerical values considered necessary to operation and maintenance, and safety precautions.

The Watchstation (300 Series) section includes questions regarding the procedures the individual must know to operate and maintain the equipment or system. A study of the items in the 200 series section provides the individual with the required information concerning what the system or equipment does, how it does it, and other pertinent aspects of operation. In the 300 series section, the questions advance the qualification process by requiring answers or demonstrations of ability to put this knowledge to use or to cope with maintenance of the system or equipment. Areas covered include normal operation; abnormal or emergency operation; emergency procedures which could limit damage and/or casualties associated with a particular operation; operations that occur too infrequently to be considered mandatory performance items; and maintenance procedures/instructions such as checks, tests, repair, replacement, etc.

The 400 series section consists of the qualification cards. These cards are the accounting documents utilized to record the individual's satisfactory completion of items necessary for becoming qualified in duties assigned. Where the individual starts in completing a standard will depend on his assignment within an activity. The complete PQS is given to the individual being qualified so that he can utilize it at every opportunity to become fully qualified in all areas of his rating and the equipment or system for which the PQS was written. Upon transfer to a different activity, each individual must requalify. The answers to the questions asked in the qualification standards may be given orally or in writing to the supervisor, the branch or division officer, or the maintenance officer as required to certify proper qualification. The completion of part or all of the PQS provides a basis for the supervising petty officer and officer to certify completion of Practical Factors for Advancement.

Record of Practical Factors

Before you can take the Navy-wide examination for advancement, there must be an entry in your service record to show that you have qualified in the practical factors of both the military requirements and the professional qualifications. A special form known as the Record of Practical Factors, NavEdTra 1414/1(plus the abbreviation of the appropriate rating), is used to keep a record of your practical factor qualifications. The form lists all practical factors, both military and professional. As you demonstrate your ability to perform each practical factor, appropriate entries are made in the DATE and INITIALS columns.

Changes are made periodically to the Manual of Qualifications for Advancement and revised forms of NavEdTra 1414/1 are provided when necessary. Extra space is allowed on the Record of Practical Factors for entering additional practical factors as they are published in changes. The Record of Practical Factors also provides space for recording demonstrated proficiency in skills which are within the general scope of the rate but which are not identified as minimum qualifications for advancement.

If you are transferred before you qualify in all practical factors, NavEdTra 1414/1 should be forwarded with your service record to your next duty station. You can save yourself a lot of trouble by making sure that this form is actually inserted in your service record before you are transferred. If the form is not in your service record, you may be required to start again and requalify in the practical factors which have already been checked off.

A second copy of the Record of Practical Factors should be made available to each man in pay grades E-2 through E-8 for his personal record and guidance.

The importance of NavEdTra 1414/1 should be emphasized continuously. It serves as a record to indicate to the petty officers and officers supervising your work that you have demonstrated proficiency in the performance of the indicated practical factors and is part of the criteria utilized by your commanding officer when he considers recommending you for advancement. In addition, the proficient demonstration of the applicable practical factors listed on this form can aid you in preparing for the examination for advancement. Remember that the knowledge aspects of the practical factors are covered in the examinations for advancement. Certain knowledge is required to demonstrate these practical factors and additional knowledge can be acquired during the demonstration. Knowledge factors pertain to that knowledge which is required to perform a certain job. In other words, the knowledge factors required for a certain rating depend upon the jobs (practical factors) that must be performed by personnel of that rating. Therefore, the knowledge required to proficiently demonstrate these practical factors will definitely aid you in preparing for the examination for advancement

NavEdTra 10052

Bibliography for Advancement Study, NavEdTra 10052 (Series), is a very important publication for anyone preparing for advancement. This bibliography contains a section listing the military references and another section listing the professional references. These sections list required and recommended Rate Training Manuals and other reference material to be used by personnel working for advancement. NavEdTra 10052 is revised and issued once each year by the Chief of Naval Education and Training Support. Each revised edition is identified by a letter following the NavEdTra number. When using this publication, be sure that you have the most recent edition.

If extensive changes in qualifications occur between the annual revisions of NavEdTra 10052, a supplementary list of study material may be issued in the form of a NavEdTra Notice. When you are preparing for advancement, check to see whether changes have been made in the qualifications. If changes have been made, see if a Notice has been issued to supplement NavEdTra 10052

The required and recommended references are listed by rate level in NavEdTra 10052. If you are working for advancement to third class, study the material that is listed for third class. If you are working for advancement to second class, study the material that is listed for second class, but remember that you are also responsible for the references listed at the third class level.

In using NavEdTra 10052 you will notice that some Rate Training Manuals are marked with ~~an asterisk~~ (*). Any manual marked in this way is MANDATORY that is, it must be completed at the indicated rate level before you are eligible to take the Navy-wide examination for advancement. Each mandatory manual may be completed by passing the appropriate nonresident career course that is based on the mandatory training manual, passing locally prepared tests based on the information given in the training manual, or in some cases, successfully completing an appropriate Class A School.

Do not overlook the section of NavEdTra 10052 which lists the required and recommended references relating to the military standards/requirements for advancement. For example, all personnel must complete the Rate Training Manual, Requirements for Petty Officer 3 & 2, NavPers 10056 (Series), for the appropriate rate level before they can be eligible to advance.

The references in NavEdTra 10052 which are recommended, but not mandatory, should also be studied carefully. All references listed in NavEdTra 10052 may be used as source material for the written examinations at the appropriate rate levels.

Rate Training Manuals

There are two general types of Rate Training Manuals. Rate manuals (such as this one) are prepared for most enlisted rates, containing information that is directly related to the professional qualifications. Basic manuals contain information that applies to more than one rate and rating. Basic Electricity, NavPers 10086 (Series), is an example of a basic manual, because many ratings use it for reference

Rate Training Manuals are revised as required to keep them up-to-date technically. The revision of a Rate Training Manual is identified by a letter following the NavEdTra number. You can tell whether any particular copy of a Rate Training Manual is the latest edition by checking the NavEdTra number and the letter following this number in the most recent edition of List of Training Manuals and Correspondence Courses, NavEdTra 10061 (Series). (NavEdTra 10061 is actually a catalog that lists current training manuals and nonresident career courses; you will find this catalog useful in planning your study program.)

Rate Training Manuals are designed to help you prepare for advancement. The following suggestions may help you to make the best use of this manual and other Navy training publications when you are preparing for advancement.

1. Study the military requirements and the professional qualifications for your rate before you study the training manual, and refer to the "quals" frequently as you study. Remember, you are studying the training manual in order to meet these "quals."

2. Set up a regular study plan. If possible, schedule your studying for a time of day when you will not have too many interruptions or distractions.

3. Before you begin to study any part of the training manual intensively, become familiar with the entire manual. Read the preface and the table of contents. Check through the index. Look at the appendixes. Thumb through the manual without any particular plan, looking at the illustrations and reading bits here and there as you see things that interest you.

4. Look at the training manual in more detail, to see how it is organized. Look at the table of contents again. Then, chapter by chapter, read the introduction, the headings, and the subheadings. This will give you a clear picture of the scope and content of the manual. As you look through the manual in this way, ask yourself some questions: What do I need to learn about this? What do I already know about this? How is this information related to information given in other chapters? How is this information related to the qualifications for advancement?

5. When you have a general idea of what is in the training manual and how it is organized, fill in the details by intensive study. In each study period, try to cover a complete unit—it may be a chapter, a section of a chapter, or a subsection. If you know the subject well, or if the material is easy, you can cover quite a lot at one time. Difficult or unfamiliar material will require more study time.

6. In studying any one unit—chapter, section, or subsection—write down the questions that occur to you. Many people find it helpful to make a written outline of the unit as they study, or at least to write down the most important ideas.

7. As you study, relate the information in the training manual to the knowledge you already have. When you read [illegible]ess, a skill, or a situation, try to se[illegible] information ties in with your own pas[illegible]ience.

8. When you have finished studying a unit, take time out to see what you have learned. Look back over your notes and questions. Maybe some of your questions have been answered, but perhaps you still have some that are not answered. Without referring to the training manual, write down the main ideas that you have learned from studying this unit. Do not quote the manual. If you cannot give these ideas in your own words, the chances are that you have not really mastered the information.

9. Use Nonresident Career Courses whenever you can. These courses are based on Rate Training Manuals or on other appropriate texts. As mentioned before, completion of a mandatory Rate Training Manual can be accomplished by passing its associated Nonresident Career Course. You will probably find it helpful to take other courses, as well as those based on mandatory training manuals. These courses help you to master the information given in the training manual, and also help you to see how much you have learned.

10. Think of your future as you study Rate Training Manuals. You are working for advancement to third class or second class right now, but someday you will be working toward higher rates. Anything extra that you can learn now will help you.

SOURCES OF INFORMATION

One of the most useful things you can learn about a subject is how to find out more about it. No single publication can give you all the information you need to perform the duties of your rating. You should learn where to look for accurate, authoritative, up-to-date information on all subjects related to the military requirements for advancement and the professional qualifications of your rating.

Some of the publications described in this manual are [illegible] change or revision from time to time– [illegible] regular intervals, others as the need arises. When using any publication that is subject to change or revision, be sure that you have the latest edition. When using any publication that is kept current by means of changes, be sure you have a copy in which all official changes have been made. Studying canceled or obsolete information will not help you perform efficiently or to advance; it is likely to be a waste of time, and may even be seriously misleading.

CHAPTER 2

MAINTENANCE FORMS AND RECORDS

In order that all commands and offices concerned with naval aviation be kept fully informed of the operational and maintenance experiences of naval aviation operating activities, a large variety of records must be maintained and many reports made. Some of the reports provide purely historical information, some furnish statistical data for analyzing efficiency and economy of maintenance and operation, and others have a bearing on the supply support furnished the activity. These records and reports are not limited to aircraft. Support equipment, man-hours, and personnel training are representative of other areas of recordkeeping and reporting.

Through analyses of the data provided, the commands and offices, for whose use the records and reports are submitted, are enabled to better control overall operations. Standardization of maintenance and material areas is improved, unsafe or uneconomical trends are spotted and corrected earlier, and, through feedback information, the service experience of other similar activities is made available to all who would find it helpful.

For each record that has to be kept, and for every report that has to be made, a governing instruction has been issued. These instructions usually give detailed instructions for the preparation of the record or report, prescribe the form and frequency of submission, and indicate the office to which they are to be forwarded. For purely local records such as training records, local instructions are provided to guide the recordkeeping.

Only a few of the forms and records pertaining to ground support equipment will be discussed in this manual. The text material of the Naval Aircraft Maintenance Program (NAMP) discusses the forms and records in detail and provides other valuable information that is pertinent to ground support equipment. A complete coverage of the NAMP is provided by OpNav Instruction 4790.2 (Series) with a basic coverage in Military Requirements for Petty Officers 3 and 2, NavPers 10056 (Series).

GSE STATISTICAL DATA REPORTING

The true measure of effectiveness of maintenance and material management in support of a weapon system is the state of readiness of that weapon system to perform its assigned mission when related to the utilization rate that can be sustained. The readiness and utilization of Ground Support Equipment (GSE) affect the readiness and utilization of aviation weapon systems. Because of this effect there is a need to provide sufficient data to enable efficient management of GSE resources in terms of readiness and utilization. Accordingly, a system for collecting, processing, and utilizing GSE statistical data for selected items of GSE has been implemented throughout the Navy.

In the GSE data collection system, GSE inventory changes, status changes, and NOR data are recorded on a source document and machine processed. This data supports the management function, allowing for the isolation of problem areas, and gives an indication of the impact of GSE readiness and utilization. Specifically, the GSE data collection system provides information to:

1. Generate GSE readiness and utilization reports.
2. Charge NOR time to a particular system/subsystem of GSE.
3. Measure the effect of supply response on GSE readiness.

4. Measure the effect of technical directive compliance on GSE readiness.

5. Measure the amount of time that GSE is awaiting maintenance.

GSE becomes subject to this reporting system upon acceptance by a reporting custodian and remains so until lost from inventory of that reporting custodian. The system is mandatory for GSE reporting custodians who are subject to and operate under the 3-M System. The scope of required reporting includes:

1. GSE inventory changes.
2. The reporting of NOR time by reason.
3. The relation of NOR time to GSE systems/subsystems.
4. The utilization of GSE in hours/cycles/starts.

The system is designed to reduce the manual accumulation of records associated with the management of GSE. It requires the support of a data services activity to process the collected data. This system provides data for GSE inventory, readiness, utilization, and information for management control of selected GSE items.

The GSE data collection system does not have application to all support equipment; instead, only selected items are involved. An appendix to the 3-M Manual lists those items of GSE on which statistical data reporting is required. It is not appropriate to include a listing of this type in this training manual. (In this section, GSE is limited to the selected items requiring statistical data reporting.)

TERMS AND CODES

Prior to entering into a discussion of the GSE data collection system operation and source documentation procedures, an explanation of some of the basic terms and codes used in this system is required. The following terms and their meaning should be studied thoroughly in order to more fully understand the discussion that follows.

Operationally Ready (OR)

Operationally ready is a condition status of an item of GSE which indicates that it is physically and mechanically capable of safely performing its designed function/mission.

Not Operationally Ready (NOR)

An item of GSE is NOR when it becomes known that a discrepancy exists which prevents the item from performing its designed function/mission completely within the definition of OR. NOR is separated into several categories.

NOT OPERATIONALLY READY MAINTENANCE (NORM).—An item of GSE is NORM when scheduled maintenance, technical directive compliance, or corrective maintenance is required, or is being performed on the item or its systems to return the item to an OR condition. NORM is separated into several categories.

Not Operationally Ready Depot Maintenance (NORDM).—An item of GSE is NORDM during all periods of time that depot level maintenance, scheduled or unscheduled, (except calibration) is being performed on the item by a depot level activity when the repair is of a short-term nature. If down time is expected to exceed 72 hours, the item will be dropped from the inventory.

Not Operationally Ready Aircraft Intermediate Maintenance (NORAIM).—An item of GSE is NORAIM during all periods of time that aircraft intermediate maintenance, scheduled or unscheduled, (except calibration) is being performed on the item of GSE by an AIMD.

Not Operationally Ready Public Works/Marine Air Base Support (NORM (PW/MABS)).—An item of GSE is NORM (PW/MABS) when scheduled or unscheduled maintenance (except calibration) is being performed on the item of GSE by a Public Works Department or a Marine Air Base Support Activity.

Not Operationally Ready Calibration (NORM CALIB).—An item of GSE is NORM CALIB when scheduled or unscheduled calibration is being accomplished on the item. Calibration is actually a depot level maintenance function but an item of GSE NORM CALIB is not reported NORDM; instead, it is reported as NORM CALIB. Qualification is performed by an AIMD and is reported NORM CALIB (scheduled or unscheduled).

NOT OPERATIONALLY READY SUPPLY (NORS).—An item of GSE is NORS when a supply demand has been made and the material/component/part(s) which have been requisitioned are not available, precluding further maintenance work. Maintenance/production control personnel determine NORS start and stop times using the following information: (1) the time the demand for material is placed on the supply activity by the material control work center, (2) the time the material is delivered to the designated delivery point, and (3) whether other maintenance can be performed on the item.

NOT OPERATIONALLY READY FACILITIES (NORF).—An item of GSE is NORF when it is unavailable for use due to a deficiency of support facilities required in the support of that item of GSE; for example, a jet engine test facility unusable due to ship/station power failure.

Awaiting Maintenance Time (AWM)

Awaiting maintenance time is that time which an item of GSE is NORM and no maintenance work is being performed. AWM does not apply when the item of GSE is NORS or NORF.

Designed Function/Mission

The designed function/mission of an item of GSE, for purposes of GSE data collection, refers to the full capabilities for which the item was designed. Some GSE is designed to fulfill more than one function. Examples of this are the MD-3B tractor, which was designed to tow and to furnish starting air for jet aircraft, and the NC-8A mobile electric power unit, which was designed to furnish a-c and d-c power, as required. GSE of this type must be capable of performing all designed functions to be OR.

Reporting Custodian

The reporting custodian is the activity having prime custody of the GSE as indicated on the appropriate Individual Material Readiness List (IMRL) or allowance list. Equipment furnished on a sub-custody basis must be reported by the supporting activity which has prime custody of the equipment.

Controlling Custodian

Controlling custodians are the operating commands and Naval Air Systems Command, the monitors, users, and compilers of data. These operating commands include COMNAVAIRLANT, COMNAVAIRPAC, etc.

Source Document

One source document is utilized in the GSE data collection system to report readiness and utilization. It is the GSE data card, discussed in detail later in this chapter.

GSE Status Codes

A GSE status code is a classification of the status of an item of GSE. A NOR condition has no bearing on the status code of an item of GSE. There are three status codes used in the GSE data collection system and they denote the purpose or use of assigned GSE.

STATUS CODE A.—Normal operational support. Status code A applies to those items of GSE in the possession of an organizational or intermediate activity and normally being utilized in support of assigned missions. NOR/Utilization reporting is required only against equipment in status code A.

STATUS CODE B.—Backup stock. This status code applies to those items of GSE in possession of an Intermediate activity and not being utilized in support of assigned mission, placed in storage, or being held in reserve; for example, an air wing departs from a carrier and items are not required in support of remaining activities.

STATUS CODE C.—Special repair/upkeep. Status code C applies to those items of GSE in possession of an intermediate maintenance activity for special repair or upkeep which are not on the repair AIMD's inventory. The designation of AIMD's responsible for special repair or upkeep and redistribution, if required, of GSE are made by the appropriate controlling custodian.

Table 2-1.—GSE transaction codes

NOR Transactions
21 . . . Facilities.
22 . . . Supply.
23 . . . Depot Maintenance (NORDM SKED)
24 . . . Aircraft Intermediate Maintenance Department (NORAIM SKED)
25 . . . Public Works/Marine Air Base Support (NORM PW/MABS SKED)
26 . . . Calibration (NORM CALIB SKED)
33 . . . Depot Maintenance (NORDM UNSKED)
34 . . . Aircraft Intermediate Maintenance Department (NORAIM UNSKED)
35 . . . Public Works/Marine Air Base Support (NORM PW/MABS UNSKED)
36 . . . Calibration (NORM CALIB UNSKED)
Inventory Change
11 . . . Gain.
12 . . . Transfer.
13 . . . Strike.
Status Change 42
A . . . Normal Operational Support.
B . . . Back up stock.
C . . . Special Repair/Upkeep.
Utilization
51 . . . Start Meter Reading.
52 . . . Stop Meter Reading.
53 . . . End of Month Close Out.
Replenishment
41 . . . Replenishment.

GSE Transaction Codes

GSE transaction codes are used to indicate NOR conditions, inventory changes, status code changes, and utilization. However, it is no longer required to report status code changes. If an item of GSE becomes other than status A, it will be dropped from the inventory until such time as it again becomes status A. Table 2-1 contains a listing of the various GSE transaction codes.

Reporting Requirement Code (RRC)

This is a single character code which indicates the type of reporting required on the item to which it is assigned.

"A".–Maintenance reporting only.

"B".–Maintenance, inventory, and readiness reporting required.

"C".–Maintenance, inventory, readiness, and utilization reporting required.

An appendix to the 3-M manual contains a listing of all GSE assigned a type equipment code (TEC) and the assigned RRC for each item. An item of GSE assigned the RRC "B" or "C" is in the GSE statistical data reporting system when entered in the master file in status code A.

SYSTEM OPERATION

Each item of GSE while in a reporting status, at any given time from acceptance until loss, is the accounting responsibility of one (and only one) controlling custodian and one (and only one) reporting custodian. Gain and loss occur simultaneously when an item of GSE changes custody. All GSE loss actions are effective as of 2400 hours on the date the transfer occurs, and all gain actions are effective as of 0001 hours the following calendar day. An item of GSE remains in the reporting custody of the transferring unit until accepted by the receiving unit.

When a reporting custodian becomes subject to this reporting system, a listing is prepared for each item of GSE subject to reporting which is in the inventory of that reporting custodian. This listing is prepared by the reporting custodian and forwarded to data services, via the analysis division, in order to establish an accurate master file of inventory data within the local services activity. This master file of data is printed out as the Master Roster Report, GSE 1, and includes such identifying information as GSE type/model/series, organization code, status code, and serial number. Once the master file of inventory data is established, it is kept current by the submission of GSE cards.

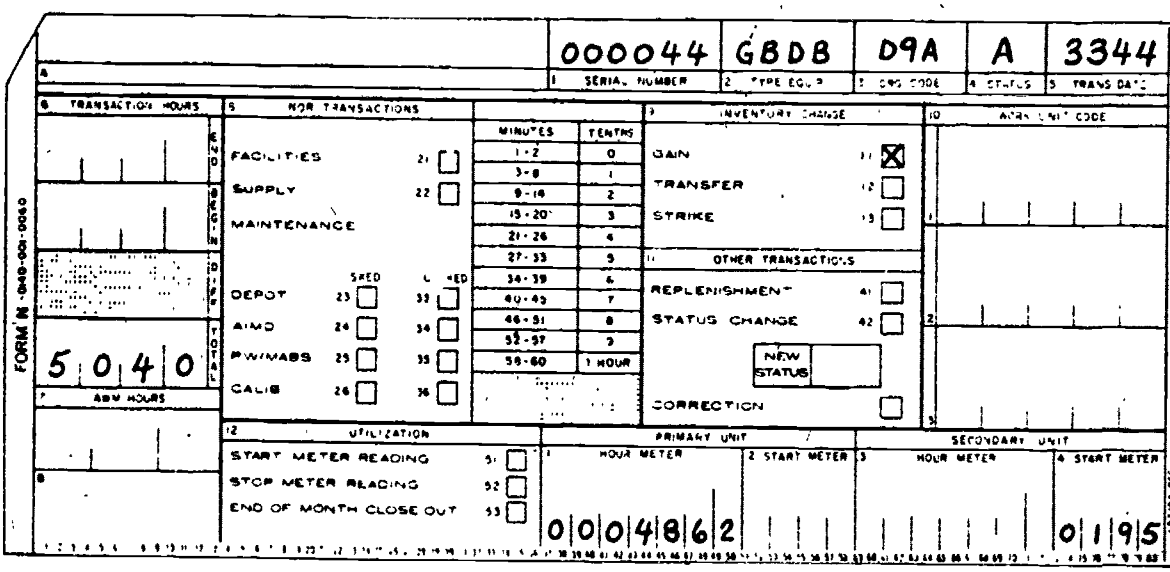
The master file and submitted GSE cards are utilized by the data services activity to prepare periodic machine reports which list and summarize certain data. These reports are supplied to the reporting custodian to provide assistance in planning and directing the maintenance effort. In addition, data from the GSE cards are forwarded to a Central Data Processing Facility, which provides data in a format to satisfy management requirements of type commanders, technical commands, and other managers.

GSE DATA CARD DOCUMENTATION

There is only one source document utilized to collect GSE statistical data. This is the GSE data card. It is used to report three distinct categories of GSE statistical data–inventory changes, NOR time by reason, and utilization by hours/cycles/starts.

Unless otherwise reported, each item of GSE is assumed to be usable for the purpose for which designed, still assigned to the same reporting custodian, and operationally ready. When NORM or NORS time is reported on the GSE card, it must be related to the particular system/subsystem causing the NOR condition by entering on the card the work unit code(s) of the faulty system/subsystem. That portion of NORM time during which maintenance was not being performed is also identified as AWM time.

For the most part, prepunched/preprinted (blocks 1 through 4) GSE cards are used. Handscribed cards may be used if prepunched/preprinted cards are not available. A supply of prepunched/preprinted cards is normally received for an item of GSE upon reporting a gain. When the supply of prepunched/preprinted cards for a particular item of GSE reaches 10 or less, a new supply can be obtained by submitting a correctly prepunched/preprinted card with the replenish code (41) checked. No other trans-



AS.195

Figure 2-1.—GSE data card reporting a gain.

action data should be made on a GSE card submitted for replenishment purposes.

All completed GSE cards are forwarded to the analysis division by 0900 on the first working day following the transaction. Here, they are sorted, counted, and forwarded to data services for machine processing.

Inventory Change Reporting

A GSE card reporting inventory change data is submitted when an item of GSE is gained (received/accepted) into a unit's custody, an item of GSE is lost (transferred/stricken) from the unit's custody, or an item in the reporting custodian's inventory is degraded to a status other than A. (See fig. 2-1.)

The GSE card reflecting a gain of an item of GSE into a unit's custody must be handscribed. From this card a supply of prepunched/preprinted GSE cards is provided to the reporting custodian by data services. These prepunched/preprinted cards are then used for other types of reporting.

The following paragraphs discuss GSE card documentation reporting inventory change data.

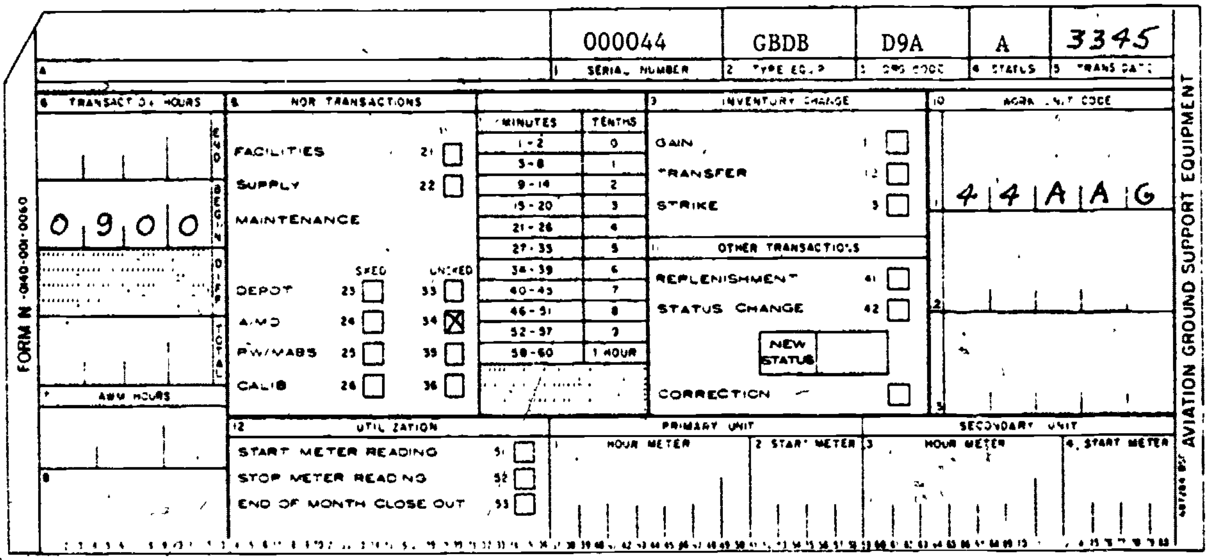
Block 1--Serial Number. The serial number of the item of GSE gained is entered in this space. This number is always reported in six characters. If there are less than six characters in the serial number, it is preceded with zeros to make six. If there are more than six characters, only the last six are reported. If there is no serial number, a six-character identification number which consists of the organization code plus a 3-character serial number is assigned by the local activity. Normally the serial number should start with 001 and subsequent numbers should be assigned sequentially; for example P9G001, P9G002, etc. This assigned serial number is affixed to the equipment and remains with the unit until stricken from the Navy's inventory.

Block 2--Type Equipment Code. The 4-character type equipment code which identifies the item of GSE by type, model, and series is entered in this space.

Block 3--Organization Code. The 3-character organization code which identifies the unit of assignment is entered here.

Block 4--Status Code. In this block is entered the appropriate status code (A, B, or C).

Block 5--Transaction Date. In this space is entered the Julian date on which the gain occurred.



AS.196

Figure 2.2.—GSE data card reporting a NORAIM (unscheduled) condition.

Block 6—Transaction Hours. The total number of clock hours remaining in the month is entered in block 6 (Total). This is computed by multiplying the number of calendar days remaining in the month by 24 hours. All gain actions are effective as of 0001 hours on the day following the day of receipt. The entry in this block must be a multiple of 24 hours, and it is preceded with zeros when the hours listed are less than the allotted space. A zero is always entered for tenths.

Block 9—Inventory Change. A checkmark is entered opposite the gain transaction code (11).

Block 12—Utilization. The total number of meter or logbook hours/starts, as appropriate, is entered in block(s) 12.1, .2, .3, and .4 at the time the equipment is gained into the activity's inventory. Some items of support equipment were designed to fulfill more than one function. The hours/starts of the primary unit of such items are recorded in spaces .1 and .2, and the hours/starts of the secondary unit are recorded in spaces .3 and .4. The entries in these spaces should always be preceded with zeros when the hours/starts listed are less than the allotted space.

The reporting of GSE loss transactions is very similar to gain reporting. When an item of GSE is lost from reporting custody or degraded from status A, a prepunched/preprinted GSE card is normally used. The Julian date on which the loss occurred is entered in block 5. The total number of clock hours remaining in the month is entered in block 6 (Total). This is computed as previously discussed for a gain transaction. All loss actions are effective as of 2400 hours on the day of the loss. A checkmark is entered opposite the appropriate loss code (12 or 13) in block 9. All hours/starts/cycles, as appropriate, are entered in block(s) 12.1, .2, .3, or .4 at the time the equipment is lost from the activity's inventory in the same manner as previously discussed.

Not Operationally Ready Reporting

As previously stated, reporting custodians are accountable for each assigned item of GSE for 24 hours each day. Each item of GSE is considered OR unless reported otherwise. Whenever an item of GSE becomes NOR, for any reason, a GSE card must be initiated. Prepunched/preprinted cards are normally used for NOR reporting. Figure 2-2 illustrates a GSE card reporting the beginning of a NORAIM (unscheduled) condition. Completion of the card blocks for this type of reporting is discussed in the following paragraphs.

Block 5–Transaction Date. The Julian date on which the transaction occurred is entered in this block.

Block 6–Transaction Hours. The time, in hours and minutes, that the item of GSE becomes NOR is entered in block 6 (Begin). The card is then retained by maintenance/production control until it is closed out.

Block 8–NOR Transaction. A checkmark is placed in the box that best indicates the reason for NOR condition. Only one box in block 8 may be checked on any one card. NOR technical directive compliance (TDC) is reported when an item is not ready solely because of the compliance with a technical directive. In this case, a checkmark is entered in the Sked box opposite the appropriate NOR transaction code in block 8, and TDC is entered in block 10.1 (Work Unit Code).

GSE undergoing periodic or calendar inspection, while in the custody of the reporting custodian, is reported as NORAIM SKED and work unit code 030 is entered in block 10.1. Damaged GSE in the custody of the reporting custodian is reported as NORAIM UNSKED.

The time a unit of GSE is NOR due to maintenance being performed by Depot customer service, excluding calibration, is reported as NORDM (scheduled/unscheduled). Likewise, the time a unit of GSE is NOR due to any type of maintenance, excluding calibration, being performed by Public Works/Marine Air Base Support is reported NOR PW/MABS (Sked or Unsked). The time a unit of GSE is NOR due to calibration, regardless of who performs the work, is reported NOR CALIB (Sked or Unsked).

If more than 1 hour is required to deliver a part to maintenance, the item of GSE is reported NORS, transaction code 22, from the time the demand was placed on the supply activity, by the material control work center. Cannibalization is considered a supply action; therefore, an item of GSE is reported NORS during the time a replacement part is being removed from another item of GSE. A NORS condition does not imply that routine upkeep (painting, corrosion control, washing, etc.) cannot be performed on the item.

An item of GSE not usable solely because of a deficiency of support facilities is reported NOR Facilities, transaction code 21. NOR Facilities is not used when an item of GSE is NOR for any other reason.

Block 10–Work Unit Code. The work unit code that identifies the system or subsystem which caused the item of GSE to be NOR is entered in this block. A discrepancy must cause an item of GSE to be NORM or NORS before a work unit code is entered in this block. A maximum of three work unit codes may be entered in this block. These codes are listed in order according to required fix times, with the system or subsystem that causes the item to be NOR the longest period of time listed first.

GSE cards reporting NOR data are closed out when the item becomes OR, the item becomes NOR for another reason, or at the end of the day (2400). (See fig. 2-3.)

The closeout time is entered in block 6 (End) in hours and minutes. The begin time is subtracted from the end time and the difference is entered in block 6 (Diff). This elapsed time is converted to hours and tenths and entered in block 6 (Total). Located near the center of the GSE card is a tenths of hour key to assist in converting minutes to tenths of an hour.

A separate card is completed each day that a NOR condition exists, including weekends and holidays, and for each individual item of GSE by serial number. It is not possible to summarize more than one GSE transaction on any one card, and one card cannot account for more than a 24-hour period. Figure 2-4 shows a GSE data card reporting a NORAIM (unscheduled) condition carried over from the previous day.

The entries in blocks 8 (NOR transaction) and 10 (WUC) on this card are the same as on the closed out card. Block 5 (transaction date) contains the new Julian date. Block 6 (transaction time) is 0000 (begin).

If the closeout was effected because the item of GSE became NOR for another reason or the item became OR, the card is closed out as shown in figure 2-5.

Blocks 5, 6, 8, and 10 are completed as previously discussed for the beginning of the NOR condition.

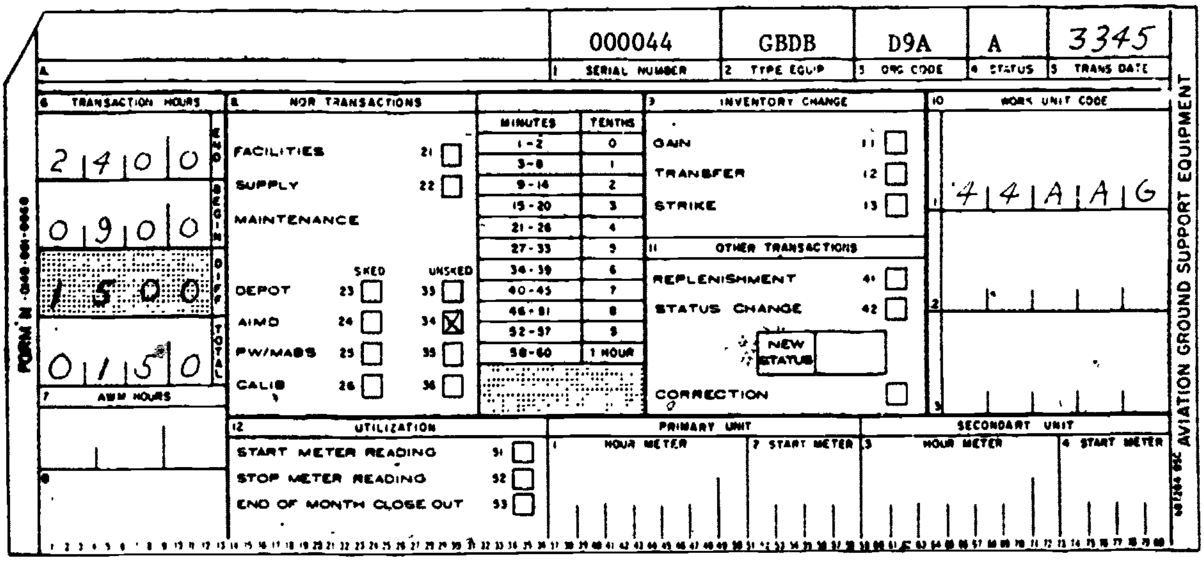


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Figure 2-3.—GSE data card reporting NORAIM (unscheduled) condition, end of day closeout.

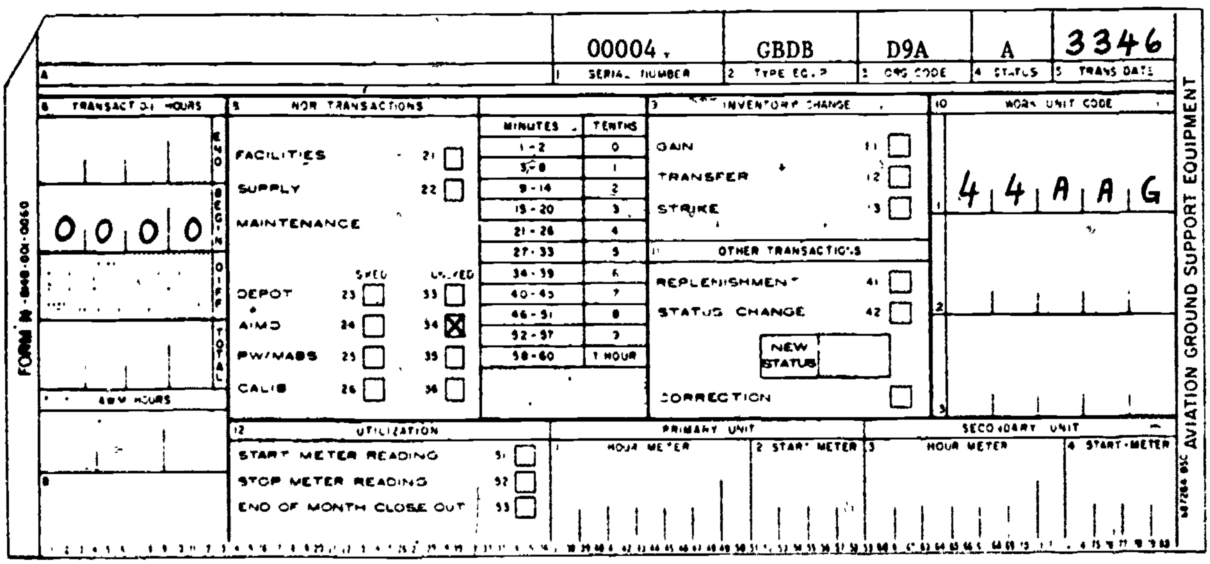

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Figure 2-4.—GSE data card reporting a NORAIM (unscheduled) condition carried over from the previous day.

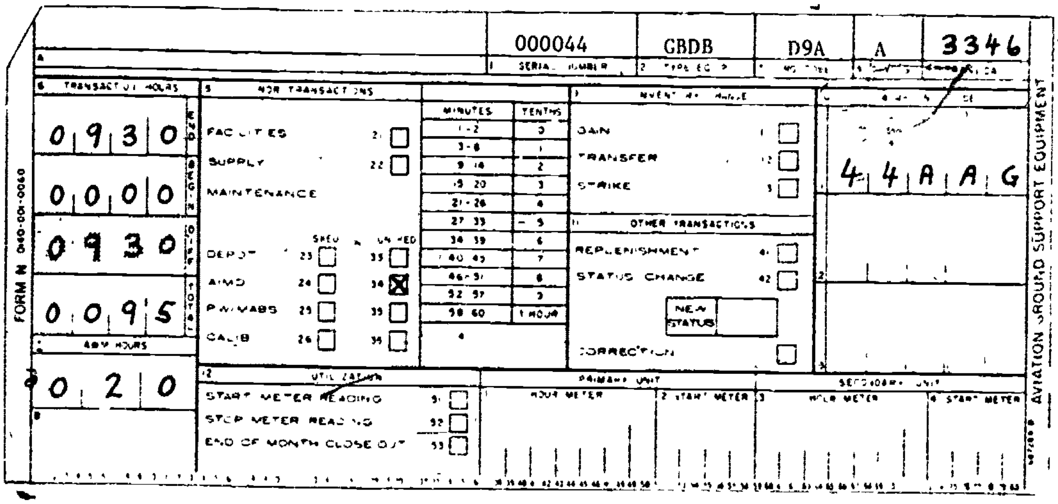

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Figure 2-5.—GSE data card reporting the end of a NORAIM (unscheduled) condition.

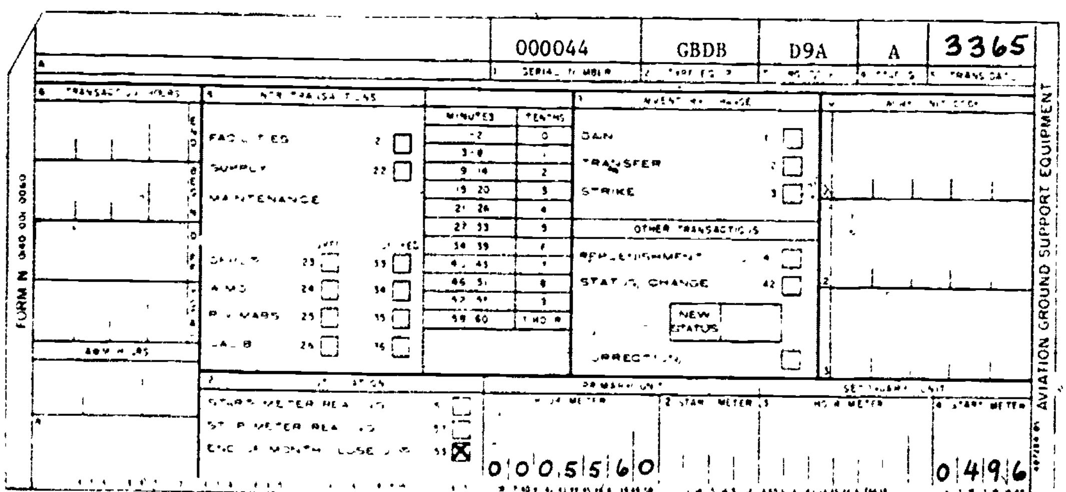

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Figure 2-6.—GSE data card reporting utilization data.

Enter in block 6 (end) the closeout time in hours and minutes. Subtract begin time from end time and enter the difference in block 6 (diff). Convert the elapsed NOR time to hours and tenths and enter in block 6 (total). Enter in block 7 (AWM hours) in hours and tenths that portion of the total NOR time during which the item of GSE was NORM and no work was being performed on the item.

If the closeout was effected due to the item becoming NOR for another reason, a new card must be initiated, as previously discussed for the beginning of a NOR condition, reflecting the new NOR reason in block 8 and the transaction date in block 5. Block 6 (transaction time) reflects a begin time of 1 minute later than the closeout time on the previous card.

Utilization Reporting

A GSE card is used to report utilization (hours/starts/cycles) for all items of GSE that are reflected in the master file at the end of the month. GSE utilization is reported the last day of each month on those units in the custody of each reporting custodian. GSE on sub-custody to squadrons or other activities remains the responsibility of the reporting custodian. Designated personnel responsible for GSE, within the activity having sub-custody, compile the utilization data on GSE cards and forward these cards to the reporting custodian on the last day of the month.

All utilization data reported is cumulative meter or logbook hours/starts/cycles since new or since overhaul. The utilization for GSE not equipped with a meter, or if the meter is broken, is reported as cumulative logbook hours.

Prepunched/preprinted cards are usually used for utilization reporting. Figure 2-6 illustrates a GSE card reporting utilization data. Completion of the card blocks is explained in the following paragraphs.

Block 5—Transaction Date. The Julian date for the last day of the month for which the card is submitted is entered in this block.

Block 12—Utilization. A checkmark is entered in the box opposite End of Month Close Out (transaction code 53). The hours being reported on the prime unit of GSE are entered in block 12.1 (Hour Meter). The cycles/starts being reported on the prime unit are entered in block 12.2 (Start Meter). If the item of GSE being reported has a secondary unit, the hours for the secondary unit are entered in block 12.3 and the cycles/starts in block 12.4

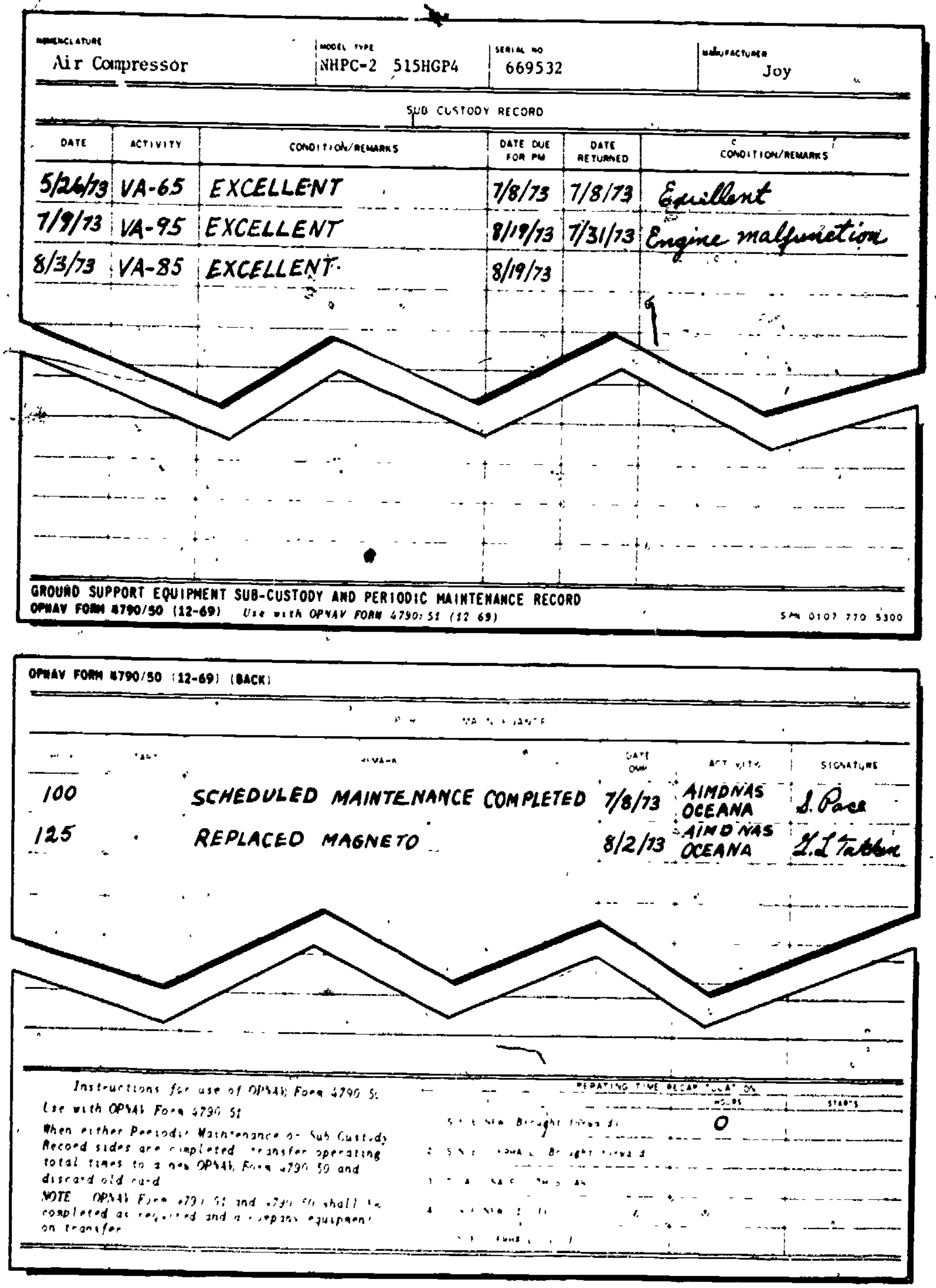
When the hour/cycle/start meter becomes inoperative or completes its cycle, a prepunched/preprinted GSE card must be completed. In this case, the Transaction Date (block 5) is the Julian date on which the meter becomes inoperative or completes its cycle. A checkmark is placed in the box opposite Stop Meter Reading (transition code 52). The total cumulative meter hours/cycles/starts since new or overhaul at the time the meter becomes inoperative or completes its cycle is entered in block(s) 12.1, .2, .3, or .4 as appropriate.

When the hour/cycle/start meter is replaced or begins a new cycle, a prepunched/preprinted GSE card must be completed. The Transaction Date (block 5) is the Julian date on which the meter is replaced or begins its new cycle. A checkmark is placed in the box opposite Start Meter Reading (transaction code 51). The total cumulative hours/cycles/starts registered on the new meter or the meter that has begun a new cycle is entered in block(s) 12.1, .2, .3, or .4, as appropriate.

From the foregoing it can be seen that when a meter becomes inoperative or completes its cycle, or a new meter is installed or begins a new cycle, the submission of two GSE cards is required—one card reporting transaction code 52 and the other reporting transaction code 51. These cards are required in order to update the data bank.

Correction Reporting

In the event that erroneous information enters the system either through faulty documentation or a data processing error, it is important that the erroneous information be extracted from the data bank and the correct information substituted for it. This is accomplished by the submission of a correction card which is identical to the erroneous card in every respect except for a 1 entered in the box opposite Correction in block 11. The two incorrect cards will cancel one another. A second card containing the correct information



NOMENCLATURE	MODEL TYPE	SERIAL NO	MANUFACTURER
Air Compressor	NHPC-2 515HGP4	669532	Joy

SUB CUSTODY RECORD

DATE	ACTIVITY	CONDITION/REMARKS	DATE DUE FOR PM	DATE RETURNED	CONDITION/REMARKS
5/26/73	VA-65	EXCELLENT	7/8/73	7/8/73	Excellent
7/9/73	VA-95	EXCELLENT	8/19/73	7/31/73	Engine malfunction
8/3/73	VA-85	EXCELLENT	8/19/73		

GROUND SUPPORT EQUIPMENT SUB-CUSTODY AND PERIODIC MAINTENANCE RECORD
OPNAV FORM 4790/50 (12-69) *Use with OPNAV FORM 4790/51 (12-69)*
S/N 0107-770-5300

OPNAV FORM 4790/50 (12-69) (BACK)

		REMARKS	DATE COMP	ACTIVITY	SIGNATURE
100		SCHEDULED MAINTENANCE COMPLETED	7/8/73	AIMDNAS OCEANA	S. Pace
125		REPLACED MAGNETO	8/2/13	AIMD NAS OCEANA	L. L. Tabor

Instructions for use of OPNAV Form 4790/50
Use with OPNAV Form 4790/51
When either Periodic Maintenance or Sub Custody Record sides are completed, transfer operating total times to a new OPNAV Form 4790/50 and discard old card.
NOTE: OPNAV Form 4790/51 and 4790/50 shall be completed as required and accompany equipment on transfer.

OPERATING TIME RECAPITULATION

	HOURS	STARTS
Brought forward	0	

AS.677

Figure 2-7.—Sub-custody and periodic maintenance record.

is then submitted with a 2 entered in block 11 opposite Correction.

GSE MAINTENANCE AND CUSTODY RECORDS

To insure an accurate maintenance history of each item of ground support equipment for which Maintenance Requirements Cards are provided, three records must be maintained–the Support Equipment Sub-Custody and Periodic Maintenance Record, the Support Equipment Custody and Maintenance Record, and the Ground Support Equipment Daily Record.

Sub-Custody and Periodic Maintenance Record

The Sub-Custody and Periodic Maintenance Record, OpNav Form 4790/50, illustrated in figure 2-7, is maintained on each applicable unit of support equipment by the supporting or using activity.

The front of the form is used to record basic item identification and sub-custody information. The back of the form is used to record operating and periodic maintenance information. It also contains instructions for use of the form. Entries are made on the periodic maintenance record by the activity having prime custody of the equipment, and who loaned such equipment on a sub-custody basis.

For the most part, the column headings on this form are self-explanatory. On the sub-custody record in the column titled Date Due for PM (periodic maintenance) enter the date on which scheduled maintenance is due. The equipment is returned to the prime custodian for the accomplishment of periodic maintenance.

On the periodic maintenance record, the columns titled Hours and Starts are used to record operating data. Some types of support equipment have hour meters to register operating time, and some have start meters to register the number of starts since, in some cases, starts are more significant from a usage standpoint than actual running or operating time. Other types of support equipment have no provisions for registering operating time; therefore, the user of the equipment must keep account of daily usage.

Custody and Maintenance Record

The Custody and Maintenance Record, OpNav Form 4790/51, illustrated in figures 2-8 and 2-9, is maintained by the supporting or using activity accountable for and having prime custody of each unit of equipment. Entries on this form are made, as required, in order to provide a maintenance history. A record is maintained on each unit of support equipment until the unit is retired.

The front of this form is divided into four major sections. The first section is used to record acceptance information; the second is a custody and transfer record; the third is the rework record; and the fourth section is the preservation/depreservation record.

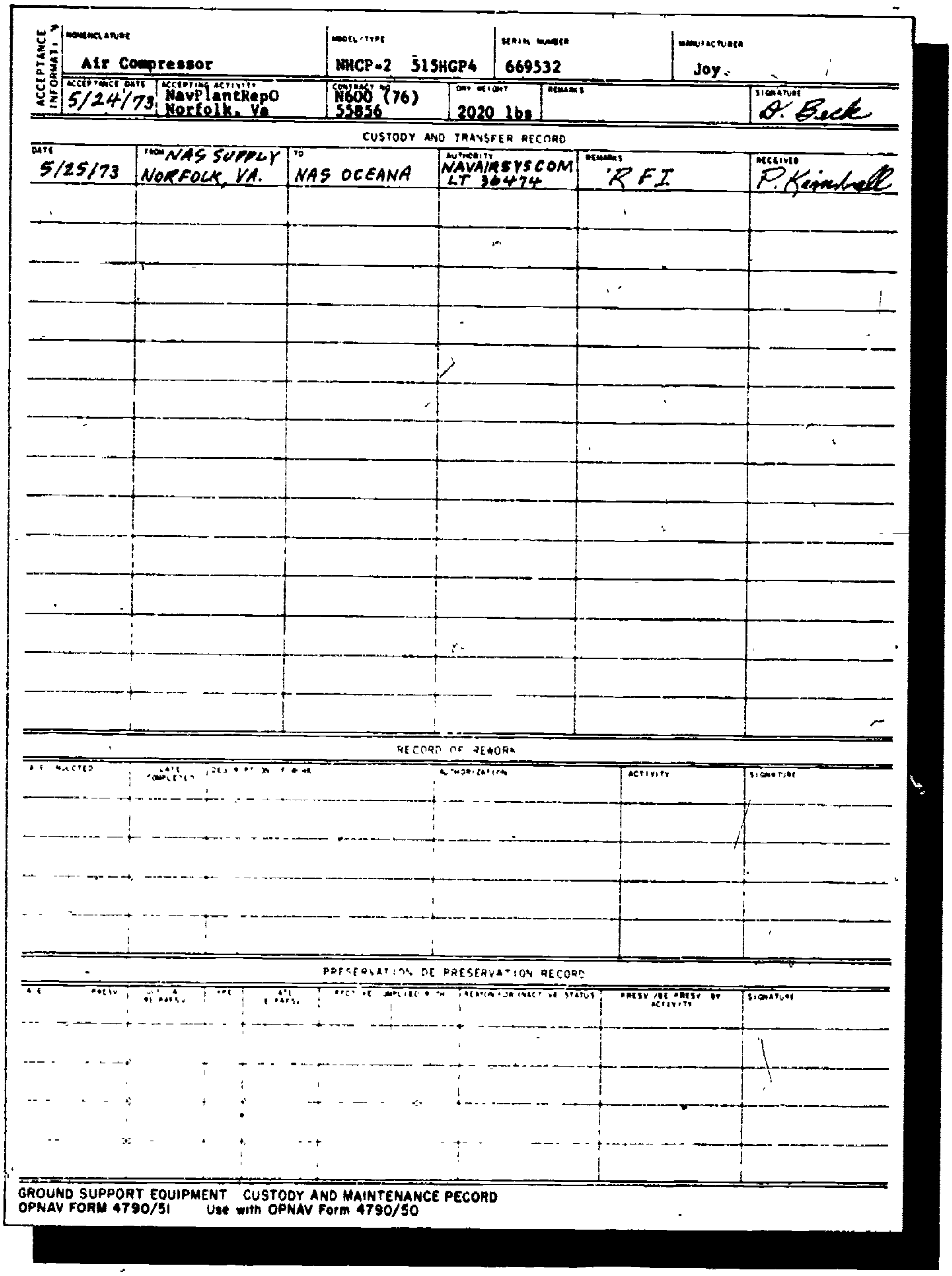
The back of this form is divided into two major sections. The first section is used to record replacement of major parts, and the second is used to record the incorporation of technical directives.

Daily Record

A Ground Support Equipment Daily Record, OpNav Form 4790/52, illustrated in figure 2-10, is maintained by the using activity for each item of support equipment. This form is kept with the equipment in a suitable container. Entries are made to reflect all preoperational (daily) maintenance performed. Additionally, this form is used to record all operating times for units not equipped with meters. Operating times are logged as hours/starts/miles, as appropriate.

These records are maintained on a monthly basis. At the beginning of each month, or upon the completion of a card (if the completion is first), the activity having primary custody of the equipment issues a new card for each item of GSE. These new cards are exchanged for the old/completed cards. The old/completed cards are retained on file for 3 months, at which time they are destroyed if no longer needed.

The current Support Equipment Sub-Custody and Periodic Maintenance Form and the Support Equipment Custody and Maintenance Record accompany the equipment when transferred between activities on a permanent basis. All three forms are available through local supply activities as listed in NavSup Publication 2002, Section II.



ACCEPTANCE INFORMATION

NOMENCLATURE	MODEL/TYPE	SERIAL NUMBER	MANUFACTURER
Air Compressor	NHCP-2 515HGP4	669532	Joy

ACCEPTANCE DATE	ACCEPTING ACTIVITY	CONTRACT NO	DRY WEIGHT	REMARKS	SIGNATURE
5/24/73	NavPlantRepO Norfolk, Va	N600 (76) 55856	2020 lbs		O. Beck

CUSTODY AND TRANSFER RECORD

DATE	FROM	TO	AUTHORITY	REMARKS	RECEIVED
5/25/73	NAS SUPPLY NORFOLK, VA.	NAS OCEANA	NAVAIRSYSCOM LT 36474	RFI	P. Kimball

RECORD OF REWORK

				ACTIVITY	SIGNATURE

PRESERVATION DE PRESERVATION RECORD

							PRESV/DE PRESV BY ACTIVITY	SIGNATURE

GROUND SUPPORT EQUIPMENT CUSTODY AND MAINTENANCE PECORD
OPNAV FORM 4790/51 Use with OPNAV Form 4790/50

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Figure 2-8.—Custody and maintenance record (front).

OPNAV FORM 4790/51 (BACK)

REPLACEMENT OF MAJOR PARTS RECORD

NAME OF PART	INSTALLATION DATA				REMOVAL DATA				JCN	ACTIVITY
	DATE	SERIAL NO	HOURS SINCE NEW	HOURS SINCE O.H.	DATE	SERIAL NO	HOURS SINCE NEW	HOURS SINCE O.H.		
MAGNETO-Y98ASZ	8/2/73	56432	0	0	8/2/73	56427	125	—	A903214489	AIMD, NAS OCEANA

TECHNICAL DIRECTIVES

[illegible]	STATUS	[illegible]	DESCRIPTION	COMPLIANCE		SIGNATURE
				ACTIVITY	DATE	
SEQ 1710	INC	R	INSTALLATION OF FOREIGN OBJECT DAMAGE CONTROL TIRES	AIMD, NAS OCEANA	8/2/73	J. Ingram

AS.679

Figure 2-9.—Custody and maintenance record (back).

NOMENCLATURE		MODEL/TYPE/EQUIP	SERIAL NO.	MANUFACTURER		CONTRACT NO.
AIR COMPRESSOR		NHPC-2	669532	JOY		N600(76)55856
INSPECTION PERFORMED (Inspector)		CUMULATIVE USAGE (To be recorded by Supervisor)				
		PRIMARY UNIT		SECONDARY UNIT		
DATE	SIGNATURE	HOURS/TENTHS	STARTS	HOURS/TENTHS	STARTS	SIGNATURE
8/3/73	S.D. Baker	4				C.E. Jones
8/4/73	C.A. Thomas	7				C.E. Jones

GROUND SUPPORT EQUIPMENT - DAILY RECORD - OPNAV FORM 4790/52 (12-69)
S/N-0107-770-5500

AS.680

Figure 2-10.—Daily record.

CHAPTER 3
PUBLICATIONS

The primary purpose of technical publications is to aid the technician in accomplishing assigned tasks. They are designed to communicate information and directions to him in a specific technical language. They are prepared by the manufacturer of specific equipment and by the Naval Air Systems Command or its field activities in accordance with specifications issued by NavAirSysCom. They set forth current, authoritative information concerned with material upkeep, check, test, repair, and operation in a manner to provide for optimum product performance. It is extremely important, and therefore mandatory, that all personnel responsible for the operation and maintenance of ground support equipment be thoroughly familiar with these publications and that they use the information contained therein in the daily execution of their technical tasks. The technician or mechanic can no longer properly perform all work without written technical aid. Modern technology is a constantly changing thing and demands continuous reference to and use of the approved technical publications.

Although some technical publications of interest to the ASE are issued by other Naval Commands, such as Naval Facilities Engineering Command and the Naval Sea Systems Command, the majority are issued by the Naval Air Systems Command. The publications issued by NavAirSysCom are known as aeronautic publications and are grouped into two major classes or groups–those issued in the form of MANUALS, and those issued in the form of LETTER MATERIAL.

When a new item of equipment is accepted by the Navy, manuals necessary to insure its proper operation and upkeep are prepared and made available to all activities using and/or maintaining the equipment. Supplemental information and other directive type publications that must be issued from time to time are issued in the form of letter material. Both manual and letter type publications may, on occasion, be properly referred to as directives. Broadly speaking, any communication which initiates or governs action, conduct, or procedures is a directive. Another term commonly used to identify manual and letter type publications is technical data.

As emphasized throughout this manual, all personnel of the ASE rating must use applicable technical publications in the performance of their duties. This chapter is devoted primarily to the type of information contained in various technical publications relative to the operation, servicing, and maintenance of support equipment.

All aeronautic publications, both manual and letter type, are assigned a title and code number. When they are available for issue, all publications, except Instructions and Notices, are listed in the Naval Aeronautic Publications Index. One of the requirements for advancement to ASE2 is to be able to use the different parts of this Index to locate and identify publications relative to the maintenance of support equipment. The contents and use of the Naval Aeronautic Publications Index are discussed in the first part of this chapter.

NAVAL AERONAUTIC PUBLICATIONS INDEX

A complete Naval Aeronautic Publications Index consists of several individual publications, each of which serves a specific purpose. They are identified as follows:

Navy Stock List of Forms and Publications, NavSup Publication 2002, Section VIII, Parts C and D (commonly referred to as the Numerical

Sequence List or Numerical Index).

Equipment Applicability List, NavAir 00-500A.

Aircraft Application List, NavAir 00-500B.

Directives Application List by Aircraft Configuration, NavAir 00-500C.

The content and purpose of each of these publications are discussed in the following paragraphs.

NAVAL STOCK LIST OF PUBLICATIONS AND FORMS (NUMERICAL INDEX)

NavSup Publication 2002 is a 13-section index of all the forms and publications used throughout the Navy and stocked by the Naval Supply Systems Command. Section VIII of this Stock List contains Naval Air Systems Command publications. This section is made up of four parts–A, B, C, and D. Parts A and B pertain to ordnance publications. Part C and Part D make up one part of the Naval Aeronautic Publications Index. Part C is the numerical listing of manual type aeronautic technical publications, and Part D is the numerical listing of letter type publications. These two parts–C and D–are referred to as the Numerical Sequence List or Numerical Index of the Naval Aeronautic Publications Index.

Part C (manual publications) is divided into subject matter groups, and all publications within a group are then listed in numerical order according to code number. For example, all manuals in the 00 series are listed first, followed by the 01, 02, 03, etc., through the 51 series. The listing includes the publication code number, stock number, title, date of the latest issue or revision, security classification, and requisition restriction code. In addition, each publication is identified as a basic issue or as a change to the basic issue. A listing of the general subject groups is shown in table 3-1.

Part D of Section VIII of the Stock List (letter type directives) is further divided into a number of subsections. Most of these subsections pertain to aircraft and are listed as Airframe Bulletins and Changes, Powerplant Bulletins and Changes. Accessories Bulletins and Changes, etc. The subsection which is of most interest to the ASE is the support equipment section. This subsection contains a listing of all Support Equipment Bulletins and Changes. The Bulletins and Changes are listed by publication number, title, security classification, and date of issue.

A table of contents and a general alphabetical cross-reference listing are provided in each Part (C and D) of the Index. In addition, instructions for using the Index are provided in Part C. Included in these instructions are the methods for procuring aeronautic publications, the forms and procedures required for ordering publications, and explanations of certain codes used in the Index.

The Numerical Index must be used to completely identify and, therefore, to order required publications. However, the other parts of the Index (discussed in the following paragraphs) must be used to determine what publications are available for a specific item of equipment and to check the applicability of publications to specific equipment.

When an applicable publication number is found in one of the other parts of the Naval Aeronautic Publications Index, it can be easily located in the Numerical Index. Here, it can be more completely identified as to title and nomenclature, stock number (for manual type publications), security classification, and any restrictions concerning the requisitioning of the publication. In addition, the date of the latest issue or revision of the publication is listed. This provides a means whereby the issue and/or revision dates of the publications on hand in an activity can be checked against the dates listed in the current issue and supplement (discussed later) of the Numberical Index, thus assuring that the publications are current. Also, the basic issue of a publication and each change to that publication are identified by different stock numbers and therefore may be requisitioned separately. However, a requisition for the basic issue automatically includes all current changes.

EQUIPMENT APPLICABILITY LIST

Basically, the Equipment Applicability List, NavAir 00-500A, is a cross-reference index

Table 3-1.—General subject classification numbers for manual type publications

General	00
Aircraft	01
Powerplants (02A Reciprocating engines, 02B Jet engines, 02F Rocket engines)	02
Accessories	03
Hardware and Rubber Material	04
Instruments	05
Fuels, Lubricants, and Gases	06
Dopes and Paints	07
Electronics	08 & 16
Instructional Equipment and Training Aids	09 & 28
Photography	10
Aviation Armament	11
Fuel and Oil Handling Equipment	12
Parachute and Personal Survival Equipment	13
Hangars and Flying Field Equipment	14
Standard Preservation and Packaging Instructions	15
Machinery, Tool, and Test Equipment	17 & 18
Ground Servicing and Automotive Equipment	19
Descriptive Data Sheets for Aviation Support Equipment	20
Chemical Equipment	24 & 39
Meteorology	50
Ship Installations	51

listing of NavAir manual type publications according to model/type part number. Since this Index contains several thousand entries, one document would be very cumbersome to use. For this reason, this Index is divided into several volumes. At the time of this writing, there are seven volumes. Each of the first six volumes contains 400 pages and Volume 7 contains the remaining entries. With the exception of several small sections in the first part of Volume 1, the Equipment Applicability List is one continuous index of model/type part numbers listed in strict alphanumerical sequence. In addition to an Introduction, the other sections in the first part of Volume 1 pertain primarily to manuals for aircraft, weapons systems, and aircraft engines. Therefore, the publication numbers are listed according to aircraft, aircraft engine, and weapons system designation. Of these sections, the one pertaining to Allowance Lists is most important to the ASE. Allowance Lists are discussed later in this chapter.

The format of the alphanumerical listing is illustrated in figure 3-1. Specific examples of model/type part numbers pertaining to support equipment were selected to illustrate some of the various codes and abbreviated statements used throughout the Index. These entries are discussed in the following paragraphs. A complete list with explanations of all codes and statements used in the Index is contained in the Introduction, located in the first part of Volume 1. This Introduction also contains other valuable information concerning the use of the Index. It is important that all users of this Index thoroughly study this section and become familiar with its contents.

NOTE: It must be emphasized that the entries in figure 3-1 were selected to illustrate the format and use of the Equipment Applicability List. Although the information concerning these entries was current at the time of this writing, all or any part of it is subject to change from time to time. Therefore, the latest edition and supplement (discussed later) of the Equipment Applicability List must be consulted in all cases.

The column headings of the Equipment Applicability List consist of two lines. (See lines (1) and (2) of figure 3-1.) Line (1) pertains to

Line	MODEL/TYPE PART NO.	VENDOR	NOMENCLATURE / TECH DATA NO.	NEXT HIGHER ASSEMBLY TYPE	TECH DATA STK NO.	SUPPL AV SC	REMARKS	SUPPL PART NO., DATA
(1)	MODEL/TYPE PART NO.	VENDOR	NOMENCLATURE	NEXT HIGHER ASSEMBLY		SUPPL	REMARKS	SUPPL PART NO., DATA
(2)			TECH DATA NO.	TYPE	TECH DATA STK NO.	AV SC		
(3)	AERO46A	98296	WEAPONS LOADER					
(4)			19-15BE-3	05	0819-008-9000	A		
(5)			19-600-65-6-1	37	0819-042-5000	A		
(6)	AHT63	82386	HYD TEST STAND					
(7)			17-15BF-39	15	0817-057-6000	A		EQUAL TO 64A99E1
(8)			17-600-23-6-1	37	0817-110-8500	A		
(9)			17-600-23-6-4	37	0817-110-9000	A		
(10)	AN6295-1	99999	REGULATOR					
(11)			03-10ABC-504	10	0803-152-5000	A		
(12)			03-30ELE-501	10	0803-360-2000	A		
(13)	A840-0031	82386	TEST STAND					
(14)			17-15BF-39	15	0817-057-6000	A		EQUAL TO AHT63
(15)	B007	36659	PLATFORM SERVICING					
(16)			19-15-21	12	0819-001-2000	A		SUPS COMPL 918104-1
(17)	K54402	88276	DOLLY					
(18)			19-15A-41	04	-- --			
(19)	378782	70210	GAS TURBINE PLUMBING					
(20)			19-105B-15	10	0819-035-4500	A		
(21)	569180	55168	FILTER ASSY					
(22)			UNDER REVIEW		-- --			
(23)	63A109J1	99999	ULTRASONIC CLEANER					
(24)			UNDER PROCUREMENT	15	-- --			
(25)	64A99E1	82386	TEST STAND					
(26)			17-15BE-39	15	0817-057-6000	A		EQUAL TO A840-0031
(27)	682570-1	99193	REFRIGERATION UNIT		378782			
(28)			19-105B-15	10	0819-035-4500	A		
(29)	918104-1	36659	PLATFORM SERVICING					
(30)			19-15-21	12	0819-001-2000	A		SUPSD COMPL BY B007

NOTE: The sequential line numbers--(1), (2), (3), etc.--in the left margin are for explanation purposes only.

AS.668

Figure 3-1.—Format of Equipment Applicability List, NavAir 00-500A.

information about the specific item of equipment. This information is listed under the appropriate headings in the line corresponding to the model/type part number, as shown in lines (3), (6), (10), (13), etc. The headings in line (2) pertain to the status of publications for each model/type part number. This information is listed on a line, or lines, under the information concerning the model/type part number. For example, the information listed in lines (4) and (5) corresponds to the headings in line (2) and pertains to the publications for the AERO46A Weapons Loader listed in line (3).

The type of information listed under each column heading is discussed in the following paragraphs.

MODEL/TYPE PART NO.–The identifying number of the specific item of equipment or system is listed in this column. Some items of equipment are identified by more than one part number. In these cases, all of the identifying numbers are listed with each number in alphanumerical sequence. For example, the numbers listed in this column on lines (6), (13), and (25) are different numbers for the same hydraulic test stand. AHT63 is the model number, A840-0031 is the manufacturer's part number, and 64A99E1 is the Navy part number.

VENDOR–The appropriate five-digit code which identifies the contractor or government agency that manufactured the item of equipment is listed in this column. Cataloging Handbooks H4-1 and H4-2 should be referred to for the interpretation of these codes. If a vendor code is not firmly established at the time the item of equipment is listed in the Index, the code 99999 is inserted. (See lines (10) and (23) in figure 3-1.) As these vendor codes are established, appropriate changes will be made in subsequent issues of this Index.

NOMENCLATURE–A brief description of the item of equipment is listed in this column. The examples (WEAPONS LOADER, HYD TEST STAND, etc.) illustrated in figure 3-1 are typical of the descriptions used throughout the Index.

NEXT HIGHER ASSEMBLY–In some cases, technical manuals are not required for a specific item of equipment because the necessary information is, or will be, included in the technical manual(s) for the next higher assembly. In these instances, the model/type part number of the next higher assembly is listed in this column. For example, the required information for the Refrigeration Unit listed in line (27) of figure 3-1 is included in the publication for the Gas Turbine Plumbing listed in line (19). As illustrated in line (27), the part number (378782) of the Gas Turbine Plumbing is listed in the NEXT HIGHER ASSEMBLY column.

SUPPL REMARKS (Supplemental Remarks)–An entry is included in this column if the number listed under the MODEL/TYPE PART NO. is supplemented with other part number information. The descriptive statements EQUAL TO in lines (6), (13), and (25), SUPS COMPL (supersedes completely) in line (15), and SUPSD COMPL BY (superseded completely by) in line (29) are examples of the entries listed in this column. Other entries sometimes listed in this column are INTERCHANGEABLE, SUPSD PART BY (superseded partially by), and SUPS PART (supersedes partially).

SUPPL PART NO. DATA (Supplemental Part Number Data)–A part number listed in this column is associated with the statement listed in the SUPPL REMARKS column. Examples of this type entry are illustrated in lines (6), (13), (15), (25), and (29). Refer to the numbers listed in this column on lines (6), (13), and (25). As explained previously, these are different numbers for the same hydraulic test stand. Although there are three different numbers, only one is listed in each space. It should be noted, however, that regardless of which number the user of the Equipment Applicability List looks up first, he will be directed systematically through all three part numbers. For example, assume that the only number an ASE has available for this hydraulic test stand is 64A99E1. When he locates this number in the Index, he is referred to part number A840-0031. By locating this number, he is referred to AHT63. When he locates AHT63 he is referred again to the original part number, 64A99E1. This type arrangement is used throughout the Equipment Applicability List when two or more numbers are listed for the same item of equipment.

TECH DATA NO. (Technical Data Number)–The applicable current technical manual and all proposed technical manuals (those which have been numbered but have not been published) are listed in this column. The technical manuals are listed by code number as illustrated by all entries in this column of figure 3-1 with the exceptions on lines (22) and (24). (The numbering system (code numbers) for technical manuals is discussed later in this chapter.) If the technical manual numbers have not been assigned, or it has not been determined if technical manuals will be procured, or if coverage will not be contained in a NavAir technical manual, a qualifying statement is entered in this column. For example, the statement UNDER REVIEW, in line (22) means that the part number has been submitted to the Naval Air Technical Services Facility (NATSF) for possible action, but no decision has been made prior to the date of the current issue of the Index. The statement, UNDER PROCUREMENT, listed in line (24) indicates that publications are being procured for this item of equipment but the publication numbers have not been assigned. The Introduction in the first part of Volume 1 of the Index should be consulted for explanations of other qualifying statements used in this column.

TYPE–A code, which corresponds to the type of technical manual, is listed in this column. For example, the number 05 in line (4) is the code for Operation and Service Instructions Manuals, and the number 37 in line (5) is the code for Maintenance Requirements Cards for Ground Support. Since the use of these particular codes is limited to the Equipment Applicability List, a complete list of the different types of manuals and their corresponding codes is listed in the Introduction in Volume 1. The different types of technical manuals applicable to the maintenance of support equipment are discussed later in this chapter.

TECH DATA STK NO. (Technical Data Stock Number)–The National Stock Number for ordering the publication is listed in this column.

AV (Availability Code)–The letter "A" in this column indicates the technical manual is available and may be requisitioned from the supply system by using the applicable stock number. Before ordering, the Numerical Index, NavSup 2002, Section VIII, Part C, and its latest supplement should be checked for the complete publication title, date, and requisition restriction code. A blank space in this column indicates the technical manual is not available as of the date of the current Index and no attempt should be made to order this manual from the supply system.

SC (Security Classification)–Technical manuals listed are unclassified unless the letter C (Confidential) or the letter S (Secret) is listed in this space.

AIRCRAFT APPLICATION LIST

The Aircraft Application List, NavAir 00-500B, contains a listing of Naval Air Systems Command technical manuals grouped according to their application to an aircraft. The aircraft are arranged by model number and are grouped in series according to their mission (Attack Series, Cargo/Transport Series, Fighter Series, etc.). The applicable technical manuals are listed by code number under each model of aircraft. The manuals are grouped in numerical sequence according to the General Classification numbers listed in table 3-1. The groups include the 00, 01, 02, 03, 05, 11, 13, 08 & 16, 17 & 18, and 19 series. Groups 00 (Allowance Lists), 17 & 18 (Machinery, Tool, and Test Equipment), and 19 (Ground Servicing and Automotive Equipment) are of most interest to the ASE.

The Aircraft Application List is especially useful for determining what manuals are available for a particular model aircraft. A listing of basic numbering categories is provided in the first few pages of the list. This listing may be used in determining the general type of equipment covered in the publication. For determining the specific item of equipment covered by a publication and the title of the publication, reference should be made to Part C of Section VIII in NavSup 2002.

DIRECTIVES APPLICATION LIST

Basically, the Directives Application List by Aircraft Configuration, NavAir 00-500C, is a listing of the active Naval Air Systems Command letter type technical directives (Bulletins and Changes) with respect to their applicability to an aircraft. It serves the same purpose for letter type technical directives as the Aircraft Application List does for technical manuals. The applicable technical directives are listed, by number, under each configuration of aircraft model. (NOTE: Configuration refers to modifications made to a basic aircraft model. For instance, A-4A, A-4B, TA-4F, etc., are all different configurations of the A-4 aircraft model.)

The directives are also grouped according to type under each configuration of aircraft model. The types of directives consist of Airframe Bulletins and Changes, Accessory Bulletins and Changes, etc. Among these types are Support Equipment Bulletins and Changes. As indicated, these support equipment directives are applicable to specific aircraft configuration(s). Such directives may involve the modification of the aircraft to accommodate certain test or other type support equipment, the modification of an item of support equipment for a particular configuration of aircraft model, or the modification of an item of special support equipment for a particular aircraft configuration.

A "General" Series is included in the last part of NavAir 00-500C. This section consists of those technical directives which are not limited to any specific aircraft but may be pertinent to equipment used in conjunction with all or, at least, several aircraft models. Like the preceding sections of this Index, the listings of directives in the General section are grouped according to type. Included are listings of Support Equipment Bulletins and Changes. As indicated previously, these directives are of a general nature and often involve improvement in performance, reliability, and/or safety of the specific item of equipment. For example, Support Equipment Change 1487 is listed in this section. This directive pertains to the NHS Hydraulic Power Supply Cart and involves modifications to improve reliability and decrease service maintenance on this item of equipment.

NOTE: Bulletins and Changes are discussed in more detail later in this chapter.

UPDATING THE INDEX

As indicated by the previous discussions, the different Lists of the Naval Aeronautic Publications Index provide various cross-reference lists whereby technicians and mechanics can locate and identify available technical publications applicable to specific items of equipment. The Index has undergone many changes to improve this system of indexing technical publications. Although the Equipment Applicability List, NavAir 00-500A, has been a vital part of the Index for several years, it has recently undergone a major revision which is reflected in the previous discussion. The listing of each change to manual type publications separately under different stock numbers is a recent change to Part C of the Numerical Index. Explanations of such changes are included in the introductory pages of the affected List. Therefore, when new issues of the lists are received, the introductory pages should be checked thoroughly for any changes that may have been incorporated.

The publications listed in the Index continually change. New equipment requires new publications. Old and obsolete equipment is retired and the applicable publications are canceled. Changes to equipment require additional publications and/or changes and revisions to existing publications. Therefore, some means must be provided to update the Naval Aeronautic Publications Index. To accomplish this, each List of the Index is updated at regular intervals by the issuance of a new List. In addition, some of the Lists are kept current by the periodic issuance of supplements between issues of the complete List. The methods used to update each List are discussed in the following paragraphs.

NOTE: The following information concerning the dates and intervals for the issuance of new Lists and supplements was current at the time of this writing. However, these dates and intervals have changed from time to time in the past. Therefore, the introductory pages of each new basic List and supplement should be checked for any changes of these dates and intervals.

The Numerical Sequence List (Parts C and D of NavSup Publication 2002) is issued annually. The effective date of each new issue is 1 September. A separate supplement for each Part is issued bi-monthly–November, January, March, May, and July. These supplements are cumulative; that is, all material from the preceding supplement is incorporated into the latest supplement. For example, the July supplement lists all publications that were issued, revised, or canceled since the issuance of the May supplement plus all of the publications that were listed in the four preceding supplements. Therefore, not more than one supplement is in effect for each Part (C and D) at any given time. Naturally, the reissue of the basic List cancels the outstanding supplement.

The publications are listed in the supplement in a manner similar to that of the corresponding Part (C and D) of the basic List. That is, the items in the supplement for Part C are listed in publication number sequence in accordance with the general subject groups shown in table 3-1. New, revised, and canceled publications are all listed together in numerical sequence.

The supplement for Part D is divided into two sections. The first section lists new and revised publications in a manner similar to that of the basic List. The second section lists all canceled publications in the same format as the first section.

The Equipment Applicability List, NavAir 00-500A, is issued annually, effective 1 November. Supplements are issued quarterly–February, May, and August. The format of the supplement is the same as that of the basic List with the addition of a column which indicates whether the listed Model/Type/Part Number is new (N), changed (C), or deleted (D). Like the supplements for the Numerical Sequence List, these supplements are also cumulative.

The remaining parts of the Naval Aeronautic Publications Index are issued semiannually. The Aircraft Application List, NavAir 00-500B is issued in March and September; the Directives Application List by Aircraft Configuration, NavAir 00-500C, is issued in January and July.

PUBLICATIONS NUMBERING SYSTEM

Code numbers are assigned to all publications in order that they may be identified, indexed, and filed. A knowledge of the numbering systems used will enable the ASE to locate any desired information with a minimum of effort. A brief explanation of the coding of publications listed in the Index is presented in the following paragraphs.

Manuals

Code numbers assigned to manuals consist of a prefix and a series of three parts. All manual type publications are listed in the Index with the prefix NA. This is the shortened form for NavAir and identifies those publications originated by the Naval Air Systems Command. However, the prefix NW appears on some of the older publications. This is the shortened form for NavWeps and indicates those publications originated by the Bureau of Naval Weapons before it became the Naval Air Systems Command. When these publications are revised the prefix will be changed to NA.

The three parts which make up the remaining portions of the number indicate the following:

Part I is a two-digit number that indicates the general subject classification of the equipment covered by the publication. Table 3-1 lists the

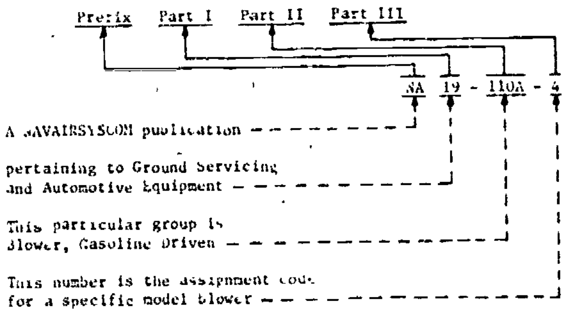

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Figure 3-2.—Identification and decoding of manual publication code number.

general subject categories and the appropriate two-digit numbers.

Part II of the publication code number consists of numbers and/or numbers and letters and indicates the specific class, group, type, or model and manufacturer of the equipment. The subject breakdowns of the 17 and 19 series are listed in table 3-2.

Part III consists of a number or numbers which designate a specific manual. For some manuals, this number designates a specific type of manual; however, for those pertaining to support equipment, this part is assigned in numerical sequence and has no reference to the type of manual.

Figure 3-2 illustrates the identification and decoding of a complete manual publication number.

Letter Type Material

There are two numbering systems used to identify letter type publications pertaining to support equipment. They are as follows:

1. Numbered in consecutive order according to specific application. For example, Support Equipment Change 590 is the 590th change that has been issued pertaining to support equipment. The changes pertaining to all support equipment are grouped together and numbered in sequence. Bulletins are numbered in the same way; however, those pertaining to specific items of auxiliary power servicing equipment are numbered separately by each item of equipment.

Table 3-2.—Subject breakdown of Series 17 and 19 manual type publications

17	**Series - Machinery, Tools, and Test Equipment**
17-1	Shop and Warehouse Machinery, Tools and Equipment General.
17-5.	Shop and Warehouse Machinery, Powered Tools and Equipment.
17-10.	Shop and Warehouse Machinery, Powered Tools and Equipment.
17-15.	Laboratory and Shop Test and Inspection Equipment.
17-20.	Instrument Calibration Procedures.
17-25.	Measurement System Operation Procedures.
17-30.	Cross-Check Procedures.
17-35.	Miscellaneous Calibration Procedures.
17-600	Ground Support Maintenance Requirements Cards.
19	**Series - Ground Servicing and Automotive Equipment**
19-1	General.
19-5	Oxygen Equipment.
19-10.	Airfield Lighting Equipment.
19-15.	Platforms and Scaffolds.
19-20.	Portable Shop Equipment.
19-25.	Fire Trucks, Miscellaneous Trucks and Trailers.
19-30.	Field Starters (Mobile).
19-35.	Air Compressors (other than for Power Plants).
19-40.	Tractors and Aircraft Towing.
19-45.	Mobile Electric Power Plants.
19-50.	Generators for Other Than Power Plants.
19-60.	Portable Heaters and Coolers.
19-65.	Pressure Controls.
19-70.	Aircraft Hydraulic Jacks.
19-75.	Generator Skid or Trailer Mounted (Gas Nitrogen).
19-80.	Motorized Material Handling Equipment.
19-105	Gas Turbine Compressors and Power Units and Enclosures.
19-110A . . .	Blower, Gasoline Driven.
19-600	Ground Support Maintenance Requirements Cards.

2. Numbered in consecutive order according to subject matter. This method covers all Naval Air Systems Command Instructions and Notices. An example is NavAir Instruction 10340.1. The number 10340 indicates the general subject of the instruction, and the .1 indicates it is the first instruction issued by the Naval Air Systems Command on that particular subject. Notices carry the general subject number only, and do not carry a point number (i.e., .1).

NOTE: Instructions and Notices are not listed in the Naval Aeronautic Publications Index.

SECURITY OF CLASSIFIED PUBLICATIONS

The Navy Supplement to the DOD Information Security Program, OpNav Instruction 5510.1 (Series), issued by the Chief of Naval Operations, is the basic security directive relating to safeguarding classified information. Its provisions apply to all military and civilian personnel and all activities of the Naval Establishment.

The manual contains detailed instructions for classifying, marking, and handling classified information, and for access to an authorized disclosure of the information.

The ASE, from time to time, has occasion to use classified publications relating to the performance of his work. Before he accepts such publications he must be cleared to the appropriate degree to handle this classified matter. It is then mandatory that he have a knowledge of and abide by the instructions in the Security Manual pertaining to handling classified material.

Publications listed in the Numerical Index (Parts C and D of Section VIII of NavSup Publication 2002) are unclassified unless otherwise marked "1" (confidential) or "4" (secret) in the column headed "PS" (physical security). As explained previously, classified publications listed in the Equipment Applicability List, NavAir 00-500A, are identified by the letter C (confidential) or the letter S (secret) in the column headed "SC" (security classification). Classified publications are identified in the same manner in the supplement to the respective Lists.

PROCUREMENT OF PUBLICATIONS

There are four main methods of procuring publications relating to the operation and maintenance of ground support equipment.

The first method is initial outfitting. The Naval Air Technical Service Facility (NATSF) automatically provides the prospective commanding officer of a newly commissioned or reactivated ship, station, or activity an outfitting of general aeronautic publications.

Specific publications obtained under Aeronautic Technical Publications Outfitting Allowance constitutes another prime source of publications. Initial distribution is provided by NATSF to a newly commissioned or reactivated activity. When supported activities change mission of aircraft, support equipment requirements often change. Such changes may require a different set of publications. Upon such a change, an Aeronautic Technical Publications Outfitting Allowance, applicable to the model designation of the aircraft and equipment involved, may be obtained by letter request from the commanding officer to NATSF.

The third source of publications is through inclusion in automatic distribution lists. The NATSF normally provides for the issue of certain future issues of new and revised publications directly to affected activities. Activities desiring to receive future issues of new and revised publications must submit a "Mailing List Request for Aeronautic Publications" (currently Form NavAir 5605/3) to the Commanding Officer, NATSF. Personnel of the support equipment work center desiring to receive particular issues, reissues, and revisions of publications should make their requirements known to the technical library so that they may be included on the next submission of Form 5605/3.

The fourth method of procuring publications is by ordering individual publications direct. Manual type publications listed in Part C of the Numerical Index must be ordered on a Single Line Item Requisitioning System Document (DD Form 1348 or DD Form 1348m). Technical letter type publications listed in Part D of the Numerical Index must be ordered on DD Form 1149. The use of any of these three forms will not result in being placed on the distribution list to receive future issues or revisions of publications ordered.

Detailed information concerning the procurement of areonautic publications may be found in the Naval Aeronautic Publications Index.

MANUAL TYPE PUBLICATIONS

As shown in table 3-1, manuals are published in a number of different subject categories. Those of special interest to the ASE are the General Manuals (00 series) and Support Equipment Manuals (17 and 19 series). Certain manuals in other series may be used occasionally, but those listed here are of special importance to the Aviation Support Equipment Technician.

GENERAL MANUALS (00 SERIES)

As indicated by the title, this series of manuals includes information of interest to all naval aviation personnel. Included are three parts of the Naval Aeronautic Publications Index (00-500A, 00-500B, 00-500C described previously), NavAir Outfitting Lists and Allowance Lists, and Aviation Training Literature.

Outfitting Lists and Allowance Lists (00-35Q Series)

Aircraft maintenance support and repair parts for aircraft maintenance repair are listed in NavAir Initial Outfitting Lists and Allowance Lists. The equipment and parts listed in these publications are made available to aircraft operating and maintenance activities in accordance with assigned operational and maintenance responsibilities through appropriate applications of Allowance Lists and Outfitting Lists.

The Aeronautical Allowance List Program is designed to cover the various types of aircraft support equipment and repair parts considered to be required by maintenance activities.

Repair parts, nuts, bolts etc., are included in the publications identified as Initial Outfitting Lists. Maintenance support equipment items such as test stands, aircraft jacks, lubricating guns, wrenches, drills, compass testers, and voltmeters are included in publications identified as Allowance Lists.

These Lists are identified by Sections. Certain sections such as A, H, and K are issued as individual publications. Others such as B, R, and Z appear as a series of publications, each of which is applicable to a specific model of equipment, model of aircraft, or type of activity.

The ASE should be especially familiar with the following sections:

Section G Allowance List, General Support Equipment. This section lists general handtools, consumable support equipment, and installed shop equipment.

Section K, Allowance List for Naval Aeronautic Publications and Forms.

Section M Allowance Lists. These Lists include motor vehicles, maintenance parts, and tools.

Section Z Initial Outfitting Lists. These list peculiar repair parts for mobile electric powerplants, precision measuring equipment, and peculiar and common ground support equipment.

Allowance Lists and Outfitting Lists, in conjunction with the IMRL's (explained later in this chapter), consist of listings of the equipment and material (both expendable and accountable) necessary to place and maintain activities of the aeronautical organization in a material readiness condition. Allowances contained in these Lists are based on known or estimated requirements and on available usage data.

All Allowance List and Outfitting List code numbers include NA as a prefix (discussed previously) followed with 00-35Q plus the section identification letter and a dash number to identify a particular section or series. For example, a section Z Initial Outfitting List which contains a listing of spare parts for hydraulic test stands is numbered NA 00-35 QZ-39.

A program closely related to the Allowance Lists and Outfitting Lists is the Aircraft Maintenance Material Readiness List (AMMRL). This program provides for the development of data and documentation needed to determine and establish firm support equipment requirements and inventory control of aircraft maintenance support equipment. Within the AMMRL there are material readiness lists, which are discussed in the following paragraphs.

The Application Data Material Readiness List (ADMRL) is used to specify the requirements for each item of aircraft maintenance support equipment against each level of maintenance and selected ranges of each aircraft, engine, propeller, and system for which each item is needed. The initial ADMRL is established by NavAirSysCom. Through the use of data processing machines this data is used to develop Individual Material Readiness Lists.

The Individual Material Readiness List (IMRL) specifies items and quantities of ground support equipment required for material readiness of the aircraft maintenance activity to which the list applies. The list applies to an activity by name. The Naval Air Systems Command Representative is responsible for the preparation of the IMRL for each activity in his cognizant area. It is prepared by extracting from the AMMRL those applicable portions which pertain to the specific aircraft and maintenance material assignments of the activity for which the list is developed.

The IMRL should be continually reviewed and updated by each activity to support current and anticipated changes in ground support equipment requirements. Because the IMRL is continually reviewed and updated and approved by the cognizant command, it is the firm mandatory material readiness list of the activity to which the list applies.

Training Literature (00-80 Series)

This series of publications is issued by authority of the Deputy Chief Naval Operations (Air). Included are various Air Safety Pamphlets and General Aviation Training Publications. For example, NA 00-80T-96, Aircraft Support Equipment, General Handling and Safety precautions is one of the training manuals in this series.

SUPPORT EQUIPMENT MANUALS (17 AND 19 SERIES)

The 17 and 19 series of aeronautic technical manuals cover most types of support equipment. The manufacturer of each item of support equipment is required to furnish adequate instructions for operating the equipment and maintaining it throughout its service life. These manuals are prepared by the manufacturer and are issued under the authority of the Naval Air Systems Command. They are then official Navy publications.

Support Equipment Manuals contain descriptive data; detailed instructions for operation, servicing, inspection, maintenance, repair, and overhaul; and illustrated parts lists. All available Support Equipment Manuals are listed in the appropriate parts of the Naval Aeronautic Publications Index. NavAir 00-500A lists available manuals in reference to the model, type, and/or part number of the equipment. All available support equipment manuals are listed in numerical order (by publication number) in Part C, Section VIII of NavSup 2002. In addition, support equipment manuals are listed (by publication number only) in NavAir 00-500B in respect to their application to each model and configuration of aircraft.

If an item of support equipment is relatively simple, all the necessary instructions may be contained in a single manual. An example is NA 19-1-60, Operation, Service, and Overhaul Instructions with Illustrated Parts Breakdown for the Aircraft Universal Towbar Assembly. More complex equipment may require two or more manuals. For example, one manual may contain operation, service, and repair instructions, while the parts breakdown is contained in a separate manual.

Regardless of the number of manuals used to contain these instructions, the terms Operation, Service, and Repair (or Overhaul) are usually used in the title of these instructions. However, some of the newer models of equipment are provided with manuals for different levels of maintenance. In this case, the manuals are titled Maintenance Instructions, Organizational Level; Maintenance Instructions, Intermediate Level; and, if required, Maintenance Instructions, Depot Level.

Operation and Service Instructions

Although sometimes issued as separate manuals, Operation and Service Instructions for each item of support equipment are usually combined into one manual, and, as previously stated, are often combined with other instructions and the parts breakdown. Operation and Service Instructions include information necessary for organizational level maintenance.

Operation and Service Instructions Manuals are divided into sections. The manuals vary as to content and number of sections. The following is a description of the sections of a typical manual.

The first section usually contains an introduction and description of the equipment. This includes a general description and purpose of the item of equipment and brief descriptions of the major components. This section also usually contains a table of specifications. These specifications include such information as the weight and overall dimensions of the equipment; capacities of the fuel, oil, and cooling systems; the manufacturer, model, and type; and leading particulars of the engine, fuel system components, electrical systems components, transmissions, etc.

In some manuals section II contains a list of special tools required for the operation and service of the equipment.

The next section gives information pertaining to the preparation of the unit for use. Instructions necessary for unpacking and assembling the unit are covered in this section. This section also includes any adjustments and inspections that must be made and any safety precautions that must be observed before the unit is operated. Some manufacturers include in this section information concerning the preparation of the unit for storage and shipment.

The next section gives complete and detailed operating procedures for the equipment. Such information as the principles of operation, the purpose and use of the operating controls, and the purpose and use of the indicating instruments are included in this section. Normal operating pressures and temperatures are also given. Safety precautions in the form of WARNINGS and CAUTIONS are inserted in the appropriate parts of the text. These same methods of presenting safety precautions are used in all support equipment instructions manuals.

The service instructions are contained in the next section. These instructions pertain to periodic inspections, maintenance, and lubrication. Charts or tables are usually used to indicate the inspection interval of systems and components. (Periodic inspections of most support equipment are performed in accordance with Maintenance Requirements Cards which are used in conjunction with the information contained in this section. Additional information concerning these inspection procedures is contained in chapter 8 of this training manual.) The specifications for oil, fuel, lubricants, etc., are included in this section. Diagrams, showing the places to be lubricated, are also included. In some manuals, troubleshooting charts are included in this section. Other manuals contain an additional section for these charts.

The Operation and Service Instructions, as well as the other parts of support equipment manuals, usually contain illustrations to clarify the text. The illustrations provided in support equipment manuals are similar to those presented in this training manual; a wide variety of graphic presentations is utilized. These include pictorial drawings (isometric drawings and reproductions of photographs), orthographic drawings, and schematic and block diagrams. Combinations of these drawings and diagrams are utilized in some illustrations.

NOTE: For detailed information concerning different types of drawings and diagrams, including the definitions of terms used in conjunction with these graphic presentations, refer to chapter 6 of this manual and to Blueprint Reading and Sketching, NavPers 10077 (Series) which also illustrates many of the different symbols used on diagrams.

Repair or Overhaul Instructions

Information pertaining to Intermediate level maintenance of support equipment is usually issued as Repair or Overhaul Instructions. In some manuals this information is titled Maintenance Instructions and covers the repair and/or overhaul of the equipment.

The title of this type manual, or section of the manual, depends upon the type of maintenance that must be performed on the equipment. Some equipment simply requires repair and replacement of defective parts. Repair, as it applies to maintenance of aeronautical equipment, is the restoration of an item of equipment to an acceptable operating condition without complete disassembly and inspection. The maintenance information required for this type equipment is usually issued as Repair Instructions.

Some items of support equipment must be overhauled at regular intervals. Overhaul is the disassembly of an item of equipment as required to permit inspection of every component part Component parts which, upon inspection, will not meet requirements as set forth in applicable specifications are restored or replaced by new parts so that after reassembly and test, the equipment will meet the requirements set forth in the applicable specifications. Maintenance information of this type is generally issued as Overhaul Instructions. The overhaul intervals (number of miles, number of starts, hours of operation, months of operation, etc.) are specified in the Overhaul Instructions.

If the Repair or Overhaul Instructions are published as a separate manual, the first section is a brief introduction. This includes the purpose and leading particulars of the item of equipment. The remainder of the manual contains complete repair or overhaul instructions and test procedures. If combined with the Operation and Service Instructions, the Repair or Overhaul Instructions are arranged in a section, or sections, following the service instructions.

Illustrated Parts Breakdown

The purpose of the Illustrated Parts Breakdown (IPB) is to assist supply and maintenance personnel in the identification, requisitioning, and issuing of parts for the applicable item of support equipment.

The IPB for some complex items of support equipment is issued as a separate manual and has its own identification number. The IPB for most items of support equipment is combined with one or more sections of the instructions manuals and is the last section or sections of the manual. An example of the title of a combined manual is Operation and Service Instructions with Illustrated Parts Breakdown.

Although the IPB appears in some manuals as one section, it is usually divided into three sections or parts—Introduction, Group Assembly Parts List, and Numerical Index. In addition to these three parts, a Table of Contents is provided. If the IPB is a separate manual, the Table of Contents is contained in the first few pages of the manual. If the IPB is combined with instructions manuals, a combined Table of Contents appears in the first few pages of the combined manual. In either case, the Table of Contents contains a List of Illustrations which plays an important role in locating parts in the IPB. This is discussed later.

The Introduction contains detailed instructions for the use of the IPB. All the information in this section should be read prior to using the remaining sections. The information in the Introduction will aid the ASE in locating the necessary part or parts quickly and easily.

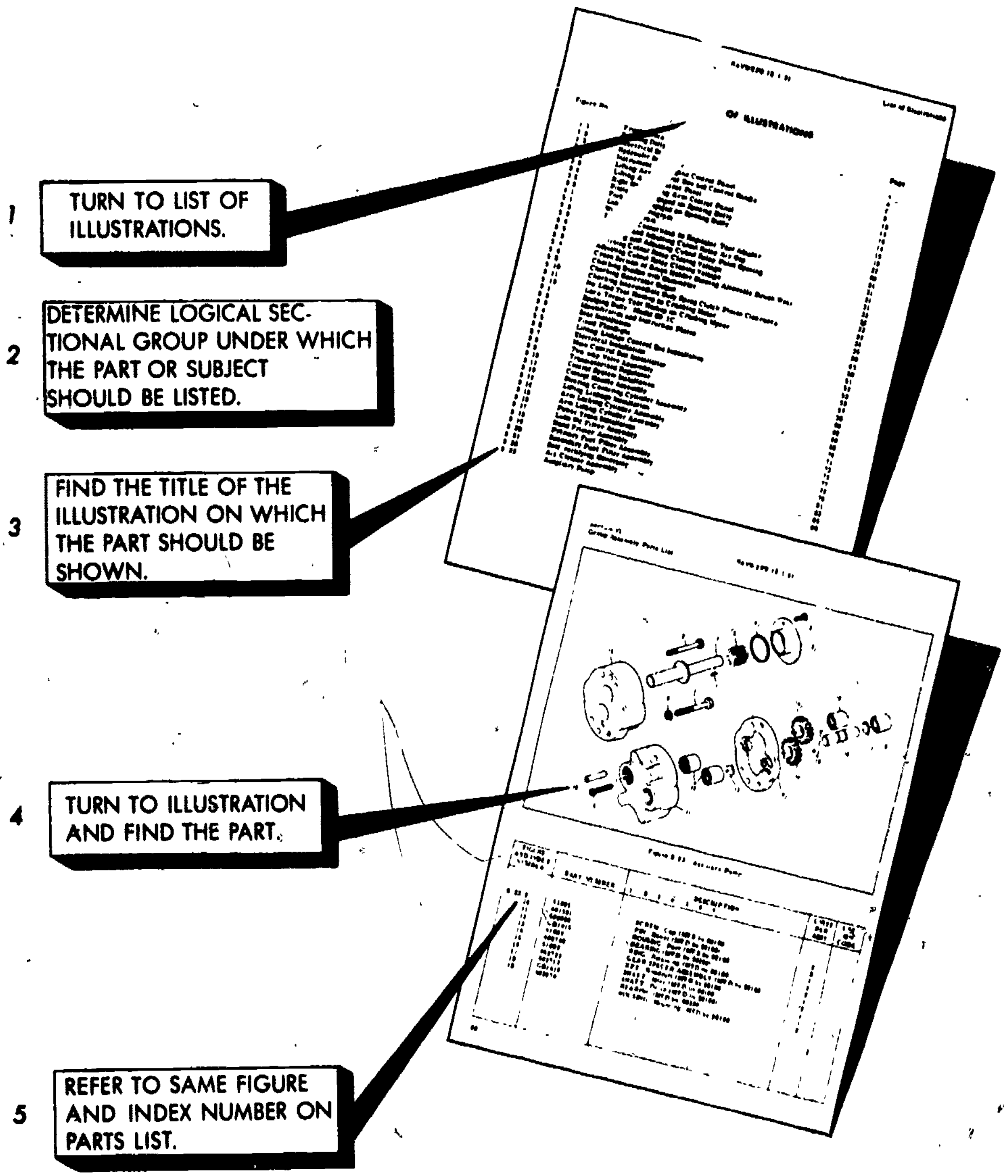
The next section, Group Assembly Parts List, lists and illustrates the assemblies and parts of the equipment. As mentioned previously, exploded views are usually used to illustrate these assemblies and parts. The parts lists are used in conjunction with the illustrations. Index numbers in the parts lists correspond to those on the illustrations. This section and the List of Illustrations, mentioned previously, are used to locate and identify a part when the part number is unknown. The steps involved in this process are presented in figure 3-3.

The last section, the Numerical Index, contains an alphanumerical listing of all the parts in the IPB. In addition to the part numbers, the Numerical Index contains such information as national stock number data, figure and index numbers, source code data, and repair code.

The Numerical Index is used to find the illustration and nomenclature of a part if the part number is known. Figure 3-4 illustrates the steps involved in this process.

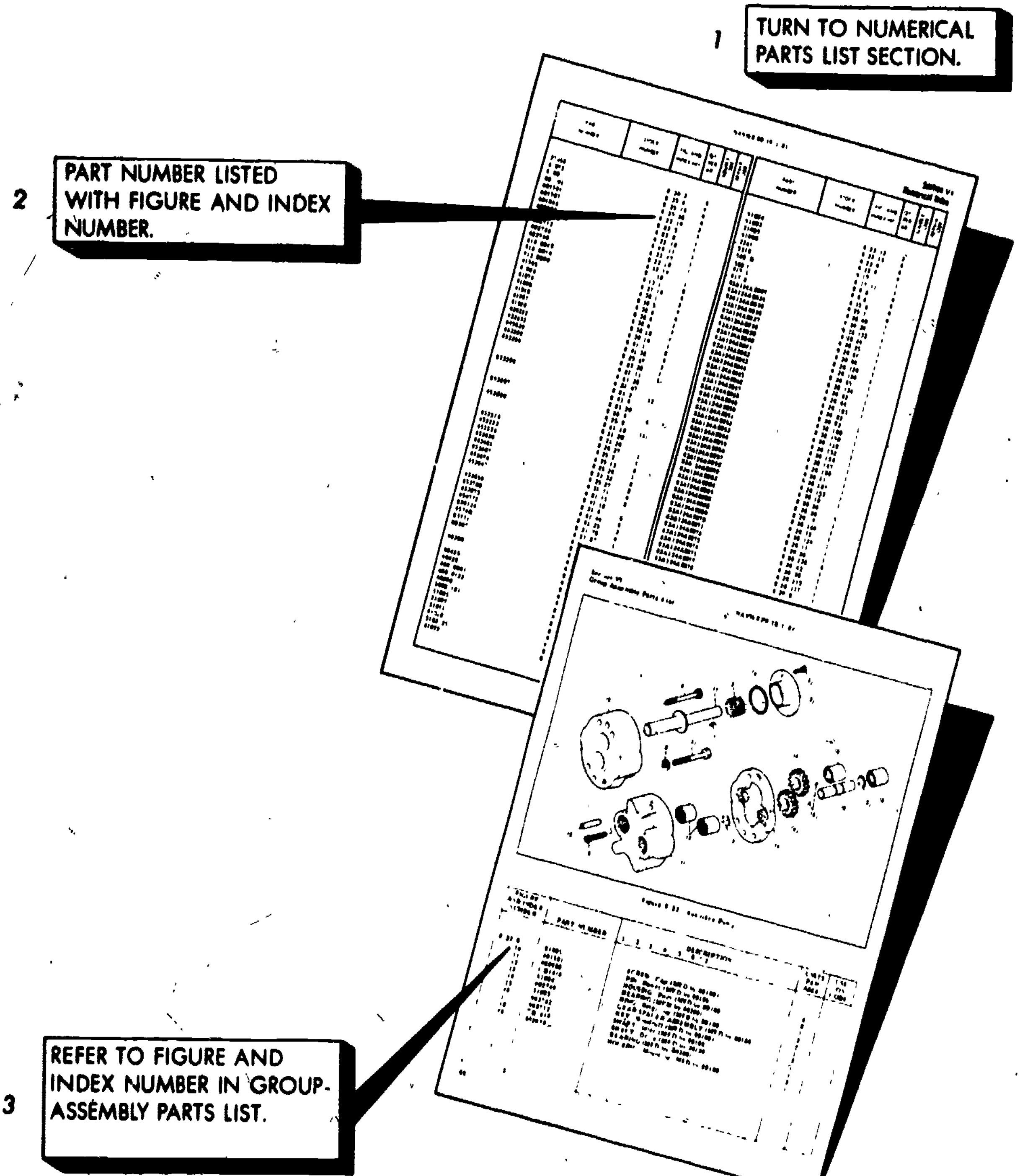
TECHNICAL INFORMATION FILE OF GROUND SUPPORT EQUIPMENT

The Military Standardization Handbook, Technical Information File of Ground Support



AS.670

Figure 3-3.—Use of the IPB when the part number is unknown.



AS.671

Figure 3-4.—Use of the IPB when the part number is known.

Equipment, MIL-HDBK-300B, provides a consolidated source of descriptive information about individual items of ground support equipment used by the Navy, Air Force, and Army. It consists of several volumes and provides descriptive information such as:

1. Official nomenclature of the item.
2. Manufacturer and model/type number.
3. Functional classification.
4. National stock number.
5. A photograph or drawing of the item.
6. Functional description (purpose).
7. Its relation to other equipment.
8. Electromechanical/mechanical description (technical details).
9. Reference data and literature available about the item.
10. Shipping data (size, weight, etc.).

UPDATING MANUALS

Modern technology is a constantly changing thing. What is considered to be the "latest" word today may be modified, totally revised, or otherwise made obsolete tomorrow. This is not always a planned or intended condition, but it must be accepted and dealt with.

These changing conditions apply to aeronautic technical publications. They require that prompt action be afforded to change and revise all material which is related to the technical information and data used by maintenance and operational personnel.

The degree of urgency of updating publications depends upon the type of information involved and the frequency of reference to the affected publications. In any event, technical data change and revision material should not be allowed to accumulate at any point.

Copies of these changes and revisions, received through the proper submission of NavAir Form 5605/3, are first delivered to the technical library. Personnel of the library make the necessary changes to the affected publications filed in the library. However, the changes affecting the publications held by the production divisions are routed to the appropriate work center. Personnel of the work center are then required to incorporate the changes into their copies of the affected publications.

The changes or revisions are prepared by the manufacturer of the specific equipment and are issued under the authority of the Naval Air Systems Command. The changes or revisions may direct write-in changes, provide replacement/additional pages, and/or provide information affecting various parts of the manual, in which case the information is prepared as supplemental data.

When incorporating changes, the instructions provided on the front page of the change should be followed exactly. Write-in material should be entered neatly and legibly using indelible ink. Text material to be deleted should have a single line ruled neatly through every line of type.

Supplemental data is supplied on pages to be filed next to the affected pages in the manual. Supplementary pages are inserted in the manual in page number order and are identified by a letter added to the page number. For example, if a supplementary page is issued bearing the number 2-16A, it is placed between pages 2-16 and 2-17. The supplementary information may be applicable to either or both of these pages.

Replacement pages are designed to replace pages already in the basic publication. They are numbered in exactly the same way as the pages they replace. The date of the change is shown on the bottom of the page in the corner opposite the page number. Prior to incorporating replacement pages they should be counted and the number noted. When the task is finished, the removed pages should be counted to make sure that the same number were removed as were put in. Also, the bottom of each removed pages should be checked for dates to make sure no new replacement pages were inadvertently missed.

On the back of each change notice cover page is a cumulative list of all changed/revised pages issued and the date of issue, since the basic date of the manual. Checking the listed pages and dates against the corresponding pages of the manual, which are also dated, provides one method of determining currentness and completeness of the manual. This page becomes the cover page of the revised manual.

In addition to the normal technical manual change and revision system described above, a Rapid Action Change (RAC) system has been developed recently to improve the timely issuance of urgently required information. Under this system, information affecting flight safety, hazards to personnel, or grounding of aircraft is disseminated via naval message and immediately incorporated in the affected manual. A manual change page follow-up is then required within 15 days of the release of the message. As indicated by the type of information disseminated in this manner, this system pertains primarily to aircraft technical manuals. However, support equipment can indirectly affect flight safety and grounding of aircraft and can directly cause hazards to personnel; therefore, the RAC system is also applicable to support equipment manuals. In addition to the message type of change, information of a less urgent nature is disseminated by RAC change pages that must be printed within 30 days after problem resolution and is generally limited to 12 pages or less.

It should be emphasized that the RAC system does not affect the normal change and revision requirements. The RAC system merely supplements the existing change system to provide for rapid issue of urgently required data.

LETTER TYPE PUBLICATIONS

There are two broad categories of letter type publications. One category pertains to information of a technical nature and includes Bulletins and Changes. This category is referred to as Technical Directives. The other category pertains to policy and administration procedures. Instructions and Notices are used to disseminate this type of information. These different forms of letter type publications are discussed in the following paragraphs.

TECHNICAL DIRECTIVES

The Technical Directive System has been established for the control and issue of all technical directives. This system standardizes the method of issuance for such directives and is the authorized means for directing the accomplishment and recording of modifications and one-time inspections of ground support equipment as well as aircraft and other aeronautical equipment. The Technical Directive System is an important element in the programs designed to maintain equipment in a safe and current state of operational and material readiness.

This system provides for two types of technical directives. The types are determined by the method of dissemination. The two types are Formal (letter type) and Interim (message type). In general terms, they are both considered as letter type publications. Such directives contain instructions or information of a technical nature which cannot be disseminated by revisions or changes to technical manuals. However, the accomplishment of a technical directive often necessitates a change or revision to the applicable technical manual. Technical directives are issued in the form of Changes, or in the case of special circumstances, by Interim Changes or Interim Bulletins.

A formal technical directive is issued as a Change, or as an amendment or revision thereto, and, as stated previously, is disseminated by letter. Formal directives are used to direct the accomplishment and recording of modifications to support equipment, as well as aircraft and related equipment. An interim technical directive is issued as a Change or a Bulletin, or as an amendment or revision thereto, and, in order to insure prompt delivery to the concerned activities, is disseminated by message. The interim technical directive is reserved for those instances to correct a safety or operational condition whenever it is considered too important to risk waiting for the issuance of a formal directive.

Each Interim Change is superseded by a Formal Change directive which will have the same number as the interim directive. Interim Bulletins are not superseded by Formal Bulletins as was previously the case. NavSup Publication 2002, Section VIII, Part D will still have many Interim Bulletins listed until they are eventually phased out.

A Change is a document containing instructions and information which directs the accomplishment and recording of a material change. a repositioning, a modification, or an alteration in the characteristics of the equipment to which it applies. A Change is issued to direct that parts be added, removed, or changed from the existing configuration or that parts or material be altered, relocated, or repositioned.

A Change may be issued in parts to accomplish distinct parts of a total directed action or to accomplish action on different configurations of affected equipment.

A Bulletin is an interim document comprised of instructions and information which directs an initial inspection to determine whether a given condition exists. It specifies what action is to be taken if a given condition is found or not found.

Sometimes it is found that a Change or Bulletin is not the complete answer to a problem, and it is determined necessary to amend or revise an outstanding directive. An Amendment is a document comprised of information which clarifies, corrects, adds to, deletes from, makes minor changes in requirements to, or cancels an existing directive. It is only a supplement to the existing directive and not a complete directive in itself. A maximum of three Amendments may be applied to any technical directive, each remaining in effect until rescinded or superseded by a Revision. A requirement for further amendment action necessitates the issuance of a Revision.

A Revision is a completely new edition of an existing technical directive. It supersedes the original directive and all existing Amendments.

Interim Bulletins are self-rescinding with rescission dates of 30 June and 31 December, whichever is appropriate for the case at hand. Rescission is the process by which a technical directive is removed from active files after all requirements have been incorporated and recorded. Rescinding dates are also projected for formal changes. Final rescission action of all technical directives is directed in Part D, Section VIII, NavSup Publication 2002. All activities maintaining files of technical directives should retain all technical directives until they are deleted from NavSup Publication 2002.

Changes and Bulletins are issued by technical personnel of the Naval Air Systems Command and are based on Contractor Service Bulletins, on reports from various Data Services, or letters of recommendation or proposed modifications from field service activities. They are automatically distributed to all activities concerned through inclusion on the Mailing List Request for Aeronautic Publications, NavAir 5605/3.

Changes and Interim Changes are assigned numbers in a numerical sequence by the Technical Directives Control Center, located at the Naval Air Technical Services Facility (NATSF), Philadelphia, Pa. As stated previously, a Formal Change which supersedes an Interim Change will have the same number as the Interim Change. Interim Bulletins are numbered similarly in another number series.

The title of a Change or Bulletin for support equipment is made up of three parts. Part one is the term "Support Equipment;" part two, the word or words "Change," "Interim Change," or "Interim Bulletin;" and part three, the sequential number. When applicable, the words "Rev. A," "Amendment 1," etc., follow the basic directive.

Changes are classified by various "action" categories. Bulletins may also be assigned an action classification, but it is not mandatory. The assigned action category serves as a priority for compliance with the various directives.

The category "Immediate Action" is assigned to directives which are issued to correct safety conditions, the incorrected existence of which would probably result in fatal or serious injury to personnel, or extensive damage or destruction of property. Immediate Action directives involve the discontinued use of the equipment in the operational employment under which the adverse safety condition exists, until the directive has been complied with. If the use of the equipment will not involve the use of the affected component or system in either normal or emergency situations, compliance may be deferred, but should be accomplished no later than 120 days from the date of issue. Immediate Action directives are identified by a border of red or black X's on the cover page, broken at the top center of the page by the words "IMMEDIATE ACTION," printed in red or black.

The category "Urgent Action" is assigned to directives which are used to correct safety conditions which, if uncorrected, could result in personnel injury or property damage. This category of directive is identified by the words "URGENT ACTION" printed in red or black ink at the top of the first page and a border of red or black diagonals around the cover page.

The compliance requirements for Urgent Action directives specify that the incorporation of the instructions must be accomplished not later than the next regularly scheduled rework or overhaul or, for equipment not reworked or overhauled on a regularly scheduled basis, not later than 18 months after the date of issuance.

Routine Action directives are issued where there are reliability, capability, or maintainability deficiencies which could, if uncorrected, become a hazard through prolonged usage or have an adverse effect on the operational life or general service utilization of equipment. The compliance requirement specifies the incorporation of the instructions not later than the next regularly scheduled overhaul or rework, or for equipment not reworked or overhauled on a scheduled basis, not later than 18 months after issuance of the directive. If accomplishment of the work requires depot level maintenance capability, the compliance may be deferred if it will seriously interfere with operational commitments or schedules. Routine Action directives are identified by the words "ROUTINE ACTION" printed in black capital letters at the top center of the cover page and no border symbols are used.

Record Purpose category is assigned to a technical directive when a modification has been completely incorporated by the contractor before acceptance by the Navy. This category of technical directive merely documents the action for configuration management purposes. Consequently, compliance information is not applicable. They are identified by the words "RECORD PURPOSES" printed in black capital letters at the top center of the cover page.

INSTRUCTIONS AND NOTICES

Instructions and Notices are directives containing information and instructions concerning policy, administration, and air operations. They are issued by all systems commands, bureaus, ships, stations, and operating activities. Those issued by the Naval Air Systems Command are known as NavAir Instructions and Notices.

Instructions are directives of a continuing nature and are effective until canceled or superseded by a later directive.

Notices are directives of a one-time nature or directives which are applicable for a brief period of time. Each Notice contains a provision for its own cancellation.

Instructions are numbered in consecutive order according to the subject covered in the Instruction. Notices are not assigned consecutive numbers because of their one-time nature or brief duration. For this reason, the date must always be used when referring to a Notice. Those Instructions and Notices pertaining to aviation maintenance may be addressed to "All Ships, Stations, and Units concerned with Naval Aircraft," or to certain activities only. Each activity maintains a file of all pertinent Instructions and Notices still in effect.

MISCELLANEOUS AVIATION PUBLICATIONS

Several unofficial publications of general interest to aviation personnel are available in most operating activities. These should be read regularly by all maintenance personnel.

NAVAL AVIATION NEWS

The Naval Aviation News, NavAir 00-75R-3, is published monthly by the Chief of Naval Operations and the Naval Air Systems Command. Its purpose is to disseminate data on aviation training and operations, aviation support equipment, space technology, missile, rocket, and other aviation ordnance developments, aeronautical safety, aircraft design, powerplants, aircraft recognition, technical maintenance, and overhaul procedures.

As its name implies, this publication is essentially a news magazine. It enables readers to keep abreast of the latest unclassified developments in every facet of naval aviation. In addition, the coverage of fleet operations and the human interest articles on the noteworthy feats and accomplishments of individuals, both officer and enlisted, make the Naval Aviation News an entertaining as well as an informational periodical.

APPROACH

Approach (NavAir 00-75-510), The Naval Aviation Safety Review, is published monthly by the U.S. Naval Aviation Safety Center and is distributed to all naval aeronautic organizations on the basis of 1 copy for every 10 persons. It presents the most accurate information currently available on the subject of aviation accident prevention.

A large number of aviation accidents are maintenance-induced; that is, they occur during preparation for, performance of, and securing from maintenance or as a result of sloppy or improper maintenance. Some aviation accidents result, either directly or indirectly, from careless use or improper maintenance of support equipment. Therefore, articles concerning aviation support equipment frequently appear in this magazine. For example, a recent article recommended that tires with military tread be used on support vehicles to decrease FOD (foreign object damage) to aircraft. In addition, many hints on general maintenance are issued in the Approach. Although these are primarily for aircraft maintenance personnel, they may also apply to the maintenance of support equipment. For example, a recent issue discussed the care of bearings, and another the use and care of torque wrenches.

The Approach magazine reports the results of accident investigations; and for those accidents that are maintenance-induced, describes what was done wrong and how it should have been done; suggests corrective measures to prevent future accidents resulting from these causes; and when appropriate, cites aeronautic technical publications which provide authority for changes in techniques or material to improve the maintenance product.

In short, the maintenance man who reads and heeds the messages in Approach is the man who benefits from other mechanics' experiences. Put Approach on your required reading list and look for it every month.

CHAPTER 4

ELEMENTARY PHYSICS

The Aviation Support Equipment Technician E is associated with some very complex machines and equipment. He is expected to understand, operate, service, and maintain these machines and equipment, and to instruct new men so that they can also perform these functions. No matter how complex a machine or item of equipment, its action can be satisfactorily explained as an application of a few basic principles of physics. In order to understand, maintain, and repair the equipment and machinery necessary to the operation of the ships and aircraft of the fleet, an understanding of these basic principles is essential. There can be no question that the technician who possesses this understanding is better equipped to meet the demands placed upon him in his everydav tasks.

Physics is devoted to finding and defining problems, as well as to searching for their solutions. It not only teaches a person to be curious about the physical world, but also provides a means of satisfying that curiosity. The distinction between physics and other sciences cannot be well defined, because the principles of physics also pertain to the other sciences. Physics is a basic branch of science and deals with matter, motion, force, and energy. It deals with the phenomena which arise because matter moves, exerts force, and possesses energy. It is the foundation for the laws governing these phenomena, as expressed in the study of mechanics, hydraulics, magnetism, electricity, heat, light, sound, and nuclear physics. It is closely associated with chemistry and depends heavily upon mathematics for many of its theories and explanations.

This manual deals primarily with the practical application of electricity and magnetism rather than the basic theory. If any background information is needed on these subjects, refer to Basic Electricity, NavPers 10086 (Series), for detailed coverage.

BASIC CONCEPTS

In any study of physics, it soon becomes obvious that specific words and terms have specific meanings which must be mastered from the very start. Without an understanding of the exact meaning of the term, there can be no real understanding of the principles involved in the use of that term. Once the term is correctly understood, however, many principles may be discussed briefly to illustrate or to emphasize the particular aspects of interest. The first part of this chapter is devoted to definitions of some physical terms and a brief general discussion of certain particular principles of vital interest to all technical personnel.

MEASUREMENT

In all branches of science, measurement is a very important consideration. In order to evaluate results, it is often essential to know how much, how far, how many, how often, and in what direction. As scientific investigations become more complex, measurements must become more accurate, and new methods must be developed to measure new things.

Measurements may be classed in three broad categories—magnitude, direction, and time. These categories are broken down into several types, each with its own standard units. Measurements of direction and time have become fairly well standardized and have comparatively few subdivisions. Magnitude, on the other hand, is an extremely complex category with many classes and subdivisions involved.

To illustrate the complexity of the magnitude category, consider only a few common examples of measurement dealing with magnitude—weight, distance, temperature, voltage, size, loudness, brightness, etc.; then consider measurements based on combinations of magnitude—density (weight per unit volume), pressure (force per unit area), thermal expansion (increase in size per degree change in temperature), etc. In addition, measurements combine categories: The flow of liquids is measured in volume per unit of time, speed is measured in distance per unit of time, rotation is measured in revolutions per minute, frequency is expressed in hertz, and so on, indefinitely. (The term "hertz," abbreviated Hz, is now used in place of what was formerly called "cycles per second.")

The importance of measurement and the necessity of selecting the proper measurement unit should be emphasized. Several systems of measurement further complicate matters. For example, distance may be measured in feet or in meters; weight in pounds or in kilograms; capacity in quarts or in liters; temperature in degrees Fahrenheit, Celsius, Rankine, or Kelvin; density in pounds per cubic foot or in grams per cubic centimeter; angles in degrees or in radians; etc. (NOTE: Celsius was formerly termed centigrade.)

In this manual, as in many other texts, specific measurements will be described when and as necessary for clarity.

Table 4-1 lists some measurements in the English system and some Metric-English equivalents.

MATTER AND ENERGY

MATTER may be defined basically as "anything that occupies space and has mass." (Mass and weight are not the same, as will be explained later in this chapter.) Matter exists naturally in three states—solid, liquid, or gas. All matter is composed of small particles called molecules. Matter may be changed or combined by various methods—physical, chemical, or nuclear. Matter has many properties; properties possessed by all forms of matter are called general properties, while those properties possessed only by certain classes of matter are referred to as special properties.

ENERGY may be defined basically as "the capacity for doing work." It may be classified in many ways, but for this discussion, energy will be classified as mechanical, chemical, radiant, heat, light, sound, electrical, or magnetic. Energy is constantly being exchanged from one object to another and from one form to another. Physics is primarily the study of matter and energy in their various forms and of the relationships that exist between them.

Law of Conservation

Matter may be converted from one form to another, such as water in the liquid form to its solid form, ice, with no change in the total amount of matter. Energy may also be changed in form with no resultant change in the total quantity of energy. In addition, a third statement has been added within the past half century: "Although the total amount of matter and energy remains constant, matter can be converted into energy or energy into matter." This statement is known as the law of conservation for energy and matter.

The destruction of matter creates energy, and creation of matter requires expenditure of energy. From this observation it may be implied that a given quantity of matter is the equivalent of some amount of energy. In common usage it is usually stated that matter "possesses" energy. For example, aviation gasoline contains energy to produce heat to make an engine run.

General Properties of Matter

Matter in all forms possesses certain properties. In the basic definition it has been stated that matter occupies space and has mass. Those two ideas contain most, if not all, of the general properties of matter.

SPACE.—The amount of space occupied by, or enclosed within, the bounding surfaces of a body is called volume. In the study of physics, this concept must be somewhat modified in order to be completely accurate. As stated previously, matter may appear as a solid, as a liquid, or as a gas—each having special properties. In a later section of this chapter it will be shown that for even a specific substance the

Table 4-1.–English and Metric measurements

ENGLISH SYSTEM

12 in.	=	1 ft	$27\ ft^3$	=	$1\ yd^3$
3 ft	=	1 yd	$231\ in.^3$	=	1 gal
5,280 ft	=	1 mi	60 mi/hr	=	88 ft/sec
1,760 yd	=	1 mi	7,000 grains	=	1 lb avoirdupois
$144\ in.^2$	=	$1\ ft^2$	16 oz	=	1 lb
$9\ ft^2$	=	$1\ yd^2$	2,000 lb	=	1 short ton
$1{,}728\ in.^3$	=	$1\ ft^3$	$1\ ft^3$ of water weights 62.4 lb		

METRIC-ENGLISH EQUIVALENTS

1 in.	=	2.5400 cm	$1\ cm^2$	=	$0.1550\ in.^2$	
1 ft	=	30.480 cm	$1\ in.^3$	=	$16.3872\ cm^3$	
1 yd	=	91.440 cm	$1\ cm^3$	=	$0.0610\ in.^3$	
1 mi	=	1609.4 m	1 grain	=	0.06480 g	
1 mi	=	1.6094 km	1 oz	=	28.3495 g	
1 mm	=	0.03937 in.	1 lb	=	453.592 g	
1 cm	=	0.3937 in.	1 lb	=	0.4536 kg	at sea level and 45° latitude
1 m	=	39.37 in	1 g	=	15.4324 grains	
1 m	=	3.2808 ft	1 g	=	0.03527 oz	
1 m	=	1.0936 yd	1 g	=	0.0022046 lb	
$1\ in.^2$	=	$6.4516\ cm^2$	1 kg	=	2.2046 lb	

volume may vary with changes in circumstances. It will also be shown that liquids and solids tend to retain their volume when physically moved from one container to another, while gases tend to assume the volume of the container. In order to clarify this concept of "occupying space," these minute particles of matter, molecules, which are in turn composed of still smaller particles, atoms, separated from each other by space which contains no matter, must be understood. This idea is used to explain two general properties of matter—impenetrability and porosity.

Two objects cannot occupy the same space at the same time; this is known as "impenetrability of matter." The actual space occupied by the atoms that make up an object cannot be occupied by any other matter. The impenetrability of matter may, at first glance, seem invalid when a cup of sand is poured into a cup of water; the result is considerably less than two cups of sand and water. However, matter has an additional general property called "porosity" which explains this apparent loss of volume. The water simply occupies space between particles of sand. Porosity is present in all material—but to an extremely wide range of degree. Generally, gases are extremely porous, liquids only slightly so, and solids vary over a wide range, from the sponge to the steel ball.

WEIGHT.—The concept of weight involves two general properties of matter—inertia and gravitational attraction. Before discussing weight, these two general properties and the concepts of motion and force must be discussed.

MOTION may be defined as the "act or process of changing place or position." The "state of motion" refers to the amount and the type of motion possessed by a body at some definite instant (or during some interval) of time. A body at rest is not changing in place or position; it is said to have zero motion, or to be motionless.

The natural tendency of any body at rest is to remain at rest; a moving body tends to continue moving in a straight line with no change in speed or direction. A body which obeys these natural tendencies is said to be in a uniform state of motion.

Every object tends to maintain a uniform state of motion. A body at rest never starts to move by itself; a body in motion will maintain its speed and direction unless it is caused to change one or the other. In order to cause a body to deviate from its conditions of uniform motion, a push or pull must be exerted on it. This requirement is due to that general property of all matter known as INERTIA. The greater the tendency of a body to maintain uniform motion, the greater its inertia.

Any change in the state of motion of a body is known as ACCELERATION, and the cause which produces it is called an accelerating force. Acceleration represents the rate of change in the motion of a body, and may represent either an increase or a decrease in speed and/or a change in direction of motion.

FORCE is the action on a body which tends to change the state of motion of the body acted upon. A force may tend to move a body at rest; it may tend to increase or decrease the speed of a moving body; or it may tend to change the direction of motion. Application of a force to a body does not necessarily result in a change in the state of motion; it may only TEND to cause such a change.

A force is any push or pull which acts on a body. Water in a can exerts a force on the sides and bottom of the can. A tug exerts a push or a pull (force) on a barge. A man leaning against a bulkhead exerts a force on the bulkhead.

In the above examples, a physical object is exerting the force and is in direct contact with the body upon which the force is being exerted. Forces of this type are called contact forces. There are other forces which act through empty space without contact—in some cases without even seeming to have any mass associated with them. The force of gravity exerted on a body by the earth—known as the weight of the body—is an example of a force that acts on a body through empty space and without contact. Such a force is known as an action-at-a-distance force. Electric and magnetic fields are other examples of these action-at-a-distance forces. The space through which these action-at-a-distance forces are effective is called a force field.

Force is a VECTOR quantity; that is, it has both direction and magnitude. A force is completely described when its magnitude, direction, and point of application are given. In a force vector diagram, the starting point of the line represents the point of application of the force.

Any given body, at any given time, is subjected to many forces. In many cases, all these forces may be combined into a single RESULTANT force, which may then be used to determine the total effect on the body.

Each body of matter in the universe attracts every other body with a force which is proportional to the mass of the bodies and inverse to the square of the distance between them. This force is called the UNIVERSAL FORCE OF GRAVITATIONAL ATTRACTION. Since every body exerts this force on every other body, when considering the forces acting on a single body, it is an almost universal practice to resolve all gravitational forces into a single resultant. At or near the surface of the earth, this becomes a fairly simple process—due to its extremely large mass, the earth exerts such a large gravitational attraction that it is entirely practical to ignore all other such attractions and merely use the earth's gravitational attraction as the resultant.

Although gravitational attraction is exerted by each body on the other, in those cases where there is a great difference in the mass of two bodies, it is usually more convenient to consider the force as being exerted by the larger mass on the smaller mass. Thus, it is commonly stated that the earth exerts a gravitational force of attraction on a body. The gravitational attraction exerted by the earth on a body is called GRAVITY.

The gravitational force exerted by the earth on a body is called the WEIGHT of that body, and is expressed in force units. In the English system, force is expressed in pounds. If a body is attracted by a gravitational force of 160 pounds, the body is said to weigh 160 pounds. The gravitational force between two bodies decreases as the distance between them increases; therefore, a body weighs less when positioned a mile above the surface of the sea than it weighs at sea level—it weighs more if positioned a mile below sea level. However, its mass remains the same regardless of its location with respect to the earth's center of gravity.

Density and Specific Gravity

The DENSITY of a substance is its weight per unit volume. A cubic foot of water weighs 62.4 pounds; the density of water is 62.4 pounds per cubic foot.

The SPECIFIC GRAVITY (S. G.) of a substance is the ratio of the density of the substance to the density of water—

$$\text{S. G.} = \frac{\text{weight of substance}}{\text{weight of equal volume of water}}$$

Specific gravity is not expressed in units but as a pure number. For example, if a substance has a specific gravity of 4, 1 cubic foot of the substance weighs 4 times as much as a cubic foot of water—62.4 times 4, or 249.6 pounds.

In the metric system the density of water is 1 gram per cubic centimeter. Hence, 1 cubic centimeter of a substance with a specific gravity of 4 weighs 4 grams. Therefore, in metric units the specific gravity of a substance has the same numerical value as its density.

Specific gravity and density are independent of the size of the sample under consideration, and depend only upon the substance of which the sample is made. See table 4-2 for typical values of specific gravity for various substances. An object with a high specific gravity is said to be more dense than an object of lesser specific gravity.

In order to apply the above formula, a great deal of ingenuity is often needed to measure the volume of irregularly shaped bodies. Sometimes it is practical to divide a body into a series of regularly shaped parts and then apply the rule that the total volume is equal to the sum of the volumes of all individual parts. Figure 4-1 demonstrates another method of measuring the volume of small irregular bodies. The volume of water displaced by a body submerged in water is equal to the volume of the body.

A somewhat similar consideration is possible for floating bodies. A floating body displaces its own weight of liquid. This may be proved by filling a container to the brim with liquid, then gently lowering the body to the surface of the

Table 4-2.–Typical values of specific gravity

Substance	Specific gravity
Aluminum	2.7
Brass	8.6
Copper	8.9
Gold	19.3
Ice	0.92
Iron	7.8
Lead	11 3
Platinum	21.3
Silver	10.5
Steel	7.8
Mercury	13.6
Ethyl alcohol	0.81
Water	1.00

liquid and catching the liquid that flows over the brim. Weighing the liquid displaced and the original body will prove the truth of the statement.

Pressure and Total Force

Pressure and force, while closely related topics, are not the same thing. A weight of 10 pounds resting on a table exerts a force of 10 pounds. However, the shape of the weight must be taken into consideration to determine the effect of the weight. If the weight consists of a thin sheet of steel resting on a flat surface, the effect would be quite different if the same sheet of steel were resting on a sharp corner.

Pressure is concerned with the distribution of a force with respect to the area over which that force is distributed. Pressure is defined as the force per unit of area, or $P = F/A$. A flat pan of water with a bottom area of 24 square inches and a total weight of 72 pounds exerts a total force of 72 pounds, or a pressure of 72/24 or 3 pounds per square inch, on the flat table. If the pan is balanced on a block with a surface area of 1 square inch, the pressure is 72/1 or 72 pounds per square inch. An aluminum pan with a thin bottom is suitable for use on a flat surface, but may be damaged if placed on the small block.

This concept explains why a sharp knife cuts with less resistance than a dull one. The smaller

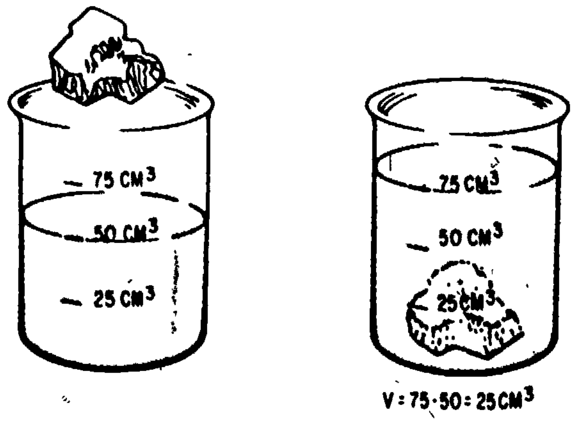


Figure 4-1.—Measuring the volume of an irregular object.

area of the sharp edge concentrates the applied force (increases the pressure per square inch) and penetrates with greater ease. For hydraulic applications, the relationship between pressure and force is the basic principle of operation. In enclosed liquids under pressure, the applied pressure is transmitted equally to every point on the surfaces of the enclosing container, and therefore the force on a given surface is dependent on the area.

Potential and Kinetic Energy

A body is said to have POTENTIAL energy if by virtue of its position or its state it is able to do work. A wound clock spring and a cylinder of compressed gas both possess potential energy since they can do work in returning to their uncompressed condition. Also, a weight raised above the earth has potential energy since it can do work in returning to the ground. Thus, potential energy results when work has been done against a restoring force. In the case of the weight, work was done against the force of gravity to raise it. The water in a reservoir above a hydroelectric plant has potential energy regardless of whether the water was placed there by work applied via a pump or by the work done by the sun to lift it from the sea and place it in the reservoir in the form of rain.

Moving bodies possess energy because, by virtue of their mass in motion, they are capable of doing work. The energy of mass in motion is called KINETIC energy, and may be expressed by the equation

$$\text{Kinetic energy} = 1/2\ mv^2$$

where m represents the mass of the body, and v is the velocity of its motion. When the moving body is stopped, it loses its kinetic energy. The energy is not destroyed, but merely converted into other forms of energy, such as heat.

STRUCTURE OF MATTER

All matter is composed of atoms, and these atoms are, in turn, composed of smaller subatomic particles. The subatomic particles of major interest in elementary physics are the electron, the proton, and the neutron. They may be considered electrical in nature, with the proton representing a positive charge, the electron representing a negative charge, and the neutron being neutral (neither positive nor negative). Although in general the composition of matter follows a consistent pattern for all atoms, the detailed arrangement of subatomic particles is different for each distinct substance. It is the combination and arrangement of the subatomic particles which imparts the distinguishing chemical and physical characteristics to a substance.

The protons and the neutrons of an atom are closely packed together in a nucleus (core), with the electrons revolving around the nucleus. Atoms are normally considered to be electrically neutral–that is, they normally contain an equal number of electrons and protons; but this condition does not actually prevail under all circumstances. Atoms which contain an equal number of electrons and protons are called balanced atoms; those with an excess or a deficiency of electrons are called "ions."

The proton and the neutron have approximately the same mass, which is approximately 1,836 times the mass of an electron. In any atom, nearly all the mass is contained in the nucleus. It may be assumed that under normal conditions any change in the composition of the atom would involve a change in the number or arrangement of the electrons (due to the smaller mass, they are more easily repositioned than are the protons or neutrons). This assumption is generally correct–the most notable exception being in the field of nuclear physics, or nucleonics. In chemistry and in general physics (including electricity and electronics), it is the electron complement that is of major concern.

ELEMENT

The word element denotes any one of over 100 natural substances such as iron, which comprise the basic substance of all matter. Two or more elements may combine chemically to form a compound; any combination which does not result in a chemical reaction between the different elements is called a mixture. The atom represents the smallest particle of an element. An atom of any one element differs from an atom of any other element in the number of protons in the nucleus; all atoms of a given element contain the same number of protons. Thus, it may be seen that the number of protons in the nucleus determines the type of matter.

The various elements are frequently tabulated according to the number of protons. The number of protons in the nucleus of the atom is referred to as the atomic number of the element.

Nucleus

The study of the nucleus of the atom, known as nucleonics or nuclear physics, has become very important in modern technology. Experiments on nuclei usually involve bombardment of the nucleus of an atom, using various types of nuclear particles. By this method the composition of the nucleus is changed, usually resulting in the release of energy. The change to the nucleus may occur as an increase or a decrease in the number of protons and/or neutrons.

If the number of protons is changed, the atom becomes an atom of a different element. This process, called "transmutation," is the process sought by the alchemists of the middle ages in attempts to change various metals into gold.

Scientists of that period believed transmutation could be accomplished by chemical means—hence the impetus given to the development of chemistry.

If, on the other hand, only the number of neutrons in the nucleus is changed, the atom remains an atom of the same element. Although all the atoms of any particular element have the same number of protons (atomic number), atoms of certain elements may contain various numbers of neutrons. Hydrogen, the sole exception to the rule that all atoms are composed of three kinds of subatomic particles, normally contains a single proton and a single electron and no neutrons. However, some hydrogen atoms do contain a neutron. Such atoms (although they are atoms of hydrogen) are known as deuterium, or "heavy hydrogen." They are called "heavy" because the addition of the neutron has approximately doubled the weight of the atom. Deuterium figured prominently in the research which led to the development of nuclear energy and the atomic bomb. The atomic weight of an atom is an indication of the total number of protons and neutrons in the atomic nucleus.

Atoms of an element which have atomic weights which differ from other atoms of that element are called isotopes. Nearly all elements have several isotopes; some are very common, and some are very rare. A few of the isotopes that occur naturally, and most of those produced by nuclear bombardment, are radioactive or have unstable nuclei. These unstable isotopes undergo a spontaneous nuclear bombardment which eventually results in either a new element or a different isotope of the same element. The rate of spontaneous radioactive decay is measured by "half-life," which is the time required for one-half the atoms of a sample of radioactive material to change (by spontaneous radioactive decay) into a different substance. Uranium after a few billion years and several transmutations, becomes lead.

Electron Shells

The physical and chemical characteristics of an element are determined by the number and distribution of electrons in the atoms of that element. The electrons are arranged in successive groups of electron shells of rotation around the nucleus; each shell can contain no more than a specific number of electrons. An INERT element (that is, one of the few gas elements which does not combine chemically with any other element) is a substance in which the outer electron shell of each atom is completely filled (as in helium and neon) or has exactly eight electrons (as in argon, krypton, and xenon). All other elements are active to varying degrees because their outer shells are not filled and do not contain eight electrons. An atom with only one or two electrons in its outer shell can be made to give up those electrons; an atom whose outer shell needs only one or two electrons to be completely filled or to have a total of eight can accept electrons from another element which has one or two "extras." Atoms that have either gained or lost electrons are called "ions."

The concept of "needed" or "extra" electrons arises from the basic fact that all atoms have a tendency toward completion (filling) of the outer shell, or the attainment of exactly eight electrons in that shell. An atom whose outer shell has only two electrons may have to collect six additional ones (no easy task, from an energy standpoint) in order to have the eight required. A much easier way to achieve the same objective is to give up the two electrons in the outer shell and let the full shell next to it serve as the new outer shell. Atoms of certain elements can also share each other's electrons to become more stable. In chemical terminology, this concept of accepting, losing, or sharing electrons is called valence. Valence is the prime determining factor in predicting chemical combinations.

COMPOUNDS AND MIXTURES

Under certain conditions, two or more elements can be brought together in such a way that they unite chemically to form a COMPOUND. The resulting substance may differ widely from any of its component elements; for example, ordinary drinking water is formed by the chemical union of two gases hydrogen and oxygen. When a compound is produced, two or more atoms of the combining elements join chemically to form the MOLECULE that is typical of the new compound. The molecule is the smallest unit that exhibits the distinguishing characteristics of a compound.

The combination of sodium and chlorine to form the chemical compound sodium chloride (common table salt) is a typical example of the formation of ionic compounds. An atom of sodium contains eleven electrons; its outer shell consists of a single electron, which may be considered "extra" (a valence of +1). An atom of chlorine, having seventeen electrons, "lacks" a single electron (has a valence of -1) to fill its outer shell. When the atom of sodium gives up its extra electron, it becomes a positively charged ion. (It has lost a unit of negative charge.) The chlorine, having taken on this extra unit of negative charge (electron) to fill its outer shell, becomes a negative ion. Since opposite electric charges attract, the ions stick together to form a molecule of the compound sodium chloride.

The attracting force which holds the ions together is known as the ionic bond.

The combination of one carbon and two oxygen atoms to form carbon dioxide is a typical example of the formation of molecular compounds. A carbon atom has four electrons in its outermost shell and an oxygen atom has six in its outermost shell. Due to the great difficulty (energy cost) for carbon to gain or lose four electrons, it shares two of its valence electrons with each oxygen atom and each oxygen atom shares two of its valence electrons with each carbon atom. Therefore, all have eight electrons in their outermost shells—hence the great stability of carbon dioxide. This type of chemical bonding is called "covalent."

Ionic and covalent bonds are generally known as "valence bonds," a term which is frequently encountered in the study of transistors.

Note that in chemical combinations, there has been no change in the nucleus of either atom; the only change has occurred in the distribution of electrons between the outer shells of the atoms. Also note that the total number of electrons has not changed, although there has been a slight redistribution. Therefore, the molecule is electrically neutral and has no resultant electrical charge.

Not all chemical combinations of atoms are on a one-for-one basis. In the case of drinking water, two atoms of hydrogen (valence of +1) are required to combine with a single atom of oxygen (valence of -2) to form a single molecule of water. Some of the more complex chemical compounds consist of many elements with various numbers of atoms of each. All molecules, like all atoms, are normally considered to be electrically neutral. There are some exceptions to this rule, however, a specific case of interest being the chemical activity in batteries.

Elements or compounds may be physically combined without necessarily undergoing any chemical change. Grains of finely powdered iron and sulfur stirred and shaken together retain their own identity as iron or sulfur. Salt dissolved in water is not a compound; it is merely salt dissolved in water. Each chemical substance retains its chemical identity, even though it may undergo a physical change. This is the typical characteristic of a MIXTURE.

STATES OF MATTER

In their natural condition, forms of matter are classified and grouped in many different ways. One such classification is in accordance with their natural state—solid, liquid, or gas. This classification is important because of the common characteristics possessed by substances in one group which distinguish them from substances in the other groups. However, the usefulness of the classification is limited by the fact that most substances can be made to assume any of the three forms.

In all matter, the molecules are assumed to be in constant motion, and it is the extent of this motion that determines the state of matter. The moving molecular particles in all matter possess kinetic energy of motion. The total of this kinetic energy is considered to be the equivalent of the quantity of heat in a sample of the substance. When heat is added, the energy level is increased, and molecular agitation (motion) is increased. When heat is removed, the energy level decreases, and molecular agitation diminishes.

In solids, motion of the molecules is greatly restricted by the rigidity of the crystalline structure of the material. In liquids, the molecular motion is somewhat less restricted, and the substance as a whole is permitted to "flow." In gases, molecular motion is almost entirely random—the molecules are free to move in any direction and are almost constantly in collision both among themselves and with the surfaces of the container.

This topic and some of its more important implications are discussed in detail under the heading "Heat" in a later section of this chapter.

Solids

The outstanding characteristic of a solid is the tendency to retain its size and shape. Any change in these values requires an exchange of energy. The common properties of a solid are cohesion and adhesion, tensile strength, ductility, malleability, hardness, brittleness, and elasticity. Ductility is a measure of the ease with which the material can be drawn into a wire. Malleability refers to the ability of some materials to assume a new shape when pounded. Hardness and brittleness are self-explanatory terms. The remaining properties are discussed in more detail in the following paragraphs.

COHESION AND ADHESION.—Cohesion is the molecular attraction between like particles throughout a body, or the force that holds any substance or body together. Adhesion is the molecular attraction existing between surfaces of bodies in contact, or the force which causes unlike materials to stick together.

Cohesion and adhesion are possessed by different materials in widely varying degrees. In general, solid bodies are highly cohesive but only slightly adhesive. Fluids (liquids and gases), on the other hand, are usually quite highly adhesive but only slightly cohesive. Generally a material having one of these properties to a high degree will possess the other property to a relatively low degree.

TENSILE STRENGTH.—The cohesion between the molecules of a solid explains the property called tensile strength. This is a measure of the resistance of a solid from being pulled apart. Steel possesses this property to a high degree, and is thus very useful in structural work. When a break does occur, the pieces of the solid cannot be stuck back together because merely pressing them together does not bring the molecules into close enough contact to restore the molecular force of cohesion. However, melting the edges of the break (welding) allows the molecules on both sides of the break to flow together, thus bringing them once again into the close contact required for cohesion.

ELASTICITY.—If a substance will spring back to its original form after being deformed, it has the property of elasticity. This property is desirable in materials to be used as springs. Steel and bronze are examples of materials which exhibit this property.

Elasticity of compression is exhibited to some degree by all solids, liquids, and gases; the closeness of the molecules in solids and liquids makes them hard to compress, but gases are easily compressed because the molecules are further apart.

Liquids

The outstanding characteristic of a liquid is its tendency to retain its own volume while assuming the shape of its container; thus a liquid is considered almost completely flexible and highly fluid.

Liquids are practically incompressible; applied pressure is transmitted through them instantaneously, equally, and undiminished to all points on the enclosing surfaces. Hydraulic apparatus can be used to increase or to decrease input forces, thus providing an action similar to that of mechanical advantage in mechanical systems. Because of these properties, hydraulic servomechanisms have advantages (as well as disadvantages and limitations) when compared with other types of servosystems.

The fluidity of hydraulic liquids permits the component parts of the system to be placed conveniently at widely separated points when necessary. Hydraulic power units can transmit energy around corners and bends without the use of complicated gears and levers. They operate with a minimum of slack and friction, which are often excessive in mechanical linkages.

Uniform action is obtained without vibration, and the operation of the system remains largely unaffected by variations in load. The accumulator (which provides the necessary pressurization of the system to furnish practically instantaneous response) can be pressurized during periods of nonaction, thus eliminating the "buildup time" characteristic of electric servos.

Gases

The most notable characteristics of a gas are the tendency to assume not only the shape but also the volume of its container and the definite relationship that exists between the volume, pressure, and temperature of a confined gas.

The ability of a gas to assume the shape and volume of its container is the result of its extremely active molecular particles, which are free to move in any direction. Cohesion between molecules of a gas is extremely small, so the molecules tend to separate and distribute themselves uniformly throughout the volume of the container. In an unpressurized container of liquid, pressure is exerted on the bottom and the sides of the container up to the surface of the liquid. In a container of gas however, the pressure is also exerted against the top surface, and the pressure is equal at all points on the enclosing surfaces.

The relationship of volume, pressure, and temperature of a confined gas are explained by Boyle's law, Charles' law, and the general law for gases.

Many laboratory experiments based on these laws make use of the ideas of "standard pressure" and "standard temperature." These are not natural standards, but are standard values selected for convenience in laboratory usage. Standard values are generally used at the beginning of an experiment, or when a temperature or a pressure is to be held constant. Standard temperature is 0°C, the temperature at which pure ice melts. Standard pressure is the pressure exerted by a column of mercury 760 millimeters high. In many practical uses these standards must be changed to other systems of measurement.

All calculations based on the laws of gases make use of "absolute" temperature and pressure. These topics require a somewhat more detailed explanation.

GAS PRESSURE.–Gas pressure may be indicated in either of two ways–absolute pressure or gage pressure. Since the pressure of an absolute vacuum is zero, any pressure measured with respect to this reference is referred to as "absolute pressure." In the present discussion, "absolute pressure" represents the actual pressure exerted by the confined gas.

At sea level the average atmospheric pressure is approximately 14.7 pounds per square inch (psi). This pressure would, in a mercurial barometer, support a column of mercury 760 millimeters in height. Thus, normal atmospheric pressure is the standard pressure mentioned previously. However, the actual pressure at sea level varies considerably; and the pressure at any given altitude above sea level differs from that at sea level. Therefore, it is necessary to take into consideration the actual atmospheric pressure when converting absolute pressure to gage pressure (or vice versa).

When a pressure is expressed as the difference between its absolute value and that of the local atmospheric pressure, the measurement is designated "gage" pressure, and is usually expressed in "pounds per square inch gage" (psig). Gage pressure may be converted to absolute pressure by adding the local atmospheric pressure to the gage pressure.

ABSOLUTE ZERO.–Absolute zero, one of the fundamental constants of physics, is usually expressed in terms of the Celsius scale. Its most frequent use is in the study of the kinetic theory of gases. In accordance with the kinetic theory, if the heat energy of a given gas sample could be progressively reduced, some temperature should be reached at which the motions of the molecules would cease entirely. If accurately determined, this temperature could then be taken as a natural reference, or a true "absolute zero" value.

Experiments with hydrogen (making use of the proven correlation with the volume, temperature, and pressure of gases, and by calculations based on this correlation) indicated that if a gas were cooled to -273.16° C (used as -273° for most calculations), all molecular motion would cease and no additional heat could be extracted from the substance.

When temperatures are measured with respect to the absolute zero reference, they are said to be expressed in the absolute, or Kelvin, scale. Thus, absolute zero may be expressed either as 0° K or as -273° C.

BOYLE'S LAW.–The English scientist Robert Boyle was among the first to study what he called the "springiness of air." By direct measurement he discovered that when the temperature of an enclosed sample of gas was kept constant and the pressure doubled, the volume was reduced to half the former value; as the applied pressure was decreased, the resulting volume increased. From these observations, he concluded that for a constant temperature the product of the volume and pressure of an enclosed gas remains constant. Boyle's law is normally stated: "The volume of an enclosed dry gas varies inversely with its pressure, provided the temperature remains constant."

In equation form, this relationship may be expressed either

$$V_1 P_1 = V_2 P_2,$$

or

$$\frac{V_1}{V_2} = \frac{P_2}{P_1}$$

where V_1 and P_1 are the original volume and pressure, and V_2 and P_2 are the revised volume and pressure.

CHARLES' LAW.–The French scientist Jacques Charles provided much of the foundation for the modern kinetic theory of gases. He found that all gases expand and contract in direct proportion to the change in the absolute temperature, provided the pressure is held constant. Expressed in equation form, this part of the law may be expressed

$$V_1 T_2 = V_2 T_1,$$

or

$$\frac{V_1}{T_1} = \frac{V_2}{T_2}$$

where V_1 and V_2 refer to the original and final volumes, and T_1 and T_2 indicate the corresponding absolute temperatures.

Since any change in the temperature of a gas causes a corresponding change in volume, it is reasonable to expect that if a given sample of a gas were heated while confined within a given volume, the pressure should increase. By actual experiment, it was found that the increase in pressure was approximately 1/273 of the 0° C pressure for each 1° C increase. Because of this fact, it is normal practice to state this relationship in terms of absolute temperature. In equation form, this part of the law becomes

$$P_1 T_2 = P_2 T_1,$$

or

$$\frac{P_1}{T_1} = \frac{P_2}{T_2}$$

In words, this equation states that with a constant volume, the absolute pressure of a gas varies directly with the absolute temperature.

The principles of Charles' law may be illustrated by the weight of Jp-4 fuel. The energy developed by an engine is determined by the mass of fuel it uses rather than by the volume, and more fuel can go into the same volume of space on a cold day than on a hot day. A single gallon of Jp-4 fuel under standard day conditions–15° C (59° F) and 29.92 in./Hg (14.7 lbs/sq in.) at sea level–will weigh approximately 6.5 pounds. If the temperature increases to approximately 50° C (122° F), the gallon of JP-4 will weigh approximately 6.3 pounds. The increase in temperature causes the molecules to become more active and the space between the molecules increases. The same mass of fuel now occupies more than one gallon of space. Referring to Charles' law, if the temperature increases, the volume must also increase to contain the same amount of mass.

The importance of this variation in the weight of fuel becomes apparent when one considers large quantities such as 10,000 gallons which may be used in large transport or patrol aircraft. Expansion and contraction can cause the aircraft's fuel to vary in weight by 2,000 pounds (a ton of fuel) or more.

GENERAL GAS LAW.–The facts concerning gases discussed in the preceding sections are summed up and illustrated in figure 4-2. Boyle's law is expressed in (A) of the figure, while the effects of temperature changes on pressure and volume (Charles' law) are illustrated in (B) and (C), respectively.

By combining Boyle's and Charles' laws, a single expression can be derived which states all the information contained in both. This expression is called the GENERAL GAS EQUATION, a very useful form of which is given by the following equation. (NOTE: The capital P and T signify absolute pressure and temperature, respectively.)

$$\frac{P_1 V_1}{T_1} = \frac{P_2 V_2}{T_2}$$

It can be seen by examination of figure 4-2 that the three equations are special cases of the general equation. Thus, if the temperature remains constant, T_1 equals T_2 and both can be eliminated from the general formula, which then reduces to the form shown in (A). When the volume remains constant, V_1 equals V_2, thereby reducing the general equation to the form given in (B). Similarly, P_1 is equated to P_2 for constant pressure, and the equation then takes the form given in (C).

It should be understood that the general gas law applies only when one of the three measurements remains constant. When a gas is compressed, work energy is converted to heat energy in the gas so that dynamical heating of the gas takes place. Experiments have shown that when air at 0° C is compressed in a nonconducting cylinder to half its original volume its rise in temperature is 90° C, and when compressed to one-tenth, its rise is 429° C.

The general gas law applies with exactness only to "ideal" gases in which the molecules are assumed to be perfectly elastic. However, it describes the behavior of actual gases with sufficient accuracy for most practical purposes.

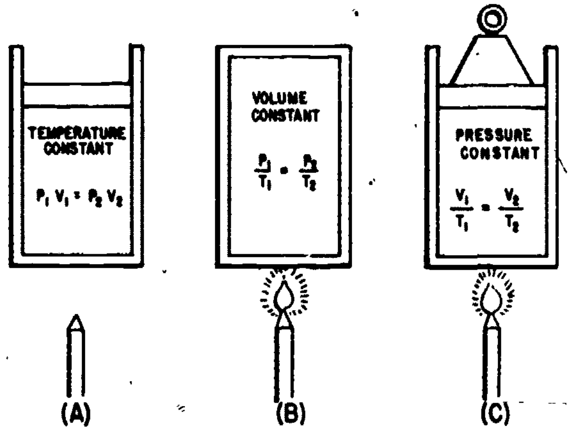


Figure 4-2.–The general gas law.

MECHANICS

Mechanics is that branch of physics which deals primarily with the ideas of force, mass, and motion. Normally considered the fundamental branch of physics, it deals with matter. Many of its principles and ideas may be seen, measured, and tested. Since all other branches of physics are also concerned (to some extent at least) with force, mass, and motion, a thorough understanding of this section will aid in the understanding of later sections of this chapter.

FORCE, MASS, AND MOTION

Each particle in a body is acted upon by gravitational force. However, in every body there is one point at which a single force, equal to the gravitational force and directed upward, would sustain the body in a condition of rest. This point is known as the CENTER OF GRAVITY, and represents the point at which the entire mass of the body appears to be concentrated. The gravitational effect is measured from the center of gravity. In symmetrical objects of uniform mass, this is the geometrical center. In the case of the earth, the center of gravity is near the center of the earth.

When considering the motion of a body, it is usually convenient to describe the path followed by the center of gravity. The natural tendency of a moving body is to move in a manner so that

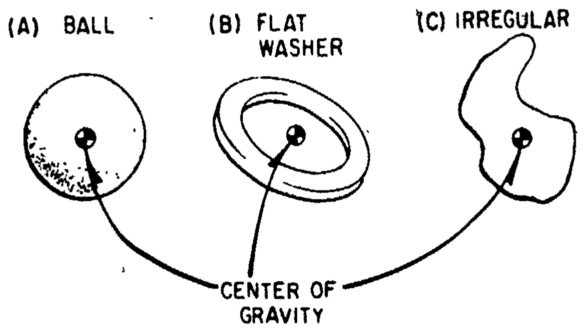


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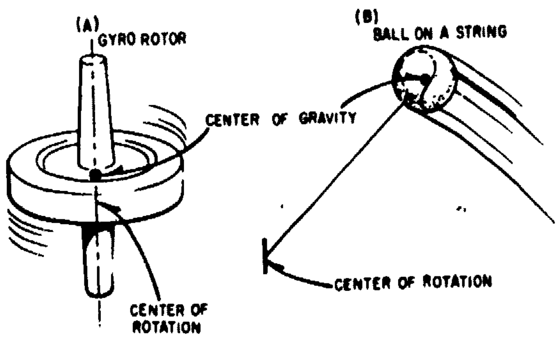
Figure 4-3.—Center of gravity in various bodies.



AT.23

Figure 4-4.—Center of gravity and center of rotation.

the center of gravity travels in a straight line. Movement of this type is called LINEAR motion.

Some moving bodies, however, do not move in a straight line but describe an arc or a circular path. Circular motion falls into two general classes—rotation and revolution.

Since objects come in many different shapes, in order to discuss rotary and revolutionary motion, it becomes necessary to consider the location of the center of gravity with respect to the body. Refer to figure 4-3 for the following discussion.

In (A), the center of gravity of a ball coincides with the physical center of the ball. However, in the flat washer, (B), the center of gravity does not coincide with any part of the object, but is located at the center of the hollow space inside the ring. In irregularly shaped bodies, the center of gravity may be difficult to locate exactly.

If the body is completely free to rotate, the center of rotation coincides with the center of gravity. On the other hand, the body may be restricted in such a manner that rotation is about some point other than the center of gravity. In this event, the center of gravity revolves around the center of rotation. This condition is illustrated in figure 4-4.

In general usage, the gyro rotor (A) is said to ROTATE about its axis, and the ball (B) is said to REVOLVE about a point at the center of its path.

Masses in Motion

MOTION may be defined as the "act or process of changing place or position." The "state of motion" refers to the amount and the type of motion possessed by a body at some definite instant (or during some interval) of time. A body at rest is not changing in place or position; it is said to have zero motion, or to be motionless.

The natural tendency of any body at rest is to remain at rest. A moving body tends to continue moving in a straight line with no change in speed or direction, and a body which obeys this natural tendency is said to be in uniform motion.

Any change in the speed or direction of motion of a body is known as acceleration and requires the application of some force. The acceleration of a body is directly proportional to the force causing that acceleration; acceleration depends also upon the mass of the body acted upon. The greater mass of a lead ball makes it harder to move than a wood ball of the same diameter. The wood ball moves farther with the same push.

These observations point to a connection between force, mass, and acceleration, and indicate that the acceleration of a body is directly proportional to the force exerted on that body and inversely proportional to the mass of that body. In mathematical form, this relationship may be expressed as

$$a = \frac{F}{m} \text{(Newton's second law of motion)}$$

or, as it is more commonly stated: Force is equal to the product of the mass and acceleration (F = ma).

If the accelerating force is applied to the center of gravity in such a manner as to accelerate the body with no rotation, it is called a TRANSLATIONAL force. A force applied in such a manner as to cause the body to rotate about a point is called a TORQUE force.

Laws of Motion

Among the most important discoveries in theoretical physics are the three fundamental laws of motion attributed to Newton. Although some of these laws have been used in explanations of various topics earlier in this chapter, they are restated and consolidated at this point to clarify and summarize much of the discussion regarding mechanical physics. This restatement and consolidation are also used to introduce additional aspects involving the applications of basic mechanical principles.

1. Every body tends to maintain a state of uniform motion unless a force is applied to change the speed or direction of motion.
2. The acceleration of a body is directly proportional to the magnitude of the applied force and inversely proportional to the mass of the body; acceleration is in the direction of the applied force.
3. For every force applied to a body, the body exerts an equal force in the opposite direction.

Momentum

Every moving body tends to maintain uniform motion. Quantitative measurement of this tendency is proportional to the mass of the body, and also to its velocity. (Momentum = mass x velocity.) This explains why heavy objects in motion at a given speed are harder to stop than lighter objects, and also why it is easier to stop a given body moving at low speed than it is to stop the same body moving at high speed.

WORK, POWER, AND ENERGY

As defined earlier, energy is the capacity for doing work. In mechanical physics, WORK involves the idea of a mass in motion, and is usually regarded as the product of the applied force and the distance through which the mass is moved (work = force x distance). Thus, if a man raises a weight of 100 pounds to a height of 10 feet, he accomplished 1,000 foot-pounds of work. The amount of work he accomplishes is the same regardless of the time involved. However, the RATE of doing the work may vary greatly.

The rate of doing work (called POWER) is defined as the work accomplished per unit of time (power = work/time). In the example cited above, if the work is accomplished in 10 seconds, power is being expended at the rate of 100 foot-pounds per second; if it takes 5 minutes (300 seconds), the rate is approximately 3.3 foot-pounds per second.

In the English system of measurements, the unit of mechanical power is called the HORSEPOWER and is the equivalent of 33,000 foot-pounds per minute, or 550 foot-pounds per second. Since energy is readily convertible from one form to another, the work and power measurements based on the conversion of energy must also be readily convertible. As an example, the electrical unit of power is the watt. Electrical energy may be converted into mechanical energy; therefore, electrical power must be convertible into mechanical power. One horsepower is the mechanical equivalent of 746 watts of electrical power, and is capable of doing the same amount of work in the same time.

The accomplishment of work always involves a change in the type of energy, but does not change the total quantity of energy. Thus, energy applied to an object may produce work, changing the composition of the energy possessed by the object. When the work stops, energy is no longer being "expended," so energy must once again be converted in form—but not necessarily into its original form.

Efficiency

Provided there is no change in the quantity of matter, energy is convertible with no gain or loss. However, the energy resulting from a given action may not be in the desired form—it may not even be usable in its resultant form. In all branches of physics, this concept is known as EFFICIENCY.

The energy expended is always greater than the energy recovered. An automobile in motion possesses a quantity of kinetic energy dependent on its mass and velocity. In order to stop the car, this energy must be converted into potential energy. When the car comes to rest, its potential energy is considerably less than the kinetic energy it possessed while in motion. The difference, or the "energy lost," is converted into heat by the brakes. The heat serves no useful purpose, so the recovered energy is less than the expended energy—the system is less than 100 percent efficient in converting kinetic to potential energy.

The term efficiency is normally used in connection with work and power considerations to denote the ratio of the input to the output work, power, or energy, $E = \frac{Wo}{Wi}$. It is always expressed as a decimal or as a percent less than unity (less than one).

Friction

In mechanical physics, the most common cause for the loss of efficiency is FRICTION. Whenever one object is slid or rolled over another, irregularities in the contacting surfaces interlock and cause an opposition to the force being exerted. Even rubbing two smooth pieces of ice together produces friction, although of a much smaller magnitude than in the case of two rough stones. Friction also exists in the contact of air with all exposed parts of an aircraft in flight.

When a nail is struck with a hammer, the energy of the hammer is transferred to the nail, and the nail is driven into a board. The depth of penetration depends on the momentum of the hammer, the size and shape of the nail, and the hardness of the wood. The larger or duller the nail and the harder the wood, the greater the friction, and therefore the lower the efficiency and less depth of penetration—but the greater the heating of the nail.

Friction is always present in moving machinery and accounts in part for the fact that the useful work accomplished by the machine is never as great as the energy applied. Work accomplished in overcoming friction is usually not recoverable. Friction can be minimized by decreasing the number of contacting points, by making the contacting areas as small and as smooth as possible, by the use of bearings, or by the use of lubricants.

There are two kinds of friction—sliding and rolling, with rolling friction usually of lower magnitude. Therefore, most machines are constructed so that rolling friction is present rather than sliding friction. The ball bearing and the roller bearing are used to convert sliding friction to rolling friction. A third type, the common (or friction) bearing, utilizes lubricants applied to surfaces which have been made as smooth as possible. Many new types of machines utilize self-lubricating bearings to minimize friction and thus increase efficiency.

Mechanical Advantage

The concept of mechanical advantage has proved to be one of the great discoveries of science. It permits an increase in force or distance and represents the basic principle involved in levers, block and tackle systems, screws, hydraulic mechanisms, and other work saving devices. However, in the true sense, these devices do not save work, they merely enable humans to accomplish tasks which might otherwise be beyond their capability. For example, a human would normally be considered incapable of lifting the rear end of a truck in order to change a tire; but with a jack, a block and tackle, or a lever, the job can be made comparatively easy.

Mechanical advantage is usually considered with respect to work. Work represents the application of a force through a distance in order to move an object through a distance. Thus, it may be seen that there are two forces involved, each with an appropriate distance. This is illustrated by the simple lever in figure 4-5.

Assuming perfect efficiency, the work input ($F_1 D_1$) is equal to the work output ($F_2 D_2$). Assuming equal distances D_1 and D_2, a force of

10 pounds must be applied at the source in order to counteract a weight of 10 pounds at the load. By moving the fulcrum nearer the load, less force is required to balance the same load. This is a mechanical advantage of force. If the force is applied in such a manner as to raise the load 1 foot, the source must be moved through a distance greater than 1 foot. Thus, mechanical advantage of force represents a mechanical disadvantage of distance. By moving the fulcrum nearer the source, these conditions are reversed.

Since the input work equals the output work (assuming no losses), the mechanical advantage may be stated as a ratio of the force or of the distances. In actual situations, friction results in energy loss and decreased efficiency, thereby requiring an even greater input to accomplish the same work.

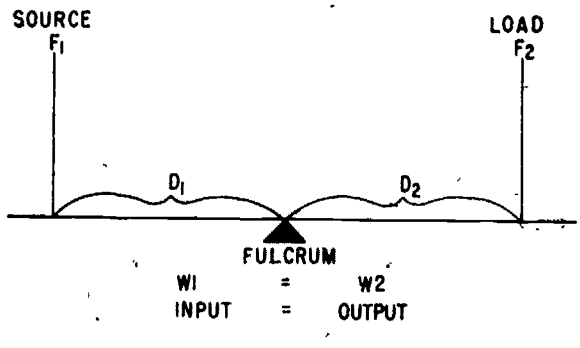


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Figure 4-5.—Mechanical advantage.

REVOLVING BODIES

Revolving bodies represent masses in motion; therefore, they possess all the characteristics (and obey all the laws) associated with moving bodies. In addition, since they possess a specific type of motion, they have special properties and factors which must be taken into consideration.

Revolving bodies travel in a constantly changing direction, so they must be constantly subjected to an accelerating force. Momentum tends to produce linear motion, but this is prevented by application of a force which restrains the object. This restraining force prevents the object from continuing in a straight line, and is known as CENTRIPETAL force. According to Newton's third law of motion, the centripetal force must be opposed by an equal force which tends to produce linear motion. This second force is known as CENTRIFUGAL force. The two forces, their relationships, and their effects are illustrated in figure 4-6 and the following explanatory example.

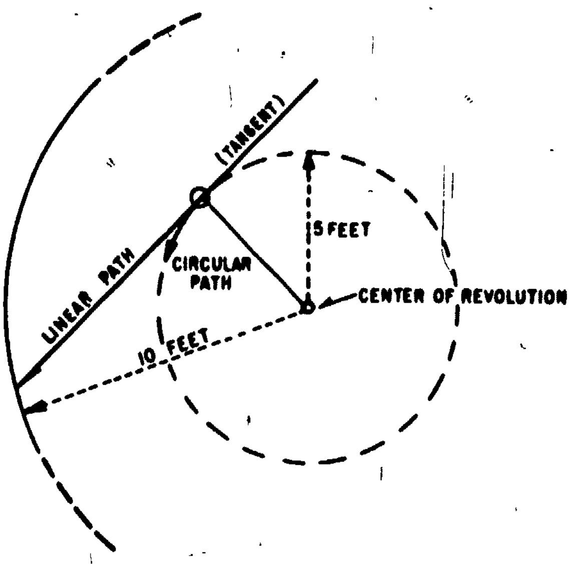

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Figure 4-6.—Forces on revolving bodies.

The various forces involved in revolving bodies may be illustrated by use of a ball and string. A slip knot is tied in the center of a 10-foot length of twine so as to shorten the line to 5 feet; a rubber ball is attached to one end of the string. Holding the other end of the line, whirl the ball slowly in a circle. Note that the ball exerts a force against the hand (through the string); and that in order to restrain the ball in its circular path, the hand must exert a force (through the string) on the ball. As the ball is revolved at higher speed, the forces increase, and the ball continues in a circular path. As the rotational velocity of the ball is gradually increased, note the increasing forces.

At some rotational speed, the forces involved become great enough to overcome inertial friction, and the knot slips. At this time, allow the velocity of the rotation to stabilize (stop increasing in rotational velocity, but not slowing down either), so that the existing conditions may be analyzed. When the knot slips, the ball is temporarily unrestrained and is free to assume linear motion in the direction of travel at that instant (tangent to the circle at the instantaneous position). The travels in a straight line until the string reaches its full length; during this time, no force is exerted on or by the hand. As soon as all the slack is taken up, there is a sharp jerk—an accelerating force is exerted in order to change the direction of motion from its linear path into a circular rotation The ball again assumes rotational motion, but with an increase in radius.

The ball does not make as many revolutions in the same time (rotational velocity is decreased), but it does maintain its former linear velocity. (The kinetic energy and the momentum of the ball have not changed.) Since the change in direction is less abrupt with a large radius than with a small one, less accelerating force is required, and the hand will feel less force. If the ball is then accelerated to the same rotational velocity as immediately prior to the slipping of the knot, the linear velocity of the ball becomes much greater than before; the centripetal and centrifugal forces are also greater.

In this example, it has been assumed that the hand is fixed at a point which represents the center of rotation. This assumption, while somewhat erroneous, does not affect the general conclusions: For practical purposes, the two forces are equal at all points along the string at any given time, and the magnitude of each force is equal at all points along the string.

In summarizing the conclusions reached by the above example and explanation, consider the following relationship:

$$\text{force} = \frac{\text{weight x velocity}^2}{\text{radius}}$$

where velocity represents the linear velocity of the ball. This emphasizes that the centripetal and the centrifugal forces are equal in magnitude and opposite in direction. Each force is directly proportional to the weight of the body and inversely proportional to the radius of rotation. Each force is also proportional to the square of the velocity.

In revolving or rotating bodies, all particles of the matter which are not on the axis of rotation are subjected to the forces just described. The statement is true whether the motion is through a complete circle, or merely around a curve: An aircraft tends to skid when changing course; an automobile tends to take curves on two wheels. The sharper the curve (smaller radius) or the higher the velocity, the greater the tendency to skid.

HEAT

Heat represents a form of energy; therefore, it must be readily exchangeable with or convertible into other forms of energy. The conversion of mechanical energy into heat through friction has been mentioned previously. When a piece of lead is struck a sharp blow with a hammer, part of the kinetic energy of the hammer is converted into heat. In the core of a transformer, electrical and magnetic energy are exchanged; but due to hysteresis and eddy currents, some of the energy is lost as heat. These are some examples of unwanted conversions, but there are many instances when the production of heat is desirable. Many devices are used almost exclusively to produce heat.

Regardless of how or why it is produced, heat possesses certain characteristics which make it important to the ASE. A knowledge of the nature and behavior of heat may prove helpful in understanding the operation of some types of electrical equipment or in determining the cause of nonoperation or faulty operation of others.

NATURE OF HEAT

There are several theories regarding the nature of heat, none of which satisfactorily explain all the characteristics and properties exhibited by heat. The two theories most commonly included in discussions regarding the nature of heat are the kinetic theory and the radiant energy theory.

In the kinetic theory, it is assumed that the quantity of heat contained by a body is represented by the total kinetic energy possessed by the molecules of the body.

The radiation theory treats radio waves, heat, and light as the same general form of energy, differing primarily in frequency. Heat is considered as a form of electromagnetic energy involving a specific band of frequencies falling between radio frequencies and light frequencies.

A common method used to produce heat energy is the burning process. Burning is a chemical process in which the fuel unites with oxygen, and a flame is usually produced. The amount of heat liberated per unit mass or per unit volume during complete burning is known as the heat of combustion of a substance. By experiment, scientists have found that each fuel produces a given amount of heat per unit quantity burned.

TRANSFER OF HEAT

There are three methods of heat transfer—conduction, convection, and radiation. In addition to these, a phenomenon called absorption is related to the radiation method.

Conduction

The metal handle of a hot pot may burn the hand; a plastic or wooden handle, however, remains relatively cool even though it is in direct contact with the pot. This phenomenon is due to a property of matter known as thermal conductivity. All materials conduct heat—some very readily, some to an almost negligible extent. When heat is applied to a body, the molecules at the point of application become violently agitated, strike the molecules next to them, and cause increased agitation. The process continues until the heat energy is distributed throughout the material. Aluminum and copper are used for cooking pots because they conduct heat very readily to the food being cooked. Wood and plastic are used as handles because they are very poor conductors of heat. As a general rule, metals are the best conductors of heat, although some metals are considerably better than others.

Among solids, there is an extremely wide range of thermal conductivity. In the original

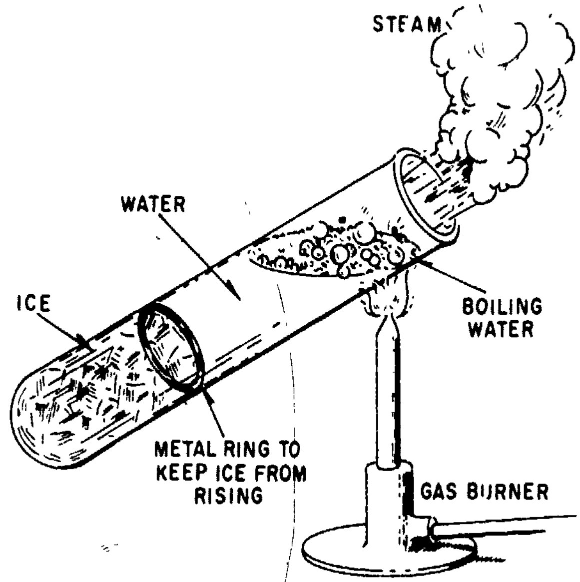


Figure 4-7.—Water is a poor conductor of heat.

example, the metal handle transmits heat from the pot to the hand, with the possibility of b... ıs. The wooden or plastic handle does not c...uct heat very well, so the hand is given some protection. Materials that are extremely poor conductors are called "insulators" and are used to reduce heat transfer. Some examples are the wood handle of soldering irons, the finely spun glass or rock wool insulation in houses, and the asbestos tape or ribbon wrapping used on steam pipes.

iquids are generally poorer conductors than m..ls. In figure 4-7, note that the ice in the bottom of the test tube has not yet melted, although the water at the top is boiling. Water is such a poor conducto that the rate of heating the water at the top of the tube is not sufficient to cause rapid melting of the ice at the bottom.

Since thermal conduction is a process by which molecular energy is transferred by actual contact, gases are generally even poorer conductors than liquids because the molecules are farther apart and molecular contact is not so pronounced. A double-pane window with an airspace between the panes is a fair insulator.

Convection

Convection is the process in which heat is transferred by movement of a hot fluid. For example, an electron tube becomes hotter and hotter until the air surrounding it begins to move. The motion of the air is upward because heated air expands in volume and is forced upward by the denser cool air surrounding it. The upward motion of the heated air carries the heat away from the hot tube by convection. Transfer of heat by convection may be hastened by using a ventilating fan to move the air surrounding a hot object. The rate of cooling of a hot vacuum tube can also be increased by providing copper fins to conduct heat away from the hot tube. The fins provide large surfaces against which cool air can be blown.

A convection process may take place in a liquid as well as in a gas. One example is a transformer in an oil bath. The hot oil is less dense (has less weight per unit volume) and rises, while the cool oil falls, is heated, and rises in turn.

When the circulation of a gas or liquid is not rapid enough to remove sufficient heat, fans or pumps may be used to accelerate the motion of the cooling material. In some cooling systems, pumps are used to circulate water or oil to help cool large equipment. Fans and blowers are sometimes used to aid convection.

Radiation

Conduction and convection cannot wholly account for some of the phenomena that are associated with heat transfer. For example, heating through convection cannot occur in front of an open fire because the air currents are moving toward the fire. It cannot occur through conduction because the conductivity of air is very low, and the cooler currents of air moving toward the fire would more than overcome the transfer of heat outwardly. Therefore, heat must travel across space by some means other than conduction and convection.

The existence of another process of heat transfer is still more evident when the heat from the sun is considered. Since conduction and convection take place only through molecular contact within some medium, heat from the sun must reach the earth by some other method. (Outer space is an almost perfect vacuum.) Radiation is the name given to this third method by which heat travels from one place to another.

The term radiation refers to the continual emission of energy from the surface of all bodies. This energy is known as radiant energy. It is in the form of electromagnetic waves and is identical in nature with light waves, radio waves, and X-rays, except for a difference in frequency. Sunlight is a form of radiant heat energy which travels great distances through cold, empty space to reach the earth. These electromagnetic heat waves are absorbed when they come in contact with nontransparent bodies. The net result is that the motion of the molecules in the body is increased, as indicated by an increase in the temperature of the body.

The differences in conduction, convection, and radiation can be compared thusly:

1. Although conduction and convection are extremely slow, radiation takes place with the speed of light. This fact is evident at the time of an eclipse of the sun when the shutting off of the heat from the sun takes place at the same time as the shutting off of the light.

2. Radiant heat may pass through a medium without heating it. For example, the plants inside a greenhouse may be much warmer than the glass through which the sun's rays pass.

3. Although conducted or convected heat may travel in roundabout routes, radiant heat always travels in a straight line. Thus, radiant heat can be stopped with a screen placed between the source of heat and the body to be protected.

Absorption

The sun, a fire, and an electric light all radiate energy, but a body need not glow to give off heat. A kettle of hot water or a hot soldering iron radiates heat. If the surface is polished or light in color, less heat is radiated. Bodies which do not reflect are good radiators and good absorbers, and bodies that reflect are poor absorbers. This is the reason white clothing is worn in the summer. A practical example of the control of heat is the Thermos bottle. The flask itself is made of two walls of "silvered" glass with a vacuum between them. The vacuum preve the loss of heat by conduction and con ion, and the "silver" coating reduces the loss of heat by radiation.

The silver-colored paint on the "radiators" in room heating systems is used only for decoration and decreases the efficiency of heat transfer. The most effective color for heat transfer is dull black; dull black is the ideal absorber and also the best radiator.

MEASUREMENT OF HEAT

A unit of heat must be defined as the heat necessary to produce some agreed on standard of change. There are three such units in common use:

1. One British thermal unit (Btu) is the quantity of heat necessary to raise the temperature of 1 pound of water 1° F.
2. One gram-calorie (small calorie) is the quantity of heat necessary to raise 1 gram of water 1° C.
3. One kilogram-calorie (large calorie) is the quantity of heat necessary to raise 1 kilogram of water 1° C. (One kilogram-calorie equals 1,000 gram-calories.) The gram-calorie or small calorie is much more widely used than the kilogram-calorie or large calorie. The large calorie is used in relation to food energy and for measuring comparatively large amounts of heat. Throughout this discussion, unless otherwise stated, the term calorie means gram-calorie. For purposes of conversion, one Btu equals 252 gram-calories or 0.252 kilogram-calorie.

The terms quantity of heat and tempe ure are commonly misused. The distinction between them should be understood clearly. For example, suppose that two identical pans, containing different amounts of water of the same temperature, are placed over identical gas burner flames for the same length of time. At the end of that time, the smaller amount of water will have reached a higher temperature. Equal amounts of heat have been supplied, but the increase in temperature is not equal. As another example, suppose that the water in both pans is at the same temperature, say 80° F, and both are to be heated to the boiling point. It is obvious that more heat must be supplied to the larger amount of water. The temperature rise is the same for both pans, but the quantities of heat necessary are different.

Mechanical Equivalent

Mechanical energy is usually expressed in ergs, joules, or foot-pounds. Energy in the form of heat is expressed in calories or in Btu's. In a precise experiment in which electric energy is converted into heat in a resistance wire immersed in water, the results show that 4.186 joules equals 1 gram-calorie, and that 778 foot-pounds equals 1 Btu. The following equation is used when converting from the English system to the metric system:

$$1 \text{ Btu} = 252 \text{ calories}$$

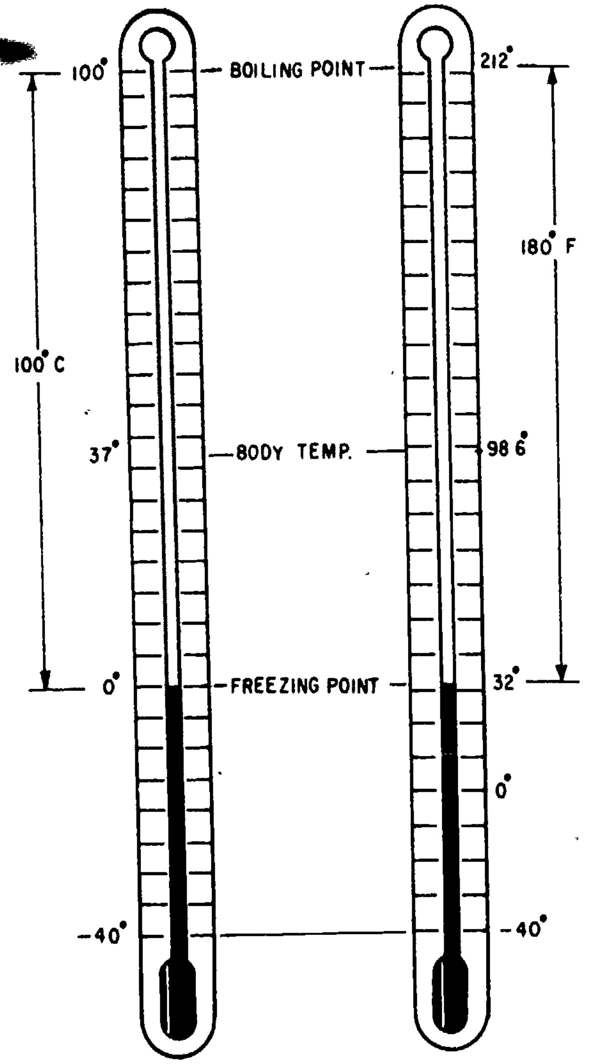
Specific Heat

One important way in which substances differ from one another is that they require different quantities of heat to produce the same temperature change in a given mass of substance. The thermal capacity of a substance is the calories of heat needed, per gram mass, to increase the temperature 1° C. The specific heat of a substance is the ratio of its thermal capacity to the thermal capacity of water at 15° C. Specific heat is expressed as a number which, because it is a ratio, has no units and applies to both the English and the metric systems.

Water has a high thermal capacity. Large bodies of water on the earth keep the air and the surface of the earth at a fairly constant temperature. A great quantity of heat is required to change the temperature of a large lake or river. Therefore, when the temperature of the air falls below that of such bodies of water, they give off large quantities of heat to the air. This process keeps the atmospheric temperature at the surface of the earth from changing very rapidly.

TEMPERATURE

If an object is hot to the touch, it is said to have a "high" temperature; if it is cold to the touch, it has a "low" temperature. In other words, temperature is used as a measure of the



AT.32

Figure 4-8.—Fahrenheit and Celsius thermometers.

hotness or coldness of an object being described. However, hotness and coldness are only relative. For example, on a cold day, metals seem colder to the touch than nonmetals because they conduct heat away from the body more rapidly. Also, upon leaving a warm room the outside air seems cooler than it really is. Going from the outside into a warm room, the room seems warmer than it really is. In other words, the temperature a person feels depends upon the state of his body.

Temperature Conversion

There are many systems of temperature measurement, and it is frequently necessary to convert from one scale to the other. The four most common scales in use today are the Fahrenheit (F), Celsius (C), Rankine (R), and Kelvin (K). The ASE is primarily concerned with the Fahrenheit and Celsius systems of temperature measurement. The following information covers these two systems.

FAHRENHEIT SCALE.—The most familiar scale to most Americans is the Fahrenheit scale which was established so that its zero point approximates the temperature produced by mixing equal quantities by weight of snow and common salt.

Under standard atmospheric pressure the boiling point of water is 212 degrees above zero and the freezing point 32 degrees above zero. Each degree represents an equal division, and there are 180 such divisions between freezing and boiling.

CELSIUS SCALE.—This scale uses the freezing point and boiling point of water under standard atmospheric pressure as fixed points of 0 and 100, respectively, with 100 equal divisions between. These 100 divisions represent the same difference in temperature as 180 divisions of the Fahrenheit scale. This ratio of 100/180 reduces to 5/9, which means a change of 1° F is equal to a change of 5/9° C. A change of 5° on the Celsius scale, therefore, is equal to a change of 9° on the Fahrenheit scale. Because 0° on the Celsius scale corresponds to 32° on the Fahrenheit scale, a difference in reference points exists between the two scales. (See fig. 4-8.)

To convert from the Fahrenheit scale to the Celsius scale, subtract the 32° difference and multiply the result by 5/9. As an example, convert 68° Fahrenheit to Celsius—

$$\frac{5}{9}(68 - 32) = \frac{5}{9}(36) = 20^\circ \text{ C}$$

To convert Celsius to Fahrenheit, the reverse procedure is necessary. First multiply the reading on the Celsius thermometer by 9/5 and then add 32 to the result–

$$\frac{9}{5}(20) + 32 = 36 + 32 = 68°F$$

One way to remember when to use 9/5 and when to use 5/9 is to keep in mind that the Fahrenheit scale has smaller divisions than the Celsius scale. In going from Celsius to Fahrenheit, multiply by the ration that is larger; in going from Fahrenheit to Celsius, use the smaller ratio.

Another method of temperature conversion which uses these same ratios is based on the fact that the Fahrenheit and Celsius scales both register the same temperature at -40°; that is, -40° F equals -40° C. This method of conversion, sometimes called the "40 rule," proceeds as follows:

1. Add 40 to the temperature which is to be converted. Do this whether the given temperature is Fahrenheit or Celsius.
2. Multiply by 9/5 when changing Celsius to Fahrenheit; by 5/9 when changing Fahrenheit to Celsius.
3. Subtract 40 from the result of step 2. This is the answer.

As an example to show how the 40 rule is used, convert 100° C to the equivalent Fahrenheit temperature:

$$100 + 40 = 140$$

$$140 \times 9/5 = 252$$

$$252 - 40 = 212$$

Therefore, 100° C = 212° F. Remember that the multiplying ratio for converting F to C is 5/9, rather than 9/5. Also remember to always ADD 40 first, then multiply, then SUBTRACT 40, regardless of the direction of the conversion.

It is important that all technicians be able to read thermometers and to convert from one scale to the other. In some types of equipment, thermometers are provided as a check on operating temperatures. Thermometers are also used to check the temperature of a charging battery.

Thermometers

The measurement of temperature is known as THERMOMETRY. Many modern thermometers use liquids in sealed containers. Water was the first liquid used. but because it freezes at 0° C, it could not measure temperatures below that point. After much experimentation, scientists decided that the best liquids to use in the construction of thermometers are alcohol and mercury because of the low freezing points of these liquids.

LIQUID THERMOMETERS.–The construction of the common laboratory thermometer gives some idea as to the meaning of a change of 1° in temperature. A bulb is blown at one end of a piece of glass tubing of small bore. The tube and bulb are then filled with the liquid to be used. The temperature of both the liquid and the tube during this process are kept at a point higher than the thermometer will reach in normal usage. The glass tube is then sealed and the thermometer is allowed to cool. During the cooling process, the liquid falls away from the top of the tube and creates a vacuum within the thermometer.

For marking, the thermometer is placed in melting ice. The height of the liquid column is marked as the 0° C point. Next, the thermometer is placed in steam at a pressure of 76 centimeters of mercury, and a mark is made at that point to which the liquid inside rises; that is the boiling point (the 100° C mark). The space between these two marks is then divided into 100 equal parts. These spacings are known as DEGREES. It is this type of thermometer that is used almost exclusively in laboratory work and in testing much Navy equipment. It is the CELSIUS thermometer mentioned earlier.

Since the range of all liquid thermometers is extremely limited, other methods of thermometry are necessary. Most liquids freeze at temperatures between 0° and -200° Celsius. At the upper end of the temperature range where high heat levels are encountered, the use of liquid thermometers is limited by the high vapor pressures of those liquids. Among the most widely used types of thermometers other than the standard liquid thermometers are the resistance thermometer and the thermocouple.

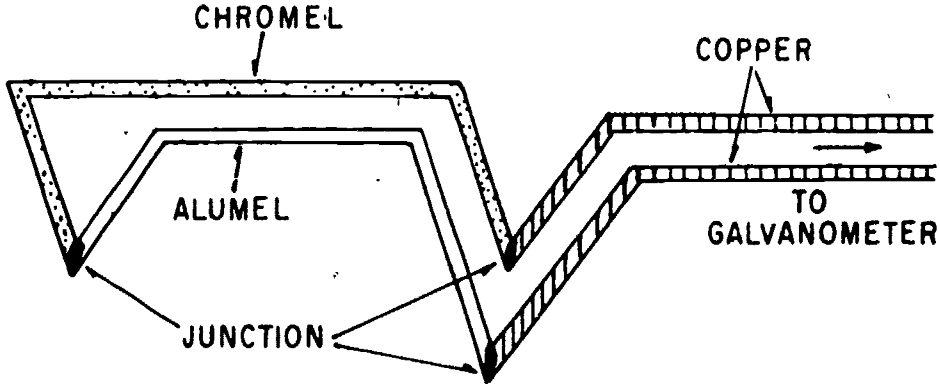


Figure 4-9.—Thermocouple.

RESISTANCE THERMOMETERS.—This type of solid thermometer makes use of the fact that the electrical resistance of metals changes as the temperature changes. The thermometer is usually constructed of platinum wire wound on a mica form and enclosed in a thin-walled silver tube. It is extremely accurate from the lowest temperature to the melting point of the unit.

THERMOCOUPLE.—The thermocouple shown in figure 4-9 is essentially an electric circuit. Its operation is based on the principle that when two unlike metals are joined and the junction is at a different temperature from the remainder of the circuit, an electromotive force is produced. This electromotive force can be measured with great accuracy by a galvanometer. Thermocouples can be located wherever the measurement of temperature is important, with wires running to a galvanometer located at any convenient point. By means of a rotary selector switch, one galvanometer can read the temperatures of thermocouples at any of a number of widely separated points.

Thermal Expansion

Nearly all substances expand or increase in size when their temperature increases. Railroad tracks are laid with small gaps between the sections to prevent buckling when the temperature increases in summer. Concrete pavement has strips of soft material inserted at intervals to prevent buckling when the sun heats the roadway. A steel building or bridge is put together with red-hot rivets so that when the rivets cool they will shrink and the separate pieces will be pulled together very tightly.

As a substance is expanded by heat, the weight per unit volume decreases. This is because the weight of the substance remains the same while the volume is increased by the application of heat. Thus the density decreases with an increase in temperature.

Experiments show that for a given change in temperature, the change in length or volume is different for each substance. For example, a given change in temperature causes a piece of copper to expand nearly twice as much as a piece of glass of the same size and shape. For this reason, the connecting wires into an electronic tube cannot be made of copper but must be made of a metal that expands at the same rate as glass. If the metal expanded at a slower rate than the glass, the vacuum in the tube would be broken by air leaking past the wires in the glass stem. The metal usually used for this purpose is an alloy called "Kovar."

The amount that a unit length of any substance expands for a 1° rise in temperature is known as the coefficient of linear expansion for that substance. The temperature scale used must be specified.

COEFFICIENTS OF EXPANSION.—To estimate the expansion of any object, such as a steel rail, it is necessary to know three things about it–its length, the rise in temperature to which it is subjected, and its rate or coefficient of expansion. The amount of expansion is expressed by equation:

$$\text{expansion} = \text{coefficient} \times \text{length} \times \text{rise in temperature}$$

or

$$e = kl\,(t_2 - t_1)$$

In this equation, the letter k represents the coefficient of expansion for the particular substance. In some instances, the Greek letter α (alpha) is used to indicate the coefficient of linear expansion.

PROBLEM: If a steel rod measures exactly 9 feet at 21° C, what is its length at 55° C? (The coefficient of linear expansion for steel is 10×10^{-6}.) If the equation $e = kl\,(t_2 - t_1)$ is used, then

$$e = (10 \times 10^{-6}) \times 9 \times (55 - 21)$$

$$e = 0.000010 \times 9 \times 34$$

$$e = 0.00306$$

This amount, when added to the original length of the rod, makes the rod 9.00306 feet long. (Since the temperature has increased, the rod is longer by the amount of e. If the temperature had been lowered, the rod would have become shorter by a corresponding amount.)

The increase in the length of the rod is relatively small; but if the rod were placed where it could not expand freely, there would be a tremendous force exerted due to thermal expansion. Thus, thermal expansion must be taken into consideration when designing ships, buildings, and all forms of machinery.

Since the coefficient of linear expansion is defined as a change in unit length, its value does not depend upon any particular length unit. Its value, however, does depend upon the size of the degree used to measure the temperature change. Table 4-3 gives the value of the coefficient of linear expansion of some substances per Celsius degree. The coefficient of expansion per Fahrenheit degree will be just 5/9 as much.

A practical application for the difference in the coefficients of linear expansion is the

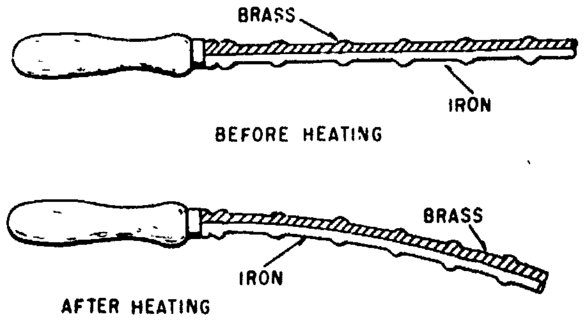


Figure 4-10.–Compound bar.

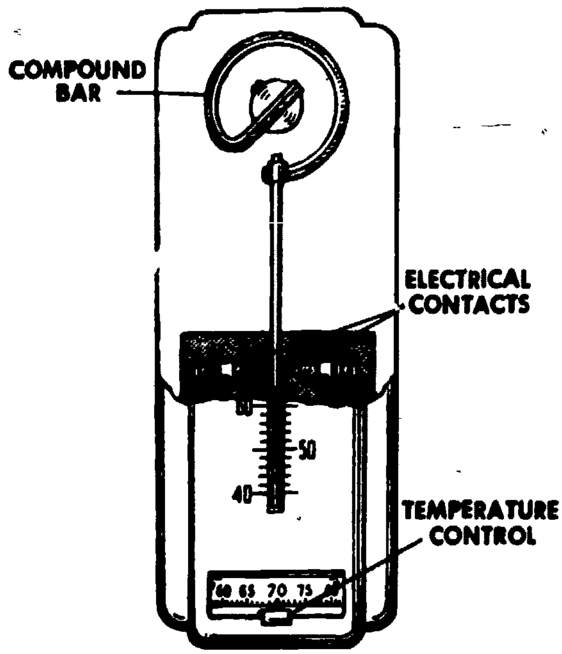


Figure 4-11.–Thermostat.

Table 4-3.–Expansion coefficients (per Celsius degree)

Substance	Coefficient of linear expansion
Aluminum	24×10^{-6}
Brass	20×10^{-6}
Copper	14×10^{-6}
Glass	$4 \text{ to } 9 \times 10^{-6}$
Kovar	$4 \text{ to } 9 \times 10^{-6}$
Steel	10×10^{-6}
Quartz	0.4×10^{-6}
Zinc	26×10^{-6}

thermostat. This instrument comprises two strips of dissimilar metal fastened (welded) together. When the temperature changes, a bending takes place due to the unequal expansion of the metals (fig. 4-10). Thermostats are used in overload relays for motors, in temperature-sensitive switches, and in electric ovens. (See fig. 4-11.)

The coefficient of surface or area expansion is approximately twice the coefficient of linear expansion. The coefficient of volume expansion is approximately three times the coefficient of linear expansion. It is interesting to note that in a plate containing a hole, the area of the hole expands at the same rate as the surrounding material. In the case of a volume enclosed by a thin solid wall, the volume expands at the same rate as would a solid body of the material of which the walls are made.

CHANGE OF STATE

A thermometer placed in melting snow behaves in a strange manner. The temperature of the snow rises slowly until it reaches 0° C. Provided that the mixture is stirred constantly, it remains at that point until all the snow has changed to water; when all the snow has melted, the temperature again begins to rise. A definite amount of heat is required to change the snow to water at the same temperature. This heat is required to change the water from crystal form to liquid form.

Heat of Fusion

Eighty gram-calories of heat are required to change 1 gram of ice at 0° C to water at 0° C. In English units, the heat required to change 1 pound of ice at 32° F to water at 32° F is 144 Btu. These values (80 gram-calories and 144 Btu) are called the HEAT OF FUSION of water. The heat absorbed by the melting ice represents the work done to produce the change of state. Since 80 calories are required to change a gram of ice to water at 0° C, when a gram of water is frozen it gives up 80 calories.

Many substances behave very much like water. At a given pressure, they have a definite heat of fusion and an exact melting point. There are many materials, however, which do not change from a liquid to a solid state at one temperature. Molasses, for example, becomes thicker and thicker as the temperature decreases; but there is no exact temperature at which the change of state occurs. Wax, celluloid, and glass are other substances which do not change from a liquid to a solid state at any particular temperature. In fact, measurements of the glass thickness at the bottom of windows in ancient cathedrals tend to indicate that the glass is still flowing at an extremely slow rate. Most types of solder used in electrical maintenance also tend to become mushy before melting.

Heat of Vaporization

Damp clothing dries more rapidly under a hot flatiron than under a cold one. A pool of water evaporates more rapidly in the sun than in the shade. Thus, it may be concluded that heat has something to do with evaporation. The process of changing a liquid to a vapor is similar to that which occurs when a solid melts.

If a given quantity of water is heated until it evaporates–that is, changes to a gas (vapor)–a much greater amount of heat is used than that which is necessary to raise the same amount of water to the boiling point. It takes 5,000 calories to heat 50 grams of water from 0° C to its boiling point at 100° C. It takes over five times as much heat (27,000 calories) to vaporize the same amount of water to steam. The amount of heat required to change 1 gram of water to vapor (540 calories) with no change in the temperature of the water is called the HEAT OF VAPORIZATION of water.

BOILING.--When water is heated, some vapor forms before the boiling point is reached. The change from water to vapor occurs as follows: As the water molecules take up more and more energy from the heating source, their kinetic energy increases. The motion resulting from the high kinetic energy of the water molecules causes a pressure which is called the vapor pressure. As the velocity of the molecules increases, the vapor pressure increases. At sea level, the atmospheric pressure is normally 29.92 inches of mercury. The boiling point of a liquid is that temperature at which the vapor pressure equals the external or atmospheric pressure.

While the water is below the boiling point, a number of molecules acquire enough kinetic energy to break away from the liquid state into a vapor. For this reason some evaporation slowly takes place below the boiling point. At the boiling point or above, large numbers of molecules have enough energy to change from liquid to vapor, and evaporation takes place much more rapidly.

If the molecules of water are changing to water vapor in an open space, the air currents carry them away quickly. In a closed container, however, they rapidly become crowded and some of them return to the surface of the water as a result of collisions with other water molecules in the vapor. When as many molecules are returning to the liquid as are leaving it, the vapor is said to be saturated. Experiments have shown that saturated vapor in a closed container exerts a pressure and has a given density at every temperature.

LIGHT

The exact nature of light is not fully understood, although men have been studying the subject for many centuries. Some experiments seem to show that light is composed of tiny particles; and some indicate that it is made up of waves.

First one theory and then the other attracted the approval and acceptance of the physicists.

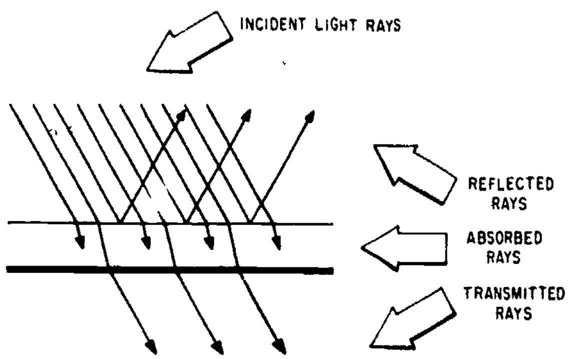


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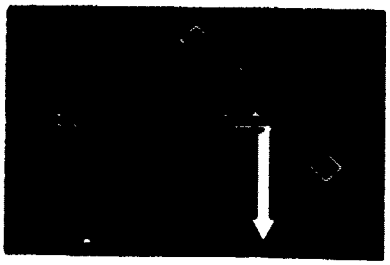
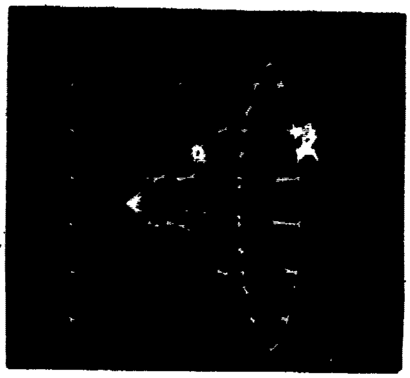
Figure 4-12.—Light rays reflected, absorbed, and transmitted.

Today there are scientific phenomena which can be explained only by the wave theory and another large group of occurrences which can be made clear by the particle or corpuscular theory. Physicists, constantly searching for some new discovery which would bring these contradictory theories into agreement, gradually have come to accept a theory concerning light which is a combination of these two views.

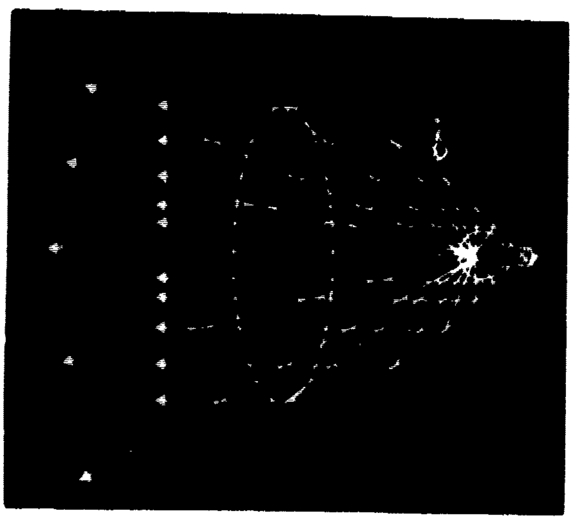
According to the view now generally accepted, light is a form of electromagnetic radiation; that is, light and similar forms of radiation are made up of moving electric and magnetic forces. The electromagnetic wave does not involve moving particles of matter, but relies on electric and magnetic force fields. The electromagnetic waves are transmitted most efficiently in the absence of matter. In the electromagnetic wave, two components are required—an electric field and a magnetic field. These two fields are mutually perpendicular to each other and to the direction of transmission. In waves that depend upon moving particles of matter, the velocity of transmission varies with the particular medium, and is comparatively slow; in the electromagnetic wave, the velocity of transmission is the speed of light (approximately 186,300 miles per second). Examples of electromagnetic waves include heat, light, radio waves, X-rays, cosmic radiation, ultraviolet rays, etc.



(A) CHANGING DIRECTION



(B) FOCUSING A BEAM



(C) ILLUMINATING AN AREA

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Figure 4-13.—Reflectors of light. (A) Changing direction; (B) focusing a beam; (C) illuminating an area.

All types of waves obey certain common laws and have common characteristics. All are periodic; that is, they all constantly repeat the same motion pattern so that each succeeding wave is the same as the previous one. Each wave displays the same relationships of wavelength, frequency, velocity of transmission, amplitude, and phase; and each is subject to the same conditions of reflection and refraction.

CHARACTERISTICS

When light waves, which travel in straight lines, encounter any substance, they are transmitted, reflected, or absorbed. (See fig. 4-12.) Those substances which permit clear vision through them, and which transmit almost all the light falling upon them, are said to be transparent. Those substances which allow the passage of part of the light, but appear clouded and impair vision substantially, are called translucent. Those substances which transmit no light are called opaque.

Objects which are not light sources are visible only because they reflect all or part of the light reaching them from some luminous source. If light is neither transmitted nor reflected, it is absorbed or taken up by the medium. When light strikes a substance, some absorption and reflection always take place. No substance completely transmits, reflects, or absorbs all the light which reaches its surface. Figure 4-12 shows how glass transmits, absorbs, and reflects light.

Reflection

Light waves obey the law of reflection in the same manner as other types of waves. Devices built specifically for the purpose of reflecting light are generally classed as mirrors. They may be of a polished opaque surface, or they may be a specially coated glass. In the case of the glass mirror, there is some refraction as well as reflection; however, if the glass is of good quality and not excessively thick, the refraction will cause no trouble. The following discussion is based on the polished surface type mirror.

Several classes of mirrors are illustrated in figure 4-13. All the devices work on the basis of the previously discussed law of reflection, and the applications are only briefly summarized here. Basically, the reflector is used to change the direction of a light beam (A), to focus a beam of light (B), or to intensify the illumination of an area (C).

In figure 4-13 (A), the angle of the reflected light may be changed to a greater or lesser degree by merely changing the angle at which the incident light impinges upon the mirror. In figure 4-13 (B), the focusing action of a concave mirror is indicated. The point of focus may be made any convenient distance from the reflector by proper selection of the arc of curvature of the mirror–the sharper the curvature, the shorter the focal length. In figure 4-13 (C), the principal of intensification of illumination for a specific area is illustrated. The flashlight is an example of this application. In the system shown, note that the light source (lamp) is located approximately at the principal focus point, and that all rays reflected from the surface are parallel; these form the principal beam, the part of greatest illumination. Also note that the reflector does not concentrate all the rays–some are transmitted without being reflected and are not included in the principal beam; these scattered rays dimly illuminate the nearby area.

Refraction

As light passes through a transparent substance, it travels in a straight line. However, as it passes into or out of that substance, it is refracted. Refraction of light waves results from the fact that light travels at slightly different velocity in different media. To help in understanding light refraction, and to make it possible to predict the outcome of specific applications, many transparent substances have been tested for refractive effectiveness. The ratio of the speed of light in air to its speed in each transparent substance is called the "index of refraction" for that substance. For example, light travels about one and one-half times as fast in air as it does in glass, so the index of refraction of glass is about 1.5. When using the law of refraction in connection with light, a "denser" medium refers to a medium with a higher index of refraction.

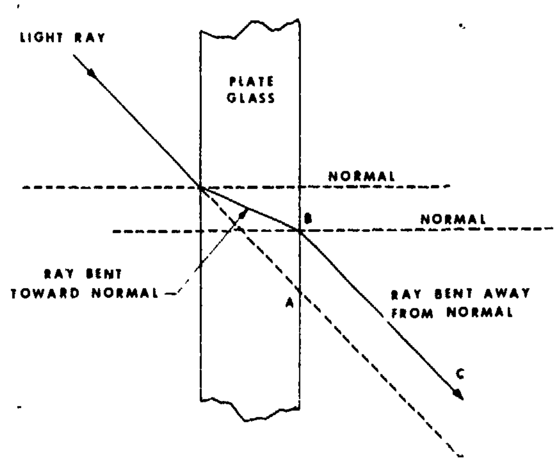

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Figure 4-14.–Refraction through plate glass.

Refraction through plate glass is shown in figure 4-14. The ray of light strikes the glass plate at an oblique angle. If it were to continue in a straight line, it would emerge from the plate at point A; but in accordance with the law of refraction, it is bent toward the normal and emerges from the glass at point B. Upon entering the air, the ray does not continue on its path but is bent away from the normal and along the BC in the air. If the two surfaces of the glass are parallel, the ray leaving the glass is parallel to the ray entering the glass. The displacement depends upon the thickness of the glass plate, the angle of entry into it, and the index of refraction for the glass.

All rays striking the glass at any angle other than perpendicular are refracted in the same manner. In the case of a perpendicular ray, no refraction takes place, and the ray continues through the glass and into the air in a straight line.

Diffusion

Reflection from a relatively smooth surface presents few problems. As shown in figure 4-15 (A), rays are reflected from a flat smooth surface in an orderly manner with all rays at the same angle and all rays parallel to each other. This is called regular or specular reflection. It is

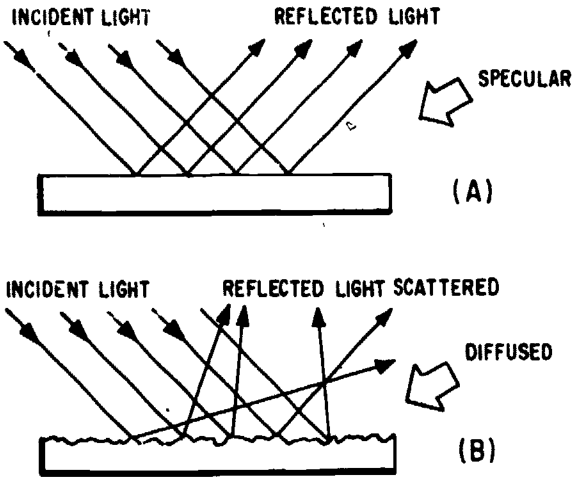

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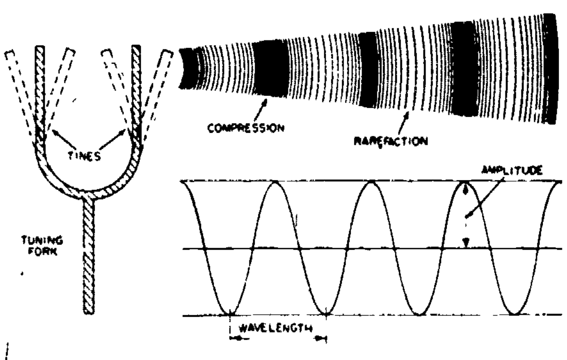
Figure 4-15.—Reflection from a plane surface. (A) Regular (specular); (B) irregular (diffused).



AT.26

Figure 4-16.—Compression and rarefaction (expansion) of sound wave.

a different matter, however, with a rough surface. The law of reflection is still valid, but due to the rough surface, the angle of incidence is somewhat different for each ray. The reflected rays scatter in all directions, as shown in figure 4-15 (B). This form of reflection is called irregular or diffused reflection.

SOUND

BASIC CONSIDERATION

The term sound is generally used in reference to hearing; but when used in physics, the term has to do with a particular type of wave motion and with the generation, transmission, detection, characteristics, and effects of those waves. The effects of sound waves are not covered in this manual.

Any object which moves rapidly to and fro, or which vibrates rapidly in such a manner as to disturb the surrounding medium, may become a sound source. Sound requires three components—a source, a medium for transmission, and a detector. As widely different as sound sources may be, the waves they produce have certain common characteristics.

Wave Motion

Sound waves are longitudinal type waves which rely on a physical medium for transmission. Since the waves are transmitted by the compression and rarefaction of particles of matter in the medium, they cannot be transmitted through a vacuum. Sound waves are similar to waves of other types in that they can be reflected, absorbed, or refracted according to laws previously discussed.

The major differences between the waves of sound and the waves of heat and light are the frequencies, the nature of the wave, and velocities of wave travel.

Wave motion involving the motion of particles of matter may be produced by the phsical vibration of a body. An example of this type wave is the sound wave which is produced by striking the tine of a tuning fork. When struck, the tuning fork sets up a vibratory motion. As the tine moves in an outward direction, the air immediately in front of the tine is compressed so that its momentary pressure is raised above that at other points in the surrounding medium (air). Because air is elastic, this disturbance is transmitted progressively in an outward direction as a compression wave. When the tine returns and moves in the inward direction, the air in front of the tine is rarefied so that its momentary pressure is reduced below that at other points in the surrounding medium. This disturbance is also transmitted, but in the form of a rarefaction (expansion) wave, and follows the compression wave through the medium.

The compression and expansion waves are also called longitudinal waves, because the particles of matter which comprise the medium move back and forth longitudinally in the direction of wave travel. Figure 4-16 is a simplified representation of the use of a tuning fork to produce a longitudinal wave. The transverse wave shown below the longitudinal wave is merely a convenient device to indicate the relative density of the particles in the medium, and does not reflect the movement of the particles.

The progress of any wave requiring movement of particles in the transmission medium involves two distinct motions–the wave itself moves forward with constant speed and, simultaneously, the particles within the medium vibrate. The period of a vibrating particle is the time required for the particle to complete one full vibration or cycle. The frequency is the number of vibrations completed per unit of time and is expressed in hertz.

Frequencies

Sound waves vary in length; a long wavelength is heard as a low sound, while a short wavelength is heard as a high wound. The frequency range between 15 and 20,000 hertz is called the audible range or normal hearing range, and the sounds heard are known as sonics. Sounds below 15 hertz are subsonics; those above 20,000 hertz are ultrasonics.

Conduction Media and Velocity of Transmission

In any uniform medium under given physical conditions, sound travels at a definite speed. In some substances, the velocity of sound is higher than in others. Even in the same medium under different conditions of temperature and pressure, the velocity of sound varies. Density and elasticity of a medium are basic physical properties which govern the velocity of sound.

At a given temperature and pressure, all sound waves travel at the same speed in air, regardless of frequency or wavelength. The speed of sound, however, does increase with temperature at the rate of 2.0 feet per second (fps) per degree Celsius. For practical purposes, the speed of sound in air may be considered 1,100 fps. Refer to table 4-4 for speed of sound in various media at different temperatures.

Table 4-4.–Comparison of velocity of sound in various media

Medium	Temperature (°F)	Velocity (ft/sec)
Air	32	1,087
Air	68	1,127
Fresh water	32	4,629
Fresh water	68	4,805
Salt water	32	4,800
Salt water	68	4,953
Steel	32	16,410
Steel	68	16,850

As previously stated, a sound wave is a compressional wave transmitted through an elastic medium. Sound travels faster through water (4,800 fps) than air (1,087 fps) because the elasticity of water is greater than that of air.

For a fixed temperature, the velocity of sound is constant for any medium and is independent of the frequency or amplitude of the disturbance. Thus, the velocity of sound in air at 0° C (32° F) is 1,087 fps and increases by 2 fps for each degree Celsius rise in temperature (1.1 fps for each degree Fahrenheit).

The velocity of sound also varies with a change in altitude. With an increase in altitude, the atmospheric pressure is reduced and the medium is less dense. Sound waves travel slower in a less dense medium. Therefore, it may be considered that the velocity of sound varies inversely with the altitude.

Characteristics

Numerous terms are used to convey impressions of sounds, including whistle, scream, rumble, and hum. Most of these are classified as noises in contrast to musical tones. The distinction is based on the regularity of the vibrations, the degree of damping, and the ability of the ear to recognize components having a musical sequence.

The ear can distinguish tones that are different in pitch, intensity, or quality. Each of these characteristics is associated with one of the properties of the vibrating source or of the waves that the source produces. Thus, pitch is determined by the number of vibrations per second, intensity by the amplitude of the wave motion, and quality by the number of overtones (harmonics) which the wave contains. A sound wave can best be described by its frequency rather than by its velocity or wavelength, as both the velocity and the wavelength change when the temperature of the conducting medium changes.

PITCH.--The term pitch is used to describe the frequency of a sound. The outstanding recognizable difference between the tones produced by two different keys on a piano is a difference in pitch. The pitch of a tone is proportional to the number of compressions and rarefactions received per second, which in turn is determined by the vibration frequency of the sounding source.

Pitch is usually measured by comparison with a standard. The standard tone may be produced by a tuning fork of known frequency or by a siren whose frequency is computed for a particular speed of rotation; by regulating the speed, the pitch of the siren is made equal to that of the tone being measured. The ear can determine this equality directly if the two sources are sounded alternately, or by the elimination of beats by regulating the speed of the siren if the two sources are sounded together.

INTENSITY.--When a bell rings, the sound waves spread out in all directions and the sound is heard in all directions. When a bell is struck lightly, the vibrations are of small amplitude and the sound is weak. A stronger blow produces vibrations of greater amplitude in the bell, and the sound is louder. It is evident that the amplitude of the air vibrations is greater when the amplitude of the vibrations of the source is increased. Hence, the loudness of the sound depends on the amplitude of the vibrations of the sound waves. As the distance from the source increases, the energy in each wave spreads out, and the sound becomes weaker.

QUALITY.--Most sounds and musical notes are not pure tones, but are mixtures of tones of different frequencies. The tones produced by most sources can be represented by composite waves in which the sound of lowest pitch, the fundamental tone, is accompanied by several harmonics or overtones having frequencies that are 2, 3, 4 or more times that of the fundamental frequency. The quality of a tone depends on the number of overtones present and on their frequencies and intensities relative to the fundamental tone. It is this characteristic of difference in quality that distinguishes tones of like pitch and intensity when sounded on different types of musical instruments (piano, organ, violin, etc.).

CHAPTER 5

TOOLS AND MATERIALS

A skilled technician can be identified by the way he handles and cares for his tools and materials. Tools are a costly investment and should be cared for and used to full advantage. There seems to be something about a good tool that helps the average technician turn out better than average work. This fact alone more than justifies the slightly higher cost of quality tools. Even more important is the fact that low quality tools become defective more readily and can result in injury to the user or damage to the equipment undergoing repair.

In the same manner, proper use of quality materials improves the quality of any maintenance task and reduces the possibility of new failures. It is the responsibility of all maintenance personnel to become thoroughly familiar with the tools and materials of his trade and be proficient in their care and use.

TOOLS

An ASE is only as good as he is proficient with the tools of his trade. Without tools and equipment with which to work, even the most experienced ASE is rendered ineffective.

Each ASE in the work center is usually issued a toolbox of common or basic handtools. It is his responsibility to keep those tools in good condition and ready for use. At the time of issue of the toolbox, he is also provided with a copy of his tool inventory. By means of this inventory he can quickly ascertain if his toolbox is complete.

Special tools for which the ASE has only occasional use are kept in a central place from which he may draw them as needed. It may be practical for special tools used frequently to be kept in individual toolboxes if sufficient quantities are available and tools are not overly subject to damage. Close-tolerance tools require cautions handling to prevent damage.

As can be appreciated from the foregoing, there is much the ASE needs to know about procurement, issue, care, and accounting for common and special tools as well as using them to perform repair and maintenance tasks on ground support equipment.

COMMON HANDTOOLS

In this manual the term "common handtools" is used to refer to small, portable power tools and nonpowered handtools that are common to the ASE, ASH, and ASM ratings. This includes such common tools as screwdrivers, pliers, wrenches, hammers, chisels, hacksaws, files, drills, sanders, etc. These tools are covered in Tools And Their Uses, NavPers 10085 (Series), and Airman, NavPers 10307 (Series), therefore, they will not be discussed in this manual.

SPECIAL TOOLS

The ASE will use many tools which are not covered in the basic manuals previously mentioned. A wide variety of special tools are furnished by the manufacturers of the support equipment, engines, and related equipment. These tools are listed in special allowance lists published by the Naval Air Systems Command, and their use is explained in the applicable manuals covering the specific support equipment, engine, or item of equipment for which they were designed. There are other tools which are peculiar to the maintenance of electrical/electronic equipments, or which have been developed since the basic manuals have been issued.

Although the following list is not complete, it is representative of the special tools most commonly used in electrical/electronics maintenance work.

Nonmagnetic Tools

Tools made of nonmagnetic materials are available through normal supply channels. They are used for performing specific maintenance task on certain classes of equipment or components, such as equipment containing magnets. These tools are normally made of beryllium-copper or plastic, are not as rugged as steel tools, and are much more easily damaged. Restricting their use to the purpose for which they were intended will prolong their useful life and increase their usefulness when required.

In addition to possible damage of the tool itself, indiscriminate use of these tools could allow them to transfer foreign particles to locations where possible trouble could result.

Good general maintenance practice involves wiping the tools before use and again after use. This is especially advisable in the case of nonmagnetic tools. A lint-free cloth dampened with an approved cleaning solvent is to be used for this purpose.

Insulated Tools

Safety considerations require use of insulated tools whenever the danger of electrical shock or short circuit exists. Many types of tools are available in insulated form directly through supply channels at little or no additional cost. These tools should be obtained and used whenever available. However, many types of insulated tools are not readily available (or are available only at considerable added expense). If essential, these tools should be procured or conventional tools may be modified. Insulated sleeving may be put on the handles of pliers and wrenches and on the shanks of screwdrivers. Tools modified in this manner should be used only for low voltage circuits because of the limitations of the insulating materials. For higher voltage uses, special insulating handles are available for many of the common types of tools.

In some instances, it is necessary to use tools which are made of insulating material, rather than merely having an insulating handle. In these instances, the tools should be requisitioned through normal supply channels, if possible. If they are not available through normal supply channels, they may be purchased on the open market.

Relay Tools

Do not use sandpaper or emery cloth to clean the contact points of relays or ignition points. Use of these abrasives will often gouge out portions of the points or leave grit from the abrasives sticking in the points which holds them partially open and will cause them to arc and burn. Likewise, the contact points supports are often bent if these abrasives are used, thereby causing misalinement of the points. Attempts to straighten them with longnose pliers cause further damage requiring replacement of the relays. This can be avoided by using a burnishing tool to clean dirty contact points. Figure 5-1 (a) illustrates a burnishing tool being used on a relay.

Burnishing tools are stocked in supply activities and may be obtained through normal supply channels. When using this tool, be sure to clean it throughly with alcohol; do not touch the tool surface prior to use.

Another useful tool in relay maintenance is a point support bender which is used to aline the relay contact points. The point support bender may be obtained through normal supply channels or manufactured locally from flat stock shaped as shown in figure 5-1 (B). The actual size may vary according to the relay being repaired, but the point support bender should be small enough to allow freedom of movement so as not to damage other parts of the relay.

Wire and Cable Strippers

Nearly all wires and cables used as electrical conductors are covered with some type of insulation. In order to make electrical connections with the wire, a part of this insulation must be removed, leaving the end of the wire bare. To facilitate the removal of this insulation, use a wire and cable stripping tool similar to the one shown in figure 5-2.

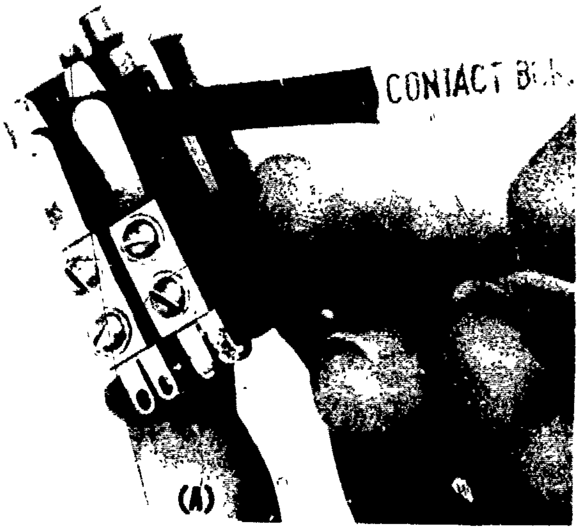
Although several variations of this basic tool are available, one of the most efficient and effective is the type illustrated. Its operation is extremely simple—insert the end of the wire in the proper direction to the depth to be stripped, position the wire so that it rests in the proper groove for that size wire, and squeeze. The tool functions in three steps as follows:

1. The cable gripping jaws close, clamping the insulated wire firmly in place. The wire must be inserted so that the jaws clamp the main section of the wire rather than the end to be stripped.
2. The insulation cutting jaws close, cutting the insulation. If the wire is not inserted in a groove, the conductor will also be cut. If the wire is positioned into too small a groove, some of the strands will be severed. If the groove is too large, the insulation will not be completely severed. Inserted properly into the correct groove, the insulation will be cut neatly and completely, and the wire will not be damaged.
3. The two sets of jaws separate, removing the clipped insulation from the end of the wire. The jaws are spring loaded to the closed position; therefore, the handles must be squeezed until the jaws reach the full open and locked position. This prevents the cutting jaws from closing (which would damage end of wire) and allows cable gripping jaws to open, releasing the wire.

If cable and wire strippers of this type are not available, an emergency stripper may be made by filing notches in the jaws of diagonal pliers or pocket fingernail clippers, using jeweler's files. Care must be taken to file the grooves into the proper positions in opposing jaws, and the size of the groove must be appropriate for the size wire on which it is to be used. When properly modified, these tools will perform satisfactorily and may be used if the more desirable stripper is not available.

Crimping Tool

TYPE MS 25037-1.—The standard tool MS 25037-1, issued for crimping solderless terminals, is for use with standard insulated copper terminal lugs manufactured according to MS 25036. The standard tool employs a double jaw to hold the terminal lug or splice. One side of the jaw applies crimping action to fasten the terminal to the bare wire when the terminal is inserted, as shown at the left in figure 5-3. When



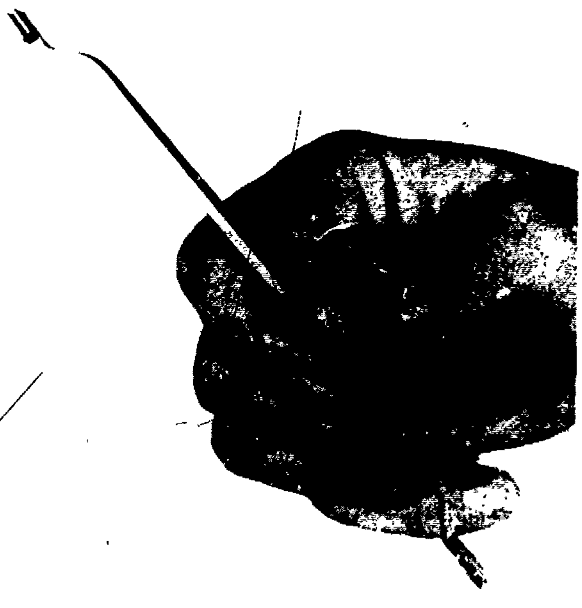


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Figure 5-1.—Relay tools.

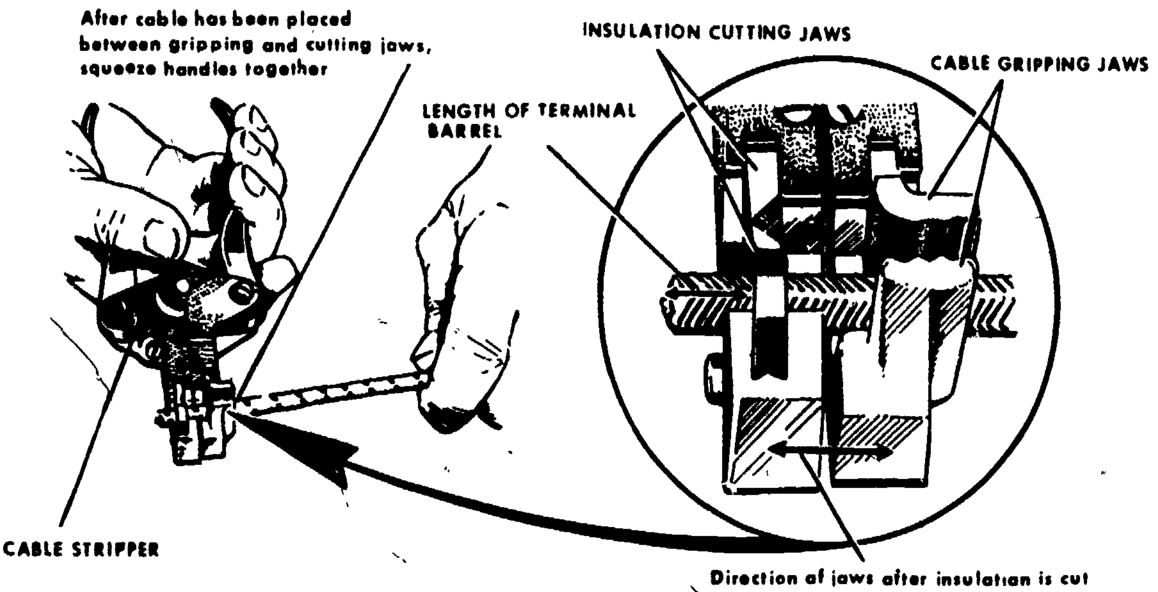

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Figure 5-2.—Wire and cable stripper.

the tool is used correctly, a deep crimp is placed in the B area of terminal lugs and splices, as shown on the right in figure 5-3. A shallow crimp is applied to the portion of the terminal or splice which extends over the insulation of the wire, as indicated by the A area in the diagrams. This clamping action is provided by a recessed portion in the other side of the divided jaw. A guard, which should be in the position shown when crimping terminals, aids in proper positioning of the terminal. However, the guard must be moved out of the way when the tool is used for crimping splices

Without the guard, the tool may be used incorrectly when crimping terminals; for example, the terminal might be inserted from the wrong side of the tool. The result is that the deep crimp is placed in the A area of the terminal and, although the wire may be held securely in place, the connection is poor. Common sense indicates that the deep crimp must clamp the metal of the terminal to the bare metal of the wire in order to provide a good electrical and mechanical connection.

The MS 25037-1 tool requires an occasional go, no-go check for wear. A No. 36 (0.106) drill rod should not enter the smaller (red or blue) nest when the tool is fully closed. If it does enter, have the tool repaired.

Installation Practices for Aircraft Electric and Electronic Wiring, NavAir 01-1A-505 contains illustrations and information on several different crimping tools along with detailed instructions for their use.

Safety Wire Pliers

When installing equipment, it is sometimes necessary to lockwire (usually referred to as safety wire) designated parts of the installation. The process of lockwiring can be accomplished faster and neater with the use of special pliers.

Safety wire pliers (fig. 5-4) are three-way pliers which hold, twist, and cut. They are designed to make a uniform twist (when used properly) and to reduce the time required in twisting the safery wire on nuts, bolts, electrical connectors, etc. To operate, grasp the wire

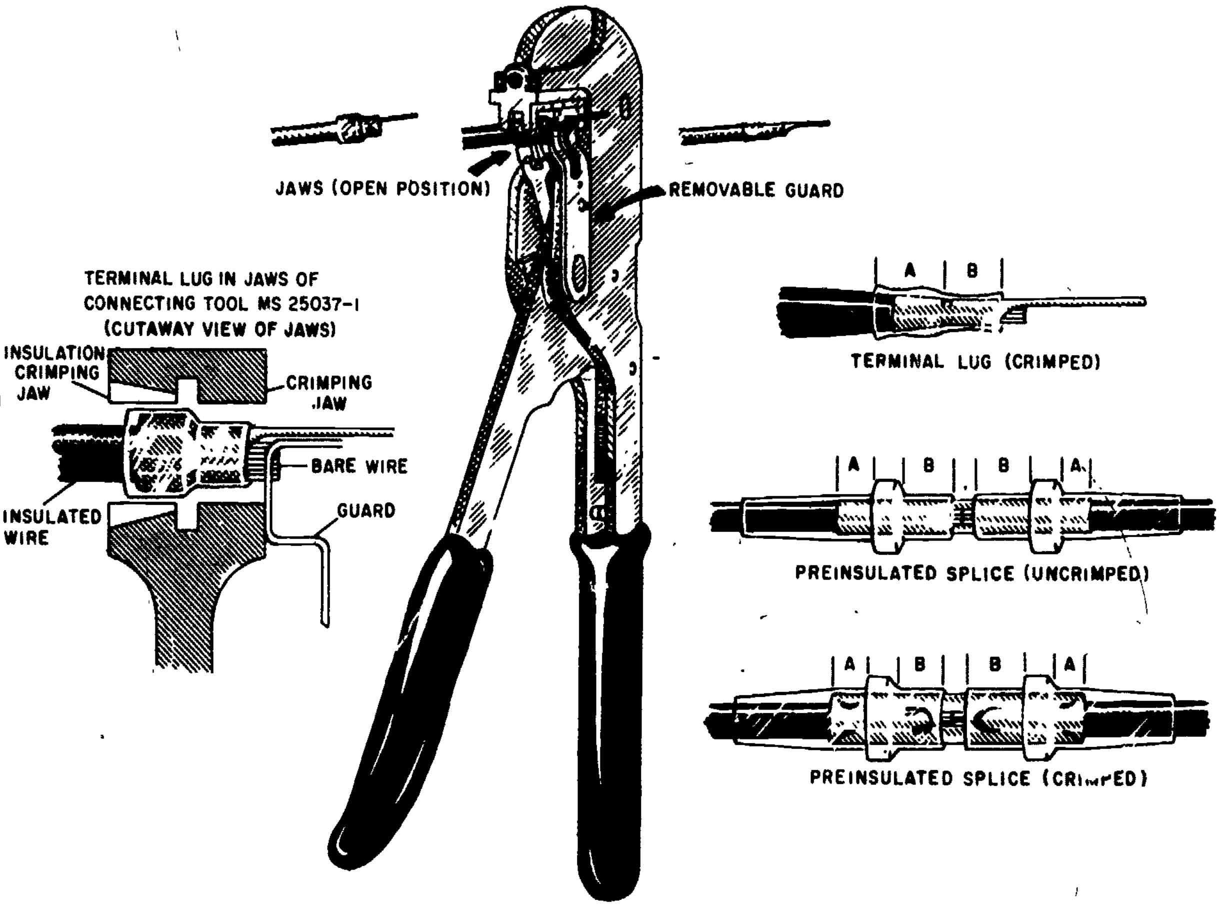

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Figure 5-3.—Crimping tool MS 25037-1.

between the two diagonal jaws of the pliers. as the handles are squeezed together, the thumb and fore finger will bring the outer (locking) sleeve into the locked position. A pull on the knob of the pliers will make a uniform twist if held properly. The spiral rod may be pushed back into the pliers without unlocking them, and by again pulling on the knob a tighter twist will be given. The wire should be installed snugly, but not so tight that the part or the wire is over-stressed. A squeeze on the handles unlocks the pliers, and the wire can be cut to the proper length with the cutting jaws.

Often the routing of the twisted wire is dictated by the particular installation, and in many instances is designated in the appropriate Operation and Service Instructions. Detailed information regarding the safety wiring of electrical connectors is contained in the previously referenced NavAir 01-1A-505. Some methods of safety wiring are discussed in chapter 8 of this manual.

Diagonal Pliers

Diagonal cutting pliers commonly called "dikes," are used for cutting small, light material, such as wire in areas which are inaccessible

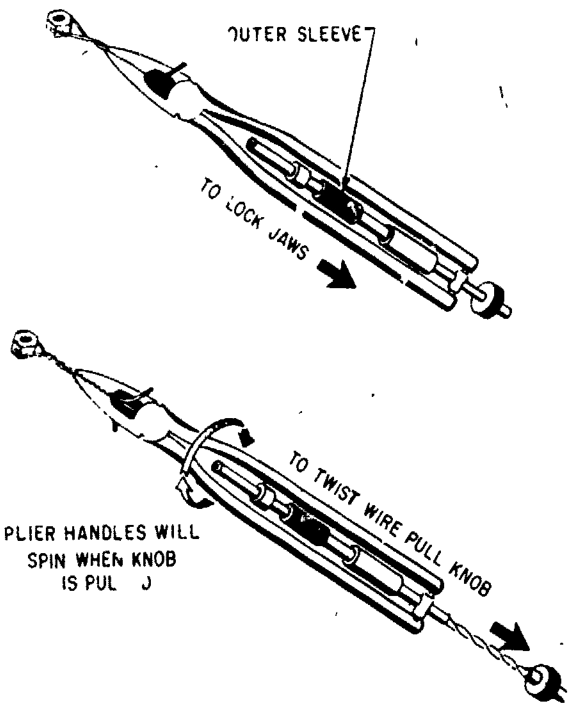

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Figure 5-4.—Using safety wire pliers.

to the larger cutting tools. The diagonal pliers are designed with approximately a 15 degree offset on the cutting edges, to permit cutting flush with a surface. These pliers should never be used to hold objects, because of the tremendous shearing force that they exert.

When using diagonal pliers to snip short lengths of wire or other materials, there is danger of flying pieces. One method of preventing or minimizing this danger is to add potting compound to the jaws of the pliers. This permits the technician to clip small bits of wire or other materials and the potting compound prevents the small bits from being propelled. Pliers of this type may be obtained through regular supply channels or a conventional pair may be modified. Refer to figure 5-5.

To modify a pair of diagonal pliers, thoroughly clean the pliers with solvent and secure the handles in closed position with tape

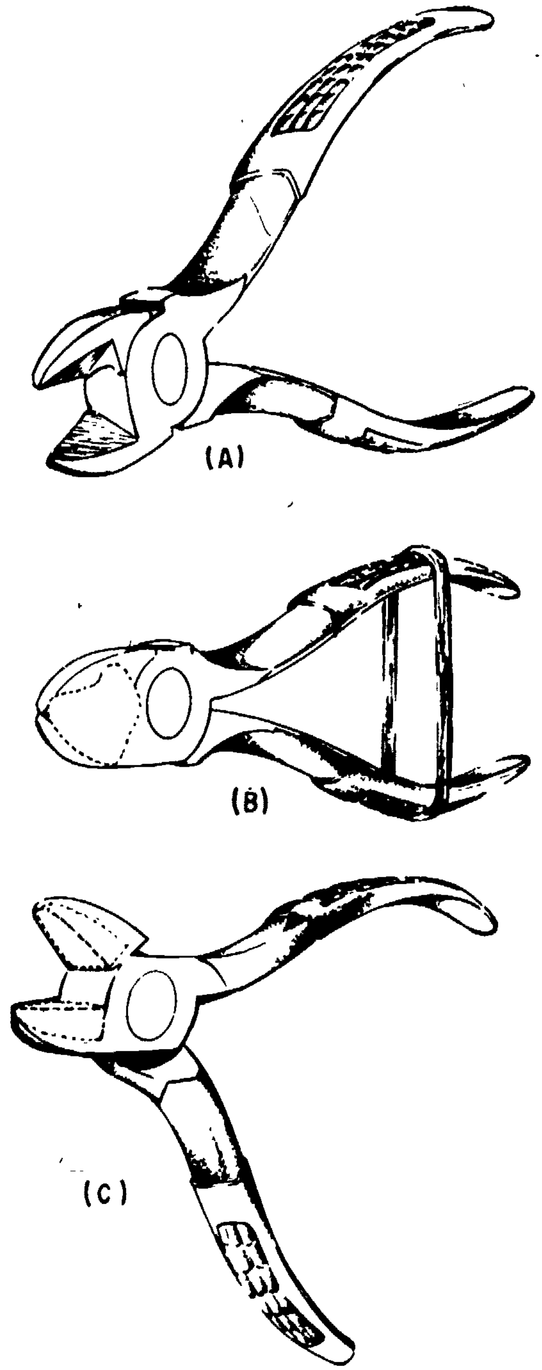

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Figure 5-5.—Diagonal pliers. (A) Without compound; (B) applying compound; (C) with compound.

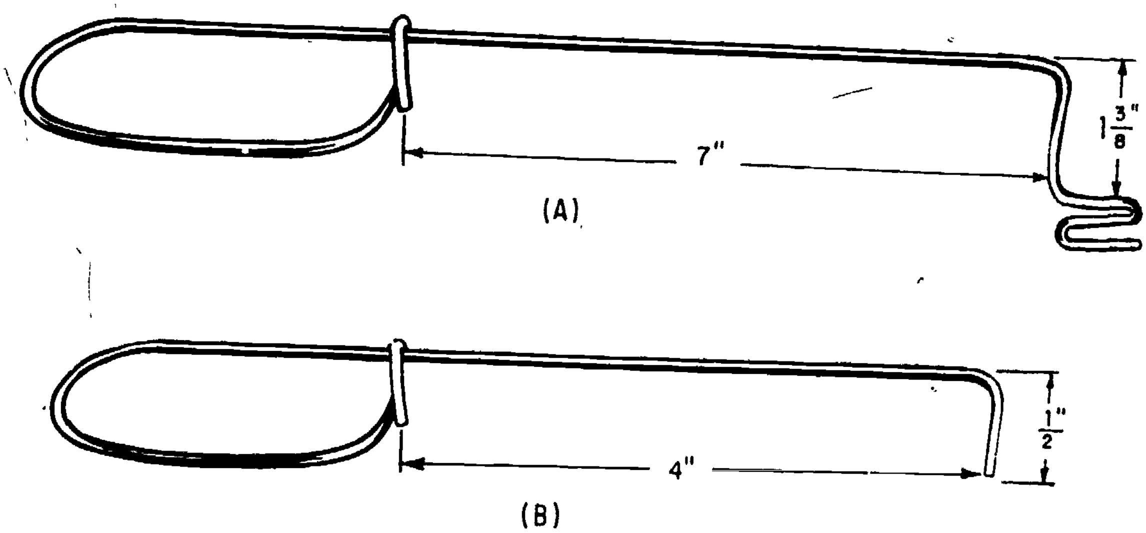

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Figure 5-6.—Brush spring compressor tools.

or a rubberband. Apply the potting compound; allow to dry for 24 hours. The jaws may then be separated by slicing them apart with a sharp cutting tool such as a knife or razor blade

Brush Spring Compressor (Lifter)

The problem of removing and installing generator brushes can be made much easier by the use of a brush spring compressor. This tool may be fabricated locally from 1/8-inch steel welding rod and used to compress the generator brush springs when removing or installing the brushes. Different versions of the tool can be made by simply bending the rod to fit the particular brush spring arrangement. The tool shown in figure 5-6 (A) was designed for a particular generator, but the one in figure 5-6 (B) can be used on several different types of generators.

Electric Soldering Equipment

The electric soldering guns and irons used in the different maintenance activities come in many types and sizes. They have a wide range of wattage ratings, especially the irons. Some will operate on 28 volts a.c. or d.c., others operate on 115 volts a.c. or d.c., and others will operate only on 115 volts a.c.

The soldering equipment designed for a.c. only normally operates on a power supply having a frequency of 60 hertz but may be used on one with a frequency of 400 hertz. This results in a lower operating temperature, but satisfactory soldering temperatures can be obtained (at the expense of increased time) without damage to the equipment.

SOLDERING IRONS.– All high quality soldering irons operate in the temperature range of 500° to 600° F. Even the little 25-watt midget irons produce this temperature. The important difference in iron sizes is not temperature, but thermal inertia (the capacity of the iron to generate and maintain a satisfactory soldering temperature while giving up heat to the joint to be soldered). Although it is not practical to try to solder a heavy metal box with the 25-watt iron, that iron is quite suitable for replacing a half-watt resistor in a printed circuit. An iron with a rating as large as 150 watts would be satisfactory for use on a printed circuit, PROVIDED that suitable soldering techniques are

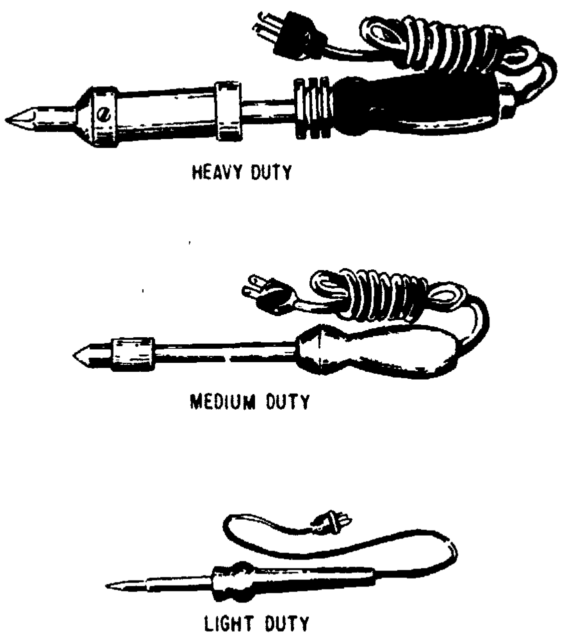

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Figure 5-7.—An assortment of soldering irons.

used. One advantage of using a small iron for small work is that it is light and easy to handle and has a small tip which is easily inserted into close places. Also, even though its temperature is high, it does not have the capacity to transfer large quantities of heat. An assortment of soldering irons is shown in figure 5-7.

Some irons have built-in thermostats. Others are provided with thermostatically controlled stands. These devices control the temperature of the soldering iron, but are a source of trouble. A well-designed iron is self-regulating by virtue of the fact that the resistance of its element increases with rising temperature, thus limiting the flow of current. For critical work, it is convenient to use a variable transformer for fine adjustment of heat; but for general-purpose work, no temperature regulation is needed.

PENCIL IRON AND SPECIAL TIPS.—The pencil iron with special tips (see fig. 5-8) is a soldering iron so versatile that it bears special mention. It is almost indispensable for soldering where the applied heat must be kept to a minimum. The iron is small in size and has a low wattage rating. This type of iron is ideal for solder work involving transistors, printed circuit repair, miniaturized components, etc.

The iron is equipped with several tips that range from one-fourth to one-half inch in size (diameter) and are of various shapes. This feature makes it adaptable to a variety of jobs. Unlike most tips which are held in place by setscrews, these tips have threads and screw into the barrel. This feature provides excellent contact with the heating element, thus improving heat transfer efficiency. A pad of "antiseize" compound is supplied with each iron. This compound is applied to the threads each time a tip is installed in the iron, thereby enabling the tip to be easily removed when another is to be inserted.

A special feature of this iron is a soldering pot (not shown) that screws in like a tip and holds about a thimbleful of solder. It is useful when tinning the ends of large numbers of wires.

The interchangeable tips are of various sizes and shapes for specific applications. Extra tips may be obtained and shaped to serve special purposes. The thread-in units are useful in soldering subminiature items. The desoldering units are specifically designed for performing special and individual functions.

Another advantage of the pencil soldering iron is its possible use as an improvised light source for inspections. Simply remove the soldering tip and insert a 120-volt, 6-watt, type 6S6, candelabra screwbase lamp bulb into the socket.

SOLDERING GUN.—The soldering gun (fig. 5-9) has gained great popularity in recent years because it heats and cools rapidly. It is especially well adapted to maintenance and troubleshooting work where only a small part of the technician's time is spent actually soldering. A soldering iron, if kept hot constantly, oxidizes rapidly and is therefore difficult to keep clean. The soldering gun eliminates this problem.

A transformer in the gun supplies approximately 1 volt at high current to a loop of copper which acts as the tip. It heats to soldering temperature in 3 to 5 seconds, but will heat to as high as 1,000°F if left on over 30 seconds. The gun is operated with a finger switch so that

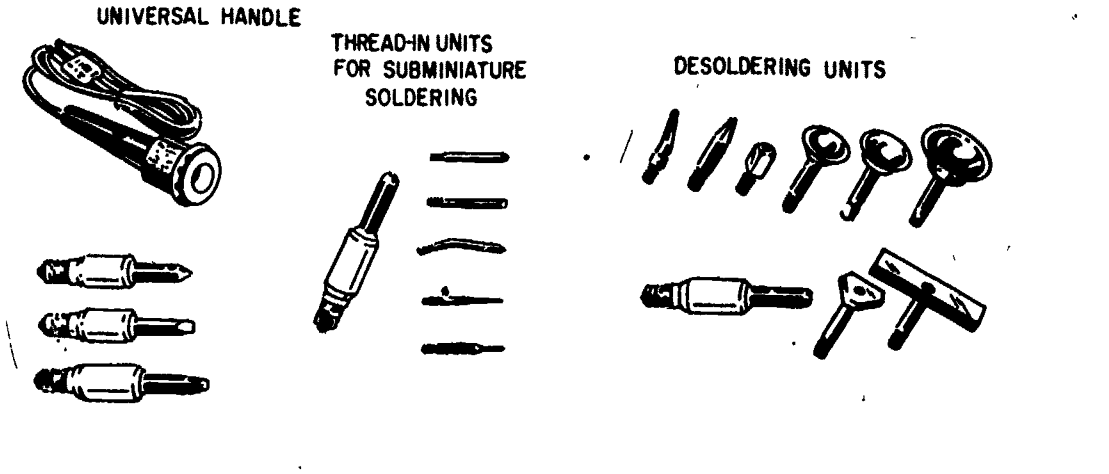

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Figure 5-8.—Pencil iron with special tips.

the gun heats only while the switch is depressed.

Since the gun normally operates only for short periods at a time, it is comparatively easy to keep clean and well tinned; thus, little oxidation is allowed to form. On the other hand, however, the tip is made of pure copper, and is susceptible to pitting which results from the dissolving action of the solder. Offsetting this disadvantage, however, is the low cost of replacement tips.

Tinning of the work is always desirable unless it has already been done. The gun or iron should always be kept tinned in order to permit proper heat transfer to the work to be soldered. Tinning also provides adequate control of the heat to prevent thermal spillover to nearby materials. Tinning of the tip of a gun may be somewhat more difficult than tinning the tip of an iron. Maintaining the proper tinning on either type, however, may be made easier by tinning with silver solder. The temperature at which the bond is formed between the copper tip and the silver solder is considerably higher than with lead-tin solder. This tends to decrease the pitting action of the solder on the copper tip.

Pitting of the tip indicates the need for retinning, after first filing away a portion of the tip. Retinning too often results in using up the tip too fast.

Overheating can easily occur when using the gun to solder delicate wiring or printed circuits. With practice, however, the heat can be accurately controlled by pulsing the gun on and off with its trigger. For most jobs, even the LOW position of the trigger overheats the gun after 10 seconds; the HIGH position is used only for fast heating and for soldering heavy connections.

Heating and cooling cycles tend to loosen the nuts or screws which retain the replaceable tips on soldering irons or guns. When the nut on a gun is loosened, the resistance of the tip connection increases, and the temperature of the connection is increased. Continued loosening may eventually cause an open circuit. Therefore, the nut should be tightened periodically.

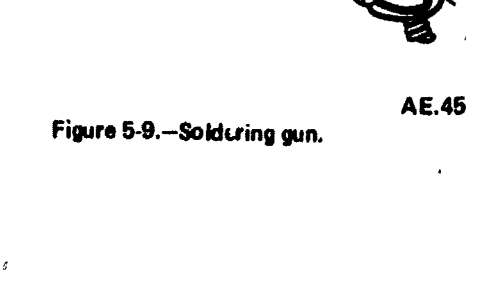

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Figure 5-9.—Soldering gun.

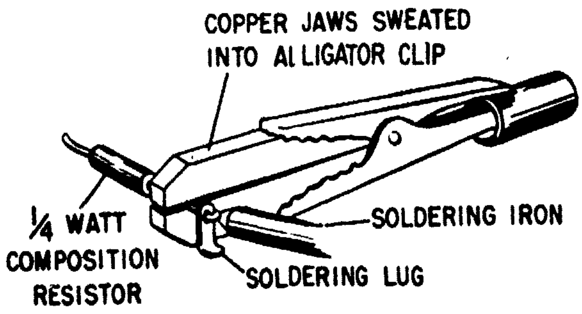

Figure 5-10.—A clamp type heat shunt in use.

To obtain best results from a soldering gun or iron, the tip must be kept free of oxide and scale. Most technicians wipe the tip on cloth, then file and retin as necessary.

A faster way is the "damp sponge" method. A dampened cellulose sponge is secured in a container such as a soapdish or metal ashtray. (The sponge is more effective than the cloth in keeping the tip clean, and presents no safety problems.) The damp sponge prevents the splattering that sometimes occurs when the heated tips are wiped off in the usual way, and also absorbs particles that may injure the technician's face. The sponge eliminates oxide and scale, so filing and retinning are kept to a minimum.

THERMAL SHUNT (HEAT SINK).—Overheating and damage of miniature resistors, capacitors, transistors, etc., can often be avoided by restricting the conduction of heat to the metal leads and preventing it from flowing into the body of the part during the soldering process. This can be accomplished by using a thermal shunt (heat sink). The term "shunt" as used here, is not intended to imply that the heat returns to the lead at some other point in the same way that current does when using an electrical shunt. The heat is dissipated into the surrounding air when using a thermal shunt. The point is, much of the heat is turned aside (shunted) and is not allowed to enter the part.

A simple and frequently used method of providing a thermal shunt is to grip the lead between the body of the miniature part and the terminal with a pair of long-nosed pliers. The metal jaws form a low-resistance heat path which funnels the flow of heat away from the part. This method has certain disadvantages; it is awkward to solder with one hand and, even more important, the technician may have a tendency to release the pliers upon removing the soldering iron and permit an unrestricted flow of heat into the part from the still molten solder. Also, steel pliers do not possess the degree of heat conductivity required for effective shunting or full protection against damage.

A more effective heat shunt is provided by a clamp, made of copper, which can be left attached to the lead until the joint cools. A good clamp shunt can be made easily by sweating small copper bars into the jaws of an ordinary alligator clip. A shunt of this type is shown in figure 5-10.

A clamp type heat shunt should be used when soldering the leads of small capacitors, resistors, transistors, choke coils, etc. The clamp should be placed near the body of the part and as far as possible from the joint being soldered. Care should be taken to avoid the formation of a low-resistance heat path between the hot soldered connection and the part. Do not allow the clamp to contact both.

The effectiveness of the clamp type heat shunt can be maintained by keeping the jaws flat and free from dirt, grease, or soldering flux so that a good contact between the clamp and the metal lead is insured. The face of the clamp turned toward the iron should be kept bright to minimize heat transfer by radiation, while the rest of the clamp body should be dull black in color.

Brush Contouring Device

The discussion that follows describes a brush contouring device that can be easily constructed in most electrical work centers. If properly used, it will insure proper brush seating and save time. Should the ASE decide to construct one of these devices, he may not want to follow the exact procedure outlined here. However, the information that is given should prove helpful as a guide.

Figure 5-11 shows the disassembled parts that are needed for constructing the device, and figure 5-12 shows an assembled view and how the device is used.

The following materials are required for the brush contouring device:

1. One piece of laminated plastic (A), 4 x 6 x 1/2 inches.
2. One brass disc (B), 1 inch thick, drilled in the center to receive a bolt for mounting.
3. One piece of angle aluminum (C), 1 x 1 x 2-1/2 inches.
4. One piece of 1/8-inch plastic (D), 2-1/2 x 3 inches.
5. One bolt (E), for mounting the disc, and two instrument mounting screws. One of these screws is to be fitted with a wingnut.

Part (B) must be turned on a lathe since its diameter is critical. This part must have the same diameter as the commutator or slipring for which the brush is being fitted.

The following steps should be used when contouring brushes:

1. Loosen the adjusting bolt in the elongated slot in part (C).
2. Using an old brush removed from the generator, motor, or electrical starter, place the

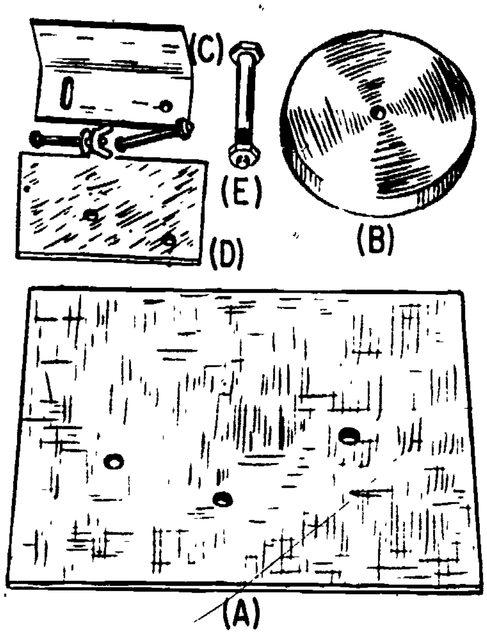

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Figure 5-11.—Parts required for contouring device.

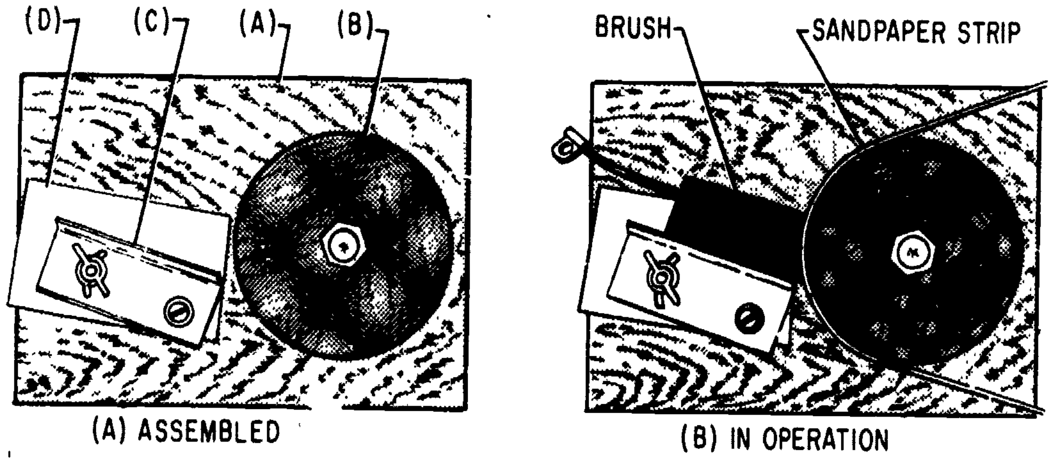

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Figure 5-12.—Brush contouring device. (A) Assembled; (B) in operation.

brush against the angle aluminum. part (C), adjusting the angle until the brush contacts the brass disc throughout its contoured surface. Lock part (C) with the wingnut. CAUTION: Use only properly seated brushes (that is, brushes that have been in use for many hours of operation) for step 2.

3. One person then holds a strip of very fine sandpaper, 1 inch wide, on the outer diameter of the brass disc, and pulls the ends alternately back and forth, keeping the sandpaper taut. The other person holds a new brush against part (C) and pushes lightly against the sandpaper until the proper contour is formed on the brush end. NOTE: Be careful to keep the brush tight against (C) during contouring.

By contouring brushes with this device instead of letting them "break in" on the generator, all carbon, dust, grit, etc. (normally produced as the new brush becomes seated) are kept out of the generator. Moreover, the brush surface is contoured at the correct angle with respect to the longitudinal axis of the brush. With the device, less run-in time is required, there is less chance of generator failure due to brushes heating, and excessive commutator and slipring wear is greatly reduced.

Clamps and Jigs

In many maintenance operations (such as fabricating or potting cable connectors; repairing small modules, terminal strips, mounting boards, or printed circuit boards; etc.), it is necessary to provide a jig or clamp to hold the component while the work is being performed, or while the potting compound is curing. The jigs may be fabricated locally by cutting mating V notches in boards which are held together by springs. Both boards are positioned in channels, with one board fixed and the other adjustable to permit the insertion of the component.

Clamps are required whenever work is to be drilled or filed, or when the component must be kept immobile while the work is being done. Standard C clamps or bench vises may be suitable for this purpose, or specially designated equipment may be listed in the technical manuals

TOOLBOXES, WORK CENTER TOOLS AND TOOLROOMS

One of the first steps usually taken when a new man reports for duty to the support equipment work center of an activity is to issue him an individual toolbox. The toolbox should contain the low-cost, high-usage handtools that will enable him to perform the tasks assigned. The purpose of the individual toolbox is to make the necessary tools for performance of assigned maintenance tasks immediately available to the individual.

Under the crew leader concept of maintenance, the crew leader's toolbox has the same type tools as the individual toolbox. It is issued to an individual of a crew, and is to be used by all members of that crew. Thus, the crew leader's toolbox will have several of the same type and/or size tool while the individual toolbox has only one or two.

When receiving a toolbox, the individual or crew leader must sign for and be responsible for the toolbox. It is each man's responsibility to take good care of his tools and to use them correctly. When a tool wears out or is lost or broken, a replacement may be obtained from the toolroom. But if a man is negligent with his tools, it is very likely disciplinary action will be taken to correct his problem.

Work center tools are the larger, low-usage, and special tools for use on specific equipments. A work center tool bin is normally utilized to make available to the technician those special tools (pertaining to the rate) and medium-usage tools needed to perform the various phases of work center maintenance. However, work center tools also include any handtools required to perform more extensive maintenance than can be accomplished from an individual toolbox or a crew leader's toolbox. To determine the types and number of work center tools allowed, refer to the applicable allowance list.

The toolroom supervisor has the responsibility for all tools, including issuance of tools, inventory of toolboxes, and ordering new tools for replacement of broken or lost tools. A toolroom is set up under the responsibility of the maintenance department. Its purpose is for the stowage and issuance of low-usage handtools and those tools which are common to more than one work center. Certain special tools are also stowed in the toolroom.

The tools used in an activity are determined by the mission of the activity and the type of support equipment to be maintained. In view of this, there is no hard and fast rule as to the type and/or number of tools that may be supplied in the different toolboxes and toolrooms. The quantity and types of tools allowed for an activity may be found in the appropriate allowance list.

Most handtools are not feasibly repairable. Due to this fact and their original low cost (compared to work center tools), they are classed as consumable. However, the activity must pay for replacements. Therefore, it is the duty of each man to help eliminate the need for replacements. One method of accomplishing this is by maintaining an inventory of tools in each toolbox so that upon completion of a job all of the tools can be accounted for. A tool that has been lost represents a waste of funds; in addition, it is a definite liability. Likewise operating support equipment in which a tool has been left may cause damage to the equipment and injury or death to personnel.

The basic objective of an inventory is to insure a proper balance between the supply of, and the demand for, those tools required for the efficient operation and maintenance of a squadron or maintenance activity. To accomplish this objective it is necessary that tools be identified and cataloged to provide accurate knowledge of the tools being used. Each item should be accounted for by formal inventory every 30 to 90 days in accordance with local instructions. The number of handtools on hand in relation to the number required by the activity should be indicated by the inventory.

Tools should be reordered as the inventory requirements dictate unless some unusual circumstance exists. For example, if a particular tool is no longer used, steps should be taken to get it removed from the inventory. Likewise, if a particular tool is needed it can be added to the inventory. In each of the situations, the work center supervisor should be made aware of the problem so that he can go through proper channels for getting the inventory corrected. If a shortage of tools exists and they cannot be obtained from the toolroom, inform the work center supervisor. He in turn will work with the toolroom supervisor in obtaining the tools required. The tools are to be replenished as they are needed. (It is unwise to wait until the number of tools needed is too large, as it is easier for the supply department to fill a small order rather than a large one.) Tools are ordered by reference to Consumable General Support Equipment for All Types, Classes, and Models of Aircraft, NavAir 00-35QG-016.

HARDWARE AND CONSUMABLE MATERIALS

Items of hardware used when installing units in support equipment are specified in the applicable Operation, Service and Repair Manual. In all instances, the proper hardware should be used; if substitution becomes necessary, care must be taken that the substitute item is satisfactory in all respects.

Prior to reinstalling the removed hardware, an inspection must be made to insure that it is not defective or damaged. It must also be determined that instructions do not forbid its reuse. Then, and only then, may the removed hardware be reinstalled.

General information regarding such mounting hardware as screws, nuts, bolts, washers, etc., is included in various Rate Training Manuals. Structural Hardware, NavAir 01-1A-8, is a valuable source for detailed information.

SUBSTITUTION OF MOUNTING HARDWARE

If the specified mounting hardware cannot be obtained, an installation may be made using suitable substitute hardware. There are several publications such as the Operations and Service Instructions, Overhaul Instructions, Illustrated Parts Breakdown, etc. that may list authorized substitutes. If a substitute is not listed the ASE may have to decide what can be used and the publication Structural Hardware, NavAir 01-1A-8 will be invaluable for this purpose. If there is any doubt about the suitability of a substitute consult the work center supervisor.

When making hardware substitutions, special

Table 5-1.—Torque values in pound-inches

Wrench size (in.)	Standard nuts, bolts, and screws		
	Bolt, stud, or screw size	Tension type nuts AN310 and AN365	Shear type nuts AN320 and AN364
1/4	4-48	4-5.5	2.5-3.5
5/16	6-40	7.5-11	4.5-6.5
11/32	8-36	12-15	7-9
3/8	10-32	20-25	12-15
7/16	1/4-28	50-70	30-40
1/2	5/16-24	100-140	60-85
9/16	3/8-24	160-190	95-110
5/8	7/16-20	450-500	270-300
3/4	1/2-20	480-690	290-410
7/8	9/16-18	800-1,000	480-600
15/16	5/8-18	1,100-1,300	660-780
1-1/16	3/4-16	2,300-2,500	1,300-1,500
1-1/4	7/8-14	2,500-3,000	1,500-1,800
1-7/16	1-14	3,700-5,500	2,200-3,300

NOTE: To convert to pound-feet, divide pound-inches by 12.

attention must be given to the following:

1. Corrosion. The chemical or metallic composition of the hardware must be such that its use does not contribute appreciably to the danger of corrosion.

2. Strength. The strength of the substitute must be the same, or greater than the ones prescribed. (When determining the strength, consideration should be given to the tensile, compression, and/or shear strength, as applicable to the specific use.)

3. Size. Substitute bolts and screws should be the same size as the prescribed item. If a detachable nut is to be used, a different thread may be tolerated; if a threaded hole or an anchor nut is involved, the thread must be the same as the one prescribed. In all cases, washers must have the same inner diameter as the prescribed item, but a different outer diameter or thickness may sometimes be permitted.

4. Length. Substitute screws or bolts must have a length which is sufficient for the particular installation, but must not be so long that they are in the path of any moving part. They

must not be in contact with other items such as electrical wiring, hydraulic lines, etc.

5. Style. Most items of mounting hardware are available in various styles. It is usually easy to find screws and bolts which are identical in all respects except for the type head. These parts are usually to be preferred as substitutes, provided they possess all required special features.

6. Special features. If a bolt is to be torqued to a given value, a torque wrench which is usable with that type part and which has the proper torque range must be available. If lockwiring is required, the part must have suitable provisions.

7. Lubrication or coating. If specific instructions call for lubrication or coating they must be followed for the substitute as well as for the prescribed hardware.

TORQUE INFORMATION

The torque table (table 5-1) may be used as a guide in tightening nuts, bolts, and screws whenever specific torque values are not specified in maintenance procedures. Using the proper torque allows the structure to develop its designed strength and greatly reduces the possibility of failure due to fatigue.

Threads must be free from grease or oil. Lubrication changes the torque value and will result in overtorquing.

When castellated nuts are used, they should be tightened to the lower torque limit; then continue tightening until the cotter pin hole is alined with slots in the nut. Do not back off the nut to aline the hole.

When it is necessary to tighten from the bolthead, use the high side of the torque range. If necessary, the maximum allowable tightening torque may be used.

When corrosion-resistant steel bolts are used, they should be lubricated with an antiseize compound. Corrosion-resistant steel bolts and nuts must be used together. Use shear nut torque values when tightening these bolts.

"TORQ-SET" SCREWS

"Torq-Set" machine screws (offset cross-slot drive) have recently begun to appear in new equipment. The main advantage of the newer type is that more torque can be applied to its head while tightening or loosening than any other screw of comparable size and material without damaging the head of the screw.

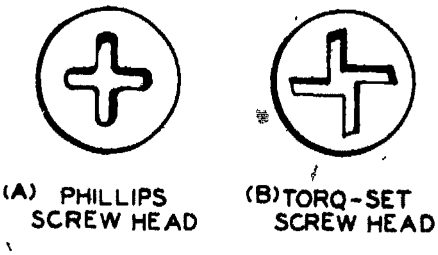

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Figure 5-13.—Comparison of Phillips and Torq-Set screwheads.

Torq-Set machine screws are similar in appearance to the more familiar Phillips machine screws.

Since a Phillips screwdriver could easily damage a Torq-Set screwhead, making it difficult if not impossible to remove the screw even if the proper tool is later used, maintenance personnel should be alerted to the differences. (See fig. 5-13.)

SAFETY WIRE

Hardware such as drill-head bolts, fillister-head screws, clips, thumbscrews, plugs, and similar items, are safetied with wire. Corrosion-resisting steel lockwire is usually used for this purpose. Annealed corrosion-resisting wire is also used for specific applications, such as where nonmagnetic qualities and heat resisting properties are desired. For securing emergency devices, where it is necessary to be able to break shear wire quickly, aluminum or copper lockwire is used. Two different methods of safety wiring are discussed in chapter 8 of this training manual.

BONDING STRAPS

A bond is any fixed union existing between two metallic objects to provide electrical conductivity between them. Such a union results from either physical contact between conductive surfaces of the objects or from the addition of a

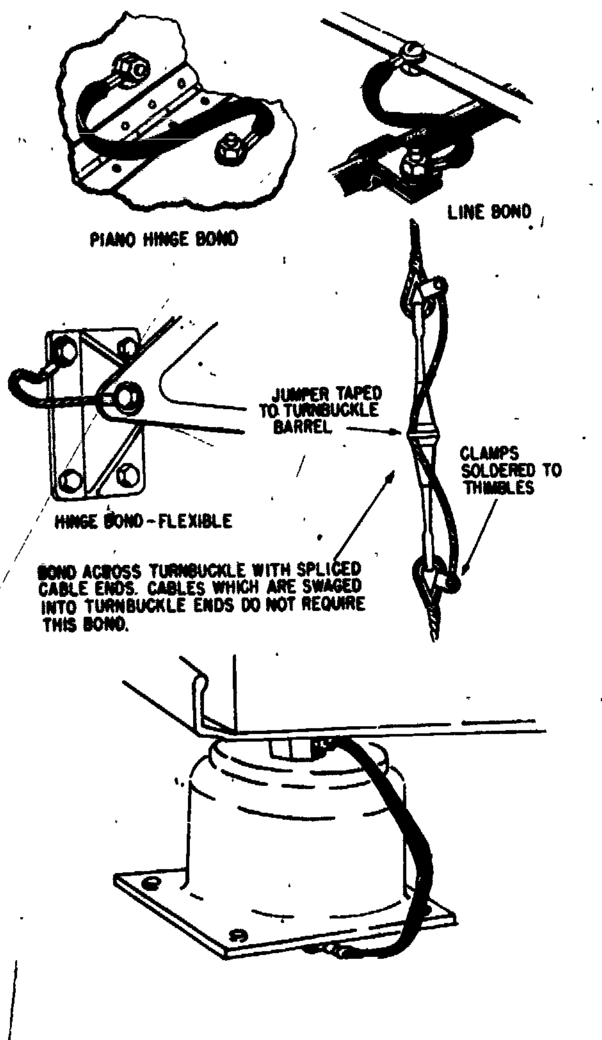

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Figure 5-14.—Bonding examples.

firm electrical connection between them. Electrical bonding is the process of obtaining the necessary electrical conductivity between the component metallic parts. An isolated conducting part or object is one that is physically separated by intervening isulation from the structure and from other conductors which are bonded to the structure.

A bonding connector provides the necessary electrical conductivity between metallic parts not in sufficient electrical contact. Examples of bonding connectors are bonding jumpers and bonding clamps. (See fig. 5-14.)

Self-tapping screws should not be used for bonding purposes nor should jumpers be fastened through plywood or other nonmetallic material. When performing a bonding operation, the contact surfaces should be cleaned of insulating finishes or surface films before assembly, and then the completed assembly refinished with a suitable protective finish.

Consult Installation Practices for Aircraft Electric and Electronic Wiring, NavAir 01-1A-505, for detailed information dealing with bonding.

SHOCK MOUNTS

Some electrical/electronic equipment is sensitive to mechanical shock and vibration; therefore, units of electrical/electronic equipment are normally shock mounted to provide some protection against vibration and shock. The specific type shock mount is prescribed in the applicable manual for the specific equipment, and substitution should not be made.

Periodic inspection of shock mounts is required, and defective mounts should be replaced with the prescribed type. In the inspection, the main factors are chemical deterioration of the shock absorbing material, stiffness and resiliency of the material, and overall rigidity of the mount. If the mount is too stiff or too rigid, it may not provide adequate protection; if it is not stiff or rigid enough, it may permit prolonged vibration following an initial shock. When determining the limits of rigidity and resiliency, consideration must be given to the weight of the mounted unit as well as the amount of vibration or shock to which it is subjected.

Shock absorbing materials commonly used in shock mounts are usually electrical insulators. For the sake of safety, it is required that each electrical/electronic unit mounted in this manner must be electrically bonded to a structural member. (See fig. 5-14.) The bonding strap should also be included in the inspection of the shock mounts, and defective or ineffective bonds should be replaced or reinstalled.

CABLE CLAMPS

Clamps are used to provide support for open wiring, and to serve instead of (or in addition to) lacing on open wiring. They are usually supplied with a rubber cushion. When used with shielded conduit, the clamps are of the bonded type (fig. 5-15 (A)); that is, provision is made for electrical contact between the clamp and conduit. Unbonded clips are used for the support of open wiring.

Long runs of cable between panels are supported either by a strap type clamp, shown in (B) of figure 5-15, or by a clamp of the type shown in (C) of the same figure. The preferred method of supporting cables for all types of runs is with the type shown in (C). When strap type clamps are used, precautions must be exercised to insure that they will hold the cables firmly away from lines, operating controls, and all movable parts.

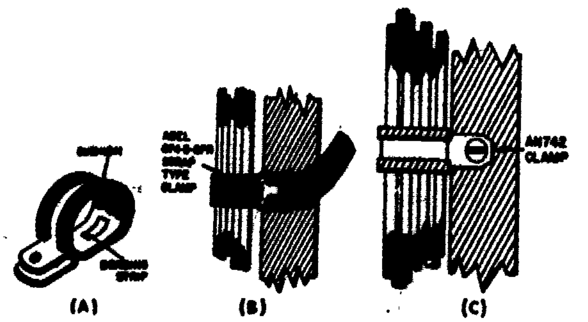

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Figure 5-15.—Cable clamps.

WIRE

Although modern technical literature has been emphasizing the use of printed circuits and microelectronic components in contemporary electrical/electronic equipment, wire is still important as a signal-carrying or current-carrying device. Therefore, as a significant part of operating equipment, wire does deserve appropriate coverage.

Since most support equipment is of conventional construction, the traditional wire conductors are still in use and probably will continue to be for some time to come. Therefore, the ASE will be required to order wire through the supply system. If the wire is of a special type, very difficult to make up (install terminals and other types of connectors on the wire), etc., it may be obtained completely assembled and ready to install on the equipment. When the task of making up the wiring or wiring harness is within the capabilities of the maintenance activity, the ASE will have to obtain the materials and perform this task. Information on the wire and materials can normally be found in the Illustrated Parts Breakdown but in some instances it may be necessary to refer to the Operation, Service and Repair Instructions or Support Equipment Changes. Additional information on the selection of wire is contained in chapter 6 of this manual.

SOLDER

There are two types of solder which are known as soft solder and hard solder. They are classified according to the material from which they are made and their melting point (temperature).

Soft solder is a tin-lead alloy and has a low melting point (428° F for 50 percent tin and 50 percent lead). The three grades of soft solder generally used for electrical/electronic work are 40-60, 50-50, and 60-40. The first figure is the percentage of tin; while the other is the percentage of lead. The higher the percentage of tin content, the lower the temperature required for melting. Also, the higher the tin content, the easier the flow, the less time required to harden, and generally the easier it is to do a good soldering job. The 40-60 grade of solder is generally used for large wires and when a higher heat is permitted, the 50-50 grade is for medium size wires and medium heat, the 60-40 grade is for small wires; printed circuits, etc. where a low heat is required.

Hard solder is made from one of several different metals that have a high melting point (1150° to 1400° F unless some other material is mixed with them). Hard solder is used when a

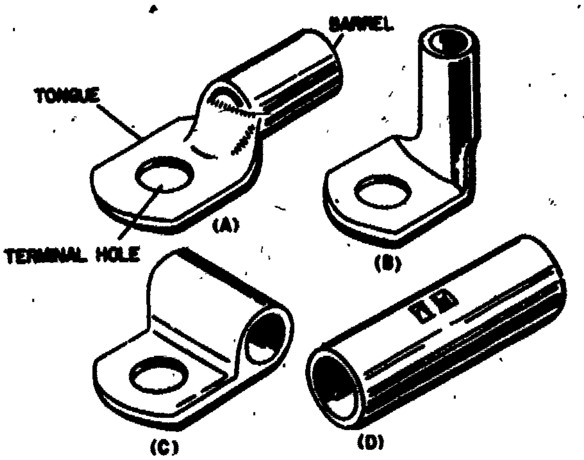

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Figure 5-16.—Basic types of solderless terminal lugs.

joint of great strength is required and where a high temperature is permitted. Silver is a good example of one of the metals sometimes used on electrical connections.

FLUXES

All common metals are covered with a nonmetallic film, usually an oxide of the material, which prevents them from making the intimate contact so necessary for a good electrical connection. The purpose of a flux is to dissolve oxide on the surfaces to be soldered, not to clean them. Flux cannot replace good cleaning methods in preparing surfaces for soldering. Without a clean intimate contact, the solder joint will result in a mechanically weak, high resistance connection.

Soft solder fluxes are divided into three general groups-rosin, organic, and chloride (sometimes called acid). The residue from the rosin-base flux is noncorrosive and electrically nonconductive, making it highly acceptable for use on electrical/electronic wiring and equipment. The organic and chloride fluxes are highly corrosive and an involved cleaning process must be used for their removal; therefore, these fluxes are not used for electrical/electronic applications.

The rosin type flux is available in two different forms. One is a paste that normally comes in a can or jar and is to be used with either solid wire or bar solder. The other is a paste in the hollow center of wire solder and is referred to as rosin-core solder. The latter is the type primarily used in electrical/electronic applications because it is easier to use and obtain good results.

The hard solder flux will usually be in a paste or liquid form. There are so many different mixtures to be used with the different hard solders that they will not be discussed in this manual.

TERMINAL LUGS

Since most wires are stranded, it is necessary to use terminal lugs to hold the strands together and facilitate fastening the wires to terminal studs. The terminals used in electrical wiring are either of the soldered or crimped type. Terminals used in repair work must be of the size and type specified on the electrical wiring diagram for the particular equipment. Soldered and crimped-type terminals may be used interchangeably but both must have the same amperage capacity and the same size hole in the lug.

The increased use of crimp-on terminals is based to a large degree upon the limitations of soldered terminals. The quality of soldered connections depends mainly upon the operator's skill. Such factors as temperature, flux, cleanliness, oxides, and insulation damage due to heat also contribute to defective connections when they are not precisely controlled.

To crimp-on solderless terminals require relatively little operator skill. Another advantage is that the use of a crimping tool eliminates the necessity of supplying power to a soldering iron. This allows terminals to be applied with a minimum of time and effort. The connections are made more rapidly, are cleaner, and are more uniform. Due to the pressures exerted and materials used, the crimped connection or splice, properly made, has an electrical resistance that is less than that of an equivalent length of wire.

The basic types of terminal lugs are shown in figure 5-16, Part (A) shows the straight type, (B) the right angle type, (C) the flag type, and (D) the splice type. There are also variations of these types, such as the use of a slot instead of a terminal hole, three- and four-way splice type connectors, and others.

Since both copper and aluminum wiring are used, both copper and aluminum terminals are necessary. Various size terminal or stud holes will be found for each of the different wire sizes. A further refinement of the solderless terminals is the insulated type; the barrel of the terminal is enclosed in an insulation material. The insulation is compressed along with the terminal barrel when crimping, but is not damaged in the process. This eliminates the necessity of taping or tying an insulating sleeve over the joint. An insulated solderless (crimp on type) terminal and splice are shown in figure 5-3, along with a crimping tool which is used for installation of these type terminals and splices.

SEALING (POTTING) COMPOUND

In some applications special environment-proof, electrical connectors are used on support equipment. However, operating conditions sometimes demand that ordinary electrical connectors, relays, etc. be given a sealing (moisture-proofing) treatment. The basis of this treatment is the application of a sealing (or potting as it is commonly called) compound.

Sealing reduces failure of electrical connectors and reinforces the wires at the connectors against failure caused by vibration and lateral pressure, both of which fatigue the wire at the solder cup.

The sealing compound also protects electrical connectors from corrosion and contamination by excluding metallic particles, moisture, and other liquids. As a result of its improved dielectric characteristics, it reduces the possibility of arc-over between pins at the electrical connectors.

The sealing compound is provided in kit form through the normal supply channels. The kits may contain just the base material and an accelerator (curing agent) which are mixed together to form the compound or it may contain several additional items for mixing and applying the compound.

There are several variations of the two types of sealing compounds that will be discussed in this manual. One of the compounds consists of a polysulfide synthetic rubber base and accelerator and is manufactured according to military specification MIL-S-8516C and is for use where the ambient temperature does not exceed 200° F. The other type of compound consists of a silicone rubber base and accelerator and is manufactured according to military specification MIL-S-23586A and is for use where the ambient temperature exceeds 185° F but does not exceed 450° F.

Chapter 8 of this manual contains general information on the use of the sealing compound. For reasons of safety and to obtain the desired results it is very important that the manufacturer's directions and safety precautions be followed in detail for storing, mixing, and applying the compound.

INSULATING SLEEVING

Insulating sleeving (commonly called "spaghetti") is used in electrical/electronic maintenance operations in many maintenance activities. Among the operations involving use of the sleeving are the fabrication of cable connectors, connection to relays and terminal strips, crimped or soldered terminal lugs or splices, tie points on terminal strips or terminal boards, etc.

METAL FASTENERS

Many types of metal fasteners are used to secure cowling, fairing, inspection plates, and access panels and doors. Therefore, an understanding of their construction will enable the ASE to use, repair, and replace them properly. There are many types of metal fasteners used in support equipment, but for this discussion the turnlock and threaded types are used as representative examples.

Turnlock Fasteners

The various stud assemblies of turnlock fasteners are either slotted for screwdriver operation or have winged heads which are used for

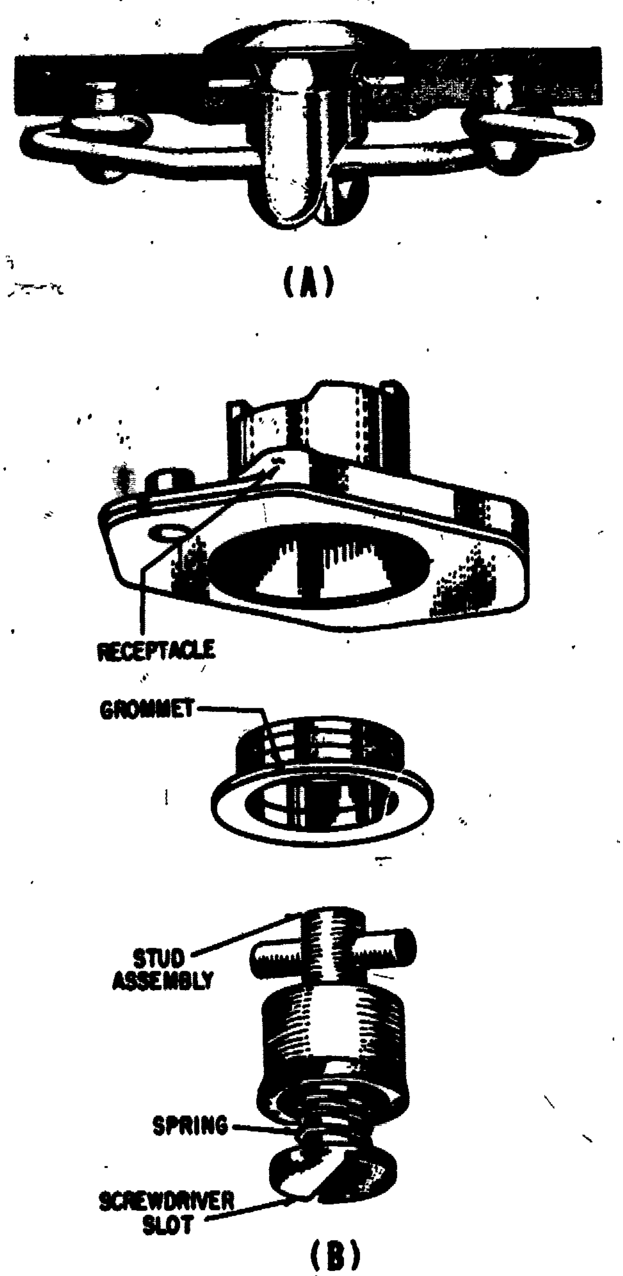

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Figure 5-17.—(A) Light duty type turnlock fastener; (B) positive lock type fastener.

fastening and unfastening. Figure 5-17 (A) shows a light duty type which is used on panels, junction box doors, and inspection plates. Part (B) of the figure shows a type of fastener in which a spring provides a positive lock of the fastener.

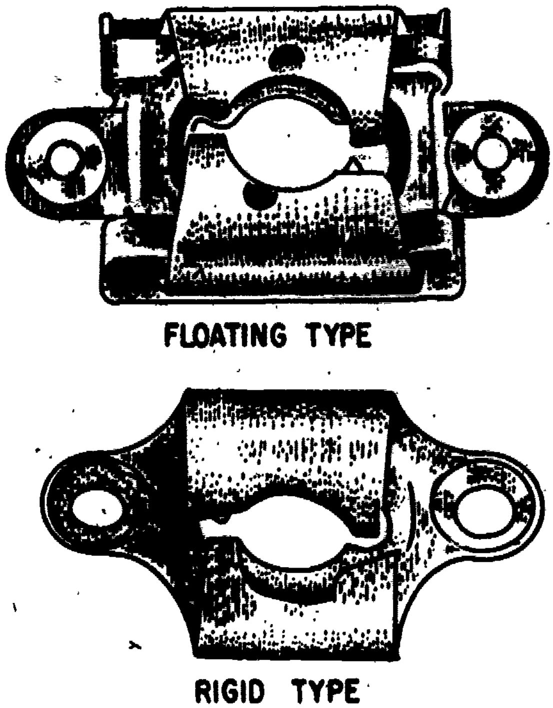

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Figure 5-18.—Fastener receptacles.

Stud assemblies are assembled at the factory and should not be disassembled. To install the assembly, compress the spring and insert the stud assembly into the grommet. Once installed into the grommet, the stud assembly cannot be removed unless the spring is again compressed.

There are various types of fastener receptacles, Representative receptacles are shown in figures 5-17 (B) and 5-18. The receptacle shown in figure 5-18 is designed in two styles—rigid and floating. The floating type is the more common since it enables the receptacle to move slightly, and therefore alinement is easier. The receptacles are manufactured from high-carbon, heat-treated steel for long dependable life. They are

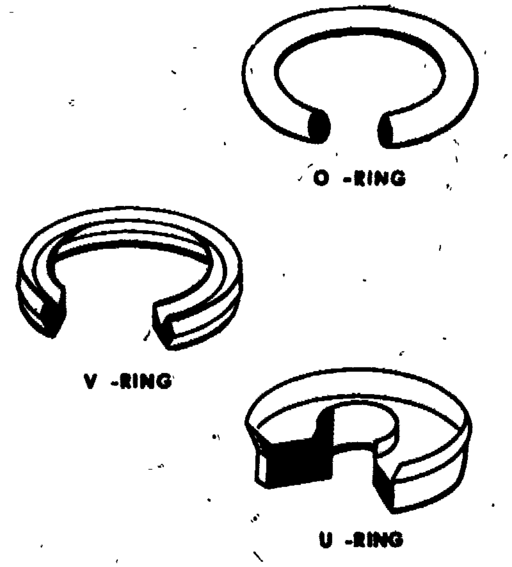

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Figure 5-19.—Packing rings.

riveted to the portion of the equipment to which the panel, door, or inspection plate is to be anchored. The correct procedure for the installation of fasteners is given in NavAir 01-1A-8, section XI. A good rule to follow when securing a panel, inspection plate, or door is to never force the fastener. If it seems hard to catch or lock, the receptacle may be damaged; forcing may only damage it more. Always compress the spring or stud fully and use an even force. If the stud does not lock, release and turn the stud slightly to realine. Always use the proper tool for locking the fasteners.

NOTE: Power tools are never used for locking or unlocking the fasteners previously discussed.

Threaded Fasteners

Although rivets are used extensively in construction of support equipment, many parts require frequent dismantling or replacement, making it more practical to use some form of threaded fastener. Furthermore, some joints

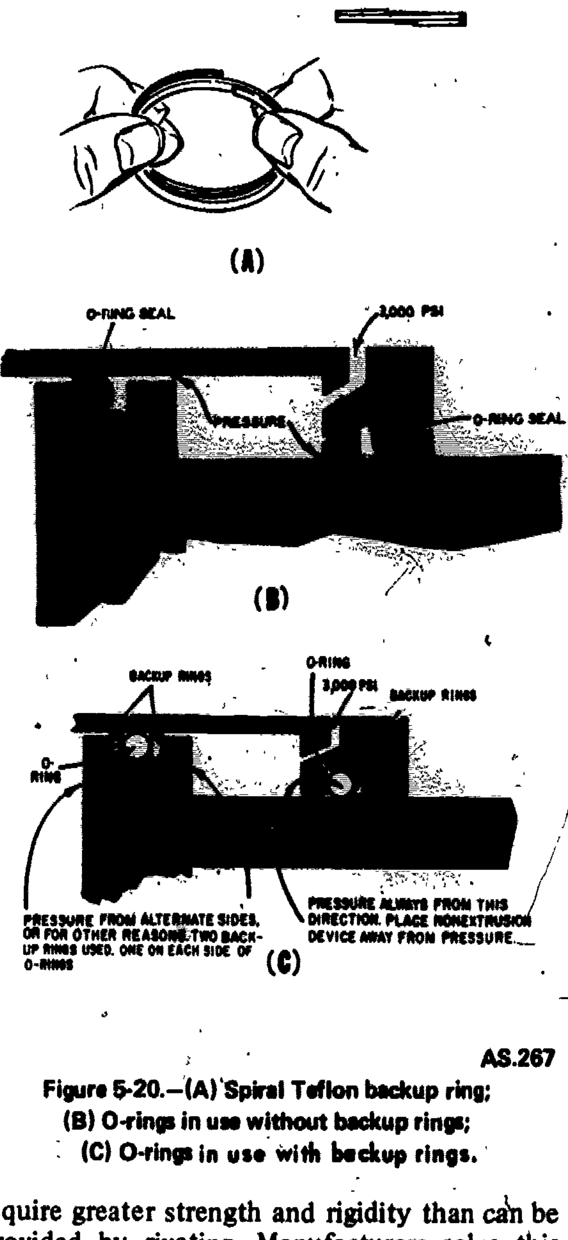

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Figure 5-20.—(A) Spiral Teflon backup ring; (B) O-rings in use without backup rings; (C) O-rings in use with backup rings.

require greater strength and rigidity than can be provided by riveting. Manufacturers solve this problem by using various types of screws, bolts, and nuts.

Bolts and screws are similar in that both have a head at one end and threads at the other, but there are several differences between them. The threaded end of a bolt is always relatively blunt, while that of a screw may be either blunt or pointed. The threaded end of a bolt must be

AS.208

Figure 5-21.—O-rings in opened and unopened shipping/stocking envelopes.

screwed into a nut, but the threaded end of the screw may fit into a nut or other female type arrangment, or may fit directly into the material bieng secured. A bolt has a fairly short threaded section and comparatively long grip length (the unthreaded part), whereas a screw may have a longer threaded section and no clearly defined grip length. A bolt assembly is generally tightened by turning its nut, and its head may or may not be designed to be turned, while a screw is always designed to be turned by its head. Another minor but frequent difference between a screw and a bolt is that a screw is usually made of lower strength materials.

SEALS

The efficient operation of any fluid system depends to a great extent upon the effectiveness of the seals. Seals are used for the purpose of preventing fluid from passing a certain point, as well as for keeping air and dirt out of the system. Seals are divided into two classes—packings and gaskets.

Packings

Packings are made of synthetic or natural rubber. They are generally used as RUNNING SEALS; that is, in units that contain moving parts, such as actuating cylinders, pumps, selector valves, etc. Packings are made in the form of O-rings, V-rings, and U-rings, each designed for a specific purpose. (See fig. 5-19.)

O-RING PACKINGS.–O-ring packings are used for preventing both internal and external leakage. This type of packing ring seals effectively in both directions, and is the most commonly used type.

In installations subject to pressures above 1,500 psi, BACKUP RINGS are used in conjunction with O-rings. Backup rings are usually made of Teflon and are used to prevent the O-rings from extruding; that is, backup rings prevent the O-ring from becoming pinched, squeezed out of shape, twisted, etc. Figure 5-20 illustrates (A) a spiral Teflon backup ring, (B) and (C) how the O-rings appear with and without the backup rings when operated under a 3,000 psi pressure.

When an O-ring packing is to be subjected to pressure from both sides, as in actuating cylinders, two backup rings must be used–one backup ring on either side of the O-ring.

When an O-ring is subject to pressure on only one side, a single backup ring is generally used. In this case the backup ring is always placed on the side of the O-ring away from the pressure.

The ASE should be able to identify the correct size and type O-ring for different applications in order to insure the best possible service.

The task of procuring and identifying the correct seal can be difficult since part numbers cannot be put directly on the seals. This situation is further confused by the fact that there is a continual introduction of new types of seals and the obsolescence of others.

Because of the difficulties with color coding, O-rings are made available in individual hermetically sealed envelopes, labeled with all pertinent data. (See fig. 5-21.) It is recommended that they be procured and stocked in these envelopes.

When selecting an O-ring for installation, information printed on the envelope should be carefully observed. If an O-ring cannot be positively identified, it should be discarded.

Manufacturers provide color coding on some O-rings, but this is not a reliable or complete means of identification. The color coding system does not identify sizes, but only system fluid or vapor compatibility and in some cases the manufacturer. Color codes on O-rings that are compatible with hydrocarbon fluid will always contain blue, but may also contain red or other colors. Color codes on O-rings that are compatible with hydrocarbon fluid will always contain red, and will never contain blue. A color stripe around the circumference indicates that the O-ring is a boss gasket seal. The color of the stripe indicates fluid compatibility: red for fuel, blue for hydraulic fluid.

The coding on some rings is not permanent. On others it may be omitted due to manufacturing difficulties or interference with operation. Furthermore, the color coding system provides no means to establish the age of the O-ring or its temperature limitations. When selecting an O-ring for installation the basic part number on the sealed envelope provides the most reliable compound identification.

BACKUP RINGS.–Backup rings are not color coded or otherwise marked and must be identified from package labels.

Backup rings made of Teflon do not deteriorate with age, are unaffected by any system fluid or vapor, and tolerate temperature extremes in excess of those encountered in high-pressure hydraulic systems. Their dash numbers indicate not only their size but also relate directly to the dash number of the O-ring for which they are dimensionally suited. They are procurable under a number of basic part numbers, but they are interchangeable; that is, any Teflon backup ring may be used to replace any other Teflon backup ring if it is of proper overall dimension to support the applicable O-ring.

V-RING PACKINGS.–V-ring packings are always installed with the open end of the V facing the pressure and are used in medium pressure, heavy duty, double acting hydraulic cylinders, such as forklift mast tilt cylinders. Male and female adapters are used in conjunction with

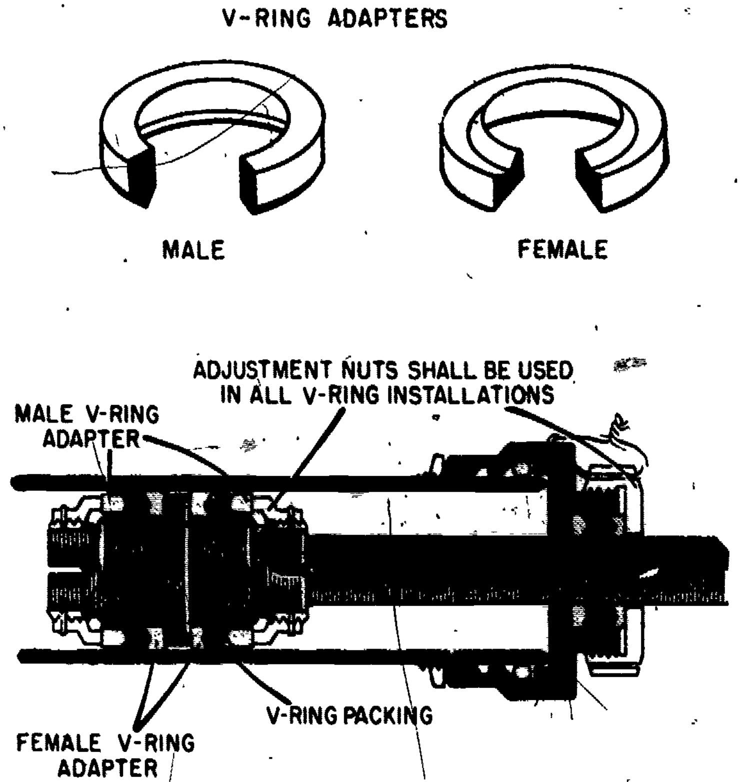


Figure 5-22.—V-ring adapters and V-ring installation.

V-rings for reinforcement. (See fig. 5-22.)

U-RING PACKINGS.—U-ring packings are used to prevent leakage in one direction only. They are used in brake assemblies and brake master cylinders. U-rings are never used where high pressures will be encountered.

Gaskets

Gaskets are used as static (stationary) seals. Their principal use in fluid systems is around the end caps of cylinders, valves, and other units. Gaskets must not be compressed into threads or against irregular or rough surfaces which would cut or otherwise damage them.

In automotive systems the joint between the cylinder block and cylinder head requires a gasket which must be able to withstand pressure and heat developed by the cylinders. It is not practical to machine the block and head surfaces flat and smooth to produce a tight joint. Consequently, gaskets are used. Head gaskets are usually made of thin soft metal, or asbestos-and-metal sheets, cut out to conform with the head and block.

Gaskets are also used to seal joints between other engine parts, for example, between the oil pan and block and between the cylinder block and manifold. Gaskets are made from different materials depending upon where it is to be used; steel, asbestos, copper, heavy paper, and cork are a few examples of gasket materials. As a rule gaskets can be used only once. The ASE should consult the latest applicable manual for proper selection of replacement gaskets.

Although the maintenance of the hydraulic systems of support equipment is the responsibility of the ASH, and the mechanical and engine section is the responsibility of the ASM, the ASE must have an understanding of the units which are controlled electrically. The ASE must be able to determine if the failure is electrical, hydraulic, or mechanical. The value of teamwork between the ASH, ASM, and ASE cannot be overemphasized.

SAFETY

In the performance of his normal duties, the ASE is exposed to many potentially dangerous conditions and situations. However, it is possible for the technician to complete a full naval career without having an accident or receiving an injury. Attainment of this goal requires that he be aware of the sources of danger, and that he remain constantly alert to those dangers. He must take the proper precautions and practice the basic rules of safety. He must be safety conscious at all times, and this safety consciousness must become second nature to him.

GENERAL SAFETY

Most accidents which occur can be prevented if the full cooperation of personnel is gained, and if care is exercised to eliminate unsafe acts and conditions. In the following paragraphs, some general safety rules are listed. These rules apply to personnel in all types of activities, and each individual should strictly observe the following precautions as applicable to his work or duty:

1. Report any unsafe condition or any equipment or material which he considers to be unsafe.
2. Warn others whom he believes to be endangered by known hazards or by failure to observe safety precautions.
3. Wear or use available protective clothing or equipment of the type approved for safe performance of his work or duty.
4. Report any injury or evidence of impaired health occurring in the course of work or duty.
5. Exercise, in the event of any unforeseen hazardous occurrence, such reasonable caution as is appropriate to the situation.

When working in a confined space, it is extremely important to be very cautious. Many personnel are unfamiliar with the hazards associated with working in confined spaces and they often take unnecessary risks which can result in injury or death. A confined space may contain highly explosive gases, toxic fumes, little or no breathable oxygen, toxic liquids or gases that may be absorbed through the skin, and liquids or chemicals that cause severe burns, rash, breathing problems, etc. It is for these reasons that equipment used by personnel working in confined spaces is a matter of considerable importance. Some of the items required are explosion and shock-proof equipment (lights, pumps, drills, ventilators, etc.), protective clothing, suitable breathing equipment, etc.

When working in an open area the ASE must be aware of the surrounding conditions and take appropriate actions; otherwise, what started as a simple job might turn into a disaster. There are many instances on record where a small careless act or two have had such results.

Safety precautions discussed herein are not intended to replace information given in instructions or maintenance manuals. If at any time there is doubt as to what steps and procedures to follow, consult your work center supervisor.

Handtools

To prevent tragic and unnecessary damage to equipment, loss of human life, or personal injury, it is necessary to develop and to practice careful, safe, and clean work habits. All tools and equipment used should conform to Navy standards as to quality and type, and should be used only in the manner and for the purpose intended. All tools in active use should be maintained in good repair, and all damaged or nonworking tools should be replaced through supply channels. When a job is completed, or when work is interrupted, all tools should be counted and returned to the toolboxes or to the tool issue room. This will eliminate the possibility of gear adrift which may become hazards to moving machinery and possibly to personnel.

Portable Power Tools

All portable power tools should be carefully inspected prior to use to insure that they are clean and in a proper state of repair. Switches should operate in a normal manner, cords should be free of defects, and the casings of all electrically driven tools should be properly grounded. When using or preparing to use any portable power tools, the cords, hoses, or cables should not be allowed to kink, nor should they be left where they may be run over or constitute a tripping hazard. They should not be allowed to come into contact with oil, grease, hot surfaces, chemicals, or sharp objects. When damaged, they should be replaced, never patched with tape.

Sparking electric power tools or equipment should never be used in any space where flammable vapors, gases, liquids, or explosives are suspected. When unplugging electrical tools or equipment from receptacles, first turn the equipment off, then grasp the plug (not the cord) to remove the plug from the receptacle. Stow the tool in its proper place.

ELECTRIC DRILL.—When using a portable power drill, grasp it firmly during operation to prevent bucking or breaking loose with possible injury to the user or damage to the tool or material. Use only straight, undamaged, and properly sharpened drill bits. Tighten the bit securely in the chuck, using the key provided (never tighten the chuck with wrench or pliers). The bit should be set straight and true in the chuck and the work firmly clamped. When drilling metal, the work should be marked with a center punch before beginning the drilling operation.

When drilling, never use the hand to hold the work being drilled Use a vise or a clamp. The same idea applies to work being soldered, filed, or sawed.

SOLDERING IRON.—The soldering iron is a fire hazard and a potential source of burns. Always assume that a soldering iron is hot; never rest the iron anywhere but on a metal surface or rack provided for that purpose. Keep the iron holder in the open to minimize the danger of fire from accumulated heat. Do not swing or flip the iron to dispose of excess molten solder—a drop may strike someone, or strike the equipment and cause a short circuit. Keep the head and hands away from the hot end of the iron; hold small soldering jobs with pliers or clamps. Position the ends of wires and cables so that they do not endanger the face or the eyes; never flip the wires to remove excess solder. When cleaning the iron, place the cleaning rag (or sponge previously mentioned) on a suitable surface and wipe the iron across it—do not hold in the hand. Disconnect the iron when leaving the work, even for a short time—the delay may be longer than pl[illegible]

GROUNDIN[illegible]fety ground, or one that is wired inc[illegible]y, is more dangerous than no ground at all The poor ground is dangerous because it does not offer full protection, while the user is lulled into a false sense of security. The incorrectly wired ground is a hazard because one of the line wires and the safety ground are transposed, making the shell of the tool "hot" the instant the plug is connected. Thus the unwary user is trapped unless by pure chance the safety ground is connected to the grounded side of the line on a single-phase grounded system, or no grounds are present on an ungrounded system. In this instance the user again goes blithely along using the tool until he encounters a receptacle which has its wires transposed or a ground appears on the system. Because there is no absolutely foolproof method of insuring that all tools are safely grounded (and because the tendency of the average sailor is to ignore the use of the grounding wire), the old method of using a separate external grounding wire has been discontinued. Instead, a 3-wire, standard, color-coded cord with a polarized plug and a ground pin is required. In this manner, the safety ground is made a part of the connecting cord and plug. Since the polarized plug can be connected only to a mating receptacle, the user has no choice but to use the safety ground.

All new tools, properly connected, use the green wire as the safety ground. This wire is attached to the metal case of the tool at one end and to the polarized grounding pin in the connector at the other end. It normally carries no current, but is used only when the tool insulation fails, in which case it short circuits the electricity around the user to ground and protects him from shock. The green lead must never be mixed with the black or white leads which are the true current-carrying conductors.

Check the resistance of the grounding system with a low reading ohmmeter to be certain that the grounding is adequate (less than 0.1 ohm is acceptable [illegible] resistance indicates greater than 0.1 o[illegible] a separate ground strap.

Some old installations are not equipped with receptacles that will accept the grounding plug. In this event, use one of the following methods:

1. Use an adapter fitting.

2. Use the old-type plug and bring the green ground wire out separately.

3. Connect an independent safety ground line. When using the adapter, be sure to connect the ground lead extension to a good ground. (Do not use the center screw which holds the cover plate on the receptacle.) Where the separate safety ground leads are externally connected to a ground, be certain to first connect the ground and then plug in the tool. Likewise, when disconnecting the tool, first remove the line plug and then disconnect the safety ground. The safety ground is always connected first and removed last.

CHAPTER 6
DRAWINGS, DIAGRAMS, AND IDENTIFICATION MARKINGS

At the beginning of World War II, the task of maintaining the support equipment was relatively simple. The aircraft were fairly small and not very complex. Therefore the quantity of support equipment needed was small and the equipment was simple. With little study and some experience, the maintenance man could become quite familiar with all the equipment used to support his unit. The equipments were not only comparatively simple, but similar in operation, and constructed in a manner which allowed ease of inspection and repair. It was possible to service, maintain, and repair this equipment with perhaps only an occasional reference to a manual or a diagram.

Presently, however, this practice is no longer possible. The larger, more complex aircraft of today demand a much greater quantity of more complex equipment to support them. It is almost impossible for any person to be thoroughly familiar with all of the various types of equipment in present use; but with a fairly good background of electrical principles and experience the ASE should be able to rapidly familiarize himself with any specific equipment.

In order to become proficient in his rating, the ASE must be able to locate parts on the equipment, trace circuits, and learn the operation of various systems and components. Drawings and diagrams are used to make this difficult task much easier, because it is very important that the ASE understands and is capable of using the drawings and diagrams provided for these purposes.

No one particular type illustration is suitable for all applications, so many different types are required. Several types, along with examples, are discussed in this chapter to acquaint the ASE with the different types of drawings and diagrams used. It should be kept in mind that there will be variations within a particular type, so the illustrations with which the ASE comes in contact may be labeled the same, but may vary somewhat from the examples shown.

Additional information on drawings and diagrams may be found in the Navy Training Manual, Blueprint Reading and Sketching, NavPers 10077 (Series). It is suggested that this manual be studied along with this chapter for a more complete understanding.

DRAWINGS

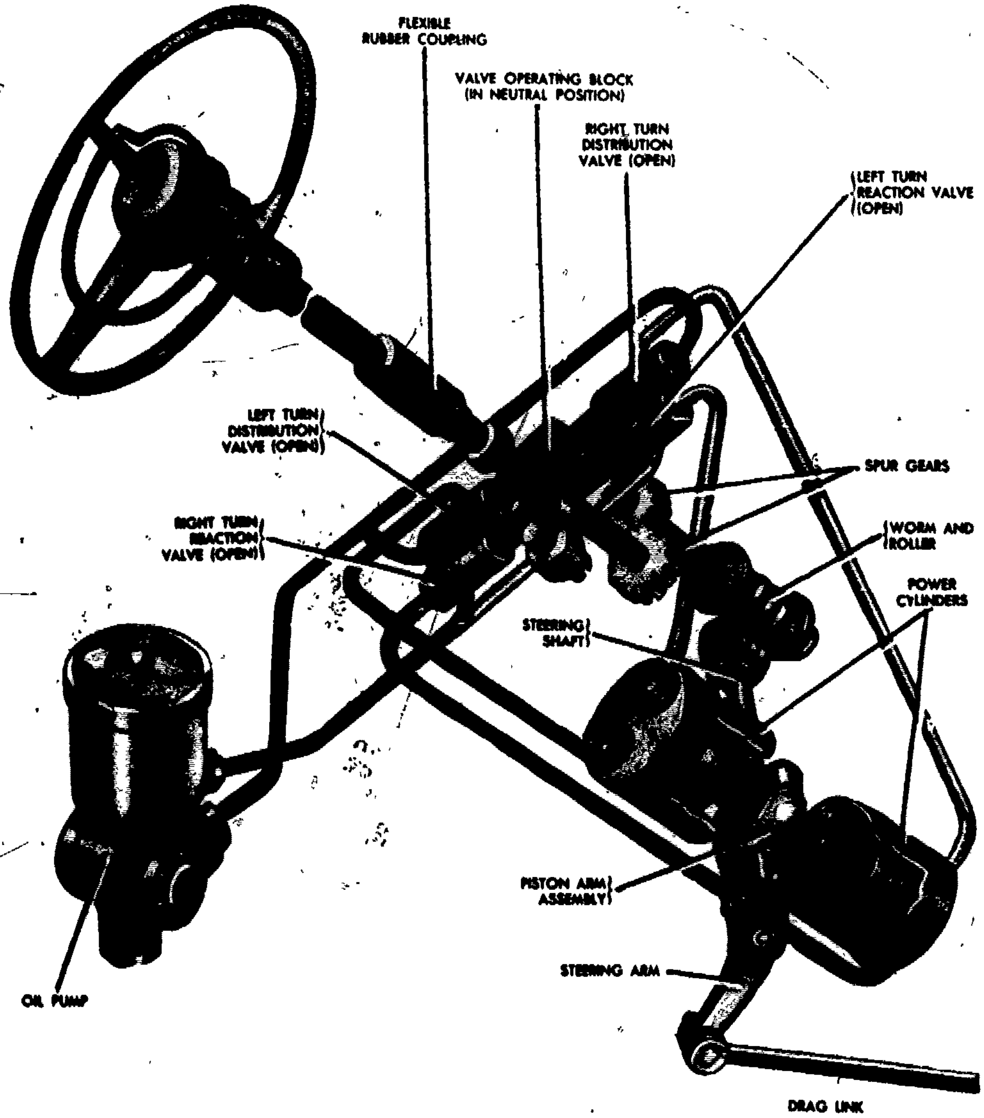
Drawings are used extensively in the AS rating. They are found in AS Training Manuals, Illustrated Parts Breakdowns, Maintenance Instructions Manuals, Operation and Service Instructions, Maintenance Requirements Cards, and other publications. The two most common types of drawings—pictorial and orthographic—are discussed in the following paragraphs.

PICTORIAL

Pictorial drawings normally show objects approximately as they appear to the observer. They may present details concerning the location, size, construction, physical relationships of size and location, or parts arrangement. They appear throughout manuals of all types, and are useful for locating and identifying systems, inspection, servicing, operation, adjustment, calibration, troubleshooting, repair, and testing functions.

Pictorial drawings may be accurately detailed representations, or they may be merely generalized indications, depending on their purpose.

Figure 6-1 is a good example of a pictorial drawing. This drawing of a power steering system identifies and locates each of the com-



AS.210

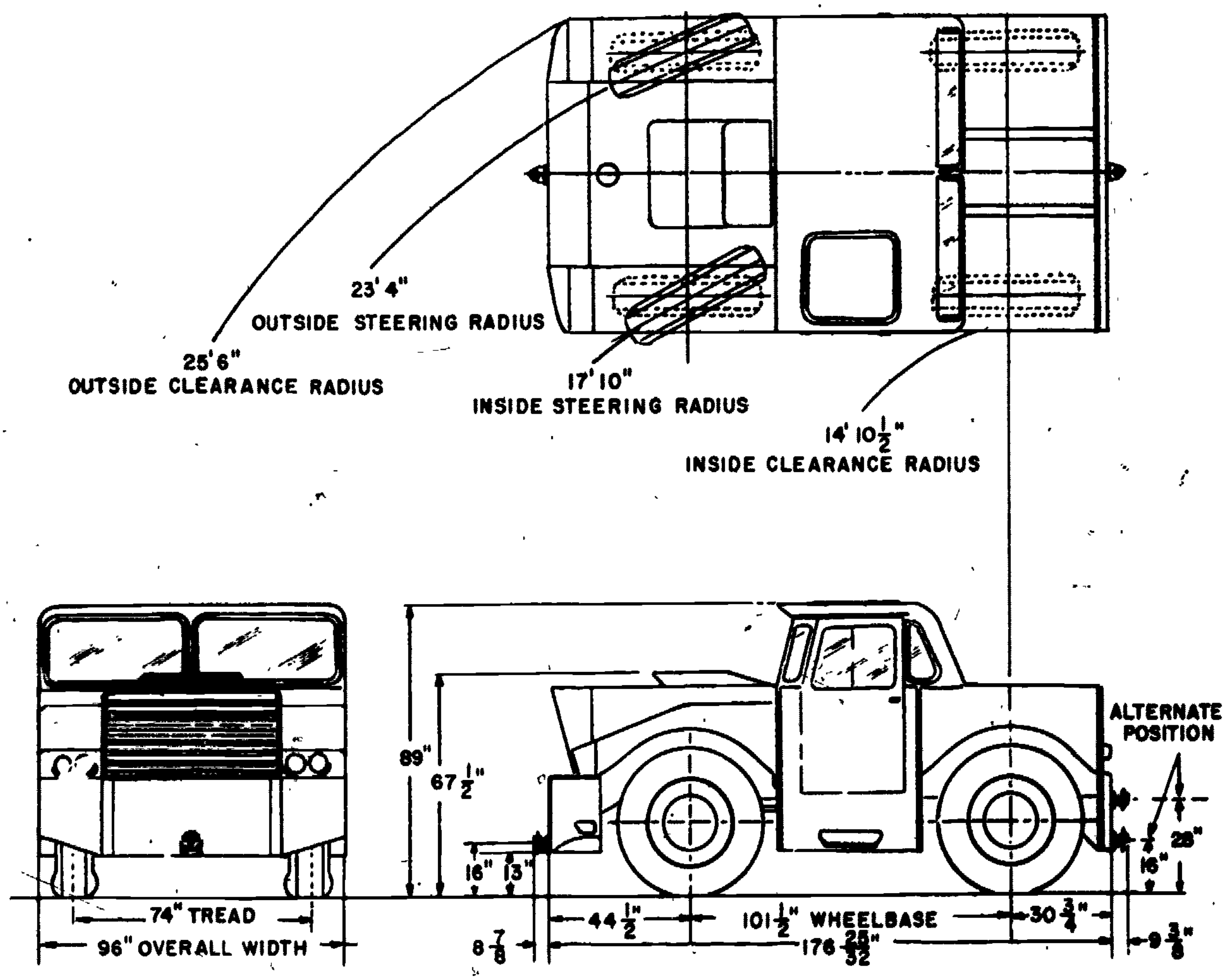
Figure 6-1.—Pictorial drawing.

ponents within the system. It is therefore a valuable aid in servicing, inspecting, and troubleshooting the system, and in removing and replacing components in the system.

Note how the two power cylinders are drawn. A portion of the outer wall of each cylinder is cut out, allowing the cylinder pistons to be seen. This is a commonly used method of showing the internal parts of components, mechanisms, etc., and is referred to as a cutaway view.

ORTHOGRAPHIC

Orthographic drawings are not as widely used in support equipment publications as pictorial drawings; however, the ASE should be able to



AS.211

Figure 6-2.—Orthographic drawing.

read such drawings. Orthographic drawings are used when it is necessary to show the exact size and shape of all the parts of complex objects. In order to do this, it is usually necessary to show two or more views of the object, as seen from different positions.

There are six possible basic views of any object because all objects have six sides—front, top, rear, bottom, right side, and left side. However, it is seldom necessary to show all possible views to illustrate an object clearly, so only the views are drawn that are necessary to illustrate the required characteristics of the object. Two-view and three-view drawings are the most common.

Figure 6-2 is an example of a three-view orthographic drawing. This drawing shows the front, right side, and top view of a tow tractor. Note that the right-side view is to the right of the front view, and the top view is above the side view. This the normal order of arrangement of the views. Had the left-side view been shown, it would have been drawn to the left of the front view, and had the bottom view been shown, it would have been placed below the side view.

It should be kept in mind that an orthographic drawing cannot be read all at once any more than a whole page of print can be read at a glance. Both must be read a line at a time. In reading a drawing, first get a general idea of the object by surveying all the views, then select one view for a more careful study. By referring back and forth to adjacent views, it will be possible to determine what each line represents.

For a detailed discussion on reading orthographic drawings, refer to Blueprint Reading and Sketching, NavPers 10077-C, chapters 1 and 2.

DIAGRAMS

A great deal of the ASE's work involves the use of diagrams. The diagrams are used in troubleshooting, testing, learning circuit or system operation, teaching, etc. An ASE that uses the diagrams and test equipment as they should be used can justly take pride in his work and will definitely be an asset to himself and his outfit.

Symbols are used on the diagrams to represent the different items. Most of these symbols can be found in Appendix II of this manual. A complete list of Graphic Symbols for Electrical and Electronics Diagrams can be found in Military Standard, MIL-STD-15-1 (Series).

The most commonly used types of diagrams are described in the following paragraphs.

WIRING

The wiring diagram presents detailed circuitry information on the electrical system. It includes the item numbers, located adjacent to each part symbol, and the wire number or color code, located adjacent to each line representing a wire, or within a break in the line. Other information about the various parts may be found on the diagram or, by using the item number, the information can be found in the Illustrated Parts Breakdown. Figure 6-3 is an example of a wiring diagram.

The wiring diagram shows in detail how a wire is routed between components. Each segment of the complete wire is shown, along with its identification number or color code, as well as each plug or terminal strip used.

A master wiring diagram is a single diagram that shows all the wiring in an item of equipment. In some cases, these diagrams would be so large that their use would be impractical; therefore, they are broken down into logical sections, such as d-c power system, a-c power system, lighting system, or individual circuits.

By breaking a system into individual circuit diagrams, each circuit may be presented in greater detail. The increased detail provides for easier circuit tracing, testing, and maintenance.

The master wiring diagram is normally consulted when replacing sections of wiring, when determining how the circuits are tied together, and when making drawings of system or circuit wiring diagrams.

The system or circuit wiring diagram is normally used when testing or troubleshooting a circuit. The idea is to use the smallest diagram that provides the necessary information to perform the particular task.

SCHEMATIC

The schematic diagram is usually very simple. It is usually the first diagram drawn by the designer. It denotes the scheme of things, which is usually the operation or layout of a system. It is not drawn to scale, and it shows none of the actual construction details of the system, such as physical location, routing, or any other details that are not essential. (See fig. 6-4.)

It should be noted that the schematic pertains not only to electrical systems but also to electronics, mechanics, hydraulics, etc. The ASE's primary concern with schematic diagrams is for understanding electrical system operation. These diagrams are easy to use because of their simplicity. Symbols are used to represent the components.

The schematic diagram is not normally used alone in troubleshooting the equipment because it does not contain enough information. However, it can be used in conjunction with the wiring diagrams for a better understanding of

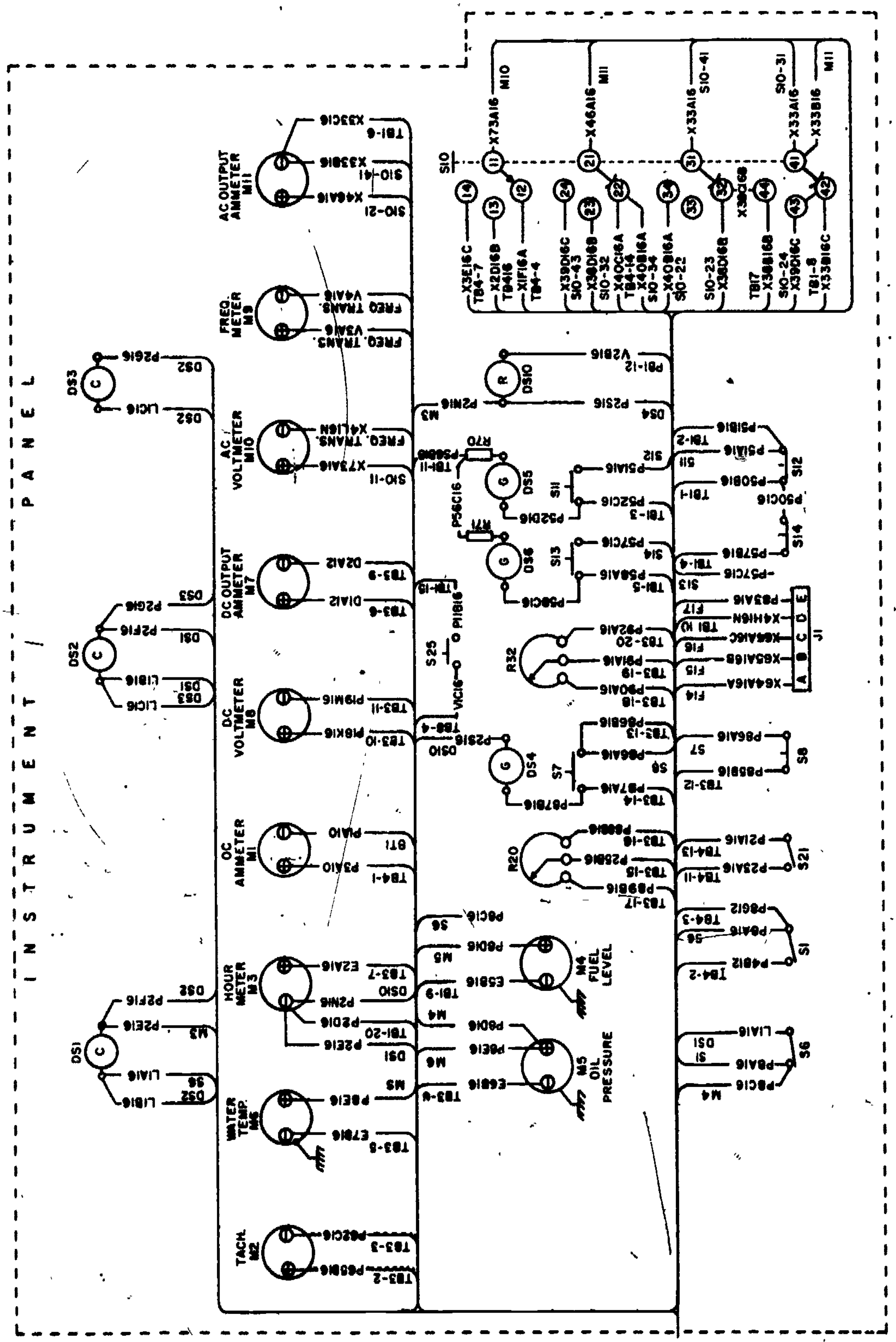


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Figure 6-3.—Wiring diagram.

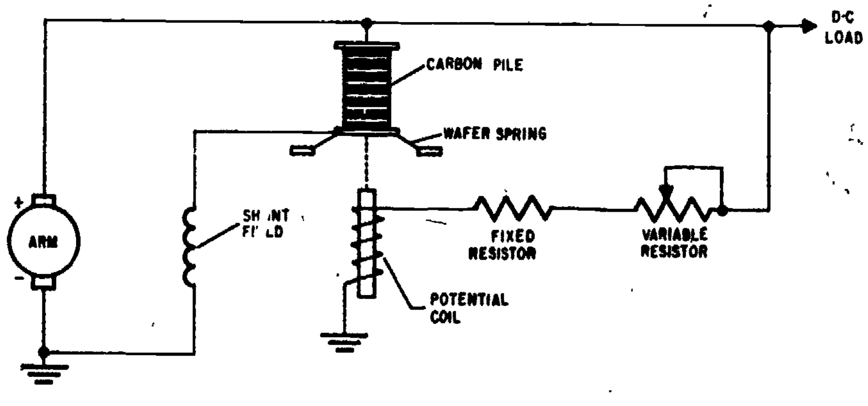

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Figure 6-4.—Schematic diagram.

system operation, which is helpful in troubleshooting.

ISOMETRIC

The isometric diagram shows an outline of the equipment, location of components, parts breakdown, and routing of wiring, cables, and tubing in the equipment. (See fig. 6-5.) Diagrams of this type are easily read and are used extensively in such publications as the Illustrated Parts Breakdown, Maintenance Instructions Manual, Operation and Service Instructions, etc. These diagrams are used extensively for illustrating many types of systems, including electrical.

PICTORIAL

The pictorial diagram shows either a picture or a pictorial sketch of an equipment or system and the connections between the components. (See fig. 6-6.) These illustrations may show only a few features of the system or many, depending upon the purpose. For example, they may show physical appearance, arrangement, location, relationship, construction details, points and methods of connecting components and systems, etc. These diagrams are used to show electrical systems, ignition systems, oil systems, fuel systems, hydraulic systems, etc., or combinations of two or more systems.

BLOCK

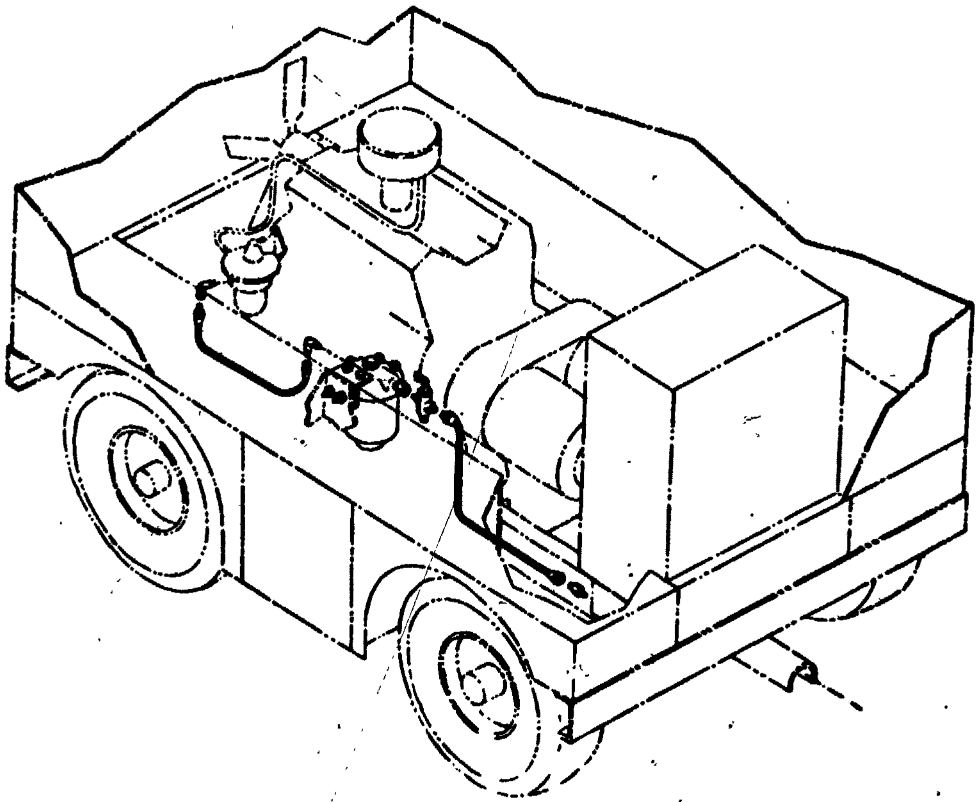
In the block diagram the major components of an equipment or system are represented by squares, rectangles, or other geometric figures, and normal order of progression of flow is presented by lines and arrowheads showing direction. (See fig. 6-7.)

These diagrams are usually rather simple and show how the components are connected in relation to one another, the direction of flow, and component identification. If necessary a few symbols may be used, values given, and signal waveforms shown.

These diagrams are used for electrical systems, fuel systems, hydraulic systems, mechanical systems, etc.

WIRING AND FLUID LINE IDENTIFICATION

Ground support equipment has to meet certain standards, but there are no set specifications or standards for identifying the wiring and fluid lines used in the equipment. The older,



AS.268

Figure 6-5.—Isometric diagram.

less complicated equipment usually has no markings or is poorly marked. In the newer, more complex or special support equipment the wiring and fluid lines are normally well marked.

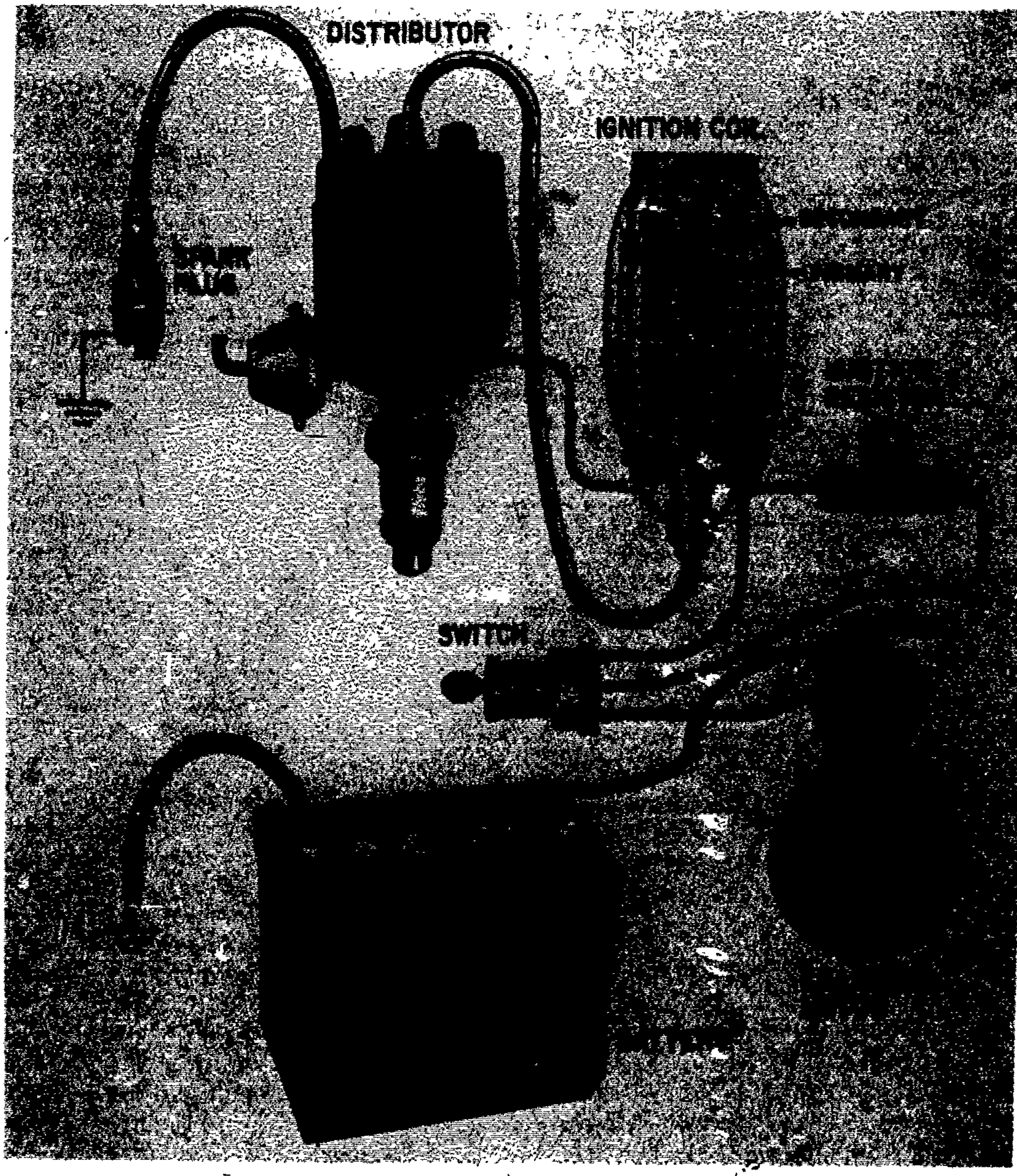
Various methods of identification are used and some of these are discussed in this section. It should be noted, as progress is made in the field of support equipment, that the manufacturers are tending to use similar or identical methods of wiring and fluid line identification for support equipment as that used in the aircraft.

WIRE AND CABLE

An important part of electrical maintenance is to be able to select the correct replacement wire or cable for a particular electrical circuit that has been damaged, or is in need of a replacement wire or cable for whatever reason. Usually enough information can be found in the Operation and Service Instructions Manual for making the selection. On some equipment the Illustrated Parts Breakdown can be used for this purpose.

When this information cannot be obtained from these manuals, the ASE must use other means of determining the correct wire size and type of wire needed. Quite often the old wire can be used for this purpose. Some of the information can be obtained from the markings on the wire, or if there are no markings a wire gage can be used to determine the wire size. With experience the ASE will be able to determine the type of wire and insulation from a visual inspection of the wire.

When making a comparison between solid



AS.270

Figure 6-6.—Pictorial diagram.

wire and stranded wire (most if not all of the wiring in support equipment will be of the stranded type) of the same gage number, the stranded wire will be slightly larger in diameter because of the air space between the strands. An accurate comparison or measurement of the wires can be made using a wire gage or a micrometer and a wire table.

The wire gage shown in figure 6-8, is used for measuring the diameter of nonferrous wires or the thickness of nonferrous sheet metal. This gage is circular in shape with cutouts in the

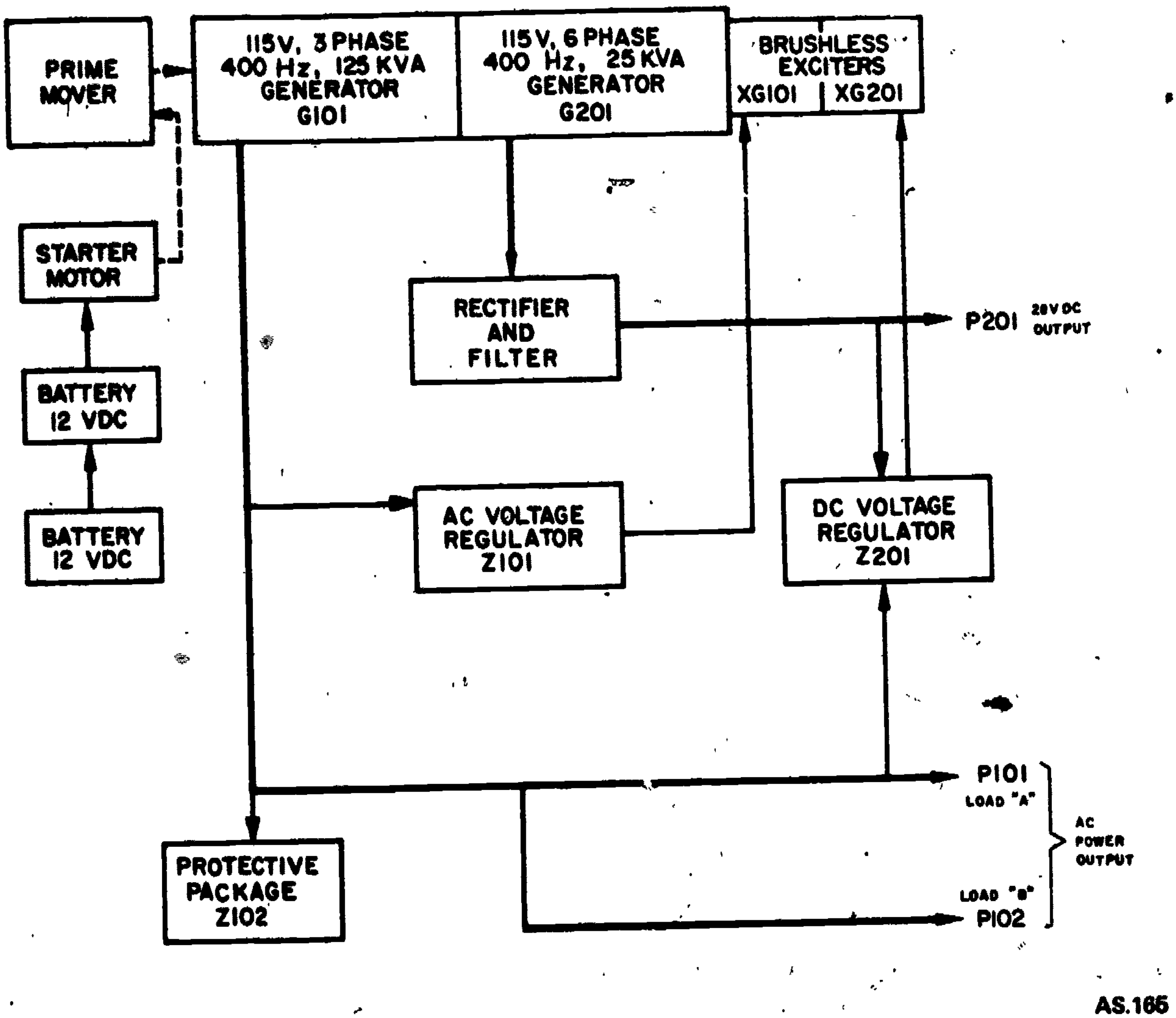


Figure 6-7.—Block diagram.

outer perimeter. Each cutout gages a different size from number 0 to number 36. Examination of the gage will show that the larger the gage number the smaller the diameter or thickness. The decimal equivalent in inches for each gage number is stamped on the opposite face of the gage.

To determine the size of a solid wire, remove a small portion (approximately 1/4 inch) of insulation from the end of the wire and apply a wire gage as shown in figure 6-8. Find the slot that will just pass the wire without forcing. The correct gage number can then be read from the face of the gage adjacent to the slot in which the wire fits.

To determine the size of a stranded wire follow the same procedures as used for a solid wire, except measure only one strand of the stranded wire. Locate the size of the single strand on a wire table such as table 6-1. Multiply the circular mil area for that particular size by the total number of strands in the wire. Now, refer to the wire table under circular mil area and find the value closest to the product; read the gage number from the center column. For example, one strand of a 37-strand wire measured with a wire gage is .0126 inch in diameter, or 28 gage. Referring to the wire table, it is found that one strand has an area of 159.8 circular mils. The circular mil area of one strand multiplied by the total number of strands provides the total circular mil area (159.8 x 37 = 5,912.6 circular mils). Referring to the wire table it is found that this product comes closest to the 6,530 circular mils listed, and by checking the center column the wire is determined to be 12 gage.

The factors used in determining correct wire size, type of wire, and insulation are explained in Basic Electricity, NavPers 10086-B, and Installation Practices for Aircraft Electric and Electronic Wiring, NavAir 01-1A-505. The applicable procedures specified in the latter manual apply also to maintenance of support equipment used by the Navy; therefore, it is important that the ASE become familiar with and follow those instructions. The information given in these publications plus that given in Military Specification MIL-W-5088 (Series) should enable the ASE to make the correct selection.

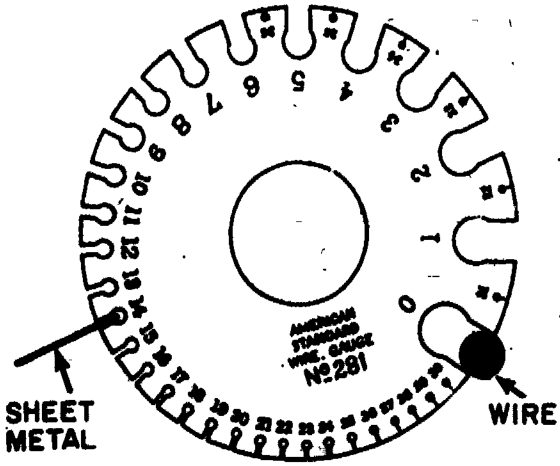
The data necessary to determine the correct wire type, size, and insulation for a given application may be summarized as follows:

1. Particular circuit application (thermocouple, high resistance, low resistance, etc.).
2. Voltage and current required by the load.
3. Length of wire required between the power source and the load.
4. Allowable power loss between the power source or point of voltage regulation and the load.
5. Location and environment of the wire (temperature, explosive, oil, abrasive, vibration, etc.).

Table 6-2, which shows the current-carrying capacity of copper and aluminum wires and cables, will be of interest to the ASE in the selection of wiring.

Alphanumerical Code

A code consisting of a combination of letters and numerals is imprinted on each wire at



AS.272

Figure 6-8.—American Wire Gage for measuring nonferrous wire and sheet metal.

prescribed intervals along its entire run. Figure 6-9 and its accompanying discussion explain the code used in wiring installations. Complete details may be found in MIL-W-5088 (Series).

The first character in the code is a prefix (numeral), referred to as the unit number. The unit number is used only in those cases having more than one given unit installed in an identical manner in the same equipment. The wiring concerned with the first such unit bears the prefix 1, and corresponding wires for the second unit have exactly the same designation, except for the prefix 2, etc.

The letter following the prefix number identifies the circuit function. The ASE is primarily concerned with function letters D, E, L, P, V, and X. The letter D denotes instruments other than engine, E denotes engine instruments, L denotes lighting, P denotes d-c power, V denotes d-c power, and d-c control of a-c systems, and X denotes a-c power.

The wire number, which follows the circuit function, consists of one or more digits and differentiates between wires in a circuit/circuits. A different number is used for wires not having

Table 6–1.—Table to be used with the American Wire Gage or a micrometer for sizing nonferrous wire or sheet metal

Wire diameter or sheet metal thickness in inches	American wire gage numbers	Circular mil area of round material
.4600	0000	211600
.4096	000	167800
.3648	00	133100
.3249	0	105500
.2893	1	83690
.2576	2	66370
.2294	3	52640
.2043	4	41740
.1820	5	33024
.1620	6	26250
.1440	7	20736
.1285	8	16510
.1140	9	12996
.1019	10	10380
.0910	11	8281
.0808	12	6530
.0720	13	5184
.0640	14	4107
.0570	15	3249
.0508	16	4107
.0450	17	2025
.0403	18	1624
.0360	19	1296
.0319	20	1022
.0284	21	810.1
.0253	22	642.4
.0225	23	509.5
.0201	24	404.0
.0179	25	320.4
.0159	26	254.1
.0142	27	201.5
.0126	28	159.8
.0112	29	126.7
.0100	30	100.5
.0089	31	79.7
.0079	32	63.2
.0070	33	50.1
.0063	34	39.7
.0056	35	31.5
.0050	36	25.0

Table 6-2.—Current-carrying capacity of wires and cables

Wire or cable size (American Wire Gage)		Continuous-duty current—amperes	
Aluminum	Copper	Single wire in free air	Wires and Cables in conduit or bundles
	22	. . . .	5
	20	11	7.5
	18	16	10
	16	22	13
	14	32	17
	12	41	23
	10	55	33
	8	73	46
	6	101	60
	4	135	80
	2	181	100
	1	211	125
	0	245	150
	00	283	175
	000	328	200
	0000 . . .	380	225
8 . . .	. . . .	60	36
6	. . . .	83	50
4	. . . .	108	66
2	. . . .	152	82
1	. . . .	174	105
0	. . . .	202	123
00 . . .	. . . .	235	145
000 . .	. . . .	266	162
0000 .	. . . .	303	190

a common terminal or connection, such as through a circuit breaker, switching device, load, etc. (See fig. 6-10.)

Wires that are segmented by the use of connectors, terminals, etc., are given different segment letters. Normally, the segment letters are in alphabetical sequence beginning at the power source. Letters I and O are not used because they could be mistaken for "one" and "zero."

The number following the segment letter identifies the size of the wire or cable.

The ground, phase, or thermocouple letter is used only when the segment of wire pertains to one of these items. The ASE is primarily concerned with the letters N, A, B, and C. The letter N denotes a ground wire; A, B, and C denote the three separate phases of an a-c power supply or source.

The suffix letters are an abbreviation of the material of which the wire is made.

Reading the information from the wire identification code shown in figure 6-9, the 2 denotes it is the second of at least two identical systems

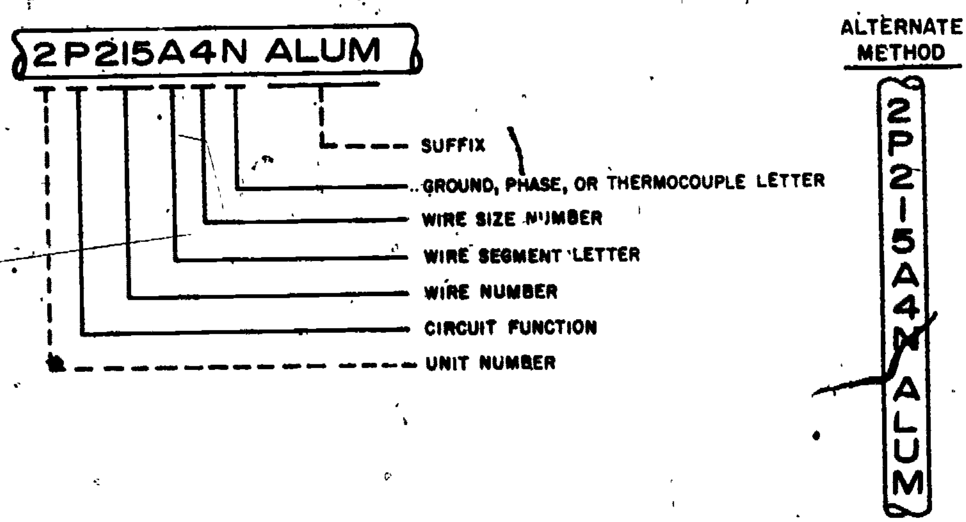


Figure 6-9.—Wire identification code.

in the equipment, the P identifies a d-c power circuit, the 215 denotes it is wire number 215, the A signifies the first segment of wire 215, the N indicates it is a ground wire, and ALUM denotes the wire is made of aluminum.

There is another method of wire and cable identification similar to the one just discussed. This method may use the complete wire identification coding or only the wire number and segment letter on the wiring in the equipment and on the diagrams for that equipment. If this method is used, the Operation and Service Instruction Manual will contain a wiring list from which these wire numbers can be cross-referenced to obtain information on the wiring. This list contains valuable information that can be used in several different ways. For example, the wiring list may contain the following:

1. Complete wire identification code, or only the wire numbers and segment letters.
2. Wire gage size of the wire.
3. Length of the wire in inches.
4. Component and terminal from which the wire leaves.
5. Component and terminal to which the wire is attached.

Color Code

Most automotive vehicle wiring is made up into a harness with all leads coming out at the proper places and with the correct lengths to connect to the accessories. This simplifies the wiring of the automotive vehicle and serves to protect the wiring. To permit easy identification of the various leads, a color code in the insulation is widely used. The ASE should consult the applicable manual or handbook for the proper selection of wiring harness and the proper color code for the vehicle which he is maintaining. A representative automotive color code is

1. RED LEAD—identifies wires that are connected to the battery and are not fused, and wiring between the generator and regulator, or between the ammeter and circuit breaker/fuse.
2. RED LEAD WITH YELLOW TRACER—the primary ignition lead.
3. RED LEAD WITH BLACK TRACER—between the ammeter and battery.
4. YELLOW LEAD—horn and light circuits, and is fused.

5. BROWN LEAD WITH BLACK TRACER—all ground connections except battery ground.

6. BLACK LEAD—connects taillight to light switch.

7. BLACK LEAD WITH RED TRACER—headlight circuit for high or bright beam.

8. GREEN LEAD—headlight circuit for low or dim beam.

FLUID LINES

The ASE is not responsible for the maintenance and repair of the fluid lines used in support equipment, but in order to perform his work safely and intelligently he must have a knowledge of fluid lines.

Fluid lines include all piping, tubing, and flexible hose used to convey liquids or gases. Although pipe is used in some applications, tubing and flexible hose are the most commonly used types of fluid lines in support equipment.

Codes and Symbols

Normally, no means of identification is required for the fluid lines used in the operation of support equipment. However, those lines used in the service and test of aircraft systems and components are usually identified by bands of paint, strips of tape, or metal tags around the line near each fitting. Various other information is also applied to the lines. This identification system is the same as that used in identification of aircraft fluid lines.

Identification tapes are applied to all lines less than 4 inches in diameter except cold lines, hot lines, lines in oily environment, and lines in engine compartments where there is a possibility of the tape being drawn into the engine intake. In these cases, and all others where tapes should not be used, painted identification is applied to the lines.

Identification tape codes indicate the function, contents, hazards, direction of flow, and pressure in the fluid line. These tapes are applied in accordance with MIL-STD-1247 (Series).

The function of a line is identified by use of a tape, approximately 1 inch wide, upon which word(s), color(s), and geometric symbols are

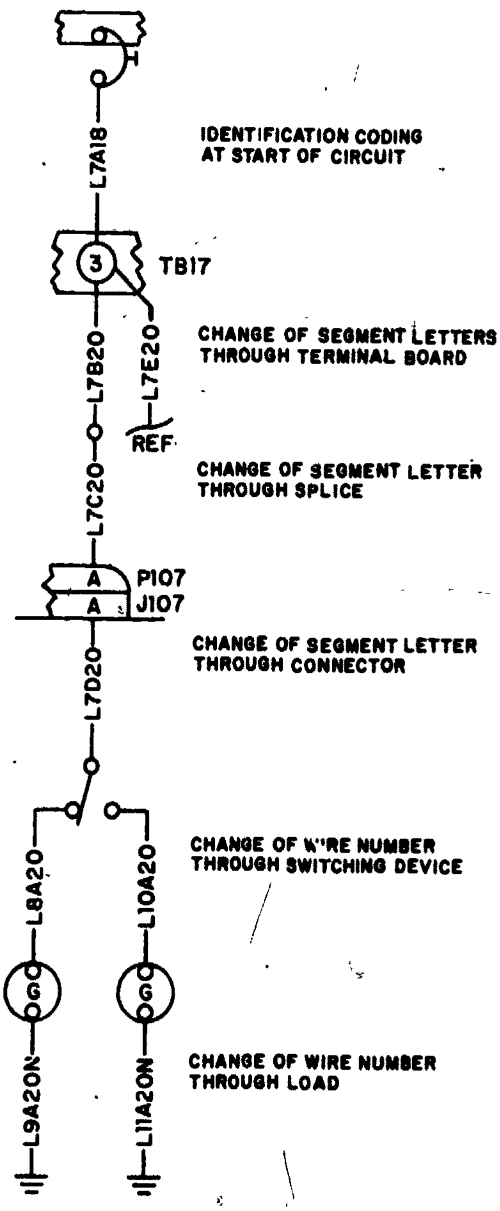


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Figure 6-10.—Example of wiring identification code utilization.

FUNCTION	COLOR	SYMBOL
Fuel	Red	
Rocket Oxidizer	Green, Gray	
Rocket Fuel	Red, Gray	
Water Injection	Red, Gray, Red	
Lubrication	Yellow	
Hydraulic	Blue, Yellow	
Solvent	Blue, Brown	
Pneumatic	Orange, Blue	
Instrument air	Orange, Gray	
Coolant	Blue	
Breathing Oxygen	Green	
Air Conditioning	Brown, Gray	
Monopropellant	Yellow, Orange	
Fire Protection	Brown	
De-Icing	Gray	
Rocket Catalyst	Yellow, Green	
Compressed gas	Orange	
Electrical Conduit	Brown, Orange	
Inerting	Orange, Green	

AM.67

Figure 6-11.—Functional identification tape data.

printed. Functional identification markings, as provided in MIL-STD-1247, are the subject of international standardization agreement. Three-fourths of the total width on the left side of the tape has a code color or colors which indicate one function only per color or colors. The function of the line is also printed in English across the colored portion of the tape, but even a non-English-speaking person can troubleshoot or maintain the system if he knows the code. The righthand one-fourth of the functional identification tape contains a geometric symbol which is different for every function. This is to insure that all technicians, whether English-speaking or not, even if colorblind, can positively identify the line function by means of the geometric design rather than by the color(s) or word(s). Figure 6-11 is a listing, in tabular form, of functions and their associated identification media as used on the tapes.

The identification-of-hazards tape shows the hazard associated with the contents of the line. Tapes used to show hazards are approximately one-half inch wide, with the abbreviation of the hazard contained in the line printed across the tape. There are four general classes of hazards found in connection with fluid lines.

FLAMMABLE MATERIAL (FLAM).–The hazard marking FLAM is used to identify all materials known ordinarily as flammables or combustibles.

TOXIC AND POISONOUS MATERIAL (TOXIC).–A line identified by the word TOXIC contains materials which are extremely hazardous to life or health.

ANESTHETICS AND HARMFUL MATERIALS (AAHM).–All materials productive of anesthetic vapors, and all liquid chemicals and compounds hazardous to life and property, but not normally productive of dangerous quantities of fumes or vapors, are in this category.

PHYSICALLY DANGEROUS MATERIALS (PHDAN).–A line which carries material which is not dangerous within itself, but which is asphyxiating in confined areas or which is generally handled in a dangerous physical state of pressure or temperature, is identified by the marking PHDAN.

Table 6-3 lists some of the fluids with which the ASE may be required to work, and the hazards associated with each.

Table 6-3.–Hazards associated with various fluids

Contents	Hazard
Air (under pressure)	PHDAN
Alcohol	FLAM
Carbon dioxide	PHDAN
Freon	PHDAN
Gaseous oxygen	PHDAN
Liquid nitrogen	PHDAN
Liquid oxygen	PHDAN
LPG (liquid petroleum gas)	FLAM
Nitrogen gas	PHDAN
Oils and greases	FLAM
JP-4	FLAM
Trichlorethylene	AAHM

Flexible Hose

Flexible hose assemblies, such as rubber and Teflon, consist of lengths of hose that are coupled with threaded end fittings. They are divided into two major groups–high-pressure and low pressure–according to their application.

The specifications of a flexible hose may be obtained by interpreting the identification code that is printed on the hose. This identification, which is a series of dots and dashes, gives the hose size, temperature range, and date of manufacture in quarter of year and year. Refer to NWOI-IA-8 for a detailed discussion of flexible hose identification.

CHAPTER 7

GROUND SUPPORT EQUIPMENT

Ground support equipment has become as important to the assigned mission of naval aviation activities as the aircraft itself. Many different types of support equipment are required for handling, servicing, loading, testing, and maintaining aircraft. The aircraft squadrons depend upon personnel of the Aviation Support Equipment Technician rating for the maintenance of this support equipment.

The ASE should know the types and uses of various equipment required for the support of naval aircraft, and this chapter introduces some representative items of various types of equipment with which the ASE may come in contact.

TYPES OF GROUND SUPPORT EQUIPMENT

Ground support equipment is classified into four major types:

1. Common (general purpose).
2. Peculiar (special purpose).
3. Standard (has government approved specifications/drawings).
4. Developmental (no government approved specifications/drawings).

All of the ground support equipment actually maintained by the ASE is included within one of two types: common (general purpose) and peculiar (special purpose). Within either of these two types there may also exist the types of standard and developmental. For example, an aircraft tow tractor being used by the Navy on a limited basis, which has no approved specifications or drawings, is classified as developmental and, because it is designed for use with many different types of aircraft, it is also included within the common (general purpose) classification.

COMMON (GENERAL PURPOSE)

Such equipment as tow tractors, mobile electric powerplants, weapons loaders, mobile cranes, hydraulic test stands, air compressors, mobile air conditioners, steam cleaners, gas turbine power units, material handling equipment, maintenance platforms, and engine trailers are included in this category.

Some representative items of common ground support equipment are described in the following paragraphs.

Tow Tractors

The tow tractor is the only means of propulsion for the majority of aircraft when the aircraft is on the ground and the engines are not running. Most present-day aircraft are too heavy and large to be moved by manpower alone.

Maneuverability of the tractor depends on its dimensions and turning radius. The smaller the dimensions and turning radius, the more maneuverable the tractor. The type of transmission may also contribute to the ease of handling of the tractor. Modern tow tractors usually employ automatic transmissions to provide a smoother coupling of the engine to the driving wheels. Automatic transmissions also free the driver from operating a clutch and allow him to concentrate more on towing the aircraft or equipment; therefore, a smoother, safer move is made.

The drawbar pull is the amount of force that the tractor can exert and is specified by the manufacturer. It is computed for a dry concrete surface and takes into consideration such things as type and size of tires, tractor weight, engine horsepower, etc. However, the drawbar pull of any tractor is dependent on the type and condition of surface on which it is being used.

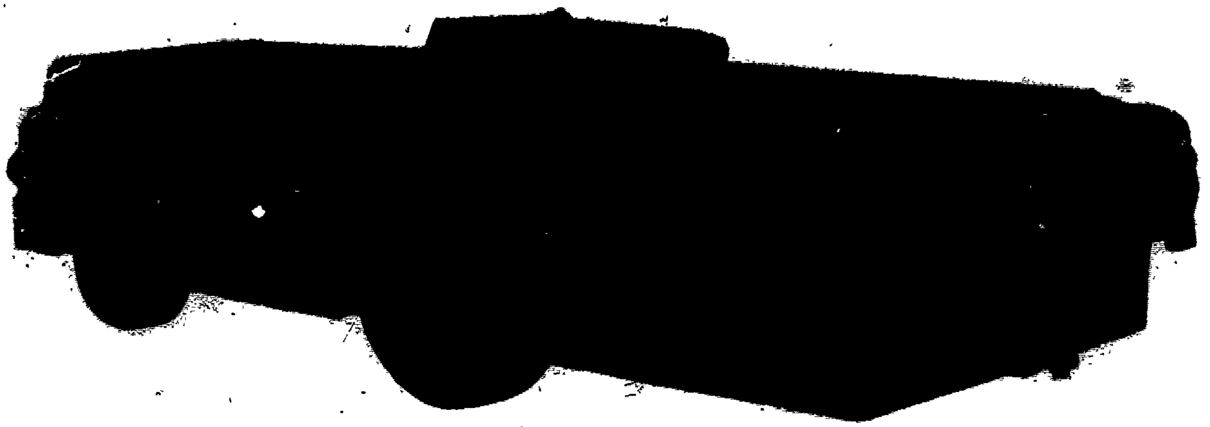

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Figure 7-1.—MD-3A tow tractor.

Dry concrete gives the most traction, hence the maximum drawbar pull for a given tractor is available on this surface; but, on a wet, fuel-soaked steel or wooden flight deck, the tractive force may be almost nil.

To find the maximum aircraft gross weight that can be safely towed with a particular tow tractor on dry concrete, multiply the tractor's drawbar pull by 10.

Equipment for supplying electrical power and/or low pressure compressed air for aircraft engine starting, servicing, or brake operation may be installed on some tractors.

Tow tractors are usually classified by one of two designations—the M series and the TA series. Some tractors may have both designations. The first two letters of the M series tractors do not have a standard meaning. The number in the M series is the model number. If a letter follows the model number, it indicates the number of modifications to that model of tractor. An A indicates the first modification, a B indicates the second modification, etc. The TA in the TA series stands for Tractor Aircraft. The numbers following the TA indicate the first two numbers of the drawbar pull. For example, the TA-75 tractor has a drawbar pull of 7,500 pounds; applying the 10 multiple mentioned above, this tractor can move aircraft up to a gross weight of 75,000 pounds.

The ASE should be aware of and keep in mind that when tractors are classified as a certain type, it does not mean they have to be exactly alike. The tractors can be made by different companies, look different, have a different arrangement of instruments and controls, and still be classified as the same type as long as they meet the Military Specifications for that type of tractor.

The ASE is likely to come in contact with tractors other than those discussed in this chapter; but the three types discussed are more widely used, in the Navy, than any other type.

MD-3 TOW TRACTOR.—This tractor was designed for use aboard aircraft carriers and will handle any type of carrier-based aircraft. It can be configured as an MD-3 (basic tractor—no gas turbine power unit), MD-3A (mounts a GTCP-100-54 gas turbine power unit), or MD-3B (mounts a GTC-85-72/73 power unit). The MD-3A is shown in figure 7-1.

The gas turbine power unit, which is mounted on the rear of the tractor, provides pneumatic power in the form of compressed air for the operation of large pneumatic equipment such as aircraft main engine starters, air conditioning

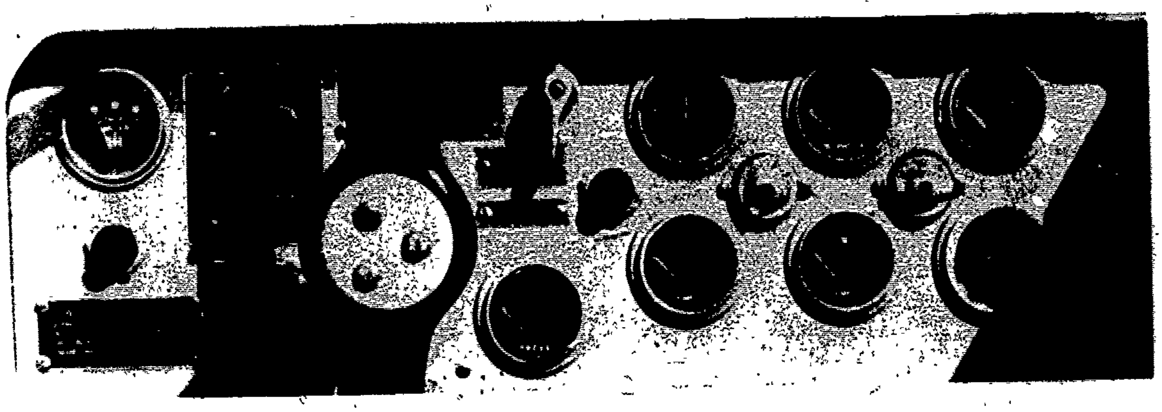

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Figure 7-2.—MD-3 instrument/control panel.

systems, and other types of equipment requiring compressed air in large volume.

The MD-3 tow tractor is a self-contained unit capable of developing 8,500 pounds of drawbar pull at an approximate speed of 1 mph on a dry, level concrete surface.

The main powerplant of the tractor is an inline horizontal, four-stroke cycle, internal combustion type diesel engine. The steering system is hydraulically assisted, and the service brakes are assisted by compressed air. Gross weight of the MD-3 tractor is 12,000 pounds.

The ASE is required to operate the tractors when training personnel, in troubleshooting, and in testing after repairs have been made. Therefore, he must be familiar with the different instruments and controls. Figure 7-2 shows the instrument/control panel, and figure 7-3 shows other controls of an MD-3 tractor. The operation of most of the instruments is covered in chapter 11 of this manual.

TA-75 TOW TRACTOR.—This is a gasoline

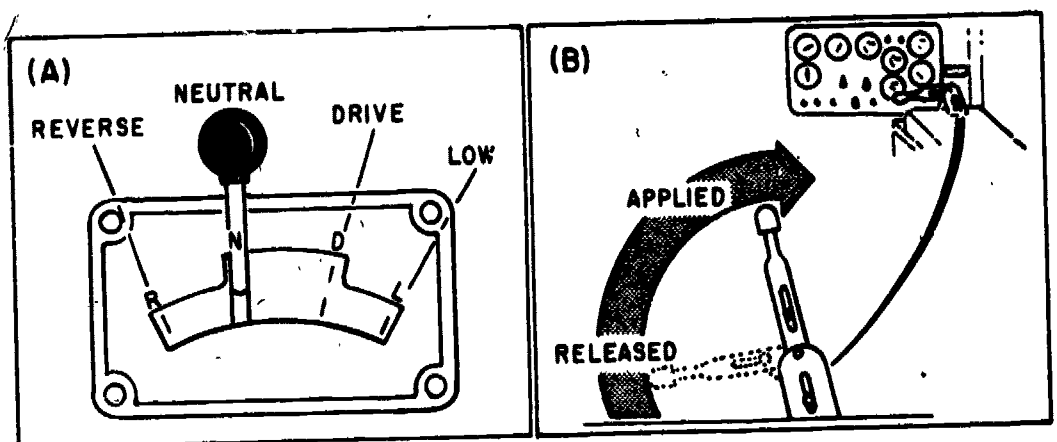

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Figure 7-3.—MD-3 controls. (A) Shift pattern; (B) parking brake lever operation.

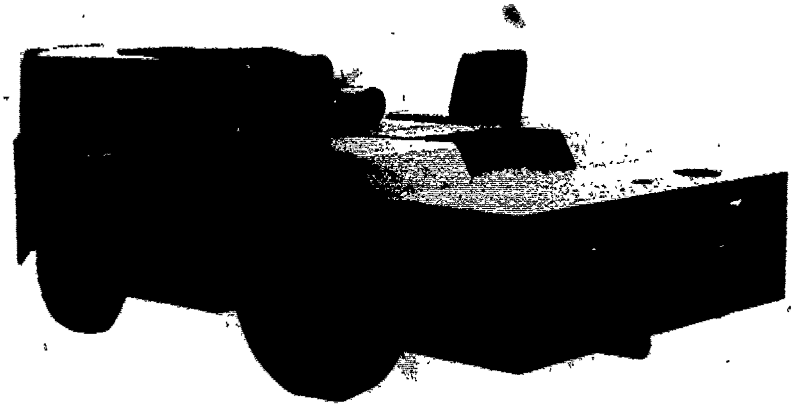

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Figure 7-4.—TA-75 tow tractor.

powered tractor intended for use on shore bases as an aircraft towing and spotting vehicle for aircraft with gross weights up to 75,000 pounds. This tractor has a drawbar pull of 7,500 pounds.

The TA-75 (fig. 7-4) has provisions for mounting a gas turbine compressor or other servicing equipment. It is equipped with an automatic transmission that has three forward speeds and one reverse speed. The speeds are selected by a pushbutton control located on the dash panel. The tractor dimensions are 10 feet long, 5 feet 6 inches wide, and 3 feet 9 inches high. The turning radius is 10 feet. The gross weight is 10,500 pounds.

TA-18 TOW TRACTOR.—This is a gasoline powered tractor for use on shore bases as an aircraft towing and spotting vehicle for large aircraft. This tractor has a drawbar pull of 18,000 pounds.

The TA-18, shown in figure 7-5, has an automatic transmission with six forward speeds and one reverse speed. The speed ranges are

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Figure 7-5.—TA-18 tow tractor.

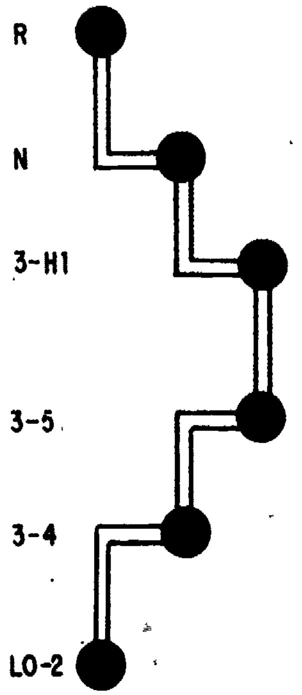

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Figure 7-6.—TA-18 transmission shift pattern.

selected by a shift lever located on top of the transmission cover. The transmission shift pattern is shown in figure 7-6. The tractor dimensions are 14 feet 10 inches long, 8 feet wide, and 5 feet 7 inches high. The turning radius is 24 feet 10 inches. The gross weight of the tractor is 25,800 pounds. Normally, the driver's compartment is open; but if the tractor is to be used in cold weather, it can be obtained with a completely enclosed cab. These cabs come equipped with windshield wipers, heater, and defroster.

Aircraft Spotting Dolly

Historically, movement of aircraft on the hangar decks of aircraft carriers has been accomplished by means of a tow bar and manpower or a tow bar and a tractor. However, as aircraft became larger and heavier, movement by manpower became impractical and parking areas on the hangar decks of carriers became too crowded to use a tractor for moving aircraft; thus, the spotting dolly came into being.

Aircraft spotting dolly, model SD-1D, (fig. 7-7) can, while providing maximum maneuverability, tow, push, and turn several types of aircraft as effectively in congested areas as in the open.

This aircraft spotting dolly utilizes a 3-cylinder, water cooled diesel engine to drive hydraulic pumps which provide power for the lift arms and the hydraulic drive motors in the wheels. The spotting dolly has a drawbar pull of

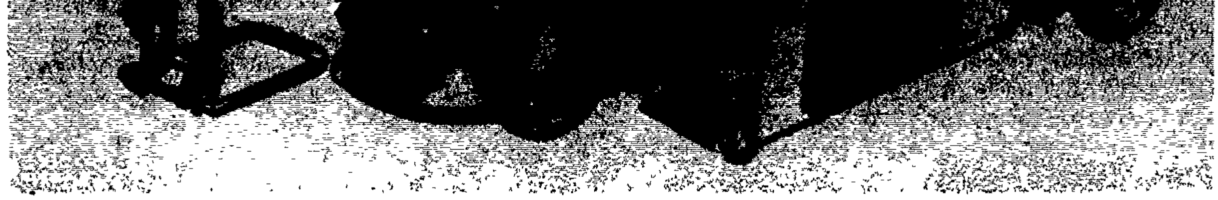

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Figure 7-7.—Aircraft spotting dolly, model SD-1D.

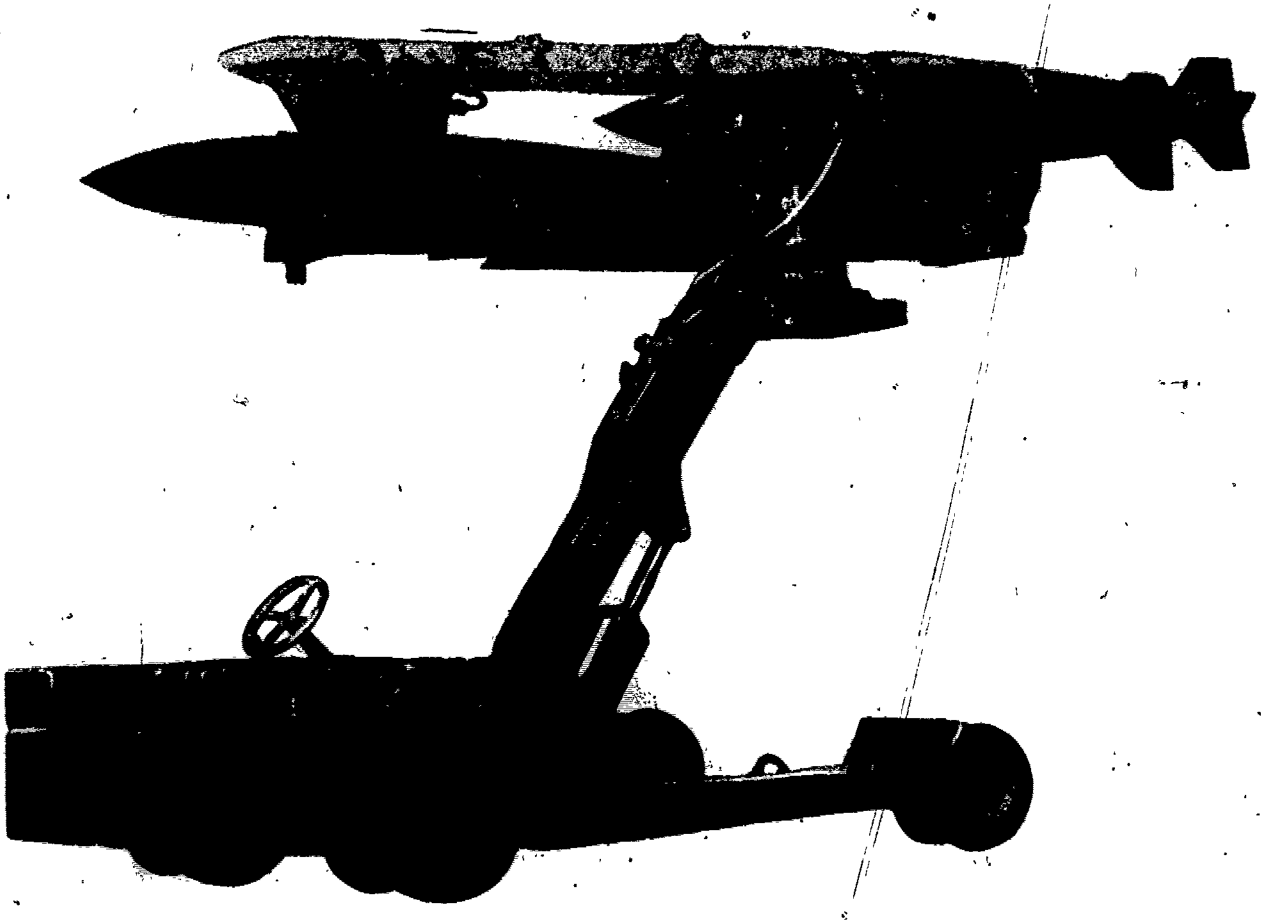

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Figure 7-8.—Aero 47A Weapons Loader.

6,000 pounds and a lifting capacity of 16,000 pounds.

The spotting dolly is of a low profile design, 29 inches high, and may be operated underneath most aircraft.

Loading of the spotting dolly is accomplished by engagement of the lift arms with the nosewheel axle of the aircraft. Several different sets of adapter pins for the lift arms are provided, enabling the operator to engage and move many types of aircraft. With the nosewheel engaged and picked up, the dolly can be turned in any direction, through 360°, with no movement of the aircraft, because the turn radius of the spotting dolly is zero feet and the pivot point is the point on the lift arms where the nosewheel axle is engaged.

The spotting dolly is a 3-wheeled unit, two of the wheels being powered and the third being a freewheeling swivel caster. Control is accomplished through a single handle on the end of the control arm. Steering is done by moving the control arm left or right; speed and direction of travel (forward or reverse) are controlled by twisting the hand grip on the end of the control arm. Lift arm control (spread, close, raise, lower) is done by pushbuttons located either on the control handle or on each side of the spotting dolly. The operator may ride on the operator's seat, or he may swing the seat out of his way and walk with the unit, controlling it with one hand. Maximum speed is 2 mph loaded and 5 mph unloaded.

The usual manner of loading an aircraft is to lower and spread the lift arms, drive the spotting dolly under the aircraft, close the lift arms to engage the adapter pins in the nosewheel axle, raise the lift arms, release the aircraft's brakes, and drive the spotting dolly in the desired direction of travel.

Aero 47A Weapons Loader

The Aero 47A Weapons Loader Aerial Stores Lift Truck (fig. 7-8) is designed primarily for use by the U.S. Navy to transport and load all internally and externally carried weapons weighing up to 4,000 pounds, including prepackaged multiple bomb racks, multiple ejector racks, and triple ejector racks, onto the various shore-based naval aircraft. All weapons lifting and manipulation functions are hydraulically powered. The vehicle is equipped with a 27.5 horsepower, multifuel burning, DJ-120 Onan engine which provides power for mobility as well as hydraulic functions.

The Aero 47A provides limited rough terrain and high flotation mobility which is controlled in a manner similar to conventional forklift trucks. It is equipped with hydraulic powered steering which provides a turning radius of 15 feet. All hydraulic motions, including the lift mechanism, incorporate deadman and failsafe features which prevent movement of the load in the event of mechanical or hydraulic failure.

This loader, in naval shore-based aircraft loading operations, provides for loading all weapons, including prepackaged multiple suspension racks, with a 2-man crew. Since the loader provides for transporting and handling prepackaged multiple suspension racks, operations such as individual weapon attachment, sway bracing, fuzing, attaching arming wires, and preliminary rack checkout can be performed as prestaging operations, and loading time at the aircraft is reduced to an absolute minimum.

The Aero 47A has conventional automotive power steering with a 30° cramp angle. The drive train consists of a single disc, dry automotive clutch, a standard 3-speed transmission, a 2-speed transfer case, and a limited slip differential to insure positive traction. Braking consists of a mechanical parking brake on the rear wheels, and hydraulic service brakes on the rear wheels and on the two inside front wheels.

Mobile Cranes

Mobile cranes are used both at shore stations and aboard ship. Those for shipboard use are usually smaller and to some degree more maneuverable than shore-based cranes. The mobile crane is an emergency vehicle primarily designed for use in aircraft salvage and rescue.

Maximum performance of the mobile crane, including its operating equipment, is dependent upon the frequency and scope of the maintenance rendered, plus the ability of the operator to properly operate the crane. Personnel to whom the crane is assigned should become thoroughly familiar with the crane's technical manual prior to actual operation of the crane.

The NS-60 mobile crane (fig. 7-9) is designed primarily to lift and carry crashed aircraft on the flight deck of an aircraft carrier. The crane is equally suitable for similar duty on shore stations, both for aircraft landing areas and for paved or unpaved operational areas.

The crane, a self-propelled vehicle, is mounted on four electrically powered wheels. Heavy-duty d-c electric traction motors and gear reduction units built within the wheel hubs provide motive power for the crane. Each wheel motor is equipped with multiple disc type spring-loaded brakes for emergency stops and parking, while a regenerative electrical braking system is used for operational deceleration of the crane.

The hook motor also operates on d-c and, because of an electrical interlock, cannot be operated simultaneously with the wheel motors.

A-c electric motors, strategically located at the point of power application, drive through reduction gear boxes to provide boom movement and steering. Each a-c motor is equipped with a multiple disc, spring-loaded brake that sets instantly when the motor's electrical power is interrupted, thus locking the boom in position. Restoration of the motor's electrical power automatically releases the motor brake.

Two generators, one a-c and one d-c, coupled directly to and driven by a 6-cylinder diesel engine, supply current to the control motors and the wheel motors. One control handle (potentiometer), located on the operator's control panel, provides control of the wheel motors or hook motor, whichever is selected by the operator,

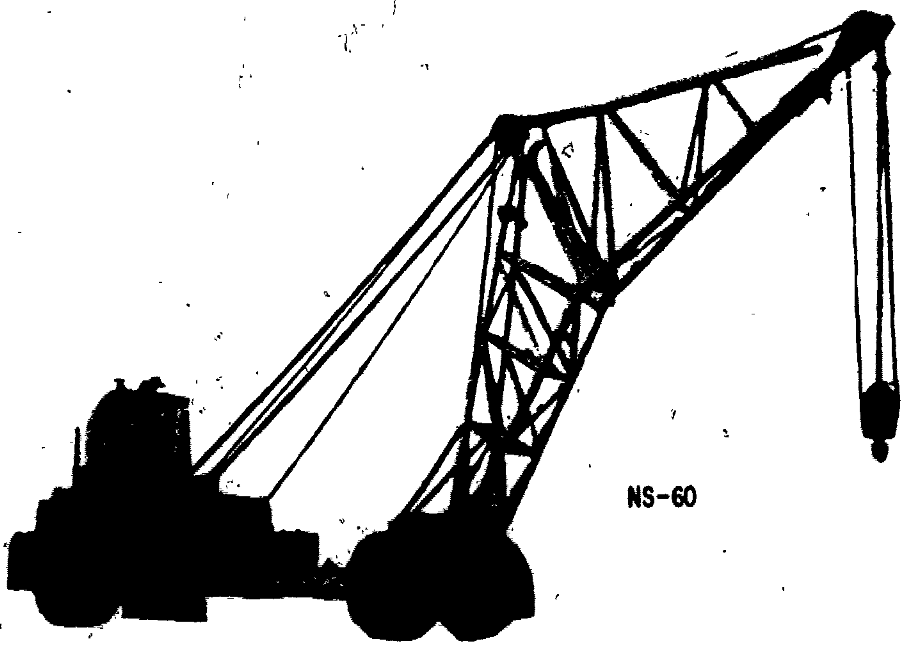

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Figure 7-9.—Mobile cranes.

while fingertip switches on the control panel provide control of steering and boom movement.

A remote control panel having a 25-foot cable is stored in a compartment on the left side of the crane. This control panel allows the operator to maneuver the crane or to operate the hook motor, boom motor, and parking brakes from any point on deck up to a maximum of 25 feet.

The crane is capable of lifting and carrying 60,000 pounds with the boom at its minimum extension. Unloaded weight of the crane is 125,000 pounds.

Attached to the front of the crane is a stationary, bulldozer type, push plate. Its purpose is to allow the crane to push away damaged aircraft or other material which cannot be picked up to clear the deck or runway.

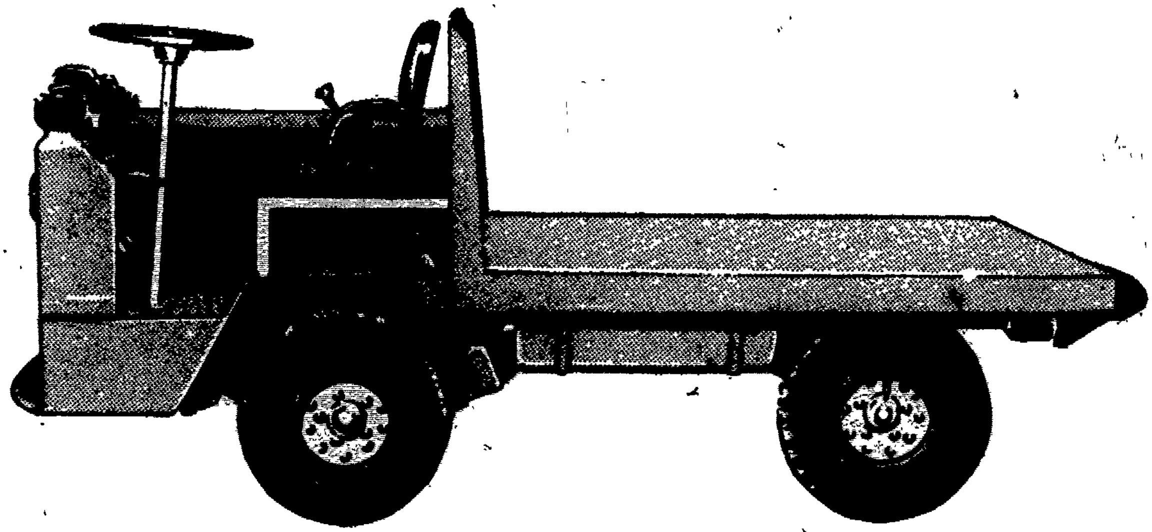

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Figure 7-10.—P-36 airfield maintenance truck.

An earlier version of the crane, the NS-50 (SC-7), is quite similar to the one just described. The main differences are the weight of the crane and its load capacity.

The MB-1A mobile crane (fig. 7-9) is designed to have good maneuverability in lifting and removing crashed aircraft from air station runways and surrounding areas. The MB-1A is made up of a 2-wheeled prime mover attached to a 2-wheeled crane.

The prime mover is powered by a diesel engine driving through a twin-disc clutch, a 5-speed transmission, a high/low-speed auxiliary transmission, and a torque-proportioning differential. The auxiliary transmission in combination with the 5-speed transmission results in 10 speeds forward and 2 speeds in reverse. The wheels of the crane are not powered.

An a-c generator, driven from the engine flywheel, supplies current for powering the hook motor, jib motor, boom motor, and steering motor. These motors are controlled by fingertip switches located at the operator's station. A remote control box is provided for controlling the hook, jib, and boom motors from a position near the point of pickup.

Air brakes are provided on all four wheels. These brakes consist of alternate discs splined to the brake drum and brake hub. Air pressure directed to a pressure plate forces the discs together for braking. Springs are used to move the pressure plate to the released position when the air is bled from the brake. Selector valves are provided to control the selection of front, rear, or both brake sets.

There are three stations where sound-powered telephones may be used. One station is in the cab by the operator, and the others are located at the left side of the crane tongue and at the rear of the crane. To use, simply plug in the phone jack at one of the station outlets.

The C-25 mobile crane (fig. 7-9) is a truck-mounted crane manufactured by Oshkosh Truck Company. It has a lifting capacity of 25 tons, has a 6-wheel drive, and a top speed of 50 mph.

Mobile Electric Powerplants (MEPP'S)

Mobile electric powerplants supply electrical power for various testing and checkout operations of aircraft. The MEPP's used today are designed for operation on shore stations and aboard aircraft carriers. On aircraft carriers these units are usually of the mobile type, with minimum vehicular dimensions and weight; they are usually designed for utmost maneuverability and mobility. On shore stations, these units may be mobile, or they may be trailer mounted and require towing.

There are many types of mobile powerplants in use. The type used depends upon the type aircraft to be serviced.

A detailed description of many of the current MEPP's in use is presented in chapter 13 of this training manual.

P-36 Airfield Maintenance Truck

The P-36 airfield maintenance truck (fig. 7-10) is a gasoline powered, platform type truck capable of hauling loads up to 3,600 pounds. It is designed for off-highway use at relatively low speeds, and is provided with a hitch on the rear of the vehicle to facilitate towing of equipment weighing up to 1,500 pounds; heavier equipment should be towed with the appropriate tow tractor.

The P-36 truck uses a V-type, 4-cylinder, air-cooled engine. The engine produces 34 horsepower at its governed speed of 2,175 rpm. The vehicle has a dry-disc type clutch and a standard-shift transmission with one reverse and two forward speeds.

Forklift Trucks

The forklift truck (fig. 7-11), usually referred to as a "forklift," is a much-used unit of material handling equipment. It is a cantilever type industrial truck and, in its various configurations, can be powered by diesel, gasoline, or electricity, and may have either three or four wheels. It contains a vertical set of rails on the front and a hydraulically powered carriage equipped with two or more forks. The length and thickness of the forks vary between units of different load capacity.

The forklift truck may have either pneumatic or solid tires, and the drive wheels may be dual or single, depending on the load capacity.

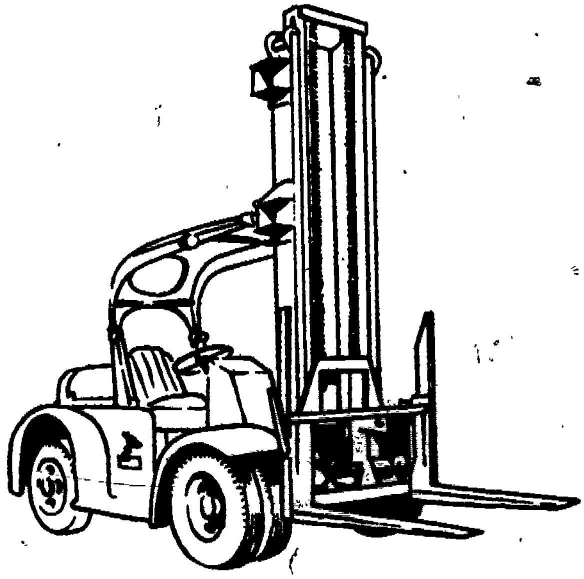

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Figure 7-11.—Forklift truck.

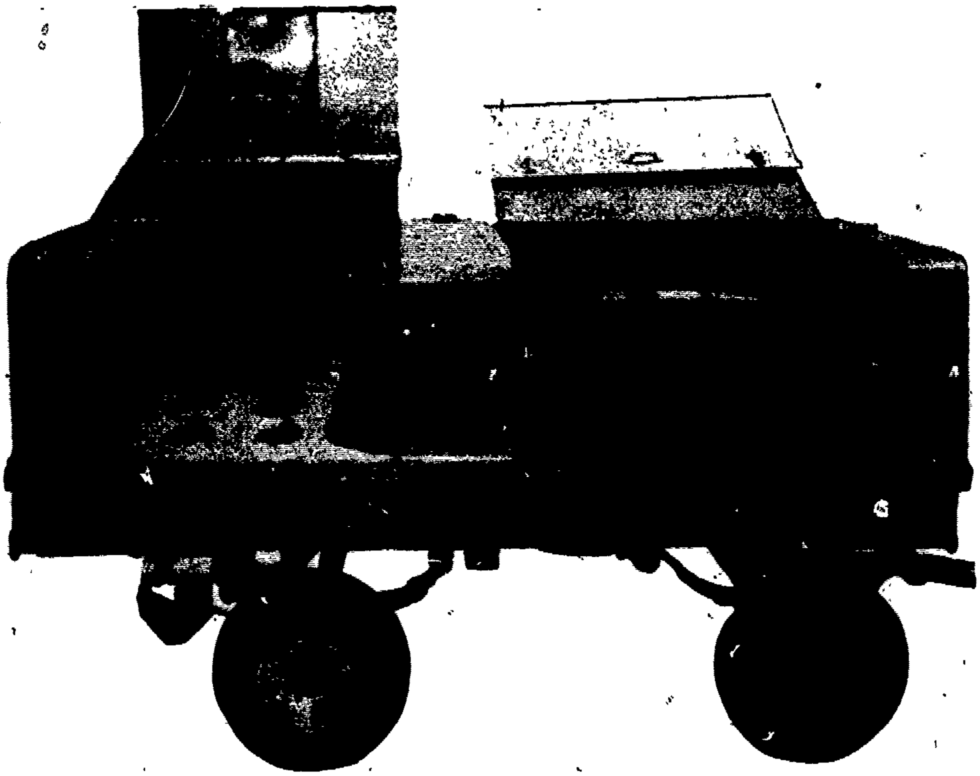
Forklift trucks are generally used to handle palletized unit loads, but may also be used to handle boxes or containers equipped with skids, as well as other large containers and packages. These loads may be moved aboard carriers, on barges, on piers, in warehouses, or in and around freight terminals.

Hydraulic Test Stands

Portable hydraulic test stands provide a means of simulating the aircraft's engine-driven hydraulic pump. By connecting a test stand to the aircraft's hydraulic system, the various actuating systems may be cycled without turning up the aircraft engine. The test stand is connected to the aircraft system at ground test couplings (quick-disconnects) provided on the aircraft

Portable hydraulic tests stands may be driven by any one of several means—air motor, electric motor, gasoline engine, or diesel engine.

MODEL 11090C TEST STAND.—The 11090C (fig. 7-12) is manufactured by Redco (Red Lion Cabinet Company). It is powered by a 6-cylinder gasoline engine and is equipped with an electric starter plus a manual handcrank.



AS.220

Figure 7-12.—Model 11090C hydraulic test stand.

This unit is designed for testing, flushing, and filling aircraft hydraulic systems. It is capable of providing a flow up to 19 gallons per minute (gpm) at 3,400 psi pressure. It can produce up to 5,000 psi pressure, but with a reduced volume. The hydraulic pump is a variable displacement type.

The Model 11090C test stand is a completely self-contained unit. It is of rugged construction, is mounted on four wheels, and has a tow bar for hand steering and for movement with a tractor. The hose lines contained within the unit are furnished with quick-disconnect couplings for both suction and pressure connections to the aircraft.

MODEL S-250 TEST STAND.—The S-250 (fig. 7-13) is manufactured by Sprague Engineering Corporation. Like the portable test stand previously described, this unit is designed for flushing, filling, or ground checking aircraft hydraulic systems.

This test stand is a 3-wheeled unit, the single front wheel being steerable. The inside of the cabinet is accessible through two front and two rear doors.

The unit is powered by a 220-volt, 40-hp motor. Flow capacity is 20 gpm at 3,000 psi. Pressures up to 5,000 psi are possible, but with a decreased volume.

MODEL AHT-64 TEST STAND.—The AHT-64 is a diesel engine driven unit, manufactured by Liquidonics, Inc., or by Sun Electric Corp. The model AHT-64 hydraulic test stand is shown in figure 7-14.

This test stand is designed to test, drain, flush, and refill aircraft hydraulic systems. It is de-

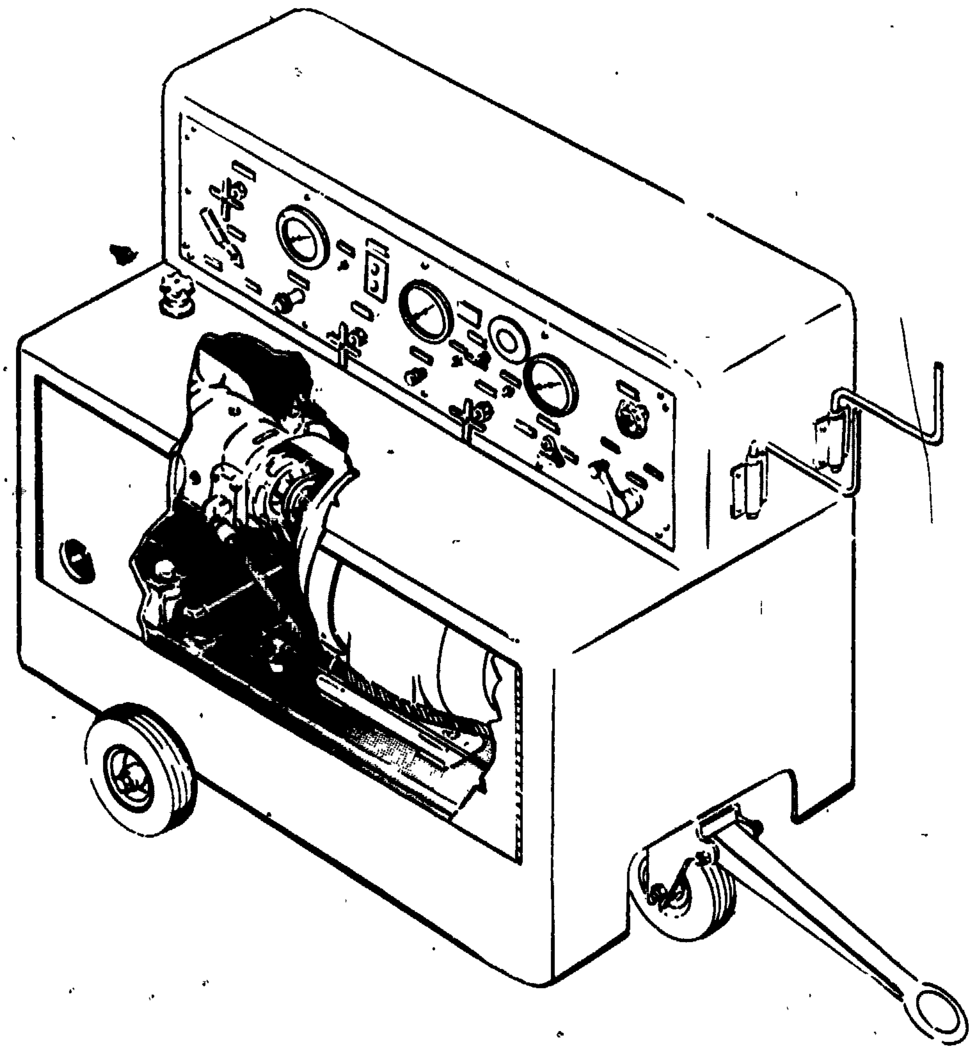


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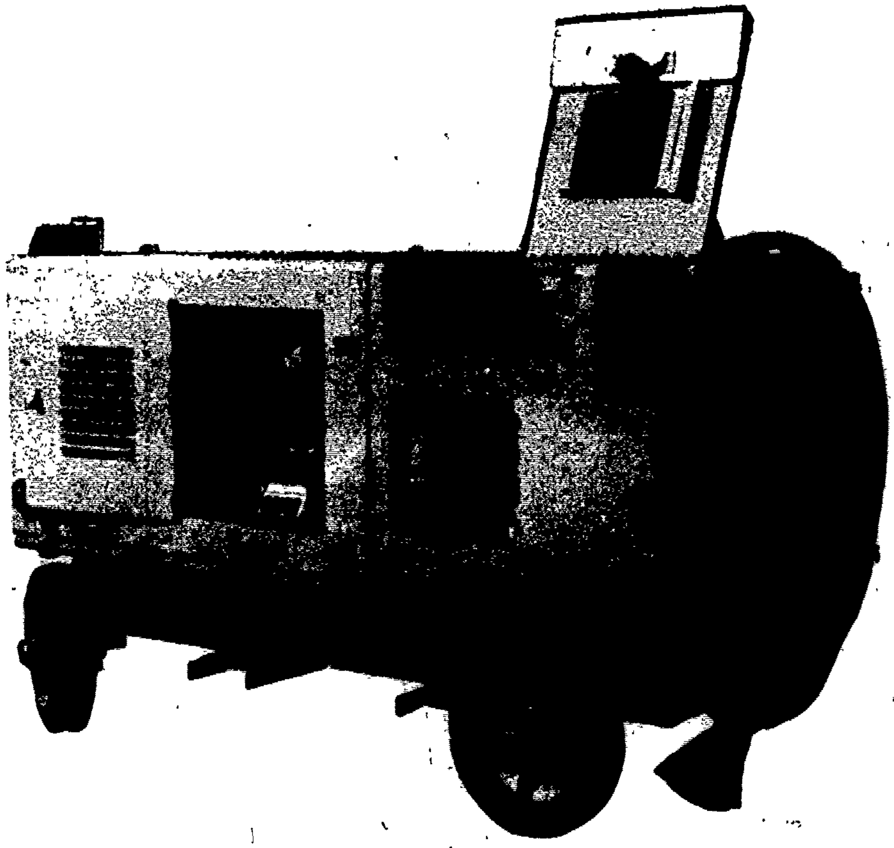
Figure 7-13.—Model S-250 hydraulic test stand.

signed to operate in the temperature range from -20° F to +125° F with a humidity as high as 100 percent. It will deliver a fluid volume of 20 gpm at a pressure of 3,000 psi, and up to 10 gpm at 5,000 psi pressure.

Another unit which the ASE may come in contact with is the model AHT-63 hydraulic test stand. It, like the model AHT-64, is manufactured by Liquidonics, Inc., or by Sun Electric Corp. and is very similiar to the model AHT-64 in size, appearance and operation. The major difference is that the model AHT-63 test stand is powered by a 220/440-volt electric motor.

Air Compressors

Air compressors supply air for paint spraying, drilling, sandblasting, riveting, etc. Air compressors may be of the stationary type (permanently mounted in hangar or shop spaces) or of



AS.222

Figure 7-14.—Model AHT-64 hydraulic test stand.

the portable type (mounted on wheels) and easily moved to where they are needed.

The stationary unit (fig. 7-15) consists of an electric motor, compressor, storage tank, centrifugal pressure release, pressure switch, and mounting pads on the storage tank. The stationary units are normally driven by an electric motor, but in some installations a gasoline or diesel engine is used.

The portable units are normally driven by a gasoline engine, but may be driven by a diesel engine or an electric motor. The portable unit in figure 7-15 consists of an electric motor, compressor, storage tank, automatic unloader mechanism, wheels, and handle for moving the unit.

The model P5R portable air compressor shown in figure 7-16 is powered by an air-cooled, 4-cylinder, V-type, gasoline engine. This air compressor is capable of continuous operation at a rated capacity of 15 cubic feet of free air per minute (cfm) at pressures up to 5,000 psig. The unit is capable of meeting all low-pressure requirements between 0 and 1,000 psig and high-pressure air servicing between 1,000 and 5,000 psig.

Mobile Air Conditioners

Mobile air conditioners are designed to provide cooling, ventilation, dehumidification, and filtration of air for electronic equipment in aircraft cabins or equipment compartments.

Although there are various types of mobile air conditioners in use by the Navy, they all have the same operating principles and, basically, the same components. Operation and servicing of mobile air conditioners is covered in chapter 15 of this manual. The units described here are representative of the units the ASE is required to maintain.

NR-2B.–This unit is a mobile, trailer mounted, electrically powered, self-contained air conditioner. (See fig. 7-17.) It requires a 440-volt, 3-phase, 60-Hz power supply and has a cooling capacity of 7 tons. The NR-2B can be used equally well for either shipboard or shore station operations.

NR-5C.–This unit is a mobile, trailer mounted, electrically powered, self-contained air conditioner. (See fig. 7-18.) It requires a 440-volt, 3-phase, 60-Hz power supply and has a cooling capacity of 22 tons. The NR-5C can be used equally well for either shipboard or shore station operations.

NR-10.–This unit is a mobile, trailer mounted, diesel engine powered, self-contained air conditioner. (See fig. 7-19.) It is powered by a 6-cylinder, liquid cooled, turbocharged, diesel engine and has a cooling capacity of 19 tons. The NR-10 is not usually found aboard ship because its height restricts movement among closely spotted aircraft.

Motor Generator Assemblies

Motor generator assemblies are designed to supply d-c or a-c regulated power for aircraft servicing, component testing, and other applications where a low voltage, high current power supply is required. There are various types of motor generator assemblies–some supply d-c power only, and others furnish d-c and a-c power. The motor generator assemblies are usually portable, mounted on a dolly with either three or four wheels. Typical type motor generator assemblies are discussed in the following paragraphs.

MODEL ATE-105 PORTABLE MOTOR GENERATOR ASSEMBLY.–The motor generator assembly shown in figure 7-20 is of two-bearing construction, having a common shaft for the motor and generator. The a-c motor rotor is overhung from an intermediate bearing, and the motor stator is overhung from an intermediate housing. The motor stator and intermediate housing are secured to the generator magnet frame. The intermediate housing contains an involute in which the cooling fan operates, pulling air in from both ends of the set through

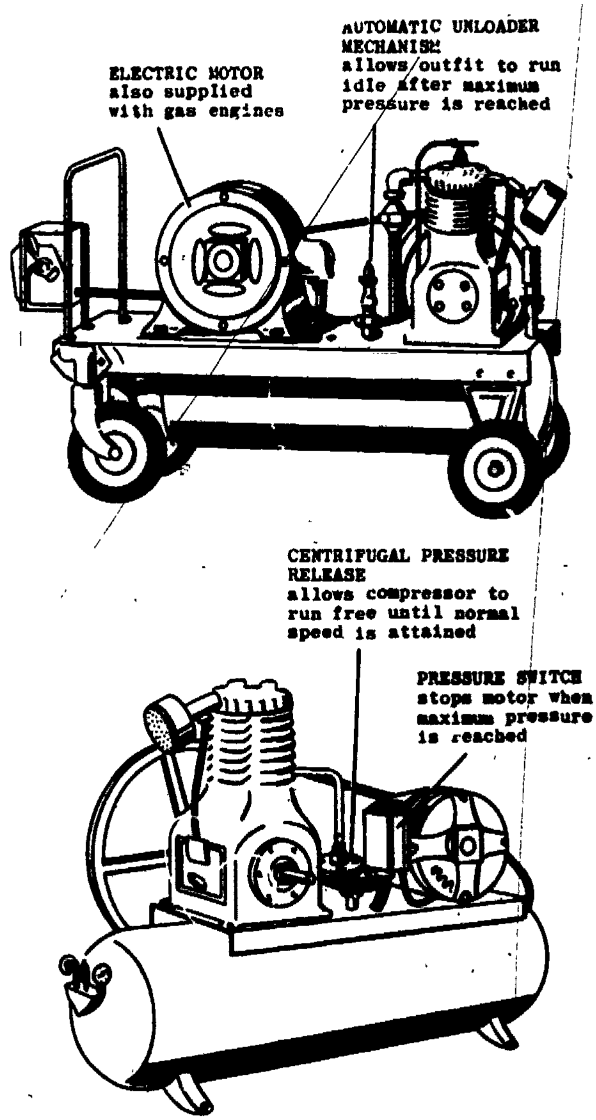


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Figure 7-15.–Air compressors.

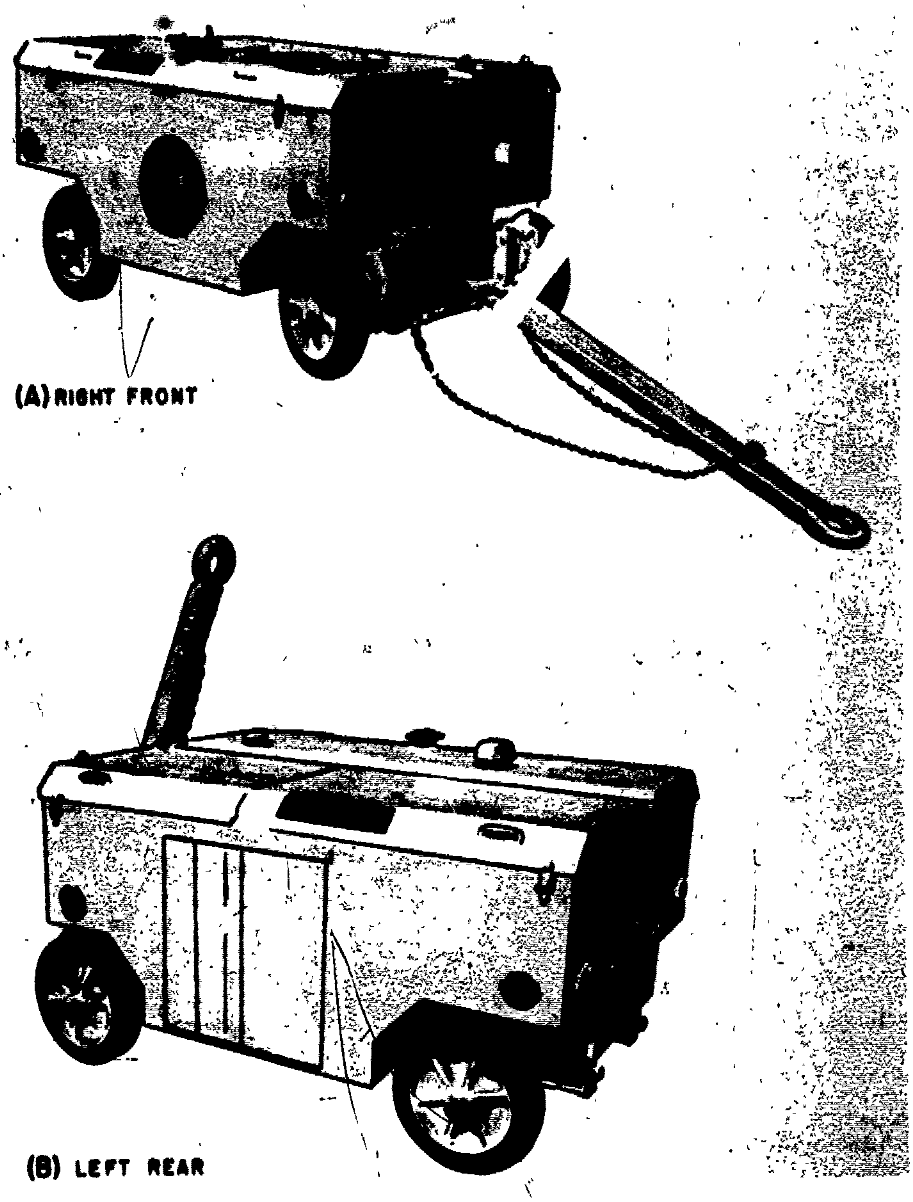

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Figure 7-16.—Model P5R portable air compressor.

screened end covers and exhausting into the center of the control box.

The generator and motor controls are housed in a drip proof control cabinet mounted on top of the motor generator. The d-c control components consist of a voltage regulator, reverse current cutout and load contactor, voltage control rheostat, d-c overload circuit breaker, ON-OFF load switch, ammeter and shunt, and voltmeter. The voltmeter and ammeter are located on a vertical hinged panel along with the manual control components. The panel, when open, provides easy access to all d-c components. The across-the-line magnetic motor starter and operating pushbutton are housed in the control cabinet on the motor end.

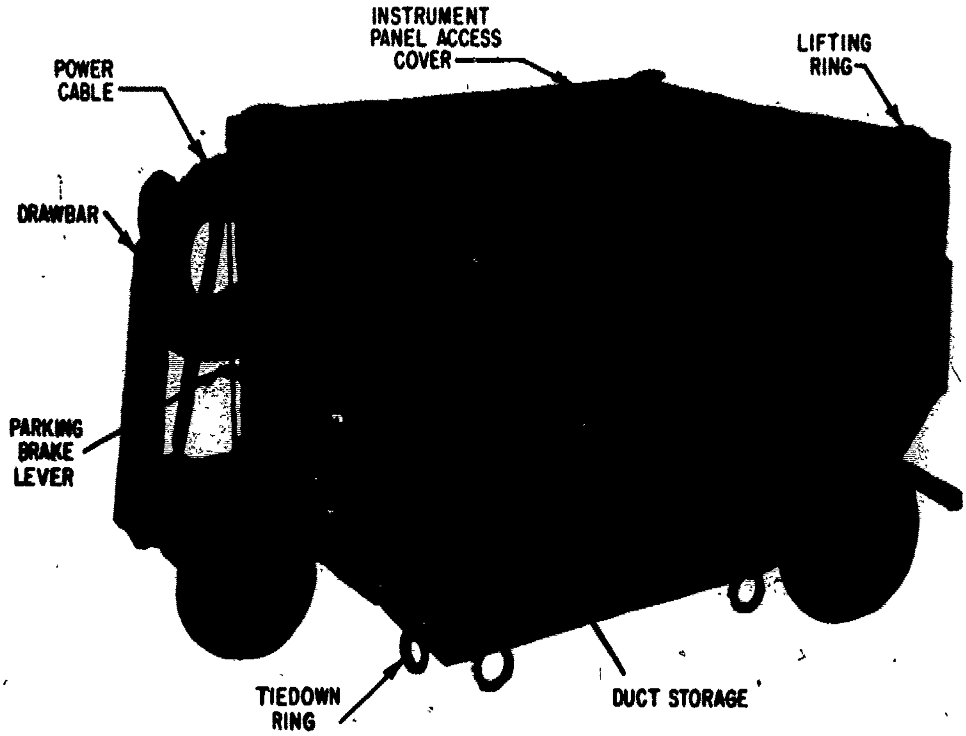

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Figure 7-17.—NR-2B mobile air conditioner.

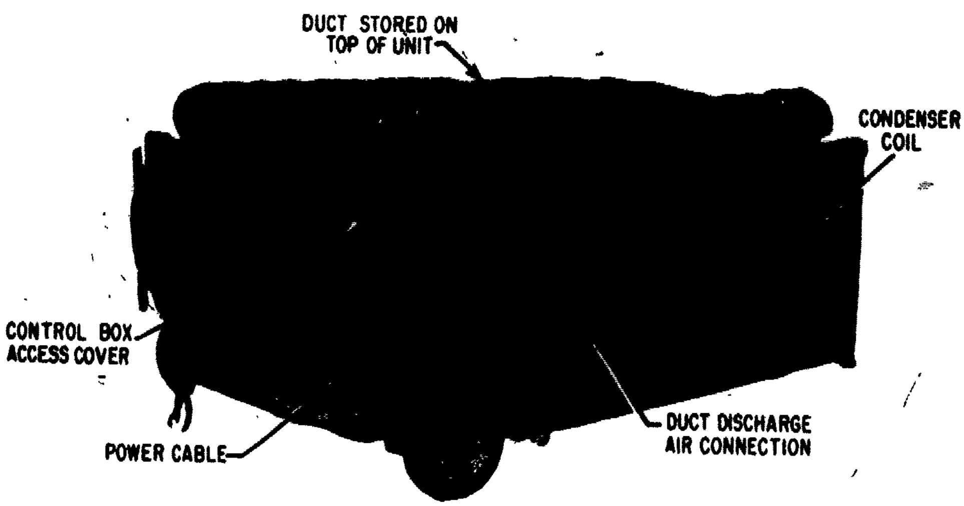

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Figure 7-18.—NR-5C mobile air conditioner.

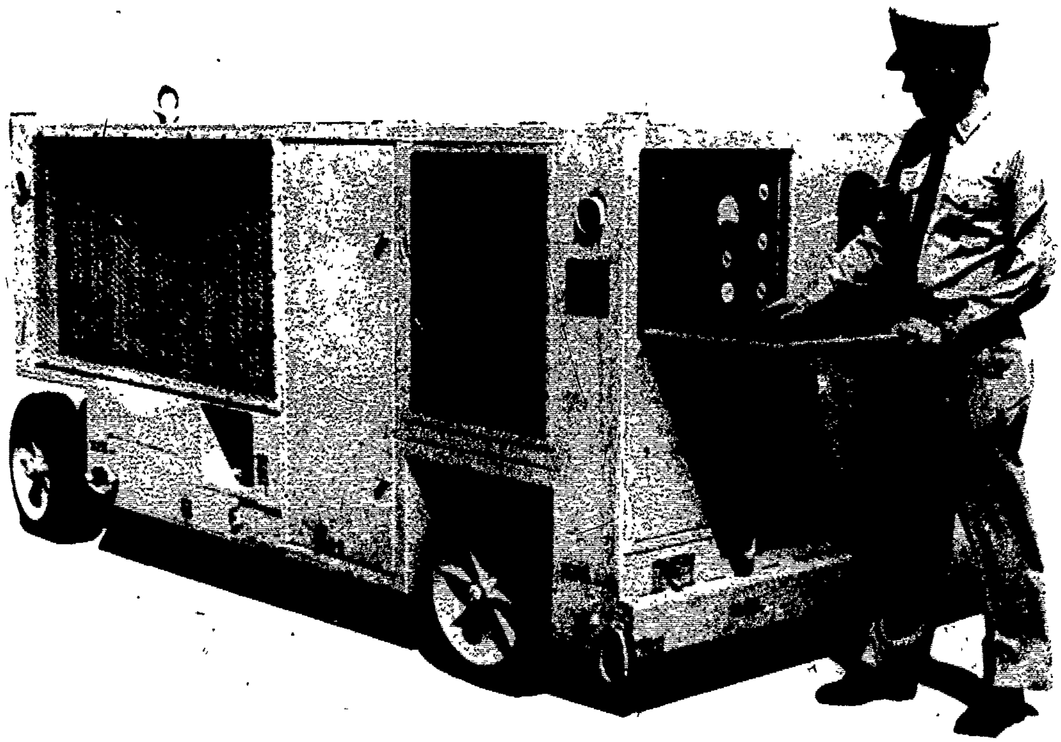

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Figure 7-19.—NR-10 mobile air conditioner.

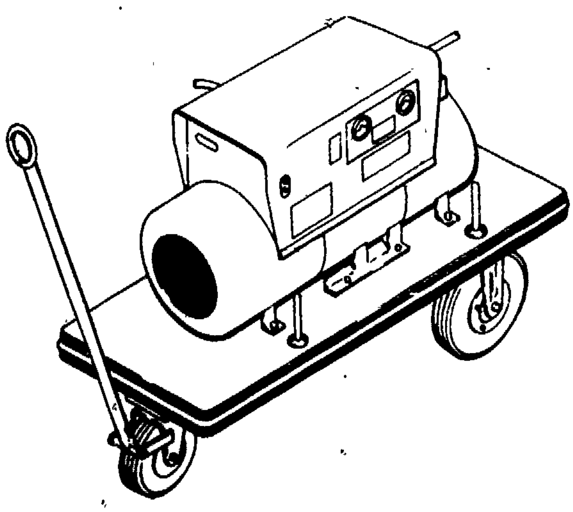

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Figure 7-20.—ATE-105 motor generator assembly.

The motor generator set is radio-noise suppressed. The output leads of the generator are suppressed by feedthrough capacitors, and the control leads from the fields are suppressed by feed-through pi filters. A-c input leads from the 440-volt supply are connected to feedthrough capacitors mounted to the top of the control cabinet directly above the motor starter. The generator suppression components are mounted to the generator magnet frame and are partially enclosed by the sheet metal end cover of the generator. The ratings of the motor and generator are:

Generator	Motor
Voltage: 24-32	220/440
Amp. Continuous: 500	60/30
Amp. Overload: 750 Intermittently	3 phase
	60 hertz

Speed—3,500 rpm
Ambient—40°C

MODEL CDM-15 PORTABLE MOTOR GENERATOR ASSEMBLY.–The motor generator assembly shown in figure 7-21 consists of three subassemblies–an a-c drive motor, a d-c generator, and an a-c generator. These assemblies are arranged in tandem; the motor assembly being in the center. The extended ends of the a-c motor serve as a common shaft for the a-c and d-c generators. The motor, which drives the generator, receives its power from a 220/440-volt a-c, 60-hertz source through a 10-foot cable. The a-c generator output is connected to its external load through a rectangular-shaped, 6-conductor, 20-foot cable. The d-c generator output is connected to its external load through an oval-shaped, 2-conductor, 30-foot cable.

The control box assembly is mounted on a gusset-bracket constructed over the d-c generator. and contains all the controls and indicators. The front panel has a d-c volt-ammeter, an a-c voltmeter, an a-c ammeter, three circuit breakers, two adjustment rheostats for d-c and a-c voltage adjustment, and three selector switches.

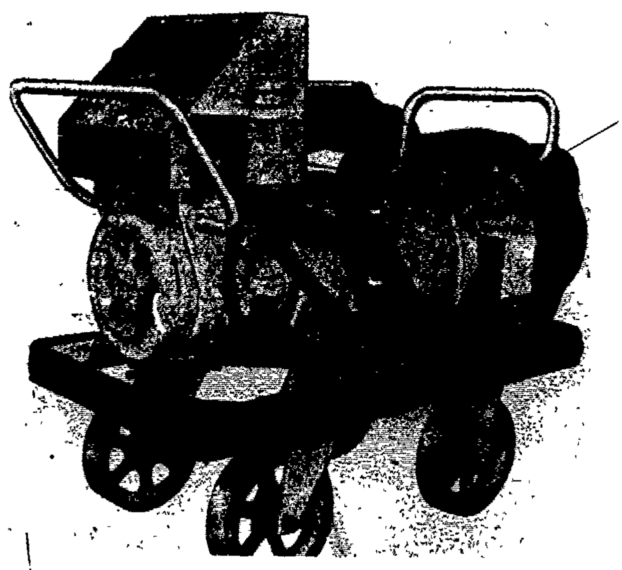

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Figure 7-21.–CDM-15 motor generator assembly.

Gas Turbine Power Units

Gas turbine power units supply compressed air for units or systems requiring air in large volume, such as air-conditioning systems, aircraft main engine starters, etc. They may also, by utilizing reduction gearing, drive generators to provide electrical power. Some gas turbine units are self-contained while others depend upon the equipment they are mounted on for fuel and electrical supplies. Although there are many types and configurations of gas turbine power units, the construction and operation are basically the same for all.

The NCPP-105, RCPP-105, RCPT-105, and GTC-85 are examples of such units with which the ASE may come in contact. Chapter 13 of this manual gives a description of the gas turbine used as an MEPP, and chapter 14 of this manual covers the operation and servicing of gas turbine units.

Trailers and Dollies

Trailers usually found as part of ground support equipment are special-use, unpowered, three- or four-wheeled vehicles. They have a towing tongue, and the front wheels are turned in a manner similar to an automobile, or are free swiveled. The wheels have either solid or pneumatic tires and two or more of the wheels are equipped with brakes to permit the trailer to be parked in any desired position.

Trailers with utility beds are used to move ordnance and miscellaneous cargo. Some equipment such as air compressors, air conditioners, engine preheaters, gas turbine power units, and preoilers are permanently mounted on trailers. The trailer permits the mobility needed for this type of equipment without the prohibitive cost of the engine and accessories that would be needed to make the unit self-propelled.

Aircraft engine service trailers are used to support aircraft engines while they are being removed from or installed in the aircraft, and to transport the engines while they are out of the aircraft. Trailers designed to have equipment permanently mounted on them usually have the equipment installed at time of manufacture.

Dollies are usually constructed as a welded steel platform and mounted on either three or four casters (wheels). One or more of the wheels are swivel type and at least two of them will be equipped with parking brakes. Tie-down rings

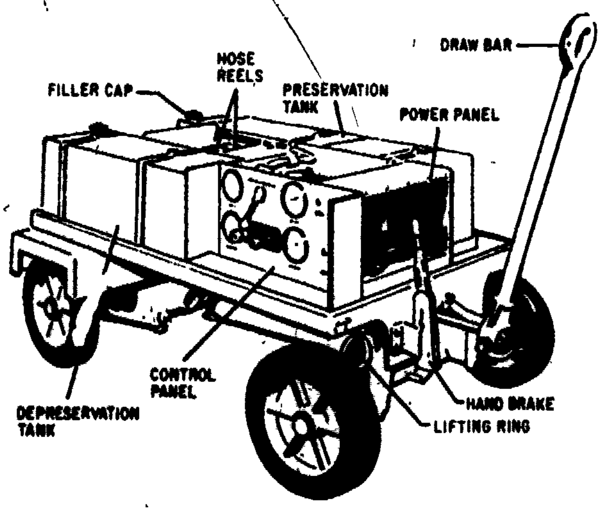

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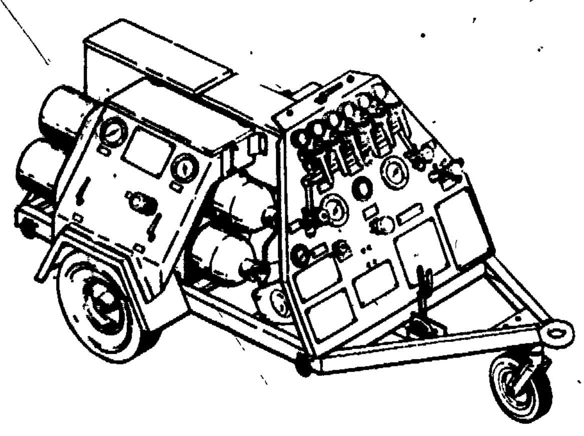
Figure 7-22.—Preservation/depreservation trailer.



AS.289
Figure 7-23.—Nitrogen servicing unit (trailer mounted).

and/or bridges are provided for securing loads on the dolly or securing the dolly on deck. Lightweight dollies are used in maintenance shops for transporting components and for mounting heavy equipment which requires mobility, such as motor generators and air compressors. Heavy duty dollies (crash dollies) are used for moving extremely heavy equipment, both aboard ship and ashore. Crash dollies are used aboard ship to aid in moving damaged aircraft and may be modified to meet the particular situation.

PRESERVATION/DEPRESERVATION TRAILER.—The preservation/depreservation trailer, figure 7-22, is of welded steel construction and so arranged as to be transportable by ship, cargo aircraft, or helicopter. Four-wheel suspension is provided with knuckle type steering on the front wheels to provide maneuverability. Internal expanding brakes are used to hold the trailer in position when in use. A tow bar is provided to permit towing by other vehicles. All doors and panels are constructed to provide a weathertight seal and are arranged so that the internal components are readily accessible by personnel for operation, adjustment, and maintenance.

Two oil tanks are provided—a depreservation oil tank of 20-gallon working capacity and a preservation oil tank of 30-gallon working capacity. Both tanks are provided with cleanout openings, drains, and filler necks.

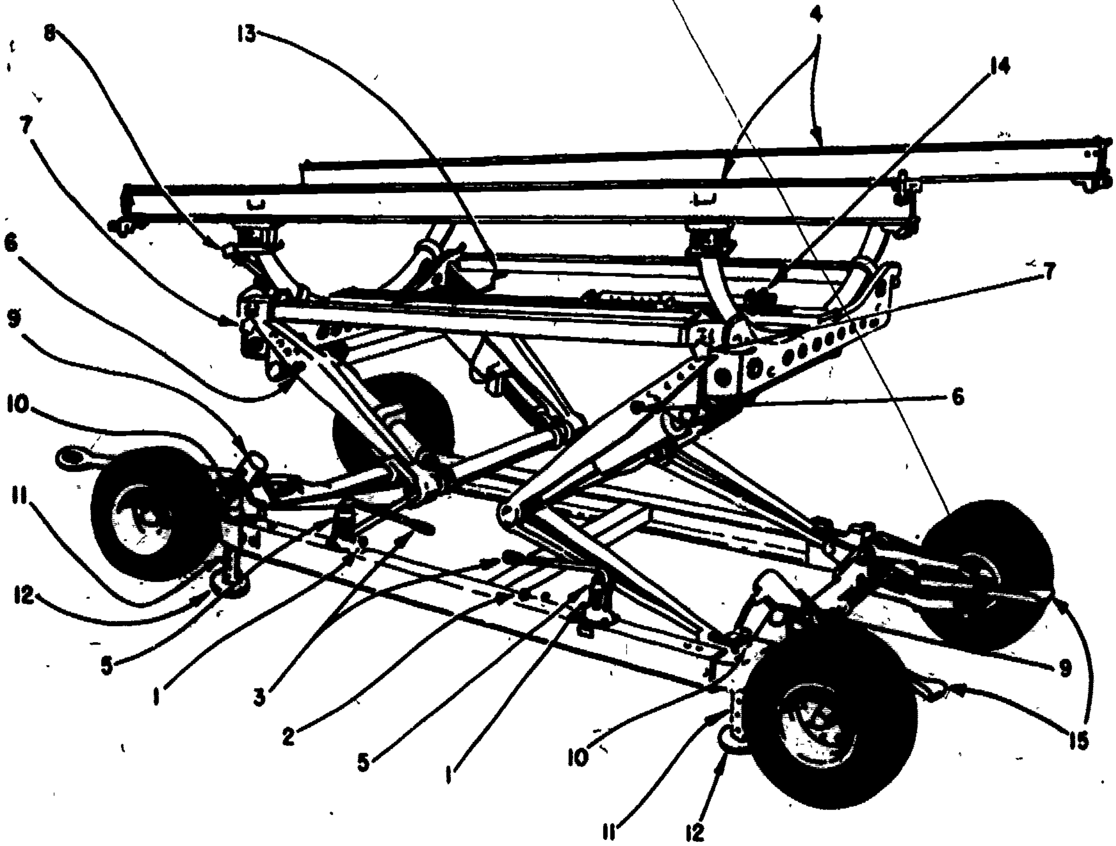
The hydraulic system consists of an electrically driven pump, capable of delivering fluid at the rate of 3 gpm against head pressures from 0 to 250 psi, and the necessary piping and control valves.

A 3-phase, 220/440-volt, 60-hertz, electrical system is provided to operate the pump motor, strip heaters, and their controls. The heaters are capable of heating the oil tanks from 0° to 121° C (32° to 250° F) within 1 hour.

NITROGEN SERVICING UNIT (TRAILER MOUNTED).—Nitrogen servicing units, similar to the model shown in figure 7-23, can be found at most naval air stations and on board aircraft carriers. This unit is designed to provide a mobile source of compressed nitrogen for servicing aircraft high pressure systems and inflating aircraft tires.

The nitrogen servicing unit is mounted on a two-wheeled trailer with a retractable, swivel caster-type front wheel.

Compressed gas cylinders are mounted to the frame in two groups of three each. A steel box is located between the cylinder groups for storage of hoses and necessary tools for system servicing. A tow bar is provided on the trailer to enable towing by other vehicles.



1. Bleed valves.
2. Selector valves.
3. Pump handles.
4. Rails.
5. Selector collars.
6. Pawl release knobs.
7. Lateral and yaw adjustment knobs.
8. Roll adjustment knob.
9. Safety pawls.
10. Lockpins.
11. Posts.
12. Steady rests (feet).
13. Winch drive.
14. Drawbar.
15. Brake pedals.

AS.228

Figure 7-24.—Engine removal/installation trailer (4000A).

Two control panels are mounted to the frame—the main panel which provides controls for high pressure system servicing, and the auxiliary panel which provides controls for aircraft tire inflating.

A chemical drier is provided to remove any moisture which may have adhered to the valves or which may have been accidentally introduced into the system. The chemical is contained in a metal cartridge or can which is changed periodically, and the nitrogen passes through the drier just before it enters the servicing hose.

ENGINE REMOVAL/INSTALLATION TRAILER.—This unit is used to facilitate removal and installation of aircraft jet engines. Adapter sets are available to adapt most any jet engine to the parallel rails of the trailer. (See fig. 7-24.) Provision is made for moving the engine about any of its axes to enable maintenance personnel to precisely position the engine

AB.288

Figure 7-25.—Crash dolly.

for removal and installation with a minimum of time and effort. The trailer is provided with a tow bar on the forward end and a pintle hook on the aft end so that the trailers can be towed individually or in tandem.

The parallel rails of the trailer are lifted or lowered hydraulically by means of hand pumps, one for each end of the rails. Mechanical ratchet locks are provided on each cylinder for optimum safety.

A hand-crank operated winch is provided to move the engine fore and aft on the parallel rails, to another stand for transportation, or to a set of stationary rails for maintenance.

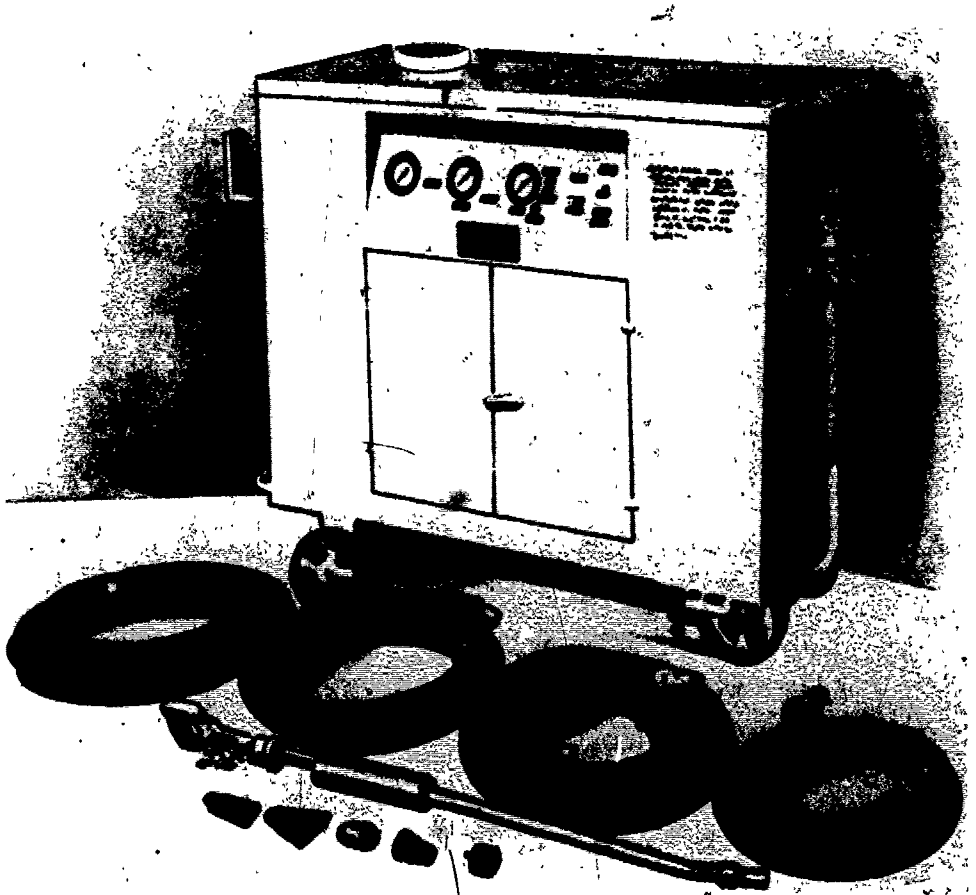


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Figure 7-26.—Steam cleaner.

CRASH DOLLIES.–These are provided on all aircraft carriers for moving heavy aircraft components, and to serve as aids in moving crashed aircraft. They are heavy duty, low-bed dollies of welded steel construction with a hard fiber top surface and four swivel shock-absorbing caster type wheels with nonsparking tread. Pipe type rails (bridges) on all four sides of the dolly provide handholds and attachments for tie-downs. (See fig. 7-25.)

These dollies can be modified in many different ways to serve specific purposes. One modification may be a steel structure to form a higher platform for use under a wing or nose section. Also, a heavy steel socket, large enough to insert a landing gear strut with the wheel broken off, is sometimes welded to the dolly. Any modification to the dolly must be sufficiently strong to safely handle the load that will be imposed upon it. Like mobile cranes, these dollies are often used to support only a portion of the aircraft's weight. Other dollies are similarly used.

Steam Cleaners

Steam cleaners are used to clean and degrease equipment and components, aircraft, machinery, machine parts, and other items which are not subject to damage through the application of moisture. (See fig. 7-26.) Most models can be used as a steam cleaner or as high- pressure hot or cold water washing and rinsing unit. In addition, they are usually equipped with a cleaning solution system whereby soap or other approved cleaning compounds may be automatically mixed with the steam or water.

Steam cleaners are usually either electrically operated or gasoline-engine driven. An electrically operated model is illustrated in the figure.

Dry Honing Machine (Vacu-Blaster)

The portable dry honing machine, shown in figure 7-27, is a compact, self-contained, lightweight unit used for safe and convenient removal of corrosion products from metal surfaces of both aircraft and equipment components through the dry honing process. The unit uses either glass beads or aluminum oxide abrasive up to 1,000 mesh.

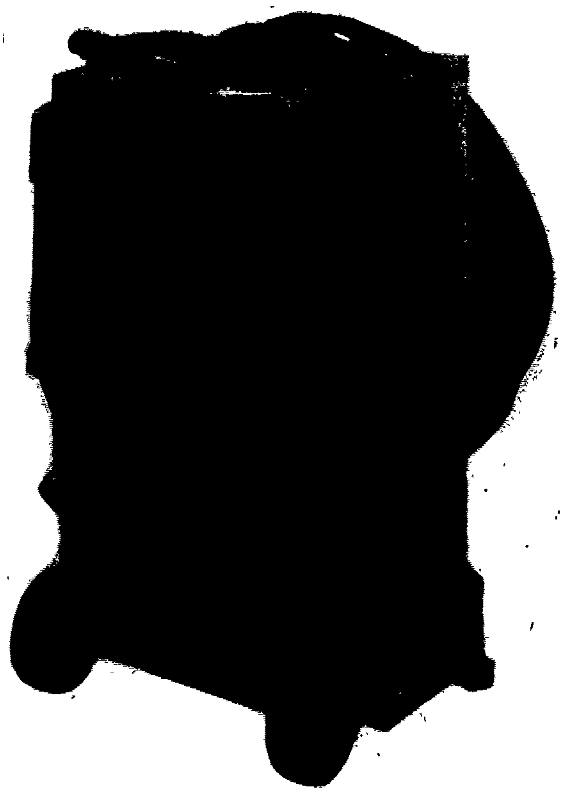

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Figure 7-27.–Portable dry honing machine.

The dry honing process of the machine utilizes compressed air, in large volume, to provide the high velocity discharge of abrasive at the center of the blast gun. Used abrasive and removed debris are pulled back into the machine by high vacuum at the outer circumference of the blast gun. Loss of abrasive material is prevented by a nylon brush on the blast gun. (See fig. 7-28).

Once the used abrasive/debris enters the machine, it is passed through an abrasive reclaim system where the debris and abrasive are seperated. The abrasive is returned to the abrasive hopper for reuse and the debris is passed into a set of cloth filter bags where it is trapped and deposited in a removable dust tray located on the bottom of the unit. This process of making

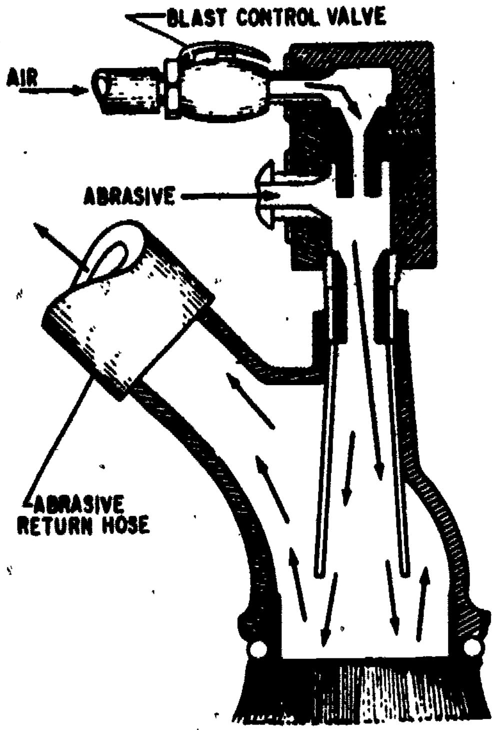

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Figure 7-28.—Blast gun head assembly.

the abrasive reuseable also gave rise to the commonly used term "vacu-blaster" for the dry honing machine.

The portable dry honing machine is operated by compressed air or, in some cases, a combination of compressed air and electricity. In these cases, the compressed air is used for blasting and the electricity is used to operate a vacuum pump.

Maintenance Platforms (Workstands)

The B-4A adjustable maintenance platform (fig. 7-29) is a hydraulically operated platform and ladder assembly, mounted on a caster equipped base, which enables personnel to work in safety at heights varying from a minimum of 3 feet to a maximum of 7 feet. All four wheels have locks to make the platform stationary.

The B-5A adjustable maintenance platform,

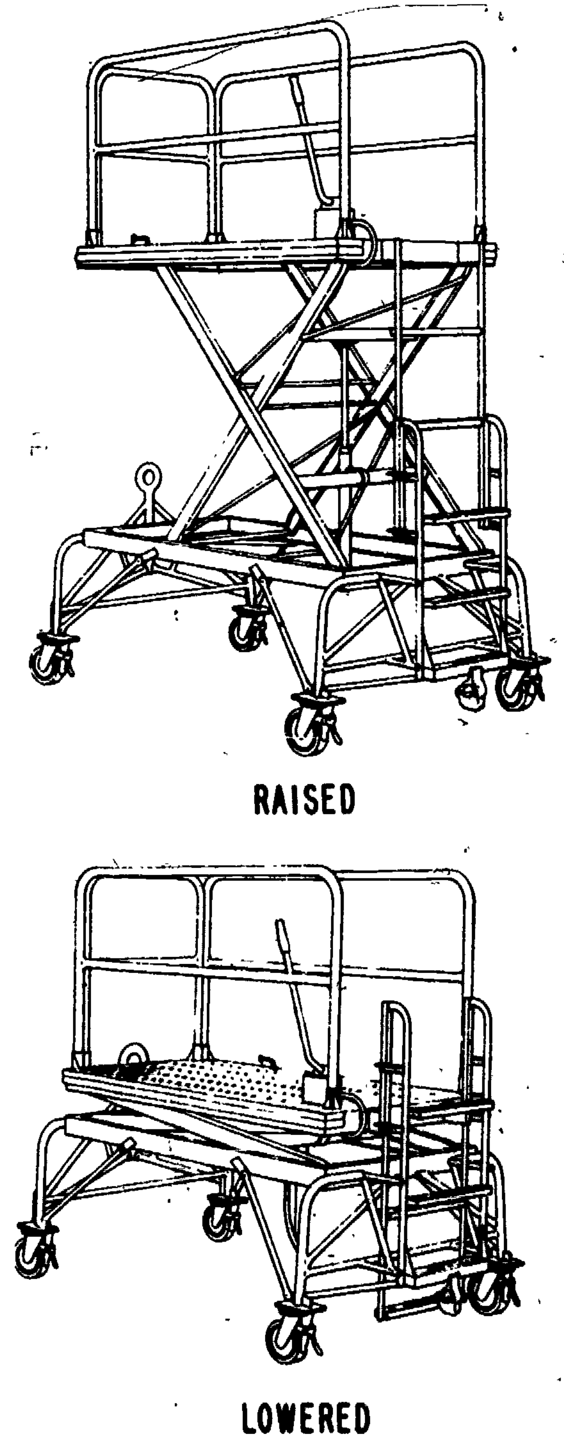

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Figure 7-29.—B-4A adjustable maintenance platform.

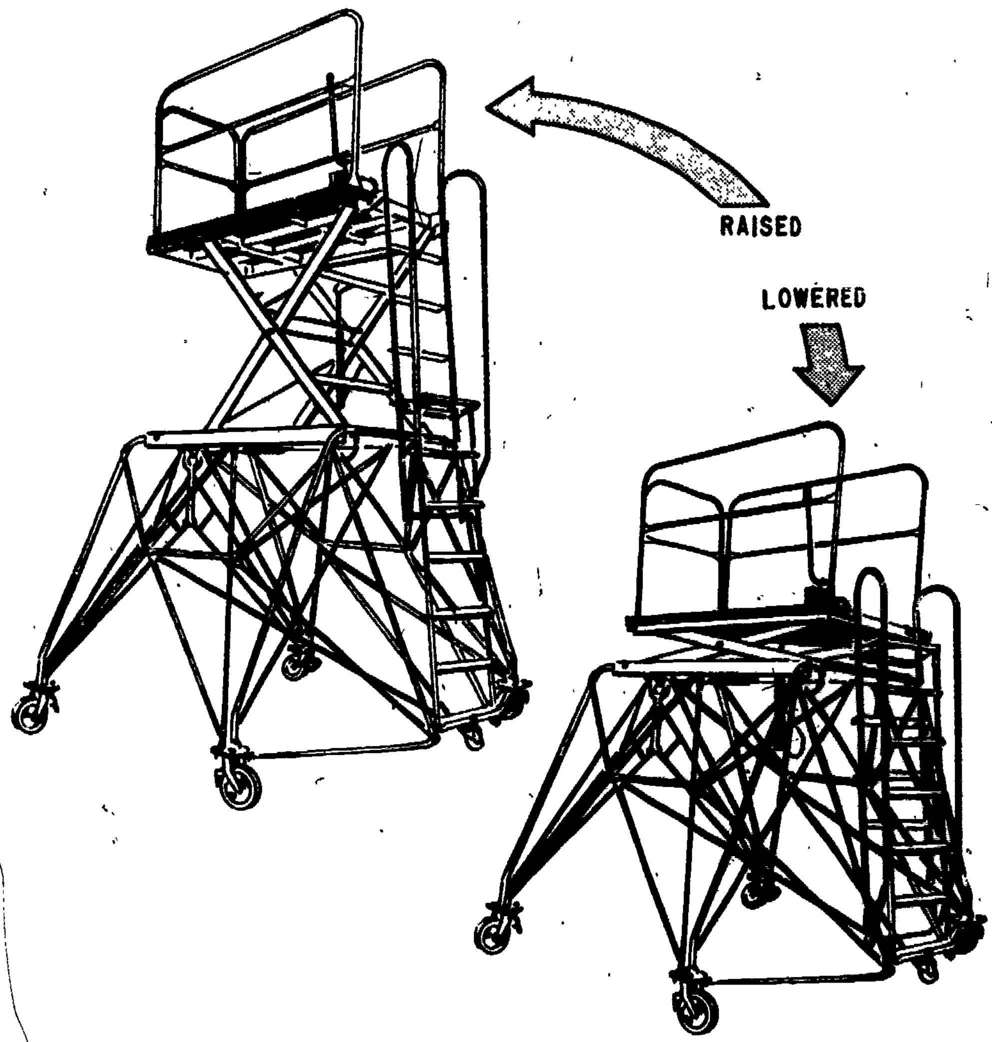

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Figure 7-30.—B-5A adjustable maintenance platform.

shown in figure 7-30, is similar to the B-4A maintenance platform, but the base on the B-5A is larger and tapers toward the top. Likewise, the ladder is designed differently and is longer. The minimum height of the B-5A is 7 feet, and the maximum height is 12 feet.

There are other types of maintenance platforms in use, but the ones already mentioned are the types with which the ASE is most likely to come in contact.

Aircraft Jacks

TRIPOD.—These are used when a complete aircraft is to be lifted. (See fig. 7-31.) They are constructed of steel tubing and brace rods or bars with a hydraulic cylinder in the center of the tripod. Each leg has a spring-loaded caster wheel to allow the jack to be moved. When weight is applied to the jack the springs are overcome, allowing steel pads, one on each leg,

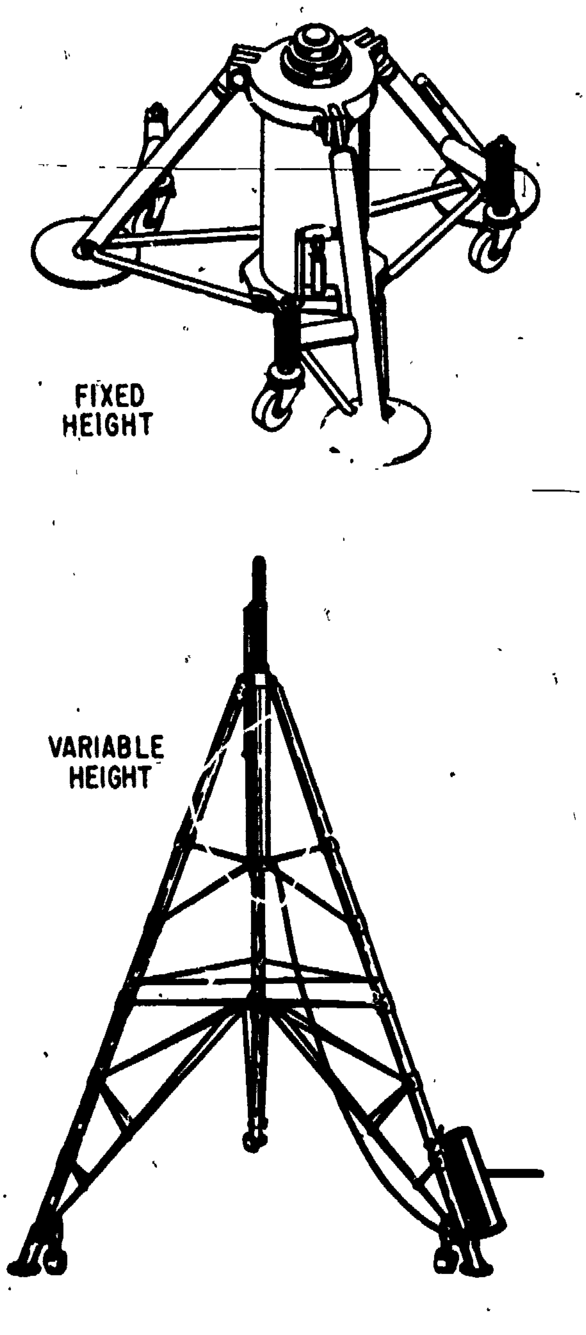

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Figure 7-31.—Aircraft tripod jacks.

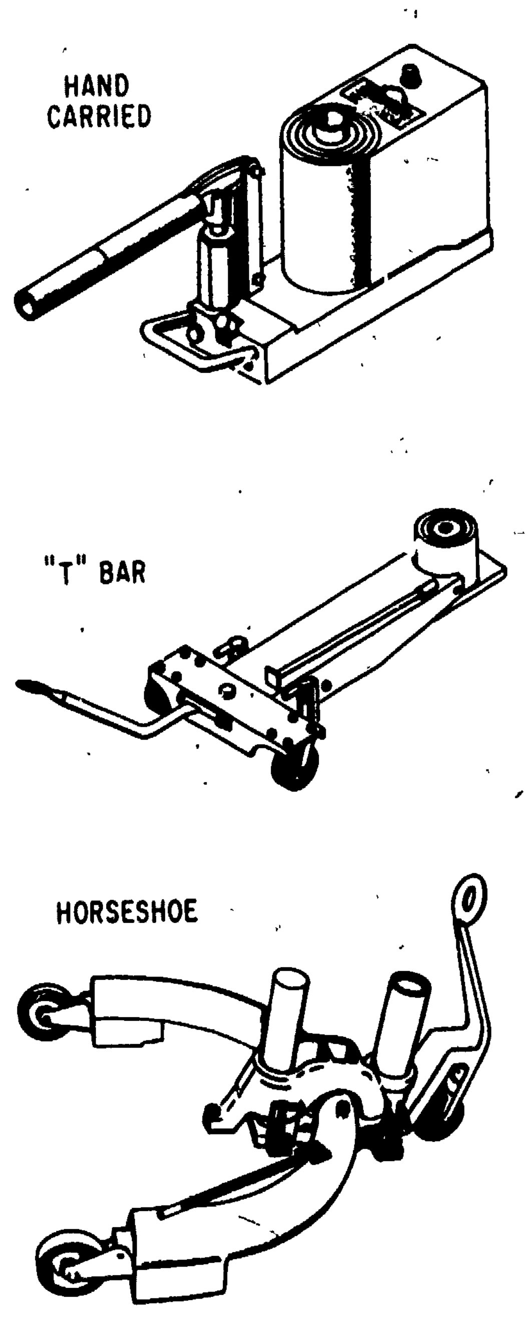

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Figure 7-32.—Axle (landing gear) jacks.

to come into contact with the floor or deck. These pads hold the jack stationary and support the aircraft weight. A hand-operated hydraulic pump is provided to enable the operator to raise the jack, and on some models, where the hydraulic reservoir is a part of the cylinder, the pump is located at the bottom of the cylinder. On other models, where the reservoir is located on one of the jack legs, the pump is located at the bottom of the reservoir.

There are two types of tripod jacks—fixed height and variable height. Those of the variable type can be changed in height by addition or removal of extension kits by the ground support equipment shop. Both types are shown in figure 7-31.

AXLE.—These are used when only one point of an aircraft is to be lifted. These jacks are also referred to as landing gear jacks.

Axle jacks are manufactured in several different types and capacities. Some types are hand carried while others are mounted on caster type wheels and provided with a tow bar. Three of the most commonly found types are shown in figure 7-32.

Ground Support Equipment Jacks

TRANSMISSION.—These were designed to facilitate removal and installation of automatic and standard transmissions. They are adjustable for height, roll, and tilt to allow precise alinement of the transmission for installation or removal. They may be hydraulic or mechanical in operation. (See figure 7-33.)

PLATFORM (FLOOR).—This jack is mounted on four steel caster wheels. The two rear wheels are swivel type to allow positioning of the jack. Platform (floor) jacks are used to lift one wheel, one side, or one end of a vehicle. They are hydraulic and are available in various types and capacities. One type and size of a platform jack is shown in figure 7-33.

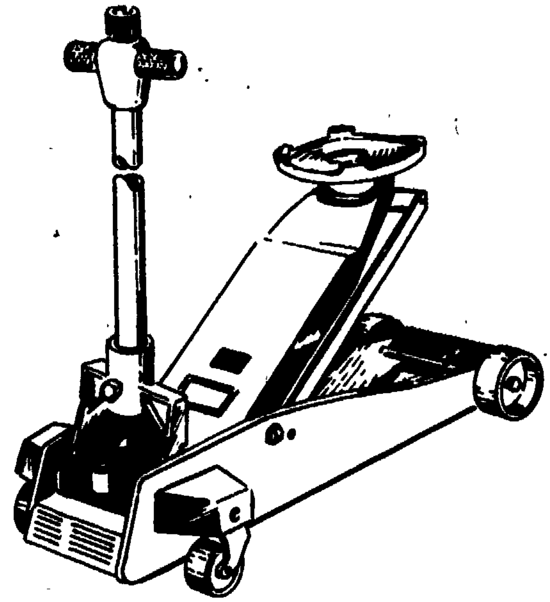
Low height and good stability are two of the factors which make this type jack well suited for the lifting operations involved in maintenance of ground support equipment.

CAUTION: Do not attempt to use any ground support equipment jack to lift an aircraft these jacks are not designed for such use.

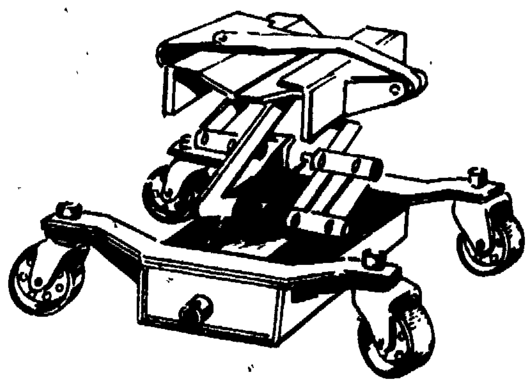
Handling and Securing Equipment

AIRCRAFT TOW BARS.—The aircraft universal tow bar, model NT-4 (fig. 7-34), is designed to tow and position all carrier based aircraft on shore stations as well as on board ships. It provides for nosewheel tow as well as for tow of aircraft having fuselage and landing gear tow rings. The maximum aircraft gross weight that can be handled by this tow bar is 90,000 pounds.

The NT-4 tow bar uses an adjustable securing chain between the bars to retain the engagement



PLATFORM (FLOOR)



TRANSMISSION

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Figure 7-33.—Ground support equipment jacks.

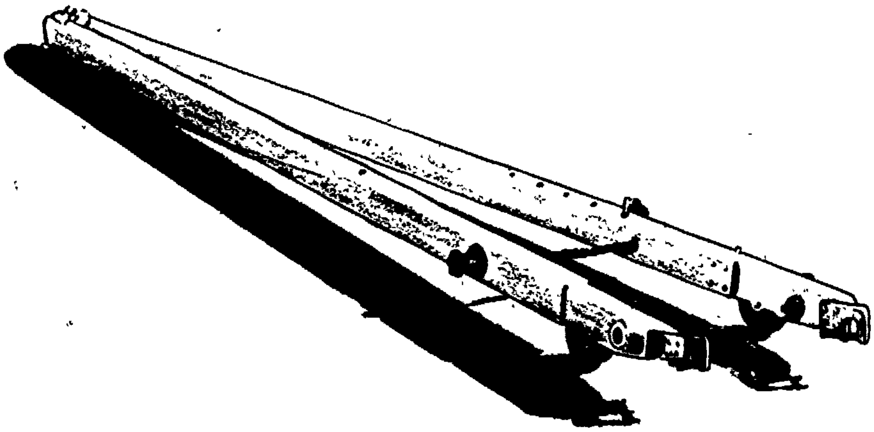

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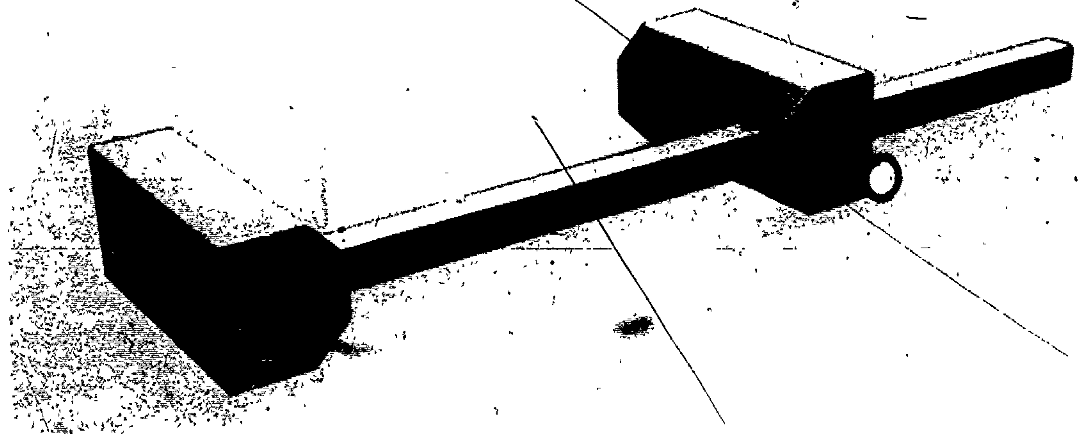
Figure 7-34.—NT-4 aircraft universal tow bar.

pins in the aircraft's nosewheel axle. This chain can be detached from one bar to allow the bars to be spread as needed for fuselage tow. Tapered pins are used for nosewheel tow, and hooks are used for fuselage or landing gear tow.

UNIVERSAL WHEEL CHOCKS.—The wheel chock most commonly used by the Navy is the model MWC-2 universal wheel chock. (See fig. 7-35.)

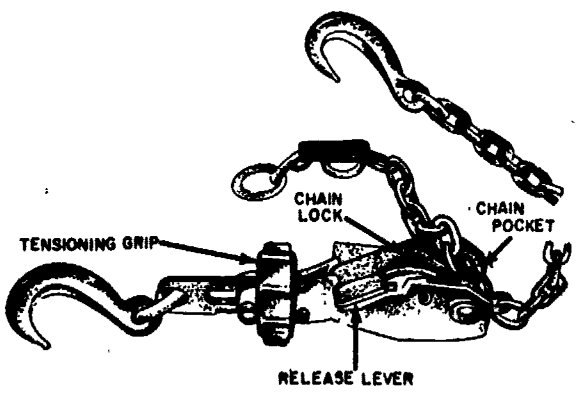
This is an all-metal chock that is adjustable to fit any wheel up to 45 inches in diameter. These universal wheel chocks can be used on ground support equipment as well as on aircraft.

UNIVERSAL CHAIN TIEDOWN.—The TD-1A universal chain tiedown (fig. 7-36) is the type most commonly used throughout the Navy. It is used for shipboard and shore station securing of aircraft and ground support equip-



AB.260

Figure 7-35.—Universal wheel chock.



AB.261
Figure 7-36.—Universal chain tiedown, model TD-1A.

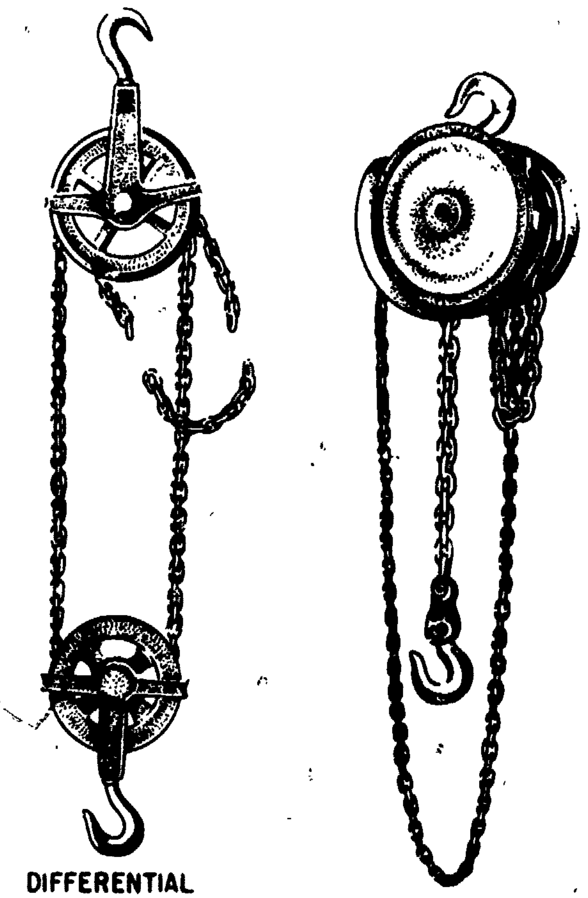
ment. The ease and speed with which it can be attached to and removed from an aircraft make it especially desirable during flight operations on board aircraft carriers where time is critical.

CHAIN HOISTS.—Chain hoists, or chain falls as they are often called, (fig. 7-37) provide a convenient and efficient method for hoisting loads by hand. Chief advantages of chain hoists are that one man can raise a load of several tons, and the load can remain stationary without being secured. The slow lifting travel of a chain hoist permits small movements, accurate adjustments of height, and gentle handling of loads. For these reasons they are particularly useful in hoisting vehicles for chassis repairs, and for component removal and replacement. Two of the most common types used for vertical hoisting operations are the spur gear hoist and the differential chain hoist.

PECULIAR (SPECIAL PURPOSE)

Ground support equipment assigned to this category is designed for use with (peculiar to) only one type or model of aircraft or weapons system. Some items of peculiar ground support equipment with which the ASE may come in contact are special jacks, jack adapters, maintenance platforms, tow bars, etc.

Care must be exercised to insure that any piece of peculiar ground support equipment is used only for the purpose for which it was



AB.11
Figure 7-37.—Chain hoists.

intended. This is necessary to prevent possible injury to personnel and/or damage to the equipment.

GENERAL SAFETY AROUND GROUND SUPPORT EQUIPMENT

Safety around ground support equipment is largely a matter of commonsense and not being in too big a hurry. Commonsense dictates what measures should be taken to make working around ground support equipment as safe as possible. Not being in too big a hurry dictates that time must be taken to perform the required safety measures. The full cooperation of all personnel working with and around ground support equipment is required, and constant vigilance must be maintained to eliminate unsafe acts.

General safety rules require that all personnel strictly observe all safety precautions applicable to their work: Each worker concerned should report to his supervisor any unsafe condition, material, or equipment; warn others who appear to be endangered by hazards or by failure to observe safety precautions; and report any injury or evidence of impaired health that occurs to himself or to others. Each worker should wear or use protective clothing or equipment prescribed for the safe performance of the work he is doing. When a hazardous condition exists, each person should exercise as much caution as is possible under the existing circumstances.

Some of the safety measures that should be used around ground support equipment are covered in the following paragraphs.

When stopping self-propelled equipment, set the handbrake or chock the vehicle. This should be done to towed equipment before unhooking from the towing vehicle. When mobile equipment is handpushed or pulled, this should be done as soon as the vehicle is stopped.

Aboard aircraft carriers, any ground support equipment that is not in use is tied down to prevent a tight turn or any tilting of the ship from causing the equipment to become a hazard to personnel or equipment. All equipment should be as clean as possible to prevent accumulation of fuel, oil, hydraulic fluid, or grease from becoming a fire hazard or causing slippage by those working with or on the equipment.

Each piece of ground support equipment should be used only for the purpose for which it was manufactured, except in an emergency, and used only by authorized personnel. The authorization should be in writing and indicate that the holder has been thoroughly checked out in the operation of the equipment and the safety practices associated with it.

Insure that the area where engine-powered equipment is operated is well ventilated; exhaust systems can be extremely dangerous because of the heat given off, especially from gas turbine equipment. Gas turbine compressors must be positioned so as to minimize hazards to personnel and material. Turbine exhaust must not be allowed to impinge directly on personnel, aircraft, equipment, explosives, or flammable materials.

To avoid undue heat exposure, a minimum distance of 8 feet from exhaust is required for the MD-3 and MD-3A, and 5 feet for the MD-3B. The 85-series turbine equipped with upward exhaust ports requires a minimum distance of 6 feet. It is emphasized that these are minimum distances.

Safety must be practiced continuously. When you get the idea these things always happen to the other guy, it is about to happen to you.

An example is the castastrophe which occurred aboard the USS Enterprise on 14 January 1969. This disaster was caused by the exhaust of a gas turbine compressor (on an MD-3A tow tractor) which ignited a Zuni rocket warhead mounted on an F-4J, initiating the subsequent explosions and fires. After it was all over, many men had lost their lives, several aircraft were lost or damaged, and the ship received major damage.

CHAPTER 8

SERVICING AND MAINTENANCE

In order for aircraft to perform their mission, ground support equipment must be available for servicing, maintaining, launching, and recovering the aircraft. To do this, the ground support equipment for which the ASE is responsible must be properly serviced and maintained. If a gas turbine compressor or mobile electric powerplant fails (due to improper servicing or poor maintenance) during starting of a flight of aircraft, the flight may get off late or not at all. Time is normally very critical under such conditions; therefore, ground support equipment in proper operating condition is of utmost importance.

SERVICING GROUND SUPPORT EQUIPMENT

The life of ground support equipment for which the ASE is responsible depends upon proper care and servicing. Most of the service requirements are simple, but nonetheless important. Servicing of ground support equipment includes replenishment of fuels, lubricants, coolants, hydraulic fluids, and other consumable materials.

All maintenance personnel should be familiar with the various types of fuels and lubricants, their specific use, and the method and frequency of application. Proper selection of fuels is also important; you would not put diesel fuel in a gasoline engine, or gasoline in a diesel engine.

Perhaps you have heard or seen what happened to the wheel bearings in an automobile when they were not properly lubricated. In some cases the bearings were damaged due to lack of grease, and in other cases by use of the wrong type of grease. This type of damage could have been avoided if the wheel bearings had been inspected at the proper interval and if the proper lubricant had been selected. Servicing modern ground support equipment is important, and a thorough knowledge of proper fuels and lubricants will make the job easier and safer for the equipment.

The following paragraphs discuss some of the fuels, lubricants, hydraulic fluids, and coolants with which the ASE may come in contact.

FUELS

Fuels for gasoline and diesel engines are byproducts of petroleum. Petroleum, often called crude oil, means "rock oil." Petroleum products include gasoline, kerosene, diesel fuel, lubricating oils, gear lubricants, and greases. Many different products are added to the raw byproducts to obtain a fuel that will perform efficiently in modern equipment.

Fuels may be contaminated by dirt, rust, water, or by accidental combination with other types of petroleum products. Avoiding such contamination is vital if the products are to serve the purposes for which they are intended. Dirt and water in fuels are primary causes of premature engine failure. Cleanliness in handling fuels is paramount.

Gasoline

Gasoline contains carbon and hydrogen in such proportions that it burns freely and liberates heat energy. It evaporates (changes to a vapor) at any temperature, and because gasoline vapors are heavier than air, they sink to the ground. To decrease the fire hazard of having the gasoline vapors in a confined place where spontaneous combustion could take place, the enclosure in which gasoline is used SHOULD BE THOROUGHLY VENTILATED THROUGH OPENINGS NEAR THE FLOOR.

If all the potential heat energy contained in a gallon of gasoline could be converted into work, a motor vehicle could run many more miles on each gallon. However, only a small percentage of this heat energy is converted into power by the engine. Most authorities consider the power losses within the engine to be:

Engine	Percent of Power Loss
Cooling system	35
Exhaust gases	35
Engine friction	5 to 10
Total	75 to 80

The question of what is ideal gasoline is more theoretical than practical. Every manufacturer recommends the octane rating of the gasoline he feels is best for the engines he produces. Besides engine design, factors like the weight of the vehicle, the terrain and highways over which it is driven, and the climate and altitude of the locality also determine what gasoline is best to use. All other factors being equal, these may be considered as some of the properties of the best gasoline: good antiknock quality, a minimum content of foreign matter, and a volatility which makes starting easy and allows smooth acceleration and economical operation.

The type gasoline recommended by the manufacturer should always be used if maximum performance is to be realized.

Diesel Fuel

Diesel fuel is heavier than gasoline because it is obtained from the residue of the crude oil after the more volatile fuels have been removed. As with gasoline, the efficiency of a diesel fuel varies with the type of engine in which it is used. By distillation, cracking, and blending of several oils, a suitable diesel fuel can be obtained for almost all engine operating conditions. Slow speed diesels use a wide variety of heavy fuels; high speed diesel engines require a lighter fuel. A poor or improper grade of fuel can cause hard starting, incomplete combustion, a smoky exhaust, and engine knocks.

The properties a manufacturer considers in specifying a fuel for a diesel engine are volatility, cleanliness, viscosity, ignition quality, and antiknock quality.

Jet Propulsion Fuels (JP)

Primarily, jet propulsion fuels (JP)are for use in jet engines. However, some types of jet fuels, JP-4 and JP-5, are well suited for use in modern, high speed diesel engines such as those used in ground support equipment. Most manufacturers specify number 1 or number 2 grade diesel fuel, JP-4, or JP-5, the selection being dependent upon availability, except in the case of a gas turbine power unit mounted on a tractor and dependent upon the tractor for its fuel supply. Here, the type of fuel used must be aviation jet fuel to meet the requirements of the gas turbine power unit. Some of the reasons that aviation fuels are more desirable for use than diesel fuels are more power output per pound, fewer contaminants, increased engine life, and greater availability aboard naval air stations and aircraft carriers

Propane and Butane

Propane and butane fuels are byprodu· of natural gas. (The natural gas is taken from a cavity in the earth.) Propane and butane fuels develop a pressure when stored because they change into a gas when released to the atmosphere. Liquid propane becomes a gas at a temperature of -43° F; liquid butane, at 33° F. Although seldom used as a fuel for automotive equipment, small amounts of these liquid gases have been used to start engines in very cold climates. Some manufacturers believe that internal combustion engines can operate more economically with butane fuel than with gasoline. Gasoline and diesel fuel, however, continue to be the most widely used fuels for internal combustion engines.

LUBRICANTS

A lubricant (oil or grease) is a substance used to reduce friction by preventing direct contact of moving surfaces with each other. The lubricant is pressed into a thin film between moving parts, and the parts rub on the film.

The word lubricant comes from a Latin word meaning "slippery." The idea is that the film of oil gives a slippery nature to surfaces. This film is constantly renewed by additional oil supplied from a pressure pump to replace oil forced out by movement of the engine parts. The effect is two sheets or layers of oil sliding over each other. Thus, friction between the two metal surfaces is reduced to a minimum.

In addition to reducing friction and wear, lubricants act as cooling agents, absorbing heat from the surfaces over which they are spread. This is true particularly of engine oil which carries heat to the engine oil pan where it is dissipated. On some engines the oil is circulated through a water-cooled oil cooler to further dissipate this heat.

Lubricants are also used as sealing agents. They fill the tiny openings between moving parts, cushioning them against damage and distortion from extreme heat.

Lubricants are also important as cleaning agents. Any grit and dirt finding their way into the engine parts often are removed by the lubricants before damage can result. Foreign matter found in old oils and greases in the bottom of the crankcase is evidence of the cleansing quality of lubricants. Some lubricants have chemicals added to make them better cleaners.

The high temperatures, speeds, and cylinder pressures of modern engines have made better grades of lubricating oils necessary. To increase efficiency, certain chemicals called additives are put into oils. Additives are resistive agents which are used against oxidation and other kinds of metal deterioration. Oil which contains additives specifically designed to help clean the piston rings and other parts of the engine as it lubricates is known as detergent oil.

Oils

Lubricating oils serve four purposes:

1. Prevent metal-to-metal contact in moving parts of mechanisms.
2. Help carry heat away from the engine.
3. Clean the engine parts as they are lubricated.
4. Form a seal between moving parts.

Moving parts that do not have enough oil will melt, fuse, or seize after a very short period of engine operation. All gears and accessory drives, as well as other moving parts of the engine subject to friction, must be bathed in oil at all times.

Greases

Greases are compounds of oil and soap. The soaps used are not ordinary laundry soaps but animal fats mixed with certain chemicals. The chief purpose of the soap is to provide a body or carrier for the oil that actually does the lubricating.

Grease is used where oil is impractical or unsatisfactory due to centrifugal force, load, temperature, or exposure. For instance, in wheel bearings grease maintains a lubricating film under heavy loads and when the equipment is stationary for long periods of time.

Grease is separated into broad classifications such as chassis, cup or water pump, wheel bearing, general purpose, etc. Also, many special purpose greases are manufactured; among these are distributor cam lobe lubricant, electric motor bearing grease, preservation grease, etc.

Particular care must be exercised to insure that the proper grease is used for any job. Severe damage can result from improper lubrication. For example, chassis grease used on a distributor cam lobe will cause arcing and burning of the breaker points as the grease melts and is thrown onto the breaker points by centrifugal force. Information as to the proper grease to use can be found in lubrication charts for the unit being serviced. Lubrication charts and their use are covered later in this chapter.

FLUIDS

Fluid is the means by which energy is transmitted from the pump to the various units to be actuated. To operate efficiently in a system, a fluid must have certain properties and characteristics. It must flow freely at extremely high and low temperatures; it must be noncorrosive to metals and must not react chemically on the seals and packings used in the system; it must have good lubricating qualities; and it is desirable that it be nonflammable.

Hydraulic Fluid

Hydraulic fluid used in naval ground support equipment such as hydraulic test stands, forklifts, aircraft jacks, aircraft spotting dollies, etc., is manufactured in accordance with Specification MIL-H-5606B. This fluid is red in color and is normally procured in 1-quart and 1-gallon containers. MIL-H-5606B hydraulic fluid has a petroleum base and MUST NOT be mixed with any hydraulic fluid which has a synthetic (vegetable) base.

Automatic Transmission Fluid

The majority of ground support equipment equipped with automatic transmissions are designed for use with type "A" automatic transmission fluid. This fluid is also used in the majority of power steering systems. Exceptions to this are equipments which use oil conforming to Specification MIL-L-2104B, SAE 10W, in the automatic transmission and power steering systems, and others which use fluid conforming to Specification MIL-H-5606B.

Brake Fluid

Most hydraulic brake systems use a non-petroleum-base hydraulic brake fluid such as Specification VV-H-910 or VV-B-680. DO NOT mix any petroleum- or mineral-base hydraulic fluid, such as MIL-H-5606B, with any synthetic-base brake fluid. Attempts to combine the two will result in formation of a jelly substance, followed by decomposition and leaking of the natural rubber seals, and very quickly in system failure. Consult the lubrication chart for the particular unit before servicing any hydraulic system, and use only the fluid recommended by the manufacturer.

COOLANTS

Nearly all multicylinder engines used in automotive and ground support equipment use a liquid cooling system. Any liquid used in this type of system is called a coolant. The two types of coolants, water and antifreeze solutions, are discussed briefly.

Water used in radiators should be clean, and should be checked often for cleanliness and quantity.

A vehicle operated in temperatures below 32° F requires an antifreeze solution in its cooling system. Without this solution the water in the cooling system freezes and can result in cracked cylinders, water jackets, cylinder heads, and radiator cores.

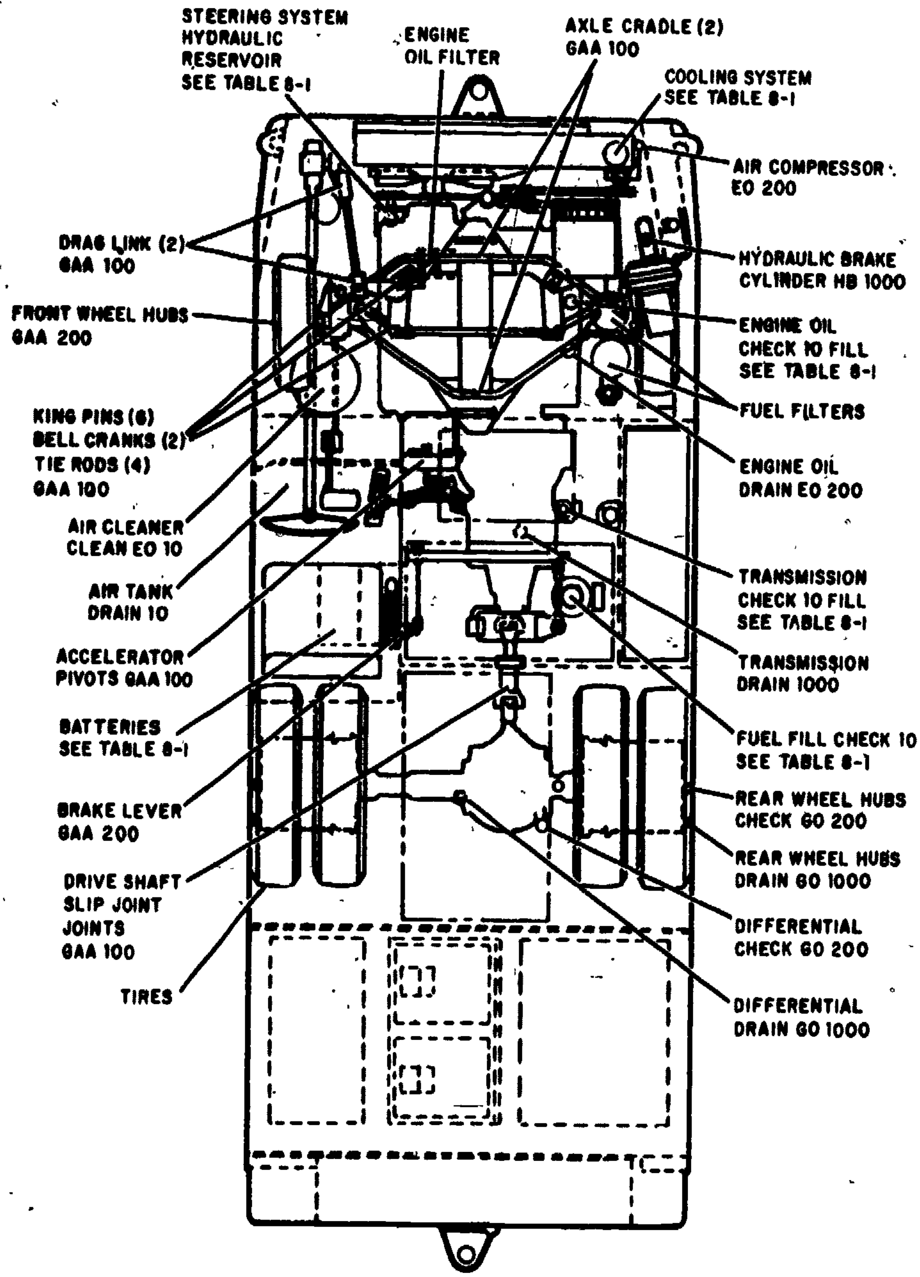
A good antifreeze solution mixes readily with water. Once mixed, the solution tends to penetrate openings and connections more readily than plain water. Prior to the first filling of antifreeze in the winter, and periodically thereafter, hose connections should be checked for tightness to insure that there are no leaks. A good antifreeze is not subject to rapid evaporation, nor does it corrode or rust the cooling system. Most antifreeze compounds contain a rust and corrosion inhibitor. Without an inhibitor in the solution, rust and corrosion form and clog radiators, causing water-cooled engines to overheat.

All antifreeze solutions require periodic checks and must be replenished when tests show that they will not give the required protection against freezing. Hydrometers are used for such testing.

Antifreeze solutions, even the so-called permanent types, are not recommended for use beyond one season; furthermore, it is recommended that different types not be mixed. Usually, when two types have been mixed, there is no way of knowing the temperature at which the mixed solutions will freeze. Then too, their ingredients sometimes react chemically and cause corrosion in the cooling system with resultant foaming that forces quantities of the liquid from the radiator.

SERVICING PROCEDURES

Usually, servicing of ground support equipment is not very complicated, but it is extremely important. The ASE should understand how and why servicing can often be so critical. For example, one item of equipment may require



AS.234

Figure 8-1.—Lubrication diagram, MD-3 tow tractor.

Table 8-1. – Lubrication and refill chart, MD-3 tow tractor

Item	Lube symbol	Type refill and service			Approximate refill capacity	Operation (Hrs. Oper.)		
		SAE	API	Military specification		Check	Clean	Refill or replace
Engine crankcase with filter Above -32°F -32°F to -10°F Below -10°F	EO	30 (20) 10W	CD	MIL-L-2104B Amd. 1 or MIL-L-9000E	9 qt	10	1,000	Oil 100 Filter 200
Air cleaner	EO	Same as engine			1 pt	10	100	100
Engine breather	EO	Same as engine			*AR	200	200	200
Transmission	Automatic transmission				13 qt	10	500	1,000
Hydraulic system	Fluid, type "A"				5 pt	10	500	1,000
Air compressor Above -32°F -32°F to -10°F Below -10°F	EO	30 (20) 10W	CC or CD	MIL-L-2104B Amd. 1 or MIL-L-9000E	*AR	10	1,000	200
Rear axle differential Below 32°F Above 32°F	GO	90 140	EP	MIL-L-2105B	4 pt	200	1,000	1,000
Wheel hubs Below 32°F Above 32°F	GO	90 140			2.75 pt (per hub)	200	1,000	1,000
Cooling system Above 32°F Below 32°F	Water and 5% corrosion inhibitor solution Ethylene glycol			O-A-00548C	22 qt	10	1,000	1,000
Brake fluid	HB	Non-petroleum base		VV-H-910	*AR	100	1,000	1,000
Fuel system		JP-5		MIL-J-5624	90 gal	10	1,000	10
Front wheel hubs	GAA	Multi-purpose lithium base NLGI Grade 1		MIL-G-10924B	*AR	200	1,000	1,000
Drag link	GAA	Multi-purpose lithium base NLGI Grade 1		MIL-G-10924B	*AR	100	500	100
Tie rod	GAA	Multi-purpose lithium base NLGI Grade 1		MIL-G-10924B	*AR	100	500	100
King pins	GAA	Multi-purpose lithium base NLGI Grade 1		MIL-G-10924B	*AR	100	500	100
Accelerator pivots	GAA	Multi-purpose lithium base NLGI Grade 1		MIL-G-10924B	*AR	100	500	100
Drive shaft	GAA	Multi-purpose lithium base NLGI Grade 1		MIL-G-10924B	*AR	100	500	500
Brake lever	GAA	Multi-purpose lithium base NLGI Grade 1		MIL-G-10924B	*AR	200	200	200
Batteries	Distilled water				*AR	100	200	100
Turbine oil				MIL-L-23699B	*AR			

*AR - As required

NOTE: Base oils used to obtain SAE 20, 10W/30 and 40 viscosity weights should meet the requirements of MIL-L-2104B.

several different types of oil, grease, fluids, etc. Selection of the correct types and proper application to the points where required can make the difference between a piece of equipment that gives excellent performance and one that is damaged beyond repair.

Complete servicing details can be found in the Operation, Service, and Repair Instructions Manual (Handbook) written for that particular type and model of equipment. Figure 8-1 and table 8-1 illustrate a small portion of the servicing information contained in the MD-3 Tow Tractor Handbook.

Servicing information can also be found in the Maintenance Requirements Cards, but it usually is not as detailed as the information contained in the above mentioned manual or handbook.

TYPES OF MAINTENANCE

No matter how well the ground support equipment is serviced and cared for, maintenance is still required in order to keep the equipment in optimum operating condition. In maintenance work of any kind, knowledge and skills of two fundamental kinds must be used: first, the technician must have specific information which applies only to the particular equipment which he may be called upon to repair or keep in good condition; and second, he must possess and be able to use certain general skills and knowledge which apply to many kinds of equipment and types of work assignments.

The specific information required consists of special procedures and processes, and of detailed step-by-step directions approved by the proper authority and recommended for a particular piece of equipment. This information is supplied in publications or checkoff lists by applicable systems commands, type commanders, or other authorized sources.

The general maintenance skills and procedures are based on knowledge which is not contained in equipment manuals. These skills must be learned during on-the-job training and from training manuals such as this one. The basic content of this section of this manual concerns the general maintenance skills and knowledge.

The maintenance performed on the equipment falls into two broad categories: (1) actions taken to reduce or eliminate failure and prolong the useful life of the equipment, and (2) actions taken when a part or component has failed and the equipment is out of service. Therefore, the types of maintenance can be considered to consist of preventive maintenance (scheduled) and corrective maintenance (unscheduled).

PREVENTIVE MAINTENANCE

In operation, items of ground support equipment are subjected to a variety of stresses, strains, and environments. If the equipment is not inspected regularly and detected discrepancies corrected, the equipment soon becomes inoperable.

When equipment comes into the work center for inspection, it should be cleaned to facilitate the inspection. Cleaning of electrical components consists of removing dust, grease, or other foreign matter from covers, chassis, and operating parts. The methods used to clean various parts and units will vary, but usually a vacuum cleaner will suffice to remove loose dust and foreign matter. If grease or other petroleum deposits must be removed, this can be done with a cloth moistened with alcohol or drycleaning solvent. After cleaning, the part should be wiped dry or allowed to air dry before power is applied.

As the unit is cleaned, it can be visually inspected for loose leads, improper connections, damaged or broken components, etc., prior to application of power. These inspection precautions are particularly applicable to new equipment, equipment returned from overhaul, equipment which has been preserved or stored for long periods of time, and equipment which has been exposed to the weather for long periods of time. A good, thorough, visual inspection will often reveal discrepancies which can be corrected at that time with a minimum amount of labor and parts. Such discrepancies, if left uncorrected, might result in major expenditure of labor and parts.

Inspections

Maintenance inspections for ground support equipment are promulgated by the Naval Air

Systems Command. With every activity using the inspection criteria prescribed for their assigned equipment, it follows that any given equipment model or series is subject to a standardized program of planned maintenance regardless of its operating location. These inspections specify the minimum requirements necessary to maintain the subject equipment; however, the depth and frequency of any inspection may be increased if required by local conditions.

Types of inspections performed by activities responsible for the maintenance of ground support equipment are:

1. Acceptance inspections. A minimum acceptance inspection consists of equipment configuration verification, functional tests of systems, and a thorough preoperational inspection. Accepting activities may increase the depth of inspection if the condition of the equipment warrants.

2. Preoperational inspections. The preoperational inspection was formerly known as a daily inspection, and on some of the older items of ground support equipment these inspections are still referred to as daily inspections. Preoperational inspections are accomplished prior to the first use of the subject equipment for that day. This inspection is basically a combination of requirements for checking equipment for verification of satisfactory functioning prior to use, plus requirements that prescribe searching for and correction of relatively minor problems to prevent their progress to a state that would necessitate major work to remedy. When completed, the preoperational (daily) inspections are signed off on the Ground Support Equipment inspections are signed off on the Ground Support Equipment Daily Record attached to the equipment to indicate that all requirements have been complied with.

If the equipment is used more than once during the day, a brief inspection should be performed prior to each use. This inspection need not be as detailed as the preoperational inspection. The Ground Support Equipment Daily Record should be checked to insure that the preoperational inspection has been completed.

Special maintenance requirements that occur at intervals more frequent than prescribed for calendar inspections are also included in the preoperational inspections on the day they become due, if practicable. (See Special Inspections, described later.)

3. Postoperational inspections. Before securing equipment, check for proper operation. After securing (stopping) the equipment, make a visual inspection for condition, fuel level, oil level, water level, etc., and service if needed so that the equipment will be ready for the next use. Replace panels, covers, etc., to protect the equipment from the weather.

4. Calendar inspections. The calendar inspection was formerly known as a periodic inspection. On some of the older items of ground support equipment, these inspections are still referred to as periodic inspections.

Calendar inspections are overall examinations of a specific item of equipment. The interval between inspections depends upon the type of equipment. The intervals may be in terms of days, weeks, months, hours, starts, etc., or some combination of these.

5. Special inspections. A special inspection depends upon occurrence of certain circumstances or conditions, or a maintenance action with a prescribed interval occurring more frequently than calendar inspections. Inspections required at intervals, such as 10 hours, 30 hours, and 7 days, etc., are usually classified as special inspections. These inspections are accomplished by the using activity if they are equipped to perform them; otherwise, they are accomplished by the activity having prime custody of the equipment.

The using activity is responsible for performing the preoperational and postoperational inspections just discussed. Acceptance inspections are performed by the accepting activity, and certain special inspections and calendar or periodic inspections are performed by the activity having prime custody of the equipment, usually the Intermediate maintenance activity.

Inspection Procedures

As stated in chapter 3, the Service Instructions are a part of the Operation and Service Instructions Manual which often contains other instructions and the parts breakdown. The Service Instructions contain the planned periodic maintenance requirements for the applicable item of equipment. The maintenance require-

Table 8-2.—Systems and inspection intervals

System	Operation	Hours operated				
		10	50	100	200	1000
Engine	Check engine oil level	X	X	X	X	X
	Change engine oil			X	X	X
	Change engine oil filter element				X	X
	Retighten cylinder head cap screws (first 200 hr only)				X	
	Lubricate carburetor linkage and choke cable				X	X
	Check engine idle speed				X	X
	Service fuel strainer			X	X	X
	Lubricate accelerator linkage		X	X	X	X
	Check engine compression					X
	Check valve clearances					X
Electrical System	Hydrometer check battery; check fluid level and clean terminals			X	X	X
	Check alternator output voltage			X	X	X
	Check operation of light and control switches			X	X	X
	Inspect, clean, regap or replace spark plugs				X	X
	Check distributor point setting				X	X
	Lubricate distributor				X	X
	Check starter brushes and commutator				X	X
	Blow dust from starter and alternator				X	X
	Lubricate starter				X	X
	Check ignition timing					X

ments contained in the manual are set forth in a manner to specify the items to be inspected or examined and the conditions to be sought in each case.

The Service Instructions contain only minor maintenance procedures, such as servicing, minor adjustments, and lubrication charts. A list of the required special tools is also provided. The applicable troubleshooting charts, Repair Instructions, or Overhaul Instructions must be consulted for the correction of major discrepancies.

In some Service Instructions the scheduled inspections are itemized in paragraph form;

however, most of the later publications present these inspections in table form. The format of these tables varies in different Service Instructions. A portion of a typical table is illustrated in table 8-2.

Maintenance Requirements Cards (MRC's)

In addition to the inspection procedures covered in the Service Instructions, Maintenance Requirements Cards (MRC's) are provided for each major type of support equipment. These cards provide the minimum requirements necessary to maintain the subject equipment in a satisfactory and effective operational readiness condition These are 5 x 8 cards arranged by rating and work area to provide the most efficient sequence of accomplishment. Assembled into sets and numbered in sequence, the cards contain pertinent information required by each maintenance man to complete each task.

Individual sets of MRC's are prepared for preoperational (daily) and calendar (periodic) inspections. Preoperational Maintenance Requirements Cards list those requirements necessary to be performed by the using activity. Calendar Maintenance Requirements Cards list the responsibilities of the activity having prime custody of the equipment. Special Maintenance Requirements Cards are contained in the same set and have the same number as the Preoperational Maintenance Requirements Cards. The Special Maintenance Requirements Cards are marked as "Special" and are performed by the using activity if so equipped; otherwise they are performed by the activity having prime custody of the equipment.

MRC sets are identified by the publication number system for manual publications described in chapter 3. NW 17-600-12-6-1 and NA 19-600-24-6-4 are examples of publication numbers identifying MRC sets for ground support equipment. The prefix NA indicates that the cards are published by the Naval Air Systems Command. NW indicates that the cards were published by the old Bureau of Naval Weapons. As the NW cards are revised, the prefix will be changed to NA. The numbers 17 and 19 are the general subject classification numbers assigned to ground support equipment. (See chapter 3.) The number 600 identifies the publication number as MRC's.

The next number (-12 and -24 in the two examples) identifies each set of MRC's with a specific item of equipment. This number is sequential for each of the 17 and 19 series and is assigned as the cards are developed.

The numbers -6-1 are assigned to Preoperational MRC's and the numbers -6-2 to the Calendar MRC's.

NOTE: Card sets presently in the system numbered NA 17 or 19-600-__-6 (Daily) and NA 17 or 19-__-7 (Periodic) will retain these identifying numbers until superseded by a new publication or until the equipment is phased out and the cards canceled.

The MRC which are available for ground support equipment are listed by publication number and title in the Navy Stock List of Forms and Publications, NavSup Publication 2002, Section VIII, Part C, and its supplements. The ordering procedure is the same as that for manual publications described in chapter 3.

NOTE: No part of any scheduled maintenance is certified (signed off) on the Maintenance Requirements Cards; therefore, they may be used as many times as their condition permits.

The Preoperational and Calendar MRC's are similar in design and arrangement; therefore, only Calendar MRC's are discussed in this manual. The cards are arranged as follows:

1. Title card.
2. List of change cards (A card).
3. Introductory cards.
4. Tools and equipment list cards.
5. Work area and diagram charts.
6. Requirements cards.

The title card contains the publication number, the type of MRC set, the type and model of the item of equipment, and the date of issue, including the latest change date. Also included are the publication number and date of issue of publications and change cards that have been superseded by the current publication.

The A card is printed on the back of the title card. Its main purpose is to list the cards of the set that have been changed, deleted, or added.

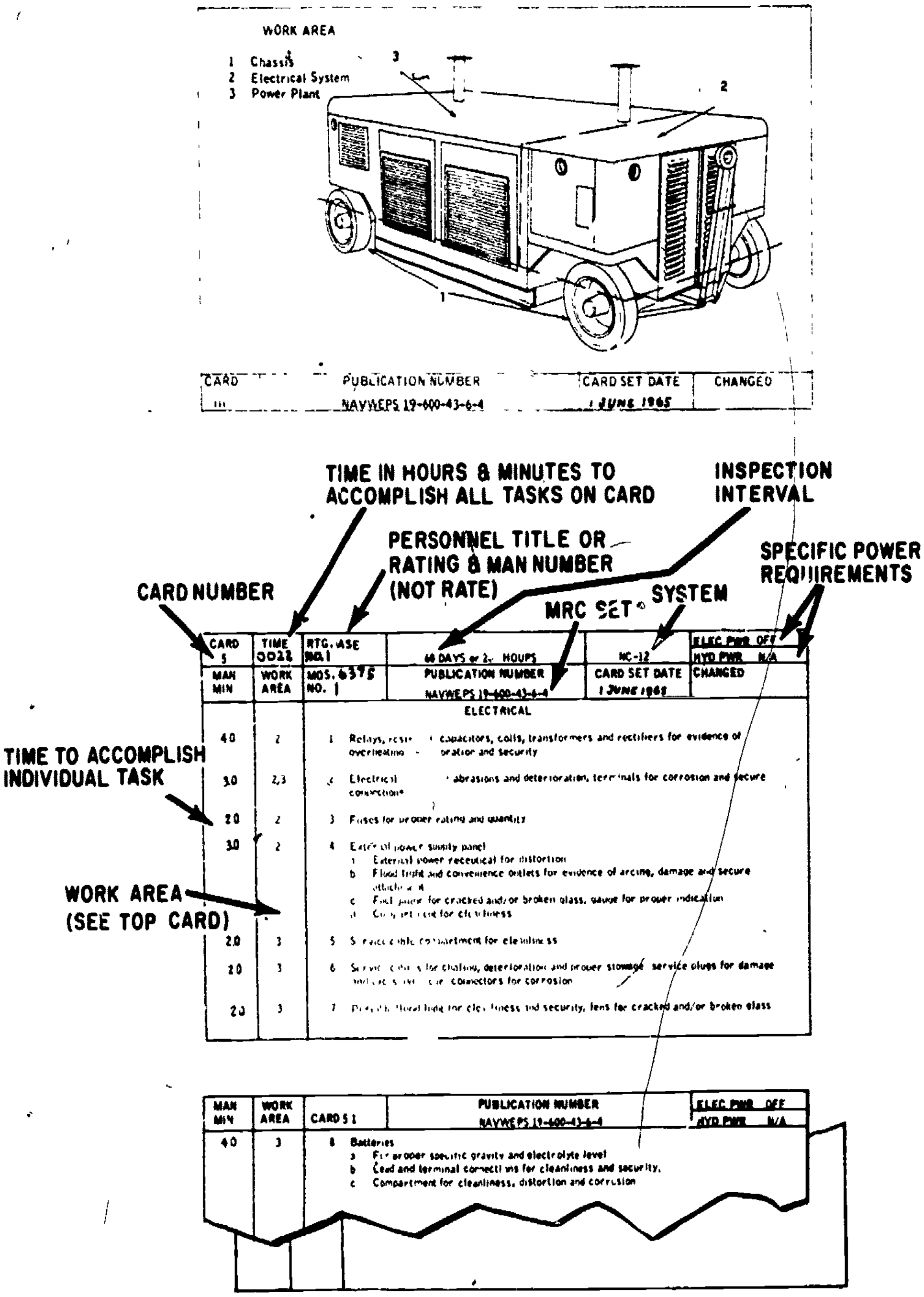


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Figure 8-2.--Sample calendar maintenance requirements cards.

The title card and A card are similar to the cover and change pages of manual publications. A new card is issued with each change to an MRC set. All card changes are listed on the A card.

The introductory cards, work area and diagram charts, and tools and equipment list cards are numbered consecutively, front and back. They are numbered in lowercase Roman numberals; that is, i, ii, iii, iv, etc., as required. As illustrated on the work area card in figure 8-2, there are four blocks across the lower part of each card. Reading from left to right, these blocks contain the card number, the publication number, the latest issue date of the card set and, if applicable, the latest change date of the respective card.

The introductory cards contain a general description of the type of requirements, the inspection schedule (weeks, hours, starts, etc.) for the type of equipment, the calendar maintenance and overhaul intervals, and the definition of standard terms used in inspection procedures. The following terms and their definitions appear on the introductory cards:

1. Note. An information item. The note precedes the item to which it refers.

2. Caution. Indicates danger to the system. The caution precedes the item to which it refers.

3. Warning. Indicates danger to personnel. The warning precedes the item to which it refers.

4. Visible or exposed. The term applied when inspection requires no further disassembly or movement of equipment, and no removal of doors or panels is required other than that specifically detailed.

5. Evidence. An indication of an existing condition; e.g., hydraulic fluid dripping from an enclosed section is evidence of a leak.

6. Damage. A harmful condition caused by an abnormal force or object.

7. Security. An item firmly, positively, and safely attached in the approved manner.

8. Specified. Refers to a definite amount, operation, or limitation

9. Obvious. Easily seen or understood, clear to the eye or mind, not to be doubted.

A work area card for the NS-50/NS-60 Mobile Airplane Crash Crane is illustrated in figure 8-2 (A). The tools and equipment lists cards contain a list of special tools and equipment necessary to perform the maintenance requirements cited on the requirements cards. Standard handtools are not included in this list.

Also included in this group of cards are lists of consumable materials, replacement parts, and reference publications. The consumable materials list includes the part, type, or specification number, and the nomenclature of such items as oils, greases, cleaning solvents, etc., required to perform the scheduled periodic maintenance requirements. The part, type, or specification number, the nomenclature, and the quantity of parts that are to be replaced at specific intervals are listed on the replacement parts list. Such items as filters and seals are included on this list. The reference publications are those publications that should be used in conjunction with the MRC's to perform the scheduled maintenance inspections. This list usually includes the appropriate Operating, Service, Repair, and Overhaul Instructions Manuals and applicable NavAir Instructions.

The requirements cards are the working items of an MRC set. These cards contain the pertinent information required by each maintenance man to complete each task. Data for each task includes a description; the time required to perform the task; the power, tools, equipment, and material requirements; and detailed information on such items as adjustments, pressures, and torque values. Instructions for troubleshooting and repair of defective systems and components are not included. The appropriate Instructions Manual must be consulted for this information.

The tasks listed on the cards are arranged in the most efficient order for accomplishment, both by the sequential arrangement of the tasks listed on the card and the sequential arrangement of the cards. This arrangement is determined by such factors as interval of inspection, different systems, power requirements, etc.

The first requirement card is numbered 1 on the front, and the back (including any required illustrations) is numbered 1.1. Required continuation cards are numbered with additional decimal suffixes, for example, 1.2, 1.3, etc. The next card is numbered 2 on the front and 2.1 on the back. Continuation cards are numbered 2.2, 2.3, etc. This numbering system continues through the card set.

The quantity and arrangement of the requirements cards vary with different types of equipment. The arrangement of the cards for one model of Gas Turbine Compressor is:

1. Card 1. Inspection intervals of 5 hours or 50 starts. System: Turbine wheel exducer. Card numbers: 1 and 1.1.

2. Card 2. Inspection intervals of 50 hours or 250 starts. System: Engine accessory section. Card numbers: 2 and 2.1.

3. Card 3. Inspection intervals of 100 hours or 500 starts. System: Trailer. Card numbers: 3 and 3.1.

4. Card 4. Inspection intervals of 100 hours or 500 starts. System: Engine and enclosure. Card numbers: 4 through 4.21.

5. Card 5. Inspection intervals of 200 hours or 1,000 starts. System: Compressor section. Card numbers: 5 and 5.1.

6. Card 6. Inspection intervals of 100 hours or 500 starts. System: Lubrication. Card numbers: 6 and 6.1.

7. Card 7. Inspection intervals: Semiannually. System: Wheel bearing lubrication. Card numbers: 7 and 7.1.

8. Card 8. All inspection intervals. System: Operational check. Card numbers: 8 through 8.4.

The introductory card of this set of MRC's lists the card numbers which are required for each inspection interval. For example, the interval of 100 hours or 500 starts requires the use of cards 3, 4, 6, and 8. In some instances, this information is given on each card.

Refer to the requirements card shown in figure 8-2 (B). Most of the information on the cards is self-explanatory and only a few of the more complicated blocks are discussed in the following paragraphs.

The numbers listed in the MAN MIN column indicate the man-minutes required to accomplish each of the tasks on the card. The total of these numbers (including those on continuation cards) appears in the TIME block. Hence, it requires one man 10 hours to perform all tasks on the requirements card shown in figure 8-2 (B).

NOTE: Many of the MRC's for support equipment do not contain the time requirements for the various tasks. As new cards are established on the different items of equipment, they will reflect the appropriate number of man-minutes.

The MOS. NO. block pertains to the Marine Occupational Specialty and corresponds to the Rating (RTG) block directly above it.

The numbers in the WORK AREA, column refer to the area numbers on the appropriate work area card as illustrated in figure 8-2 (A).

The Electrical Power (ELEC PWR) and Hydraulic Power (HYD PWR) blocks indicate by the entry ON or OFF whether or not power is required to accomplish the tasks listed on the particular card. If completion of the work stated on the card does not require power and the work may be accomplished safely with the power on, N/A (Not Applicable) is entered in the appropriate blocks.

In addition to the tasks, many items of information to aid the mechanic in the performance of the tasks are listed at appropriate places on the cards. These items are in the form of NOTES, WARNINGS, CAUTIONS, etc.

A Maintenance Action Form (MAF), described in Military Requirements for Petty Officer 3 & 2, NavPers 10056 (Series), is used to initiate a periodic inspection. A single copy MAF is issued to the check crew personnel each time a segment of the MRC set is issued for accomplishment. (In the case of ground support equipment which is not provided with MRC's, the MAF is issued alone, and the scheduled inspection listed in the applicable Service Instruction Manual is accomplished.)

When the inspection or servicing requirements specified on the cards are fulfilled, the MAF is completed by the person accomplishing the work and returned with the MRC's to the work center supervisor. Any uncompleted MRC's are also returned to the supervisor. The supervisor issues the necessary MAF's for correction of discrepancies which cannot be corrected by the periodic maintenance inspection crew.

Upon completion of the inspection, appropriate entries are made in the applicable Ground Support Equipment Sub-Custody and Maintenance Record, and Ground Support Equipment Custody and Maintenance Record. These forms are discussed in chapter 2 of this manual.

CORRECTIVE MAINTENANCE

With the preventive maintenance program presently in effect, the need for corrective maintenance should be limited to only the corrective actions required by normal wear. However, due to unqualified personnel operating the equipment, and to just plain carelessness, this is not the case. These two factors account for the major portion of the corrective maintenance actions required. AS personnel can do two things that will help eliminate these problems; first, become well qualified on all the equipment assigned; and second, take advantage of every situation where it is possible to teach others in the proper operation and care of the equipment.

When a malfunction does occur, the trouble obviously must be located and repairs made. Equipment that has a malfunction should be tagged to indicate the malfunction and should not be used unless required in an emergency. Even a minor malfunction could progress to the point of being a safety hazard to personnel, equipment, and surrounding objects.

Troubleshooting

Troubleshooting performed by a maintenance crew consists mainly of isolating and correcting malfunctions which are found during operational checks and periodic inspections, or during the checking of discrepancies after a piece of equipment has been used. Some troubles may be rather simple and obvious, while others will be complex and time consuming. The technician will find through experience that the more familiar he becomes with his equipment the simpler his troubles will seem. Although experience and familiarity with the equipment are necessary, the technician must also use a systematic, logical approach for the isolation of troubles.

The process of component isolation by logical reasoning and thought will eliminate unnecessary replacement of equipment components, and a saving of both time and labor will be realized. The technician should analyze the information he has at hand, such as the indications obtained from the operational check, or the information contained in the operator's discrepancy report. He can them eliminate, by logical reasoning, many of the system's components as possible sources of trouble. He may often isolate the trouble to a particular component, allowing replacement of one component instead of a haphazard exchange of components in hopes of finding the trouble.

NOTE: The operator's discrepancy report should be considered very carefully, because the operator may not be thoroughly familiar with the equipment and the report may be in error. Operational checks should be performed under load or operating conditions; otherwise, the malfunction may not be apparent or indications may be misleading.

In order for the technician to become a proficient troubleshooter he must utilize the various aids available to him. The wiring diagrams, functional drawings, and troubleshooting information contained in the appropriate equipment manual should be fully utilized. This information is especially useful in checking power distribution and other electrical circuits throughout the different components of the system. Voltage and resistance charts are also a great aid when isolating a trouble to a particular part or subassembly.

These are but a few of the aids to efficient troubleshooting. The ability of a troubleshooter will depend upon his proficiency in utilizing the tools and information at his command.

The first logical step after the unit has been delivered to the shop, screened, and inducted into the repair channels is a visual check of the unit as previously described. It should be thoroughly inspected for broken leads, parts that are burned, loose mountings, and any other indications of failure. If no defects are found, power may be applied to the equipment. The unit should be observed for any signs of overheating or excessive current consumption.

In the preliminary check, the experience of the technician is an important factor, and the knowledge gained from previous difficulties with the equipment often serves as a guide in knowing what to expect. Both the experienced and the inexperienced technician can find assistance in preliminary checking by consulting the Service Instruction Manual for the specific equipment involved, since these manuals often give detailed procedures for making the initial inspections. However, many electrical faults do not result in symptoms which can be detected visibly or audibly, and it is frequently necessary to resort to other methods of detecting component failure.

Voltage measurements, which are often used to find defective parts, are made at various points in the area suspected of being at fault. The observed voltage values are then compared with the normal voltage values; from this comparison the defect can often be isolated. Voltage checks are most effective when applied after previous checks have been made to partially localize the defect. This is true because modern equipment is complex and a great deal of time would be required to check all the voltages present in all the circuits.

Resistance measurements are used in a manner similar to voltage measurements except that electrical power must be removed, then resistance values are measured with an ohmmeter.

The resistance values are then compared with the normal values given in the maintenance publications. This method, like the voltage measurement method, is most effectively used after the trouble has been isolated to a particular unit or circuit, since reliance on resistance measurement alone is too time consuming to be efficient. After the trouble has been isolated, the ohmmeter is a very useful instrument and often leads the technician to the trouble quickly.

Current measurements may also be made in various circuits of the equipment to detect the presence of abnormal current values. After the currents have been measured, the readings are compared with the normal values given in the maintenance manuals.

After locating the malfunction in the equipment, steps are taken to make the necessary repairs. General repair materials and procedures for making general repairs are covered later in this chapter. For information on specific repair materials and procedures for a particular type and model of equipment refer to the Operation, Service and Repair Manual (Handbook) along with Parts Breakdown and Overhaul Instructions.

Performance Testing

It is necessary to make a check of the equipment's performance after each periodic inspection or corrective maintenance. The system performance check is a complete operational check of the system in all modes of operation. This check serves to determine if any other malfunctions are present and allows evaluation of overall system performance.

Final Checks

The final check consists of a complete and thorough inspection of all the components, and replacement of all inspection panels, plates, and other equipment removed during the inspection or while performing maintenance. This includes the use of safety wire, stop nuts, and other means for securing equipment when needed.

The final checks also include removal and stowage of workstands, power vehicles, and other equipment. Collect, clean, account for, and stow all tools in their respective places. The last but very important check to make is the condition of the working area. Insure all loose materials such as nuts, bolts, washers, bits of safety wire, and other articles are picked up and properly disposed of and the working area is left in a clean condition.

NOTE: If an area is left cluttered and dirty after a job, it becomes a safety hazard to personnel and equipment. Personnel may fall, equipment may skid, or the litter may be picked up and ingested by jet engines. These engines are especially susceptible to foreign object damage (FOD) by anything left adrift.

REPAIR MATERIALS AND PROCEDURES

Ground support equipment is usually composed of assemblies and subassemblies with interconnecting cables and connectors. The ASE must become proficient not only in the operation but also the repair of these systems. Therefore, he must become familiar with general repair materials and the procedures for using these materials. In the following paragraphs a variety of components are discussed, including likely malfunctions that are apt to develop and the methods of correcting these malfunctions.

MOTORS AND GENERATORS

Rotating machinery should be inspected and cleaned at prescribed intervals and whenever repairs to the machinery are made. For such cleaning and inspection, the following procedure is suggested:

1. Unfasten and remove end covers.
2. Remove any dust and dirt from machine and end covers, using clean, dry, compressed air or a soft brush.
3. Loosen, gently remove, and inspect brushes, being extremely careful not to nick or mar edges of brush. Note the location and position from which each is removed so that it can later be replaced in exactly the same position.
4. Check commutators or sliprings for excessive wear, pitting, dirt, thrown solder, or other defects. A highly polished commutator or slipring is desirable, but a dark-colored one should not be mistaken for a burned one. If the surface is dirty, clean with a lint-free cloth moistened with a cleaning solution, then wipe dry. Avoid finger marking the commutator or slipring surface; body acids are corrosive.
5. Secure all brushes in their holders, making certain they are replaced in exactly the position from which they were removed. Be very careful that the brush spring does not snap down and break the brush.
6. Replace and secure end covers.

Sliprings

Sliprings are solid metal rings mounted on the rotor of a-c machines for transferring the power to or from external circuits through brushes or wipers. Sliprings are usually made of copper, bronze, or other nonferrous metals.

While they vary in size and type, the maintenance of sliprings in essentially the same for all types. They should be inspected periodically for wear, grooving, and cleanliness. Normally, the surface of the rings should be bright and smooth.

The connection to the rings is by brushes or wipers. Wiper contacts are used with devices that do not require high current and consequently require only light pressure when making contact. Excessive pressure will result in excessive wiper wear, because the wiper contact is usually of a softer material than the rings. Any contacts showing considerable wear should be replaced.

Grease and oil can be removed from the sliprings by using an approved cleaning solvent. Moisten a clean lint free cloth with the solvent and wipe the grease or oil from the sliprings. Care should be used to prevent the solvent from entering the bearing, because solvent will neutralize oil or grease and cause the lubricant to flow out of the bearing.

A high-resistance film or coating can be removed from the sliprings by using No. 0000 (or finer) sandpaper or crocus cloth, folded over a thin, flat stick so good contact will be made. Apply a light even pressure with the stick and rotate the shaft slowly by hand. Dust and dirt can be blown out by using clean dry low-pressure air. Direct the air so the dust and dirt will be blown out of the component; otherwise, damage may result to the component.

If sliprings are rough, scratched, or grooved, corrective action must be taken. They can be smoothed with a fine sandpaper or crocus cloth if the damage is minor. However, care should be exercised not to cause high and low spots that will interfere with high-speed operation. If the sliprings show excessive damage, the component must be replaced.

Commutators

Commutators have been called the "soft spot" of d-c machinery because they require considerable maintenance. Unlike the slipring, the commutator is a series of copper segments separated by insulators. When the brushes make contract with a pair of segments, an armature coil is connected into the circuit. Thus, when the motor or generator is moving, the brushes and commutator switch coils in and out in the proper sequence.

The normal appearance of the commutator is a shiny, smoothly worn, chocolate brown color. A blackened or pitted commutator is caused by poor brush and segment contact, open or shorted coils, overloads, etc. If the brushes are causing the blackened appearance, they should be replaced and the commutator should be cleaned. Cleaning is accomplished by using an approved cleaning solvent, No. 0000 sandpaper, or crocus cloth, as was used for the sliprings. Never use emery cloth to clean sliprings or commutators, because the emery grit is an electrical conductor and will cause a short circuit. Another much used method of cleaning the commutator utilizes a commutator stone. An advantage of this method is that the stone can be used while the prime mover is turning the commutator. The stone is very fine and will give the commutator a very clean, smooth surface unless the commutator has more than minor damage. Clean dry low-pressure air should also be used for removing dust, dirt, and other foreign matter.

If the fault is other than brush and segment contact (that is, a short or open coil), the machine should be sent to overhaul.

Another fairly common defect is high mica. As the copper segments of the commutator wears down, the mica, which is the insulation separating the segments, does not. Consequently, the mica may be higher than the segments. The high mica lifts the brush every time it passes underneath; this results in arcing because the brush is constantly breaking contact. High mica can be detected by rubbing the fingernail over the surface of the commutator. There should be a small depression between the segments, but if there is high mica, this depression disappears. Undercutting is the remedy for high mica, but the undercutting operation should be attempted only under the advice and guidance of an experienced repairman.

Brushes

Brushes are found in numerous sizes and shapes and are made of various materials and compounds. Many brushes used in equipment are made of a composition of graphite and other forms of carbon. In all probability, the majority of the maintenance an ASE will perform on rotating machinery will be concerned with brushes. Brushes should be checked for wear, chipping, oil soaking, sticking in the brush holders, spring tension, length, and area of contact with the commutator. If for any reason a brush is removed, it should be marked or tagged so it may be replaced in the same brush holder and in the same position it occupied before removal.

Brushes that show excessive or improper wear, chipping, or that are oil soaked should be replaced. Consult the maintenance manual for the CORRECT replacement.

It is important that the brushes be changed before they are completely worn away in order to prevent damage to the equipment in which they are used.

In order that the technician can tell when replacement is necessary, a brush marking system has been developed. Brushes are marked with a readily noticeable groove in their edge to indicate allowable wear. This groove extends from the top of the brush down to a point of 75 percent of the brush wearing depth. (The top is the end opposite the wearing face.) Thus, if the brush is worn down to the groove, it must be replaced. If no groove is present, consult the equipment manual for acceptable minimum brush lengths.

Some new brushes are ready for use; that is, the brush face is slightly concave so that it conforms to the shape of the commutator. However, some new brushes are not ready for use and must be sanded in. This sanding or seating, can be accomplished by wrapping the fine sandpaper around the commutator. The paper is placed sand side up with a lap following the direction of normal rotation of the device, and is held in place by a rubberband. Do not use glue or tape. The brushes are placed in their holder under spring tension, and the armature is rotated slowly by hand in the direction of normal rotation. In so doing, the contact surfaces of the brushes are sanded until their contact surfaces match the curvature of the commutator. The carbon dust from the brushes must be removed from the device by dry compressed air followed by cleaning with safety solvent.

Bearings

Antifriction bearings are either of ball or roller construction. Although either type may be found, the most commonly used in rotating electrical machinery is the ball type.

Ball bearings may be classified as open or sealed. Sealed bearings are prelubricated and require almost no attention during normal operation of the equipment in which they are installed; open bearings require periodic cleaning and lubrication. Do not assume a motor or generator uses sealed bearings—check the maintenance manual for the equipment being serviced.

For proper maintenance and lubrication of ball bearings, the detailed recommendations of the manufacturer as given in the Service Instruction Manual should always be followed. In the inspection of ball bearings, the assembly is slowly rotated. Bearings showing pronounced stickiness or bumpy operation should be replaced. The bearings are also inspected for cracks, rough or pitted surfaces, and damaged balls.

Open type ball bearings may be cleaned and lubricated as follows:

1. Wipe the outside of the bearings clean, using a clean cloth.
2. Wash the bearings thoroughly in cleaning solution in accordance with specifications.
3. Shake off excessive cleaning solution and lay the bearing on a clean surface to thoroughly dry before repacking.
4. Relubricate by packing the bearing one-fourth to one-third full with the prescribed lubricant.
5. Wipe off any excess lubricant.

Excessive lubrication leads to bearing trouble, and may result in too much grease in the slipring or commutator compartment of the machine. Brush and slipring wear increase appreciably if a large amount of lubricant is present. Further, a large amount of lubricant may result in "soaking" of the brushes; also, it may mix with the carbon dust from the brushes and short out the segments of the commutator. Insufficient lubrication will, of course, result in wear, heating, and possible seizing of the bearing.

NOTE: To prevent damage to the bearings during removal and installation, always use the tools specified in the maintenance manual for the equipment being serviced.

Bushings

A bushing is sometimes referred to as a friction bearing. The friction bearing provides a bearing surface between two metal surfaces which have been machined to close tolerances. A bushing is a cylindrical or sleeve type bearing sometimes used to support the end of a rotating shaft. Most bushings are used in places where friction is not a major factor. They are often found in starters where they are used to support the starter armature shaft. A bushing is usually made of a metal which is softer than that of the shaft which it supports. This provides a bearing surface which may be replaced when worn. Even though the bushing is used in places where friction is not the major factor, it is used to reduce friction.

In order for the bushing to reduce friction, some type of lubrication must be provided. Several methods are employed to lubricate the bearing surface between the bushing and the shaft which it supports, one of which is to make the bushing of a porous metal and impregnate it with a lubricant. An example of this method is a graphite-impregnated bronze bushing.

Removal and installation of bushings require the use of special bushing drivers which are available in various sizes. After installation, some bushings must be reamed to fit the shaft they are to support. Hand reamers are available in various sizes for this purpose.

CIRCUIT PROTECTORS

To protect the electrical systems of ground support equipment from damage and failure caused by the excessive current, two kinds of protective devices are used—fuses and circuit breakers.

Fuses

The simplest protective device is the fuse. A fuse is a length of wire or metal ribbon enclosed in a suitable insulating body. This wire or

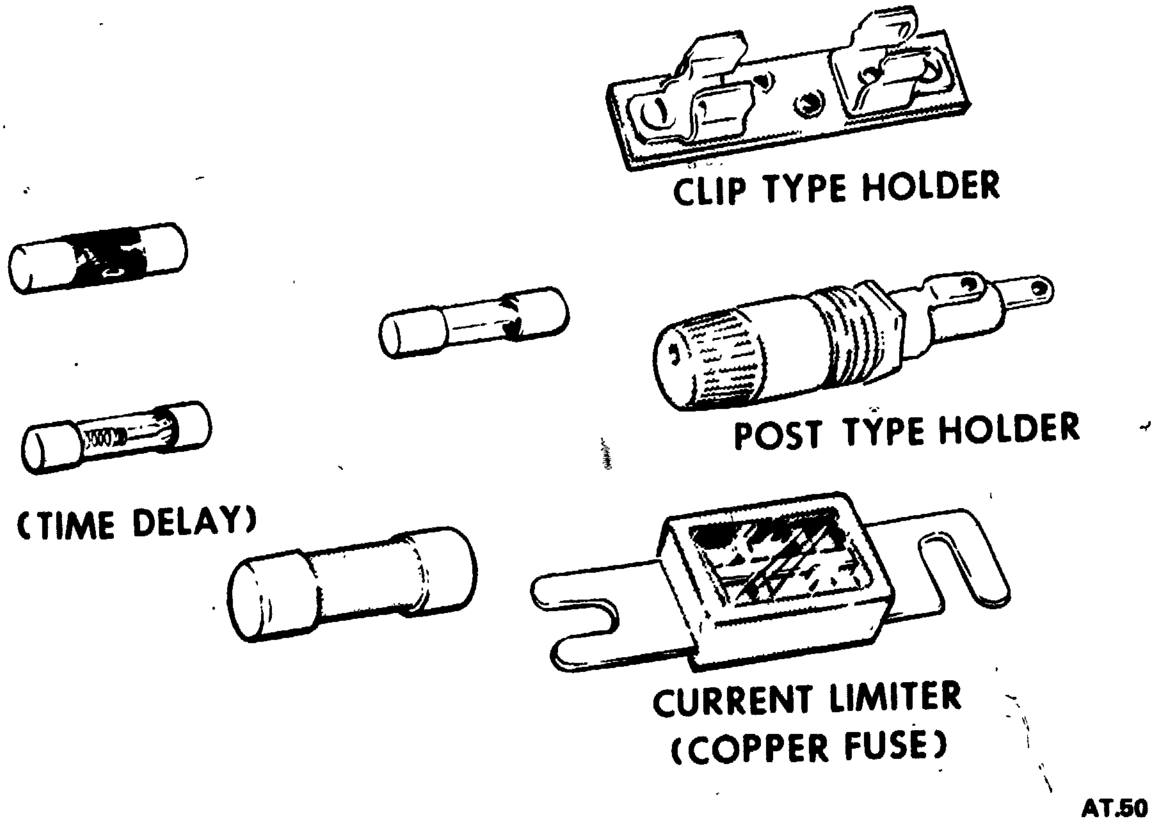

Figure 8-3.—Common fuses and fuse holders.

ribbon, referred to as the fuse link or fuse element, is usually constructed of an alloy which has a low melting point, and is of a size which will carry a predetermined amount of current indefinitely. A larger amount of current will cause the fuse element to heat and melt, opening the circuit to be protected. A fuse is always placed in series with the protected circuit. When a fuse element is melted, the fuse is said to be "blown."

Fuses are usually rated in terms of current and voltage. Current ratings may be in amperes or a fraction of an ampere. The voltage rating is the maximum voltage the fuse construction will safely handle without arcing; when a fuse blows, the entire applied voltage of the circuit appears across it. Therefore, the voltage rating of the fuse should be higher than the maximum circuit voltage.

Normally, when a circuit is overloaded the fuse blows; however, all blown fuses are not the result of current overload. Abnormal production of heat, aging of the fuse element, poor contact due to loose connections, corrosion within the fuse holder, and the temperature of the surrounding atmosphere are conditions which will alter the protection characteristics of a fuse.

The type of fuse most commonly used in ground support equipment is the cartridge fuse which consists of an element enclosed in a tube of insulating material (glass or bakelite), having a metal cap on each end for contact with the fuse holder. Some common types of fuses and holders are shown in figure 8-3.

The dimensions of cartridge fuses vary with the current and voltage rating and the application. Current and voltage ratings are usually stamped on the end caps.

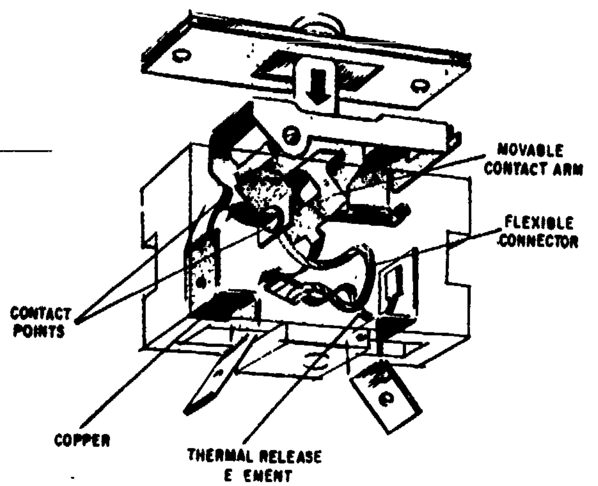

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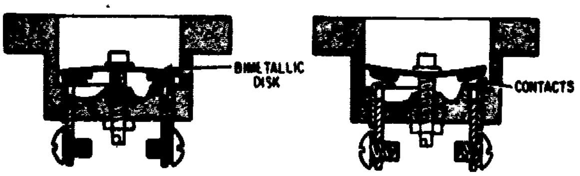
Figure 8-4.—Pushbutton reset, thermal circuit breakers.



AE.56
Figure 8-5.—Automatic reset, thermal circuit breaker.

Cartridge fuses are further classified as instantaneous or delayed-action types. The instantaneous fuse will carry its rated current indefinitely but will quickly blow and open the circuit when its rated capacity is exceeded. Delayed-action fuses, commonly called "slow-blow" fuses, are used for equipment, such as electric motors, which require more current for starting than for normal running. An instantaneous type fuse that would provide ample running protection might blow during the starting period when high current is required, so a delayed-action fuse is used.

Delayed-action fuse elements can be constructed in several ways. The one most commonly used has a heater element in series with the fuse element, and current above that of the rated value for a short time has little or no effect on the fuse or heater elements. However, prolonged overloads cause the heater to become hot enough to melt the junction between the elements, opening the circuit. (See fig. 8-3.)

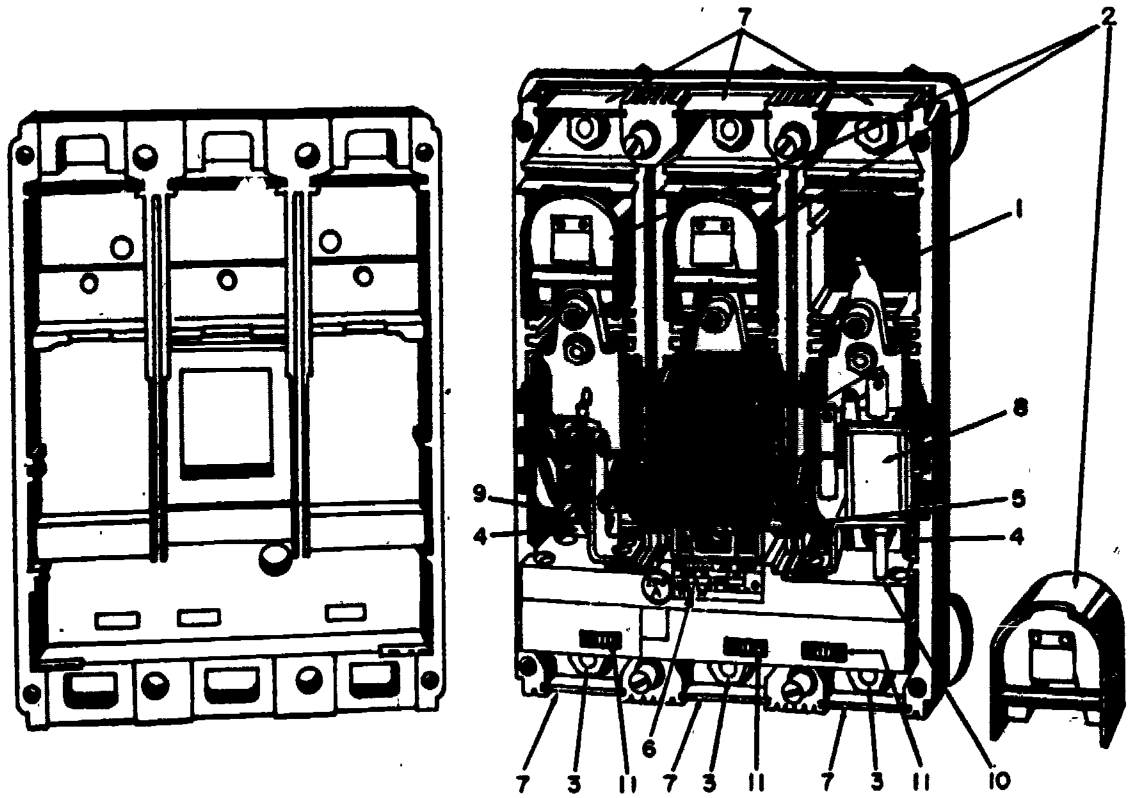
In power circuits that carry high current, such as mobile electric power plant aircraft service cables, another protective device is used. It is called a current limiter, but is still classified as a fuse. (See fig. 8-3.) Current limiters are constructed with a copper link of predetermined size which melts and opens the circuit if the overload occurs. Current limiters are also rated by current and voltage.

Circuit Breakers

A circuit breaker is designed to break a circuit and stop the current flow when the current exceeds a specific value. It is commonly used in place of a fuse and may sometimes eliminate the need for a switch. A circuit breaker differs from a fuse in that it "trips" to break the circuit and may be reset, while a fuse melts and must be replaced. Circuit breakers, like fuses, are rated in amperes and volts.

Circuit breakers are commonly categorized according to the way the circuit breaking action is initiated. The three types most commonly used are thermal, magnetic, and thermo-magnetic, the most widely used of these being the thermal type. Thermal circuit breakers are divided into subcategories according to the means by which they are reset.

The pushbutton reset type circuit breaker consists of a bimetallic, thermally (heat) actuated, spring loaded mechanism which closes two electrical contacts when set. This type is shown in figure 8-4. The thermal release element is made by welding together two strips of different metals having different thermal expansion rates. A heater is mounted around, or close to, the element and the movable contact is mounted on the element itself. An excessive current causes the heater to heat the element and, as the element expands, it bends because of the different thermal expansion rates. As the element bends, it releases a locking mechanism. This release permits spring loading to rapidly separate the movable and stationary contacts. The circuit



1. Stationary contact.
2. Arc suppressors.
3. Terminal stud nuts and washers.
4. Trip unit line terminal screw—outer poles.
5. Trip unit line terminal screw—center pole.
6. Trip unit nameplate.
7. Terminal barriers.
8. Shunt trip.
9. Auxiliary switch.
10. Hole for shunt trip undervoltage release plunger.
11. Instantaneous trip adjusting wheels.

BE.244

Figure 8-6.—Thermo-magnetic circuit breaker.

breaker in figure 8-4 is shown in its tripped condition; as indicated by the arrows, when the pushbutton is pushed in, the movable contact mechanism engages the thermal release element to lock the contact points together until another current overload causes the thermal element to move downward and release the movable contact again.

A visual indication of the tripped condition of this circuit breaker is provided by the pushbutton; when tripped, the pushbutton is in the fully extended position and a white ring plus an inner red section of button is showing. This type can be manually tripped by pulling the pushbutton out, but it should not be used as a switch.

The toggle lever type operates in the same manner as the pushbutton type, with the exception that the tripped condition is indicated by the toggle lever being in the OFF position.

This type may properly be used as a switch.

Manual resetting of either of the above types is accomplished by resetting the actuator (either pushbutton or toggle lever) whenever the thermal element cools sufficiently to raise to its normal position ready for reengagement with the movable contact mechanism.

An automatic reset circuit breaker is shown in figure 8-5. This circuit breaker consists of a conductive bimetallic snap-acting disk which bridges two electrical contacts. When this disk is heated by excessive current passing through it, it snaps to the opposite position, opening the contacts.

The automatic reset circuit breaker has no manual reset and cannot be opened manually. After a short time, when the bimetallic disk has cooled sufficiently, it will snap back to its original position, resetting the circuit breaker. If a constant overload exists, the circuit breaker will intermittently break the circuit. The automatic reset circuit breaker gives no visual indication of being tripped or set.

The magnetic circuit breaker is of the switch/toggle variety and is magnetic rather than thermal is operation. This type can be made to open almost instantly when more than the rated current flows in the circuit. An electromagnet is placed in series with the contacts and the contacts are mounted on an armature. When excessive current flows through the device the armature is pulled toward the electromagnet, opening the contacts and thereby the circuit. The armature is then latched in the off or tripped position. To reset this circuit breaker, the armature is unlatched and returned to the normal position. Visual indication of the tripped condition is provided by the toggle lever, which will be in either the off position or midway between off and on, depending on the manufacturer's design.

Thermo-magnetic circuit breakers, such as that shown in figure 8-6, are being used extensively. This circuit breaker contains two trip devices—one thermal and one magnetic.

The automatic trip devices of this circuit breaker are "trip free" of the operating handle; this means the circuit breaker cannot be held closed by the operating handle if an overload exists. When the circuit breaker has tripped, the handle rests in the center position. To reset after automatic tripping, the handle must be moved to the extreme OFF position, which resets the latch in the trip unit; then the handle must be moved to the ON position.

Maintenance

Maintenance of fuses is very simple; if there is any doubt as to the condition of a fuse, a continuity test will readily indicate whether the fuse element is open or closed. If the fuse is defective, replacement is the only cure.

Occasionally the fuse holders will become defective. Here again, the maintenance required is very simple; make a visual inspection and a continuity test, and if the holder is defective it must be replaced.

Circuit breaker maintenance presents a little more difficulty due to the possibility of a change in current capacity. This change may result from usage over a period of time and is difficult to detect. If the current-carrying capacity of the unit increases, circuit protection value is reduced. If the current-carrying capacity decreases, the circuit breaker will open with less than rated current. Under the latter condition, the circuit breaker is the last component suspected, because its opening usually indicates a circuit failure. An ammeter can be used to measure the current through the breaker, but replacement of the breaker is usually the easiest and surest test for an over-sensitive circuit breaker.

The usual maintenance of breakers involves a visual inspection of the terminals, and continuity checks. If a breaker malfunctions or appears to be operating improperly, it should be removed and replaced by a new device of the same type and rating.

SWITCHES

A switch may be described as a device used for making, breaking, or changing connections in an electrical circuit. Switches are rated in amperes and volts; the rating refers to the maximum allowable voltage and current of the circuit in which the switch is to be used. Since it is placed in series, all the circuit current passes through the switch; because it opens the circuit, the applied voltage appears across the switch in the open circuit position. Switch contacts should be opened and closed quickly to minimize arcing; therefore, switches normally utilize a snap action.

Many types and classifications of switches have been developed. A common designation is by the number of poles, throws, and positions. The number of poles indicates the number of terminals at which current can enter the switch. The throw of a switch signifies the number of circuits each blade or contactor can complete through the switch. The number of positions indicates the number of places at which the operating device (toggle, plunger, etc.) will come to rest. Figure 8-7 presents the schematic symbols of some typical switches.

An example of switch position is a toggle switch which comes to rest at either of two positions, opening the circuit in one position and completing it in another. This is called a two-position switch. A toggle switch which is spring loaded to the OFF position and must be held in the ON position to complete the circuit is called a single-position switch. If the toggle switch will come to rest at any of three positions, it is called a three-position switch. A complete description of a switch may include several designations, e.g., double-pole, double-throw, center-off.

Another means of classifying switches is the method of actuation; that is, toggle, pushbutton, precision, and rotary types. Further classification can be accomplished by a description of switch action such as on-off, momentary on-off, on-momentary off, etc. Momentary contact switches hold a circuit closed or open only as long as the operator deflects and holds the actuating control.

The most common type of switch is the toggle switch. Toggle switches have their moving parts enclosed. A double-pole, double-throw, on-off-on toggle switch is shown in figure 8-8. These switches have many uses and are used extensively for applying power to various circuits. Some of the switches are provided with a luminous tip on the lever toggle so as to be visible in the dark.

Pushbutton switches have one or more stationary

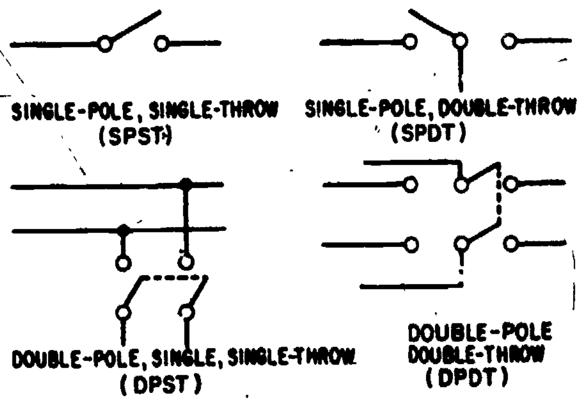


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Figure 8-7.—Symbols of commonly used switches.

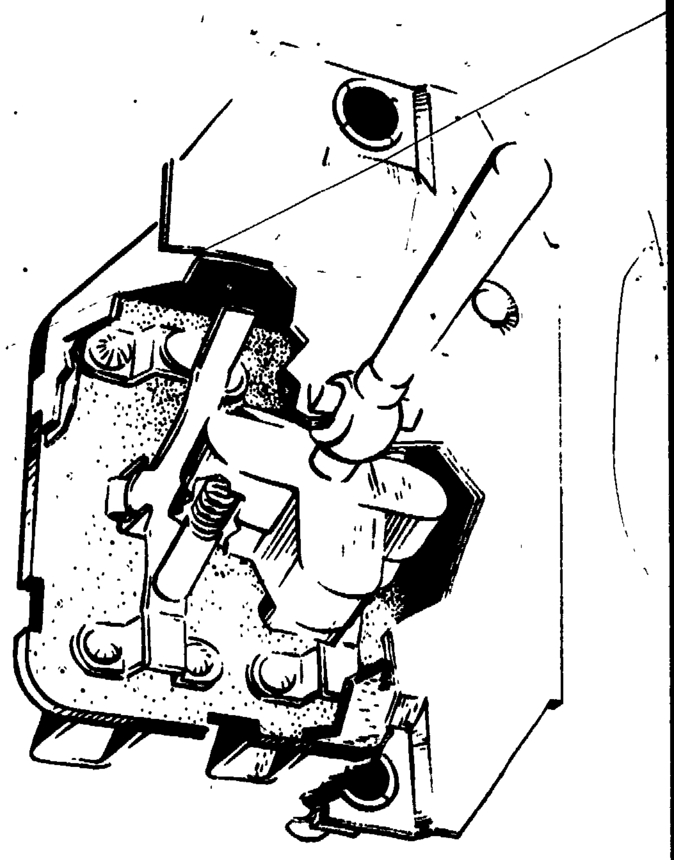

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Figure 8-8.—Toggle switch.

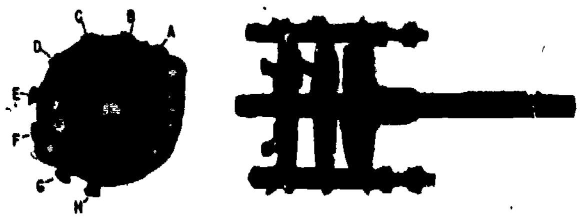

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Figure 8-9.—Rotary selector switch.

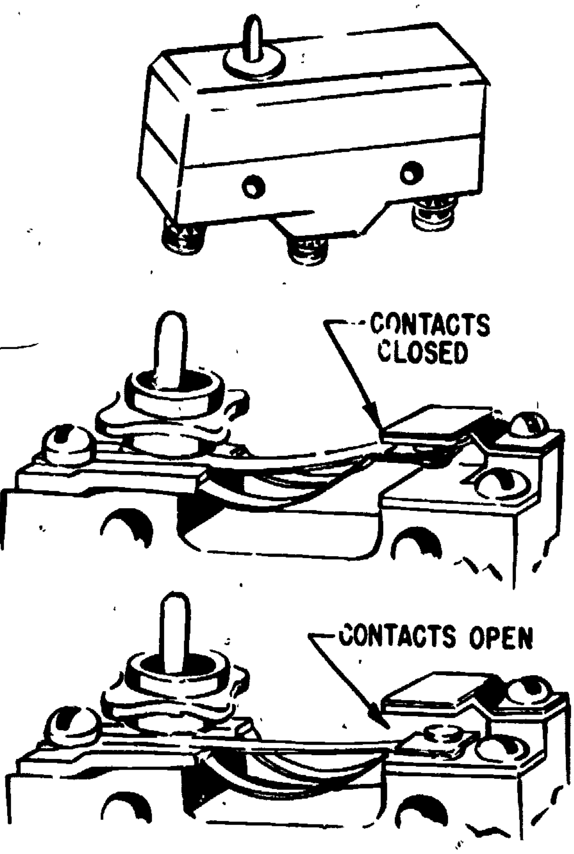

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Figure 8-10.—Microswitch.

contacts and one or more movable contacts. The movable contacts are attached to the pushbutton by an insulator. These switches are spring loaded and are usually of the momentary contact type. They have many uses, such as indicator light checks and circuit reset. The push-on . push-off type switch is seldom used, bu. . . found on occasion.

A rota. . selector switch may perform the functions of a number of switches. As the knob of a rotary selector switch is rotated, it opens one circuit and closes another. This can be seen by examination of figure 8-9.

On the wafer shown in this figure the contact is now from A to E. If the switch is rotated clockwise, as viewed, the circuit from A to E is opened and the circuit from A to D is completed. Some rotary switches have several layers of wafers and operate as a large number of switches simultaneo. .y. Ignition switches and voltmeter selector switches are typical examples of this type.

Mechanically operated switches are used in many types of installations, such as for interlock switches to disable the starter circuit on equipments having automatic transmissions. An interlock such as this prevents starting if the shift mechanism is in any position other than neutral. They are widely used because of their small size and excellent dependability. (The term Microswitch, although frequently used in referring to all switches of this type, is a trade name for the switches made by the Microswitch Division of the Minneapolis . Honeywell Regulator Company.)

Microswitches will open or close a circuit with a very small movement of the tripping device. They are usually of the pushbutton variety, and they usually depend on one or more springs for their snap action. For example, the heart of the Microswitch is a beryllium copper spring, heat-treated for long life and unfailing action. The simplicity of the one-piece spring contributes to the long life and dependability of this switch. The basic Microswitch is shown in figure 8-10.

Pressure-operated switches usually have Bourdon tubes, syphons, or diaphragms against which fluid (gas or liquid) operates to actuate the switch.

Thermal switches usually incorporate a bimetallic strip or sheet that bends or snaps at a desired temperature to actuate the switch. An example of this type switch is the signal light flasher unit.

Maintenance

While the switch itself is relatively simple to check, it sometimes offers difficulty to maintenance because of its location in inaccessible places. After a visual inspection of the connections and the switch, a continuity test will indicate any malfunctions. When the switch mechanism is found to be defective, it normally is not repairable and therefore should be replaced.

When enclosed switches are used, failure to seal properly around cable openings is the most common cause of troube. Condensation can short across the switch terminals, or it can corrode the switch actuators and make them inoperative. Condensation can be considerably reduced by carefully sealing the openings, or by using hermetically sealed switches. (Hermetic sealing also prevents dust and dirt from reaching the contacts, thereby reducing the possibility of high resistance shorts and open circuits.)

Some switches are damaged during installation, particularly those with a plastic housing. Proper care in installing or replacing plastic-enclosed switches will help to eliminate this type of trouble.

Some switch assemblies are equipped with adjustments which enable them to operate at a preset temperature, pressure, position, etc. Caution should be exercised in making these adjustments; if they are not accurate, damage to the switch or to the equipment can result.

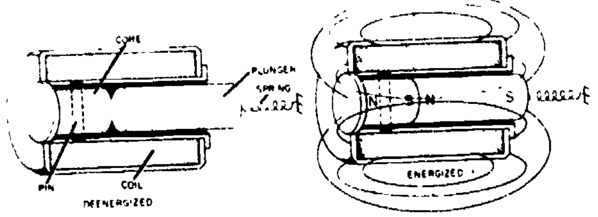

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Figure 8-11.—Solenoid action.

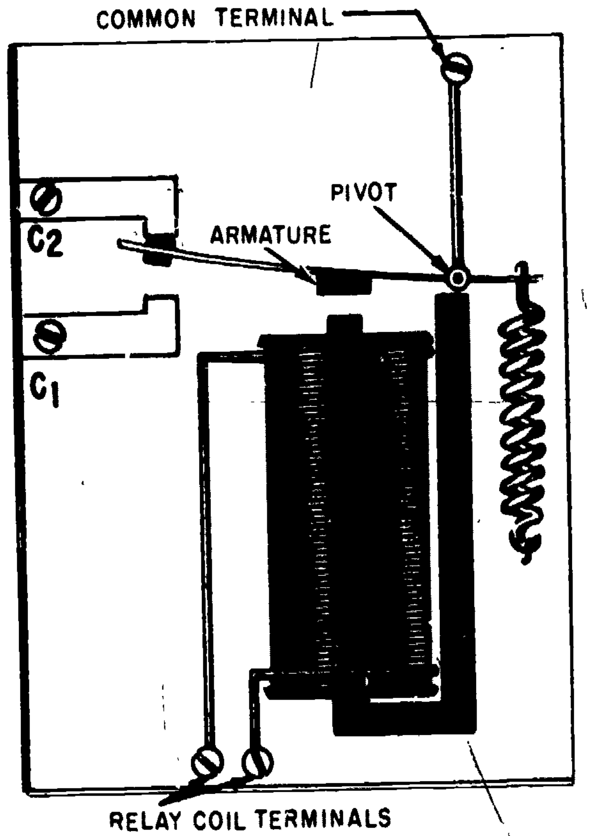

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Figure 8-12.—Relay construction.

SOLENOIDS

A solenoid is an electromagnet formed by a conductor wound in a series of loops in the shape of a helix (spiral). Inserted within this spiral or coil is a soft-iron core and a movable plunger. The soft-iron core is pinned or held in position and is not movable. The movable plunger (also soft iron) is held away from the core by a spring when the solenoid is deenergized. (See fig. 8-11.)

When current flows through the conductor, a magnetic field is produced. This field acts in every respect like a permanent magnet having both a north and a south pole. The total magnetic flux produced is determined by the generated magnetomotive force and the permeability of the medium through which the field passes. (Permeability is the ease with which a substance conducts flux.)

In much the same way that electromotive force (voltage) is responsible for current in a circuit, magnetomotive force is responsible for external magnetic effects. The magnetomotive force (mmf) which produces the magnetic flux in a solenoid is the product of the number of turns of wire and the current through the coil. If the current is expressed in amperes, the magnetomotive force is expressed in ampere turns.

From this it can be seen that a prescribed magnetomotive force can be produced by using either a few turns of large wire (high current) or many turns of small wire (low current).

The soft-iron core will also influence the strength of the magnetic flux produced by the coil. The strength of the field is greatly increased by use of a soft-iron core rather than air because of the greater permeability of iron. Consequently by using an iron core a greater flux density can be produced for a given number of ampere turns.

The magnetic flux produced by the coil results in establishing north and south poles in both the core and the plunger. These poles have such a relationship that the plunger is attracted along the lines of force to a position of equilibrium when the plunger is at the center of the coil. As shown in figure 8-11, the deenergized position of the plunger is partially out of the coil due to the action of the spring. When voltage is applied, the current through the coil produces a magnetic field which draws the plunger within the coil, resulting in mechanical motion. When the coil is deenergized, the plunger returns to its normal position because of spring action. It is interesting to note that the effective strength of the magnetic field on the plunger varies with the distance between the two. For short distances, the strength of the field is strong; and as distances increase, the strength drops off quite rapidly.

Solenoids are used for electrically operating hydraulic valve actuators, carbon pile voltage regulators, power relays, and mechanical clutches. They are also used for many other purposes where only small movements are required. One of the distinct advantages in the use of solenoids is that a mechanical movement can be accomplished at a considerable distance from the control. The only link necessary between the control and the solenoid is the electrical wiring for the coil current. Since solenoids are used in ground support equipment and are subject to failure, the ASE should be able to test and maintain them.

Maintenance

The first step to be taken in checking an improperly operating solenoid is a good visual inspection. The connections should be checked for poor soldering, loose connections, or broken wires. The plunger should be checked for cleanliness, binding, mechanical failure, and improper alinement. The mechanism that the solenoid actuates should also be checked for proper operation.

The second step is to check the energizing voltage with a voltmeter. If the voltage is too low, the result is less current flowing through the coil and a weak magnetic field. A weak magnetic field can result in slow or ineffective operation. It could also possibly result in chatter or inoperation. If the energizing voltage is too high, it will in all probability damage the solenoid by either overheating or arcing. In either case the voltage should be reset to the proper value so that further damage or failure will not result. The solenoid should then be checked for opens, shorts, and increased or decreased resistance.

If the solenoid winding is open, current cannot flow through the coil and the magnetic field is lost. A short results in fewer turns and higher current. However, the short will normally have some resistance (poor contact) and result in a weaker magnetic field. A high-resistance coil will reduce coil current and also result in a weak magnetic field. To check for opens, shorts, and correct resistance, an ohmmeter should be used. Another check possible with the ohmmeter is to determine if the coil winding is shorted to ground. If the coil is open, shorted, or has appreciably increased in resistance, the solenoid should be replaced.

RELAYS

Relays are electrically operated control switches, and are classified according to their use as control relays or power relays. Control relays are usually known simply as relays; power relays are called contactors. Power relays control the heavy power circuits of an electric system.

The function of a control relay is to use a relatively small amount of electrical power to signal or to control a large amount of power. Where multipole relays are used, several circuits may be controlled simultaneously.

The control relay permits the operator to control contactors at other locations in the equipment, and the heavy power cables need be run only through the contactors. Only lightweight control wires are connected to the control switches. Safety is also an important reason for using relays, since high power circuits can be switched remotely without danger to the operator.

Control relays, as their name implies, are frequently used in the control of low power circuits or other relays, although they also find many other uses. In automatic relaying circuits, a small electric signal may set off a chain reaction of successively acting relays, which then perform various functions. Control relays can also be used in so-called "lockout" action to prevent certain functions.

Another important function of control relays in ground support equipment is for "sensing" undervoltage and over-voltage, reversal of current, excessive currents, phase and amplitude, polarity, etc.

In general, a relay consists of a magnetic core and its associated coil, contacts, springs, armature, and the mounting. Figure 8-12 illustrates the fundamental construction of a relay. When the circuit is energized, the flow of current through the coil creates a strong magnetic field which pulls the armature downward to contact C1, completing the circuit from the common terminal to C1. At the same time, the circuit to contact C2, is opened.

The clapper relay (fig. 8-13) contains the same components but has multiple sets of contacts. As the circuit is energized, the clapper is pulled to the magnetic coil. This physical movement of the arm of the clapper forces the pushrod and movable contacts upward. As many sets of contacts as required may be built onto the relay; thus, it it possible to control many

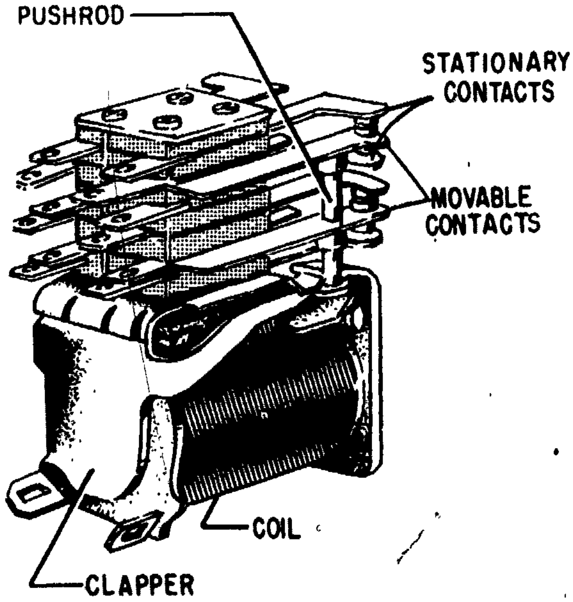

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Figure 8-13.—Clapper type relay.

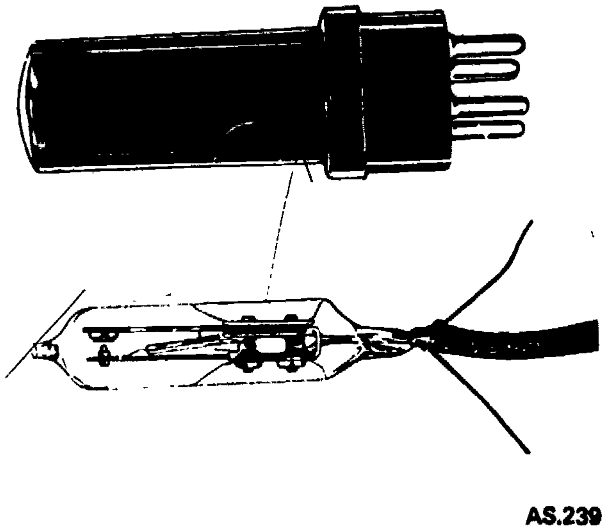

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Figure 8-14.—Thermal time delay relay.

different circuits simultaneously. To the maintenance man, this type of relay can be a source of trouble because motion of the clapper arm does not necessarily assure tandem movement of all the movable contacts. Referring to figure 8-13,

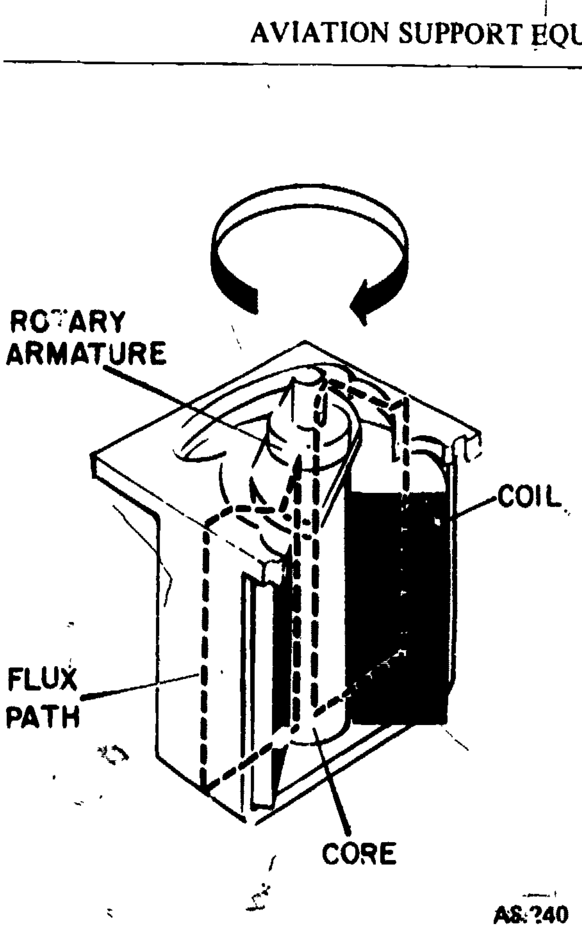

Figure 8-15.—Rotary type relay.

if the pushrod were broken, the clapper arm might push the lower movable contact upward but not move the upper movable contact.

A thermal time delay relay (fig. 8-14) is constructed to produce a delayed action when energized. Its operation depends on a thermal action such as that of a bimetallic element similar to that used in a thermal circuit breaker. A heater is mounted around, or close to, the element, and the movable contact is mounted on the element itself. As the heat causes the element to bend (because of the different thermal expansion rates), the contacts close to operate a relay. The delay time of the bimetallic strip is usually from 1/2 to 1 1/2 minutes, and is predetermined at manufacture by using metals with different expansion rates, or by increasing or decreasing the distance between the fixed and movable contacts.

One common form of time delay relay utilizes a lag coil (slug). This can be a large copper slug that is located at one end of the winding, or a tubular sleeve that is located between the winding and the core. The lag coil acts as a short-circuited secondary for the relay coil. The counter magnetomotive force due to the current induced in the lag coil by the changing relay coil current delays the flux buildup or decay in the airgap, and hence the closing or opening of the armature. A short slug near the armature end of the core has relatively more effect on the closing time, and one at the heel end has more effect on the release time.

Another type of relay is the latch-in relay. This relay is designed to lock the contacts in the deenergized position until the relay is either manually or electrically reset. Two windings are used; one is the trip coil and the other the reset coil. When the trip coil is energized, it acts on a spring-loaded armature on which the relay's movable contact is mounted. After the contacts open they are held in the open position by a mechanical latch. The mechanical latch is unlatched when the reset coil is energized, thus allowing the relay's contacts to close again.

The rotary type relay (fig. 8-15) is not as commonly used as the clapper type. This relay operates on the principle of an electric motor, but only through a small arc. When wafer switch assemblies are installed on the shaft, this type of relay provides a switching device of any degree of complexity. Many circuits can be controlled by a simple control circuit associated with the relay.

Another possible classification of relays is the method of packaging; namely, open, semisealed, and sealed. The clapper type (fig. 8-13) is an example of the open relay. Semisealed relays have protective covers and are sealed against entrance of dust, moisture, and foreign material into the contacts or mechanism. A hermetically sealed relay is generally considered one that is encased with glass, plastic, or metal. Besides being independent of temperature and humidity changes, hermetically sealed relays also have the advantage of being tamper-proof.

Maintenance

The relay is one of the most dependable electromechanical devices in use; but like any other mechanical or electrical device in ground support equipment, relays occasionally wear out or become inoperative for one reason or another. Should an inspection determine that a relay is defective, the relay should be removed immediately and replaced with another of the same type. Care should be exercised in obtaining the same type replacement because relays are rated in voltage, amperage, type of service, number of contacts, continuous or intermittent duty, and similar characteristics.

Relay coils usually consist of a single solenoid. If a relay fails to operate, the coil should be tested for open circuit, short circuit, or ground. An open coil is a common cause of relay failure.

Formation of film on the contact surfaces of a relay may be considered another principal cause of relay trouble. Although film will form on the contacts by the action of atmospheric and other gases, grease film is responsible for a lot of contact trouble. Carbon formations, caused by the burning of a grease film or other substance (during arcing), also can be troublesome because carbon forms rings on the contact surfaces. As the carbon rings build up, the relay contacts are held open.

When current flows in one direction through a relay, the contacts may be subjected to an effect called "cone and crater." The crater is formed by transfer of the metal of one contact to the other contact. the deposit being in the form of a cone.

Some relays are equipped with ball shaped contacts and in many applications this type of contact is considered superior to the flat surface because dust or other substances are not as readily collected on a ball shaped surface. In addition, a ball shaped contact can penetrate film easier than can a flat contact. When cleaning or servicing ball shaped relay contacts, exercise extreme care to avoid flattening or otherwise altering the contact's rounded surfaces.

Under normal operating conditions, most relay contacts spark slightly; however, this type of sparking must not be confused with the spitting and arcing which causes burning and pitting of the contacts.

Most relays require some maintenance and care. Contact clearances or gap settings must be maintained in accordance with the relay's operational specifications. Relay contact surfaces must be kept clean and in good operating condition.

For detecting potential relay trouble during preventive maintenance, check for charred or burned insulation on the relay, and for darkened or charred terminal leads coming from the relay. Both of these indicate overheating. If there is even a slight indication that the relay has overheated, it should be replaced with a new relay of the same type. Overheating is sometimes caused by the power terminal connectors not being tight enough; screw connections should always be checked during preventive maintenance.

Cleanliness must be emphasized in the removal and replacement of covers on semisealed relays, because the entry of dust or other foreign material may cause contact discontinuity. When the relay is installed in a position where there is a possibility of contact with fuel fumes, extra care should be taken with the cover gasket. Any damage to the gasket, or incorrect seating of the gasket, increases the possibility of igniting vapors.

ELECTRICAL CABLES, CONNECTORS, AND TERMINALS

As defined in the training manual, Basic Electricity, NavPers 10086 (series), a cable is either a stranded conductor (single conductor cable) or a group of conductors insulated from each other (multiconductor cable). A wire is defined as a single, solid conductor. However, these definitions are not always strictly observed in everyday communication; in ground support equipment work, the words wire, wires, and cables are often used interchangeably.

Connectors are devices attached to the ends of cables and sets of wires to provide easy installation and removal. Connectors consist of two sections—the fixed section called the receptacle or jack, and a removable section called the plug. Plug assemblies may be of the straight type or the 90° type, while receptacle assemblies may be the wall-mounting, box-mounting, and integral-mounting types.

A terminal is practically self-explanatory. In

Table 8-3.—Standard color code for chassis wiring

Circuit	Color
Grounds, grounded elements, and returns	Black.
Heaters or filaments, offground	Brown.
Power supply B plus	Red.
Screen grids	Orange.
Cathodes	Yellow.
Control grids	Green.
Plates	Blue.
Power supply, minus	Violet (purple).
A-c power lines	Gray.
Miscellaneous, above or below ground returns, etc.	White.

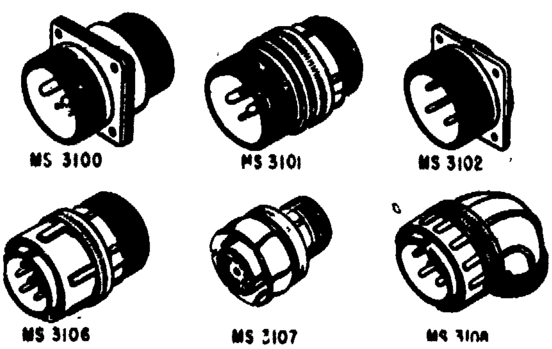

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Figure 8-16.—Connector shell types.

general, a terminal is a piece of electrical hardware attached to the end or termination of a wire which is to be connected to a terminal post of some type. The terminal may be soldered or solderless as described and illustrated in chapter 5 of this manual.

To make maintenance easier, each interconnecting wire cable installed in a piece of equipment is marked with a combination of letters and numbers which identify the wire, the circuit to which it belongs, its gage size, and other information necessary to relate the wire to a wiring diagram. This marking is called the cable identification code. Wire identification coding was discussed in chapter 6 of this manual.

A Military Standard color code has also established a uniform wiring code for identification of circuits containing electron tubes. The standard colors to be used in chassis wiring for the purpose of circuit identification of the equipment are given in table 8-3.

Connector Construction and Identification

In the discussion which follows, the word "connector" is used in a general sense. It applies equally well to connectors designated by "AN" numbers and those designated by "MS" numbers. AN numbers were formerly used for all supply items cataloged jointly by the Army and Navy. Many items, especially those of older design, continue to carry the AN designator even though the supply system has shifted over to MS (Military Specification) numbers.

AN specification numbers for connectors have been generally superseded by MS numbers. However, in many instances, connectors are still referred to as "AN connectors."

Electrical connectors are designed to provide a detachable means of coupling between major components of electrical equipment. These connectors are constructed to withstand the extreme operating conditions imposed by continuous service. They must make and hold electrical contact without excessive voltage drop despite extreme vibration, rapid shifts of temperature, etc.

These connectors vary widely in design and application. Each connector consists of a plug assembly and a receptacle assembly. The two assemblies are coupled by some type of coupling device (coupling nut, pressure fitting, etc.), and

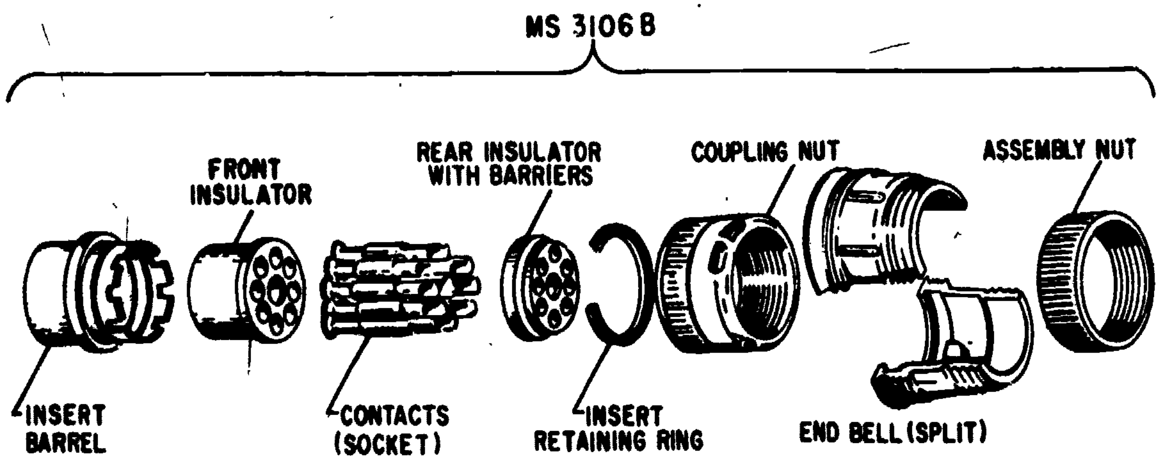

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Figure 8-17.–Exploded view of a split-shell connector.

each consists of an aluminum shell containing an insulating insert which holds the current-carrying contacts. The plug is usually attached to a cable end and is the part of the connector on which the coupling device is mounted. The receptacle is the half of the connector to which the plug is coupled, and the receptacle is usually mounted on a part of the equipment.

There are wide variations in shell type, design, size, layout of contacts, and style of insert. Six types of connector shells are shown in figure 8-16.

Connector MS 3100 is a wall-mounting receptacle. It is intended for use with conduit to eliminate the necessity of installing conduit boxes.

Connector MS 3101 is a cable-connecting receptacle, and is used with cable or in other installations where mounting provisions are not required.

MS 3102 is a box-mounting receptacle, and is intended for use where a detachable connection is required on a shielded box or unit of equipment.

MS 3106 is a straight plug which is used when circuits are to be connected where space limitations are not critical. It consists of a front shell (usually referred to as an "insert barrel"), a coupling ring, the insert, an insert retaining device, and a rear shell.

MS 3107, a quick-disconnect plug, is used where very rapid disconnections must be made. A special coupling device is used instead of a coupling ring; otherwise it is similar to MS 3106.

MS 3108, a 90° angle plug, is similar in construction to MS 3106 except that the rear shell provides a right angle bend which is required where space is limited.

There are six classes of MS connectors, each designed for a particular kind of application. A letter designation is used, as in MS 3106E, where E is the shell type indicator. The shell indicators are:

A–Solid shell.
B–Split shell.
C–Pressurized.
E–Environment resistant.
K–Fireproof.
R–Environment resistant (lightweight).

Solid shell connectors are used where no special requirements, such as fireproofing or moistureproofing, must be met. The rear shells are made from a single piece of aluminum.

Split shell connectors allow maximum accessibility to soldered connections. The rear shell is made in two halves, either of which may be removed. Figure 8-17 shows an exploded view of one type of a split-shell connector.

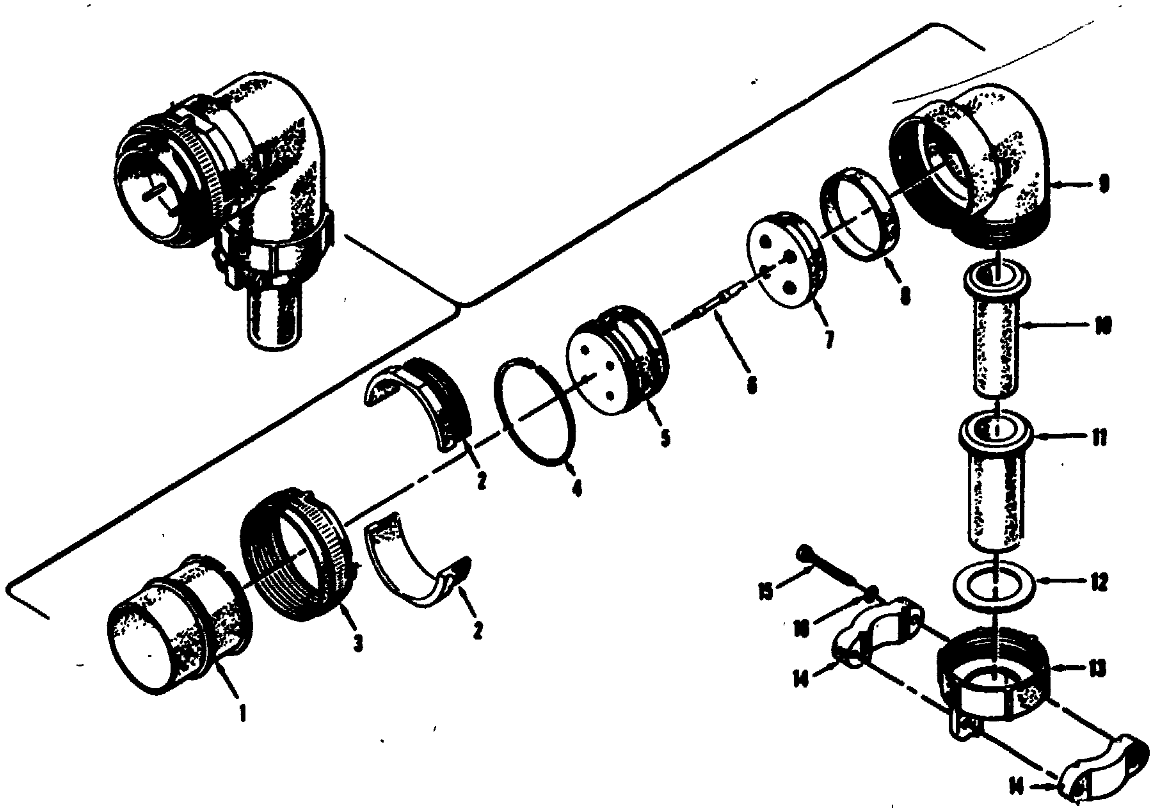

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Figure 8-18.—Exploded view of an environment resistant angle connector.

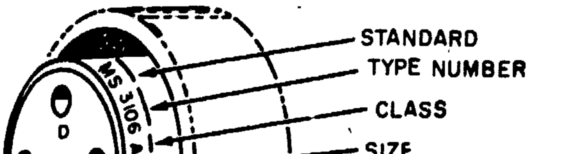

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Figure 8-19.—MS connector marking.

Pressurized connectors provide a pressuretight feed-through for wires that pass through walls or bulkheads of pressurized compartments. The contacts are usually molded into the insulator, and the shell is spun over the assembly to seal the bond.

Fireproof connectors are made under specifications which require that the connector maintain effective electrical service for a limited time even when exposed to fire. The inserts are made of a ceramic material, and special crimp type contacts are used.

Environment resistant connectors are used in areas where changes in temperature may cause condensation, or where there is likely to be vibration. The components of this kind of connector are shown in figure 8-18.

Each connector is given an identification symbol, called the MS part number. This symbol indicates the shell type, the shell design, the size, the insert type, the insert style, and the insert position. An example is the designator MS 3106A18-4SX. (Refer to fig. 8-19.)

1. The standard letters indicate that the connector was manufactured to Government Standards.

2. The type number indicates the type of shell. (Refer to fig. 8-16.)

3. The class letter indicates the design of the shell and the purpose for which the connector is normally used.

4. The size number indicates the shell size, either by outside diameter of the mating part of the insert, or by the diameter of the coupling threads, in sixteenths of an inch.

5. The insert arrangement number indicates the arrangement of the contacts in the insert, but not the number of contacts.

6. The contact style letter indicates that the contacts are of one of two styles: socket (female), indicated by the letter "S", or pin (male), indicated by the letter "P".

7. The insert rotation letter indicates an alternate insert position. Insert rotation letters W, X, Y, or Z, indicate that the insert has been rotated, with respect to the shell, a specified number of degrees from the normal position. If the insert is in the normal position, no letter is used.

NOTE: For more detailed information on types and designations of connectors, refer to NavAir 01-1A-505, Handbook of Installation Practices for Aircraft Electric and Electronic Wiring.

It will sometimes be necessary for the ASE to fabricate a cable using connectors. The type of connector to be used is specified in the Service and Overhaul Instruction Manual for the particular equipment. Following is an outline of the procedure for fabricating a cable:

1. Disassemble the connector to allow access to the contacts, and devise a means of holding the connector so that both hands are free. A small bench vise is useful for this purpose.

2. Cut the cables to the correct length.

3. Strip the wire ends with a wire stripper or knife. If a knife is used, avoid cutting or nicking the wire strands.

4. Tin the bare wire ends.

5. Run the wires through the connector assembly and coupling nuts.

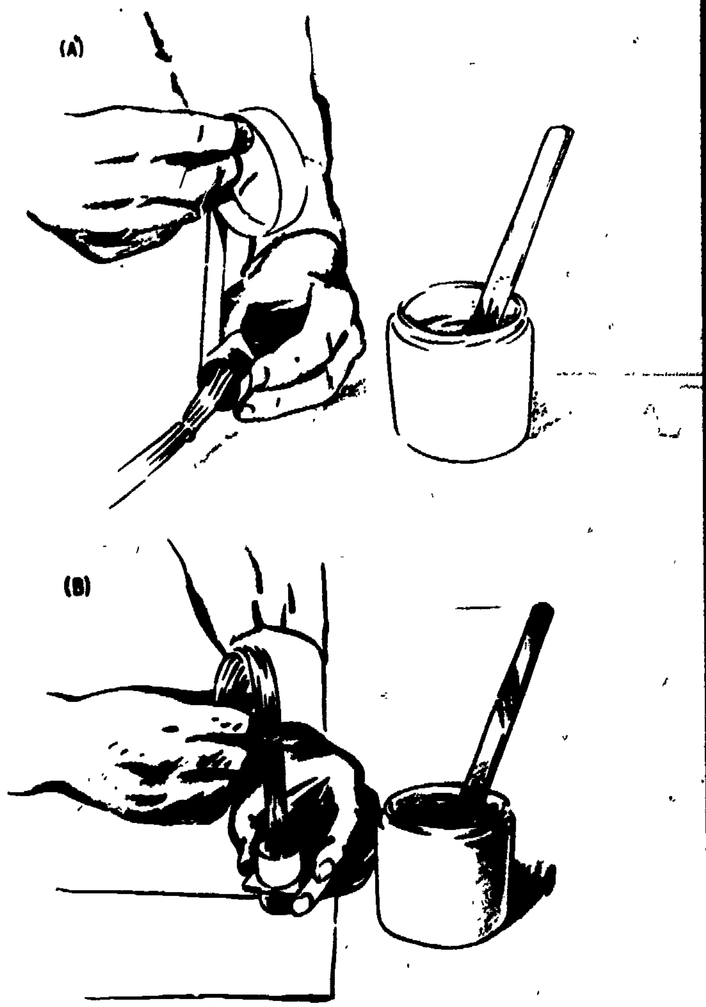

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Figure 8-20.—(A) Making a mold from masking tape; (B) finished potted plug.

6. See that all surfaces are clean.

7. Flow rosin-core solder into the connector terminals.

8. Insert each wire into its terminal by holding the tip of the soldering iron against the terminal. As the solder melts, push the wire into the cavity, and then hold the wire steady while the solder cools.

Care should be taken to avoid injuring the connector insulation with the soldering iron. When soldering the connector, follow a prearranged sequence; the recommended sequence is to start from the bottom connection and work from left to right, moving up a row at a time. After soldering the connections, the shields, if used, are soldered to a common terminal on a ferrule. The cable is then laced and the connector reassembled and moisture proofed if necessary.

Fabricating instructions are contained in NavAir 01-1A-505, Handbook of Installation Practices for Aircraft Electric and Electronic Wiring.

Moistureproofing (potting), though not required on environment-resistant type connectors, will sometimes be required on other types of connectors because of the operating environment of the equipment. Sealing compounds and their applications are covered in chapter 5 of this manual.

Detailed instructions for performing sealing operations may be obtained from Avionics Change 376. A summary of these sealing operations is as follows:

1. Prepare a used connector by removing existing sealants, and cleaning. The cleaning solvent used must clean thoroughly, evaporate quickly, and leave no residue. Remove all sleeving from the wires. Resolder loose or poorly soldered connections and add a length of wire approximately 9 inches long to each unused pin. Remove any excess rosin from around the pins and the insert; a stiff bristle-brush is helpful in doing this. Now repeat the cleaning operation and seperate the wires evenly.

In preparing a new connector, solder wiring to the connector pins as required for the intended use and, in addition, the spare wires mentioned above. Remove the excess rosin, clean and spread the wires.

2. Obtain the proper sealing compound for the environment of the connector and thoroughly mix the accelerator and base compound. (See chapter 5.)

3. Place the plugs or receptacles on a work bench, arranging them so that gravity will draw the sealer to the bottom of the plug. Box receptacles or plugs without back shells must be fitted with a mold which may be made from masking or cellophane tape, or an equivalent, that will retain the sealant during the curing process. If the back shell is used, apply a thin coating of oil to the inner surfaces to prevent the compound from adhering. [See fig. 8-20 (A) and (B).]

4. The compound is applied with a spatula, putty knife, or paddle and should be tamped around the base of the pins. The shell or mold being potted should be completely filled, or at least to a depth to cover 3/8 inch of insulated wire.

5. The compound is allowed to cure; the average curing time is 24 hours, but will vary according to the ambient temperature.

If it is desired that the entire connector assembly be sealed against moisture entering or collecting between the plug and the receptacle, it is necessary to install a preformed packing (O-ring) over the barrel of the plug. This provides a seal when the two parts are engaged securely. If properly installed, this seal prevents condensation, created by variations in temperature or barometric pressure, from occurring within the connector assembly. Preformed packings (O-rings) are available for this purpose through normal supply channels. Due to aging of these rings in service, it is necessary to examine them each time the connector is disassembled, and if deteriorated, they must be replaced.

The purpose of soldering a short length of wire to each spare pin is to provide for two eventualities: to allow for growth requiring additional circuits to be included in the connector, or to replace a wire which may have failed within the connector by making a splice to one of the spare wires.

In the event a spare wire is not available in the connector and a single wire must be replaced, the back shell may be removed. This may require considerable force, depending on how well the sealant adhered to the shell. Access to the desired lead and solder cup may be obtained by cutting away the compound with a knife. If a center wire of a large connector is defective and is beyond easy reach from the side, it may be better to remove the sealant from the center with longnose pliers until sufficient area is exposed to allow the defective lead to be repaired. The plug may be returned to its original condition by applying sealant to the connector in the manner previously described.

The new compound will adhere satisfactorily to the old compound remaining in the connector.

CABLE MAINTENANCE AND REPAIR

In the maintenance of cables and connectors, the first consideration is a thorough visual inspection. This check should reveal such defects as corrosion, chafing, loose connections, loose or broken strands, evidence of overheating, and battered or improperly mated connectors. Further checks can be made to ascertain if there are any open or shorted conductors in the cable. An ohmmeter is usually utilized to perform these checks.

CAUTION: Many ohmmeters are supplied with test leads which are slightly larger than female sockets used in the connectors. Forcibly inserting these probes will irreparably damage the sockets. Care must be exercised to prevent such damage.

In checking a suspected conductor, for either an open or a short, it may be necessary to apply a slight pressure to the conductor, or to simulate vibration. Shorts are often caused by moisture, foreign particles, or a defective solder connection at the plug terminals. Therefore, it is advisable to check the connectors carefully before replacing the cable.

In ground support equipment, conduit is eliminated wherever possible. Its elimination facilitites cable installation and maintenance. In replacing a cable, take particular care to replace it in the exact position in which it was installed originally. Do not attempt to reduce the length of the cable by taking what may seem to be a logical shortcut.

Replacement of Wiring

When installing or replacing wire or wire bundles, insure that there is no excessive slack along the run. Normally, slack should not exceed 1/2-inch deflection with normal hand pressure. A sufficient amount of slack should be allowed at each end to provide for:

1. Easy removal and connection of plugs.
2. Replacement of terminals two times.
3. Prevention of mechanical strain on the wires.

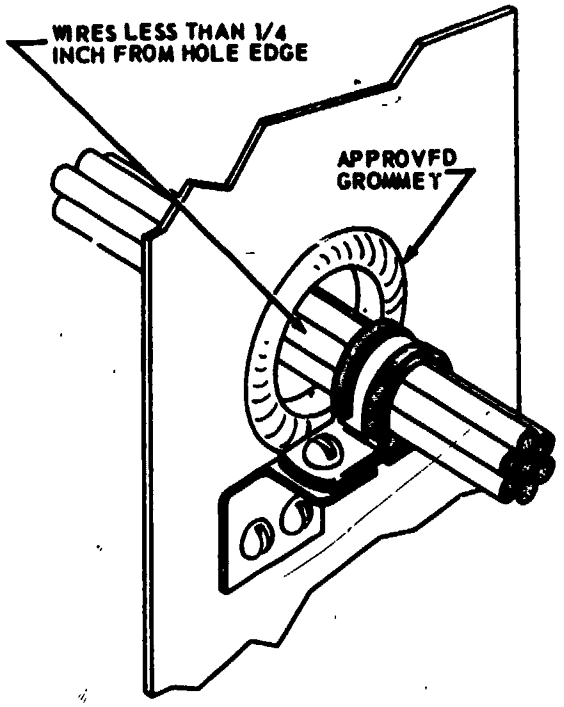

Figure 8-21.—Cable clamp and grommet at bulkhead hole.

4. Free movement of shock and vibration-mounted equipment.
5. Shifting of equipment for maintenance.

Bends in individual wires should normally be limited to a minimum bend radius of 10 times the diameter of the bundles; however, where the wire is suitably supported at each end of the bend, a minimum bend radius of 3 times the diameter of the bundles is acceptable.

Wires passing through a bulkhead or structural member must be supported at the hole by a cable clamp, or by use of an approved supporting grommet in the hole if less than 1/4-inch clearance exists between the wire and the edge of the hole. (See fig. 8-21)

Maintain a clearance between wiring and any movable control. If this cannot be done, install guards to prevent contact of the wiring with the control. When the wiring must be routed parallel to plumbing carrying flammable fluids, maintain as much separation as possible. Never

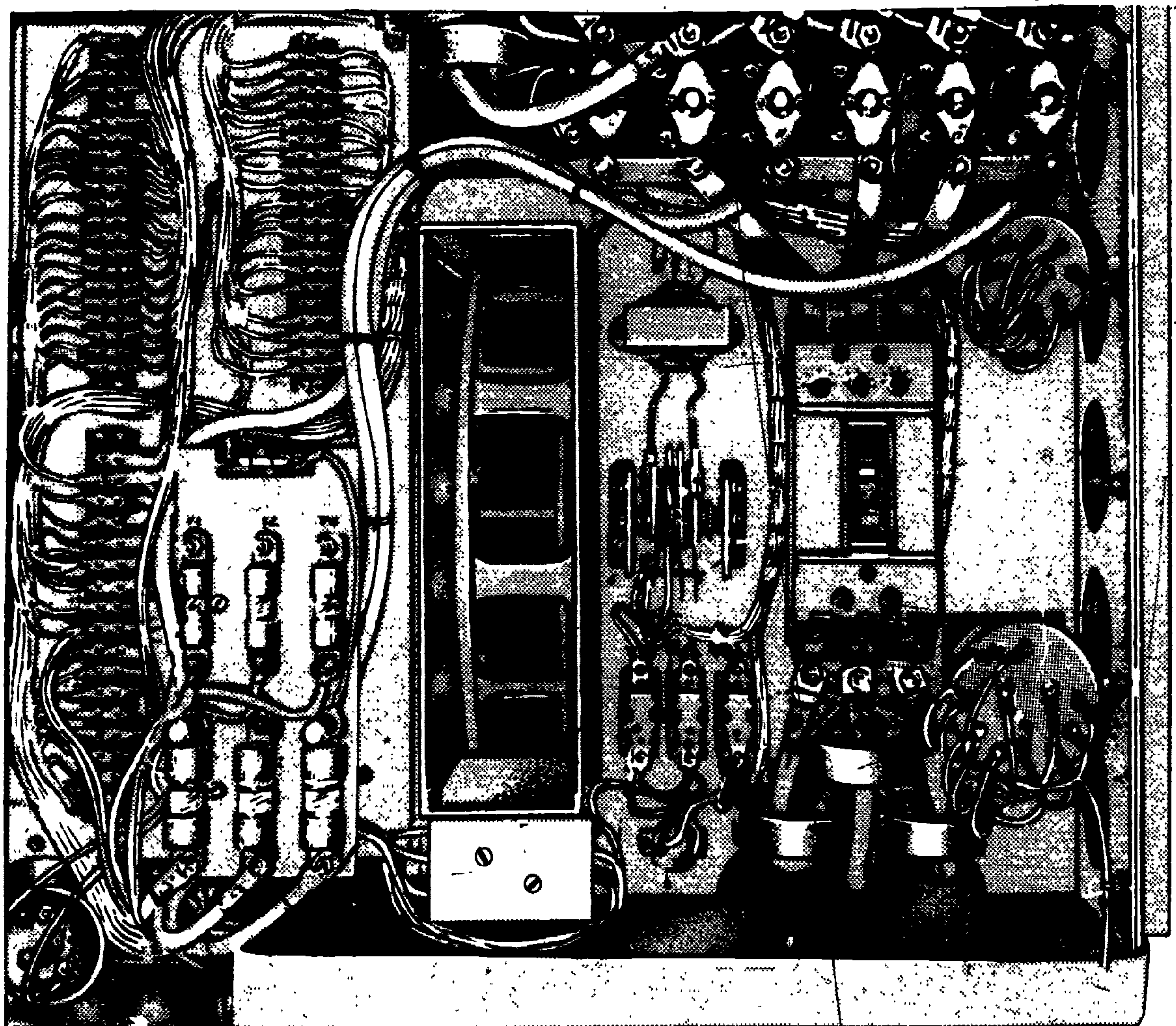

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Figure 8-22.—Wire bundles laced and tied in an electrical control panel.

support any wire or wire bundle from a plumbing line carrying combustible liquids.

Cable clamps should be installed so that the mounting screws are above the wire bundle. Otherwise the weight of the cable may bend and break the clamp. It is also desirable that the back of the clamp rest against a structural member if practical. Be careful not to pinch wires in the cable clamp.

LACING AND TYING.—Wire groups and bundles are laced or tied with cord to provide ease of installation, maintenance, and inspection. It keeps the cables neatly secured in groups and bundles to help avoid possible damage from chafing or equipment operation. A typical example is the electrical control panel of the NC-10 illustrated in figure 8-22.

Tying is the securing together of a group or

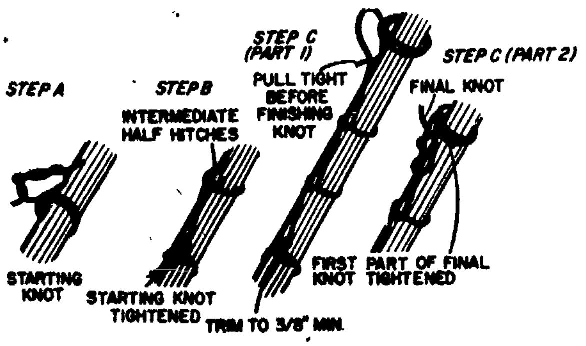

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Figure 8-23.—Single cord lacing.

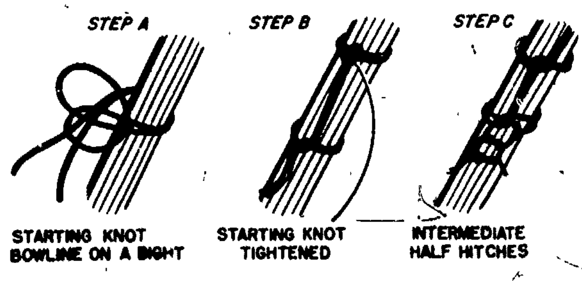

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Figure 8-24.—Double cord lacing.

bundle of wires by means of individual pieces of cord ties around the group or bundle at regular intervals.

Lacing is the securing together of a group or bundle of wires inside enclosures, by means of a continuous piece of cord, forming loops at regular intervals around the group or bundle. A wire group is two or more wires tied or laced together to give identity to an individual system. A wire bundle is two or more wires or groups tied or laced together to facilitate maintenance.

Use cotton, nylon, or fiberglass cord for lacing or tying. Cotton cord must have been waxed to make it moisture and fungus resisting. Nylon and fiberglass cords are in themselves moisture and fungus resisting, and are not usually waxed. Use pressure sensitive vinyl electrical tape only where the use of tape instead of cord is specifically permitted.

When lacing or tying, observe the following precautions:

1. Lace or tie bundles tightly enough to prevent slipping, but not so tight that the cord cuts into or deforms the insulation.

2. Do not place ties on that part of a wire group or bundle that is located inside a conduit.

3. Lace wire groups or bundles only inside enclosures, such as junction boxes. Use double cord on groups or bundles larger than 1 inch in diameter. Use single or double cord for groups or bundles 1 inch or less in diameter.

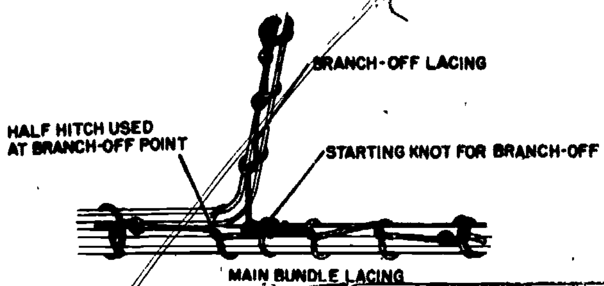

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Figure 8-25.—Lacing a branch-off.

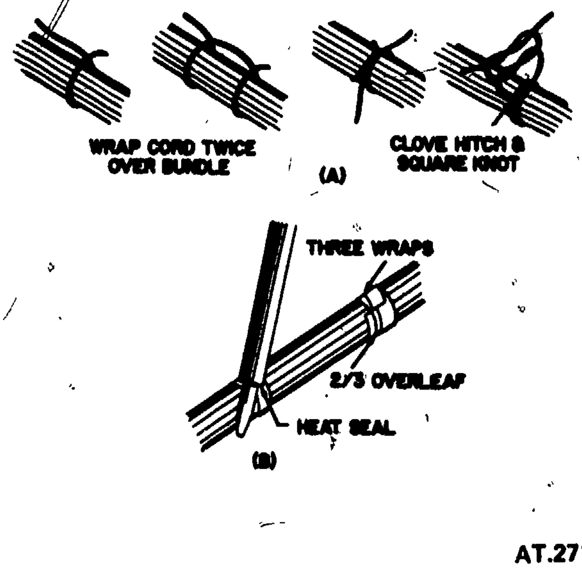

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Figure 8-26.—Tying groups or bundles.

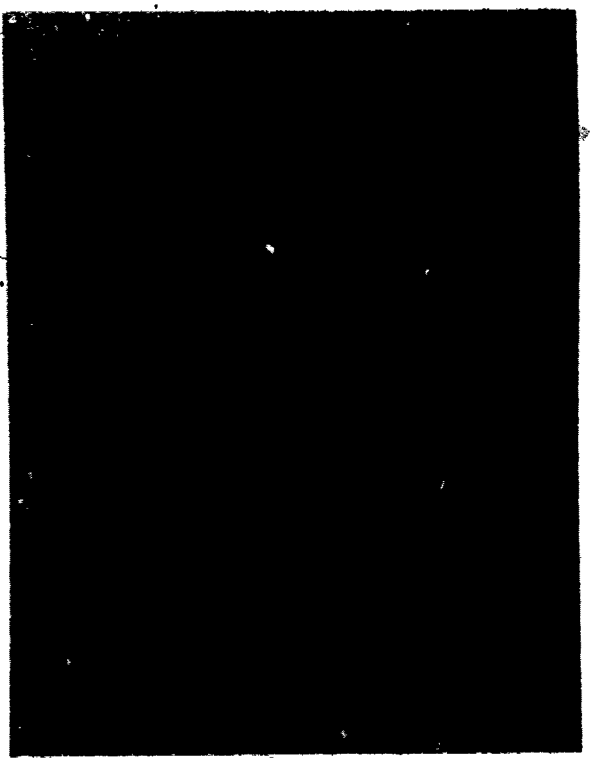

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Figure 8-27.—Installing self-clinching cable strap.

Lace a wire group or bundle with a single cord as follows:

1. Start the lacing at the thick end of the wire group or bundle with a knot consisting of a clove hitch with an extra loop. (See fig. 8-23.)
2. At regular intervals along the wire group or bundle, and at each point where a wire or wire group branches off, continue the lacing with half hitches. Space half hitches so that the group or bundle is neat and securely held.
3. End the lacing with a knot consisting of a clove hitch with an extra loop.
4. Trim the free ends of the lacing cord to 3/8-inch minimum.

Lace a wire group or bundle with a double cord as follows:

1. Start the lacing at the thick end of the wire group or bundle with a bowline on a bight. (See fig. 8-24.)
2. At regular intervals along the wire group or bundle, and at each point where a wire group branches off, continue the lacing with half hitches, holding both cords together. Space half hitches so that the group or bundle is neat and securely held.
3. End the lacing with a knot consisting of a half hitch, using one cord clockwise and the other counterclockwise, and then tying the cord ends with a square knot.
4. Trim the free ends of the lacing cord to 3/8-inch minimum.

Lace a wire group that branches off the main wire bundle as follows:

1. Start the branch-off lacing with a starting knot (fig. 8-25) located on the main bundle just past the branch-off point. When single cord lacing is used, make this starting knot the same as for regular single cord lacing. When double cord lacing is used, use the double cord lacing starting knot.
2. End the lacing with the regular knot used in single and double cord lacing, as previously described.
3. Trim the free ends of the lacing cord to 3/8-inch minimum.

Tie all wire groups or bundles where supports are more than 12 inches apart. Space ties 12 inches or less apart.

Make a tie as follows:

1. Wrap cord around wire group or bundle, as shown in (A) of figure 8-26.
2. Make a clove hitch, followed by a square knot with an extra loop.
3. Trim free ends of cord to 3/8-inch minimum.

When tying sleeves to wire groups or wire bundles, the ties are made the same as for wire groups and bundles.

When it is permissible to use tape, the following method should be employed:

1. Wrap tape around the wire group or bundle three times, with a two-thirds overlap for each turn. (See (B) of fig. 8-26.)
2. Heat-seal the loose tape end with the side of a soldering iron heating element. Do not use tape for securing wire groups or bundles which may require frequent maintenance.

Self-clinching cable straps are adjustable, lightweight, flat, nylon straps, with molded ribs or serrations on the inside surface to grip the wire. They may be used instead of individual cord ties for fast securing of wire groups or bundles. Cable straps are available in various sizes and colors to clamp and identify different sizes of wire groups or bundles.

Select a strap of the desired color and size for the wiring bundle and install, using the tool specified for the size strap selected. (See fig. 8-27.)

SHIELDING, BONDING, AND GROUNDING

Shielding is the enclosing of cables or electrical units in metal to prevent electrical interference. Formerly, shielding was accomplished by enclosing all electronic and electrical equipment and cables. To shield a cable, it was sometimes enclosed in a conduit (metal tube or pipe). In modern equipment, however, conduit has practically been eliminated. With the exception of some ignition system harnesses, electric cables which may generate electrical interference are shielded satisfactorily by installing them where the metal covering of the equipment provides the shield. Thus, when replacing a cable it is important that it be installed in the position in which it was originally installed.

Cables which carry the ignition spark for an engine are often shielded by a woven metal braid. This braid provides flexibility and ease of installation. Where shielded cables are used, it is very important that each end of the cable be well grounded.

Bonding and grounding connections are made for the following purposes:

1. To provide power current return paths.
2. To protect personnel from shock hazards.
3. To prevent accumulation of static electrical charges.

Bonding is the electrical connection of two or more conducting objects not otherwise adequately connected. Grounding is the electrical connecting of a conducting object to the primary structure for the return of current. The primary structure is the frame (chassis) of the equipment and is the electrical ground.

When making bonding or ground connections observe the following general precautions and procedures:

1. Bond or ground parts to the primary structure where practical.
2. Make bonding or grounding connections in such a way as not to weaken any part of the structure.
3. Bond parts individually whenever possible.
4. Make bonding or grounding connections against smooth clean surfaces.
5. Install bonding or grounding connections so that vibration, expansion or contraction, or relative movement incident to normal service use will not break or loosen the connection.
6. Locate bonding and grounding connections in accessible areas to permit easy inspection and replacement.
7. Do not compression-fasten bonding or grounding connections through any nonmetallic material.

Hardware used to make bonding or grounding connections is selected on the basis of mechanical strength, current to be carried, and ease of installation. Where connections are made by aluminum/copper jumpers to a structure of dissimilar material, a washer of suitable material is installed between the dissimilar metals so that any corrosion which may occur will occur in the washer (which is expendable) rather than in the structure.

When repairing or replacing existing bonding or grounding connections, use the same type of hardware as in the original connection.

Clean bonding and ground surfaces thoroughly before making the connection. Remove all oil, grease, paint, anodized film, or other nonconducting material from an area slightly larger than the connection.

Apply a coating of petrolatum compound to the bonding or grounding surface of an aluminum structure and clean the surface thoroughly, using a steel wire brush with pilot as shown in figure 8-28. Then wipe off the petrolatum compound with a clean dry cloth.

Prepare magnesium alloy surfaces for bonding or grounding as follows:

1. Remove grease and oil from the surface with Stoddard solvent.

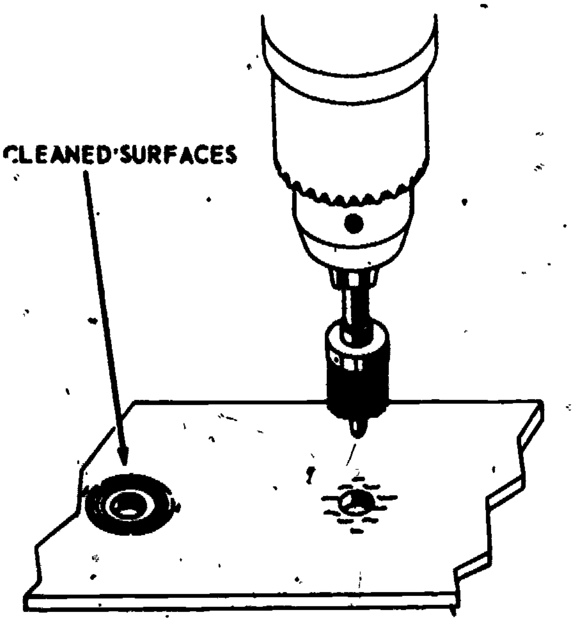

Figure 8-28.—Cleaning a bonding connection.

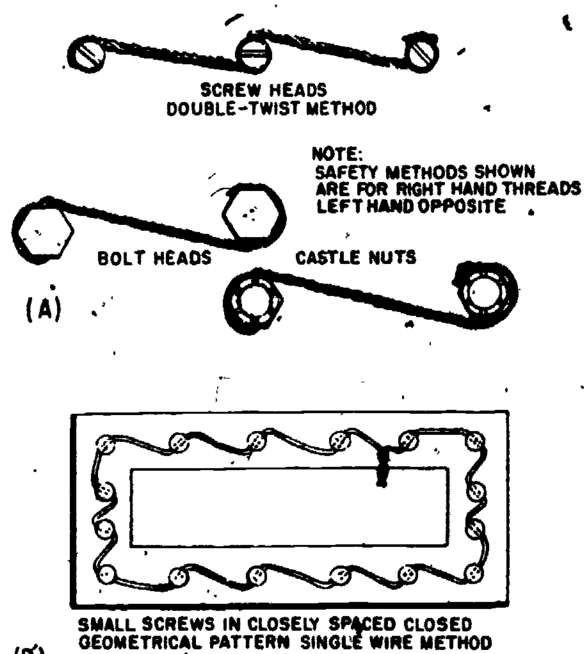

Figure 8-29.—Safety wiring nuts, bolts, and screws.

2. Remove paint, if present, from the surface with an approved paint remover.

3. Brush the area liberally with chrome pickle solution for 1 minute, then rinse within 5 seconds by brushing with clean water.

4. Dry thoroughly.

When the surface is corrosion-resisting or plated steel, clean the bonding or grounding surface as described in steps 1 and 2 above. Do not remove zinc or cadmium plate from steel surfaces. After cleaning a connection and attaching the bonding or grounding connection, refinish the surfaces in accordance with approved practices.

SAFETY WIRING

Some equipment parts require positive (safety) locking devices. The use of safety wire is one accepted method of providing this positive locking measure.

The most common application of safety wire is the tying together of nuts, bolts, screws, and connector parts to prevent them from coming loose due to vibration.

One accepted method of safetying nuts, bolts, and screws is known as the double-twist method. Twisting may be accomplished by hand, or special safety wire pliers may be used. (See fig. 8-29 (A).) If the twists are made by hand, the final few twists should be made with pliers in order to apply tension and secure the ends of the wire properly. The safety wire should always be installed and twisted so that the loop around the head stays down and does not tend to come up over the bolthead, causing a slack loop. Care must be exercised when twisting the wires together to insure that they are tight but not overstressed to the point where breakage will occur under a slight load or vibration. Always use new safety wire on every job and take care to use pliers only on the ends of the wire so as not to nick the wire. If safety wire becomes nicked, discard it and use a new piece. When the final twists are made with pliers, cut off the loose ends that have been nicked by the pliers and bend the end of the wire around the bolt or screw head to protect personnel from the sharp ends.

The single wire method of safety wiring (fig. 8-29 (B)) may be used on small screws in a closely spaced area provided the screws form a closed geometrical pattern. Note that any loosening tendencies will pull against the tension of the wire. Never "back off" or over-torque in order to aline holes for safety wiring.

Safety wire electric connectors only when specified on engineering drawings or when experience has shown the connector will not stay tight. Electric connectors are usually safety wired in areas of high vibration, and in locations not readily accessible for periodic maintenance inspection.

When it is necessary to safety wire electric connectors, use 0.032-inch diameter safety wire whenever possible. On small parts with holes 0.045-inch nominal diameter or smaller, use 0.020-inch diameter safety wire. If the connector to be safety wired does not have a wire hole, remove the coupling nut and drill a No. 56 (0.046-inch diameter) hole diagonally through the edge of the nut. Figure 8-30 shows a properly safety wired connector.

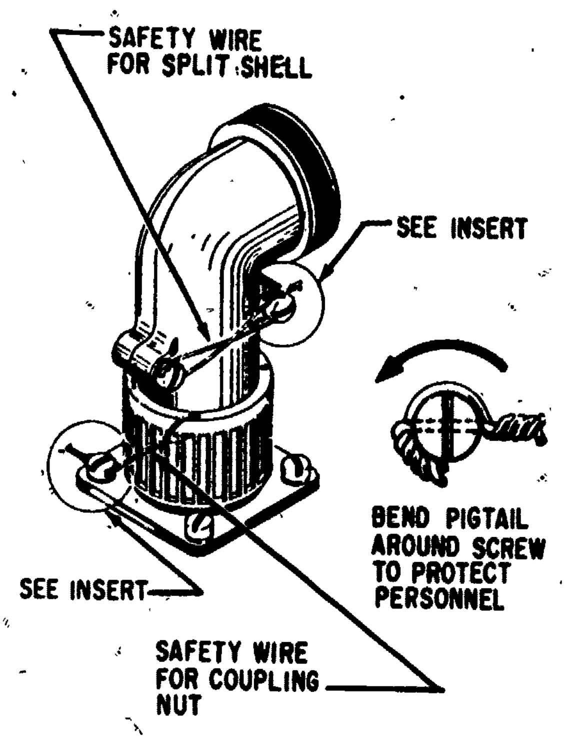

Figure 8-30.—Safety wiring a connector.

PRINTED CIRCUIT REPAIR

The trend toward replaceable units has led to several new methods of construction of electronic equipment, an example of which is the printed circuit. This type circuit is designed for speed and economy of manufacture and speed and ease of maintenance, as well as saving of space and weight.

Circuit Construction

One method of manufacturing a printed circuit is the "photoetching" process. A plastic or phenolic sheet with a thin layer of copper coating may be used. The copper coating is covered with a light-sensitive enamel. A template of the circuit that will ultimately appear on the plastic sheet is placed over it and the entire sheet is then exposed to light. The area of the copper that is exposed reacts to the light, and this area is then removed by an etching process. Exposure of the printed circuit is similar to a photographic exposure. The enamel on the unexposed circuit protects the unexposed copper from the etching bath that removes the exposed copper. After the etching bath, the enamel is removed from the printed circuit. This leaves the surfaces in a condition for soldering parts and connections.

Some manufacturers use machinery to mount standard parts like capacitors, resistors, and tube sockets—further speeding manufacture. Circuits thus produced operate as well as conventional circuits and are as easily repaired.

Repair Technique

The Navy Electronics Laboratory tested many standard capacitors and resistors soldered to terminals of various types. These were subjected to vibrations far in excess of those encountered in military ships, aircraft, and other vehicles. Although the connections were deliberately made without wrapping the wires around the terminals before soldering, there were no failures. (See fig. 8-31.) Similar tests, with equally encouraging results, have been conducted by a

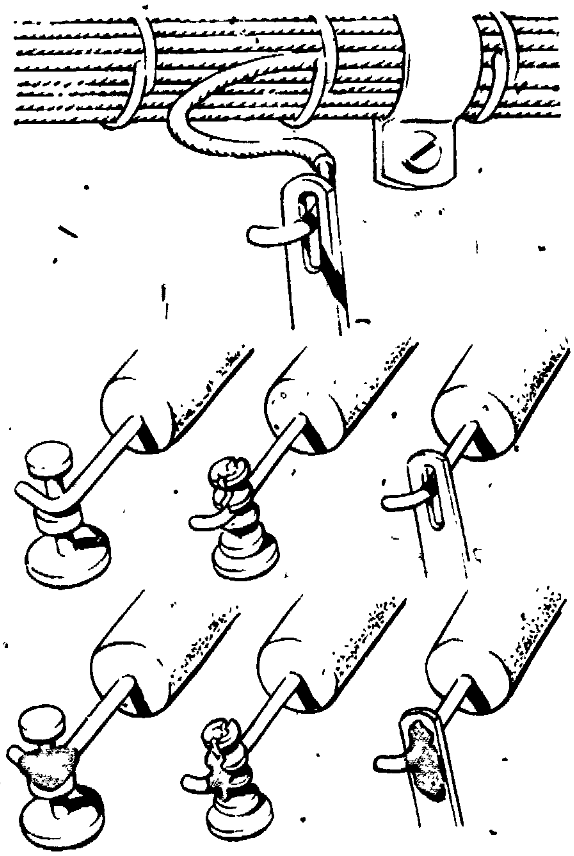
AS.206

Figure 8-31.—Soldering method recommended by the Navy Electronics Laboratory.

number of commercial electronics firms.

The advantages to be gained from using connections that depend on solder for strength are:

1. Ease of assembly.
2. Ease of removal for test or replacement.
3. Less chance of poor soldering (lack of solder in joints and/or rosin joints) since faulty soldering is more readily detected by visual or electrical inspection methods than when the wire is wrapped before soldering.
4. Less heat required in soldering and unsoldering.
5. Less strain on parts since their leads do not receive as much pulling and twisting as with the conventional wrapping technique.

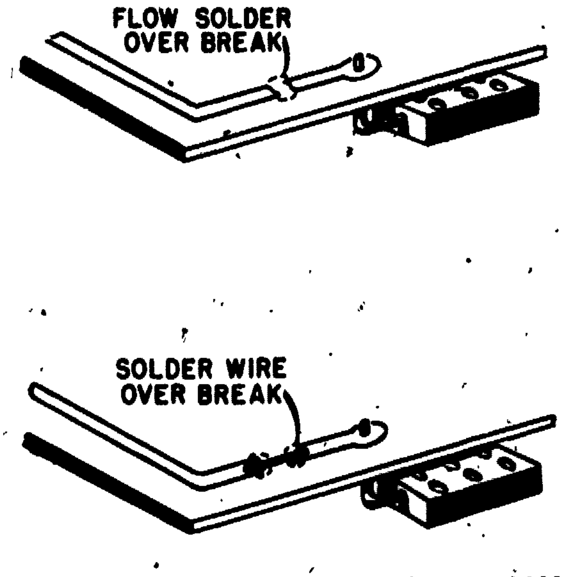

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Figure 8-32.—Repairing breaks in foil.

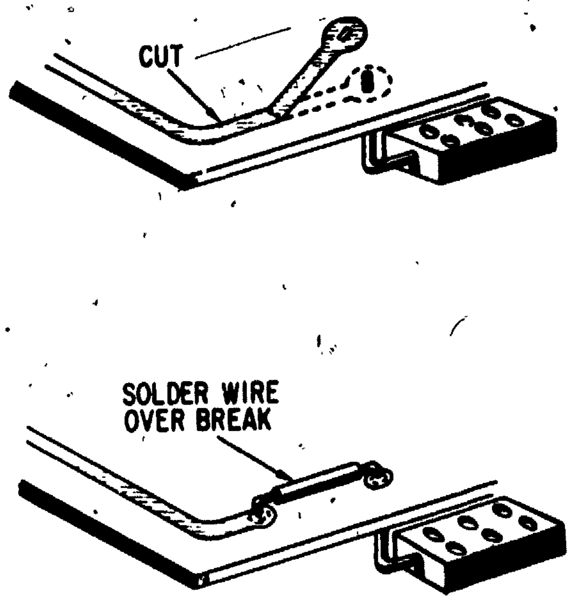

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Figure 8-33.—Repairing raised portion of foil.

Therefore, it is recommended that small parts be connected with no more than one-half turn of wire around the terminal, followed by a simple and neat soldering job. This procedure is especially advantageous in printed circuit work.

The printed circuit presents certain difficulties in soldering, techniques that are not common to conventionally wired circuits. Certainly these printed circuits cannot be repaired in a careless manner; but with a little care and commonsense, satisfactory repairs can be made.

Should a printed circuit become broken, it is easily repaired by placing a short length of bare copper wire across the break and soldering both ends to the print; or, if the break is small, simply flow solder across it. (See fig. 8-32.) When performing these operations, do not apply too much heat, and do not permit solder to flow to other printed areas.

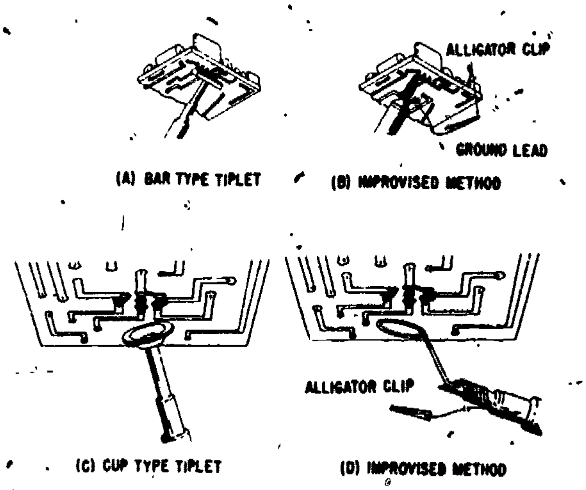
The phenolic boards used for printed circuits are similar to the phenolic strips used for conventional terminal strips and mounting boards. There has been no difficulty in soldering to the metal connectors on these terminal strips and mounting boards, so there should be none in soldering printed circuits. In rare cases where excessive heat causes separation of printed conductors from the phenolic board, repairs can be made by using jumper wires. (See fig. 8-33.)

Parts Replacement

In the previous paragraphs, repair of the printed portion of the printed circuit board was discussed. In the following paragraphs, parts such as transistors, resistors, capacitors, etc., which have soldered connections are discussed.

Removal of a part from a printed circuit board without damaging the printed circuit or the associated parts requires that the soldering tool be used with precision and skill.

UNSOLDERING.–When it is necessary to do any unsoldering, the pencil iron and special tips become quite useful. Figure 8-34 (A) illustrates the use of special tips to unsolder multiple terminals. However, it is possible to do the unsoldering with the improvised method illustrated in figure 8-34 (B). A ground lead connected from the tip of the soldering iron to the frame or chassis will prevent damage to transistors and other parts due to leakage current in the soldering iron. Often it is more convenient,



AS.249
Figure 8-34.–Unsoldering multiple terminals.

and it is always safer, to completely remove the module and work on it on an insulated surface.

The general procedure recommended for removing soldered parts is applicable to most connections. A chassis holding jig, as shown in figure 8-35, can be easily fabricated to hold the printed circuit boards. The use of such a jig allows the worker to make repairs easily and safely. (For details in constructing the jig, refer to NavShips 900,000.100.)

Position the board in a jig so that the terminals to be unsoldered are facing out and down. Place the tip of a hot pencil soldering iron under and against the terminal. The solder will flow to the soldering tip, and may be removed from the tip by wiping. Remove sufficient solder from each of the terminals to free the part. When the terminals have been loosened, lift the part from the board. The part to be removed should never be pried or forced loose. Any attempt to force a part loose may result in a broken or separated printed circuit panel. If the terminals do not pass easily through their holes, chances are that all the solder has not been removed. Remove any solder left in the terminal hole after removing the leads, by applying the soldering iron to the hold just long enough to soften the solder, and then poke the softened solder out with a toothpick, scribe, or small brush.

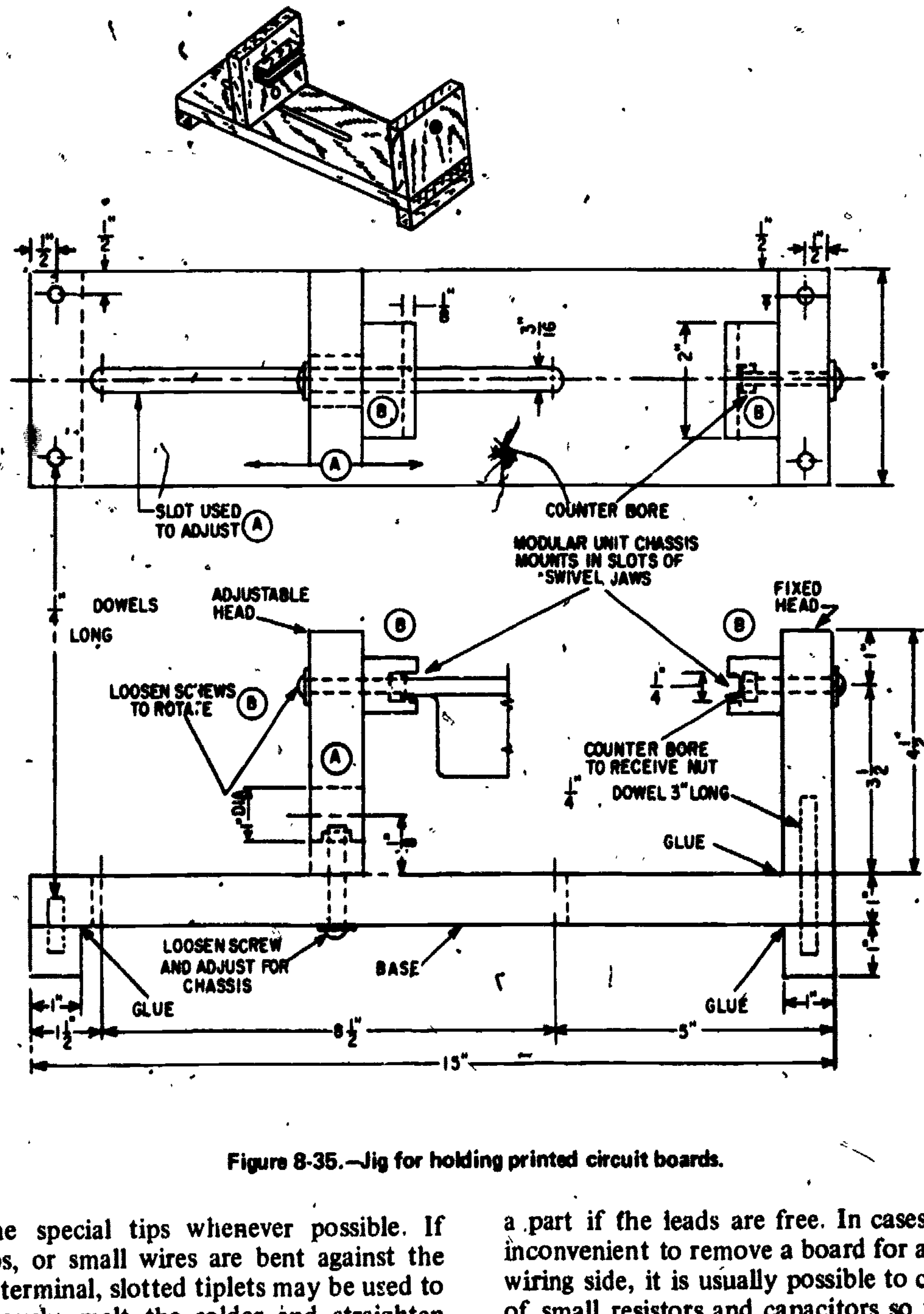


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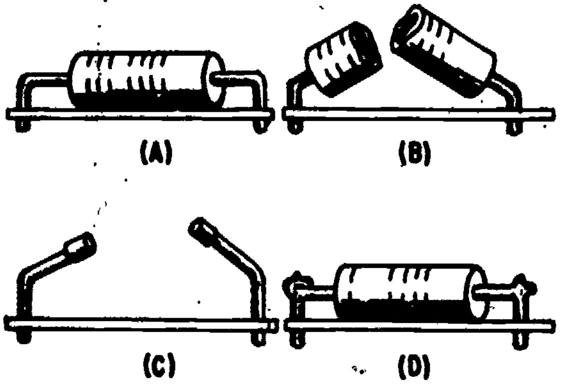
Figure 8-35.—Jig for holding printed circuit boards.

Use the special tips whenever possible. If leads, tabs, or small wires are bent against the board or terminal, slotted tiplets may be used to simultaneously melt the solder and straighten the leads.

Parts such as resistors and small capacitors are most conveniently removed if first cut to free their leads. Much less heat is required to remove a part if the leads are free. In cases where it is inconvenient to remove a board for access to the wiring side, it is usually possible to cut the leads of small resistors and capacitors so that a small portion of the lead is exposed. The new part can then be soldered to the old leads. This technique is shown in figure 8-36.

The bar tiplet will remove straight-line multi-



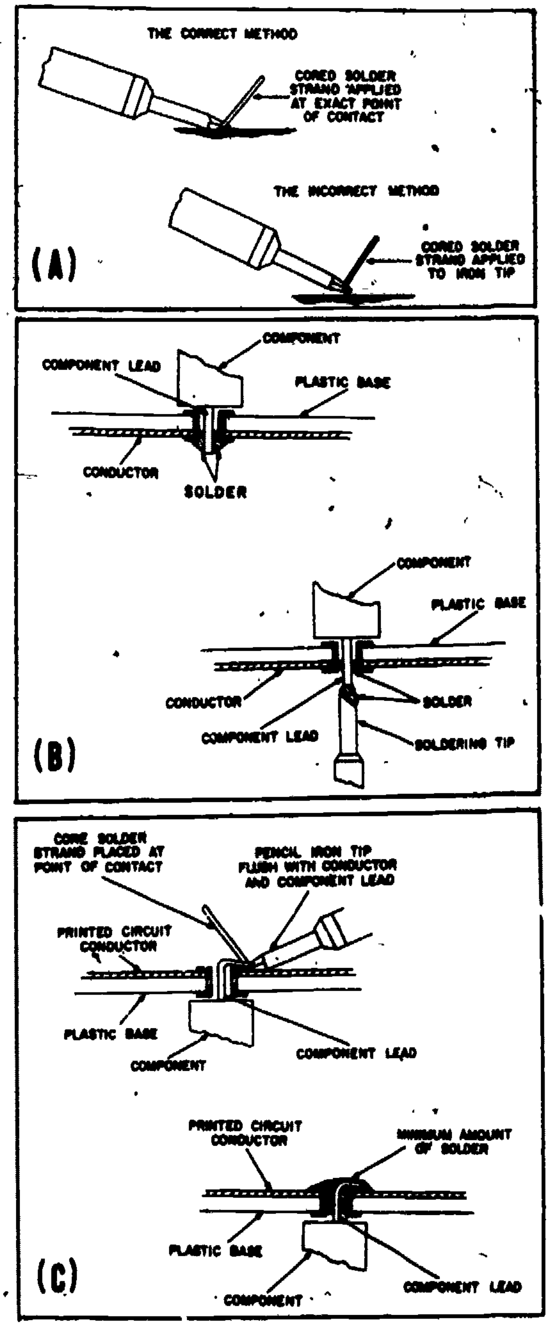
AT.268
Figure 8-36.—Replacement of a resistor on a printed circuit.

terminal parts quickly and efficiently, as shown in figure 8-34 (A). The same thing can be done by individually heating each solder connection and brushing away the melted solder.

With the latter method, particular care must be taken so that loose solder does not stick to other parts or the printed panel where it may cause a short. Another way is to improvise a tip to cover all the connections simultaneously, as illustrated in figure 8-34 (B). Care must be exercised to see that this tool contacts only the terminals to be unsoldered—nothing else. Do not allow the tool to remain in contact too long at a time.

The cup tiplet, the triangle tiplet, and the hollow cube tiplet are specially designed to withdraw solder from circular or triangular mounted parts in one operation, as shown in figure 8-34 (C). If these tools are not available, an improvised tip may be used by shaping it to cover the terminals. The same procedures and precautions given for unsoldering straight-line terminals apply here.

Most of the components mounted on a printed circuit board can be removed by the method described. If a problem arises which has not been covered here, spend a little time thinking about the best way to remove the part. The planning done prior to beginning work on a printed circuit will save time in the end.



AS.250
Figure 8-37.—Soldering techniques.

AS.251

Figure 8-38.—Reducing tip heat.

In some cases, excess solder at a printed circuit connection may make removal difficult. The following method may be helpful in such cases: Coat a piece of clean copper braid (such as a braided ground strap or length of cable shield) with a noncorrosive solder flux and apply it to the connection. Heating the braid with a soldering iron will cause the excess solder to transfer to the braid. Be careful not to overheat.

SOLDERING.—There is quite an art to proper soldering, and much experience is required before becoming proficient. The proper length of time that heat must be applied depends on a number of factors which will normally vary from one connection to another. These are the kind and amount of metal involved, the degree of cleanliness, the ability of surrounding materials to withstand heat, and the heat transfer characteristics.

Tinning the work is virtually always desirable unless it has already been done. In any event, the iron should be tinned in at least one spot, or heat transfer to the desired region with adequate control of the heat spillover to nearby materials becomes quite difficult.

Maintaining proper tinning of the tip is easier if the tip is tinned with silver solder. This is because the temperature at which the bond between the copper tip and the silver solder is formed is considerably higher than with lead-tin solder. Retinning of the tip too frequently, using conventional solder, results in using up the tip material faster than required, especially if much filing is done when preparing the surface for tinning.

Cleanliness is a prime prerequisite for efficient, effective soldering. Due to the temperatures involved and the presence of oxygen in the atmosphere, heated metals can be expected to oxidize rapidly, and the oxide must be removed, or penetrated, before a good solder joint can be made.

The proper method of solder removal and application is illustrated in figure 8-37 (A), (B), and (C). Part (A) illustrates the correct and incorrect methods of solder application. The correct method for removing solder from a component without damaging the printed wiring circuits is shown in (B). Part (C) shows the correct method for applying solder to a replaced component.

SOLDERING TEMPERATURE.—All high quality irons have an operating temperature range of 500° to 600° F. This also applies to 25-watt midget irons. The important difference in iron sizes is not temperature, but rather the capacity of the iron to generate and maintain a satisfactory soldering temperature while giving up heat to the joint to be soldered. Naturally, a 25-watt iron would not be used to solder a heavy box; however, it would be quite suitable for replacing a half-watt resistor in a printed circuit. A 150-watt iron may be satisfactory for use on a printed circuit provided proper soldering techniques are used. (See fig. 8-38.) Advantages of using a small iron for small work are that it is light, easy to handle, and has a small tip that is easily inserted into close places.

A well-designed iron is self-regulating by virtue of the fact that the resistance of its element increases with rising temperature, thus limiting the flow of current. For critical work, it is convenient to have a variable transformer for fine adjustment of heat; but for general-purpose work, no temperature regulation is needed.

EQUIPMENT REMOVAL AND REINSTALLATION

Planning is the most important step in equipment removal and installation. Planning must include such items as obtaining the proper tools, removing hazards to personnel and equipment, shop space, and reinstallations prior to the actual removal. If these things are not considered and plans made accordingly, there may be time lost, personnel injuries, or equipment damage.

To remove a major unit for maintenance, periodic check, or lubrication, plan the removal carefully. The route the unit must take from its mounts to the shop space must be clear. This includes clearing beneh space or other area in the shop where the unit is to be placed.

Before disconnecting electrical connectors or cables, either tag each connector and cable or make a diagram showing their respective positions and identify them. This insures that they will be replaced properly when the time comes to reinstall the unit. Most equipments are made so there are no identical connectors or cables, but occasionally such a condition does exist. On such occasions improper installation is prevented by tagging the connectors or cables with the proper identification information written on the tag.

Even though the maintenance problem may be basically electrical, mechanical connections will also be involved in the removal of the major unit. Some mechanical connections must be noted so they may be reconnected in a particular position. These mechanical connections may be gears, splined shaft and coupling, quick disconnect devices, or any of various others. Whatever the type of connection, consideration must be made for their alinement upon reinstallation.

The necessary and proper tools must be obtained. Wrenches, screwdrivers, pliers, and if the equipment is extremely heavy, a hoist, may be required. If help is needed, personnel must be obtained. The entire removal procedure must be thoroughly explained to them, emphasizing to each man his specific job. The person in charge of the removal will issue all instructions timed so that the result will be a smooth effective operation. The work should be done with caution to eliminate the possibility of injury to personnel or damage to the equipment. Observe all the safety precautions.

When the major unit is in the shop, certain precautions should be followed prior to disassembly or removal of assemblies or subassemblies. The outside of the unit should be cleaned, as discussed in the previous section. When the dust covers are removed, any gaskets in use should be inspected. If found damaged, new ones must be obtained.

It should be emphasized that the correct procedure for removing or reinstalling any particular major unit, assembly, or subassembly will be found in the maintenance manuals for the equipment.

Reinstallation is usually just the reverse of the removal procedure. Although installation procedures are listed in the appropriate equipment manual, this phase of the operation presents a great deal of trouble. Most of the troubles result from carelessness and oversight c he part of the technician. Specific instances ... loose cable connections, switched cable terminations, and improper bonding.

Before quick-disconnect couplings are connected, their shafts should be checked for alinement. If the shafts are at an angle to each other, they may bind. When linkages are connected, the connecting pin or bolt must be checked to insure that with the motion of the linkage it will not catch or cause the linkage to bind.

Electrical connectors must be connected carefully to prevent bending or breaking the connecting pins. Do not attempt to connect a plug to the wrong receptacle.

All connections must be made securely. All connections, both mechanical and electrical, should be inspected to insure that they are properly alined. Any positive locking device that is required, such as stop nuts, safety wire, cotter pins, etc., must be installed.

MURPHY'S LAW

There is no doubt that all Aviation Support Equipment Technicians (E) are familiar with Ohm's law. There is another law with which the technician may not be quite so familiar. This law, known as Murphy's law, states that "IF AN AIRCRAFT PART CAN BE INSTALLED WRONG, NO MATTER HOW REMOTE THE POSSIBILITY, SOMEONE WILL INSTALL IT THAT WAY." This law was written about aircraft but history proves it applies as well to support equipment. To ignore this law can cause problems that range from embarrassment of the technician to actual destruction of equipment, injury, and death to personnel. Each month The Naval Aviation Safety Review, Approach, presents the problems caused by maintenance personnel when Murphy's law was proven ture.

For the ASE, the danger areas are installation of cable connector plugs on the wrong receptacles, crossing lines, installing tubes in the wrong sockets, etc. The possibilities are endless, and the good maintenance technician must be constantly alert to the dangers. Do not become victim to proving that Murphy's law is true.

CHAPTER 9
TEST EQUIPMENT

Many chapters of this training manual present basic principles and concepts of some of the equipment the technician will encounter. An understanding of the theory of operation of this equipment forms only a portion of the knowledge necessary to successfully perform the maintenance tasks required. A thorough knowledge of electrical and electronic test equipment is also needed.

The test equipment discussed in this chapter is typical of equipment currently in use. The purpose of this chapter is to acquaint the technician with some of the different types of test equipment (from the standpoints of theory of operation and general operational and maintenance procedures). No attempt is made to include theory beyond that necessary to describe the operation of the test set under discussion. Whenever the technician must use a piece of test equipment with which he is not familiar, he should consult the appropriate instruction manual. These publications contain detailed and specific information on the particular equipment.

Many of the general purpose test instruments are described in Basic Electricity, NavPers 10086 (Series) and Basic Electronics, NavPers 10087 (Series). Test equipment ranges from the simple basic meter to the complex multi-purpose systems test equipment.

METERS

All ground support equipment shops are equipped with various types of meters for measuring electrical quantities. For basic electrical measurements (voltage, current, and resistance), the permanent magnet moving-coil meter movement is in universal use. This movement is based on the principle of the D'Arsonval galvanometer. The meter is constructed so that it is portable, and the movement is provided with a pointer and scale for indicating deflections of the moving coil. This meter movement may be used as an ammeter, a voltmeter, or an ohmmeter, depending on the other components used with it and how it is connected into the circuit.

The permanent-magnet, moving-coil meter movement will operate only on direct-current of the correct polarity. If reverse polarity is used the moving-coil and pointer will try to move backwards and the meter movement will be damaged; therefore, when it is used as a d-c ammeter or a d-c voltmeter, polarity must be observed. To adapt the meter movement for measuring alternating current and voltage, a rectifier is used to convert the a.c. to d.c.

Several different methods are used to supply power for the meter movements. Some meters are powered by batteries installed in the meter case, some receive power from the circuit being tested, others are supplied through an electrical power cord which is plugged into a power receptacle. A vacuum tube voltmeter (VTVM) is an example of the latter type. The power to operate some meters (such as the megger) is produced by manual operation of a handcrank to drive a generator.

Some meters are designed to be used for measuring more than one electrical quantity, and are called multimeters. Before discussing any one particular type meter, a brief review of each of the basic meters is presented.

AMMETER

The amplitude of current flow through the basic meter movement limits it to measuring a fixed range of only a fraction of an ampere. To overcome this limitation, and to protect the mechanism, a current shunt is used. This device,

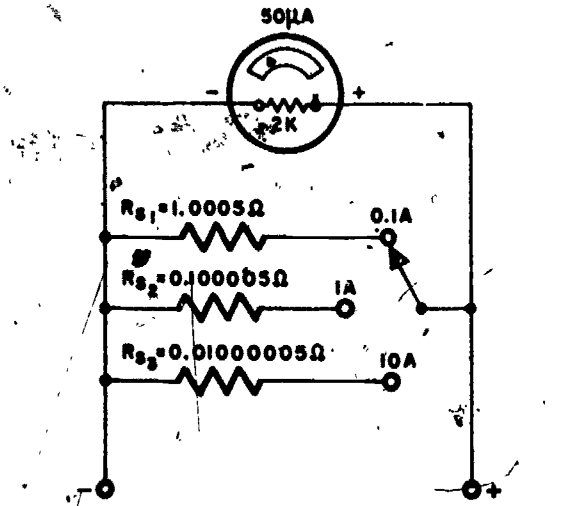


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Figure 9-1.—Simplified schematic diagram of an ammeter.

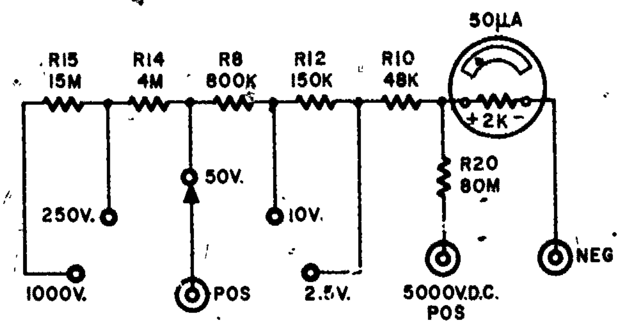

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Figure 9-3.—Simplified schematic diagram of a d-c voltmeter.

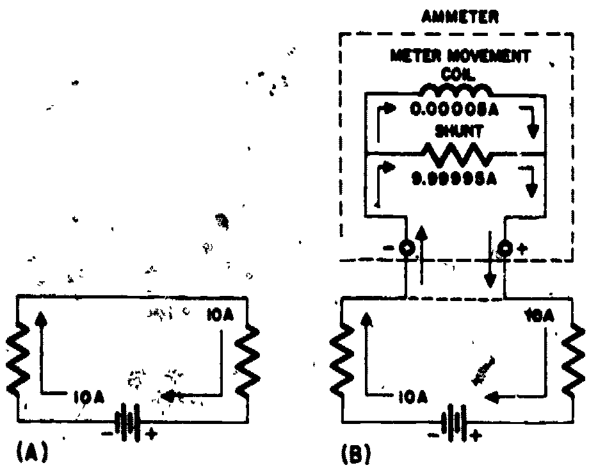

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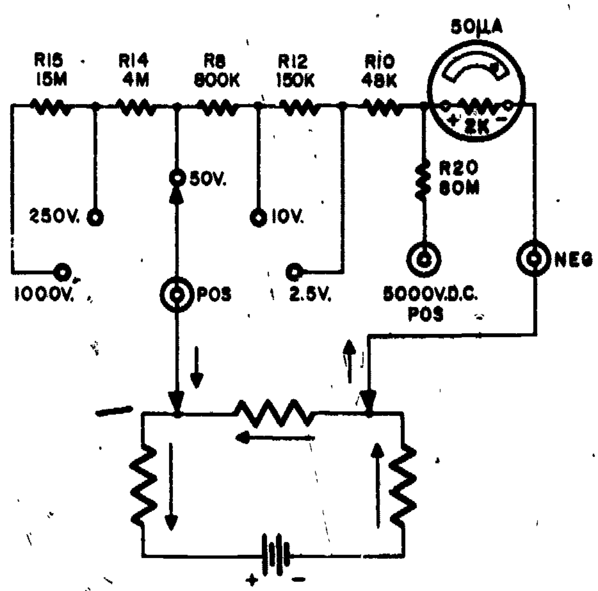
Figure 9-2.—(A) A circuit showing current flow; (B) an ammeter connected into the circuit.



AS.255

Figure 9-4.—Voltmeter connected to a circuit.

which is actually a resistance of low value, permits the instrument to serve as a d-c ammeter in the measurement of relatively large direct currents. By using a rectifier with the basic meter and shunt the instrument may be used to measure large values of alternating current.

(See fig. 9-1.) The shunt and meter movement are connected in parallel with each other in respect to the circuit being tested; therefore, the current distribution between meter movement and shunt is inversely proportional to their individual resistance. Thus, the shunt (which has less resistance) carries the majority of the current. Since the meter coil carries only a small portion of the circuit current, the ammeter is capable of measuring relatively large values of

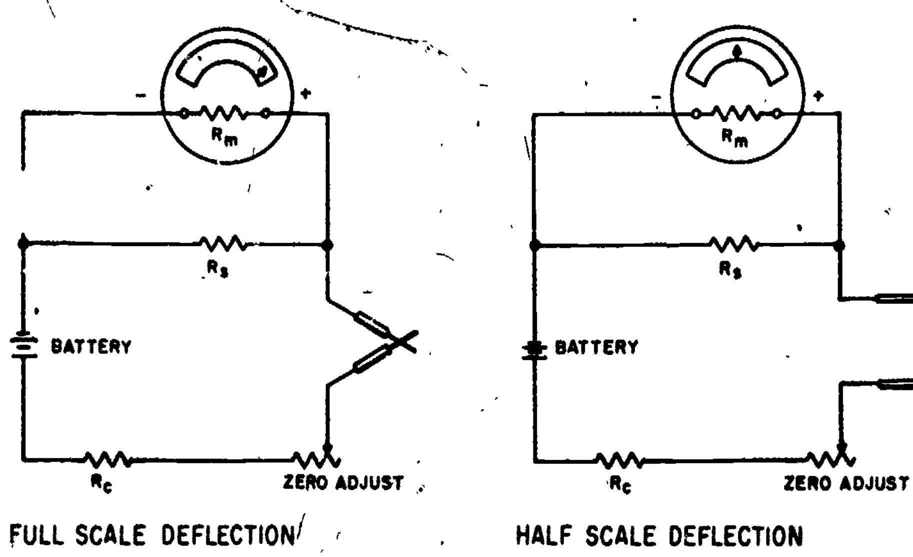


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Figure 9-5.—Basic ohmmeter circuit.

circuit current. The instrument may be adapted to a variety of current ranges by the use of shunts of different values which are switched in or out as required.

Figure 9-2 (A) illustrates current flow in a circuit and figure 9-2 (B) shows how an ammeter is connected into the circuit. The circuit is opened and the ammeter (meter movement coil and shunt) is connected in series with the circuit so that all circuit current will flow through the shunt and meter movement coil.

As mentioned earlier, polarity must be observed when connecting a d-c ammeter into a circuit. The negative (black) lead or (-) terminal of the meter must be connected to the negative side of the circuit and the positive (red) lead or (+) terminal of the meter must be connected to the positive side of the circuit.

VOLTMETER

The same type of meter movement is used in the voltmeter as that used in the ammeter. But instead of using a shunt, a high resistance resistor commonly called a "multiplier" is used. The multiplier is connected in series with the meter movement (fig. 9-3) to limit the current

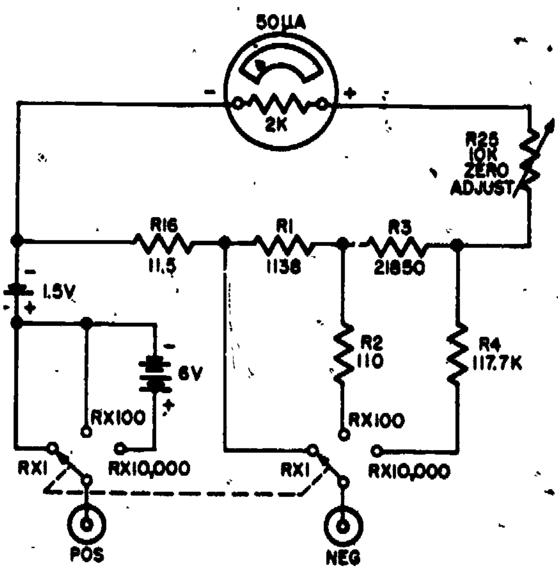

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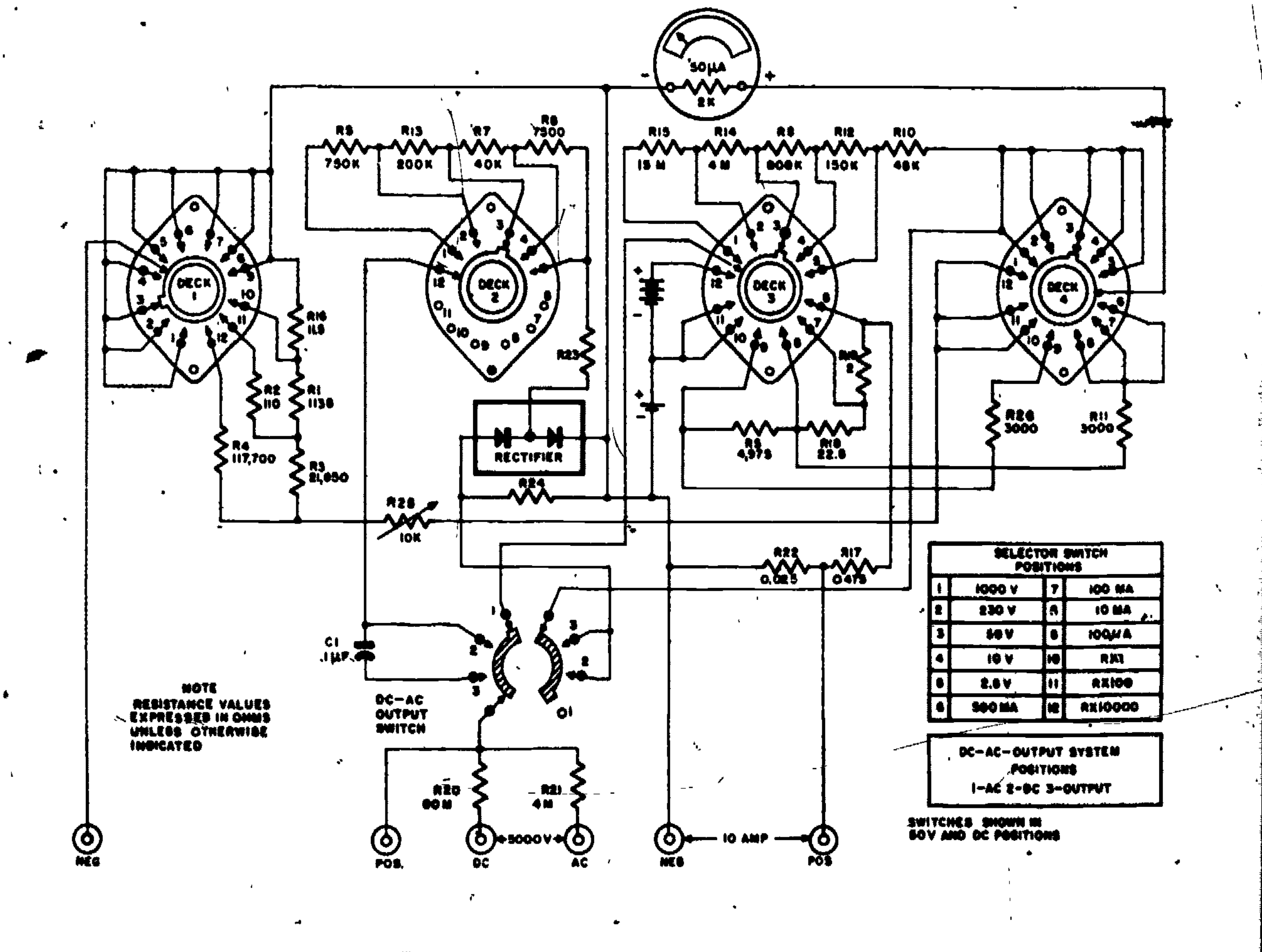
Figure 9-6.—Simplified schematic diagram of an ohmmeter.

flow. Since the value of the multiplier is constant for any given application, the flow of current through the coil is proportional to the



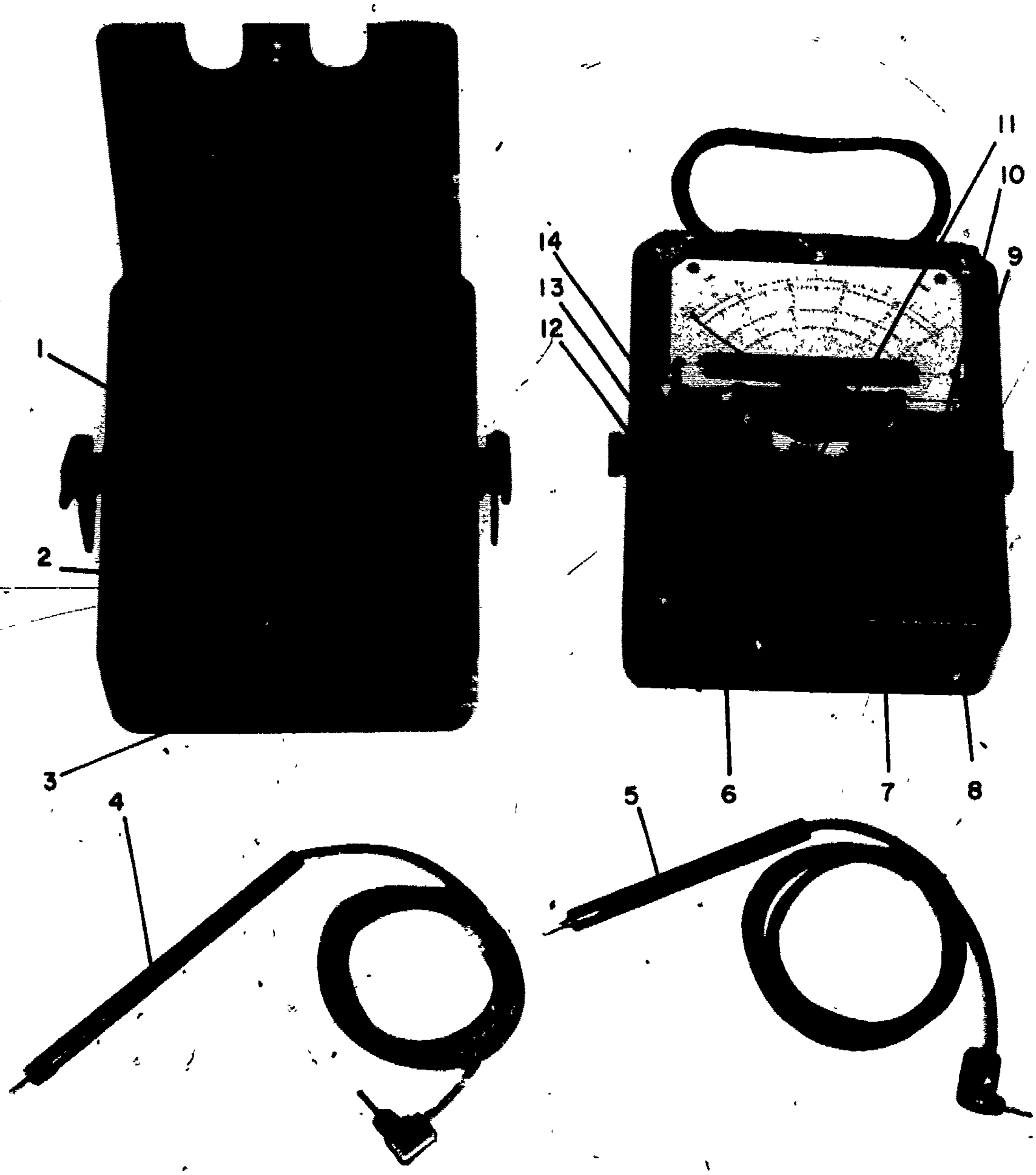
AE.237

Figure 9-7.—Schematic diagram of a multimeter.

voltage under measurement. By proper calibration of the dial, the meter may be made to indicate voltage although it is actually activated by current. In practice, the voltage ranges of the meter are established by the use of different values of multipliers (determined by resistance of meter movement and voltage to be measured). Usually voltmeters will have different multipliers built in, and they are selected by moving a test lead to another test jack or by moving a selector switch to another position.

The voltmeter is connected in parallel with the component (fig. 9-4) or circuit from which a voltage reading is being taken. Care should be used when taking a voltage reading to insure correct polarity and that the range of the meter is not exceeded.

When taking voltage readings of unknown polarity, tap the meter leads lightly on the circuit connections while observing the meter needle. If needle movement is backward, reverse the meter leads to obtain correct polarity. A selector switch is provided on some meters for this function; if so, it is to be used instead of reversing the meter leads. If the value of the voltage to be measured is unknown, start with the highest voltage scale of the meter and work down until the proper voltage range is selected.



1. High voltage probe.
2. Alligator clips.
3. Telephone plug.
4. Standard test lead (red).
5. Standard test lead (black).
6. Function switch.
7. Current and voltage range selector.
8. +5,000 VDC multiplier.
9. +1,000 VDC (red lead).
10. 1,000 VAC (red lead).
11. Zero ohms.
12. +10 amps (red lead).
13. +Volts/MA/ohms (red lead).
14. Common (black lead).

AS.257

Figure 9-8.—Multimeter AN/PSM-4C.

OHMMETER

An ohmmeter is used to measure resistance and check continuity (complete path for current flow). The ohmmeter uses the same basic meter movement as the ammeter and voltmeter. It may use shunts, multiplier resistors, or a combination of both. The ammeter and voltmeter discussed receive their power from the circuit being tested, but the ohmmeter has its own power supply consisting of one or more small batteries contained in the meter case. A variable resistor is provided on the front of the meter and is used to compensate for any change in battery voltage, thus providing the technician with the means to set the meter to zero. By shorting the test leads together and turning the variable resistor as necessary the meter should zero. However, if the battery voltage is too low, the meter cannot be zeroed and the batteries must be replaced.

Prior to checking a circuit with an ohmmeter the circuit power must be disconnected; otherwise the ohmmeter will be damaged. Analysis of the circuit in figure 9-5 shows that full-scale deflection is obtained when the meter probes are shorted together, and that less than full-scale deflection is obtained when the resistance to be measured, R_X, is connected into the circuit. If the meter now reads one-half of its former current, it follows that the total circuit resistance has doubled, indicating that R_X is equal to the total circuit resistance.

Since the ohms-calibrated scale is nonlinear, the midscale portion represents the most accurate portion of the scale. However, the usable range extends with reasonable accuracy on the high range end to ten times the midscale reading, and on the low range end to one-tenth of the midscale reading.

To extend the range of an ohmmeter, the proper values of shunt and series resistors and battery voltages are connected into the circuit so that with the test leads shorted the meter will read full scale. Figure 9-6 shows a simplified schematic diagram of an ohmmeter section taken from a typical volt-ohm-milliammeter.

MULTIMETER

The ASE is often required to measure voltage, current, and resistance when performing electrical/electronic maintenance and to eliminate the necessity of using more than one meter, the multimeter is used. The multimeter combines a voltmeter, ammeter, and ohmmeter in one unit. It includes all the necessary switches, jacks, and additional devices arranged in a compact, portable case utilizing one meter movement. Figure 9-7 illustrates a schematic diagram of a multimeter circuit.

The multimeter AN/PSM-4C (fig. 9-8) is designed to permit the technician to make measurements of voltage, resistance, and current by the use of only one self-contained portable instrument. It has the capability of measuring a-c or d-c voltage, resistance, or direct current in a wide range of values. The cover, which contains a compartment for storage of leads and accessories, remains with the instrument at all times and forms a watertight seal when clamped over the face of the meter. While the instrument is in use the cover clamps to the back of the meter case, thereby keeping the storage compartment convenient to the operator.

The AN/PSM-4C is provided with a pair of standard test leads (one red and one black) which are used for most applications of the instrument. These leads have elbow probes on one end to connect into the circuit jacks on the instrument and probe tips on the other end with threaded shoulders for alligator clips. These test leads are used to make all measurements except d-c voltage over 1,000 volts.

For measuring d-c voltages over 1,000 volts, a special high voltage probe is provided, and is used in conjunction with the standard black lead. One end of the lead has a threaded tip which screws onto a post in the face of the meter (labeled 5,000 VDC MULTIPLIER). The other end of the lead has a high voltage multiplier assembly enclosed in a red plastic housing with a clear plastic end and terminated in a clip at the end of a short piece of flexible wire. The clear plastic end allows the operator to observe the glow of a neon lamp when there is high voltage present. The neon lamp is in series with a 100-megohm resistor within the housing. When a high voltage is being measured, the current passes through the lamp (making it glow), through the resistor, and through the armature of the meter.

There are three controls on the face of the meter. One is a 10-position rotary-switch in the lower left-hand corner which is used as a function switch. Five of the positions on this switch are used to set up different resistance scales. Two of the positions are for selection of d-c voltage measurement (direct and reverse). The normal position of the switch is in the DIRECT position. If a negative voltage is to be measured, the switch is moved to the REVERSE position. (NOTE: Never switch leads to read a reverse or negative voltage.) One position of the switch is marked ACV; in this position the meter may be used to read a-c voltage. A rectifier in the instrument changes the a-c voltage to an equivalent d-c value which is applied to the meter. One position is marked OUTPUT. In this position the a-c portion of mixed a-c and d-c voltage may be read. One position of the switch is used when measuring direct current and is marked DC with three ranges (UA, MA, AMPS) indicated to the right of the letters DC.

In the lower right-hand corner is an eight-position switch used to select current and voltage ranges. Near the center of the meter is a control marked ZERO OHMS. This control, which is a continuously variable adjustment, is used to zero the meter thus compensating for battery aging in the ohmmeter circuits. This control is adjusted until the meter indicates full-scale deflection (indicating zero ohms) when the function switch is set at one of the resistance range positions and the meter probes are shorted together. To prevent erroneous readings when switching to a different position, a check of the meter zero indication is always necessary.

The multimeter AN/PSM-4C is designed to make the following electrical measurements:

1. Direct current up to 10 amperes.
2. Resistances up to 300 megohms.
3. D-c voltages up to 5,000 volts.
4. A-c voltages up to 1,000 volts.
5. Output voltages up to 500 volts.

Input impedance for measuring d-c voltages is 20,000 ohms per volt and is accurate to within 3 percent of full-scale (4 percent for the 5,000 VDC scale). When measuring a-c voltages, the input impedance is 1,000 ohms per volt and is accurate to within 5 percent of full scale.

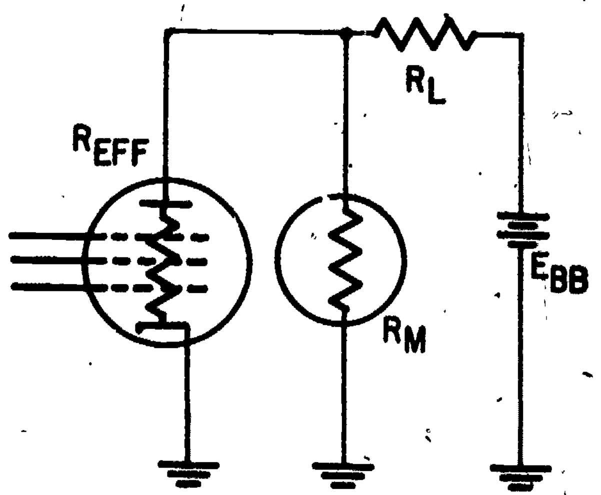


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Figure 9-9.—Loading effect created by meter resistance.

Under normal conditions, no routine service inspection is necessary beyond visual examination at established inspection periods. If the instrument is to be stored for periods of 6 months or longer, the batteries must be removed to prevent corrosion. The periodic inspection should include removal of the battery case cover to facilitate inspection of battery connections. If the instrument is used under extreme temperature conditions, a visual inspection of all parts should be made at least once a month. The only periodic maintenance required is inspection, test, replacement of batteries, and calibration.

VACUUM TUBE VOLTMETERS

The AN/PSM-4C ordinary voltmeter has several disadvantages that make it practically useless for measuring voltages in high impedance circuits. For example, suppose that the plate voltage of a pentode amplifier is to be measured. (See fig. 9-9.) When the meter is connected between the plate and cathode of the electron tube, the meter resistance R_m, is placed in parallel with the effective plate resistance R_{eff}, thereby lowering the effective plate resistance.

The effective plate resistance is in series with the plate load resistor, R_L, and this series circuit appears across the supply voltage, E_{bb}, as a voltage divider. Since the overall resistance is lowered, it follows that current through R_L will increase, the voltage drop across R_L will also increase, and the voltage drop across R_{eff} will decrease. The result is an incorrect indication of plate voltage, and is called loading effect.

Calculation of Loading Effects

Before the voltmeter is connected, the plate current is determined by the effective resistance of the plate circuit, the plate load resistor, and the plate voltage. If the tube has an effective resistance of 100,000 ohms, a plate load resistance of 100,000 ohms, and the plate power supply is constant at 200 volts, then the plate current is 200v/200,000 or 0.001 ampere. The plate voltage (plate to cathode) is 0.001 x 100,000, or 100 volts.

Assume that the voltmeter used to measure the plate voltage of the tube has a sensitivity of 1,000 ohms per volt and that the selected meter range is from 0 to 250 volts. The meter will then have a resistance of 250,000 ohms. This resistance in parallel with the tube resistance of 100,000 ohms produces an effective resistance of 71,400 ohms in series with the plate load resistor. The total resistance across the B supply is therefore 171,000 ohms instead of the 200,000 ohms before the meter was applied, and the current through the plate load resistor is 200v/171,400, or 0.00117 ampere. Across the plate load resistor the voltage drop is 0.00117 x 100,000, or 117 volts, and the plate-to-cathode voltage on the tube is 200 - 117, or 83 volts when the meter is connected, thus causing an error of 17 volts. The lower the sensitivity of the meter, the greater the error will be; in this example, the error of 17 volts when the reading should be 100 volts is a 17 percent error.

A meter having a sensitivity of 20,000 ohms per volt and a 250-volt maximum scale reading would introduce an error of about 1 percent. However, in circuits where very high impedances are encountered, such as in grid circuits of electron tubes, even a meter of 20,000 ohms per volt sensitivity would impose too much of a load on the circuit.

VTVM Advantages

Another limitation of the alternating current, rectifier type voltmeter is the shunting effect at high frequencies of the relatively large capacitance of the meter's rectifier. This shunting effect may be eliminated by replacing the usual metallic oxide rectifier with a diode electron tube; the output of the diode is applied to the grid of an amplifier in which the plate circuit contains the d-c meter. Such a device is called an electron tube voltmeter or a vacuum tube voltmeter, usually abbreviated VTVM. Voltages at frequencies up to 500 megahertz and sometimes even higher, can be measured accurately with this type of meter. The frequency limitation is determined by the model of VTVM.

The input impedance of a VTVM is large, and therefore the current drawn from the circuit whose voltage is being measured is small and in most cases negligible. The main reason for using a vacuum tube voltmeter is to overcome the loading effect by taking advantage of the VTVM's extremely high input impedance. A VTVM that is used extensively for electronics maintenance is contained in the TS-505 multimeter.

Figure 9-10 shows a front panel view of the TS-505. The VTVM measures d-c voltages from 0.05 volt to 1,000 volts (in 9 ranges), and a-c voltages from 0.05 volt to 250 volts rms (in 7 ranges), at frequencies from 30 Hz to 1 MHz. With the RF adapter that is used with the d-c voltage measurement circuit, RF voltages may be measured from 0.05 volt to 40 volts rms at frequencies from 500 Hz to 500 MHz. Resistances from 1 ohm to 1,000 megohms may be measured.

The operation of the meter is virtually self-explanatory. However, two of the controls which may not be clearly understood by studying their respective markings are:

1. OHMS ADJUST: Used to adjust meter pointer to infinity (∞) on the OHMS scale when the function switch is set to the ohms position.

2. ZERO ADJUST: Used to set the meter pointer on zero when the function switch is set

on OHMS, +DC, -DC, or AC, or to set the pointer at midscale when the function switch is set to the ± DC position.

The accuracy of this meter is good, being 5 percent for d-c voltages and 6 percent for a-c and RF voltages. The meter movement requires 1 ma for full-scale deflection.

Input impedance to the meter is 6 megohms at audio frequencies, 40 megohms on the 1,000-volt d-c range, and 20 megohms on all other ranges.

Power requirements for meter operation are 98 to 132 volts, single phase, 50 to 1,000 Hz, at about 21 voltamperes.

The removable cover of the TS-505 contains accessories such as alligator clips, an RF adapter, and miniature probe tips. The miniature tips slip over the regular tips when working in confined areas.

Do not attempt to use this instrument unless you have studied the technical manual which sets forth the operating procedures, or unless you have been instructed in its proper usage, under the direction of your shop supervisor.

Two peculiarities of this meter are:

1. In order for it to provide accurate readings it must warm up. This usually takes about 10 minutes, and during this period, the meter pointer normally drifts rapidly.

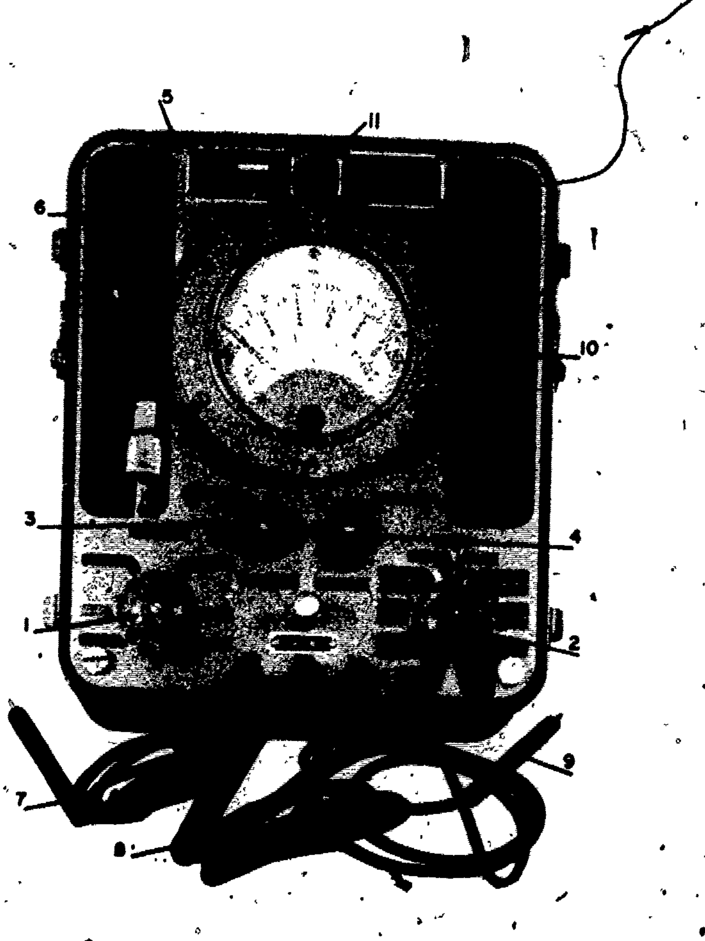
2. Voltage measurements cannot be read directly on the meter scale when the function switch is set at the ± DC position.

The purpose of the ± DC position (zero center scale) is to determine the polarity of an unknown d-c voltage or to indicate a zero d-c voltage input to the multimeter.

CAUTION: The maximum d-c voltage which may be applied to the multimeter when the function switch is set at the ± DC position is one-half of the voltage indicated by the panel marking opposite the range switch setting.

The major difference between any VTVM and a conventional multimeter is that the VTVM utilizes a vacuum tube in its input. For a detailed explanation of the circuitry of the TS-505 VTVM consult the manufacturer's manual or the Operation and Service Instruction Manual.

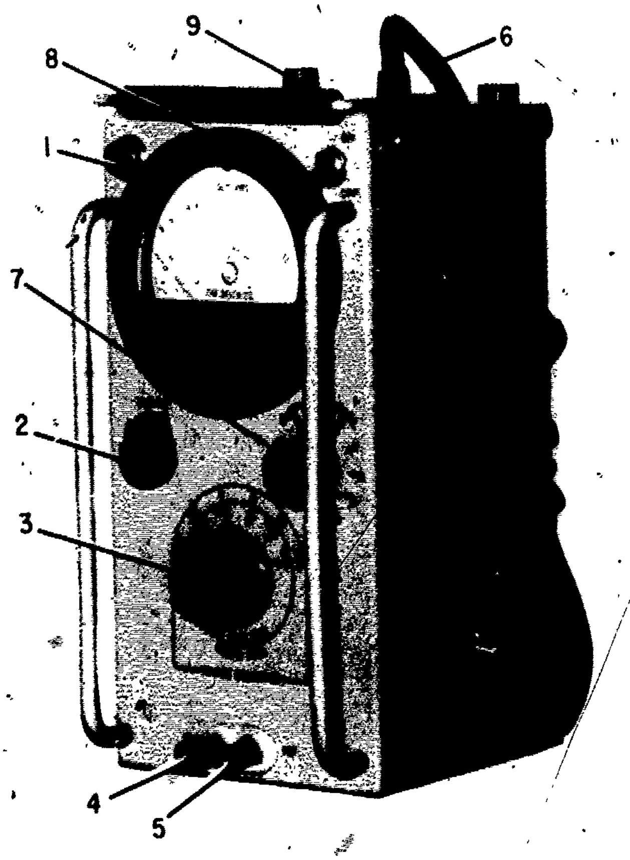
Another VTVM type multimeter is the ME-6D/U shown in figure 9-11. This meter is a highly sensitive and accurate instrument used to measure a-c voltages by the vacuum tube voltmeter principle. As with the TS-505 this meter is self-contained and portable. It operates on a power source of 117 volts ±10 percent, 50 to 400 hertz, single phase a.c. All operating controls,



1. **Function switch.**
2. **Range switch.**
3. **Zero adjust.**
4. **Ohms adjust.**
5. **Meter.**
6. **A-c line cord (power cord).**
7. **Common probe (black).**
8. **D-c probe (black, special tip).**
9. **Ohms probe (green).**
10. **A-c probe (red).**
11. **Indicator lamp (glows red with power on).**

AT.94

Figure 9-10.—Multimeter TS-505.



1. Indicator lamp.
2. Output jack.
3. Range selector (rms).
4. Ground terminal.
5. Input terminal.
6. Power cord.
7. Output control.
8. Power switch.
9. Power fuse.

AS.258

Figure 9-11.--Multimeter ME-6D/U.

signal input terminal posts, signal output jack, and the pilot lamp are located on the front panel. The power fuse is replaceable from the top surface of the case.

An auxiliary purpose of this meter is to serve as a high gain amplifier. Maximum voltage gain of about 4,500 can be achieved. The output waveshape up to 23 volts a.c. is essentially distortionless.

A unique feature of the meter is the stability of the gain in the amplifier system. This feature is achieved by feeding back part of the amplified voltage to the input circuit. This action provides meter readings that are practically independent of variations in line voltage, tube aging, and circuit component replacement.

An understanding of the functions of the operating controls is necessary for intelligent operation of the equipment. The proper sequence of the controls and their functions are:

1. POWER ON-OFF SWITCH–This switch controls the application of primary power to the equipment. The pilot lamp (green) glows when this switch is in the ON position.

2. INPUT AND GROUND TERMINALS–These terminal posts receive the signal from the equipment under test. The input signal must be within the frequency range of 15 Hz to 250 kHz, and within the amplitude range of 500 microvolts to 500 volts rms. The magnitude of an a-c input signal superimposed on a d-c potential should not exceed 1,000 volts. FAILURE TO OBSERVE THIS PRECAUTION MAY CAUSE BREAKDOWN OF THE INPUT CIRCUIT.

3. OUTPUT CONTROL–This control is a potentiometer and is used to control the output voltage when the instrument is used as a high gain amplifier. Approximately 23 volts is available at the output jack when the maximum allowable input signal is fed into the input jack. The output impedance varies with the setting of the output control with a maximum impedance of 10,000 ohms.

4. RANGE SELECTOR–This is a six-position rotary-switch used to control the input signals. No attenuation of the input is presented with the switch in the .005 V setting, and maximum attenuation is presented with the switch in the 500 V position.

5. OUTPUT JACK–The output jack is a telephone type jack connector designed to receive a standard telephone plug with a grounded sleeve. A maximum signal of 23 volts is available at this jack if the range selector is set so that the meter deflection is full scale with the output control in its maximum position.

MEGGER

A megger is an instrument that applies a high voltage to the component under test and measures the current leakage of the insulation. Thus a capacitor or insulated cable can be checked for leakage under much higher voltages than an ohmmeter is capable of supplying. It consists of a handdriven, d-c generator and an indicating meter. The name megger is derived from the fact that it measures resistances of many megohms.

There are various resistance ratings of meggers with full-scale values as low as 5 megohms, and as high as 10,000 megohms. Figure 9-12 shows the scale of a 100-megohm, 500-volt megger. Notice that the upper limit is infinity and that the scale is crowded at the upper end. The first scale marking below infinity represents the highest value for which the instrument can be accurately used. Thus, if the pointer goes to infinity while making a test, it means only that the resistance is higher than the range of the set.

There are also various voltage ratings of meggers (100, 500, 750, 1,000, 2,500, etc.). The most common type is the one with a 500-volt rating. This voltage rating refers to the maximum output voltage of the megger and is dependent upon the speed at which the armature is driven by the handcrank. When the megger's armature reaches a predetermined speed, a slip clutch prevents the armature from being driven any faster, thus maintaining voltage at a constant value. The voltage rating is important, for the application of too high a voltage to even a good component will cause a breakdown. In other words, do not use a 500-volt megger to test a capacitor rated at 100 volts.

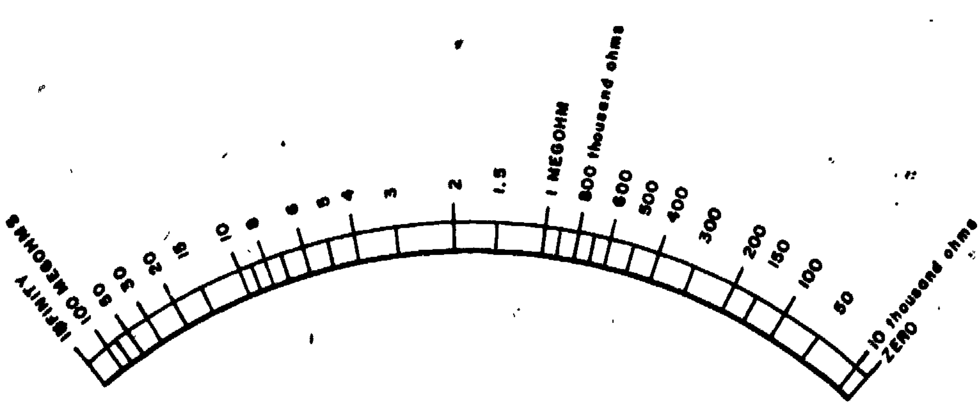
Meggers are used to test the insulation resistance of conductors in which shorting or breaking down under high voltage is suspected. In some situations, meggers are used in the prevention of unnecessary breakdowns by maintaining a record of insulation resistance of power and high voltage cables, motor and generator windings. These records will reflect fluctuations in resistance and aid in determining when the components should be replaced to prevent a breakdown.

Meggers are used for testing capacitors whose peak voltages are not below the output of the megger. They are also used for testing for high resistance grounds or leakage on such devices as antennas and insulators.

TESTING WITH METERS

Several rules are set forth below and are intended as a guide to follow when making the tests described.

1. Always connect an ammeter in series.
2. Always connect a voltmeter in parallel.
3. Never connect an ohmmeter to an energized circuit.
4. Select the highest range first then switch to the lower ranges as needed.



AT.92

Figure 9-12.—Scale of 100-megohm, 500-volt megger.

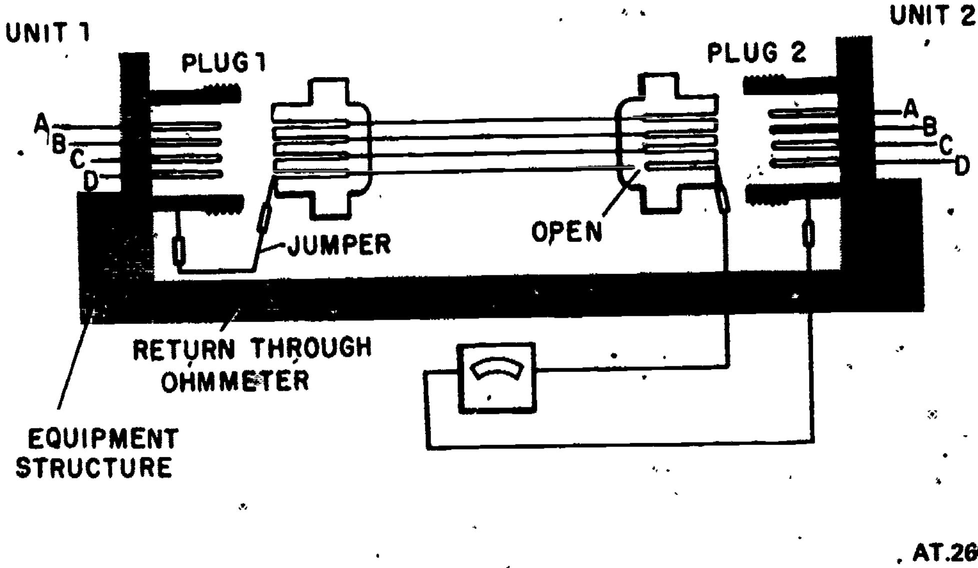


Figure 9-13.—Continuity test.

5. When using an ohmmeter, select a scale that will result in a midscale reading.

6. Do not leave the selector switch of a multimeter in any resistance position when the meter is not in use because the leads may short together and discharge the meter's battery. There is less chance of damaging the meter if it is left on a high a-c volts setting or in the off position if it has one. Meters that have an off position dampen the swing of the needle by connecting the meter movement as a generator. This prevents the needle from swinging wildly when the meter is moved.

7. View the meter from directly in front to eliminate parallax (distortion due to sight angle).

8. Insure proper polarity when measuring d-c voltage or current.

9. Do not place meters in the presence of strong magnetic fields.

10. Never attempt to measure the resistance of a meter or a circuit with a meter in it as the current required for ohmmeter operation may damage the meter. This also applies to circuits with low filament current tubes and some types of crystal diodes.

11. When measuring high resistance, be careful not to touch the test lead tips or the circuit as body resistance will shunt the circuit and given an erroneous reading.

12. Discharge filter capacitors before making resistance measurements. This is extremely important when testing power supplies that are disconnected from their loads. If a capacitor discharges through the meter, the surge may burn out the meter movement.

13. Connect the ground lead of the meter first when making voltage measurements. Work with one hand whenever possible.

14. When working on a live electrical circuit, have a qualified man standing by to assist in case of accidental electrical shock.

Precautions to be followed in the use of the megger are as follows:

1. When making a megger test, the equipment must not be energized. It must be disconnected entirely from the system before it is tested.

2. Observe all rules for safety in preparing equipment for test and in testing, especially when testing installed high voltage apparatus.

3. Use well-insulated test leads, especially when using high range meggers. After the leads are connected to the instrument and before connecting them to the component to be tested, operate the megger and make sure there is no leak between the leads. The reading should be infinity. Make certain the leads are not broken—do this by touching the test ends of the

leads together while turning the crank slowly. The reading should be approximately zero.

4. When using high range meggers, take proper precautions against electric shock. There is sufficient capacitance in most electrical equipment to "store up" sufficient energy from the megger generator to give a very disagreeable and even dangerous electric shock. Because of a high protective resistance in the megger, its open circuit voltage is not as dangerous, but care should be exercised.

5. Equipment having considerable capacitance should be discharged before and after making megger tests in order to avoid the danger of receiving a shock. This can be accomplished by grounding or short circuiting the terminals of the equipment under test.

Continuity Test

Open circuits are those in which the flow of current is interrupted by a broken wire, defective switch, or any other condition which does not allow current to flow. The test used to check for opens (or to see if the circuit is complete or continuous) is called continuity testing.

An ohmmeter is excellent for making a continuity test. In an emergency however, a continuity tester can readily be made from a flashlight. Normally, continuity tests are performed in circuits where the resistance is very low (such as the resistance of a copper conductor). An open is indicated in these circuits by a very high or infinite resistance.

The diagram in figure 9-13 shows a continuity test of a cable. Notice that both connectors are disconnected and the ohmmeter is in series with the conductor under test. The power must be off. Checking conductors A, B, and C, the current from the ohmmeter will flow through plug No. 2, through the conductor, and plug No. 1. From this plug it will pass through the jumper to the chassis, which is "grounded" to the structure. The structure will serve as the return path to the chassis of unit 2 completing the circuit to the ohmmeter. The ohmmeter will indicate a low resistance.

Checking conductor D will reveal an open. The ohmmeter will indicate maximum resistance because current cannot flow.

Where the equipment structure cannot be used as the return path, one of the other conductors may be used. For example, to check D a jumper is connected from pin D to pin A of plug 1 and the ohmmeter leads are connected to pins D and A of plug 2. This technique will also reveal the open in the circuit.

Grounded Circuit Test

Grounded circuits are caused by some conducting part of the circuit making contact either directly or indirectly with the metallic framework. Grounds may have many causes, the most common of which is perhaps the fraying of insulation from a wire allowing the bare wire to come in contact with the metal ground.

Grounds are usually indicated by blown fuses or tripped circuit breakers. Blown fuses or tripped circuit breakers, however, may also result from a short other than ground. A high resistance ground may also occur where not enough current can flow to rupture the fuse or open the circuit breaker.

In testing for grounds, the ohmmeter is usually used but other continuity testers may also be used. By measuring the resistance to ground of any point in a circuit, it is possible to determine if the point is grounded. By considering figure 9-13, one possible means of testing a cable for grounds can be seen. If the jumper is removed from pin D of plug No. 1, a tester for grounds is made for each conductor of the cable. This is accomplished by connecting one meter lead to ground and the other to each of the pins of one of the plugs. A low resistance will indicate that a pin is grounded. Both plugs must be disconnected from their respective units; if only one plug is removed, a false indication is possible because a conductor may be grounded through the unit.

Test for Shorts

A short circuit, other than a grounded one, is one where two conductors accidentally touch each other directly or through another conducting element. Two conductors with frayed insulation may touch and cause a short. Too much solder on the pin of a connector may short to the adjacent pin. In a short circuit, sufficient current may flow to blow a fuse or trip a circuit breaker. However, it is possible to have a short between two or more conductors with the only indication being a malfunction of the equipment. For example, in a group of indicator lights designed to indicate individual circuit operation, a short between two of the power carrying conductors leading to the lights would cause more than one of the lights to illuminate when actually only one circuit is energized.

As when checking for a ground, the device used for checking for a short is the ohmmeter. By measuring the resistance between two conductors a short between them may be detected by a low resistance reading. In figure 9-13 by removing the jumper and disconnecting both plugs, a short test may be made. This is performed by measuring the resistance between the two suspected conductors.

Shorts are not restricted to cables as they may also occur in other components, such as transformers, motor windings, capacitors, etc. The major test method for testing such components is a resistance measurement, and then comparing the indicated resistance with the resistance values given on schematics or in maintenance manuals.

Voltage Test

The voltage test must be made with the power applied; therefore, the prescribed safety precautions must be followed to prevent injury to personnel and damage to the equipment. The technician will find in his maintenance work that a voltage test is of utmost importance; it is used not only in isolating malfunctions to major components but also in the maintenance of subassemblies, units, and circuits. Before checking a circuit voltage, a check on the voltage of the power source should be made to be sure that the specified voltage is being impressed across the circuit.

Obviously, the voltmeter is used for voltage tests. In using the voltmeter make certain that the meter controls are positioned for the type voltage (a.c. or d.c.) to be tested and has a scale of adequate range. Since defective parts in a circuit may cause higher than normal voltages to be present at the point of test, the highest voltmeter range available should be used at first. Once a reading has been obtained, determine if a lower scale can be employed without damaging the meter movement. If so, use the lower scale to obtain a more accurate reading.

Another consideration in the circuit voltage test is the resistance and current in the circuit. A low resistance in a high current circuit would result in considerable voltage drop; whereas, the same value resistance in a low current circuit may be negligible. Abnormal resistance in part of a circuit can be checked either with an ohmmeter or voltmeter. Where practical, an ohmmeter should be used, in that the test is then carried out with the circuit deenergized.

Resistance Test

Before checking the resistance of a circuit or of a part, make certain that the power has been turned off and capacitors in the associated circuit are discharged. To check continuity, always employ the lowest ohmmeter range. If a high range is used, the meter may indicate zero, even though appreciable resistance is present in the circuit. Conversely, to check a high resistance, use the highest scale, since the low range scale may indicate infinity though the resistance is less than a megohm.

In making resistance tests, take into account that other circuits may be in parallel with the circuit to be measured, in which case an erroneous conclusion may be drawn from the reading obtained. To obtain an accurate reading if other parts are connected across the suspected circuit, one end of the circuit to be measured must be disconnected from the equipment. For example, many of the resistors in major components and subassemblies are connected across transformer windings. To obtain a valid resistance measurement, the resistor to be measured must be isolated from the shunt resistances.

The majority of the circuits encountered in ground support equipment are low current circuits. Also many of the schematics indicate the required voltages at many test points. Thus, if a certain stage is suspected, a voltage check should be made. A voltmeter placed from the test point to ground should indicate the voltage as given on the schematic.

Many manuals also contain voltage charts where all the voltage measurements are tabulated. These charts usually indicate the sensitivity of the meter used to obtain the voltage readings for the chart and to obtain comparable results, the technician must use a voltmeter of the same sensitivity as that specified. Make certain that the voltmeter is not loading the circuit while taking a measurement. If the meter resistance is not considerably higher than the circuit resistance, the reading will be markedly lower than the true circuit voltage. (To calculate the meter resistance, multiply the rated ohms-per-volt sensitivity value of the meter by the scale in use. For example, a 1,000 ohms-per-volt meter set to the 300-volt scale will have a resistance value of 300,000 ohms.) (See table 9-1.)

Resistance tests are also used for checking a part for grounds. In these tests, the sections to be tested should be disconnected from the rest of the circuit so that no normal circuit ground will exist. It is not necessary to dismount the part to be checked. The ohmmeter, set for a high resistance range, is then connected between ground and each electrically separate circuit of the part under test. Any resistance reading less than infinity indicates at least a partial ground. Capacitors suspected of being short circuited can also be checked by a resistance measurement.

To check a capacitor suspected of being open, you can, without removing it, temporarily shunt a capacitor of known condition across it, and recheck the performance of the circuit.

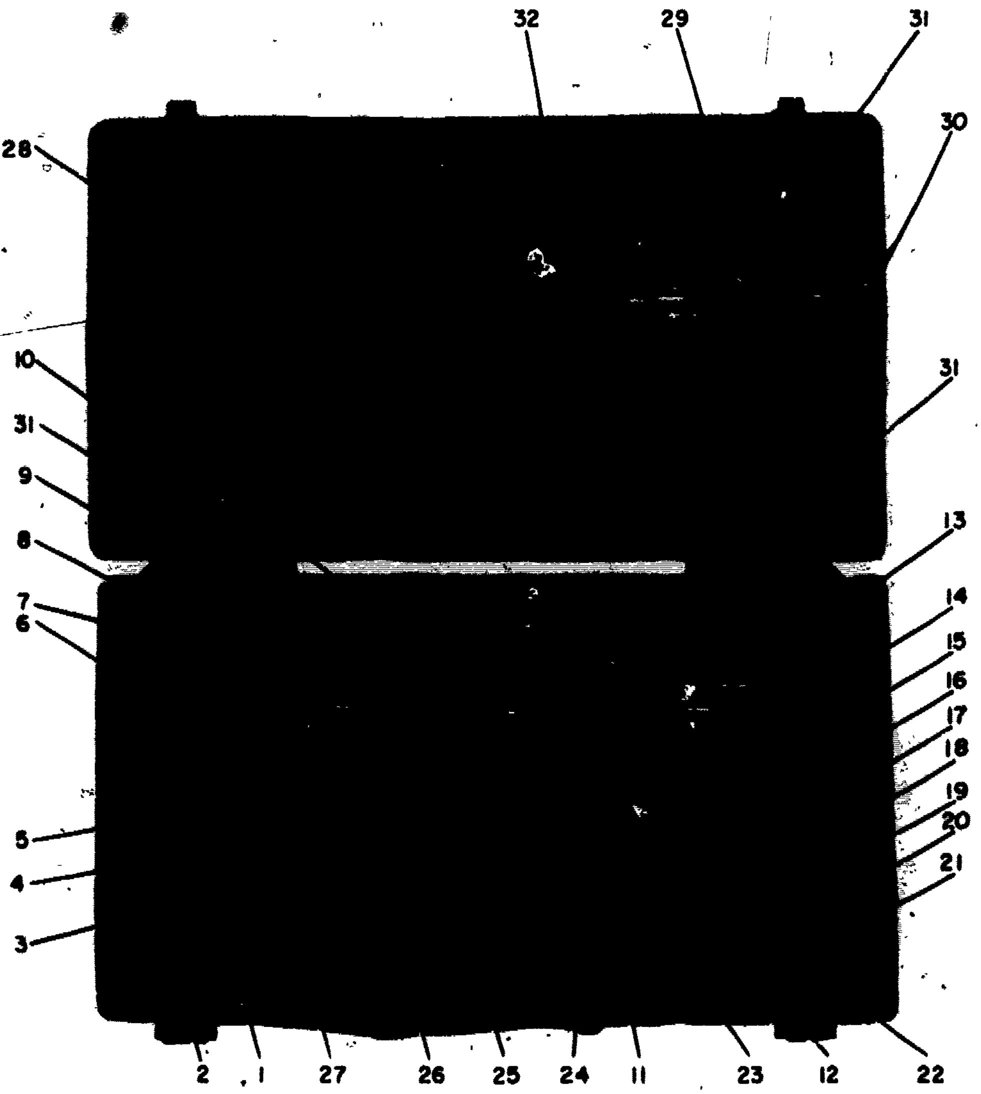
Current Test

To measure the current in a circuit, the ammeter must be placed in series with the circuit. This introduces the problem of obtaining an accurate current reading. Ohms law states that the current in a circuit is equal to the voltage applied divided by the total resistance. It thus becomes obvious that adding the resistance of an ammeter to a circuit will reduce the current in the circuit. For accurate measurements and to protect the meter, shunt resistors are switched across the meter movement as described in Basic Electricity, NavPers 10086 (Series).

Table 9-1.—Circuit loading effect—VTVM vs. non-electronic voltmeter

Range (Volts)	Input resistance		Circuit loading effect
	VTVM	Nonelectronic voltmeter*	
5	10 megohm	0.1 megohm	Nonelectronic voltmeter 100 times that of VTVM.
10	10 megohm	0.2 megohm	Nonelectronic voltmeter 50 times that of VTVM.
50	10 megohm	1.0 megohm	Nonelectronic voltmeter 10 times that of VTVM.
100	10 megohm	2.0 megohm	Nonelectronic voltmeter 5 times that of VTVM.
500	10 megohm	10.0 megohm	Nonelectronic voltmeter same as that of VTVM.
1,000	10 megohm	20.0 megohm	Nonelectronic voltmeter one-half that of VTVM.

*Nonelectronic voltmeter-20,000 ohm-per-volt type.



1. Fuse lamp.
2. Line adjust control.
3. Pilot light.
4. Power switch.
5. Filament voltage.
6. Filament selectors.
7. A-c line cord.
8. Grid jack.
9. Bias control.
10. Plate jack.
11. Shunt control.
12. Neon lamp.
13. Meter.
14. Meter reverse switch.
15. Rectifier switch.
16. OZ4 switch.
17. Gas 2 switch.
18. Gas 1 switch.
19. Mut. Cond. switch.
20. Diode switch.
21. Line Adj. Switch.
22. Function switch.
23. Suppressor selector.
24. Cathode selector.
25. Screen selector.
26. Plate selector.
27. Grid selector.
28. A-c line cord.
29. Test leads.
30. Pin straighteners.
31. Adapters.
32. Tube test data manual.

AE.243

Figure 9-14.—Electron Tube Test Set TV-7/U.

In many cases it will not be necessary to measure the current in a circuit as it can be easily calculated by dividing the measured voltage drop in the circuit by the resistance of the circuit.

COMPONENT TESTERS

The components considered to be the most essential in electronic circuits are electron tubes and transistors. Test equipments for these components, representative of those in general use, are discussed in this section.

ELECTRON TUBE TESTER

The TV-7/U (fig. 9-14) is a typical, general-purpose, electron tube tester. It is designed to enable the technician to quickly and accurately determine the condition of electron tubes. Tests that can be made include, but are not limited to, tests for shorts, noise, gas, cathode leakage, and quality.

The front panel controls adjust (or switch) the various voltages necessary for testing. The tube data chart (book type), which is supplied with the equipment, lists the control settings and the test specifications for the various types of tubes generally used.

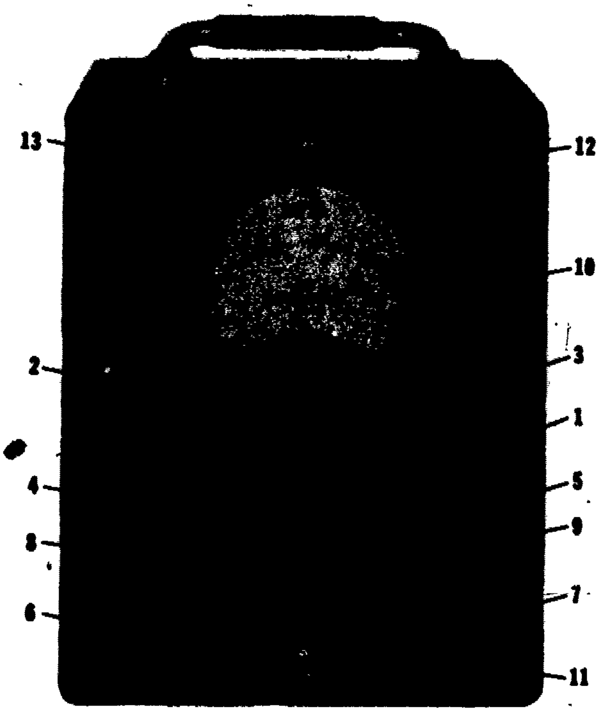
Before inserting a tube for testing, refer to the tube data chart and insure that the front panel controls are set to the positions for that tube type in order to prevent possible damage to the equipment or the tube.

TRANSISTOR TESTER

Test Set, Transistor TS-1100/U (fig. 9-15) is designed to measure the beta parameter (characteristics) of a transistor when the transistor is connected in a circuit, and to measure beta and I_{CO} parameters with the transistor removed from the circuit.

The characteristics of the test set are:

1. Range of beta 10 to ∞ in a single band.
2. Leakage current measurements: 0 to 50 microamperes.
3. Temperature range: 0° C to +50° C.
4. Power Supply: Battery operated.



AT.112

Figure 9-15.—Test set, transistor TS-1100/U.

The equipment contains two separate battery power supplies. One provides the power for the internal circuits, and the other furnishes the bias voltage required for the transistor under test. Either the mercury type or zinc-carbon batteries may be used for operation of the test set.

The following controls, as seen on the front panel (fig. 9 15), are incorporated in the test set:

1. POWER switch (labeled ON-OFF): Turns the internal power source on or off.
2. PNP-NPN (transistor select) switch: Selects proper collector bias polarity for the type transistor under test.
3. BETA switch: Permits readout of beta.
4. BIAS SELECT switch: Used to set proper collector bias voltages (nominally 3, 6, or 12 volts). Also checks the condition of internal battery when in the TEST position.
5. RED LINE SET control: Adjusts the amplitude of the test signal.

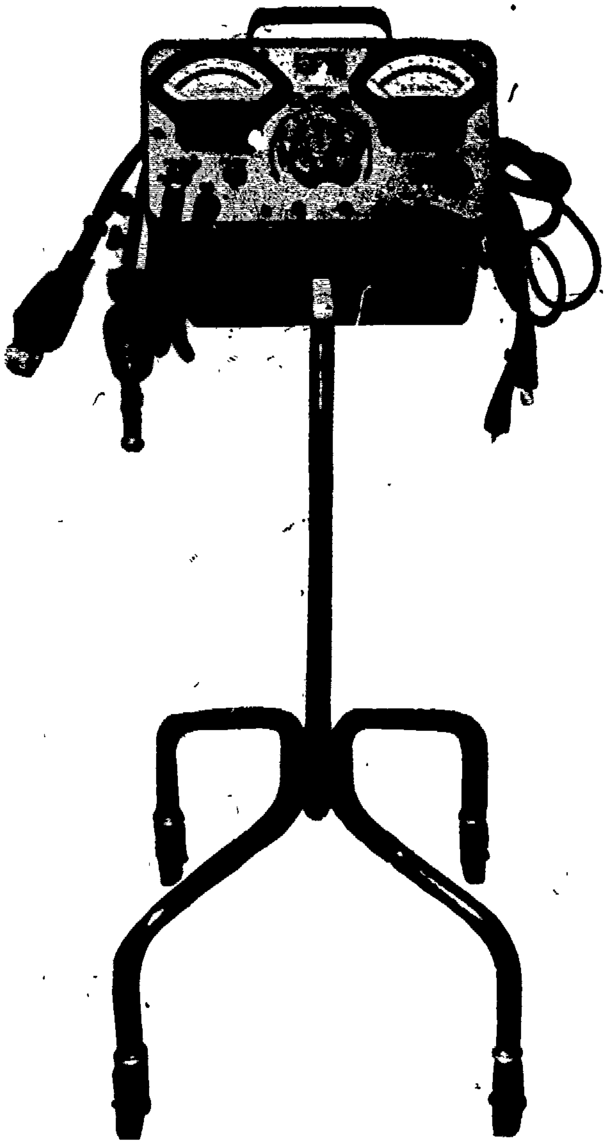


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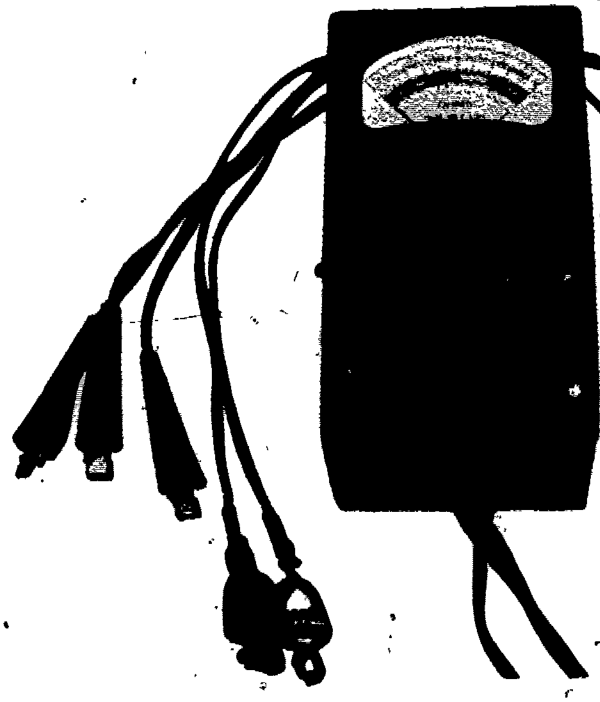
Figure 9-16.—Battery/starter tester.



AS.260

Figure 9-17.—Ignition coil tester.

6. SHORT switch (labeled CB, CE, BE): Enables measurement of a short circuit or a low impedance in the collector-base (CB), collector-emitter (CE), or base-emitter (BE) circuits.

7. I_{co} switch: Enables readout of transistor leakage.

8. SHORT indicator: The indicator lamp will light when a short circuit or low impedance exists in either the transistor under test or in the surrounding circuitry. If the lamp lights, this indicates a load of less than 500 ohms.

9. TEMPERATURE indicator: The indicator lamp will light when the ambient temperature surrounding the equipment exceeds 122° F. This indicates that the equipment is operating in an environment beyond that for which it has been designed, and that measurement inaccuracies will arise.

10. METER: Indicates magnitude of beta; indicates magnitude of I_{co}; and indicates the condition of the internal battery. (The battery is good when the meter needle moves under the green band on the dial.)

11. PROBE connector: For connecting the cables (furnished with the test set) to the transistor to be tested.

12. TRANSISTOR socket (labeled E-B-C): Enables direct connection between the test set and transistor to be tested.

13. BATTERY DISCONNECT switch (upper left corner of panel—not labeled): Disconnects

the internal battery when the front cover is snapped in place.

For proper procedure in operating the test set, refer to Technical Manual for Test Set Transistor TS-1100/U, NavShips 93277.

AUTOMOTIVE TESTERS

All automotive test equipment is designed and constructed to perform tests of one or more specific types. These tests are used to determine the proper operation of the battery, starter, ignition, and generator of the automotive electrical system. Without proper test equipment, the ASE would be handicapped, and many manhours would be utilized in a hit and miss system of troubleshooting. Every ASE should learn to use available test equipment properly and familiarize himself with the contents of all applicable instruction manuals.

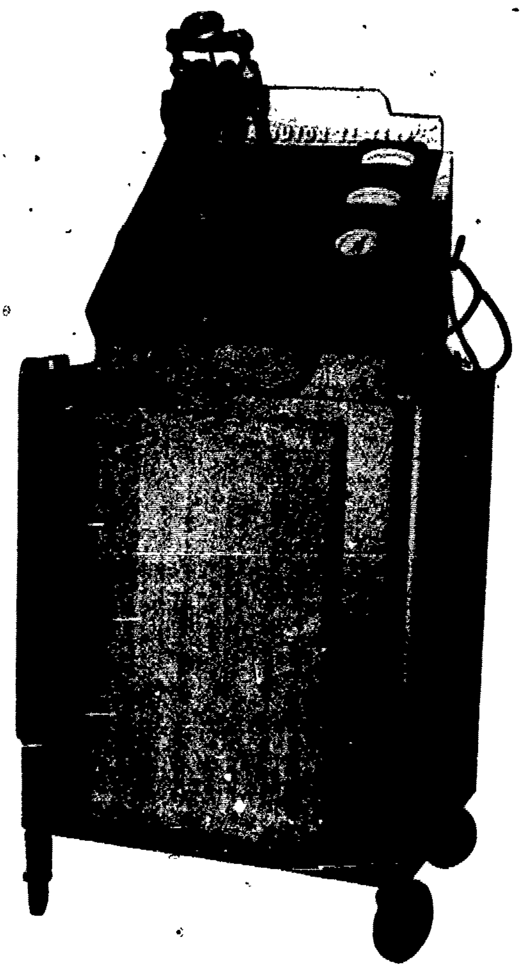
Many automotive electrical system troubles can be located by use of voltmeters, ammeters, and/or ohmmeters which were discussed earlier in this chapter.

BATTERY/STARTER TESTER

A battery/starter tester (fig. 9-16) is an instrument used for checking the condition of the starting system of a vehicle. The tester consists of a voltmeter, an ammeter, and a carbon resistor. The resistor may be adjusted to place a load on the battery. With the battery/-starter tester the ASE can make a battery capacity test and a cranking voltage test, check the insulated circuit and switches within the system, check the starter ground circuit, and make a starting motor amperage draw test.

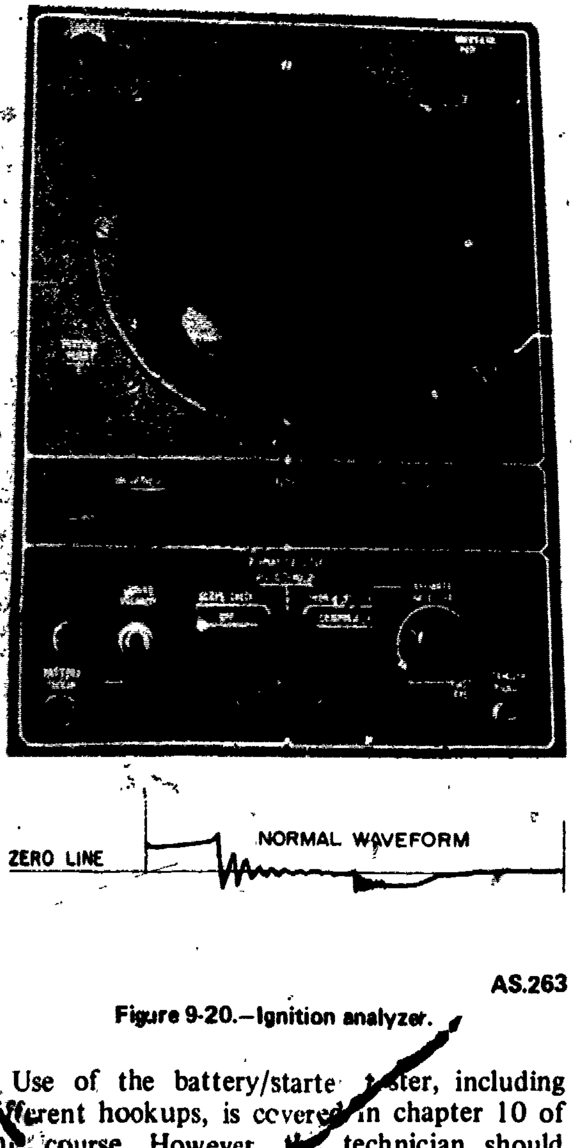
AS.261

Figure 9-18.—Capacitor tester.



AS.262

Figure 9-19.—Distributor tester.



AS.263

Figure 9-20.—Ignition analyzer.

Use of the battery/starter tester, including different hookups, is covered in chapter 10 of this course. However, the technician should always refer to the manual for the test instrument.

IGNITION COIL TESTER

An ignition coil tester (fig. 9-17) is an instrument that simulates an ignition system. Whether the coil is operating in the ignition system or the ignition coil tester, the coil functions the same.

The main function of an ignition coil is to take electrical energy from the vehicle's low voltage system and transform that energy into the high voltage necessary to jump a spark plug gap. When a coil becomes defective, some of its energy will be lost in the coil itself. If enough energy is lost, there will not be a sufficient amount left to cause a spark. A slight amount of energy loss in a coil may not affect ignition performance; however, once a coil starts to break down, it takes only a short time before it fails completely. Early detection for slight coil defects is an important feature of the coil tester.

Coil troubles can be grouped into three general classifications:

1. Shorted turns in the primary or secondary windings.
2. Insulation breakdown between turns of wires and coil case.
3. Broken wires in either the primary or secondary windings.

All of these troubles can be detected by making a coil capacity test and a secondary continuity test. The manufacturer's manual for the test equipment will show how to hook up the tester and gives the readings that should be obtained.

Sometimes coil troubles show up only when the coil is at operating temperature. For this reason, provision is made for the tester to quickly heat the coil to operating temperatures.

CAPACITOR TESTER

A capacitor tester (fig. 9-18) is used to measure the series resistance, capacity, and leakage of ignition capacitors. In addition to testing capacitors, the capacitor tester also serves as a convenient, low range ohmmeter permitting resistance measurements to be made of fuel gages, horn relays, overdrive circuits and many other electrical components and circuits.

The manufacturer's manual gives information on how to use the particular equipment to the best advantage.

DISTRIBUTOR TESTER

Distributor testers are variable-speed devices designed to drive uninstalled distributors at various speeds for testing. The distributor tester (fig. 9-19) is a self-contained electrically operated device used for testing and analyzing ignition distributors. It functions to determine whether the distributor being tested meets the manufacturer's specifications. The unit provides for accurately checking the cam angle, spark advance (vacuum and mechanical), and cam lobe accuracy of distributors having either clockwise or counterclockwise rotation. The unit operates on 115-volt, 60-hertz alternating current.

IGNITION ANALYZER

The ignition analyzer (fig. 9-20) is a cathode ray-oscilloscope measuring and testing device. It is engineered specifically to give quick, important information concerning an automotive ignition system.

There are several manufacturers of ignition analyzers and slight variations in operation may be encountered, so before using an analyzer with which you are not familiar, always check the manufacturer's manual.

The ignition analyzer will indicate the following information about the operating condition of an ignition system of any vehicle using a 6- or 12-volt ignition system.

1. Ignition coil polarity.
2. Spark plug firing voltages.
3. Secondary system insulation.
4. Available secondary ignition voltage.
5. Secondary circuit resistance.
6. Distributor point dwell.
7. Distributor cam lob accuracy.
8. Breaker point action.
9. Ignition voltage reserve.
10. Point arcing.
11. Point bounce.
12. Erratic point closing.
13. Spark plug condition.

The ignition analyzer produces an image of a waveform on a screen which indicates what is occurring in the ignition system. The technician simply checks what he sees on the screen against a normal waveform. (See fig. 9-20.) Any variations of the normal waveform can be interpreted by checking the manufacturer's manual.

Most ignition analyzers are powered by 115-volt 50- to 60-hertz single-phase alternating current. The ignition analyzer is a portable device; it can be moved about easily and can be plugged into any standard electrical outlet. Make sure the machine is grounded before turning it on.

Controls for the ignition analyzer are located on the front panel convenient to the operator, and are clearly identified as to their functions. A pilot light on the panel indicates whether the ignition analyzer is on or off.

UNIVERSAL ENGINE ANALYZER

The universal engine analyzer illustrated in figure 9-21 is manufactured by the Simpson Company and is representative of the automotive electrical test equipment available to the ASE. This engine analyzer combines many of the features of the automotive testers discussed previously.

1. Tachometer–The tachometer is designed for use on 6-, 12-, 24-, and 32-volt electrical systems of both distributor and magneto ignition systems. The rpm ranges are represented on two scales–a 0-1,000 rpm scale and a 0-8,000 rpm scale.

2. Dwell meter–The dwell meter can be used on 6-, 12-, 24-, and 32-volt systems. It indicates the dwell interval for 4-, 6-, and 8-cylinder engines.

3. Vacuum gage–The vacuum gage indicates manifold vacuum in both inches and millimeters of mercury.

4. Fuel flow and pressure gage–The fuel flow and pressure gage indicates pressure in psi and fuel flow in pints per minutes.

5. Cylinder condition analyzer–The cylinder analyzer accurately pinpoints the location and extent of compression leaks before engine disassembly.

6. Timing advance indicator–The timing indicator performs speedy initial timing checks and fast accurate measurement of distributor advance mechanism operation while the engine is running. A tachometer is provided with this test indicator.

7. Coil tester–The coil tester is capable of testing the coil primary and secondary windings for opens, continuity, grounds, stress voltages, and insulation leakage.

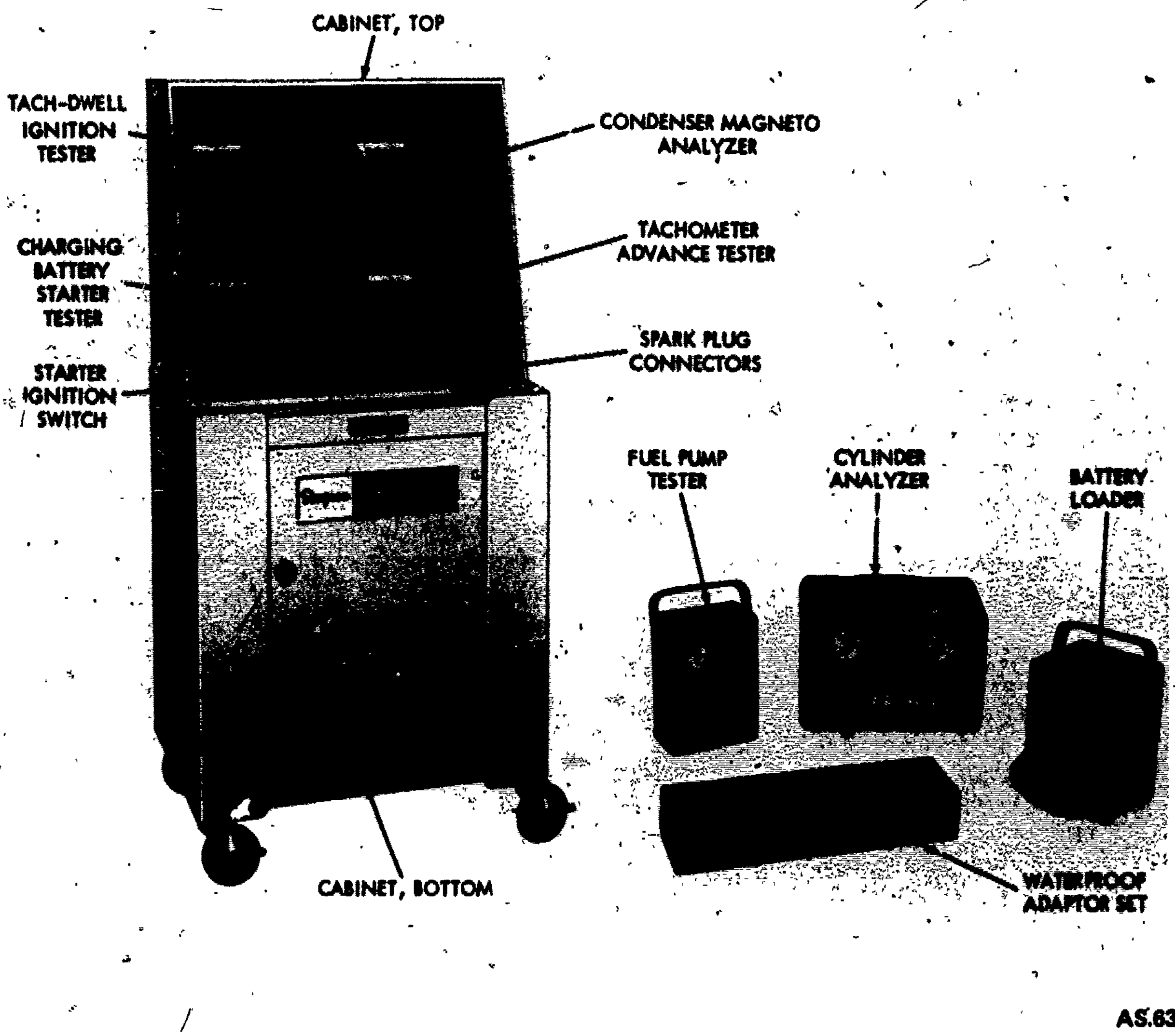


Figure 9-21.—Universal engine analyzer.

8. Condenser tester—The condenser tester is capable of performing the three basic functions required in testing condensers: series resistance, leakage, and capacity.

9. Ammeter—The ammeter is capable, by use of shunts, of measuring currents up to 300 amperes. As with all of these components, it works on voltages of 6, 12, 24, 32.

10. Voltmeter—The voltmeter is capable of measuring voltages of 6-, 12-, 24-, and 32-volt systems.

11. Ohmmeter—The ohmmeter is capable of providing continuity readings and accurate resistance readings to 100,000 ohms.

12. Battery-starter tester—The battery-starter tester quickly and accurately tests starter cranking voltage, battery capacity and condition, starter amperage draw and circuit resistance of switches, cables, and connections.

13. Generator and voltage and current Regulator Tester—This tester measures the voltage and amperage of and resistance in generators. alternators, voltage and current regulators, relays, and wiring of all 6-, 12-, 24-, and 32-volt a-c and d-c systems. Specific testing capabilities include current draw of a-c and d-c generator fields, a-c and d-c generator outputs, regulator

opening and closing voltages, and voltage and current regulator settings.

14. Ignition tester–This unit measures the resistance and insulation (leakage) of both primary and secondary ignition circuits.

15. Remote starter-ignition switch–The remote starter-ignition switch provides engine starte. and ignition control from underhood positions.

16. Accessories–The accessories include a complete kit of all required connectors, adapters, and charts necessary for checking both waterproof and nonwaterproof automotive systems.

17. Stand–The stand is a completely enclosed storage cabinet, designed for storing all the analyzer components.

Notice in figure 9-21 that several of the items mentioned above have been combined into one single component. These components may be removed from the analyzer stand and used as individual testers. Each of the large components is provided with its own carrying handle.

GENERATOR-ALTERNATOR TESTER

The generator-alternator tester Model GAT-620 (fig. 9-22) is manufactured by the Sun Electric Corporation. This tester is designed to accurately test 6-, 12-, and 24-volt light and heavy duty automotive generators, alternators, and regulators. The tester has one 12-volt battery and two 6-volt batteries connected in series and tapped so that a 6-, 12-, or 24-volt circuit can be obtained. The tester has a 1 1/2-hp, constant speed, 220-volt, single-phase, 60-hertz, electric motor to drive the generator or alternator.

The generator or alternator and regulator can be mounted on the tester and tested for proper operation. The opening and closing voltages and currents of the regulator relays can be checked and adjustments made if needed. The manufacturer's manual covers the step by step procedures for making these different tests and adjustments on the charging system components.

Figure 9-23 illustrates the different components of the GAT-620 control panel. A more detailed description of the components is given in table 9-2.

AS.264
Figure 9-22.—Generator-alternator tester.

ELECTRICAL LOAD BANK TESTERS

Electrical powerplants may perform well under a light load or no load, but perform unsatisfactorily under a heavy load (within load limits for which they were designed). The electrical load bank testers are designed to load and test the generators, alternators, rectifiers, electrical systems, and prime movers (engine or electric motor) of electrical powerplants. When a load is placed on the powerplant, it in turn places a load on the prime mover, and in so doing, the prime mover performance is checked.

Table 9-2.—Functional description of GAT-620 controls and instrumentation

1. TACHOMETER—Speed indicator with 0 to 5,000 rpm range.
2. BEAM TACHOMETER CONTROL—Measures pulley speed/electronically.
3. FIELD CURRENT AMMETER—D-c type to measure Field Current Draw.
4. FIELD CIRCUIT SWITCH—Automatically selects test panel circuitry for A and B type field circuits.
5. FIELD CONTROL—A manually controlled variable resistor used to control generator field current or perform Relay Tests. The OPEN-REG. CYCLE position incorporates a cycle switch opening Battery Circuit to Regulator and Field Circuit to Generator to cycle Charging System.
6. FIELD RELAY TEST SWITCH—Automatically selects test panel circuitry for Field Relay closing Voltage Tests.
7. RELAY INDICATOR LAMP—Indicates closing of Field Relays.
8. FIELD SELECTOR SWITCH—In REGULATED position, connects Variable Control in series with Regulator and Field Leads. In MANUAL position, connects Variable Control in series with Field Circuit Switch and Generator Field Lead.
9. TEST LEADS—Only three required. The BATTERY, FIELD, and AUX Leads provide the necessary connections between Generator and Test Panel.
10. REGULATOR RECEPTACLE—Receives quick plug-in connector of Regulator Test Leads. Connector plugs on Test Leads are same as on the vehicle and cannot be improperly connected.
11. DOUBLE CONTACT VOLTAGE REGULATOR TEST SWITCH—Used in conjunction with the voltage regulator test of double contact type voltage regulator.
12. SHORTING CONTACT LIGHT—Indicates operation of the "shorting" contacts in double contact type voltage regulators.
13. SERIES CONTACT LIGHT—Indicates operation of the "series" contacts in double contact type voltage regulators.
14. D-C AMMETER—Indicates rate of charge or discharge.
15. METER POLARITY SWITCH—Selects D-C AMMETER polarity to match polarity of unit being tested.
16. LOAD CONTROL—The control has three positions:
    OFF—No Load applied.
    1/4 OHM—For Voltage Regulator Testing.
    VARIABLE LOAD—Manually controlled carbon pile type variable resistor used in conjunction with Generator Alternator Output Testing and Current Regulator Tests.
17. CUTOUT RELAY TEST BUTTON—Opens battery circuit and inserts Cutout Relay Indicator Lamp circuit.
18. CUTOUT RELAY INDICATOR LAMP—Serves as Tester Battery Circuit Pilot Light and indicates closing of Cutout Relay.
19. D-C VOLTMETER—Used to measure voltages during tests.
20. VOLT SCALE SELECTOR SWITCH—Selects voltmeter scale range required for unit being tested.
21. VOLTMETER SELECTOR SWITCH—Selects circuit for connecting Voltmeter internally to test panel circuitry or to EXTERNAL Leads.
22. EXTERNAL VOLTMETER LEADS—For testing any portion of charging circuits.
23. VOLTAGE SELECTOR—Selects tester battery voltage for the voltage of unit being tested. (6, 12, or 24 volts.)
24. BATTERY DIRECT BUTTON—This tester uses a Diode and a Resistor connected in parallel between the BATTERY Lead and batteries. Current to battery flows through Diode and Resistor. Current flow from battery is limited by the Resistor, eliminating heavy arcing should BATTERY Lead become grounded. Depressing the BATTERY DIRECT Button, bypasses the Resistor and Diode.
25. POLARITY SWITCH—Selects tester ground polarity to match ground polarity of unit being tested.
26. MOUNTING PAD WITH GUIDE SLOT—To accommodate vises for mounting of Alternator and Generators.
27. RETAINER BAR BOLTS—Provides quick mounting of Alternator Mount Plate or Generator vise.
28. PULLEY ALIGNMENT GUIDE—To simplify proper pulley alinement when mounting Alternator or Generator in tester.
29. GENERATOR LOCK LEVER—Permits adjustment of Generator speed, and locks Generator at any fixed speed.
30. GENERATOR BELT GUARD—Provides operator protection by enclosing Generator drive belt and pulley.
31. REGULATOR MOUNT—Adjustable, to position Regulator as on the vehicle.
32. MOTOR SWITCH—On-Off Switch to control Drive Motor.
33. MOTOR REVERSING SWITCH—Controls direction of Generator rotation as viewed from drive end.

Therefore, the electrical load bank testers are an indispensable item of test equipment in keeping the electrical powerplant operating at peak efficiency.

There are many types and models of load banks in use. Testing capabilities vary in that some types are designed for a.c. only or d.c. only while others are designed for both a.c. and d.c. The type and amount of the particular powerplant's power output will determine which load bank can be used.

NT-1 FIELD TEST UNIT

The NT-1 (fig. 9-24) is designed for loading and testing only the d-c output of electrical powerplants. Its load capabilities are:

1. Servicing power at 28 volts, up to 500 amperes.
2. Transformer rectifier at 28 volts, up to 200 amperes.
3. Jet starting at 33 volts, up to 1,000 amperes (intermittent).

It is mounted in an enclosed cabinet equipped with hinged covers that are open during operation for access to the control panel and to allow air flow over the load resistors.

For application to a particular powerplant, refer to the Operation and Service Instructions for the particular powerplant.

A-1 LOAD BANK

The A-1 load bank (fig. 9-25) is designed for loading and testing only the a-c output of electrical powerplants equipped with 120/208-volt, 3-phase, 4-wire, wye, 400-hertz alternators. It provides resistive loads up to 60 kw and reactive loads up to 40 kvar.

It is mounted on a 4-wheeled trailer and enclosed in a weatherproof cabinet. The cabinet is equipped with hinged panels which are kept open during operation to permit access to the control panel and to allow airflow across the load resistors.

For application to a particular powerplant, refer to the Operation and Service Instructions for the particular powerplant.

MLB-1 LOAD BANK

The MLB-1 load band (figs. 9-26 and 9-27) is designed for loading and testing both the a-c and d-c output of many types of electrical powerplants. Its load capabilities are:

1. A-c resistive loads up to 187.5 kw at 120/208 volts, 400 hertz.
2. A-c reactive loads up to 124 kvar at 120/208 volts, 400 hertz.
3. D-c servicing loads up to 1500 amperes at 28 volts.
4. D-c jet start loads up to 1500 amperes at 28 volts.

It is mounted on a 4-wheeled trailer and enclosed in a removable steel, weather-resistant housing. Generated heat from the load modules is dissipated by cooling fans. All operating controls and instrumentation are located on a common panel at the rear of the unit. (See fig. 9-27.)

For application to a particular powerplant, refer to the Operation and Service Instructions for the particular powerplant.

GAS TURBINE ENGINE (COMPRESSOR) TEST EQUIPMENT

Certain tests can be made on gas turbine engines with standard test equipment, but other tests and calibrations require special equipment. It was for this reason that the next two items of test equipment were designed. With this equipment, many tests and calibrations can be made on several different models of gas turbine engines.

UNIVERSAL GAS TURBINE ENGINE TEST STAND

The universal gas turbine engine test stand, model 281150-60, figure 9-28, is termed universal since it can be used to test and check all of the types of gas turbine engines found in ground support equipment. The engine to be tested is mounted on the stand. The stand also provides electrical power, fuel, and oil for engine testing.

The gas turbine engine analyzer is used in conjunction with the test stand to provide controls and instrumentation.

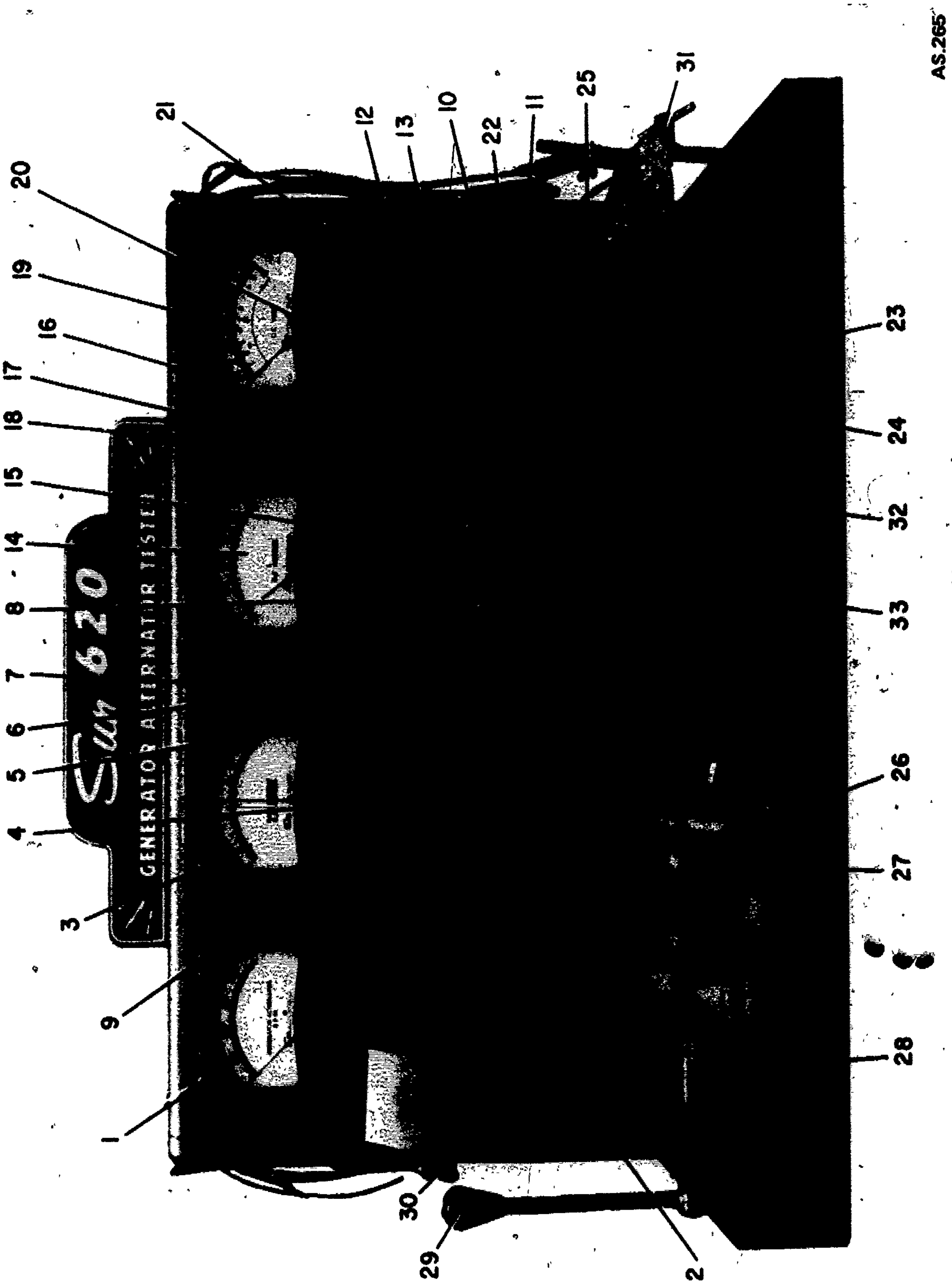


Figure 9-23.—GAT-620 controls and instrumentation.

Nomenclature for figure 9-23.

1. Tachometer.
2. Beam tachometer control.
3. Field current ammeter.
4. Field circuit switch.
5. Field control.
6. Field relay test switch
7. Relay indicator lamp.
8. Field selector switch.
9. Test leads.
10. Regulator receptacle.
11. Double contact voltage regulator test switch.
12. Shorting contact light.
13. Series contact light.
14. D-c ammeter.
15. Meter polarity switch.
16. Load switch.
17. Cutout relay test button.
18. Cutout relay indicator lamp.
19. D-c voltmeter.
20. Volt scale selector switch.
21. Voltmeter selector switch.
22. External voltmeter leads.
23. Voltage selector.
24. Battery direct button.
25. Polarity switch.
26. Mounting pad with guide slot
27. Retainer bar bolts.
28. Pulley alinement guide.
29. Generator lock lever.
30. Generator belt guard.
31. Regulator mount.
32. Motor switch.
33. Motor reversing switch.

Because the test stand is adaptable to many different gas turbine engines, it may be necessary to procure, as special tools, those adapter assemblies required for mounting a specific engine in the test stand. Listed in the manufacturer's instruction manual are the needed parts, plus the instructions for mounting the engine.

GAS TURBINE ENGINE ANALYZER

The gas turbine engine analyzer, part number 281069, figure 9-29, is a lightweight, portable unit. The analyzer instrumentation is attached to panels, which are mounted in a case. The hinged door on the case contains storage space for the analyzer cables and a very sensitive pressure gage. Attached to the hinged door is a schematic wiring diagram and a speed conversion chart to convert tachometer rpm indications to actual engine rpm for the different engines that can be tested.

The analyzer provides a lightweight, portable testing unit which incorporates an electrical system with associated meters and indicators, and a hydraulic and pneumatic system with associated gages and controls for checking and controlling performance of gas turbine engines.

The analyzer should be used only by personnel thoroughly trained in its use, and who possess a thorough knowledge of the electrical, hydraulic, and pneumatic systems and components of the particular engine being tested. These requirements are a prerequisite for satisfactory use of the analyzer and correct interpretation of test results. Constant reference

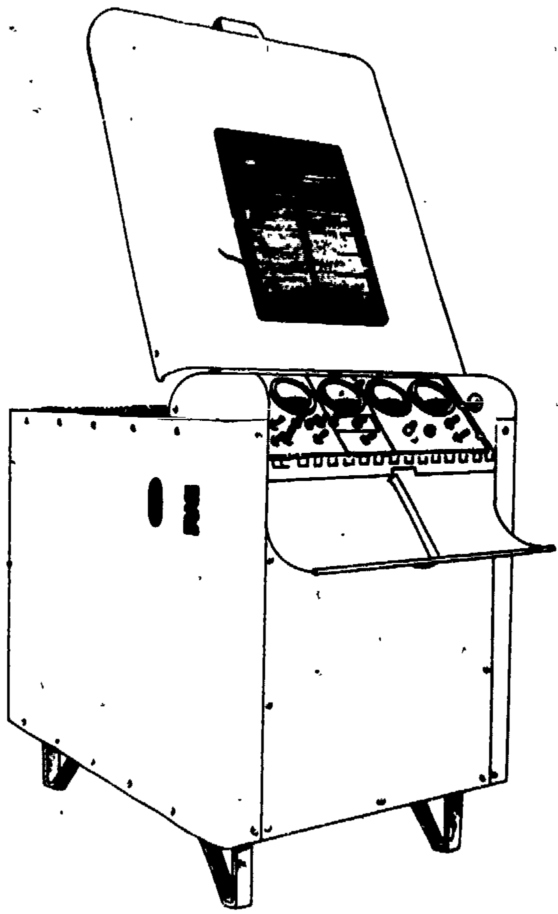


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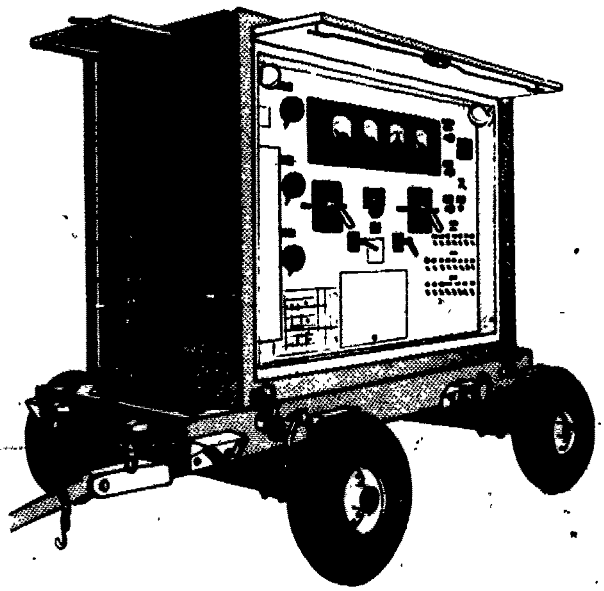
Figure 9-24.—NT-1 field test unit.



AS.266

Figure 9-25.—A-1 load bank.

should be made to the applicable technical manual for electrical and pneumatic schematics and engine performance requirements.

The analyzer may be used while the engine is installed in its service installation (fig. 9-30) or while installed on the universal gas turbine engine test stand (fig. 9-28).

The analyzer may be used for measuring turbine engine rpm, temperature, pressures, output frequencies, and testing of electrical circuit components. It may also be used for monitoring (checking) the engine during operation, for functional checking of engine performance by controlling the load, for static checks of electrical components (such as a fuel solenoid valve without running the engine), and to motor the engine for preservation and depreservation.

For proper functioning, the analyzer depends on electrical, hydraulic, and pneumatic systems connected to the engine through electrical cables, fuel, oil, and air pressure lines.

Reference must be made to the applicable engine technical manual for the procedures necessary to connect the electrical, hydraulic, and pneumatic systems of the analyzer into the systems of the engine being tested.

CARE AND HANDLING OF TEST EQUIPMENT

All maintenance shops are provided with a variety of test equipment to be used in maintaining the many different types of equipment it supports. However, there are very few spare test sets. When a test set becomes inoperative, shop maintenance suffers. Therefore, every man must use the test equipment only for the purposes and in the manner for which it was designed. Protect the equipment from physical harm that may result from dropping, falling, or any other careless misuse, and always observe proper operating techniques.

One of the chief causes of test set failure is carelessness. The user can be careless in operating procedure or in handling the set. The usual carelessness in operating procedure is improper selection of range for the quantity to be measured, such as attempting to measure 250 volts on the 50-volt scale of a meter. If there is any doubt about proper usage of a test set, it is wise to refer to the manual issued with the set.

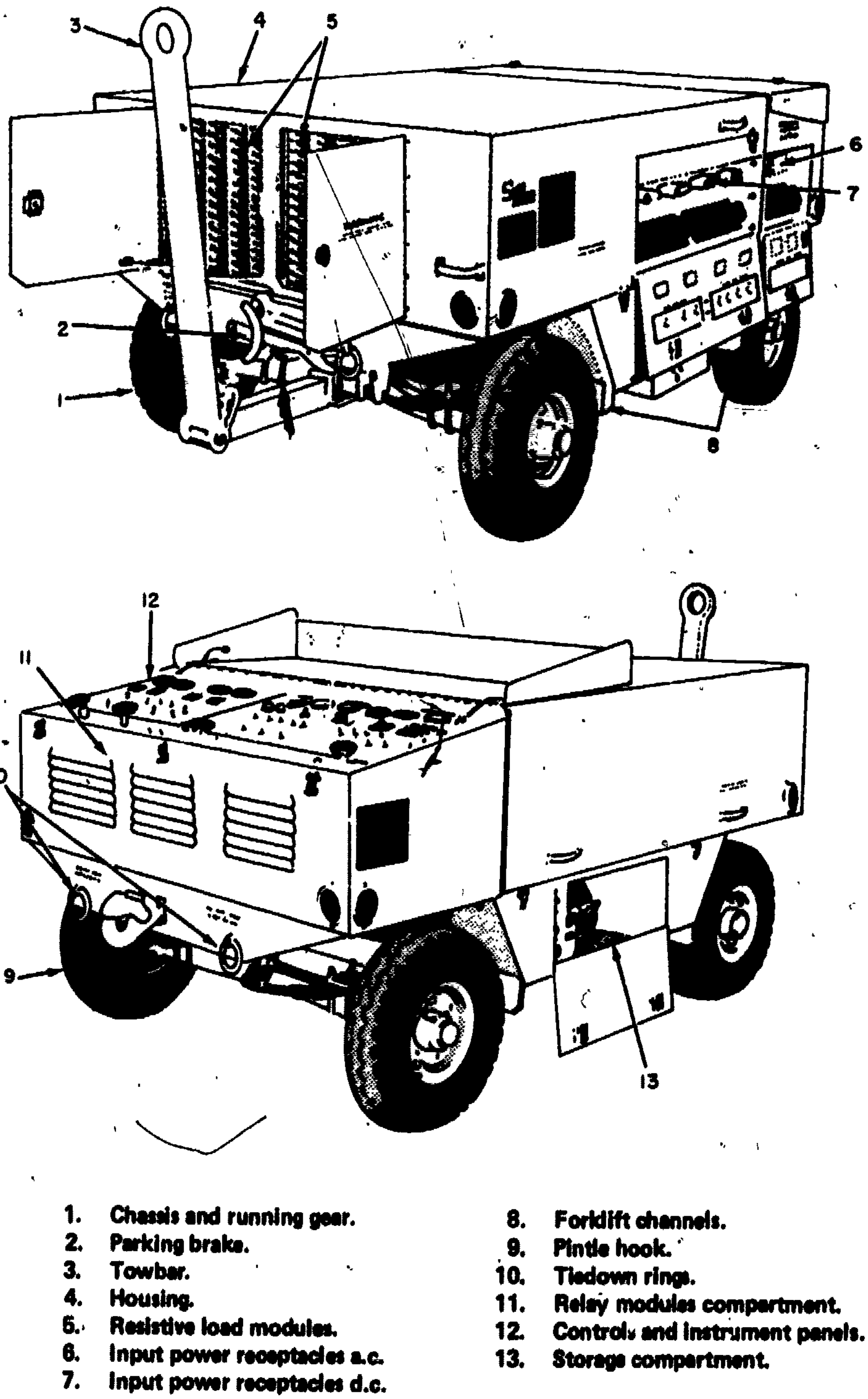
Much damage to test equipment results from improper handling. Technicians often place test sets near the edge of the bench where they can easily be knocked off or pulled off by the test leads. Read the instructions for proper handling and operating procedure, and think while using the equipment.

CALIBRATION

Most test equipment is sensitive and, due to normal use over a period of time, the maximum calibration tolerance will be exceeded; therefore, periodic calibration is required to insure optimum performance. Likewise, many tests and adjustments on support equipment are critical and accurate test equipment is required.

The Naval Air Systems Command calibration program is comprised of two segments—qualification and calibration.

Qualification is accomplished at the intermediate level of maintenance by qualification laboratories designated by the Naval Air Systems Command (usually at the AIMD). Qualification is accomplished in accordance with established intervals or as specified by the Naval Air Systems Command.



1. Chassis and running gear.
2. Parking brake.
3. Towbar.
4. Housing.
5. Resistive load modules.
6. Input power receptacles a.c.
7. Input power receptacles d.c.
8. Forklift channels.
9. Pintle hook.
10. Tiedown rings.
11. Relay modules compartment.
12. Controls and instrument panels.
13. Storage compartment.

AS.308

Figure 9-26.—MLB-1 load bank.

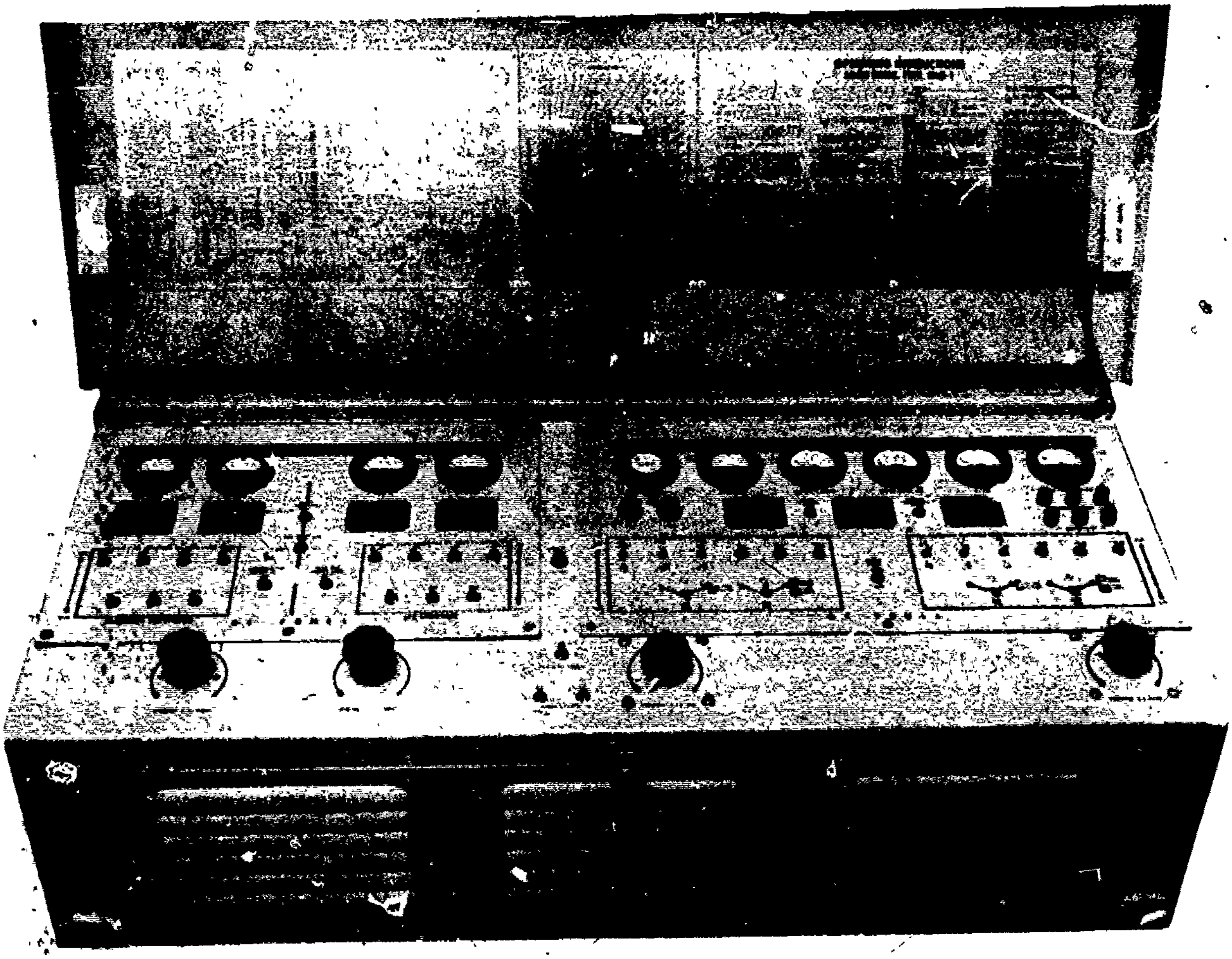


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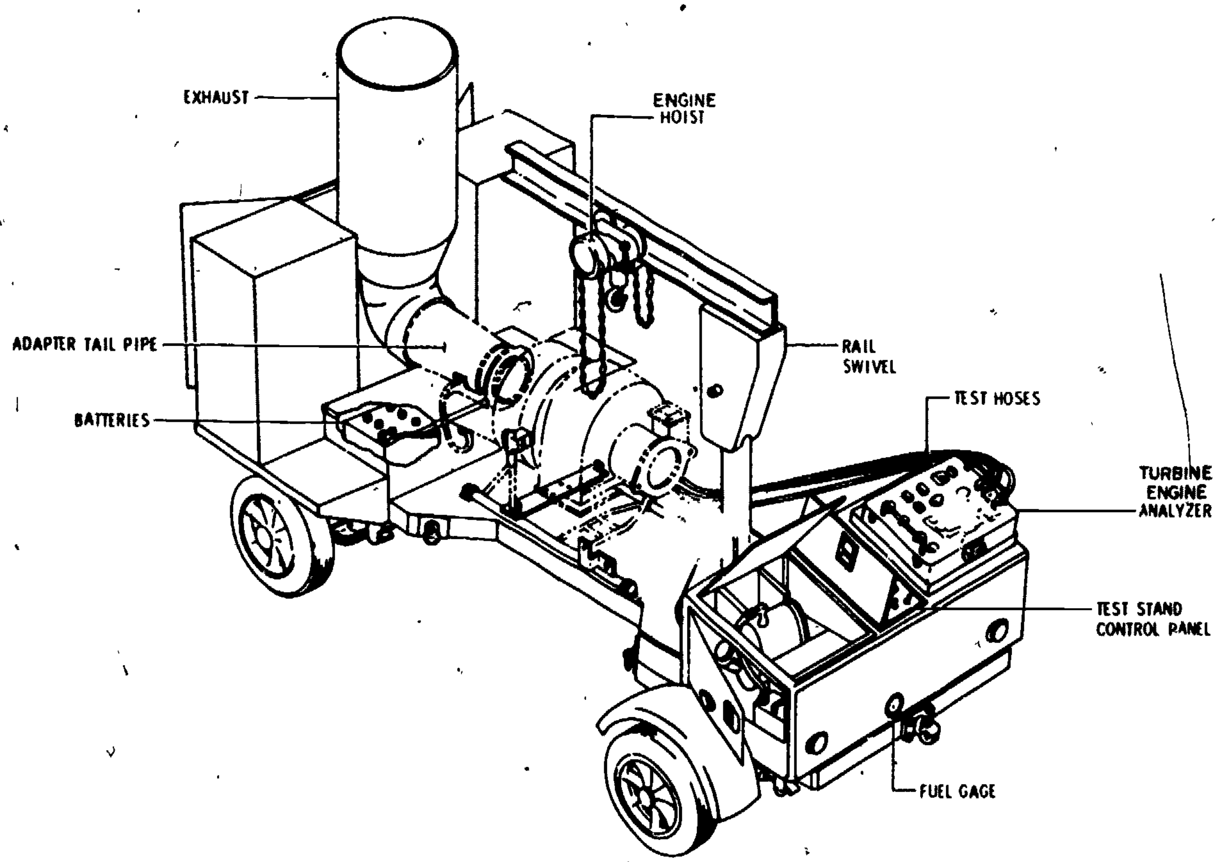
Figure 9-27.—MLB-1 operating controls and instrumentation.

The qualification laboratory issues a local directive promulgating a recall schedule of equipment for qualification and, once an item has been qualified, a tag or decal is affixed to the item showing the activity, the date qualified, and the date that the item is again due for qualification.

Prior to using an item of test equipment the tag or decal must be checked to insure that the equipment is not overdue for qualification. Any item found to be overdue for qualification will not be used until it has been qualified. Also, any newly acquired equipment must be qualified prior to being used.

Calibration is accomplished at the depot level of maintenance in calibration laboratories designated by the Naval Air Systems Command. If an item of test equipment cannot be qualified it is then sent by the qualification laboratory to the cognizant calibration laboratory for repair and/or calibration.

NOTE: A complete breakdown of the Naval Air Systems Command calibration program is



AS.135

Figure 9-28.—Universal gas turbine engine test stand.

contained in OPNAVINST 4790.2, volume II, chapter 7.

REPAIR

Repair of test equipment will be accomplished by the qualification laboratory if possible. However, if an item of test equipment cannot be repaired by the qualification laboratory it will be sent to the cognizant calibration laboratory for repair and calibration. Repair by the individual technician will not be attempted.

HANDLING

Some equipments may require special handling; however, there are several precautions which apply to test equipments in general. Rough handling, moisture, and dust all affect the useful life of such devices. Bumping or dropping a test instrument, for example, may destroy the calibration of a meter or short circuit the elements of an electron tube within the instrument. Creasing or denting coaxial test cables will alter their characteristics, thereby

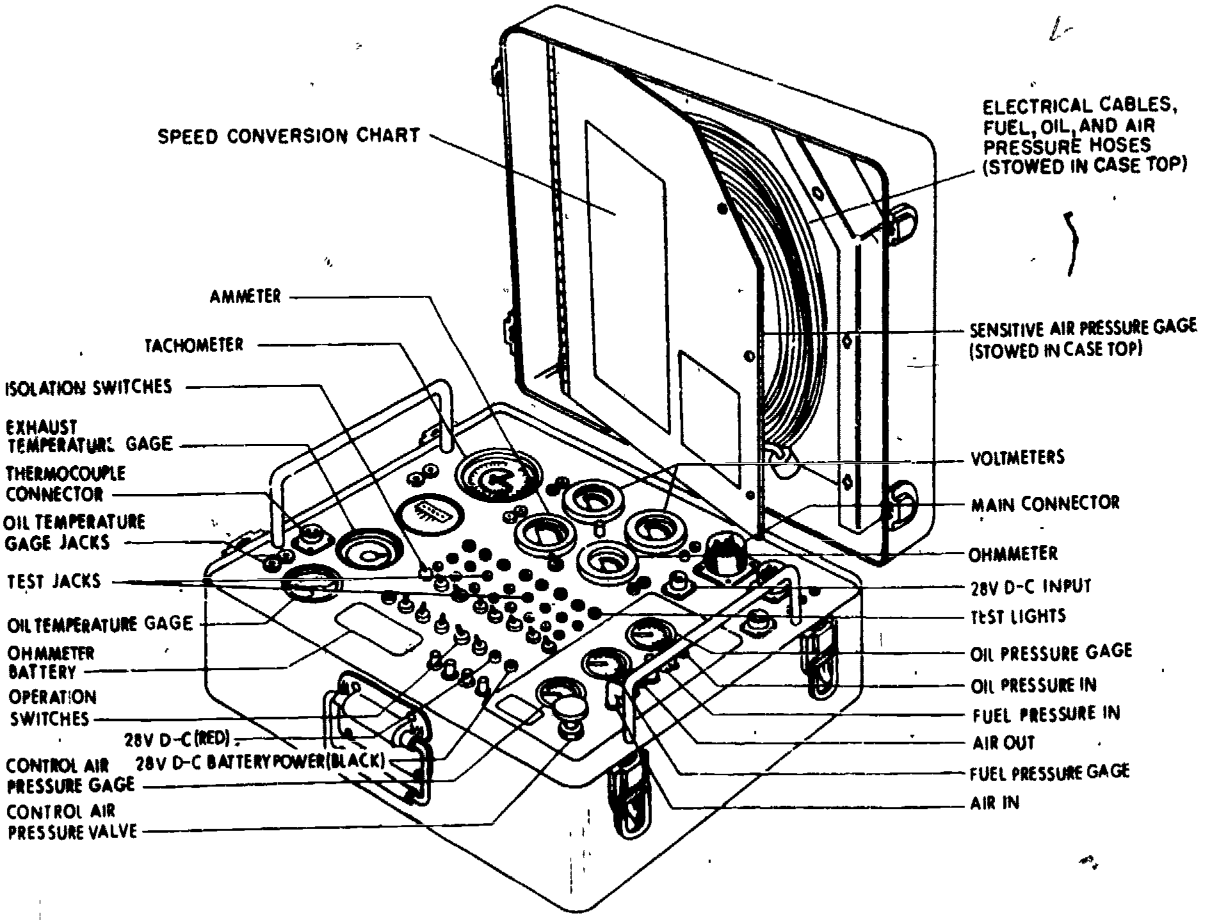


Figure 9-29.—Gas turbine engine analyzer.

affecting the accuracy of any measurements made with these cables.

To reduce the danger of corrosion to untreated parts, always store test equipment in a dry place when it is not in use. Excessive dust and grime inside test equipment also affects its accuracy. Be sure that all the assembly screws which hold the case of the test equipment in place are tightened down securely and, as an added precaution, all dust covers should be installed when the equipment is not in use.

Meters are the most delicate parts of test equipments. In order to insure that the meter will maintain its accuracy, these additional precautions should be followed:

1. Make certain that the amplitude of the input signal under test is within the range of the meter.

2. Keep meters as far away as possible from strong magnets.

3. When servicing an item of electrical equipment which contains a meter, disconnect the meter from the circuit before making resistance or continuity tests.

(The latter precaution will eliminate the possibility of burning out the meter.)

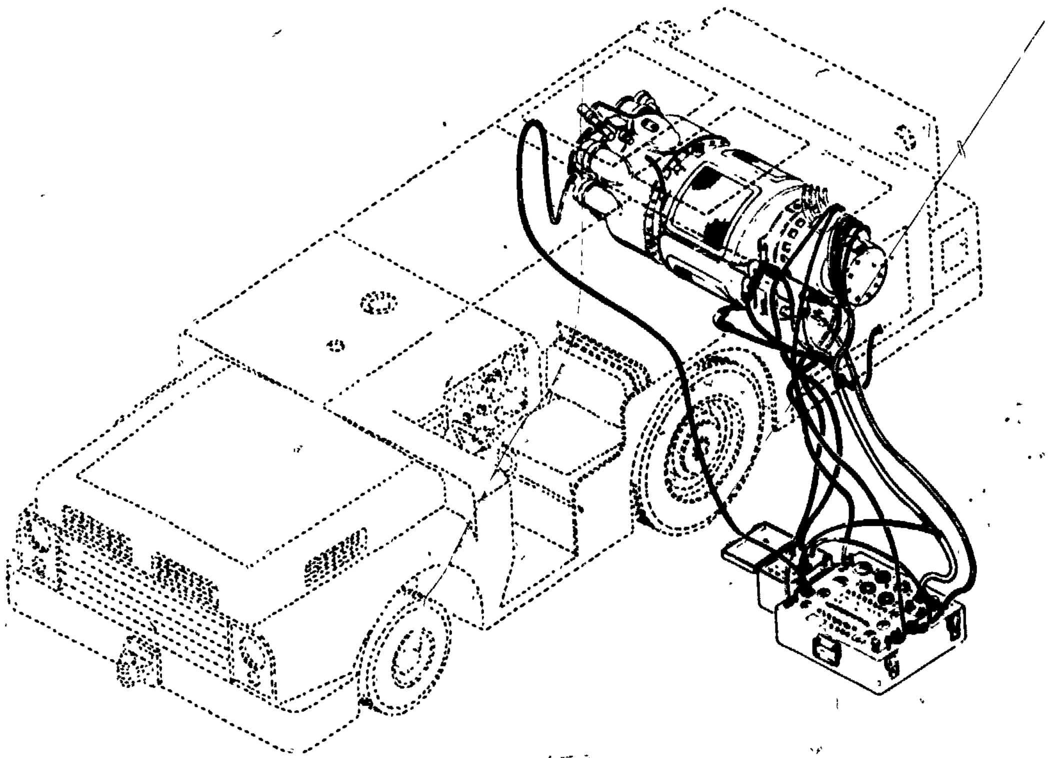


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Figure 9-30.—Analyzer connected to engine in service installation.

The instructions for properly stowing test equipment cables and other accessories, as set forth in the instruction manuals accompanying the equipment, should be carefully read and strictly followed. Improper stowage of accessories results in changes in cable characteristics, intermittent shorts in cables and leads, and, in general, unreliable test indications.

CHAPTER 10

AUTOMOTIVE ELECTRICAL SYSTEMS

In order for the Aviation Support Equipment Technician E to maintain automotive electrical systems, it is necessary that he have an understanding of the various automotive electrical power systems and their associated equipment. He must also have a fundamental knowledge of the means by which automotive electrical power is produced, regulated, controlled, and distributed. With this basic understanding he will be able to recognize and analyze electrical problems and take corrective action.

Basic Electricity, NavPers 10086 (Series), contains a detailed explanation of the principles of electricity and will not be repeated.

The electrical systems of most automotive equipments have dual functions. One of these may be called the performance function that is, supplying the electrical energy that is required to crank and operate the engine. The other function is to supply power for lights, heater, electrical accessories, instruments, and gages.

It is easier, however, to troubleshoot an electrical system by breaking it down into five circuits. Each of these circuits can be isolated and checked individually. (See fig. 10-1.)

The charging circuit supplies all the electric power used by the vehicle. The ignition circuit produces the high voltage necessary for the spark plugs to achieve ignition. The cranking circuit includes the starter.

The lighting and accessory circuits furnish power to operate the safety and convenience devices of the vehicle, such as lights, horn, heater, instruments, and gages.

BATTERIES

The battery most commonly used in automotive equipments is a lead-acid type battery. It is called a lead-acid type battery because its active ingredients are lead and sulfuric acid. The battery is not a storage tank for electricity, but actually stores energy in a chemical form. The battery will meet the electrical system's demands for electrical power under varying conditions unless the battery's capacity is exceeded. For example, the battery can be used to supply limited amounts of power for a limited time without operating the generator, or the battery will aid the generator in meeting the electrical system's power demands under low RPM and/or heavy load conditions.

Active materials within the battery react chemically to produce a flow of direct current whenever lights, starter, or other current consuming devices are connected to the battery. This current is produced by chemical reaction between the active materials of the plates and the sulfuric acid of the electrolyte.

CONSTRUCTION

A battery consists of a number of cells connected together. The number of cells depends on the voltage desired. Three cells are connected in series to make up what is commonly referred to as a 6-volt battery; the 12-volt battery is made up of six cells connected in series; and the 24-volt battery has twelve cells connected in series. Some books and other written material on batteries state that the cell has a voltage of 2.0 volts, but each cell will produce approximately 2.15 volts (no load) if a very accurate voltmeter is used and the cell is fully charged. When the cells are connected in series to form a battery, it makes a noticeable difference in the battery voltage (6.45 volts for the 6-volt battery, 12.9 volts for the 12-volt battery, and 25.8 volts for the 24-volt battery). However, for practical purposes this manual will

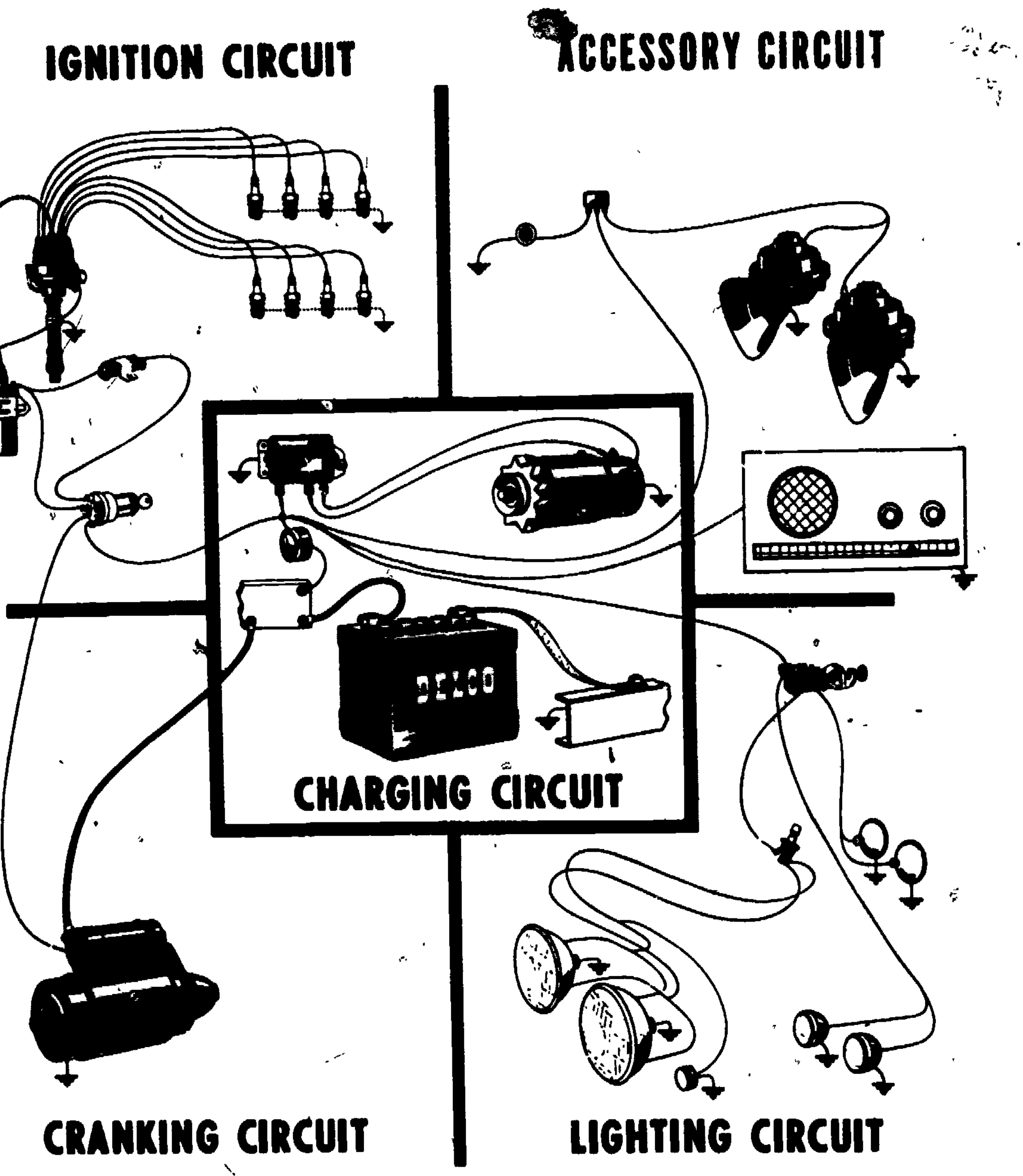

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Figure 10-1.—Circuit breakdown of an automotive electrical system.

also refer to the cell as having a voltage of 2.0 volts.

Each cell consists of two kinds of lead plates, known as positive and negative. (See fig. 10-2.) These plates are insulated from each other by suitable separators (usually wood, rubber, or glass) and are submerged in a sulfuric acid solution (electrolyte).

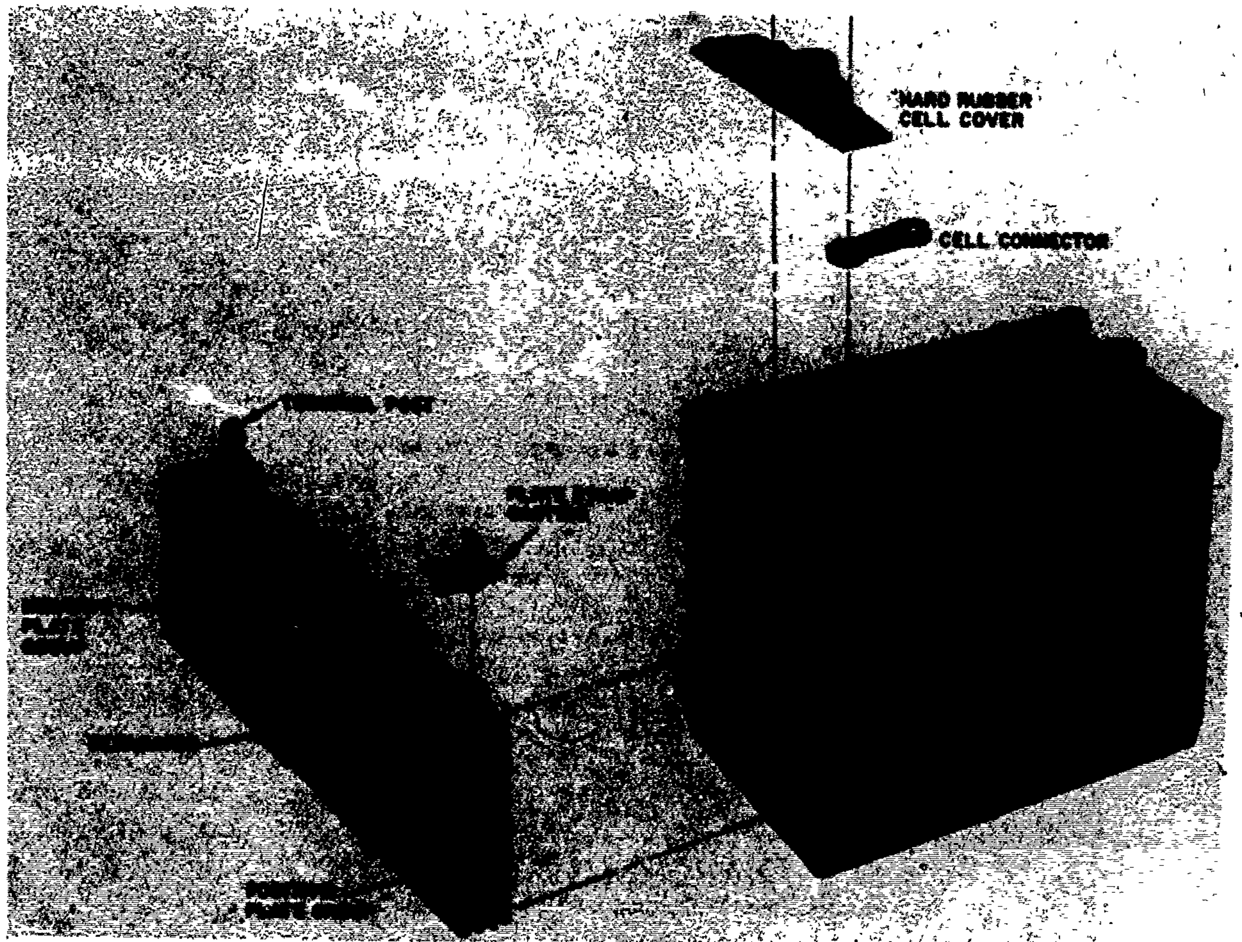

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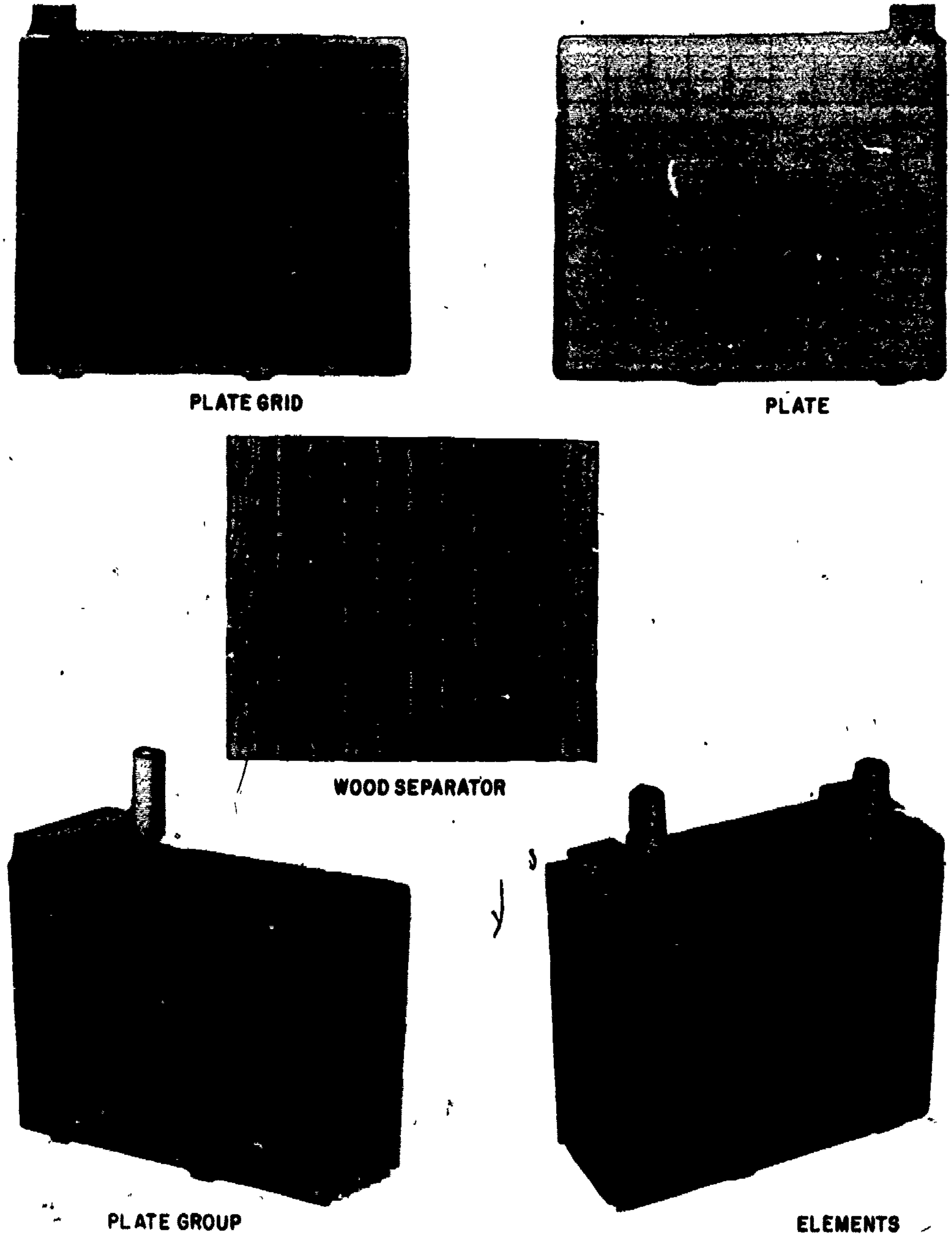
Figure 10-2.—Battery construction and nomenclature.

The backbone of both the positive and negative plates is a grid made of a stiff lead-antimony alloy casting. (See fig. 10-3.) The grid, usually composed of vertical and horizontal crossmembers, is designed to give the plates physical strength and, at the same time, to provide adequate conductivity for the electric current produced by the chemical reaction. The active material, composed chiefly of lead oxides, is applied to the grids in paste form, then allowed to dry. The plates are then put through an electrochemical process that converts the active material of the positive plates into brown colored lead peroxide, and the negative plates into gray, sponge lead.

After the plates have been formed, they are built into positive and negative groups. The plates of each group are permanently joined by melting a portion of the lug on each plate to form a solid weld with a connecting post strap. (This process is termed lead burning.) The connecting post strap to which the plate is burned contains a cylindrical terminal which forms the outside connection for the cell. The negative group of plates has one more plate than the positive group, to provide a negative plate on



AS.273

Figure 10-3.—Cell element construction.

both sides of all positive plates. These groups are shown in figure 10-3.

The assembly of a positive and negative group, together with separators, is called an element. An element immersed in electrolyte is referred to as a cell. Since battery plates are more or less a standard size, the number of plates in a cell is, roughly, a measure of the battery capacity.

A battery container, or case, is a receptacle for the cells that make up the battery. It is made of hard rubber, plastic, or a composition material that is resistant to acid and mechanical shock. Most batteries are assembled in a one-piece container with three, six, or twelve compartments for the individual cells. One element and enough electrolyte to cover the plates are inserted into each cell compartment. (See fig. 10-2.)

Stiff ridges are molded in the bottom of the container to provide support for the plates and a sediment space for the flakes of active material that drop off the plates during the life of the battery.

A hard rubber or plastic cell cover, provided with openings for the two terminals of the element and a vent plug, is placed on each cell. The cells are sealed with pitchlike compound and connected in series by burning cell connectors on the terminals. The vent plug allows accumulated gas to escape and prevents the electrolyte from splashing outside the battery; it is also the means by which water and/or acid are added to the cell.

OPERATION

The lead acid-type automotive batteries have their plates immersed in a solution of sulfuric acid and water. The detailed theory of operation of the lead-acid battery is covered in the chapter entitled "Batteries" in Basic Electricity, NavPers 10086 (Series).

RATING

Lead-acid batteries are rated by their voltage and their ampere-hour capacity. Each cell has a rated voltage output of approximately 2.0 volts. A higher voltage is obtained by connecting more cells in series. Lead-acid batteries are manufactured in multiples of 2 volts, such as 6-volt, 12-volt, and 24-volt.

Standard automotive batteries have a 20-hour discharge rate. The 20-hour discharge rate of a battery is equal to the constant current in amperes which the battery, starting with an initial electrolyte temperature of 80° F, can supply continuously for 20 hours before the voltage has dropped to the low voltage limit at which the discharge should be stopped. For example, a battery rated by the manufacturer as a 6-volt, 120-ampere-hour (A.H.) capacity would be discharged at 1/20 of 120 or 6 amperes, until the voltage has dropped to its specified limiting voltage. The number of hours required for the discharge, 20, multiplied by the rate of 6 amperes gives a battery rating of 120-ampere hours. The voltage and ampere-hour rating of a battery is usually stamped on the battery case.

As a lead-acid battery discharges, the sulfuric acid is absorbed by the plates and the electrolyte is gradually converted into water. This action provides a guide in determining the state of discharge of the lead-acid cell. All that is necessary to determine the state of charge of a battery is to determine the percentage of sulfuric acid remaining in the electrolyte. This is easily accomplished by using a hydrometer. It measures specific gravity instead of percentage; however, in this case the two amount to the same thing. Listed below are specific gravity readings of a lead-acid battery in various states of charge.

1.265-1.290 Fully charged battery
1.235-1.260 Three-fourths charged
1.205-1.230 One-half charged
1.170-1.200 One-fourth charged
1.140-1.165 Barely operative
1.100-1.135 Completely discharged

In extremely hot or extremely cold climates some of these specific gravity readings will vary from those given, even after corrections are made.

The specific gravity of an electrolyte is actually a measure of its density. The electrolyte becomes less dense as its temperature rises, and more dense as its temperature falls. Thus, a high temperature means a low specific gravity and a low temperature means a high specific gravity.

The hydrometer is marked to read specific gravity at only one temperature, 80° F. Under normal conditions, the temperature of the electrolyte will not vary much from this mark. However, large changes in temperature require a correction in the reading.

For every 10° change in temperature above 80° F, add 0.004 to the specific gravity reading. For every 10° change in temperature below 80° F, subtract 0.004 from the specific gravity reading. Assume that a hydrometer reading of 1.280 is obtained when checking a cell. A thermometer in the cell indicates an electrolyte temperature of 60° F. That is a difference of 20° from the normal of 80° F. to obtain the true specific gravity reading, subtract 0.008 from 1.280. Thus, the specific gravity of the cell is actually 1.272. A specific gravity correction chart, similar to the one shown in figure 10-4, is usually found on the hydrometer. It consists of a thermometer to provide the actual temperature of the electrolyte and a table of correction values for different temperatures.

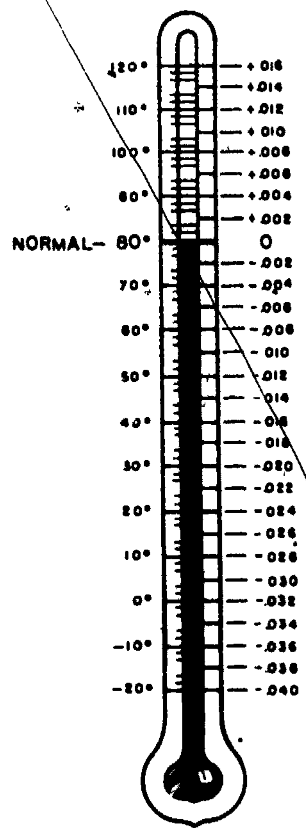


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Figure 10-4.—Specific gravity temperature correction chart.

CHARGING

A battery indicating a hydrometer reading below 1.240 specific gravity at 80° F should be removed and charged. Except in extremely hot climates, never allow the specific gravity to drop below 1.225; in very hot climates this reading indicates a fully charged battery.

When a rundown battery is brought into the shop, it should be recharged immediately. There are several methods for charging batteries; only direct current is used with each method. If only alternating current is available, a rectifier or motor generator must be used to convert to direct current. The two principal methods of charging are (1) constant current, and (2) constant potential (constant voltage). Constant current charging may be used on a single battery or a number of batteries in series. Constant potential charging is used with batteries connected in parallel. The constant potential method of charging is most often used because it is the simplest method, and batteries do not require constant observation while being charged.

Constant Current Charging

In the constant current method, the battery is connected to a charging device that supplies a steady flow of d-c current. A rheostat is built into the charger to adjust the current flow to the battery. Once the rheostat is set, the current remains constant. The usual charging rate is 1 ampere per positive plate per cell. Thus, a 21-plate battery (which has 10 positive plates per cell) should have a charging rate no greater than 10 amperes. When using this method of charging a battery, check the battery frequently, particularly near the end of the charging period. When the battery is gassing freely and the specific gravity remains constant for 2 hours the battery is considered to be fully charged.

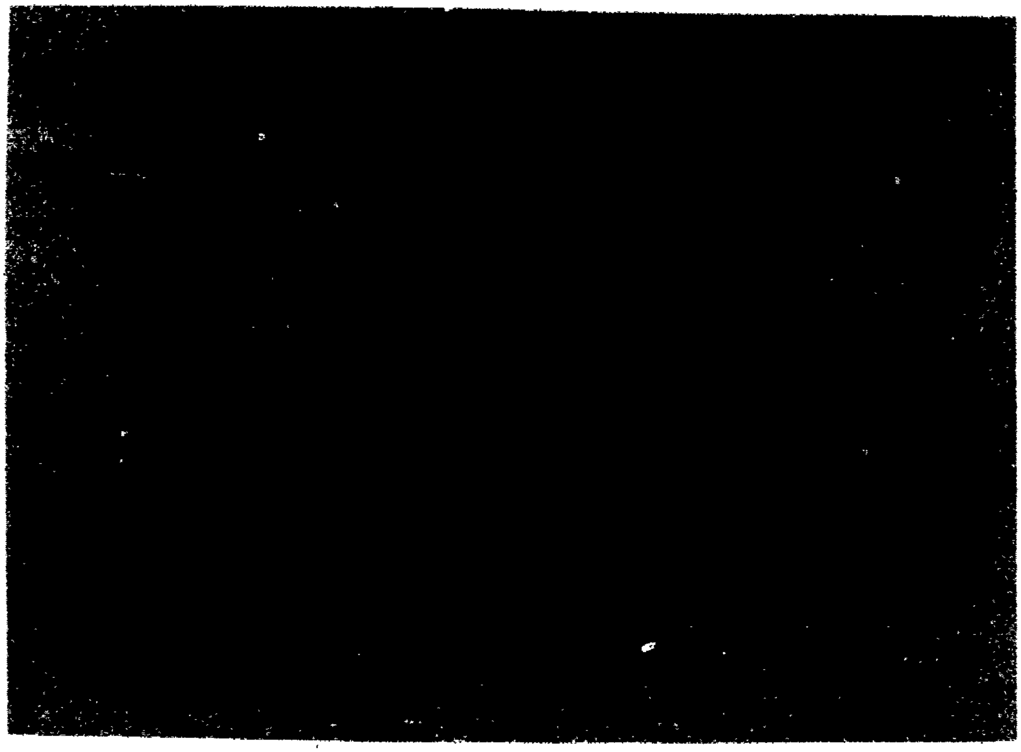

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Figure 10-5.—Constant current battery charger.

The main disadvantage of constant current charging is that the charging current remains at a steady value unless it is adjusted. A battery charged with too high a current rate will overheat and damage the plates, making the battery useless.

A battery charger of the constant current type is shown in figure 10-5.

Constant Voltage Charging

Constant voltage charging, also known as constant potential charging, is accomplished by a motor-generator set, or by a transformer-rectifier. With a constant voltage, the initial current flow to a discharged battery is high because of the difference between battery voltage and the output voltage of the charger. As the state of charge of the battery increases, its voltage increases, reducing the difference in voltages between the charger and the battery. This decreasing voltage differential causes the charging current to gradually taper off to a very low value at the time the battery is fully charged.

Constant voltage chargers are available in many designs and capacities, both stationary and portable. The charger shown in figure 10-6 is the portable constant voltage type.

Charging Practices

Connecting the battery to the charger, turning on the charger and, after a period of time, turning off the charger and disconnecting the battery, sounds simple and easy. But, to insure the safety of personnel and equipment, certain precautions must be observed before, during, and after the charging period.

1. Clean and inspect the battery thoroughly, removing any corrosion present by using a

solution of bicarbonate of soda and water. Insure that this solution does not enter the cells. Check the container (case) for cracks and breaks.

2. Remove the vent caps and inspect the battery internally. If the electrolyte level is low, add distilled water (or drinking water if distilled water is not available) to bring the level of the electrolyte to approximately three-eighths inch above the plates, or to the level specified by the battery manufacturer.

3. Place the vent caps in the cell openings, but do not tighten them down. The vent caps prevent spraying of electrolyte out of the cells during charging, and keep foreign material out of the cells.

4. Connect the battery to the charger, insuring that the positive cable is connected to the positive terminal and the negative cable is connected to the negative terminal.

5. Insure that the charging area is well ventilated, because batteries on charge release hydrogen gas which is highly explosive.

6. Do not allow smoking in the vicinity of batteries being charged.

7. Always connect the battery to the charger before turning on the charger, and disconnect the battery only after turning off the charger. This is to preclude the possibility of creating any spark which could cause an explosion and fire.

8. Take frequent hydrometer readings of each cell and record them. The specific gravity can be expected to rise during the charge; if it does not, remove the battery and dispose of it.

9. Keep a constant watch for excessive gassing. This is especially important when using the constant current method of charging. Be especially watchful at the very beginning of the charge when using the constant voltage method. Reduce the charging current or voltage if excessive gassing takes place.

SELF-DISCHARGE

Discharge takes place in batteries even when they are not in use. The rate of discharge varies with temperature and specific gravity of the electrolyte. Self-discharge changes the specific gravity of the electrolyte, just as normal discharge does. Inactive, charged batteries should be stowed in a cool, dry place to reduce self-discharge. After a battery has been activated, the state of charge should be checked periodically (whether in use or not) and recharged in necessary. A battery will be damaged if it is allowed to remain in a discharged condition. A good charge is especially important in cold weather to prevent freezing. A battery that is completely discharged will freeze at about 18° F, but a battery that has a specific gravity of 1.260 will freeze at about -75° F.

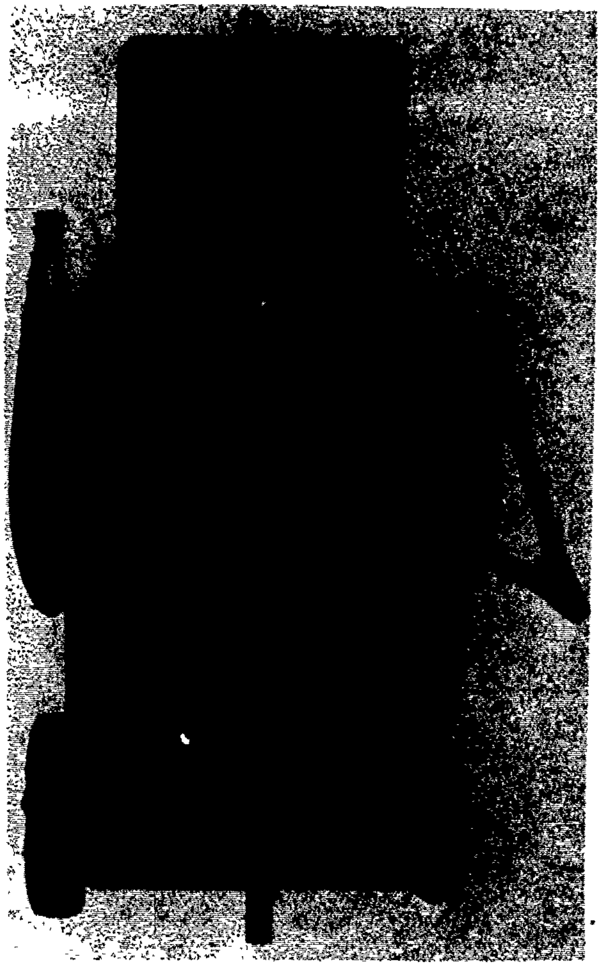

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Figure 10-6.—Portable constant voltage battery charger.

PLACING IN SERVICE

New batteries may be received full of electrolyte and fully charged. In this case, all that is necessary to make them ready for service is to properly install them in the equipment. Most batteries, however, are received "dry and charged".

Dry charged batteries will retain their state of full charge indefinitely so long as moisture is not allowed to enter the cells. Therefore, dry charged batteries should be stowed in a cool dry place. Moisture and air entering the cells will cause the negative plates to oxidize, thus losing their charge. If dry charged batteries are allowed to stay in this condition for a long period of time, damage to the batteries will result. Dry charged batteries must be activated and recharged before placing in service.

To activate a dry charged battery, remove the vent restrictors from the vent caps and remove the vent caps. Fill all the cells to the proper level with electrolyte having a specific gravity of 1.275, or as specified by the battery manufacturer. Best results are obtained when the battery and the electrolyte are at a temperature between 60° F and 80° F, and in no case is the temperature of the electrolyte to exceed 90° F. Some gassing will occur while filling the battery due to the release of carbon dioxide, a product of the drying process, or hydrogen sulfide caused by the presence of some free sulfur. These gases and odors are normal and are no cause for alarm.

Allow the battery to stand for at least 1 hour after filling with electrolyte. If at the end of 1 hour the level has fallen, add more electrolyte to restore it, and replace the vent caps. If electrolyte is spilled on the battery, it should be removed using a solution of bicarbonate of soda and water, being careful not to allow the solution to get into the cells. The exterior of the battery should then be flushed with fresh water.

The battery should then be given an initial charge in accordance with the manufacturer's instructions. In the absence of instructions, the initial charge should be given at the rate of 1 ampere per positive plate per cell. For example: a battery having 9 plates per cell (4 positive plates) should be charged initially at the rate of 4 amperes. This charge should be continued until the specific gravity of all cells show no increase over a period of 2 hours. If the temperature of the battery exceeds 100° F, the charge must be stopped and the battery allowed to cool.

Usually no adjustment of the specific gravity is necessary, but if it should exceed 1.300 in any cell, it should be reduced to some value between 1.275 and 1.300. The specific gravity can be reduced by removing some electrolyte with a hydrometer syringe and replacing it with distilled or drinking water.

NOTE: The procedures described herein must not be attempted by anyone without thorough checkout by experienced personnel. Battery electrolyte is a very hazardous substance to handle.

Although a premixed electrolyte is usually available for servicing dry charged batteries, the ASE may be required to use concentrated sulfuric acid that must be mixed with pure water to obtain the proper specific gravity for electrolyte.

Mixing electrolyte is dangerous because concentrated sulfuric acid can burn clothing and, if it comes into contact with the skin or eyes, severe burns will result. Listed here are some safety precautions that must be observed when working with concentrated sulfuric acid or electrolyte.

1. Wear approved goggles, gloves, aprons, and boots.

2. The container in which the electrolyte is mixed should be a lead-lined tank or a heavy plastic container. Materials such as glass or earthenware may crack due to the heat generated during the mixing operation and should not be used.

3. Always pour acid into water slowly while constantly, but gently, stirring the solution. Never pour water into concentrated acid because the chemical reaction will generate heat so rapidly that the solution will boil and splash out of the container.

4. Be alert for sprays and splashes when opening containers and during mixing. If acid spills, neutralize with bicarbonate of soda or ammonia, and flush with an abundance of water.

5. If acid is spilled or splashed on any part of the body, neutralize with a solution of bicarbon-

ate of soda and water, or ammonia and water, and immediately shower or flush the affected area with large amounts of water. Should the eyes be affected, flush with an abundance of fresh water and seek medical attention immediately.

6. Insure that an adequate supply of first aid material is immediately available at all times for the neutralization of acid.

7. Do not carry electrolyte in open-top containers, and insure that glass containers are protected against breakage.

8. Never allow containers of electrolyte to be placed near heating pipes, or to stand in the sun for any length of time.

Table 10-1 shows the quantities of water and acid to mix for obtaining a certain specific gravity. For example, an electrolyte of 1.300 specific gravity is produced by mixing five parts of water to two parts of acid, when starting with 1.835 specific gravity acid. If 1.400 specific gravity acid is used, two parts water and five parts acid will give the same results.

Allow the mixed electrolyte to cool to room temperature before adding it to the battery cells. Hot electrolyte will destroy the cell plates rapidly. Do not add the electrolyte if its temperature is above 90° F. After filling the battery cells, allow the electrolyte to cool again because more heat is generated by its contact with the battery plates. Next, take hydrometer readings.

The specific gravity of the electrolyte will correspond closely to the values given in the mixing chart if the water and acid are mixed in the proper quantities.

Table 10-1.—Electrolyte mixing chart

Specific gravity desired	Using 1.835 sp. gr. acid		Using 1.400 sp. gr. acid	
	Parts of water	Parts of acid	Parts of water	Parts of acid
1.400	3	2	--	--
1.345	2	1	1	7
1.300	5	2	2	5
1.290	8	3	9	20
1.275	11	4	11	20
1.250	13	4	3	4
1.225	11	3	1	1
1.200	13	3	13	10

MAINTENANCE AND TESTING

Battery maintenance and testing should always begin with a thorough visual inspection. Look for signs of corrosion on or around the battery. Clean the top of the battery with a stiff bristle brush, being careful that the particles brushed off do not get on the skin or clothing. Wipe the top of the battery with a cloth moistened with either ammonia or baking soda dissolved in water.

Remove the cables and inspect the terminal posts to see if they are deformed or broken. Clean the terminal posts and the inside surfaces of the cable clamps before replacing them on the terminal posts. Inspect the battery holder (cradle) and the battery holdown device. Inspect the battery for a cracked or bulging case and the sealing compound on top of the battery for leaks or cracks.

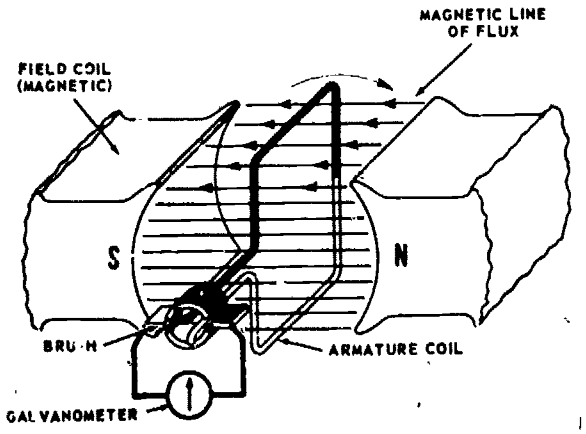
Remove the vent cap from each cell and check the electrolyte level of the battery. Make sure the vents in the vent caps are free of any obstructions.

The state of charge and the ability of a battery to withstand loads must meet the manufacturer's specifications before checking any other part of an electrical system.

The battery load test is recommended by most battery manufacturers. This test indicates how well the battery will perform under normal cranking load conditions. The BATTERY-STARTER tester, discussed in chapter 9 of this manual, is the instrument used to make this test.

GENERATING SYSTEMS

The generator is a machine which applies the principle of electromagnetic induction to convert mechanical energy, supplied by the engine, into electrical energy. The generator restores to



AS.276

Figure 10-7.—Simple direct-current generator.

the battery the energy that has been used in cranking the engine. Whether the energy required for the rest of the electrical system is supplied directly by the generator, by the battery, or by a combination of both, depends on the conditions under which the generator is operating.

There are two types of generators used in automotive equipments. The d-c generator supplies electrical energy directly to the battery and/or electrical system through various regulating devices. The a-c generator (alternator) has the same function as the d-c generator, but because only d.c. can be used to charge a battery, a device called a rectifier must be employed to convert the current from a.c. to d.c.

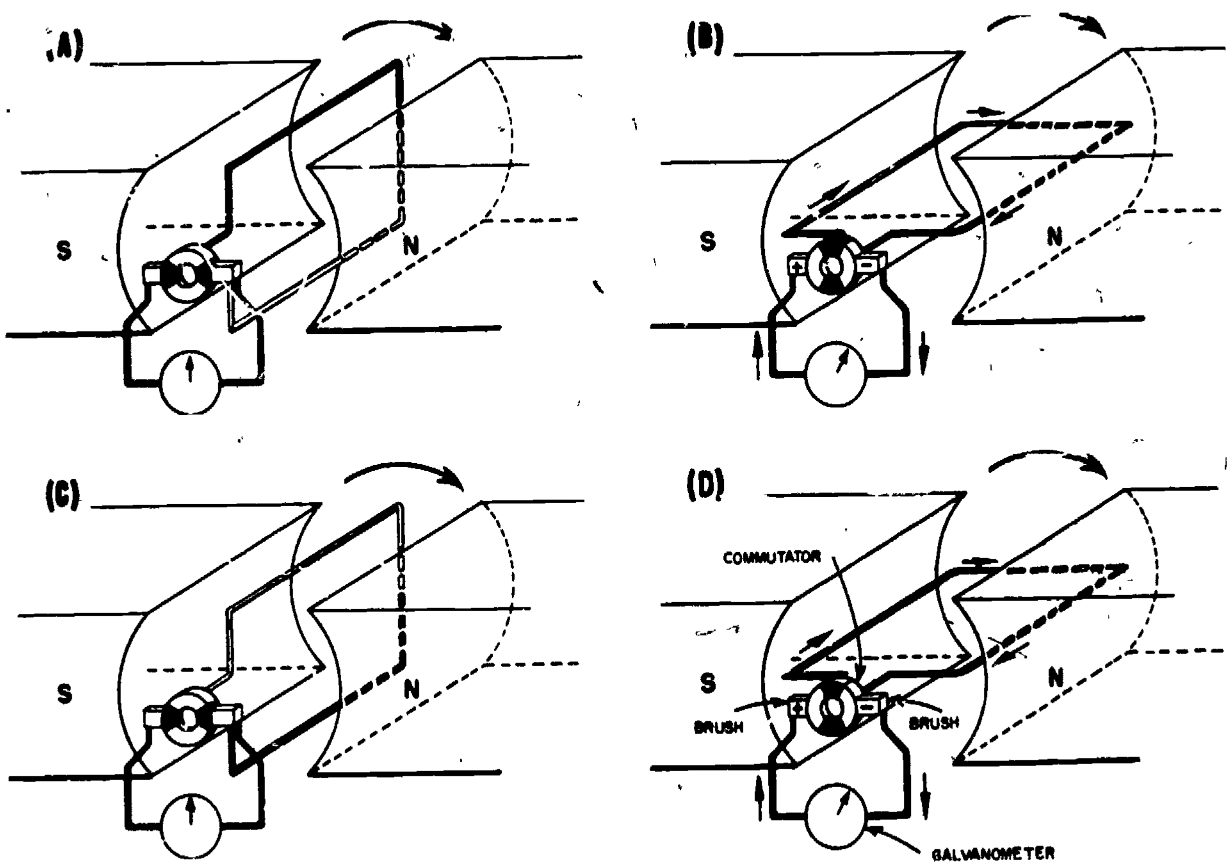


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Figure 10-8.—Generating direct-current electrical energy.

D-C GENERATOR

The essential parts of a direct-current generator are the armature coil, commutator with brushes, and a stationary field coil. A simple d-c generator is illustrated in figure 10-7. The commutator is a ring split into two segments which are insulated from each other. The two ends of the armature coil are connected to opposite commutator segments. The dial and pointer in figures 10-7 and 10-8 represent a galvanometer, an instrument with zero in the center of the scale and a pointer that will move in either direction, measuring small amounts of current. Notice how the two brushes are mounted on opposite sides of the commutator to permit each brush to be in contact with a different segment as the armature turns.

In position A of figure 10-8, the armature is rotating clockwise, the black side of the armature coil is moving toward the north pole, and the white side is moving toward the south pole. At this very instant both sides of the armature coil are parallel to the lines of flux, and no lines are cut; therefore, no voltage or emf is induced into the armature coil.

In position B, the armature coil has rotated 90 degrees, both sides of the armature coil are cutting maximum lines of flux, and maximum voltage is induced into the armature coil, causing maximum current to flow as indicated by the galvanometer.

In positions A and C (0 and 180 electrical degrees), no lines of flux are cut; therefore, no voltage is induced into the armature coil and there is no current flow as indicated by the galvanometer. In positions B and D, both sides of the armature coil are cutting maximum lines of flux, thereby inducing maximum voltage.

In studying figure 10-8, note carefully that when the black side of the armature coil is under the influence of the north pole the current flow is OUT, and when the black side of the armature coil comes under the influence of the south pole in position D the current flow is IN. As the armature rotates at certain positions (0 and 180 electrical degrees) the current flow will change directions within the armature coil, and this changing directions of the current is referred to as alternating current. When current was flowing OUT, the segment attached to the black side of the armature coil was making contact with the negative (-) brush, but when the current starts to flow IN, the segment switches to the positive (+) brush. This switching action of the commutator segments changes the a.c. within the armature coil to d.c. within the external circuit. Current always flows the same direction through the galvanometer.

The direction of current flow in the armature coil during rotation can be determined by using the left-hand rule for generators. The left-hand rule is applied as follows. Extend the left hand so that the THUMB points in the direction of conductor movement (side of armature coil), and the FOREFINGER points in the direction of magnetic flux (north to south). By pointing the MIDDLE FINGER 90 degrees from the forefinger, it will point in the direction of current flow within the conductor.

The generators in figures 10-7 and 10-8 are used for explanation purposes only. The output of these generators would be a low d-c voltage, varying between zero and maximum. A generator must have several loops or turns of wire in each armature coil for sufficient voltage (emf) to be induced into the coil; likewise, the armature must have the several coils distributed evenly around the armature core. The coils or armature windings are connected to each other and to the commutator segments in such a way that the voltage impulses overlap and produce a steady output voltage. This may be compared to the overlapping of power impulses in an 8- or 12-cylinder engine.

The armature core (see fig.10-9) on which the armature windings or coils are mounted is made of laminated soft iron. The core is laminated to reduce eddy currents, and is made of soft iron for permeability.

The purpose of the field windings (field coil) (fig.10-9) is to increase the strength of the magnetic field so that more current will be induced in the armature windings as the armature rotates. In most generators the field windings are connected in parallel with the armature winding (that is, across the brushes); this arrangement is called a shunt-field winding. Figure 10-10 represents a shunt-wound generator with only one armature coil. About 8 to 12 percent

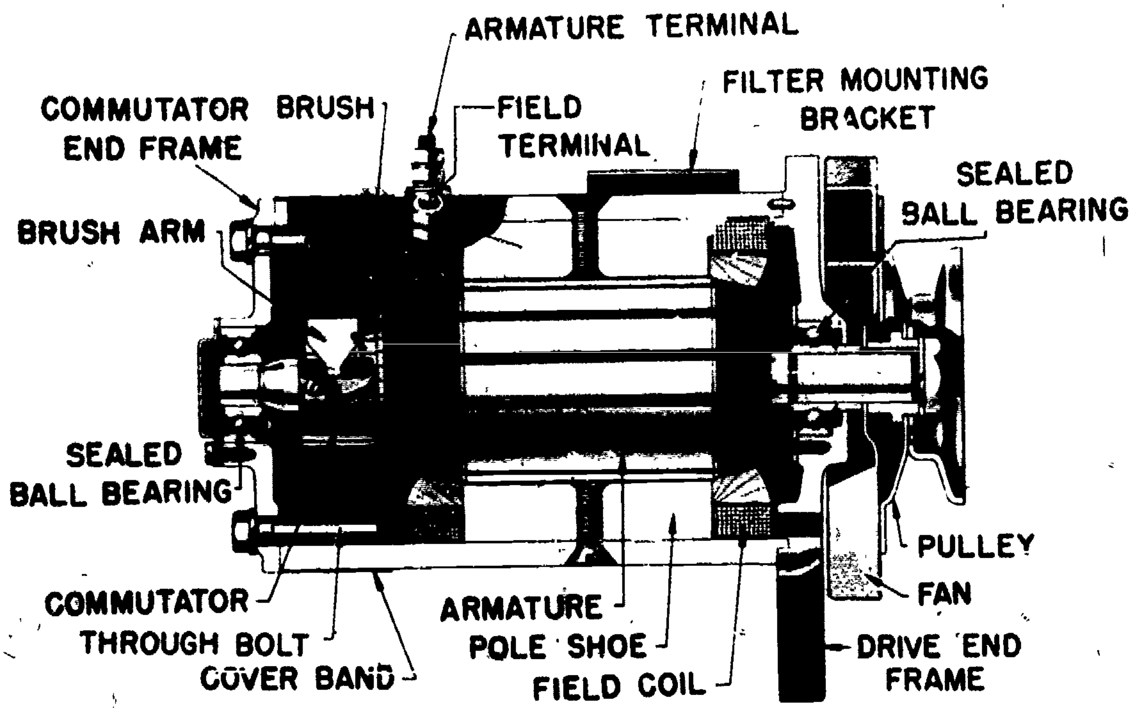

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Figure 10-9.—Sectional view of a d-c generator.

of the total current generated by the armature is shunted through the field coils for producing the magnetic field under normal load conditions.

The three basic factors that determine a generator's output are the speed of armature rotation, the number of armature conductors, and the strength of the magnetic field. Any one of these factors could be used to control the generator voltage and current. However, the simplest method is to control the strength of the magnetic field and thus limit the voltage and current output of the generator. This concept has application to charging systems and will be discussed later in this chapter.

A-C GENERATOR (ALTERNATOR)

The output requirements of automotive electrical generators have increased considerably in recent years. This is because of the growing popularity of and need for power consuming electrical accessories such as two-way radios, any radiotelephones for communications, heavy-duty heaters, and air conditioners.

A conventional d-c generator that would produce the required amount of electricity at both a high and low speed range would be so large that its practical application would be limited. An a-c generator (alternator) has been developed that can be used in conjunction with a rectifier (fig.10-11) to produce enough power to fulfill almost any need over a speed range varying from idle to top engine speed.

Because of the small size of the alternator, it can be adapted to almost any piece of equipment. It is constructed to withstand vibrations and high speeds that are encountered in normal service.

The alternator and the conventional d-c generator operate on the same theory; the field produces lines of force that are cut by the loops of the armature winding, thus inducing alternating current. Basically, the two generators are composed of the same functional parts—a rotor, a stator, and a device for extracting direct current from alternating current.

In the d-c generator, the stator is the field, the rotor is the armature, and the device for extracting direct current from alternating current is the commutator and brush assemblies.

In the alternator (fig. 10-12), the stator is the armature, the rotor is the field, and the device for extracting direct current from alternating current is the rectifier. The rectifiers are mounted in the housing of the alternator.

The stator (armature) of the alternator is the section in which the current is induced. It is made of a slotted laminated ring with the conductors placed in the slots. The current generated in the windings is transferred to the rest of the system through three stationary terminals.

This arrangement has many advantages over a d-c generator armature. All the current generated in the d-c armature must be transferred to the system through brushes. Where the output is high, the brushes have to be very large to handle the power. In the alternator, this problem is eliminated because the armature windings are stationary; hence, only low voltage field current passes through the alternator's brushes. Since the armature windings are stationary, they are not affected by centrifugal force as are the loops in the armature of a d-c generator.

The rotor in the alternator compares in function with the field (stator) of a d-c generator. The rotor (fig. 10-13), is made in four parts—a coil, a core, and two rotor halves or spiders. The rotor is assembled by placing the coil on the core and then fitting the rotor halves around them. These are assembled on a shaft, and the coil leads are connected to slip rings.

Because of the rugged construction of the rotor halves, this unit can be rotated at very high speeds without damage. The limiting factor is the rpm rating of the bearings that hold the shaft in the housing.

A basic alternator (fig. 10-14) consists of one winding or loop in the stator and a single pair of poles in the rotor. When the rotor of this

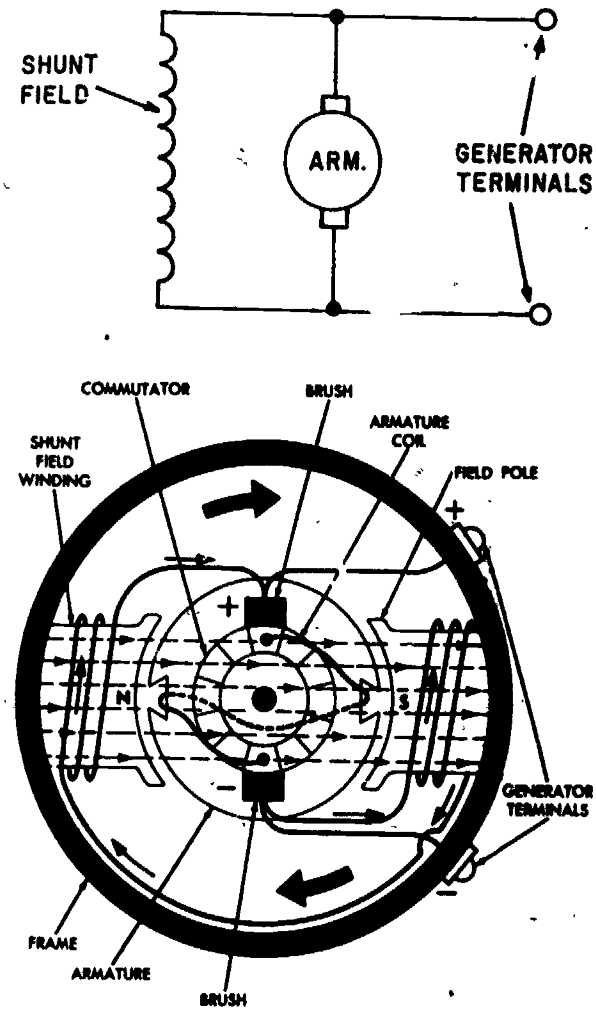

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Figure 10-10.—A shunt-wound generator.

machine is turned through 360 degrees, it induces a single cycle of alternating current. If a rotor with six pairs of poles were put in the basic alternator (fig. 10-15), six cycles of alternating current would be generated every time the rotor made one complete revolution.

If two more loops were added to the stator (fig. 10-16), six cycles of alternating current would be generated in each loop for every revolution of the rotor. This type of machine is called a 3-phase alternator.

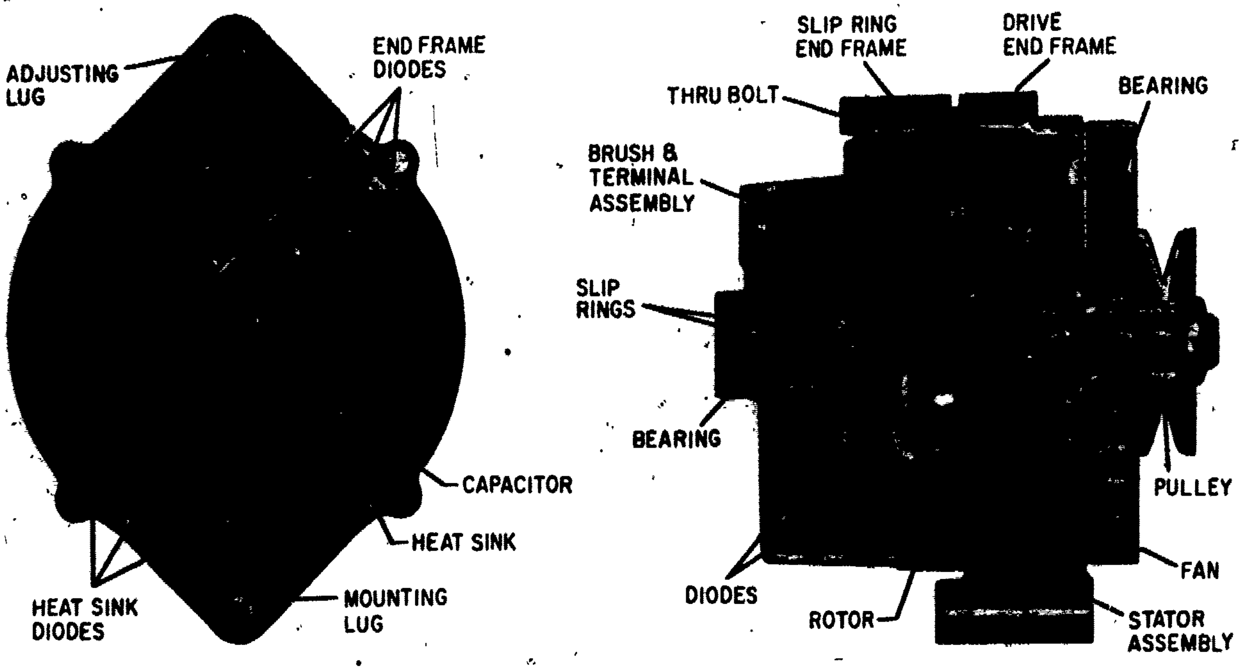

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Figure 10-11.—Alternator.

Rectifiers

The battery and other electrical accessories in the automotive electrical system operate on direct current which flows in one direction only. For this reason it is necessary to change the alternating current to direct current. This function is performed by rectifiers. The type of rectifier used in modern automotive alternators is shown in figure 10-17—the semiconductor (diode).

Modern alternators have these semiconductor rectifiers (diodes) internally mounted within the alternator. The type of diode most commonly used is the silicon diode. The main advantages of diodes over the previously used metallic rectifiers are that they have a higher current carrying capacity, are of more rugged construction, and are small in size.

Identification of diode polarity varies greatly with the alternator model and manufacturer; some are plainly marked with a + or - sign, some are marked with red and black lettering, while others are threaded to indicate polarity—left for positive, right for negative.

Automotive alternators use six diodes to provide full wave rectification of the alternator's 3-phase a-c internal output to provide d-c current at the output terminal of the alternator. (See fig. 10-18.) These six (three positive—three negative) are mounted internally—three pressed or threaded into the end frame or diode plate, and three pressed or threaded into a heat sink or diode plate mounted on the end frame.

WATERPROOF GENERATORS

On many military vehicles, the generator is made watertight by sealing the generator so that water cannot enter. In addition, corrosion-resistant stainless steel bearings are used.

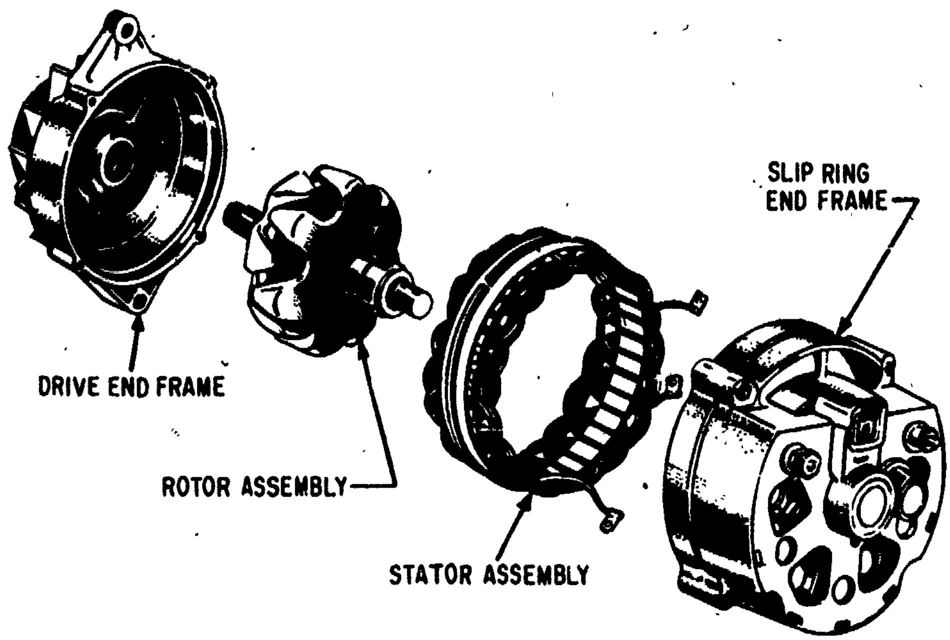

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Figure 10-12.–Disassembled alternator.

The commutator end bearing is packed with heat-resisting grease, while the drive end bearing is lubricated by an oil reservoir. Neither bearing requires attention between generator overhauls. The generator leads are enclosed in waterproof conduit that is fitted with a waterproof coupling for attachment to the generator.

GENERATOR OUTPUT CONTROL

To provide control of the output of automotive generators, the charging system incorporates a regulator. Basically, a regulator is an automatic switching device which maintains the battery in a satisfactorily charged condition without damaging the electrical system.

Regulation is needed on d-c generators and a-c generators or alternators because, with no regulation, output continues to increase as generator speed increases.

There are several types of regulator assemblies used to acc⌃ .nplish generator control, but the

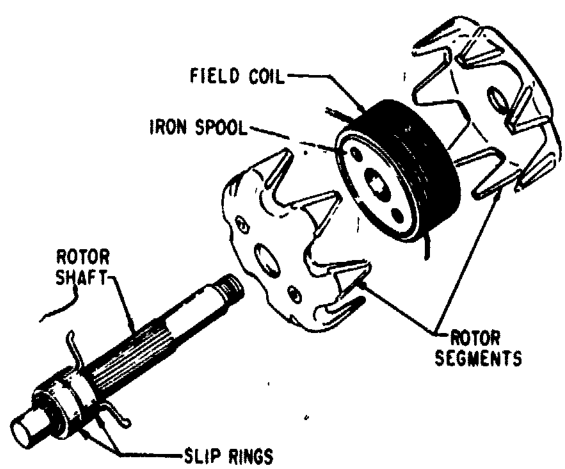

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Figure 10-13.– Exploded view of an alternator rotor.

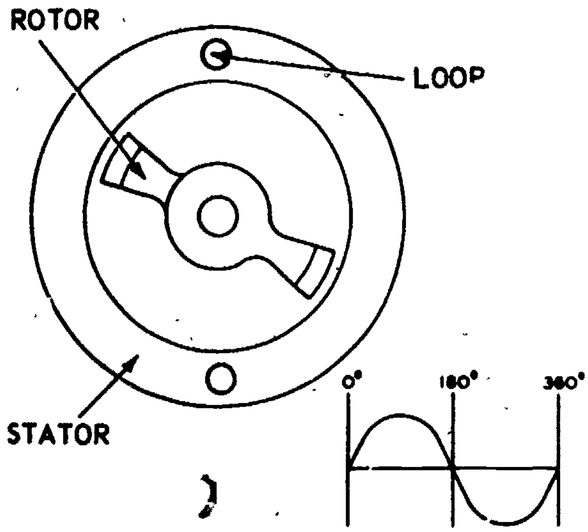

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Figure 10-14.—A simple alternator.

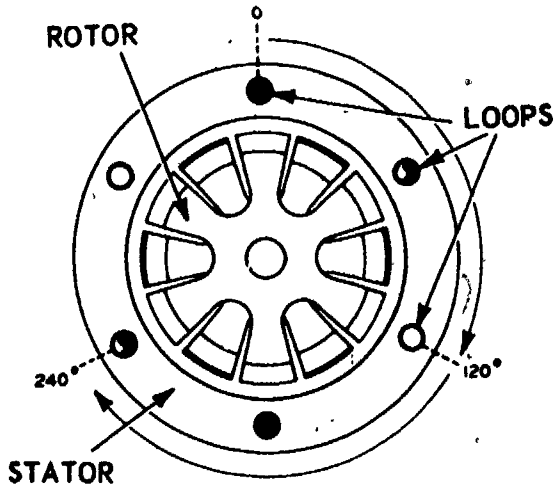

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Figure 10-16.—Three-phase alternator.

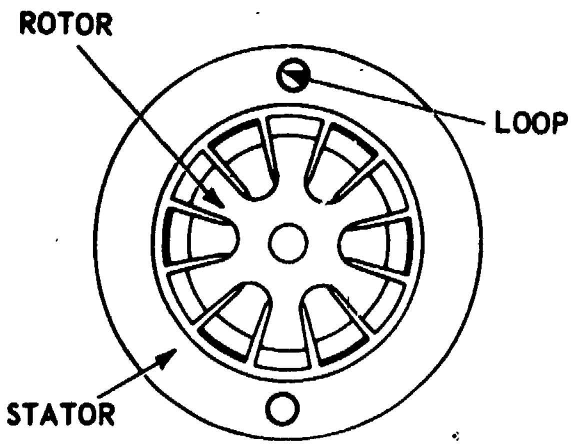

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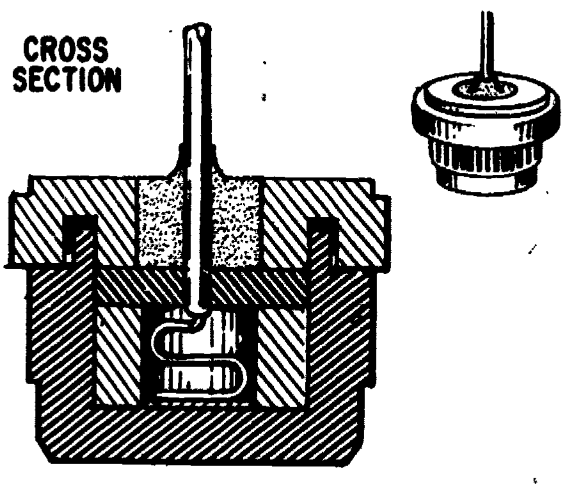
Figure 10-15.—A basic alternator with six pairs of poles in the rotor.



AS.285

Figure 10-17.—Semiconductor (diode) rectifier.

types most commonly used in automotive systems are the vibrating-contact, the transistorized, and the transistor.

CAUTION: Each model regulator is designed for use on only one polarity system. On electrical systems the polarity of the regulator, generator, and battery must be the same. When installing any one of these three units, do not make any connections until the polarities have been checked.

D-c Generator Regulation

The vibrating-contact regulator (fig. 10-19) is the type most commonly used on d-c generator equipped vehicles. The regulator consists of a reverse current relay, a voltage regulator, a current regulator, and two resistors.

There are two types of circuits in use for systems using d-c generators and vibrating-contact regulators. One is referred to as a type "A" or standard duty circuit in which the generator field circuit is connected to the armature terminal inside the generator and is grounded externally through the regulator contacts. The other is referred to as a type "B" or heavy duty circuit in which the generator field circuit is connected to the armature terminal inside the regulator and is grounded inside the generator.

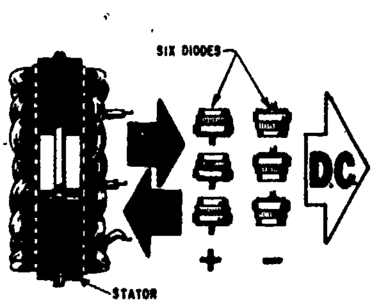
Generally, testing of either of the circuit types is done in the same way with these exceptions: the way the field control is connected for the reverse current relay check, and the way the generator is polarized.

NOTE: The d-c charging system components and the tests for d-c charging systems discussed in this chapter are for type "A" circuits.

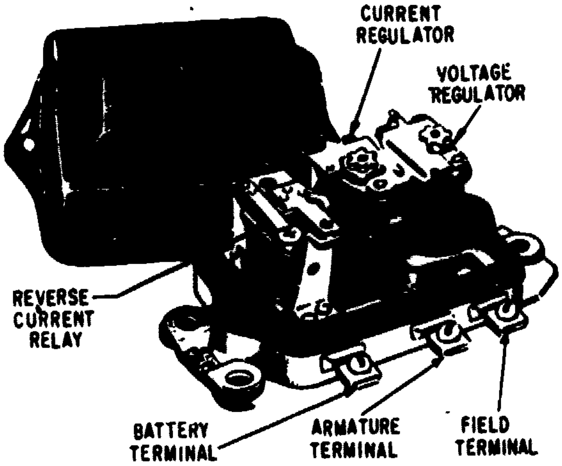
The regulator shown in figure 10-19 controls voltage and current by automatically cutting resistance in or out of the field circuit of the generator. Varying the amount of resistance in the field circuit changes the amount of current passing through the generator fields. This, in turn, changes the strength of the magnetic field produced in the generator. Thus, generator output is regulated by controlling field current.

REVERSE CURRENT RELAY.–The reverse current relay prevents the battery from discharging through the generator when the engine is stopped or is running at slow speed. When the speed of the generator is increased and the output voltage of the generator becomes higher than that of the battery, the reverse current relay closes, completing the circuit from the generator to the battery.

When the speed of the generator is decreased and the output voltage of the generator becomes lower than the voltage of the battery, the reverse current relay opens, opening the circuit between the generator and the battery.



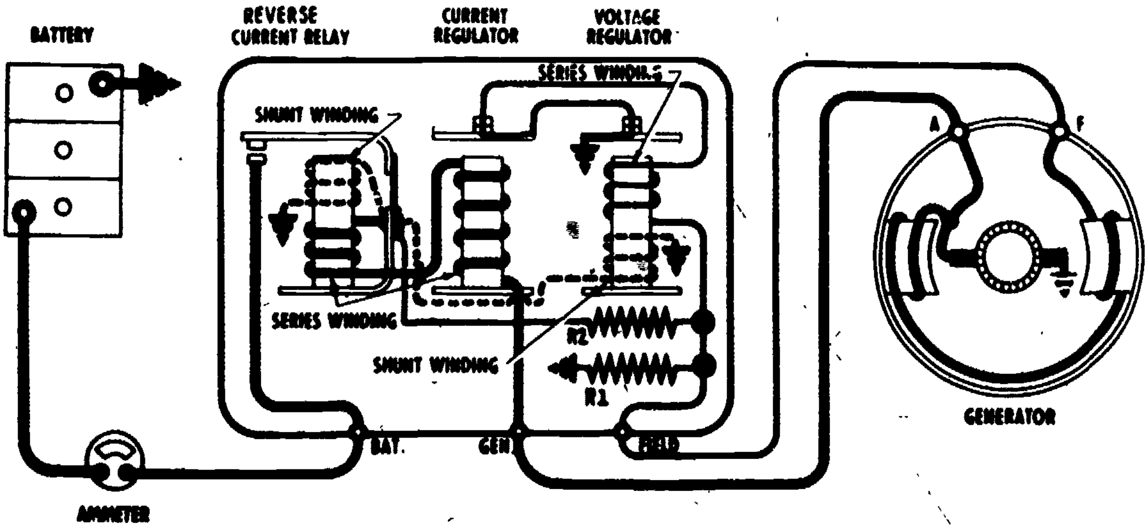
AS.44
Figure 10-18.–Function of the alternator diodes.



AS.882
Figure 10-19.–Three-unit, vibrating-contact, d-c regulator.

The reverse current relay (fig.10-20) has two windings on a single core–one consists of a few turns of heavy wire in series with the charging circuit; the other consists of many turns of fine wire and is shunted across the generator.

The windings and core of the reverse current relay are assembled in a frame, and a flat steel armature with a contact point is attached to the frame by a hinge. A flat spring holds the contact



AS.287

Figure 10-20.—D-c charging circuit with a vibrating-contact regulator.

points open when the battery voltage is higher than that of the generator.

VOLTAGE REGULATOR.—The voltage regulator (fig. 10-20) prevents circuit voltage from exceeding a preset value and maintains a constant voltage in the system. It has a series winding of many turns of fine wire and is shunted across the generator. The shunt winding consists of a few turns of heavy wire.

The windings and core of the voltage regulator are assembled in a frame, and a flat steel armature with a contact point is attached to the frame by a hinge. A coil spring (not shown) is attached between the armature and regulator base to hold the contact points in the closed position when the voltage regulator is not working.

CURRENT REGULATOR.—The current regulator protects the generator and charging circuit from overload by limiting current output to a preset value.

The current regulator (fig.10-20) has a single winding of a few turns of heavy wire in series with the generator output, and the entire output of the generator passes through this winding.

Except for the single winding, the construction of the current regulator is the same as the voltage regulator.

RESISTORS.—Current and voltage regulators use two common resistors mounted on the back of the regulator base, and are referred to here as R1 and R2. R1 (fig. 10-20) is connected between the regulator field terminal and ground at the regulator base, and R2 is connected between the regulator field terminal and the reverse current relay frame.

R1 is connected in series with the generator field coils when either the voltage or the current regulator operates. R2 is connected in parallel with the generator field coils and helps to dissipate the surge of induced voltage which occurs in the field coils when either the voltage or the current regulator operates. This induced voltage surge is due to the sudden drop of field current and the resultant decrease in strength of the magnetic field. Dissipation of this induced voltage surge reduces arcing at the voltage and current regulator contact points.

OPERATION.—The charging system shown in figure 10-20 is in a static condition. Notice that the reverse current relay contacts are open; the current regulator and voltage regulator contacts are closed. With the contacts of the two regulators closed, the generator field circuit has minimum resistance and, as the generator is driven and speed increases, the output voltage builds up because of the unrestricted increase of field voltage and current.

When the generator output voltage builds up to where it is higher than the battery voltage, the current through the shunt winding of the reverse current relay creates a magnetic field strong enough to overcome the tension of the armature spring and close the contacts. With the contacts closed, the generator is connected to the battery and the generator output flows through the series winding of the reverse current relay to the battery, adding strength to the magnetic field created by the shunt winding.

Once the generator output voltage reaches the value for which the voltage regulator is adjusted, the magnetic field created by the winding of the voltage regulator overcomes the tension of the armature spring and pulls the armature down, opening the contacts. This inserts R1 in series with the generator field coil with the result that generator field voltage and current are decreased, and generator output voltage is reduced. The surge of high voltage induced in the generator fields, because of the sudden drop in field strength, is dissipated across R2. The reduction in generator output voltage is accompanied by a weakening of the magnetic field of the voltage regulator winding which allows the contacts to close. When the contacts close, R1 is removed from the field circuit, field voltage and current increase, and generator output voltage increases. This cycle may be repeated as many as 200 times per second (hence the name "vibrating contact") to maintain a constant voltage in the charging system.

When electrical load requirements are high, the current regulator operates to keep the generator from exceeding its rated maximum current output. When the generator current output reaches the value for which the current regulator is set, current flow through the series winding of the current regulator creates a magnetic field strong enough to overcome the tension of the armature spring, pull the armature down, and open the current regulator contacts. This inserts R1 in series with the generator field coil circuit, thereby decreasing generator field voltage and current and reducing output current. This reduction is accompanied by a weakening of the magnetic field of the series winding of the current regulator which allows the contact points to close. When the contact points close, R1 is removed from the field coil circuit, field voltage and current increase, and generator output current increases. This cycle is repeated as many as 50 times per second to limit the generator output current to a set value.

When the generator speed decreases to a point where generator output voltage becomes less than that of the battery, current from the battery flows back to the generator, through the series winding of the reverse current relay, canceling the magnetic field created by the shunt winding of the reverse current relay. This allows the armature to return to its original position, opening the contact points and breaking the circuit between the generator and the battery.

The regulator assembly (fig. 10-19) provides control of the generator under all conditions. Either the current regulator or the voltage regulator may be operating at any one time, but in no case do they both operate at the same time.

A-c Generator Regulation

While the regulator for an a-c generator (alternator) performs the same function as does the regulator for a d-c generator, there are differences in its makeup just as there are differences between the alternator and the d-c generator.

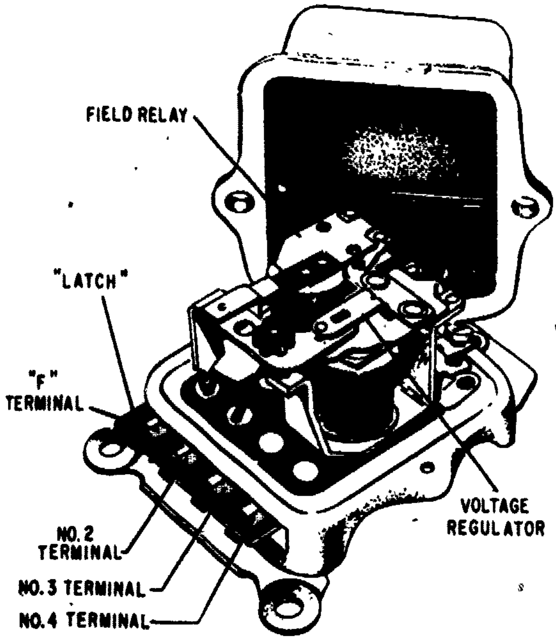
A reverse current relay is not required in an a-c charging system because the diodes in the alternator prevent reverse current flow; thus the battery cannot discharge through the alternator. Also, a current regulator is not required because of the design characteristics of the alternator which maintain current within the limits of the alternator throughout its operating range.

An alternator equipped vehicle may use any one of three types of regulators—vibrating-contact, transistorized, or transistor. The type used depends upon the vehicle manufacturer.

VIBRATING-CONTACT.—The vibrating-contact regulator (fig. 10-21) is the one most commonly used on alternator equipped vehicles and consists of a field relay and a voltage regulator.

The two-unit, double-contact regulator is suitable for use in systems using a warning light or an ammeter. The information presented here refers to a charging system using an ammeter.

The voltage regulator unit operates to limit



AS.883

Figure 10-21.—Two-unit, vibrating-contact, a-c regulator.

generator voltage to a preset value, whereas the field relay unit operates to connect the generator field winding and regulator winding directly to the battery.

Operation.—The operation of the double unit regulator is briefly discussed in the following paragraphs. Refer to figure 10-22 during this operational discussion.

On some circuits, a condenser may be connected to the number 4 regulator terminal. CAUTION: Do not connect anything to the number 4 terminal other than a condenser.

When the switch is closed, the field relay winding in the regulator is connected directly to the battery. The magnetism created in the relay coil attracts the relay armature toward the core, causing the contacts to close. This connects the generator field winding directly to the battery, allowing current to flow from the battery to ground, through the generator field windings to the F terminals of the alternator and regulator. Current continues to flow through the voltage regulator lower contacts, the field relay contacts to the regulator number 3 terminal and back to the battery.

When the generator begins to operate, a-c voltages are generated in the stator windings, and these voltages are then changed or rectified to a d-c voltage which appears at the output terminal of the alternator.

As the speed of the generator increases, the voltage at the "BAT" terminal of the generator also increases. This impresses a higher voltage through the field relay contacts and across the voltage regulator shunt winding. The increased magnetism created by the higher voltage across the winding causes the lower contacts to separate, and field current then flows through a resistor, resulting in reduced field current. This reduced field current causes the generator voltage to decrease, which decreases the magnetic pull of the voltage regulator shunt winding. The spring causes the contacts to reclose, and the cycle then repeats many times per second to limit the generator voltage to a preset value.

As the generator speed increases even further, the resistor connected across the contacts is not of sufficiently high value to maintain voltage control on the series (lower) contacts. Therefore, the voltage increases slightly, causing the upper or shorting contacts to close. When this happens, the generator field winding is shorted and no current passes through the winding. With no current in the field winding, the generator voltage decreases, which also decreases the magnetism in the shunt winding, and the upper or shorting contacts open. With these contacts open, field current flows through the resistor and the field winding. As the voltage increases, the contacts reclose.

This cycle then repeats itself many times per second to limit the generator voltage to a preset value during high generator speeds. Thus, the regulator functions to control the generator output voltage throughout its operating speed range.

TRANSISTORIZED.—In the transistorized type of regulator, a single transistor works with a conventional voltage regulator unit containing a vibrating-contact point to control the generator voltage to a preset value. (See fig. 10-23.)

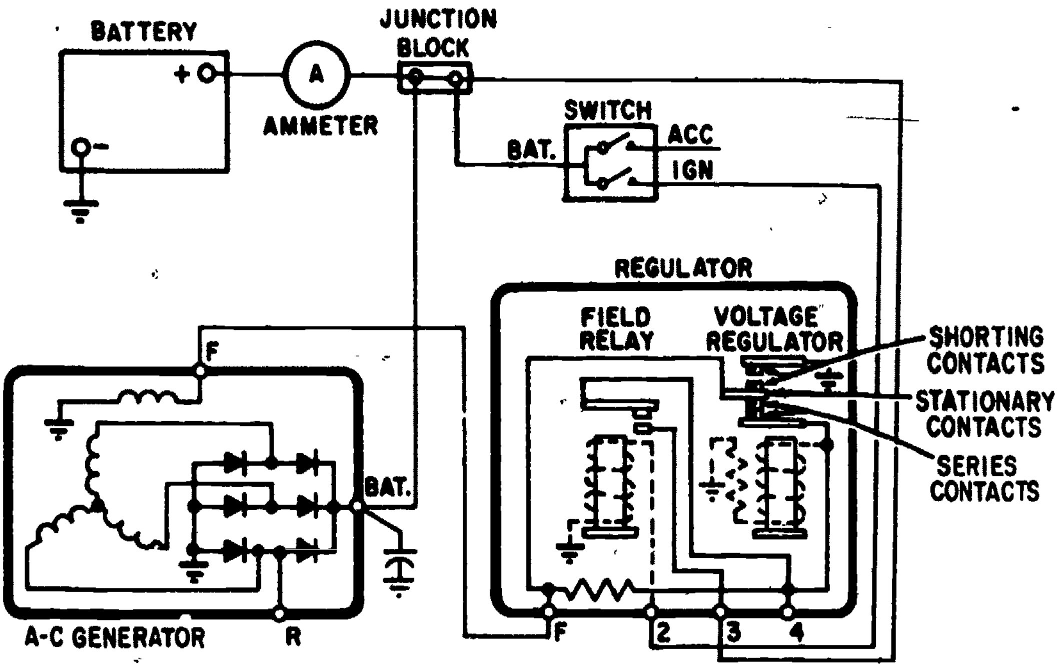


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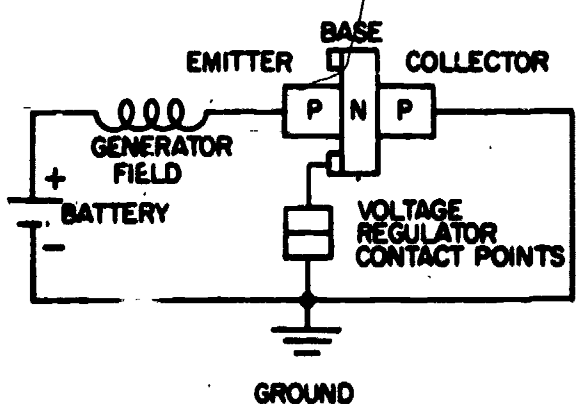
Figure 10-22.—A-c charging circuit using a vibrating-contact regulator.

The generator field current passes through the emitter-collector of the transistor, and the field current is "turned on" and "turned off" by opening and closing the emitter-base circuit through the regulator contact points. In this arrangement, current passing through the contact points is greatly reduced, and the life of the regulator is increased over that of a conventional, vibrating contact regulator.

NOTE: For a complete and detailed explanation of transistors and transistor theory, refer to Basic Electronics, NavPers 10087 (Series).

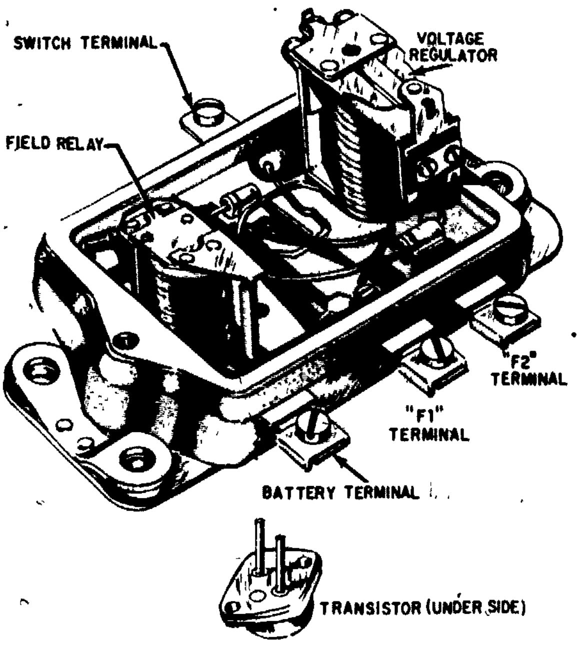
An example of this type of regulator is the four-terminal unit illustrated in figure 10-24. It consists of a field relay, a transistor, and a voltage regulator.

Operation.—When the ignition switch is closed (fig.10-25), the winding on the field relay is connected across the battery. Current passing through the field relay winding creates magnetism which attracts the armature to the core,



AS.288

Figure 10-23.—Simplified transistorized regulator circuit.



AS.48

Figure 10-24.—Transistorized regulator.

causing the field relay contacts to close. This connects generator field winding F2 to the battery. The field circuit is completed to ground through the emitter-collector of the transistor, and through the emitter-base of the transistor and the voltage regulator contact points, which are normally held closed by the helical spring.

When the field relay contacts close, the two windings on the voltage regulator are also connected across the battery. The resulting magnetism is not strong enough, however, to overcome the adjusted tension of the helical spring and cause the voltage regulator contacts to open. The generator field circuit is therefore completed to ground as soon as the ignition switch is closed, and the generator field windings carry full field current, producing a d-c voltage at the "BAT" terminal on the generator when the generator is in operation. When the generator speed increases, the voltage increases. This voltage is impressed across the two windings on the voltage regulator unit. When the voltage reaches the value at which the magnetism created by both windings overcomes the spring tension, the armature is attracted toward the core and the contact points separate.

With the voltage regulator contact points open, there is no emitter-base current, and consequently no emitter-collector current. The generator field current, therefore, is "turned off" when the voltage regulator contacts are open. With no field current, the generated voltage immediately decreases. This smaller voltage results in less current through the voltage regulator shunt winding, and consequently less magnetism. The weakened magnetic pull on the armature is then overcome by the spring, which pulls the armature away from the core and recloses the contacts. This cycle then repeats many times per second, resulting in a constant generated voltage which is determined by the adjusted spring tension. With higher spring tension, more magnetic pull is required to open the contacts; therefore, the voltage will rise to a higher value before the contacts will open, and a higher voltage setting results. Similarly, reduced spring tension gives a lower voltage setting.

Note in figure 10-25 that the voltage regulator accelerator winding, which is connected to the regulator F-2 terminal and to ground through a resistor and the voltage regulator contacts, carries no current at all when the voltage regulator contacts are open. Thus, when the contacts open, the magnetic pull, created by the shunt winding connected directly to ground, allows the armature spring to reclose the contacts in a very short interval of time. Once closed, the magnetic pull of the accelerator is restored and is added to the magnetic pull of the shunt winding. The contacts immediately reopen. The accelerator winding, therefore, speeds up or accelerates the frequency of vibration.

The resistor connected across the emitter and base of the transistor acts to prevent emitter-to-collector current "leakage" when the voltage regulator contacts are open under high temperature conditions. There is a tendency for some current to "leak through" when there are too many free electrons present at high temperatures even though the contacts are open.

The diode (upper center) is connected directly across the generator fields. If the voltage regulator contacts opened without a diode in the

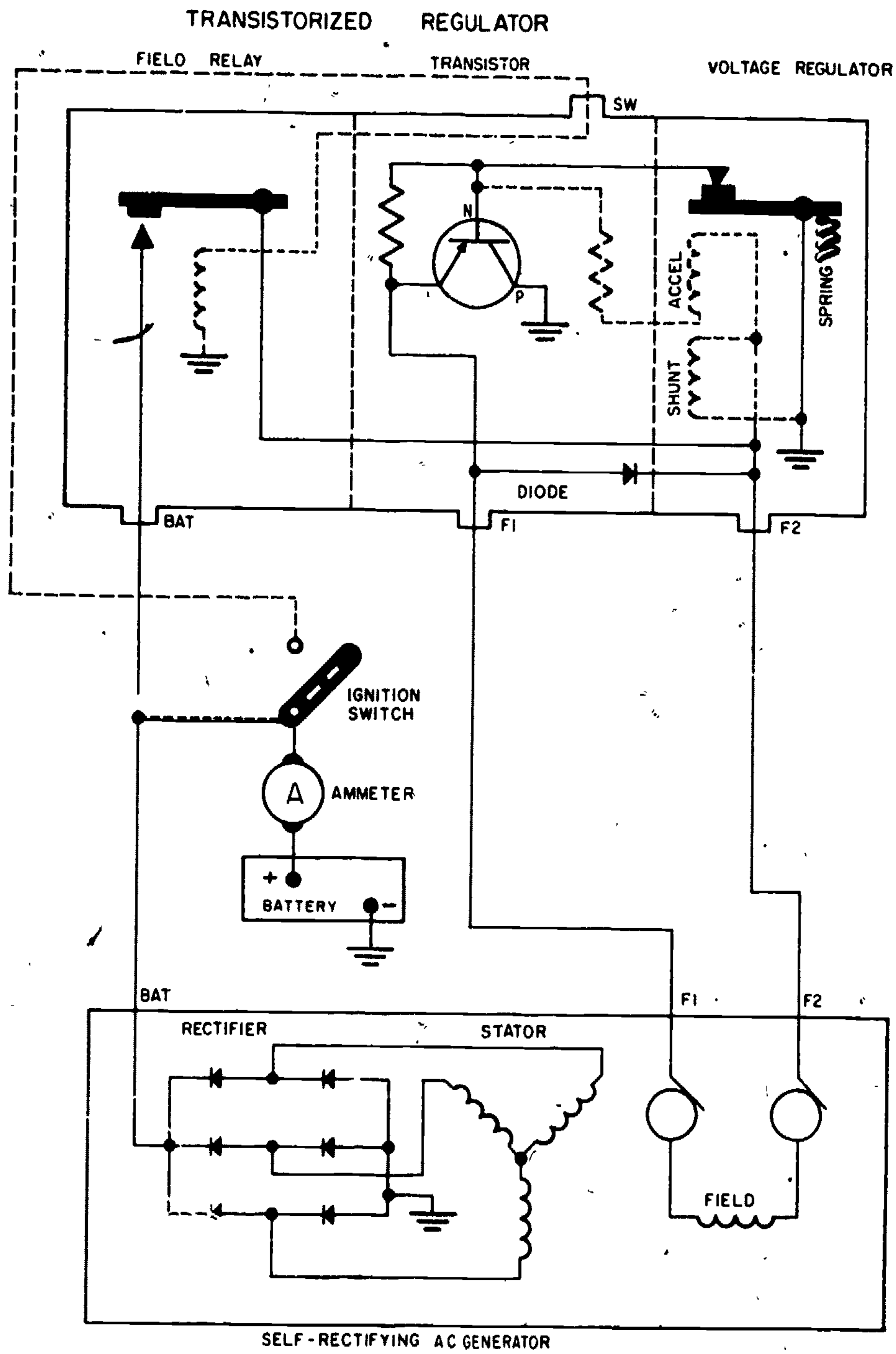


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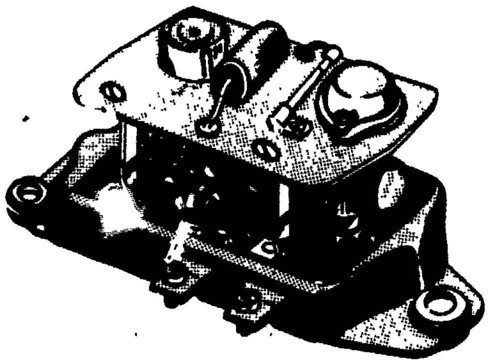
Figure 10-25.—A-c charging circuit using a transistorized regulator.



AS.50

Figure 10-26.—Transistor regulator.

circuit, the sudden interruption of field current would cause a high voltage to be induced in the field coils. The high voltage would cause breakdown of the transistor. This diode provides an alternate circuit in which the current can flow without inducing a high voltage in the field winding.

When the ignition switch is opened, the field relay shunt winding is disconnected from the battery. A spring then pulls the armature away from the core, opening the contacts and disconnecting the generator field windings from the battery.

TRANSISTOR.—The transistor regulator shown in figure 10-26 is a Delco-Remy model used on some Navy equipment. It has only two terminals, contains no moving parts, and limits the generator voltage through the combined action of the two transistors.

From the wiring diagram shown in figure 10-27, it may be seen that the charging circuit consists of the a-c generator, the regulator, the battery, the field relay, the junction block, the wiring, and either an ammeter or the indicator light.

Operation.—When the ignition switch is closed, the winding in the field relay is connected to the battery. The resulting magnetism created in the core overcomes the relay spring tension and pulls the armature toward the core, closing the contacts. This completes the circuit from the battery to the POS terminal of the regulator, and also connects the winding of the indicator light relay to the battery.

The magnetism created in the core of the indicator light relay due to battery voltage is insufficient to overcome the spring tension and open the normally closed contacts. The contacts open when the generator voltage increases to a value greater than battery voltage, at which time the generator is charging the battery and the indicator light is turned off by opening of the contacts.

The transistor regulator performs one function only—to control the generator field current so as to limit the generator voltage to a preset value. The voltage setting may be adjusted externally by relocating a screw in the base of the regulator. The screw contacts the series of resistors marked R7 through R10 in figure 10-27 and makes a connection to ground at the point of contact. Internal voltage adjustment is accomplished by turning a slotted head screw on the potentiometer which varies the potential between diode D2 and resistor R5. The transistors in the regulator operate in the same manner as previously described.

MAINTENANCE AND REPAIR

The ASE may soon learn the hit-and-miss method of troubleshooting, maintenance, and repair of electrical systems. This type of work can, however, result in a great waste of time and may result in serious damage to one or more of the components of the electrical system. Wrong adjustments by maintenance personnel who thought they knew how have ruined many regulators, generators, and batteries. The technician can easily determine if a wire is "hot," but to know the voltage and the amount of current flowing in the wire requires the use of instruments. A few quick checks with a properly connected voltmeter and/or ammeter will help isolate electrical troubles, and can further locate them in one of the units or circuits of the system.

A good visual inspection should be made of the charging circuit before actual testing begins. Inspect the battery case for cracks and leaks. Make sure the battery posts, clamps, or cables

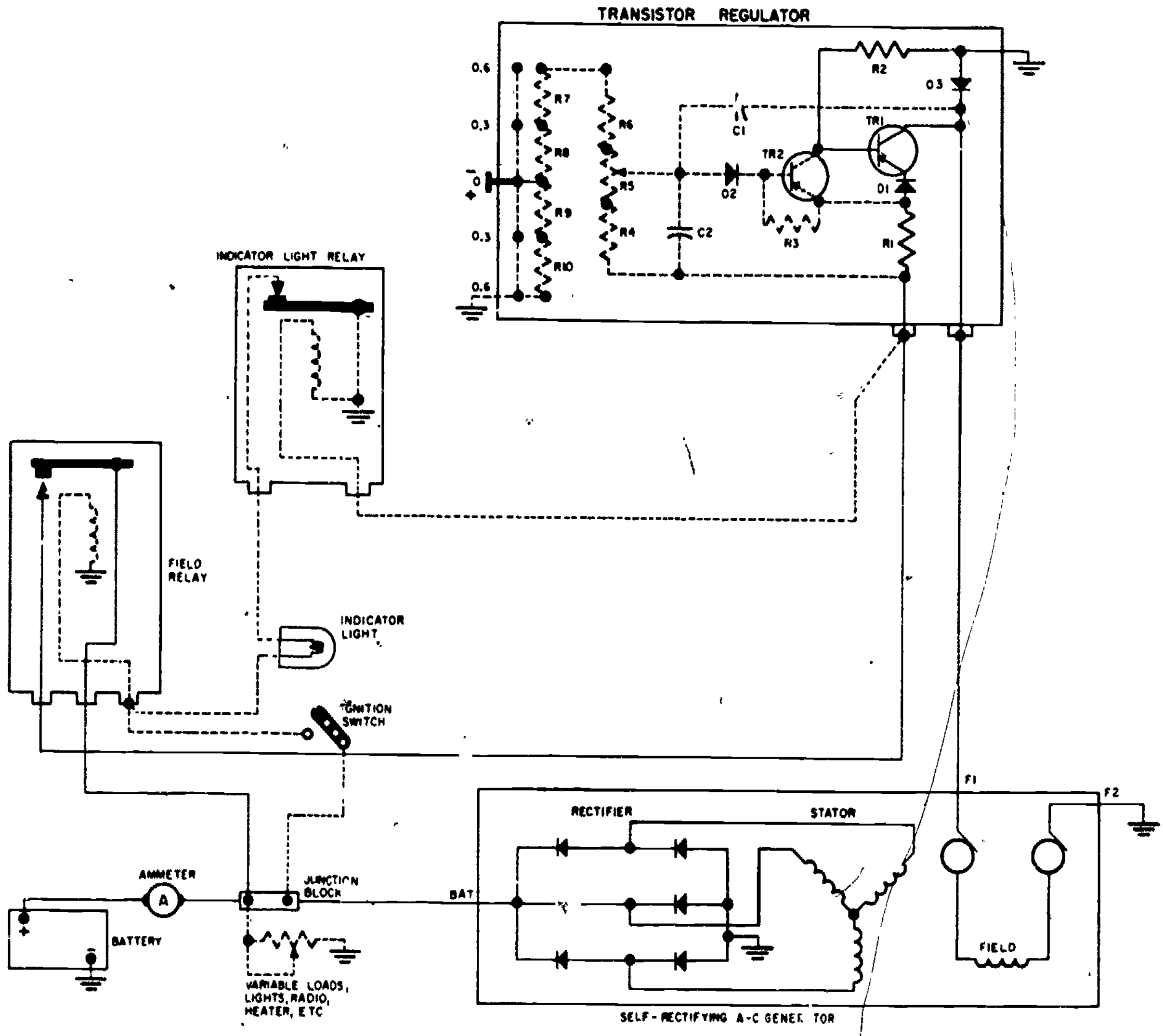


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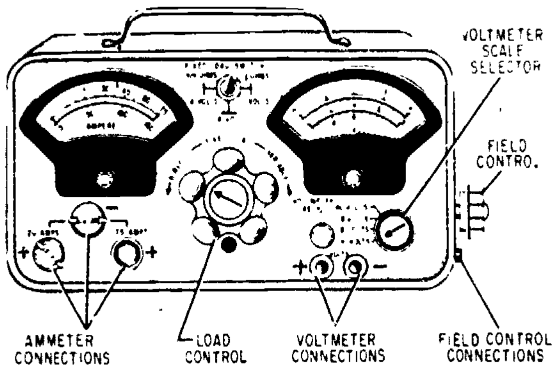
Figure 10-27.—A-c charging circuit using a transistor regulator.



AS.884

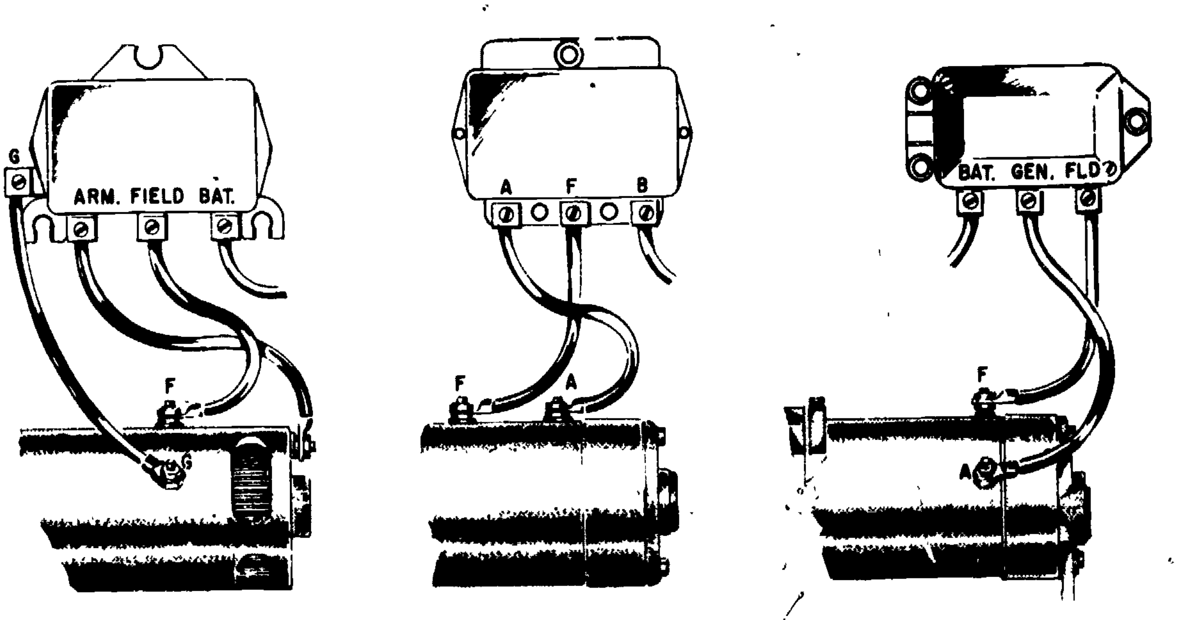
Figure 10-28.—Volt-amp tester.

are not broken and that the connections are not corroded or loose. Also check for insulation chaffing that could expose bare wire. The top of the battery should be clean and dry. Dirt and electrolyte on top of the battery causes excessive self-discharge. Be sure that the battery carrier is solidly mounted and in good condition and that the battery hold-down is properly tightened. A loose battery carrier or battery holddown will allow the battery to be damaged by vibration and jarring. An excessively tightened battery hold-down may buckle or crack the battery case.

Raised cell covers or a warped battery case may indicate that the battery has been overheated or overcharged. This may be important when analyzing the results of the electrical tests. Check the level of the electrolyte in the battery. Under normal conditions, if distilled water has to be added to the electrolyte frequently, this indicates a high-charging rate. These conditions require that the charging rate be checked and adjustments made if required. Likewise, if a battery has to be replaced, the charging rate should be checked to insure the charging system is operating properly to prevent damage to the new battery and the electrical system.

Make a visual check of the wiring, being especially watchful for loose or dirty connections and frayed wires.

The following quick checks for battery charging troubles will determine whether the genera-



AS.291

Figure 10-29.—Markings and locations of generator and regulator terminals.

tor and regulator units are operating properly. If er is operating improperly, these checks will show which unit is at fault so that proper adjustments and repairs can be made.

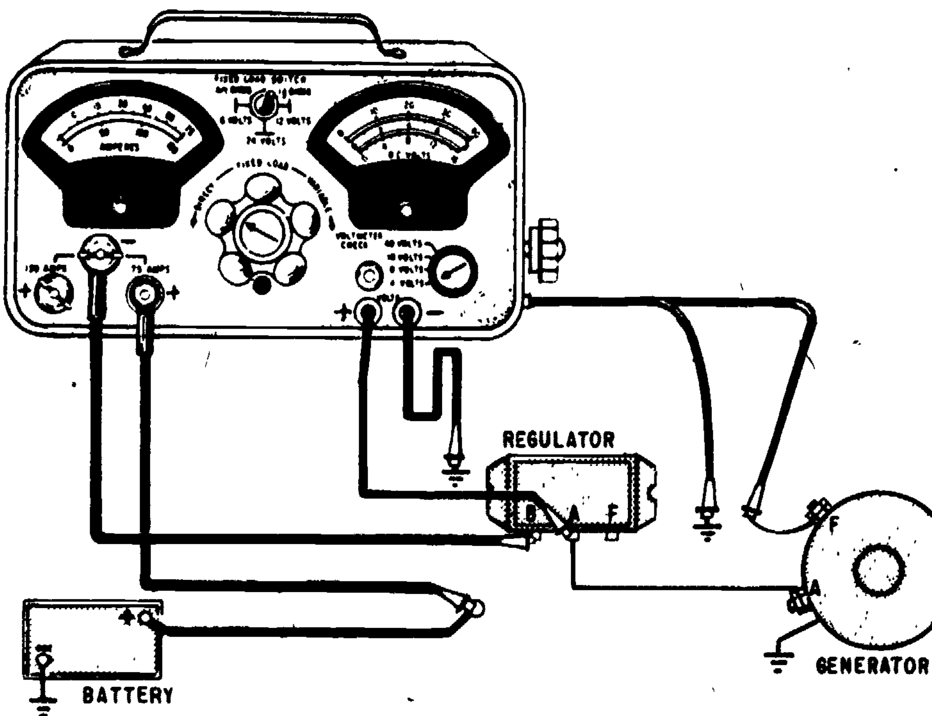
CAUTION: These checks are for charging systems equipped with d-c shunt type generators and must not be attempted on any system using an a-c generator.

A fully charged battery and a low charging rate on the dashboard ammeter soon after starting the engine indicate normal operation of the regulator.

A continued high charging rate with a fully charged battery indicates trouble in the regulator or a grounded generator field. Check the cause for this condition by disconnecting the lead from the F (field) terminal of the regulator. This opens the generator field circuit. If the charging rate then drops off immediately, the regulator is at fault. If not, the generator field is grounded either in the wiring harness or in the generator itself.

The same check can be made by removing the regulator cover and opening the voltage regulator points manually. If this also causes the output to fall off, the trouble is almost sure to be the result of a maladjusted regulator.

With a low battery and low or no charging rate, first check for loose connections, corroded terminals, and frayed or damaged wires which produce high resistance, causing the voltage regulator to operate as though the battery were fully charged. If the charging rate is not affected by repairing these faults, insure all circuits (except ignition) are turned off and momentarily ground the F terminal of the regulator with the generator operating at medium speed. Avoid high generator speeds since the generator is unregulated when the field is grounded and excessive speeds may produce a dangerously



AS.885

Figure 10-30.—Reverse current relay tests.

high generator voltage.

If the generator output increases, check the voltage regulator, ammeter, battery, and wiring in between the components for open or high resistance connections. But if there is no output or the output remains low, the trouble is in either the wiring harness or the generator. The wiring harness can be checked by grounding the F terminal at the generator. If the output increases, the trouble is in the wiring harness; if the output remains the same, the generator is at fault. If there is no output, the generator may have lost its residual magnetism and will require polarizing (explained later in this chapter). If polarizing does not correct the malfunction, the generator will have to be removed, disassembled, the malfunction located, and repairs made.

WARNING: Do not operate a generator with the field circuit complete and the armature circuit disconnected (open) for more than a second or two—this is open-circuit operation and will cause the generator field windings to burn out.

REGULATOR CHECK AND ADJUSTMENT

All the equipment necessary to test regulators and generators for either d-c or a-c charging circuits is combined into a convenient and portable piece of test equipment—the volt-amp tester (VAT). (See fig. 10-28.)

There are many makes and models of volt-amp testers in use, but all are equipped with a voltmeter and an ammeter and have basically the same controls—a voltage scale selector, an amperage scale selector (or separate connections for each amperage scale), and a load control rheostat. A field control rheostat may also be included. Reference must be made to the operator's instruction manual for the unit in order for the operator to make correct hookups and follow correct test procedures.

NOTE: The test procedures presented in the following section are representative of tests which can be made and are not to be used in lieu of those given in the applicable maintenance instructions manual for any specific equipment. Inexperienced personnel must not attempt testing and adjusting procedures until trained to do so.

Regulators for D-C Shunt Type Generators

The location of generator and regulator terminals and the markings used for the terminals are different in various systems and makes of equipment. The ASE must be able to locate and identify these terminals before test connections can be made. Some of the markings and locations in general use for regulator and generator terminals are shown in figure 10-29.

Prior to making any test of the charging system, the engine should be started and run for at least 15 minutes to allow the charging system components to come up to operating temperature.

REVERSE CURRENT RELAY TEST.—Refer to figure 10-30. Select the 75 (upper) amp scale, either by selecting the proper cable connection as in the figure, or by the amp scale switch, whichever is appropriate for the VAT being used. Set the load control knob to the direct position. Set the voltage scale selector switch to the lowest scale position that includes the value to be measured. Set the field control to the open position.

Connect one lead of the voltmeter to the armature terminal of the regulator and the other to a good ground. The voltmeter lead connected to ground must match the ground polarity of the system to be tested.

Disconnect the battery lead from the battery terminal of the regulator and connect the negative lead of the ammeter to this terminal. Connect the positive lead of the ammeter to the battery lead that was disconnected from the regulator terminal.

Disconnect the field lead from the field terminal of the regulator and connect one lead of the field control to this lead. Connect the other field control lead to a good ground.

With the engine warmed up and the VAT connected as shown, adjust engine speed to approximately 1,500 rpm, or to the speed specified by the vehicle manufacturer for a generator check. Slowly rotate the field control clockwise while observing both the ammeter and the voltmeter, and note the voltage indicated just as the ammeter pointer begins moving. This is the closing voltage of the reverse current relay. Refer to manufacturer's specifications to determine if this reading is within limits. Continue to rotate the field control clockwise until about a 10-ampere charge rate is indicated; then slowly rotate the field control counterclockwise while watching the ammeter for the highest indication to the left of zero. This is the amount of reverse current required to open the relay. Again, refer to manufacturer's specifications to determine if this reading is within limits.

The closing voltage of the reverse current relay is adjusted by changing the tension on the spring holding the contacts open. Increasing the tension increases the closing voltage requirement; decreasing the spring tension decreases the closing voltage requirement. On some regulators, adjusting screws are provided for this purpose; on others, you must bend the bar to which the spring is attached.

The amount of reverse current required to open the relay is adjusted by changing the airgap between the armature and the relay coil. Normally, the ASE should not disturb the original setting. However, if it is necessary to do so to obtain a proper reverse current adjustment, follow the manufacturer's instructions exactly as given. If the reverse current relay is not adjusted properly, the current and voltage regulators cannot be adjusted satisfactorily.

VOLTAGE REGULATOR TEST.–The VAT connections for making this test are the same as previously given for the reverse current relay test with two exceptions (fig.10-31). The field control lead that was connected to ground is now connected to the field terminal of the regulator, and the voltmeter positive lead is connected to the battery terminal of the regulator.

With the VAT connected as illustrated, set the load control knob to the 1/4-ohm position, and the field control to direct. With the engine

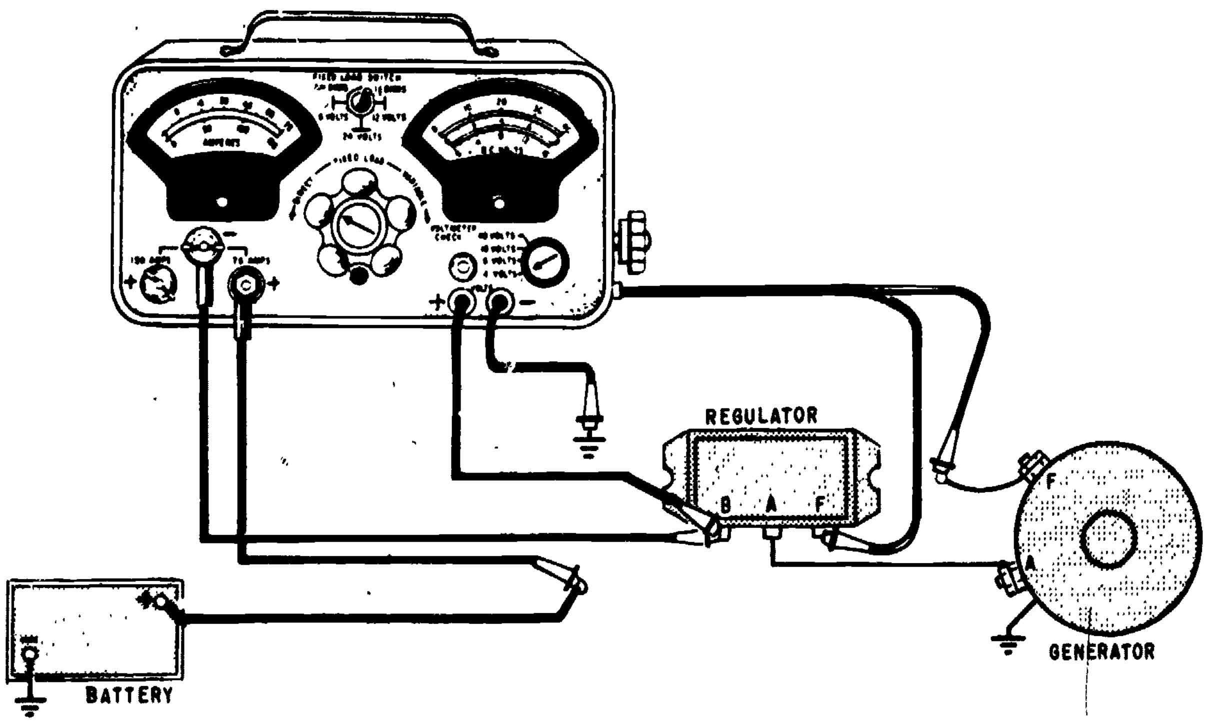
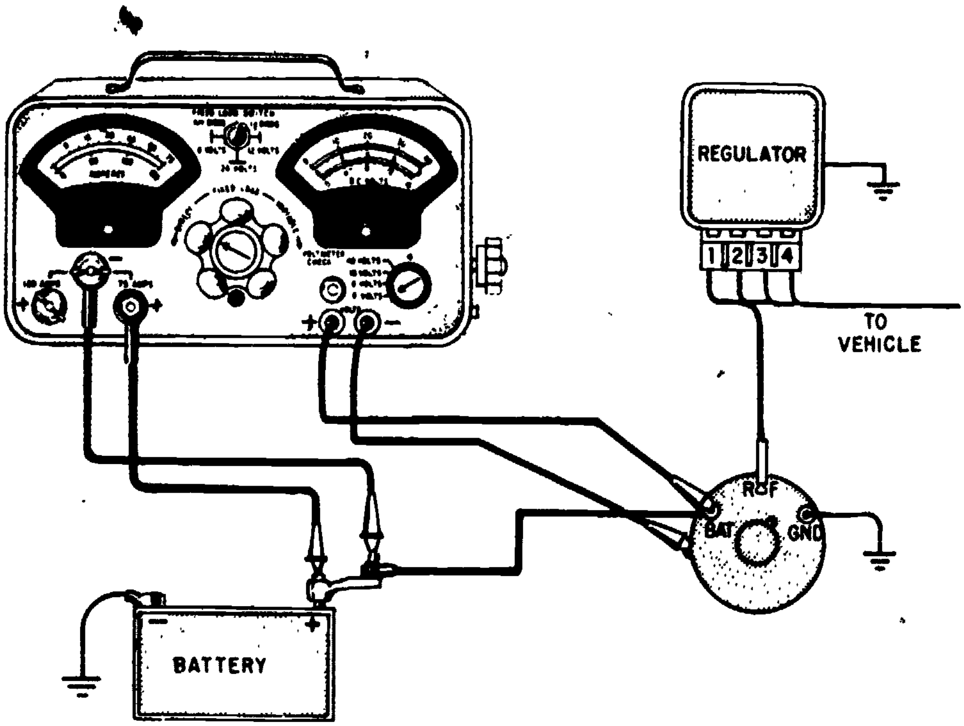


Figure 10-31.–Voltage and current regulator test.



AS.887

Figure 10-32.—Voltage regulator test.

operating at 1,500 rpm, rotate the field control to open and back to direct to cycle the regulator. The voltage now indicated by the voltmeter is the setting of the voltage regulator. Refer to the manufacturer's specifications to determine if this reading is within limits.

If adjustments are necessary, remember that the voltage regulator must always be set above the reverse current relay closing voltage; otherwise, the reverse current relay will never close, since the voltage regulator will hold the voltage below the value required to operate the relay.

Voltage regulator adjustments are made in the same manner as those for the reverse current relay; that is, by adjusting the tension of the spring attached to the armature. This adjustment is made with adjustment screws or by bending the bars to which the spring is attached, as appropriate. However, on the regulator units, the spring holds the points closed instead of open as on the reverse current relay. Once an adjustment has been made, the regulator must be cycled as previously described and the setting rechecked.

CURRENT REGULATOR TEST.—With the VAT connected as shown in figure 10-31, operate the engine at 1,500 rpm and rotate the field control to the direct position. Turn the load control knob to the variable load position until the voltmeter indicates the voltage of the system being checked; 6, 12, or 24 volts. The indication now provided by the ammeter is the setting of the current regulator. Refer to the manufacturer's specifications to determine if this reading is within limits.

Adjustments of the current regulator are made in the same manner as those previously described for the voltage regulator.

Regulators for A-C Generators

There are a variety of types of a-c regulators in use on automotive vehicles, and check and adjustment procedures vary from type to type.

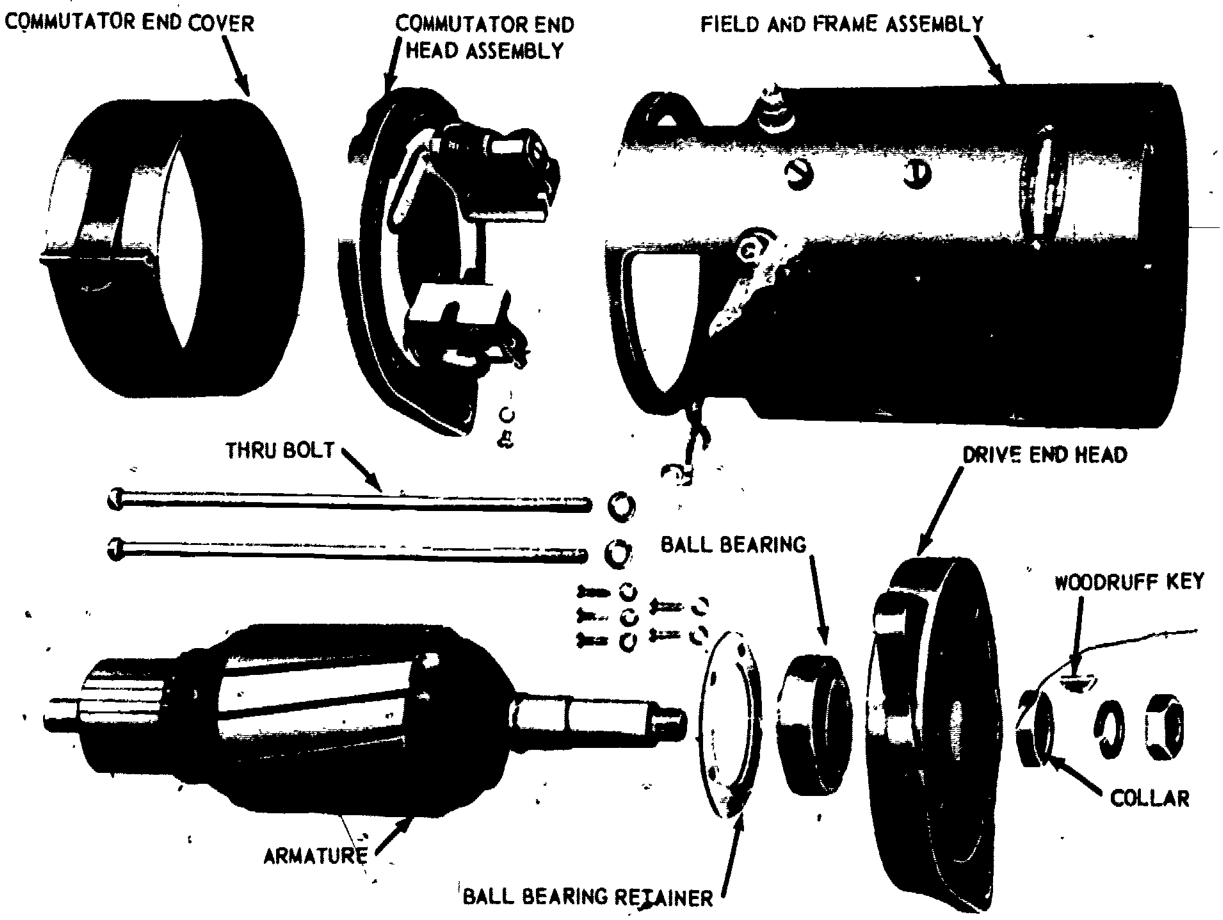
The test procedures presented here are for representative units and are not to be used in lieu of those given in the applicable maintenance instructions manuals for any specific equipment.

When servicing the a-c charging circuit, the following precautions must be observed:

1. Insure that the polarity of the system being serviced is known so that the battery is connected properly, because reversed battery polarity will damage rectifiers and regulators.

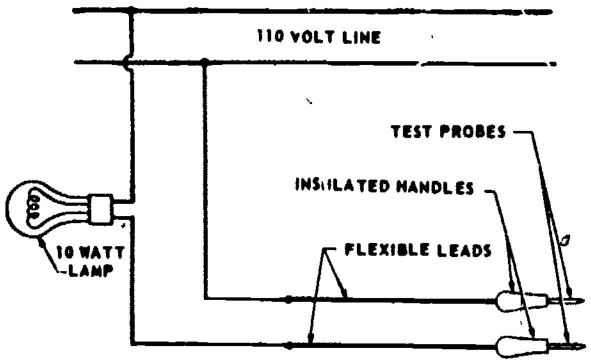
2. When using booster batteries for starting a vehicle, insure that they are connected properly to the vehicle battery; that is, negative cable from booster battery to negative terminal on vehicle battery, and positive booster cable to positive terminal. Failure to do this will result in damage to the rectifiers and regulators.

3. Unless the system includes a load relay, grounding the alternator output terminal will damage the alternator and/or circuits. This is true even when the system is not in operation, because no circuit breaker is used and the

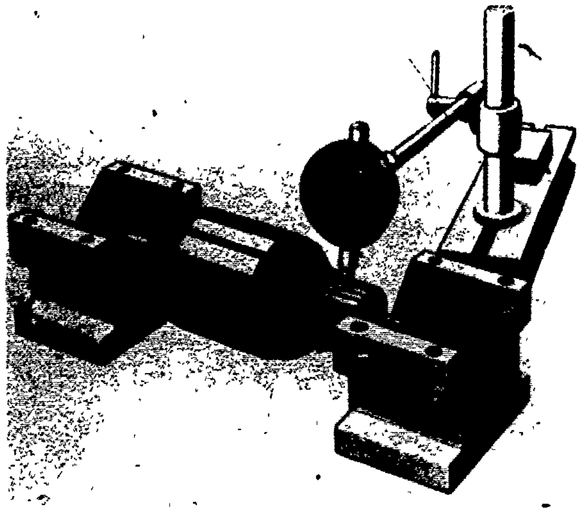


AS.293

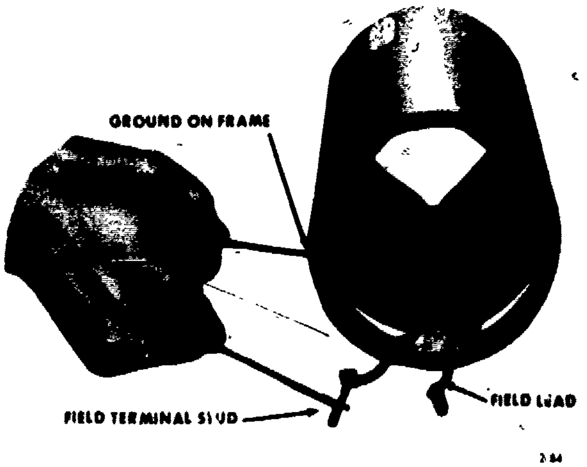
Figure 10-33.—Two-brush, d-c generator.



AS.294
Figure 10-34.—Test probes with test lamp.



AS.296
Figure 10-36.—Measuring commutator out-of-round.



AS.295
Figure 10-35.—Testing field coils for grounds.

battery is connected to the alternator output terminal at all times. The field or load relay acts as a circuit breaker in that it is controlled by the ignition switch.

4. Insure that you do not short the adjusting tool to the regulator base when making adjustments to the voltage regulator. To do so may result in damage to the regulator. The tool should be insulated by taping or by fitting with a plastic sleeve.

5. When charging a vehicle battery with a fast charger, insure that the vehicle battery cables are disconnected unless the fast charger is equipped with a special alternator protector, in which case the vehicle battery cables need not be disconnected. Also, the fast charger should never be used to start a vehicle, as damage to rectifiers will result.

6. Insure that the alternator belt is adjusted to the proper tension.

7. To prevent damage to the system, the ignition switch should be OFF and the battery ground cable disconnected before making any test connections.

8. The vehicle battery must be fully charged or a fully charged battery should be installed for accurate test purposes.

9. Do not attempt to polarize an a-c generator. Any attempt to do so will damage the generator and the regulator.

VIBRATING-CONTACT REGULATOR.—Refer to figure 10-32. With the system warmed up as outlined under d-c regulators, and the VAT controls set as outlined under d-c regulators, remove the cable from the battery positive post and connect a switching device to the battery post which will allow the circuit to be opened between the battery and the alternator battery terminal. Connect the battery's positive cable to the opposite side of the switching device. This switching device will be open during the following tests.

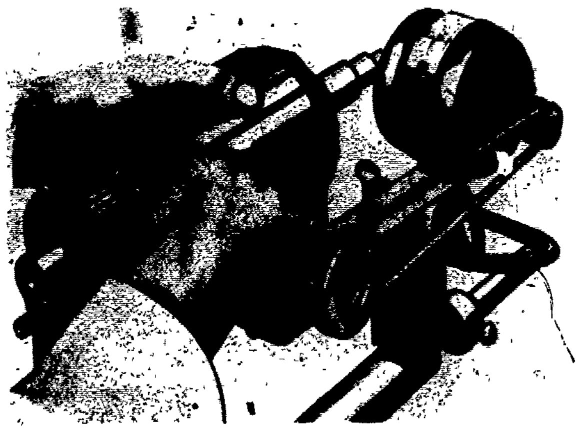
Connect the voltmeter positive lead to the battery terminal of the alternator, and the negative lead to a good ground. Connect the negative lead of the ammeter to the battery cable on the switching device, and the positive lead of the ammeter to the battery positive post.

Adjust engine speed to 1,500 rpm and operate for at least 15 minutes to stabilize system temperature. Cycle the system by bringing the engine back to idle, stopping, and restarting the engine. Adjust speed to 2,500 rpm and rotate the load control knob to the variable load position until the ammeter indicates about 15 amperes. The indication provided by the voltmeter is the voltage setting of the series (lower) contacts. Rotate the load control to the ¼-ohm position and again check the voltmeter. The indication on the voltmeter is the voltage setting of the shorting (upper) contacts. Refer to the manufacturer's specifications to determine if these readings are within limits. Bring the load control back to direct and the engine back to idle.

If adjustments are necessary, they are made in the same manner as for a d-c regulator—changing spring tension by adjustment screws or by bending spring attachment bars.

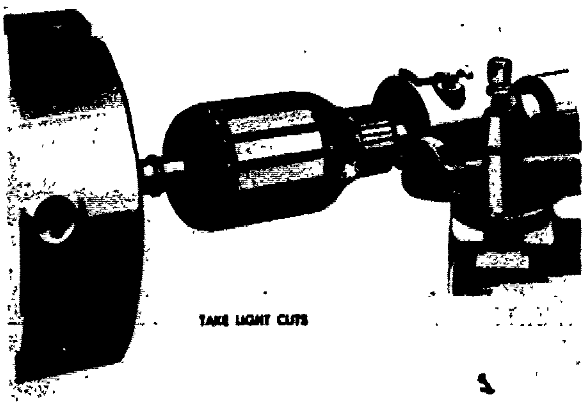
TRANSISTORIZED REGULATOR.—This type regulator is tested and adjusted the same as the vibrating contact just described.

TRANSISTOR REGULATOR.—With the VAT connected as shown in figure 10-32, adjust engine rpm to 1,500 and operate for at least 15 minutes to stabilize system temperature. Rotate the load control knob to the direct position. The voltmeter now indicates the setting of the



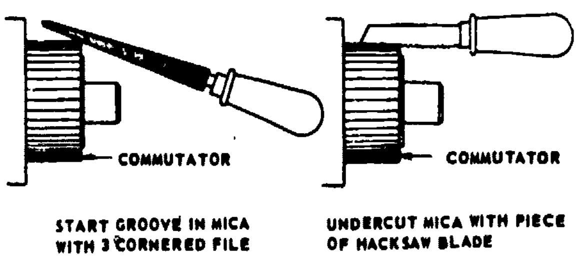
AS.298

Figure 10-38.—Undercutting commutator mica with an undercutter.



AS.297

Figure 10-37.—Turning down a commutator.



AS.299

Figure 10-39.—Undercutting commutator mica with a hacksaw blade.

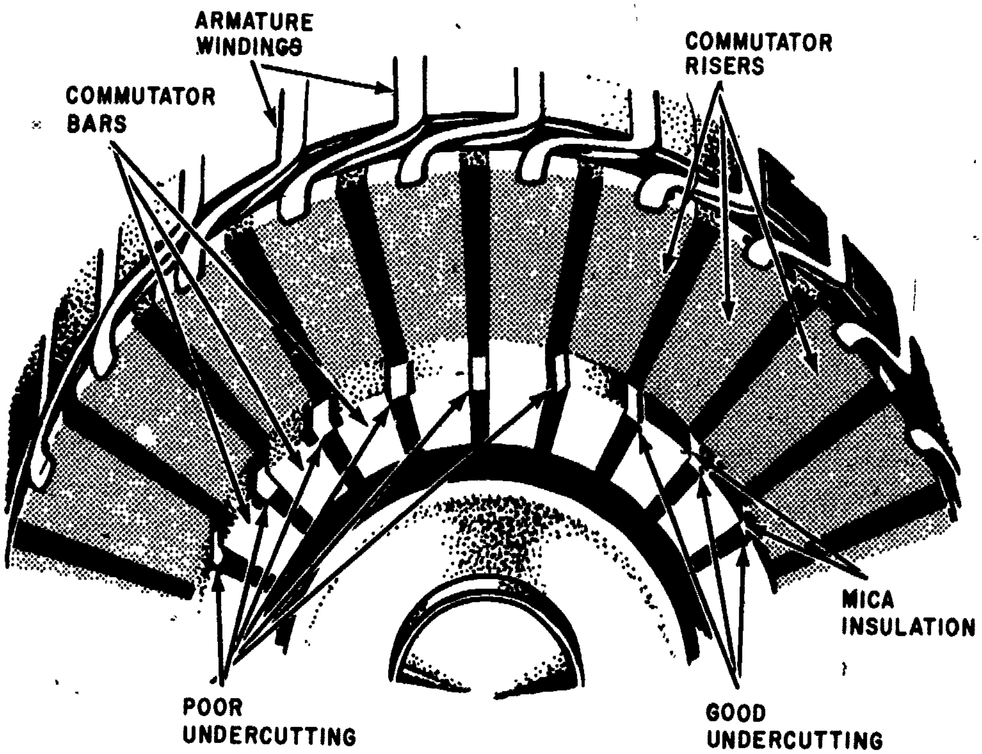


Figure 10-40.—Example of good and poor mica undercutting.

voltage regulator. Refer to the manufacturer's specifications to determine if this reading is within limits.

If adjustment is necessary, remove the pipe plug on the front of the unit to gain access to the voltage adjustment screw.

GENERATOR REPAIR AND CHECK

If the generator output voltage and/or current specified by the manufacturer cannot be obtained from the generator when performing the tests for regulators, the generator must be removed from the vehicle for disassembly, test, and repair.

D-C Generators

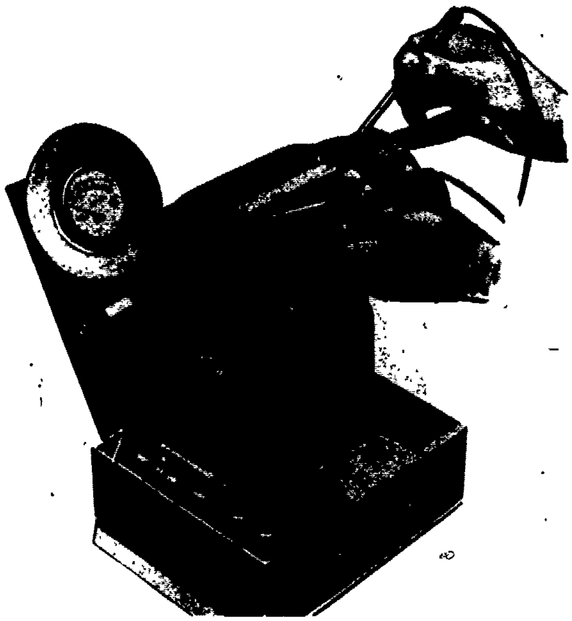
D-c generators (fig. 10-33) consist of four main subassemblies or components; the frame and field assembly, the armature, the commutator end head assembly, and the drive end head. The frame and field assembly is composed of the pole shoe, the field coils, and the frame which supports the remaining main components of the generator. The field coils supply the magnetic field which is necessary to generate electricity. The pole shoes and frame supply the path for the magnetic field. The armature consists of a laminated iron core fixed to a shaft, and the copper windings which are wound in slots in the core. The ends of these windings are connected to the commutator, which consists of a number of copper segments that are insulated from each other and from the core and shaft.

The commutator end head is a cast-iron head that closes one end of the frame and supports one of the armature bearings. The commutator end head also supports the brush holders and brushes that contact the commutator and carry the electricity from the revolving armature. The drive end head closes the drive end of the frame and also supports a bearing for the armature shaft.

D-c generators vary in design because of the different electrical and mechanical characteristics desired for particular installations. The size, type of mounting, type of drive, or the voltage and current output differ, but all d-c generators include the four components just described.

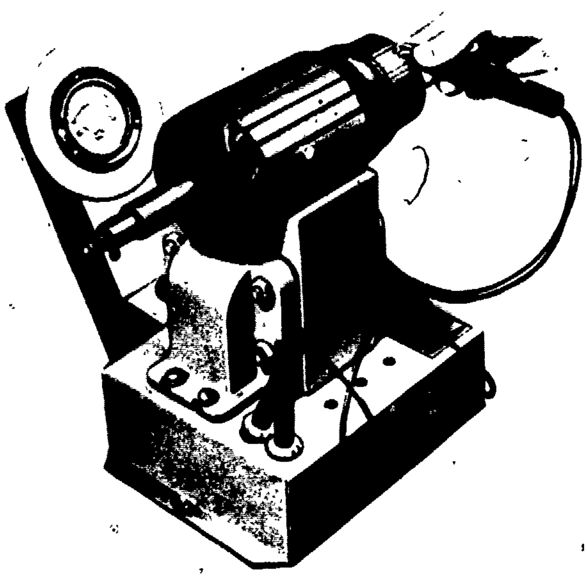
Automotive generators are disassembled only when major repairs are to be made. Other than cleaning commutators and replacing worn brushes during periodic maintenance checks on the vehicle, automotive generators need few major repairs during normal service life. However, if neglected, generators will develop troubles that cannot be remedied in the field. In this case, the generator must be removed from the vehicle and taken to the shop for repairs.

DISASSEMBLY.—Disassembling the d-c generator at other than major overhaul bases is generally limited to removing the commutator



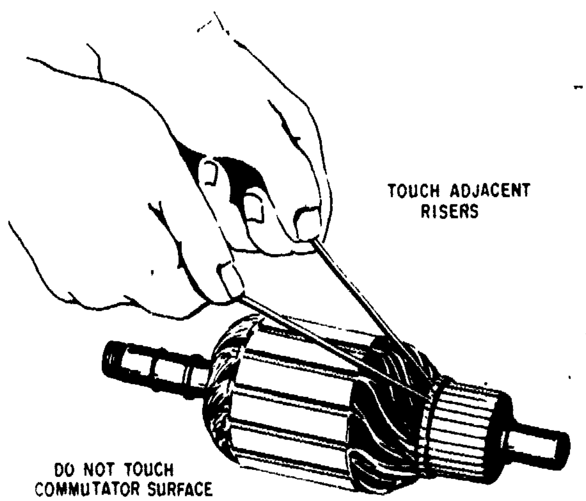
AS.302

Figure 10-42.—Testing armature for grounds.



AS.301

Figure 10-41.—Testing armature for short circuits.



AS.303

Figure 10-43.—Testing armature windings for open circuits.

end head assembly and drive end head so that the armature and bearings can be removed for testing and inspection. The field coils are not generally removed from the frame. The coils are tested in the frame, and if found defective, the field coil and frame assembly is replaced as a unit.

Although d-c generators differ in size, number and arrangement of brushes, and other construction details, disassembling them requires practically the same procedures for all. Once the ASE has disassembled one kind of d-c generator, the disassembly of others will follow almost the same pattern.

After removing the cover band, carefully examine the generator. Study the brush arrangement to obtain a mental picture of the brush lead connections. Make a sketch to aid in the replacement of wires. Most generators have marks, either scratched or center-punched, on the adjacent edges of the frame assembly and end heads to help in alining these parts during assembly. If these marks are not clearly discernible, make new marks.

Place the generator on end when removing the end heads as the bearings that center the armature are attached to these heads. This prevents possible damage from the heavy armature dropping down on the field coils. Also, disconnect the field coil leads from the brush assembly before the brush end of the generator is removed. In most cases the brush holders and brushes come away from the commutator end head. When removing the end head, be sure that the brushes have been taken from the holders so they are not damaged in sliding off the commutator. Never remove the brushes from the holders by pulling on the pigtails without first easing the spring tension against the brushes.

TESTING FIELD COILS.—As mentioned previously, it is not necessary to remove field coils from the frame to test them. However, the grounded ends must be disconnected from the frame.

Tests for grounds, shorts, and open circuits in field coils can be made with an ohmmeter. The ohmmeter, when connected to the field coil ends, will measure the actual resistance of the coil. If the specified resistance of a field coil is given in the manufacturer's manual—also obtained by measuring a new coil—values obtained through tests can be compared. For example, a short-circuited field coil would have practically no resistance and the ohmmeter would indicate near zero. The ohmmeter would indicate excessively high resistance in a coil having an open circuit. By following the manufacturer's instructions in using the ohmmeter, field coil tests can be made quickly and accurately.

A test lamp circuit (fig. 10-34) can also be used to test the generator field. Place one point of the test lamp circuit on the field terminal end of the coils and the other point on the grounded end. If the lamp lights, the field circuit is complete. Because of the resistance in the field coil wire, it should not burn with normal brilliancy. Normal brilliancy of the test light bulb indicates a possible short circuit between the coils of the field. If the light does not burn, the field winding is open.

A grounded field coil can be found by placing one test probe on the field terminal stud and the other on the generator frame (fig. 10-35). If the test lamp lights, the field is grounded. The ground may be caused by frayed wires at the coil ends. In most cases, grounds and open circuits in field coils cannot be satisfactorily repaired and the defective field coil is replaced.

ARMATURE TEST AND REPAIR.—The armature must be cleaned before it is inspected. Do not allow cleaning fluid to soak into the armature windings. Use low-pressure compressed air to blow off all loose dirt, then use a cloth dampened in an approved cleaning fluid to wipe off the armature.

Inspect the commutator riser bar connections for signs of melted solder and loosened connections. Small specks of melted solder indicate that the generator has been overheated from operating at an overload. To eliminate a possible breakdown in the future, armatures found in this condition should not be reassembled with the generator. Commutator riser bar connections loosened from handling or for other reasons, except overheating, can be soldered. Always use rosin flux in soldering electrical connections. Never use an acid flux as it promotes corrosion.

Check commutator out-of-round by placing the armature in V-blocks and using a dial indicator as shown in figure 10-36. If runout exceeds 0.001 of an inch, or if the commutator is rough or has mica insulation sticking up between segments, the commutator must be turned down.

When it becomes necessary to turn down the commutator, mount the armature in a lathe, preferably on the armature shaft bearing seats. If that is impossible, the armature may be mounted in the lathe on the armature shaft centers. In turning down a commutator, position the cutting tool on a 90° angle with the commutator and approximately one-thirty second of an inch below the centerline of the armature shaft. (See fig. 10-37.)

When turning down the commutator, take small cuts and do not remove any more material than is necessary. If it is necessary to turn the commutator down so much that the ends of the commutator segments are less than one-sixteenth of an inch thick, discard the armature. When the ends of the segments are less than one-sixteenth of an inch, the commutator bars become so thin that they do not have sufficient strength to retain their shape.

After cutting the commutator, use 0000 sandpaper to smooth off any burrs that may be left; then undercut the mica one-thirty second of an inch. Mica can be undercut by using a machine made especially for that purpose (fig. 10-38). If a mica undercutter is not available, use handtools and cut the mica as shown in figure 10-39.

Use care in undercutting mica so as not to widen the commutator slots by removing metal from the bars. Figure 10-40 shows examples of good and poor undercutting.

There are two practical tests for locating shorts, opens, and grounds in armatures—the growler test and the bar-to-bar test.

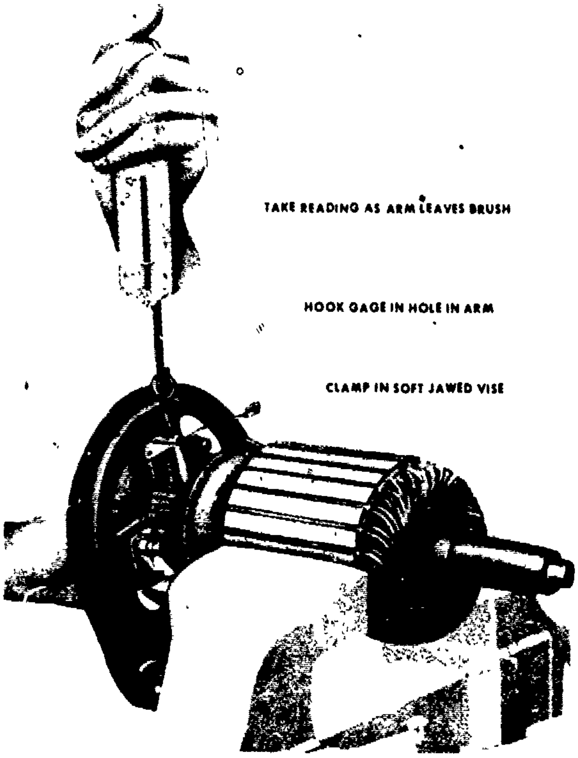
To test for short circuits, place the armature on the V-block of the growler and apply power. With a thin metal strip (hacksaw blade is good) held over the core, rotate the armature slowly through a complete revolution. If a short is present, the steel strip will become magnetized and vibrate. To determine whether the short is in the armature windings or the commutator, clean between the commutator segments and repeat the test. Should the thin metal strip still vibrate, the armature is short circuited internally and must be replaced.

Not all armatures can be tested for short circuits by the steel strip method because, on some armatures, short circuits will be indicated by excessive vibration of the sawblade all around the armature during the test. With these armatures, test for short circuits by using the milliampere contacts on an a-c milliammeter as shown in figure 10-41. In doing so, keep the armature stationary in the V-block and move the contacts around the commutator on adjacent bars (segments) until the highest reading is obtained. Then turn the armature to bring each pair of segments under the contacts and read the milliammeter at the same time. The readings should be nearly the same for each pair of adjacent bars. If a winding is short circuited, the milliammeter reading will drop almost to zero.

Test the armature for grounds by using the test light circuit which is a part of most modern growlers. (See fig. 10-42.) Place the armature on the V-block and touch one of the test probes to the armature iron core. Touch the other probe to each commutator segment riser in turn. If a winding is grounded, the bulb in the base of the growler will light. In contacting armature surfaces with the test probes, do not touch bearing or commutator brush surfaces because the arc will burn or pit the smooth finish. Replace the armature if it is grounded.

In testing individual armature windings for open circuits, use the test probes as shown in figure 10-43. Place them on the riser part of adjacent commutator bars, not on the brush surfaces. If the test lamp does not light, there is a break somewhere in the winding. Repeat this test on every pair of adjacent bars. Do this by moving the probes from bar to bar. Should you find an open winding, the fault may be at the commutator connectors where it is possible to make repairs. If a winding is open circuited internally, the armature should be discarded.

CHECK BEFORE GENERATOR REASSEMBLY.—Before reassembling the generator, inspect the bearings and bushings. If they are worn considerably, replace them or service them according to manufacturer's instructions. Clean the bearings by revolving them in cleaning fluid until all grease and dirt are removed.



AS.304
Figure 10-44.—Measuring brush spring tension.

Remove the cleaner with low-pressure compressed air. Do not spin the bearings with the air as the high turning speed may damage them; and if blown from your hand, the spinning bearing may injure personnel working near you. After cleaning the bearings, repack them with the grease recommended by the manufacturer, not ordinary cup grease or chassis lubricant.

Replace any defective insulator, screw, washer, wire lead, stud, or similar small part. While inspecting the field coils or armature before testing them, rewrap or apply insulating shellac to chafed or bare wires. If a coil is to be rewrapped, see that the coil does not extend beyond its original position so that the rotating armature can strike it.

ASSEMBLING THE GENERATOR.—Reassembly of a generator is the reverse of dis-

AS.289
Figure 10-45.—View of an a-c generator slip ring end frame assembly.

assembly and no trouble should be encountered. Replace all worn or broken parts and assemble the generator end frames so that they line up with the field frame assembly. Install new brushes and seat them. Check the generator brush spring tension.

Brush spring tension is measured with a scale and hook, as shown in figure 10-44. This tension will vary between 15 and 60 ounces, depending on the generator. Consult the manufacturer's specifications for the proper brush spring tension to use. If tested spring or springs do not meet specifications, they must be replaced because the tension of a brush spring cannot be satisfactorily adjusted.

POLARIZING.—The generator's initial buildup of voltage comes from the residual magnetism in the pole shoes of the field coils. The direction of the last current to flow through the field windings determines the generator polarity. In testing field coils with a test lamp, or in making improper connections during the installation or testing of the generator on the vehicle, the generator polarity can be reversed. The generator will build up voltage that will cause current to flow in either direction, depending on the polarity of the residual magnetism in the pole shoes. The generator polarity must be the same as the battery polarity in order to have current flow in the proper direction to charge the battery. After the generator has been repaired and installed, or when a generator has been disconnected, it must be polarized prior to starting the engine.

Generators using an "A" (externally grounded) circuit are polarized by momentarily shorting a jumper lead between the battery terminal and the armature terminal of the regulator.

Generators using a "B" (internally grounded) circuit are polarized by disconnecting the field lead at the regulator and momentarily touching this lead to the battery terminal of the regulator.

A-C Generators

The a-c generator (alternator) shown in figure 10-12 consists of four main subassemblies or components—the slip ring end frame assembly, the stator assembly, the rotor assembly, and the drive end frame. The slip ring end frame assembly (fig. 10-45) is composed of the rear rotor shaft bearing, the diode rectifiers and heat sink, the brushes and brush holder, and a capacitor to limit voltage surges across the diodes. The stator assembly (fig.10-12) is composed of a laminated iron frame and has the windings for the three phases wound through and around it. The rotor assembly (fig. 10-13) is composed of the slip rings, the field windings, the rotor shaft, and two rotor segments. The drive end frame mounts the front rotor shaft bearing and provides lugs for mounting the alternator to an engine and for adjusting drive belt tension.

DISASSEMBLY. - Scribe a line across the area where the drive end frame, stator assembly, and slip ring end frame join, to aid in replacing these components in their original position during reassembly.

Remove the thru-bolts and separate the drive end frame and rotor assembly from the stator assembly by inserting a flat tool in the stator frame slot. The separation is made between the stator frame and the drive end frame because the stator windings are connected to the diodes in the slip ring end frame assembly. Once the drive end frame and the rotor assembly are removed, tape the slip ring end frame assembly rotor shaft bearing to prevent entry of dirt, and also tape

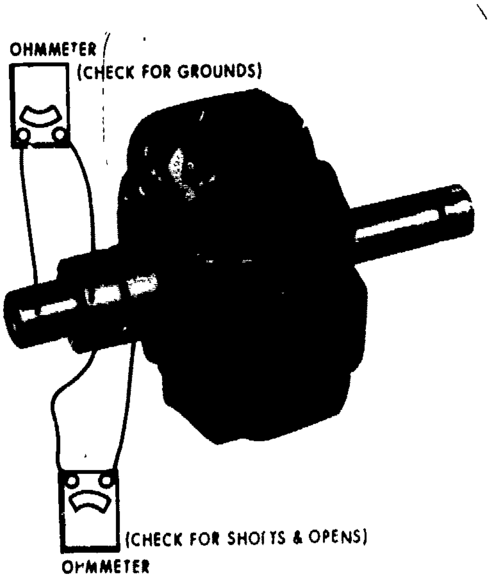


Figure 10-46.—Testing the rotor for grounds, shorts, and opens.

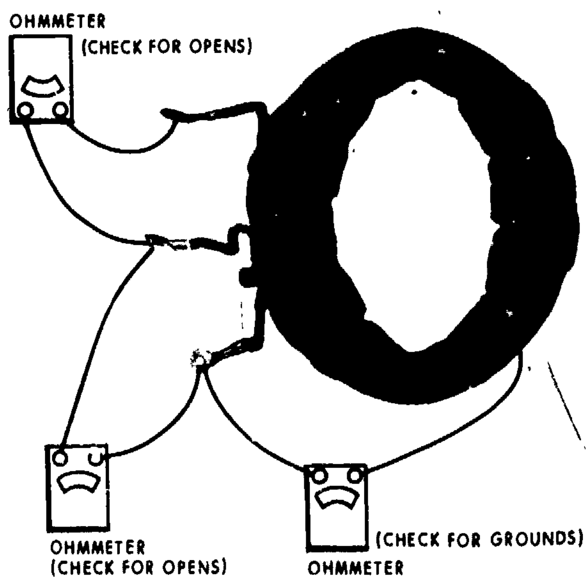
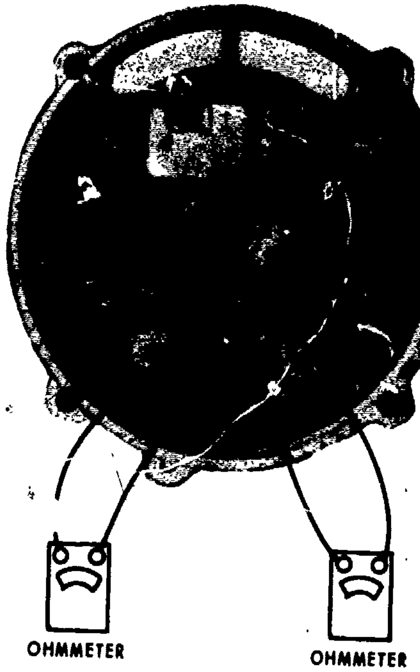
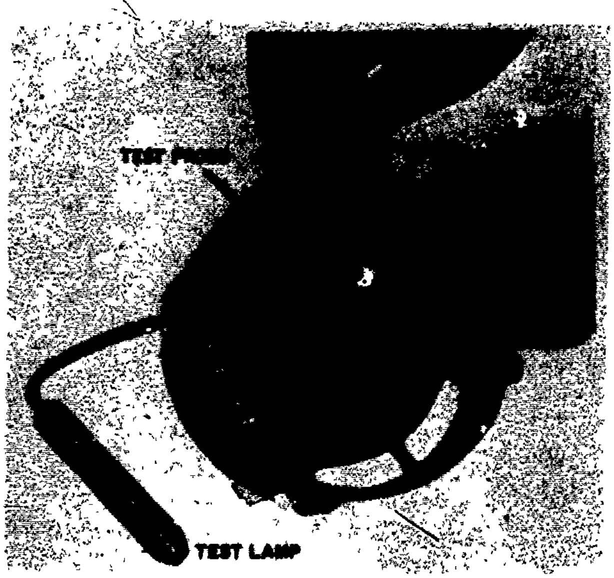


Figure 10-47.—Testing the stator for opens and grounds.



AS.56
Figure 10-48.—Testing diodes with an ohmmeter.



AS.893
Figure 10-49.—Testing diodes with a test lamp.

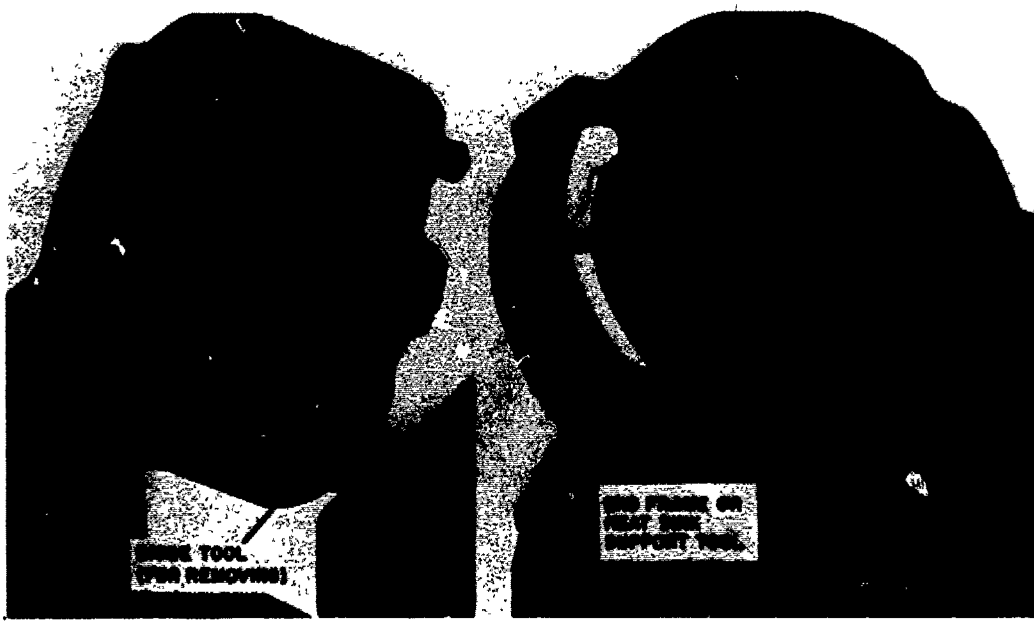
the bearing area of the rotor shaft on the slip ring end. Place the rotor assembly in a soft-jawed vise and tighten just enough to allow removal of the drive pulley retaining nut. Remove the pulley, fan, and collar and then separate the drive end frame from the rotor assembly. Remove the three stator lead attaching nuts from the diodes and remove the stator assembly from the slip ring end frame assembly.

No further disassembly is required in order for the ASE to make electrical tests on the four major subassemblies and their components.

TESTING THE ROTOR.—The rotor is tested for grounds, shorts, and opens. To test for grounds, connect a test lamp or an ohmmeter from either slip ring to the rotor shaft (fig. 10-46). A low ohmmeter reading or lighting of the test lamp indicates that the rotor winding is grounded. To test the rotor winding for opens and shorts, connect an ohmmeter or a test lamp to both slip rings as shown in figure (10-46.) An ohmmeter reading below the specified resistance value indicates a short, whereas a reading above the specified value, indicates an open. If the test lamp does not light when connected to both slip rings, the winding is open.

TESTING THE STATOR.—The stator windings are tested for opens and grounds after the stator has been removed from the slip ring end frame assembly. If the ohmmeter reading is low or if the test lamp lights when connected between each pair of stator leads (fig. 10-47), the stator winding is electrically good. A high ohmmeter reading or failure of the test lamp to light when connected between any two of the stator leads indicates an open winding. A low ohmmeter reading or lighting of the test light when connected between any of the stator leads and the stator frame indicates a grounded winding. It is not practical to test the stator windings for shorts because of the very low resistance of the windings. However, if all other test results are within specifications and the generator will not produce rated output, shorted stator windings are indicated.

TESTING THE DIODES.—With the stator windings disconnected, each diode may be tested with an ohmmeter by connecting one test lead to the diode lead, and the other ohmmeter lead to the diode case, as shown in figure 10-48.



AS.894

Figure 10-50.—Removing diodes.

Note the reading. Then reverse the ohmmeter leads to the diode and again note the reading. If both readings are very low or very high, the diode is defective. A good diode will give one low and one high reading. An alternate method of testing each diode is to use a test lamp with a battery having a voltage no greater than that of the system being tested. Connect one of the test leads to the diode lead, and the other test lead to the diode case, as shown in figure 10-49. Then reverse the lead connections. If the lamp lights in both checks, the diode is defective. Or, if the lamp fails to light in either direction, the diode is defective. When checking a good diode, the la will light in only one of the two checks.

DIODE REPLACEMENT.—Use the manufacturer's specified tools, if available, and a press or vise to remove and install the diodes as shown in figures 10-50 and 10-51. If the manufacturer's tools are not available, suitable substitutes may be used, but particular care must be exercised to prevent damage to the diodes or the slip ring end frame assembly.

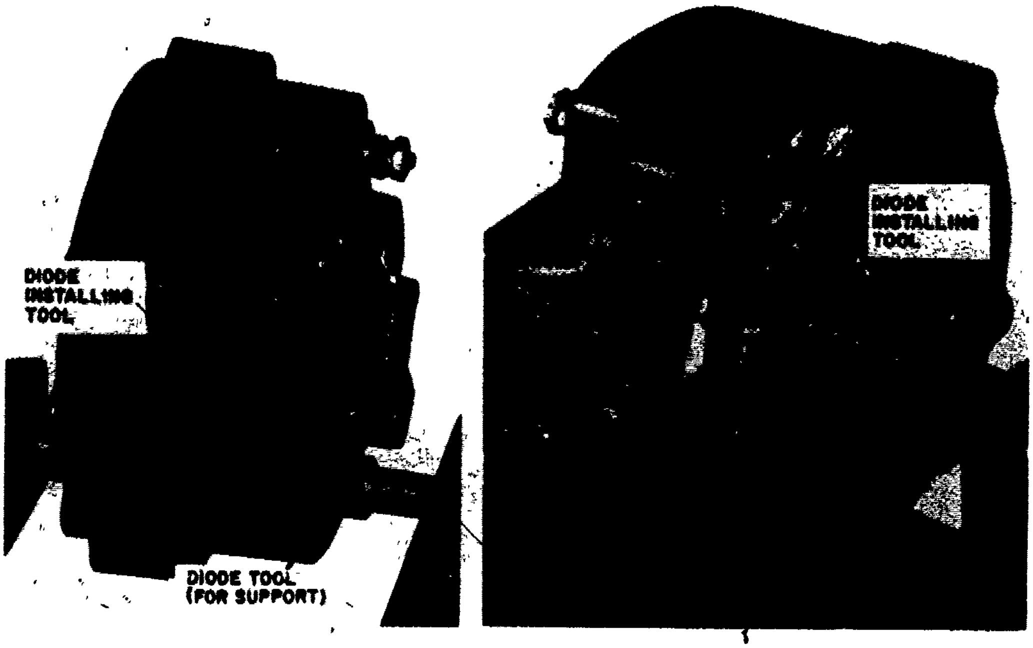
CAUTION: Do not strike any of the diodes while removing or installing, as the shock may cause damage to the diode being removed or installed as well as to others already installed.

Once all the diodes are installed, test them as previously described before assembling the generator to insure that they are still in satisfactory condition.

SLIP RING SERVICING.—If the slip rings are dirty, they may be cleaned and finished with 400 grit or finer polishing paper, or with crocus cloth. Spin the rotor, in a lathe if possible, and hold the polishing material against the slip rings until they are clean.

CAUTION: The rotor must be rotated so that the slip rings are cleaned evenly. Cleaning by hand without spinning the rotor will result in flat spots which will cause excessive brush wear and noise. Slip rings which are out of round, or very rough, must be turned in a lathe, using the same procedure as previously described for d-c generator armatures.

BEARING REPLACEMENT AND LUBRICATION.—Remove the bearing retainer plate and oil seal assembly and, using suitable adapters, press the bearing from the drive end



AS.895

Figure 10-51.—Installing diodes.

frame. Clean the bearing using an approved cleaning solvent, and dry with low pressure compressed air.

CAUTION: Do not allow the air to spin the bearing—this results in rapid wear of the bearing because it has no lubrication.

Inspect the bearing. If it is in satisfactory condition, it may be reused. However, if while turning the bearing by hand any rough spots or excessively worn balls are found, it must be replaced. If the bearing is to be reused, fill it one-quarter full with special grade ball bearing grease and reinstall it in the drive end frame. If the bearing retainer plate felt oil seal is hardened or excessively worn, the retainer plate and seal assembly should be replaced.

The bearing in the slip ring end frame assembly must be replaced if its grease supply is exhausted. No attempt should be made to relubricate and reuse this bearing.

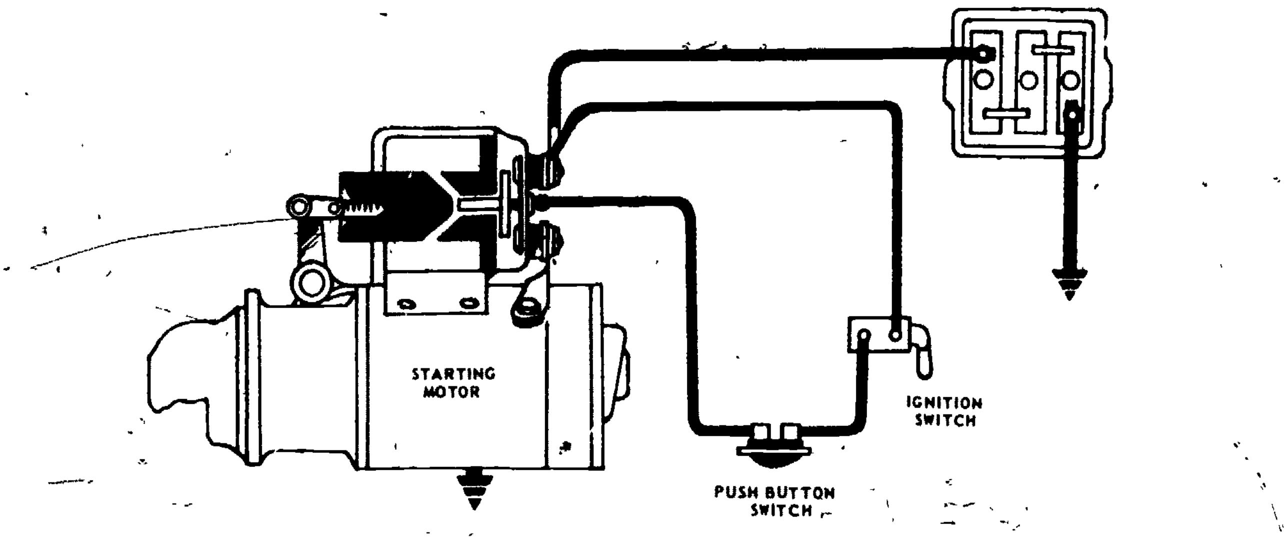
To replace this bearing, press the old one out of the slip ring end frame by using a tube or collar the same diameter as the outside of the bearing. Press from the outside while supporting the inside with a hollow cylinder to prevent breakage of the slip ring end frame. Install the new bearing by placing a flat plate over the bearing and pressing it in from the outside until the bearing is flush with the outside of the slip ring end frame. Support the inside with a hollow cylinder to prevent breakage of the slip ring end frame.

ASSEMBLY.—Reassembly is essentially the reverse of the disassembly procedure given in the preceding section. However, there are a few points to remember:

1. When assembling the drive belt pulley to the rotor shaft, secure the rotor in a vise only tight enough to tighten the nut to the torque specified by the manufacturer.

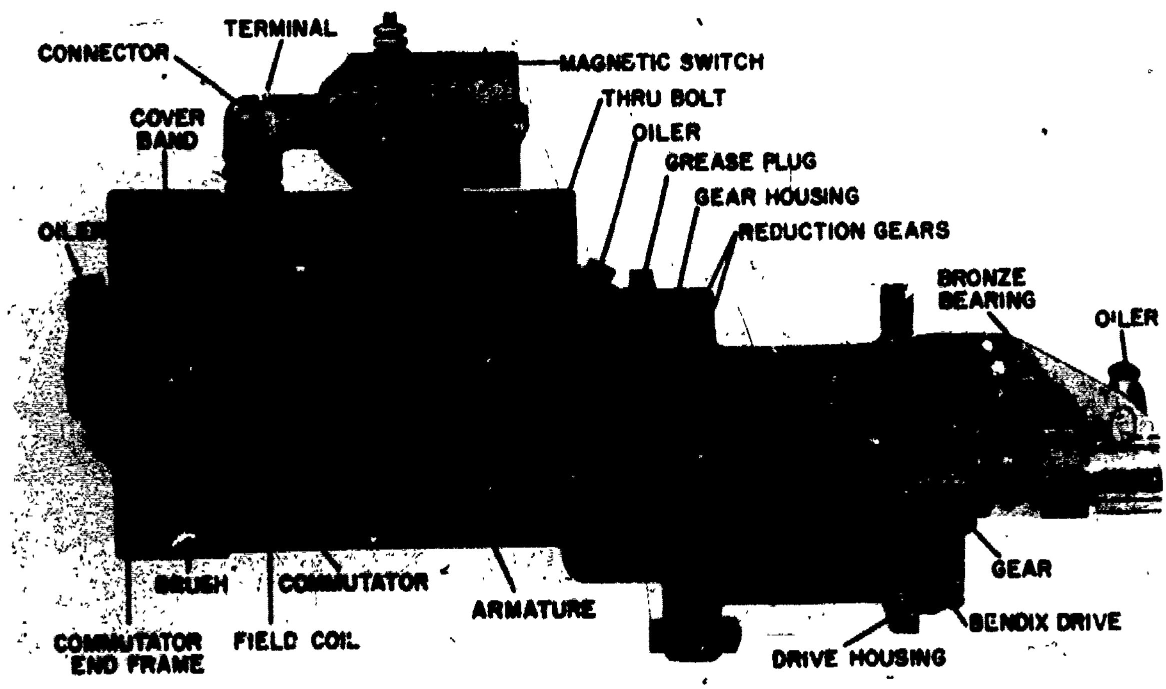
2. Insure that the bearing areas of the rotor shaft are free of dirt or grime.

3. When installing brushes, exercise care to prevent chipping or other damage to them.



AS.305

Figure 10-52.—Electric starter system.



AS.307

Figure 10-53.—Sectional view of a heavy-duty starter.

STARTING SYSTEMS

The major components of an electrical starter system are a battery, a starter motor, a switch for controlling the starter, a drive unit to transmit the power of the starter motor to the engine's flywheel ring gear, and the essential wiring.

The electric starters used on ground support equipment are remotely controlled by a push-button switch or by an ignition switch having a start position. An electric starter system using a remote control switch is shown in figure 10-52.

Automotive equipment starters also incorporate, as a part of the drive unit, a means of preventing the starter from being driven by the engine once the engine is started and is running under its own power.

STARTING MOTOR

A d-c starting motor changes electrical energy into mechanical energy. In a motor, a current is sent through the armature and the field: the attraction and repulsion between the magnetic poles of the field and coil alternately push and pull the armature around. This rotation (mechanical energy), when properly connected to the flywheel of an engine, causes the engine to rotate.

Starting Motor Construction

Figure 10-53 is a sectional view of a heavy-duty starter. This starter employs a magnetic switch to control the starter, a reduction gear driving head, and a Bendix drive. These units will be discussed later in this chapter.

Except for the drive end and control mechanism, the general construction characteristics of the starter motor are similar to the d-c generator.

The connections and arrangements of the armature coils are such that current is flowing in all the coils at the same time (series wound). This allows each coil to add its turning effort to the others, so they all work together to turn the motor armature.

The field windings are used to increase the strength of the magnetic field, and thereby increase the power of the motor. The field windings are connected in series with the brushes and armature windings, so the current that flows through the field windings also flows through the armature windings. A heavy conductor is used in both the fields and the armature so the resistance of the motor windings is very low. This permits an extremely large current to flow, so that the motor develops high torque.

Types of Starter Drives

A starting motor makes use of a gear reduction to transmit its cranking power to the engine. The method most commonly used to obtain this gear reduction is the use of a large-diameter ring gear on the engine flywheel and a pinion gear of much smaller diameter on the starter motor armature shaft. In operation, the pinion engages and drives the ring gear, thereby turning the engine flywheel and the engine. The ratio between the pinion and ring gear will be different on engines of different size and horsepower, but will usually be between 10:1 and 16:1. Thus, the starter motor armature will revolve 10 to 16 times for every one revolution of the engine flywheel. When the pinion is engaged with the ring gear, the starter motor turns 2,000 to 3,000 rpm, turning the engine at speeds up to 300 rpm. During operation, the engine may reach speeds of 3,000 to 4,000 rpm and, should the pinion fail to disengage from the ring gear after the engine is started, the starter motor could be rotated by the engine at speeds up to 64,000 rpm. This high speed would throw the windings from the slots in the armature and the segments from the commutator. To prevent this, various methods of engaging and disengaging the pinion with the ring gear have been devised.

BENDIX DRIVE.—This type drive (fig. 10-54) consists of a pinion and sleeve (shaft) assembly, a drive spring, and a drive head. The pinion, counterweighted on one side and having internal spiral threads, is mounted on a sleeve having external threads that match those of the pinion. The sleeve is a loose fit on the motor armature shaft. One end of the sleeve is bolted to the drive spring and the other end of the drive spring is bolted to the drive head. The drive head is keyed and bolted to the armature shaft by the shank of the same bolt that holds the drive spring to the drive head.

When the starter is not operating, the pinion is disengaged and away from the ring gear. When the starter motor is energized, the armature immediately starts to rotate at high speed. The pinion does not rotate immediately with the armature shaft but trys to remain stationary because of the inertia of the counterweight, and runs along the revolving threaded sleeve until it meets or engages the ring gear. Should the pinion meet but not engage the ring gear, the drive spring is compressed, allowing the pinion to turn and engage the ring gear. When the pinion and ring gear are engaged, the pinion is driven by the starter motor, through the drive spring, and turns the engine. The drive spring compresses to absorb the shock of initial pinion engagement and cushions the starter drive against the compression of the engine as the engine is being turned. When the engine fires and runs on its own power, the ring gear drives the pinion at a higher speed than the starter motor and the pinion runs back along the threaded sleeve to its original, disengaged position. There are several other versions of Bendix drives in use, but they all operate on the same principle and have essentially the same construction.

OVERRUNNING CLUTCH.–The overrunning clutch drive (fig. 10-55) consists of a shift collar, a clutch spring, a shell and sleeve assembly, a pinion, a clutch rotor, and a set of rollers. The shell and sleeve assembly has internal splines and is a loose fit on the external splines of the starter motor armature shaft. The rotor is connected to the pinion and the steel rollers are located in tapered notches in the shell. Springs and plungers hold the rollers in the position shown in figure 10-55.

When the solenoid is energized, the drive unit is moved along the armature shaft and the pinion engages the ring gear. Should the pinion meet the ring gear but not engage it, the clutch spring compresses, allowing the solenoid plunger to continue moving to close the contacts and energize the starter motor. As the starter motor starts to rotate, the pinion turns and is engaged with the ring gear by the action of the clutch

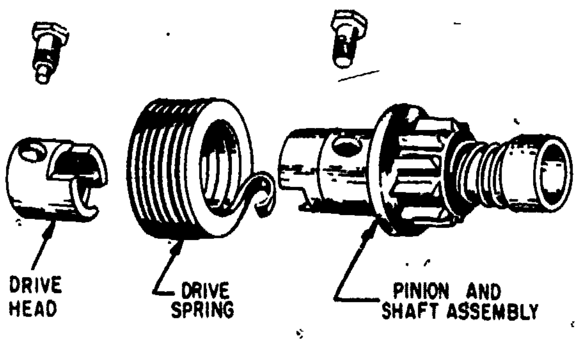


Figure 10-54.–Bendix drive construction.

spring expanding. The rotor is now stationary and, as the starter motor rotates the shell, the rollers are forced tightly into the small end of the tapered notches to cause the shell and rotor to rotate together as a unit. Because the rotor is connected to the pinion, the engine is turned. After the engine is running, the ring gear drives the pinion at a higher speed than that of the starter motor and tends to work the rollers back toward the large end of the tapered notches, and against the springs and plungers. This frees the rotor from the shell and the pinion overruns the starter motor armature shaft, preventing the starter motor from being driven by the engine even though the pinion is still engaged with the ring gear. When the solenoid is deenergized, a spring returns the drive unit back to its original position, disengaging the pinion from the ring gear.

GEAR REDUCTION DRIVEHEADS.–Gear reduction driveheads provide a greater gear reduction than that of a pinion and ring gear and are used in conjunction with Bendix drive units on heavy duty starters. Starters which incorporate this added gear reduction are referred to as double reduction starters.

Figure 10-53 illustrates a starter with a gear reduction drivehead. The gear on the armature shaft does not engage directly with the ring gear, but with an intermediate gear which drives the starter pinion. This drive permits the use of a small starter motor running at high speeds to

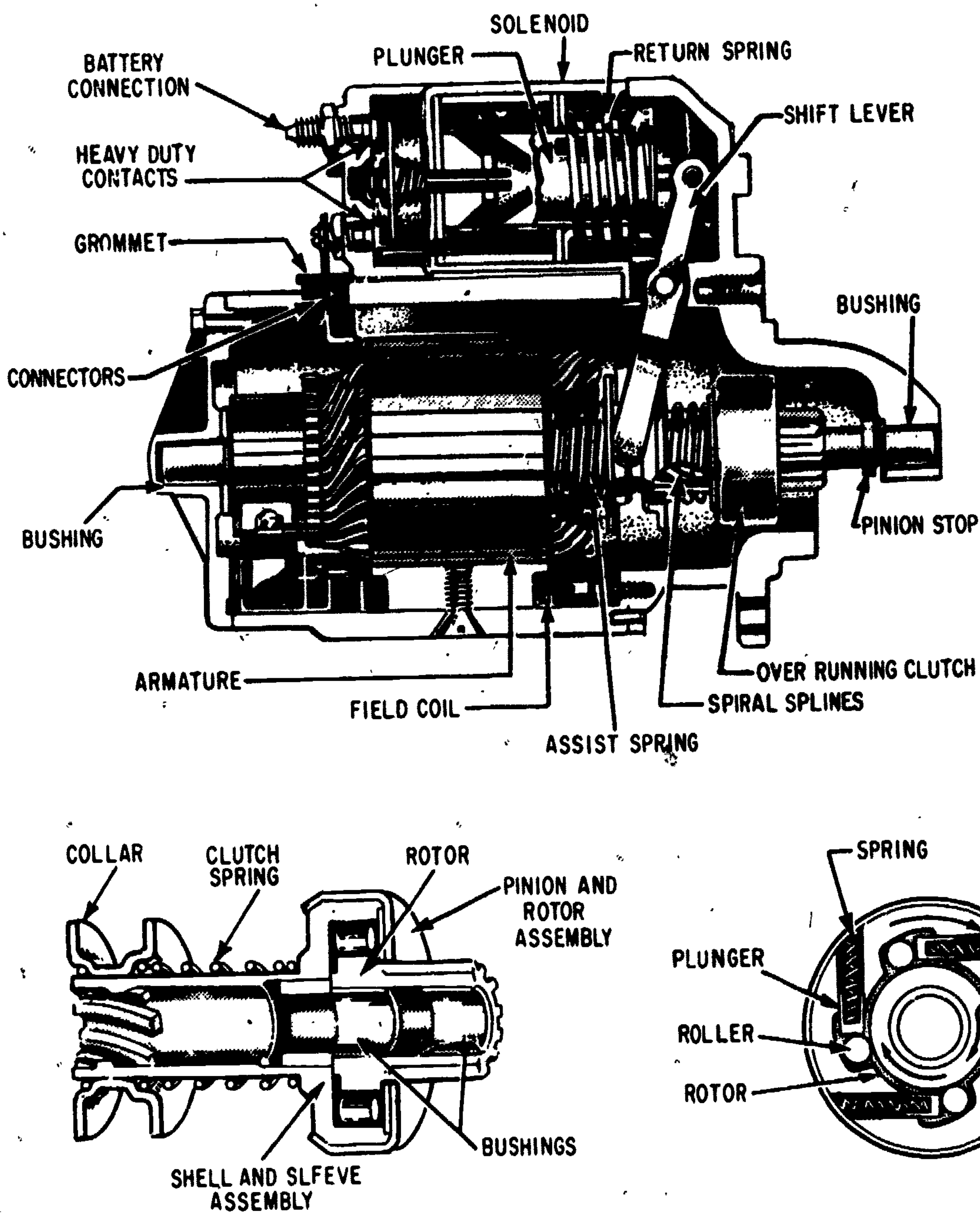


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Figure 10-55.—Solenoid shift starter and overrunning clutch drive.

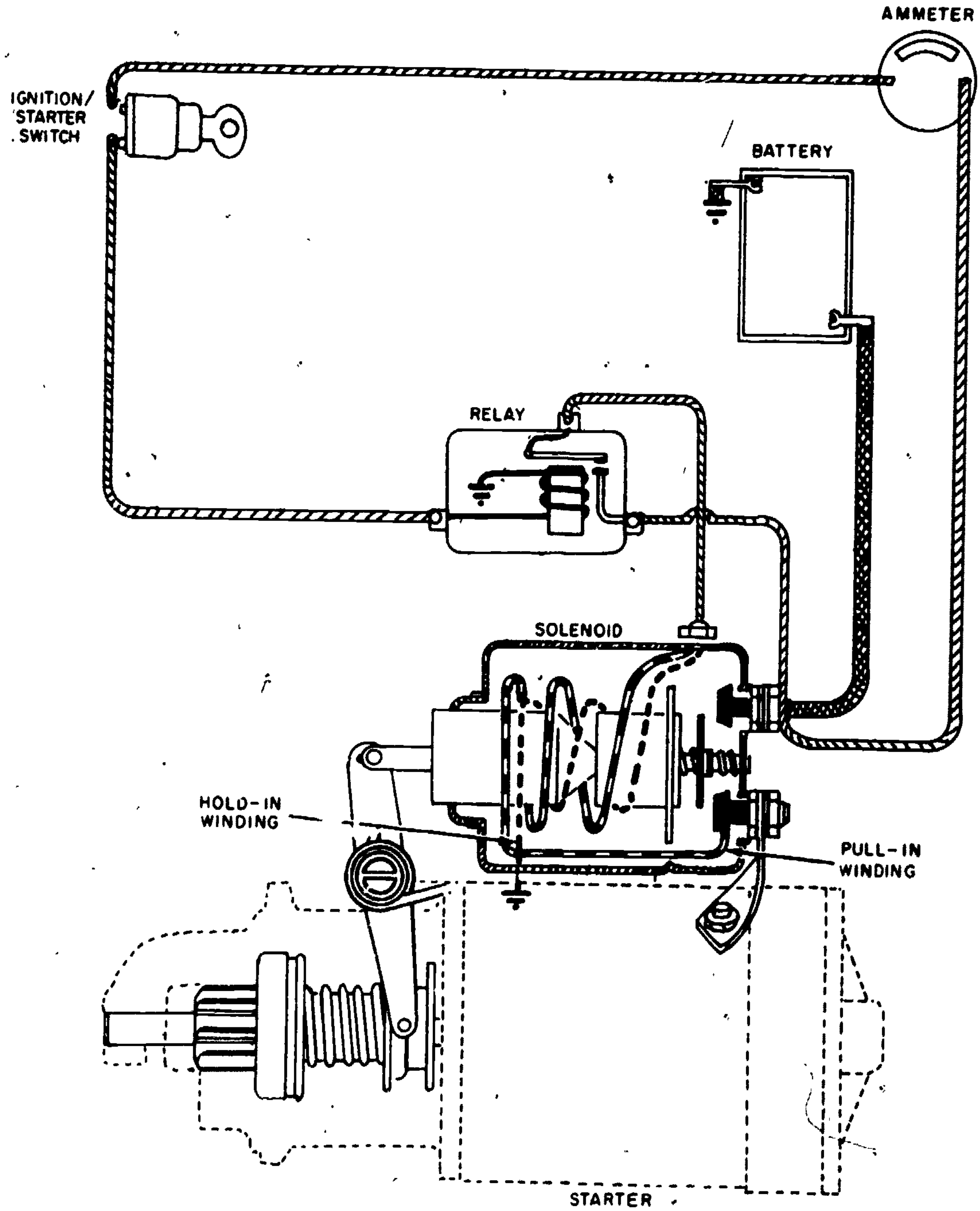

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Figure 10-56.—Control system for a starter with overrunning clutch drive.

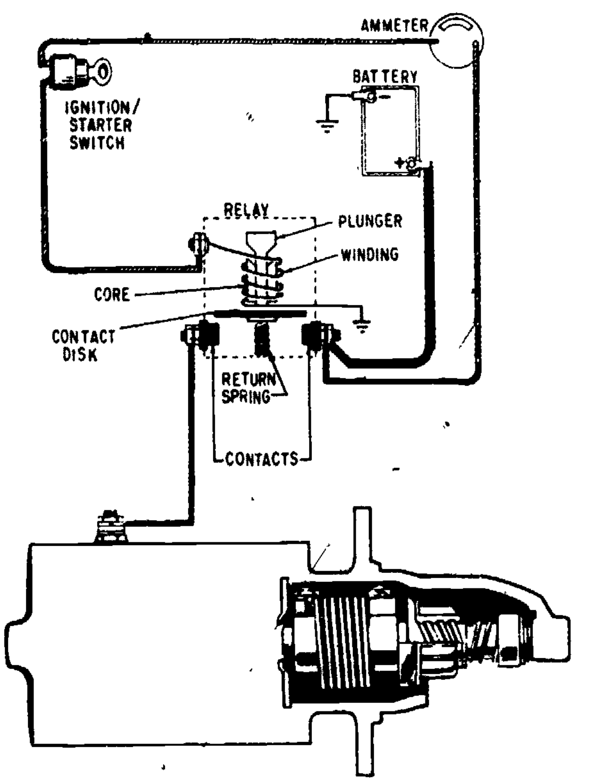

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Figure 10-57.—Control system for a starter with Bendix drive.

provide additional breakaway, or starting torque, and greater cranking power. The armature of a starter of this type may turn as many as 40 times for each revolution of the flywheel when cranking an engine.

STARTER MOTOR CONTROLS

Starter motor controls can be divided into two groups; operating and safety. The operating controls provide the operator with the means to start the vehicle's engine, while the safety controls prevent the starter from being operated when a situation exists whereby damage could possibly be done to the vehicle or the starter.

There are several types of operating and safety control devices and circuits in use, but the ones discussed in this manual are those most widely used on ground support equipment.

NOTE: The discussions presented in the following sections are of representative control devices and circuits and do not apply to any specific unit.

Operating Controls

In the Navy today, all starter motor control systems on ground support equipment make use of electrically operated control devices and small-wire, low-current, remote-control circuits which eliminate the need for long and heavy battery cables to be run to the operator's compartment. These remote control circuits make the starter system easy to operate, because the operator has only to close a switch on the control panel of the vehicle in order to energize the starter.

SOLENOID.—On starters which have overrunning clutch drives, a solenoid is used to shift the pinion into engagement with the ring gear (fig. 10-55), and also to close a set of heavy duty contacts to complete the circuit from the battery to the starter motor. Mechanical linkage is used to connect the solenoid plunger to the shift lever which moves the pinion. Remote control of the solenoid (fig. 10-56) is accomplished by a low current control circuit using a pushbutton switch or an ignition switch with a start position. In some systems a relay is used to control current flow to the solenoid, and the remote control circuit is used to control the relay. When the control circuit to the solenoid is completed, a path for current flow is created through both the pull-in and the hold-in windings. The combined magnetic fields of these windings pull the solenoid plunger in so that the pinion is shifted into engagement with the ring gear, and the heavy duty contacts of the solenoid are closed.

While different size wire is used for the two windings, they both have approximately the same number of turns. The heavy pull-in winding is needed to pull the plunger in, but once the plunger movement is completed, the hold-in winding is sufficient to hold the plunger in. The pull-in winding is grounded through the very heavy winding of the starter motor. Closing the solenoid contacts completes the power circuit to the starter motor and, at the same time, shorts out the pull-in winding.

When the ignition/starter switch is opened, current flow through the control circuit stops, and the relay opens. However, the circuit through the hold-in winding is still completed through the pull-in winding and the closed heavy duty contacts. Current flow through the hold-in winding is in the same direction as when the control circuit was closed, but current flow through the pull-in winding is now in the opposite direction. With the same number of turns in both windings, and the same current, the magnetic fields produced are equal but opposite and counteract each other. The plunger is thereby released and is returned by a spring to its original position, opening the heavy duty contacts and breaking the power circuit to the starter motor.

RELAY.–A heavy duty relay is used with starters that have Bendix drives. The purpose of the relay (fig. 10-57) is to complete the power circuit between the battery and the starter motor, and it is controlled by a low-current remote control circuit having either a push-button switch or an ignition switch with a start position.

When the control circuit to the relay is closed, a path for current flow through the relay winding is created and the magnetic field produced pulls the plunger in, closing the heavy duty contacts, and energizing the starter motor. When the control circuit is opened, current flow through the relay winding is stopped and the magnetic field collapses. The plunger is released and is returned to its original position by the return spring, opening the contacts and breaking the power circuit to the starter motor.

Safety Controls

Safety controls are incorporated in ground support equipment starter systems to prevent engagement of the starter after the engine is running and, on self-propelled equipment, to prevent the vehicle's engine from being started unless the transmission shift lever is in a non-drive position.

The safety devices discussed here may be used in any combination desired by the manufacturer. Reference must be made to the applicable maintenance manuals for the particular unit before attempting troubleshooting or repair of the starter control system.

NEUTRAL SAFETY SWITCH.–All ground support equipment equipped with automatic transmissions incorporate some form of a neutral

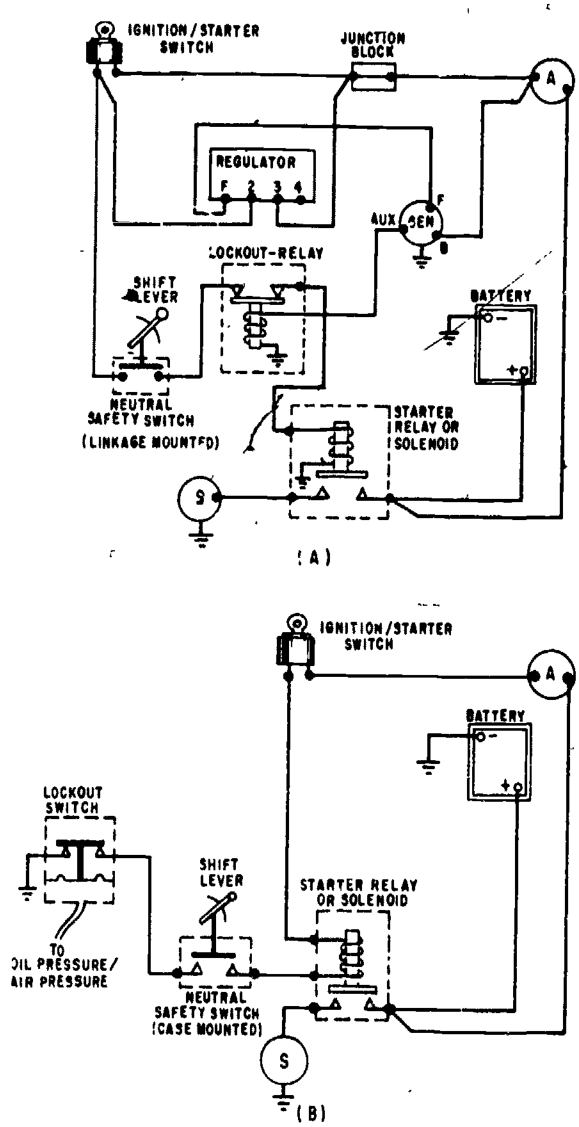

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Figure 10-58.–Starter safety control combinations.

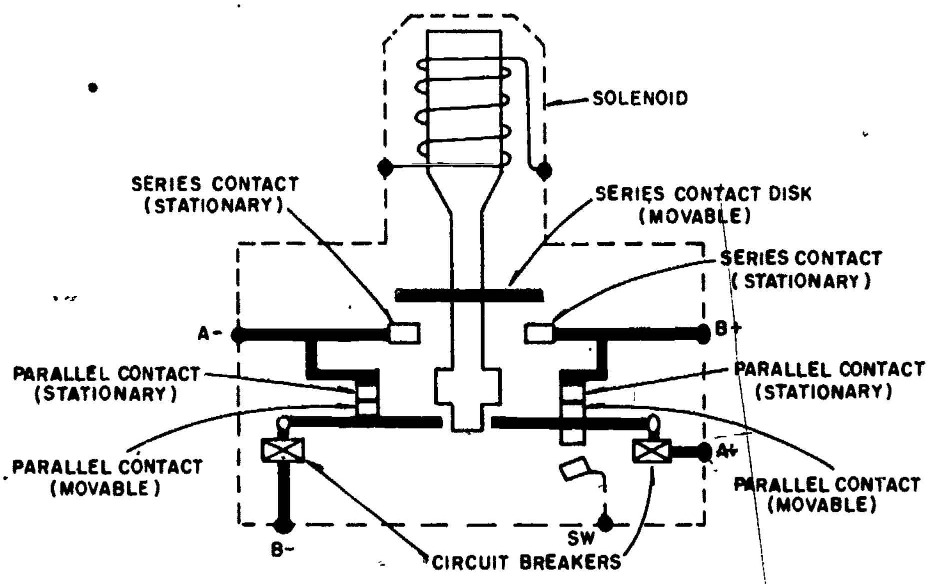

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Figure 10-59.—Solenoid operated series-parallel switch.

safety switch to eliminate the possibility of the engine being started with the transmission selector lever in a position to drive the vehicle.

The switch is mounted either on the transmission shift linkage or in the transmission case. When it is mounted on the transmission shift linkage it is connected in series with the starter switch and the starter relay or selenoid winding, as in figure 10-58 (A). When it is mounted in the transmission case it is connected in series with the starter relay or solenoid winding and ground, as in figure 10-58 (B). Regardless of location or connections, the switch is open in all positions of the transmission shift lever except neutral and/or park, and is actuated by the transmission shift linkage.

STARTER LOCKOUT RELAY.—This device is actuated by generator output voltage and prevents the starter from being energized when the engine is running.

The normally closed contacts of the lockout relay, figure 10-58 (A), are connected in series with the starter switch and the starter relay or solenoid winding. One end of the lockout relay winding is connected to the output of the generator, and the other end to ground. When the generator output voltage reaches a value great enough to energize the lockout relay (usually 6-8 volts), the lockout relay contacts open, opening the control circuit to the starter relay or solenoid winding. The contacts of the lockout relay remain open as long as generator output voltage is equal to or above that required to energize the lockout relay. Connection to generator output voltage is made at the generator so that operation of the lockout relay is not dependent upon operation of the generator regulator.

When the engine is shut down, the contacts of the lockout relay return to the closed position as generator output voltage drops to a value below that required to energize the relay.

STARTER LOCKOUT SWITCH.—This device is used to accomplish the same purpose as the starter lockout relay—prevent the starter from being energized when the engine is running. It is actuated by engine oil pressure, or when used with a two-stroke cycle diesel engine, by air pressure from the collector box of the engine blower.

The diaphragm-operated lockout switch contacts, figure 10-58 (B), are connected in series with the starter relay or solenoid winding and ground. When the engine is started and oil or air pressure builds up sufficiently to move the diaphragm (usually 10-15 psi of oil pressure or 2-3 inches of water gage air pressure), the switch contacts are opened and the circuit between the winding of the starter relay or solenoid and ground is opened.

When the engine is shut down, the contacts of the lockout switch return to the closed position as oil or air pressure decreases to a value below that required to actuate the lockout switch.

SERIES-PARALLEL STARTING SYSTEM

On diesel engines, where the starter power and speed requirements are high, a voltage higher than 12 volts in the starter system is often necessary to insure adequate starter performance. Most diesel engines will start at a cranking speed of 200 rpm but, under adverse conditions such as freezing temperatures, it is often impossible to obtain such cranking speeds with a 12-volt system. By using a 24-volt starter system, much higher cranking speeds can be produced by a starter motor of the same physical size as that used for a 12-volt system. Lighting that meets highway regulations has not yet been developed for operation on 24 volts, making it necessary to have a 12-volt system also to handle all accessory loads for highway operated vehicles, such as aircraft crash/rescue trucks and shore-based aircraft cranes.

The series-parallel starting system is designed to provide a means of connecting two batteries in series for starting, and then reconnecting the two batteries in parallel for operation of the equipment after the engine is started. For example, two 12-volt batteries connected in parallel provide 12 volts; connected in series they provide 24 volts.

There are two types of series-parallel starting systems in use; one uses an insulated starter motor and an overrunning clutch drive, while the other uses a grounded starter motor and a Bendix drive. The system using a grounded starter motor is the one most commonly used on ground support equipment and it is the one discussed here.

The heart of any series-parallel starting system is the series-parallel switch. It may be operated either manually or by a solenoid, and most modern equipment uses the solenoid operated type. Figure 10-59 shows a solenoid operated series-parallel switch with its internal components. These components are the same for a manually operated switch, and the switches are

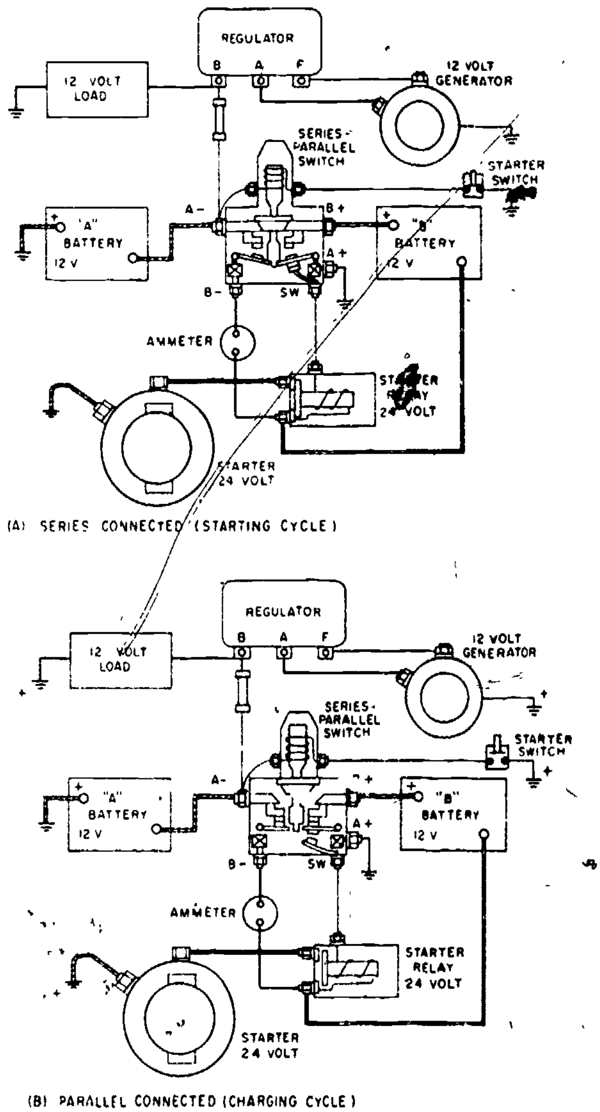

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Figure 10-60.—Grounded type series-parallel starting system.

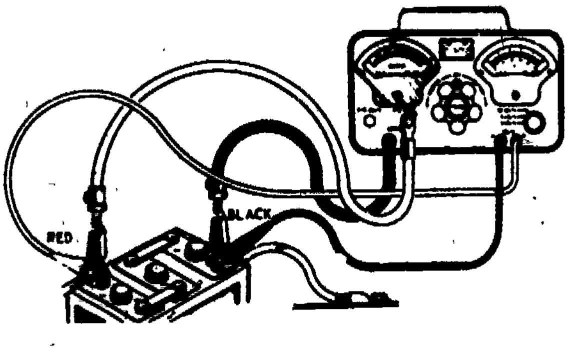

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Figure 10-61.—Tester connections for a battery capacity test.

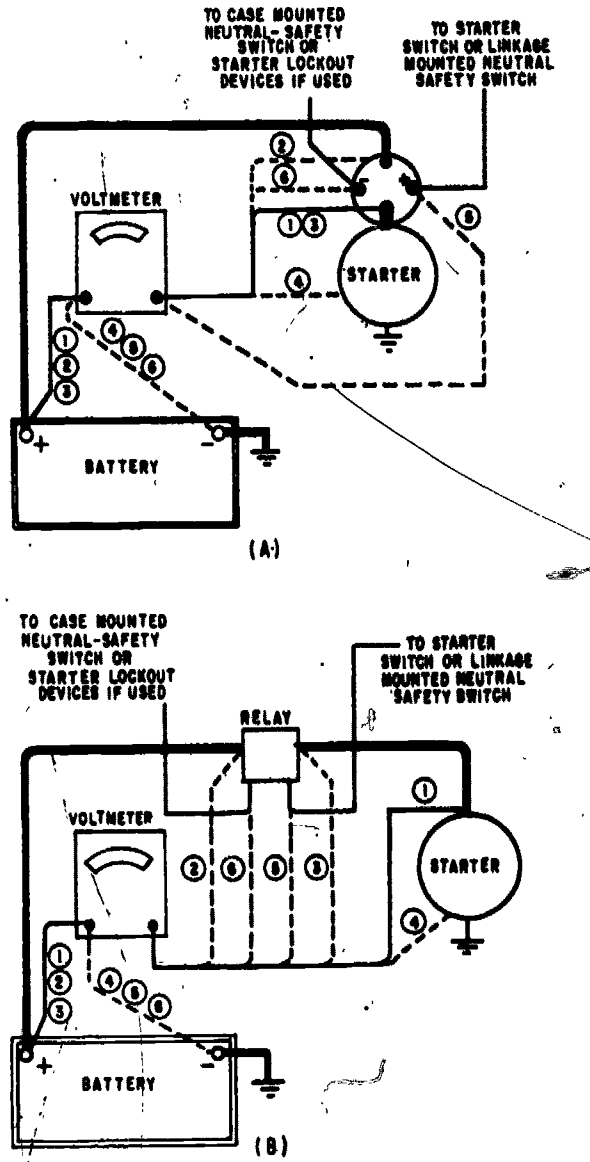

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Figure 10-62.—Voltmeter connections for checking starting system circuit resistance.

the same for either an insulated or a grounded type system.

The circuit breakers shown in figure 10-59 at the A+ and B- terminals are mounted within the switch case and are of the automatic reset variety. On older model series-parallel switches, fuses were used and located externally at these points.

Series Connected (Starting Cycle)

Figure 10-60 (A) shows a series-parallel starting system with the batteries connected in series.

With the starter switch closed, the control circuit to the solenoid winding is completed from the A- terminal to ground through the starter switch. The solenoid is energized, the plunger is pulled in, and three actions take place, in this order: the parallel contacts between the A- and B- terminals and between the A+ and B+ terminals are opened, the series contacts between the A- and B+ terminals are closed, and the starter relay control circuit contacts between the A+ and the switch (SW) terminals are closed.

One end of the starter relay winding is connected to ground at the A+ terminal and the other end is connected to B- at the starter relay battery terminal. As the batteries are now connected in series, 24-volts is applied to the relay winding causing its contacts to close and apply 24-volts to the starter motor. The starter motor rotates and the pinion of the Bendix drive engages the ring gear, cranking the engine. As shown in figure 10-60 (A), all the power required to operate the 12-volt lights and accessories during the starting cycle is taken from the "A" battery.

Parallel Connected (Charging Cycle)

Figure 10-60 (B) shows a series-parallel starting system with the batteries connected in parallel.

When the starter switch is released, the control circuit to the solenoid is opened. The solenoid plunger is released and moved out to its original position by a return spring. The three operations that took place when the plunger moved in now occur in the reverse order—the starter relay control circuit contacts between the A+ and SW terminal are opened, the series contacts between the A- and the B+ terminals are opened, and the parallel contacts between the A- and B- terminals and between the A+ and B+ terminals are closed. The starter relay is now deenergized, its contacts are opened, and the power circuit to the starter motor is opened.

With the generator now as the power source, the charging current is delivered to the A- terminal and divides to charge both batteries. The path to the "A" battery is direct, while the path to the "B" battery is through the closed parallel contacts, out the B- terminal and through the ammeter. The ammeter indicates one half of the total charging current (that delivered to the "B" battery) as an indication of charging system operation.

All the power required to operate the 12-volt lights and accessories is now taken from the generator or, when generator output is not available or is insufficient, equally from both batteries.

CAUTION: When performing any maintenance on a vehicle equipped with a series-parallel starting system, extreme care must be exercised to avoid grounding of any of the series-parallel switch terminals. For example, grounding of a terminal by a wrench or by an oil measuring dip stick would cause a tremendous surge of current through the circuits with possible serious damage to the equipment and injury to maintenance personnel. Exposed terminals are often taped and shellacked so that grounds cannot easily occur. Also, never close the starter motor relay contacts while the series-parallel switch is in the parallel position, because the heavy flow of current in the charging circuit will trip circuit breakers, blow fuses, or burn out wiring.

MAINTENANCE AND REPAIR

The starting system requires little maintenance if used properly, but if a malfunction does occur, the ASE must know how to troubleshoot the system and correct the malfunction.

When the starter cranks the engine slowly, or not at all, tests must be made to determine whether the malfunction is in the battery, starter motor, circuit wiring, or some other component of the system. Many conditions besides defects in the starter motor can result in poor starter performance or no performance at all.

Prior to making any test, visually inspect the complete system. Insure that all connections are clean and tight, that wiring is not frayed or otherwise damaged, and that the starter mounting bolts are tight.

There are many methods that can be used to test starting systems to determine their condition, and some of these methods require the use of test equipment that may not be available to the ASE in fleet units. With this in mind, the tests presented here are such that they may be performed using a minimum of test equipment.

Starting System Tests

As the starting system is completely dependent upon the battery for operation, troubleshooting of the starting system must begin with the battery.

BATTERY CAPACITY TEST.—Although specific gravity and open circuit voltage readings provide a general indication of battery condition, a more accurate indication can be obtained by making a capacity test, using a battery-starter tester.

NOTE: If the specific gravity of the battery is 1.220 or less, do not attempt to make a capacity test. The battery must be removed and slow-charged until fully charged before testing.

In order to make a capacity test, the ampere-hour rating of the battery must be known.

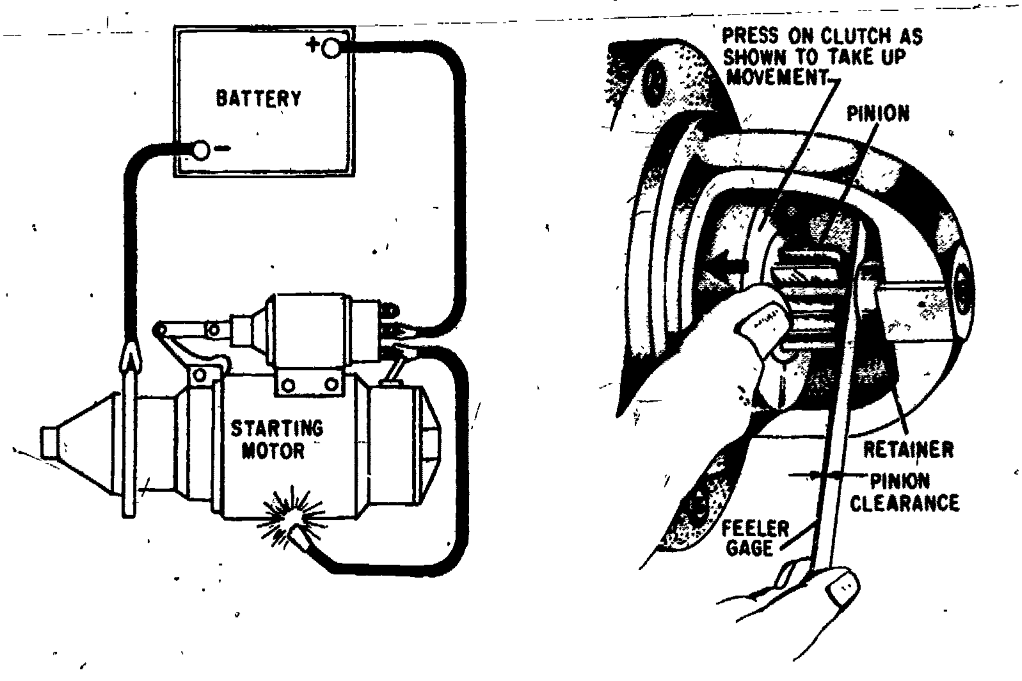

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Figure 10-63.—Pinion clearance test hookup and procedure.

This is generally stamped on the battery case. If it is not, reference must be made to the manufacturer's instruction manual for the particular equipment.

Set the tester voltmeter scale selector switch to a scale position higher than the voltage of the battery to be tested, and the load control knob of the tester to the OFF position.

CAUTION: If connection to the battery is made with the load control knob in any position other than OFF, severe arcing will occur at the battery posts, with the possibility of a battery explosion and personnel injury.

Connect the battery-starter tester as shown in figure 10-61 and turn the load control knob clockwise until the ammeter reading is three times the ampere-hour rating of the battery; for example, 180 amperes for a 60-ampere-hour battery. With the tester ammeter reading the specified load for 15 seconds, note the voltmeter reading. A reading of 9.5 volts or more for a 12-volt battery, or 18.5 volts or more for a 24-volt battery, indicates ample capacity. Readings lower than these indicate that the battery should be replaced.

VOLTAGE DROP (RESISTANCE) TESTS.—High resistance or an open in the starting system can be located by using an accurate, expanded-scale voltmeter to check the voltage drop across various points as shown in figure 10-62.

If the vehicle to be tested is gasoline powered, remove the ignition coil high tension lead from the distributer and ground it (standard ignition), or ground the primary distributer terminal of the coil (transistorized ignition), to prevent the engine from starting while making the voltage drop tests.

NOTE: The voltage readings (drops) used here are general averages and are not to be used in lieu of the vehicle manufacturer's specifications.

For testing a starting system equipped with a solenoid operated, overrunning clutch type starter, make the voltmeter connections as shown in figure 10-62 (A).

CAUTION: Do not operate the starter motor for an extended length of time, as it can be severely damaged from overheating. Operate for a maximum of 30 seconds and then allow it to cool for two minutes before resuming cranking.

Test 1.–With the voltmeter leads connected between the battery positive post and the starter motor terminal, attempt to crank the engine. Voltage reading (drop) should not exceed 0.5 volt. If the drop exceeds 0.5 volt, the high resistance is in the starting system rather than the starter motor. If the drop does not exceed 0.5 volt, perform test 4 to determine if the high resistance is in the starter motor or in the starter motor ground circuit.

Test 2.–With the voltmeter leads connected between the battery positive post and the battery terminal of the solenoid, attempt to crank the engine. Voltage drop should not exceed 0.1 volt. If the drop exceeds 0.1 volt, the high resistance is in either the battery cable connections or the battery cable between these test points.

Test 3.–With the voltmeter leads connected between the battery positive post and the starter motor terminal of the solenoid, attempt to crank the engine. Voltage drop should not exceed 0.5 volt. If the drop exceeds 0.5 volt, the high resistance is in the solenoid. Either its contacts are burned or they are not closing.

Test 4.–With the voltmeter leads connected between the battery negative post and the starter motor frame, attempt to crank the engine. Voltage drop should not exceed 0.1 volt. If the drop exceeds 0.1 volt, the high resistance is in the ground circuit between the battery and the starter motor (ground cable, cable connections, or starter mounting). If the voltage drop does not exceed 0.1 volt, the starter must be removed for further testing.

CAUTION: Prior to performing test 5, the voltmeter scale selector switch must be set to a scale position above battery voltage to prevent damage to the voltmeter.

Test 5.–With the voltmeter leads connected between the battery negative post and the solenoid switch terminal, attempt to crank the engine. Available voltage should not be less than battery voltage. If a reading lower than this is obtained, the high resistance is in the starter switch circuit (neutral safety switch, starter switch, connections, or wiring). If correct voltage is indicated, if the solenoid does not operate, and if the system is equipped with a neutral safety switch or starter lockout devices connected in the solenoid ground circuit, perform test 6. If the solenoid is grounded internally, the starter must be removed for further testing.

Test 6.–With the voltmeter leads connected between the battery negative post and the ground terminal of the solenoid, attempt to crank the engine. Voltage drop should not exceed 0.1 volt. If the drop exceeds 0.1 volt, the high resistance is in the solenoid ground circuit (wiring, connections, neutral safety switch, or starter lockout devices).

If the results of tests 5 and 6 on a solenoid operated, overrunning clutch type starter system are within limits and the solenoid does not operate, the starter must be removed for further testing. When the above tests are to be applied to a starting system equipped with a Bendix drive type starter, the test procedures are the same, as shown in figure 10-62 (B), except that where the word "solenoid" is used, use the word "relay". The maximum allowable voltage drops for both systems are the same.

Starter Motor Test and Repair

When it is determined that a malfunction of the starting system is in the starter, the starter must be removed from the vehicle for disassembly, test, and repair. The starter motor and drive assembly are removed as a unit.

DISASSEMBLY.–Disassembly of the starter at other than major overhaul is limited to removing the commutator end head and pinion housing so that the armature, drive assembly, and bearings can be removed. The field coils are tested in the frame, and if found defective, the field coils and frame are replaced as an assembly.

Although starters will differ in size, type of drive, brush arrangement, and other construction details, disassembly requires practically the same procedures. Once the ASE has disassembled one kind of starter, the disassembly of others will follow the same pattern.

If the starter is equipped with a solenoid, remove the attaching bolts from the solenoid housing and the connector strap from the

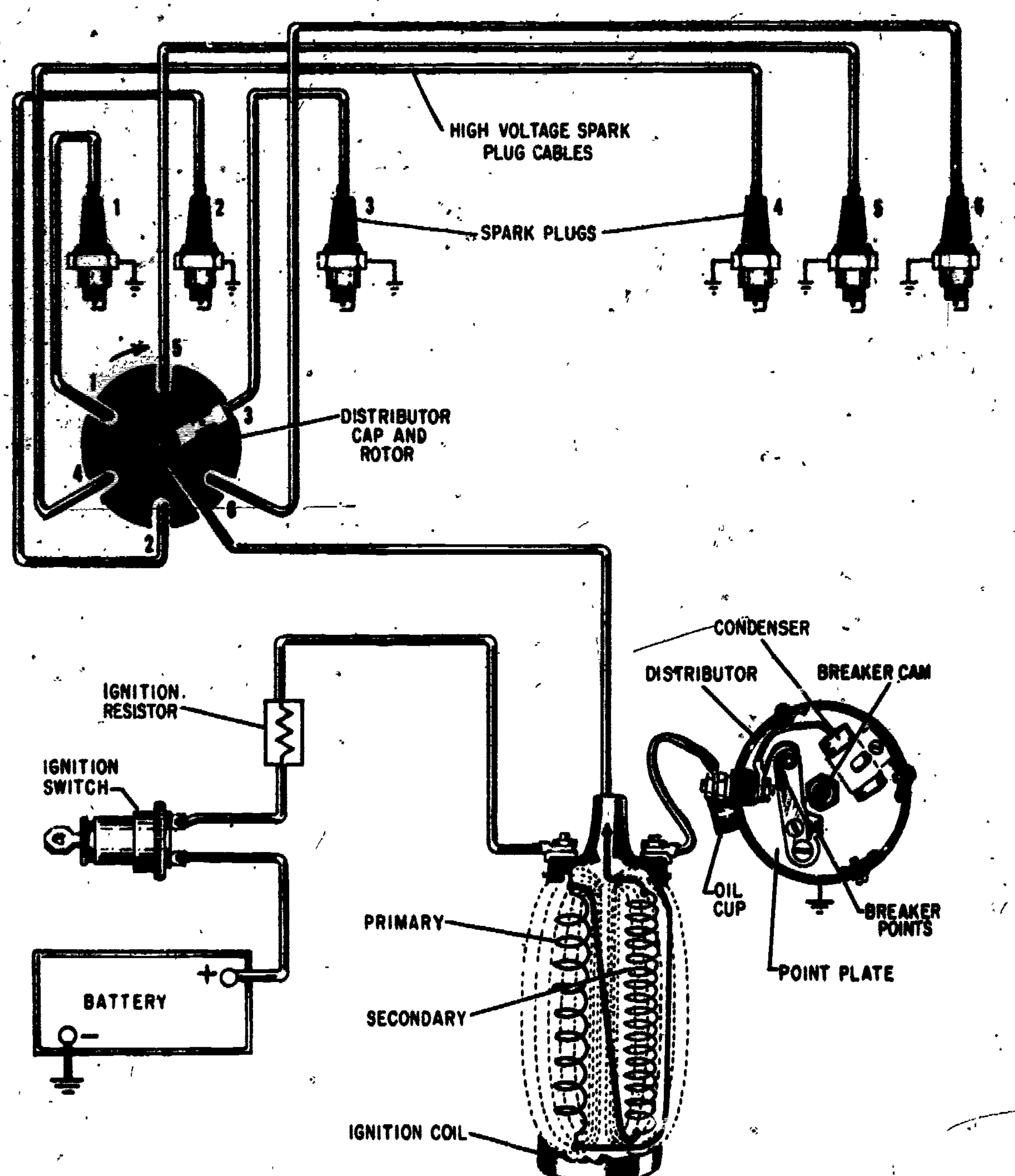

Figure 10-64.—Conventional battery ignition system.

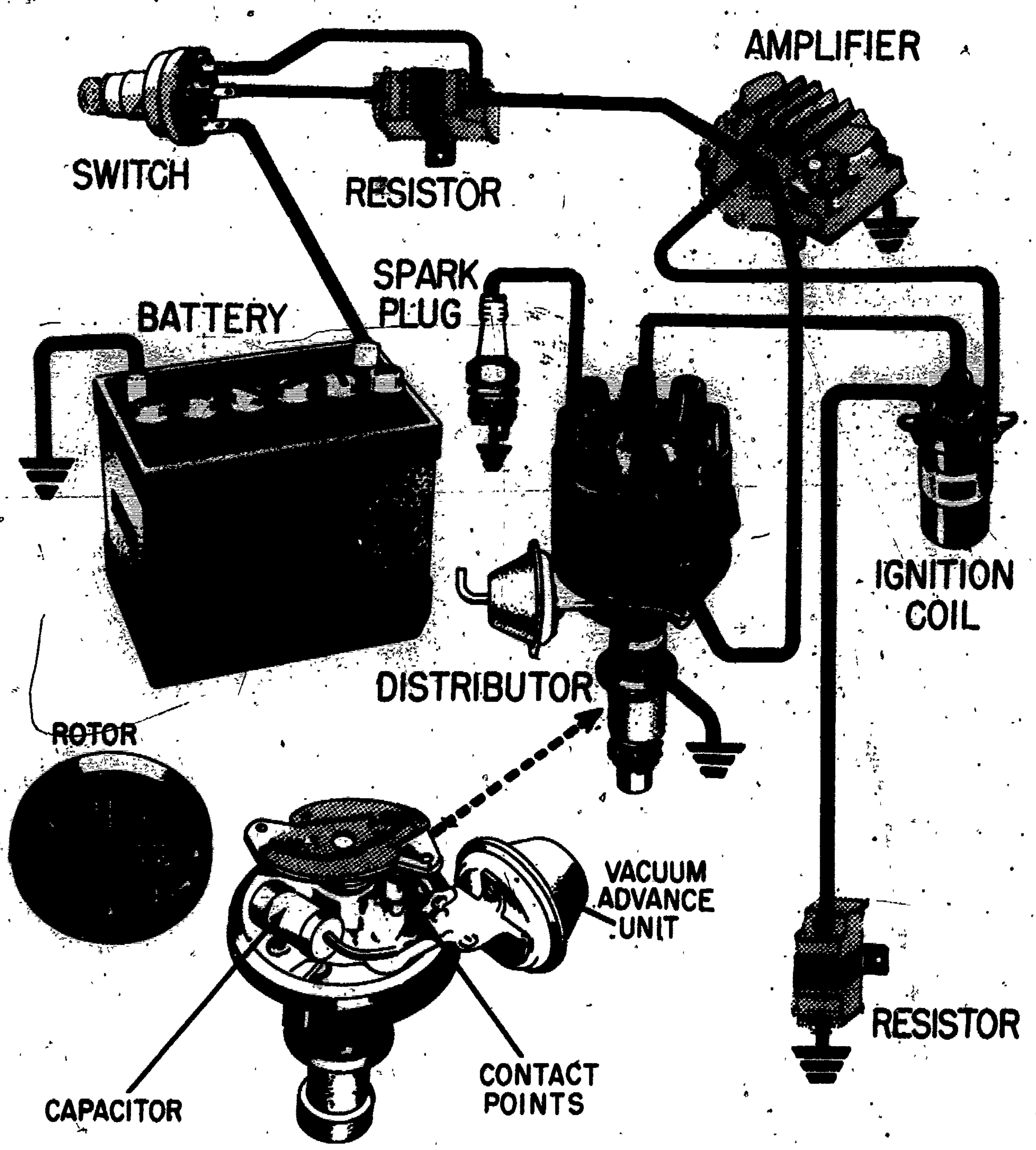

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Figure 10-65.—Contact controlled transistor battery ignition system.

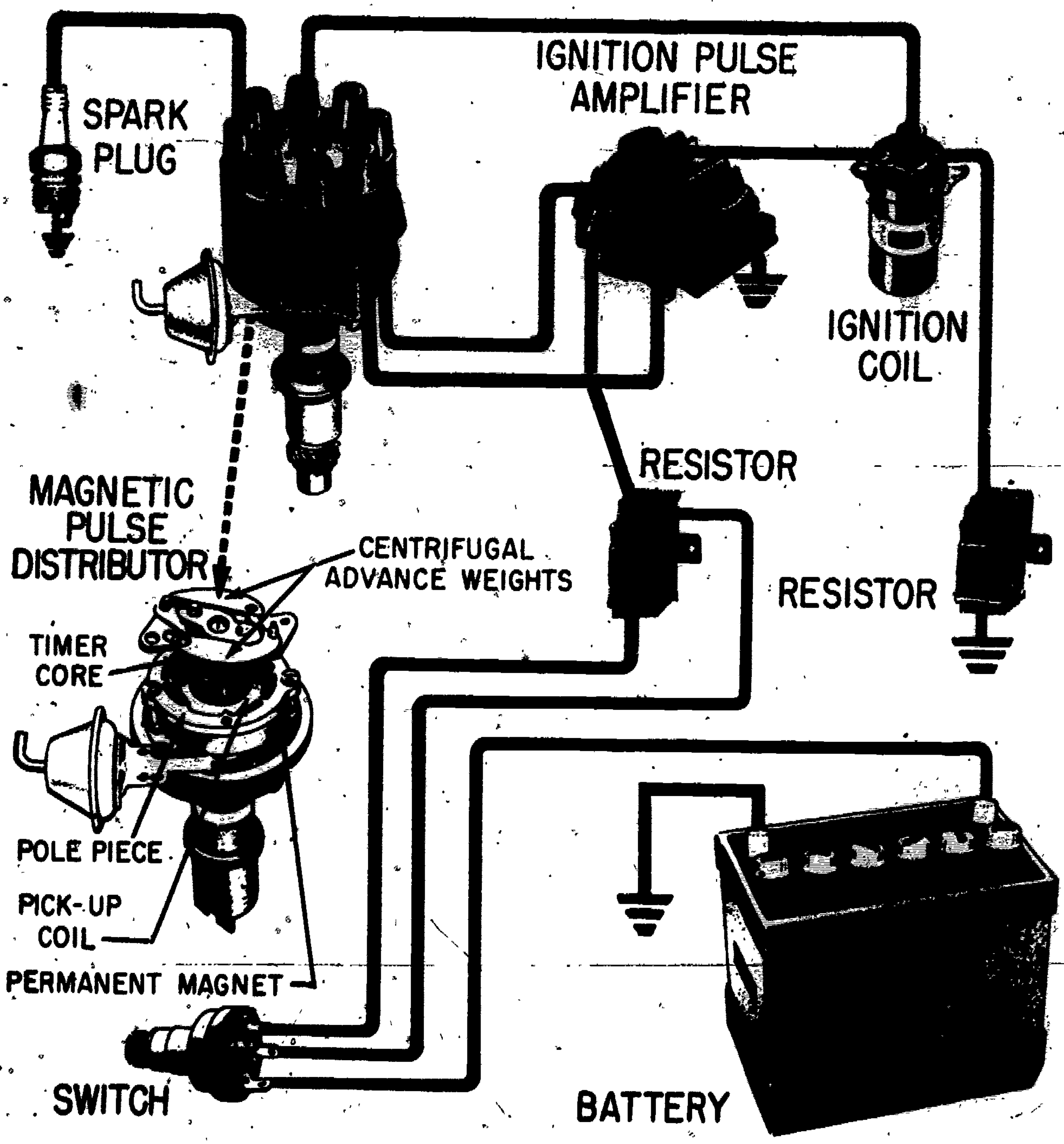

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Figure 10-66.—Transistor controlled magnetic pulse battery ignition system.

solenoid motor terminal. Slide the plunger out and remove the solenoid. Starters are generally equipped with locating dowels to insure correct alinement during reassembly but, to guarantee correct alinement, scribe a line on the pinion housing, field frame, and commutator end frame.

Stand the starter on the pinion housing and remove the through bolts. Remove the commutator end frame and the field frame assembly from the armature. When the field frame is being removed, hold the brushes away from the commutator to prevent them from snapping over the end of the commutator and being chipped. Remove the armature, drive assembly, and shift lever (overrunning clutch type) from the pinion housing. Remove the snap ring or drive head screws and remove the drive assembly from the armature.

Inspect all components for evidence of burning, rubbing, arcing, overheating, broken wires, or escessive wear.

CLEANING.–Clean all parts in an approved solvent except the armature, field coils, and, when used, the overrunning clutch drive unit. A rag, dampened with clean solvent, may be used to wipe off the outside of the armature, field coils, and the overrunning clutch if they are oily. If no oil is present, use a dry, soft brush and low pressure air.

A Bendix drive may be cleaned in solvent. The overrunning clutch drive is factory packed with lubricant and must never be placed in solvent, as the lubricant will be removed and subsequent clutch failure will result.

TESTING FIELD COILS.–Refer to the section of this chapter covering repair of d-c generators.

ARMATURE TEST AND REPAIR.–Refer to the section of this chapter covering repair of d-c generators.

DRIVE ASSEMBLY TEST.–The overrunning clutch pinion should turn freely in the overrunning direction and should not slip in the cranking direction. If the pinion turns roughly in the overrunning direction, it indicates that the rollers are chipped or the rotor is worn, and the drive assembly must be replaced. If the pinion slips in the cranking direction, the drive assembly must be replaced. If the pinion teeth are burred or chipped, the drive assembly must be replaced.

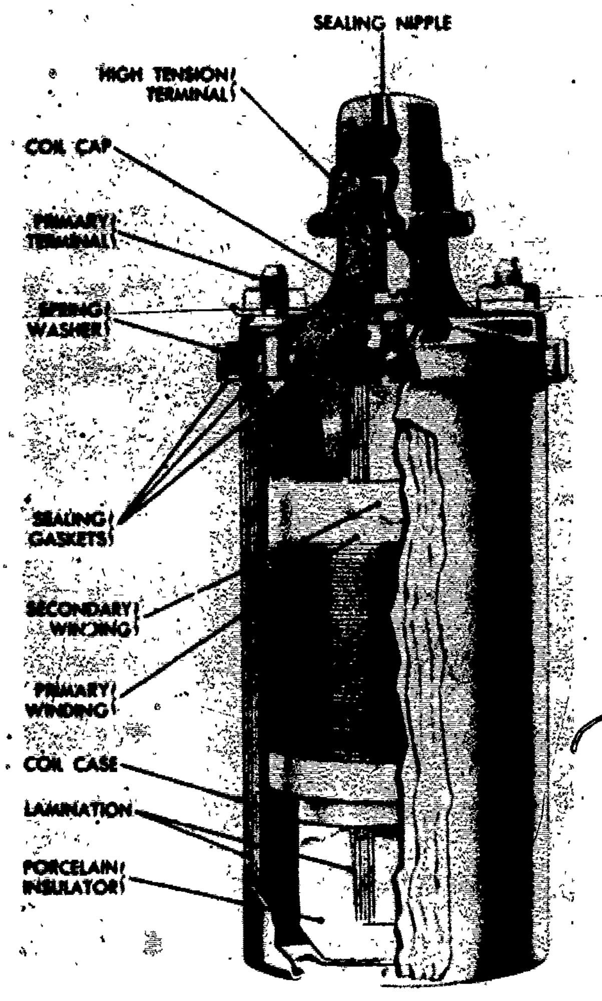

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Figure 10-67.–Cutaway view of an ignition coil.

If the pinion of the Bendix drive does not move freely on the threaded sleeve, or if the teeth are burred or chipped, the drive assembly must be replaced. If the drive spring is distorted or broken, replace the spring.

CHECK BEFORE REASSEMBLY.–If the brushes are chipped, worn to within one-half of their original length, have frayed leads, or are oil soaked, they must be replaced.

Insure that the brushes slide freely in the holders, or if fastened to moveable arms, that the arms move freely and are properly alined.

Inspect the armature shaft bushings and replace them if they are excessively worn.

Check all soldered connections. Check the pinion housing for cracking.

ASSEMBLY.—Assembly of the starter is done in the reverse order of disassembly. Lubricate the bushings with a few drops of light engine oil. Wipe a thin coating of graphite grease on the armature shaft splines of an overrunning clutch type starter. On a Bendix drive type starter, apply a light film of engine oil to the spiral splines of the drive sleeve.

When soldering is required, use rosin core solder only. If any grommets are used, they must be in good condition and installed properly.

PINION CLEARANCE.—Overrunning clutch type starters must have at least the specified clearance between the pinion and the thrust washer, retainer, or pinion housing with the pinion in the cranking position, and this clearance must be checked and corrected, if necessary, after assembly of the starter is completed. With less than the specified clearance, the pinion housing will be broken and major damage done to the starter motor and possibly to the vehicle's engine.

Each manufacturer specifies the clearance for his particular equipment, and reference must be made to the applicable maintenanace manual to obtain the clearance specifications for the starter being tested.

A representative pinion clearance test hookup and test procedure is shown in figure 10-63.

Disconnect the starter motor lead from the solenoid motor terminal and carefully insulate the motor lead. Using a battery of the same voltage as the solenoid, connect one lead to the solenoid switch terminal and the other to the starter or solenoid frame. Connect a jumper wire from the solenoid motor terminal to the starter frame as shown in figure 10-63. This will energize the solenoid and shift the pinion into the cranking position where it will remain as long as the battery is connected.

CAUTION: Do not keep the battery connected longer than a few minutes as overheating of the solenoid may occur.

Push the pinion back toward the commutator end to eliminate any play in the linkage, and then measure the distance between the pinion stop and the pinion.

There are no provisions for adjustment of the pinion clearance on enclosed shift lever type starter motors. Therefore, if the pinion clearance is not within the limits specified by the manufacturer, inspect the shift lever yoke buttons and solenoid linkage for excessive wear.

On the open shift lever type starter motors, adjustment is made by changing the length of the solenoid linkage or by loosening the solenoid mounting bolts and moving the solenoid.

INSTALLATION.—Insure that the mounting flange of the starter and the mounting flange or pad of the engine are spotlessly clean. This is necessary for proper grounding of the starter motor and also for correct mechanical alinement of the drive unit with the ring gear. Install the starter and tighten the bolts to specifications. Connect the wiring, making sure that all connections are clean and tight.

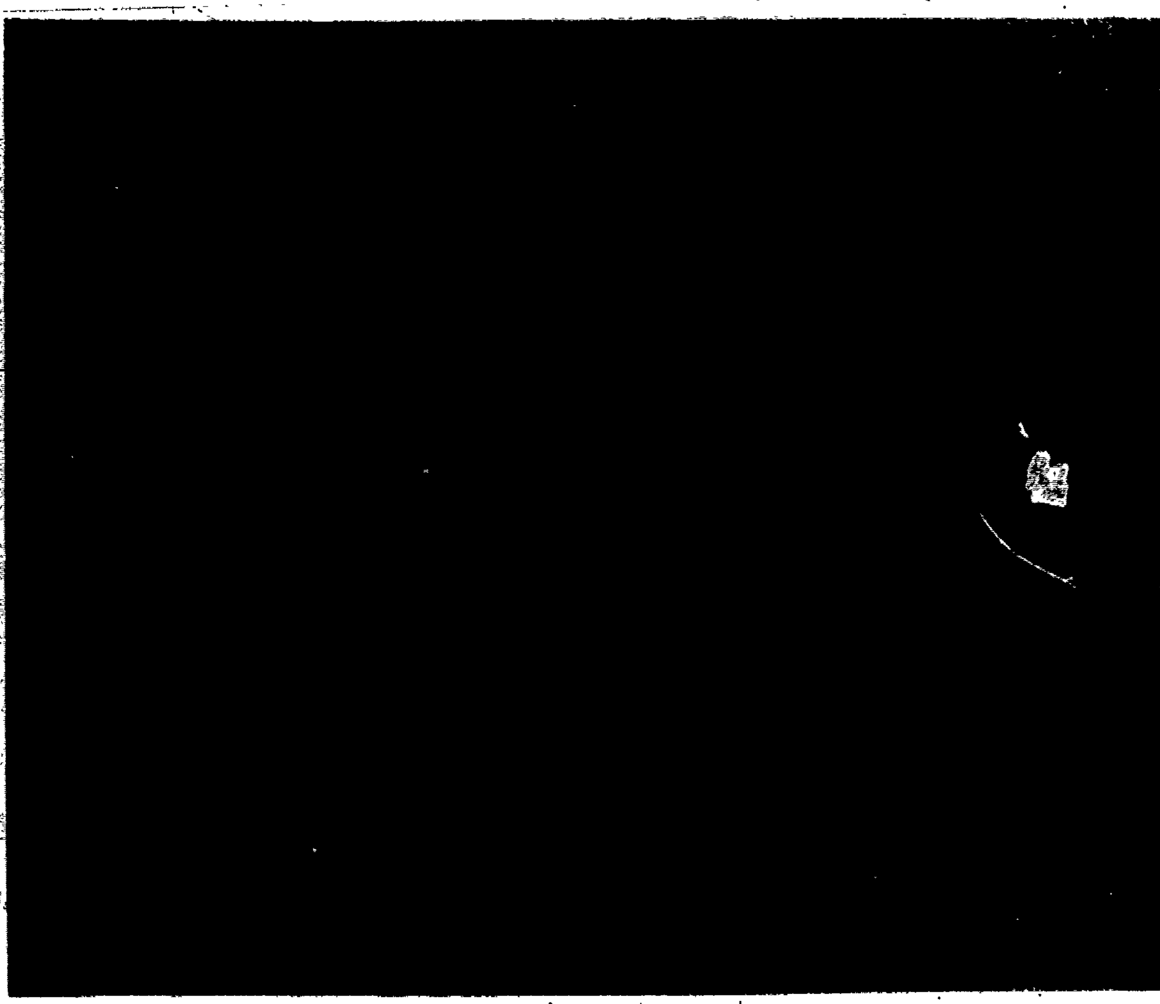
WATERPROOF STARTERS

Some vehicles are equipped with starters that are sealed to prevent entry of water or dust and, while starters of this type are tested and repaired in the same way as any other starter, special sealing compounds are used by the manufacturer to accomplish the waterproofing. Care must be exercised during assembly to insure that these compounds are applied in the specified locations to reseal the starter.

IGNITION SYSTEMS

Ignition of the fuel-air mixture in an engine cylinder may be accomplished by either of two methods—by heat of compression as in diesel engines, or by electric spark as in gasoline engines. This section pertains to ignition by electric spark only.

Spark ignition may be subdivided into two classes—battery and magneto. With either, the fundamental job is to step up low voltage to a much higher value (15,000 to 20,000 volts) and to deliver the high voltage to the spark plugs at the proper time. The high voltage is capable of



AS.316

Figure 10-68.—Side and top views of a distributor.

pushing current from one spark plug electrode to the other through the high resistance set up by the gas pressure in the combustion chamber.

BATTERY SYSTEMS

The voltage of the vehicle battery is not high enough to force a current across the spark plug electrodes. To obtain the high voltage necessary (approximately 20,000 volts), a step-up pulse transformer (ignition coil) is used. The high voltage created is then delivered to the spark plug of the correct cylinder at the right time by the distributor. The high voltage forces a current across the spark plug electrodes, creating a spark, which ignites the air-fuel mixture in the cylinder.

A battery ignition system consists of two circuits, the primary and the secondary, regardless of whether the system is conventional (fig. 10-64), contact controlled, transistor (fig. 10-65), or transistor controlled magnetic pulse (fig. 10-66). Some components of these circuits will be different for each system, but their purpose is the same—to create the high voltage necessary to fire the spark plug and deliver this high voltage to the correct spark plug at the right time.

Conventional System

Figure 10-64 illustrates the two circuits and their components for a conventional system using a 12-volt or a 24-volt battery.

IGNITION RESISTOR.—An ignition resistor, sometimes called a ballast resistor, is used in all conventional ignition systems that operate on 12 or 24 volts. The resistor reduces the voltage and current flow across the breaker points. During low speed operation, primary circuit current flow is high and the temperature of the resistor increases, its resistance increases, and current flow decreases, thus prolonging breaker point life. During high speed operation, primary circuit current flow is low and the temperature of the resistor decreases, its resistance decreases, and current flow increases, thus meeting high speed requirements. During starting, when starter current draw might decrease the voltage available to the coil to a point where starting would be difficult, the resistor is bypassed, allowing full battery voltage to flow to the coil to insure that a strong spark is created at the spark plugs even under adverse conditions.

IGNITION COIL.—The primary winding of the ignition coil consists of a few hundred turns of heavy wire wrapped around a laminated soft-iron core (fig. 10-67). When current is flowing in the primary circuit, a magnetic field is set up about this coil. The secondary winding consists of many thousand turns of very fine wire around the primary coil. The magnetic field from the primary coil surrounds or "links" the turns of wire on the secondary winding (fig. 10-64).

If the flux linking a coil is varied or changed in any way, an electromotive force is induced in the turns of the coil. This is a manifestation of the basic principle upon which both the electric generator and the induction coil work. In an induction coil, such as an ignition coil, a magnetic field is set up by current from the battery flowing through the primary circuit. Unless this current flow is changing to vary the strength of the magnetic field, no voltage is induced in the secondary winding.

Since both the primary and secondary windings of an induction coil are stationary windings, some means other than movement of the windings is used to change the magnetic flux linking the coils. This effect is created by a make-and-break device (breaker points) in the primary circuit. When the breaker points are closed, current flows throught the primary coil, and the magnetic field builds up around it. The magnetic lines of force link the primary and secondary windings and induce voltage in each winding. In the primary winding, the induced voltage opposes the battery voltage. For this reason, the magnetic field is not built up instantly, but requires a fraction of a second to reach full strength. This is called the saturation time.

BREAKER POINTS.—The make-and-break device, which consists of a set of contact points and a spring, is located in the distributor. The purpose of this device is to open the primary circuit, causing the magnetic field to collapse. This collapse induces a high voltage in the secondary winding, and causes a brief but strong flow of current in the secondary circuit. The flow of current in the secondary circuit causes a spark as it flows across the gap of the particular spark plug which is connected into the secondary circuit by means of the distributor.

The collapse of the magnetic field also induces a high voltage in the primary coil.

CAPACITOR.—If the flow of current through the primary circuit due to the collapsing field were allowed to continue, it would cause arcing across the breaker points. To reduce this arcing, a capacitor condenser is wired in parallel with the breaker points and grounded through the distributor housing. The capacitor takes up the current from the induced primary voltage, allowing the magnetic field to collapse very quickly and induce a high secondary voltage. The result is a good hot spark, which is required to ignite the fuel-air charge.

Induced voltages in the primary and secondary windings depend on the number of turns of wire in the two windings. The voltage induced in the secondary winding when the field collapses may be as high as 25,000 volts. The spark is usually created across the plug gap at a lower voltage—approximately 10,000 volts.

DISTRIBUTOR.—Figure 10-68 is a side and top view of distributor unit.

The distributor cap has a center terminal for the high-tension lead from the secondary coil, and separate terminals for leads to the spark plugs. The cap fits over the bowl of the distributor housing that contains the capacitor, rotor, breaker points, and the breaker cam. The breaker cam and the rotor rotate at one-half engine speed on a shaft which is driven from the camshaft. The rotor conducts the high voltage from the secondary to the separate spark plug leads.

The mechanism is timed so that the rotor is adjacent to one of the spark plug leads each time the primary circuit is broken. In figure 10-64 the spark plugs and cylinders are numbered in a standared manner, beginning with number 1 at the front of the engine, back to number 6 (6-cylinder engine) at the rear of the engine. The leads from the distributor cap are arranged so that the rotor will make contact and send high voltage to the spark plugs in the following firing order—1-5-3-6-2-4.

BREAKER CAM.—The breaker cam is six-lobed for a 6-cylinder 4-stroke cycle engine. Therefore, the breaker points will open and close six times with each revolution of the distributor shaft. These contact points close and open the primary circuit, so that six times in each two revolutions of the engine, the magnetic field in the coil will be built up and allowed to collapse. The breaker cam and rotor rotate together, and the rotor is alined with the proper spark plug contact each time a cam lobe opens the primary circuit, collapsing the magnetic field and producing a high voltage in the secondary circuit.

TIMING ADVANCE UNIT.—Timing advance is accomplished in the distributor. A short time is required to ignite and burn the air-fuel mixture and develop power, and this time is practically the same at all engine speeds. At high speeds, the timing must be advanced so that the sparks will occur earlier than at low engine speeds if combustion is to be completed at the most effective time in the operating cycle.

There are two types of automatic timing advance mechanisms, and they may be used separately or together. The centrifugal advance mechanism (fig. 10-68) is operated by a pair of weights that are thrown out against spring tension as the engine speed increases. Movement of the weights advances through a linkage to the breaker cam. This mechanism, usually found in the lower part of the distributor housing, provides a smooth advance and retard of the timing with changes in engine speed.

The vacuum-advance mechanism advances and retards the timing according to engine load, and uses a spring-loaded diaphragm connected by a linkage to the distributor and by a vacuum passage to the carburetor. The opening to the carburetor is on the atmospheric side of the throttle when the throttle is in idling position. There is no advance in this position since the opening is under atmospheric pressure. As the throttle is opened, it swings past the opening of the vacuum passage, exposing the advance mechanism diaphragm to intake manifold vacuum. The diaphragm operates the advance-mechanism linkage and rotates the breaker plate and

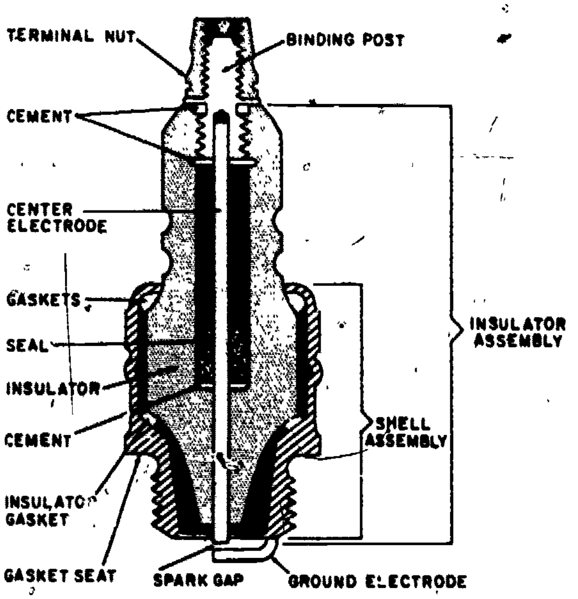


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Figure 10-69.—Cutaway view of a spark plug.

breaker points in the direction of distributor rotation, causing the breaker points to be opened earlier, advancing the time that the spark occurs in the cylinder.

SPARK PLUGS.—Spark plugs are installed in each cylinder of an engine to provide the fixed air gap across which the high voltage from the coil jumps to create the spark that ignites the air-fuel mixture in the cylinder. A cutaway view of a spark plug is shown in figure 10-69.

Transistor Systems

The transistor ignition system is a relatively new development in battery ignition. It is designed to overcome some of the drawbacks of the conventional ignition system.

The output of the conventional ignition is limited to the amount of current in the primary circuit. Approximately 5 amperes of current can be carried in the primary circuit and maintain a reasonable breaker point life. This is because the breaker points will arc and burn if more current is interrupted. Another factor limiting the output is the length of time the breaker points remain closed; and as the engine speed increases, this time becomes increasingly short.

NOTE: Transistors are discussed in Basic Electronics; thus, the ASE should review that manual for a better understanding of transistor ignition systems.

The transistor is a device with the ability to switch large currents through the action of a very small control current. The switching action involves no movi[illegible] and is instantaneous when the cir[illegible]ned properly. In a contact contro[illegible]tem, conventional breaker points turn the transistor emitter-base circuit ON and OFF at the proper time in relation to the engine timing. Because of the low voltage being controlled by the breaker points (1/2 to 3/4 ampere), their life is greatly increased over what it would be in the conventional ignition system.

There are several advantages offered by the transistorized ignition system—extended breaker point life, extended periods between engine tuneups, extended spark plug life, and higher available voltage at the spark plugs.

There are two basic types of transistorized ignition systems. The basic difference between the two is the manner in which the emitter-base circuit within the transistor is controlled. This control can be exercised by either mechanical or electronic means.

CONTACT (BREAKER POINT) CONTROLLED SYSTEM.—A comparison between the conventional ignition system and a representative contact controlled transistor system can be made by observing the two simplified wiring schematics shown in figure 10-70.

In the conventional system, when the ignition switch is closed, current flows through the ignition coil primary winding and the breaker points. The primary current creates, in the coil, a magnetic field which collapses when the distributor breaker points open. This induces a high voltage in the coil secondary winding which is then used to fire the spark plug.

It should be noted in the conventional system that the distributor breaker points carry the full primary current. Since the amount of current that the breaker points can carry is limited, the output that can be obtained from the coil is also limited.

In the contact controlled system, it should be particularly noted that the distributor breaker points carry only the very small emitter-base current of the transistor, and the larger current of the coil primary is carried through the emitter-collector of the transistor. When the distributor breaker points open, the emitter-base current is stopped along with the emitter-collector current, which is the same as the coil primary current. The magnetic field in the coil then collapses, and the high voltage in the coil secondary needed to fire the plug is produced.

The resistor connected to the coil primary winding establishes the proper amount of primary current. The use of a capacitor in the distributor is optional.

A contact controlled transistor ignition system is shown in figure 10-65. The system shown illustrates the ignition switch type of resistor bypass which functions during cranking. On other systems, the resistor bypass lead may be connected to a terminal on the starter motor solenoid or to a separate relay.

TRANSISTOR CONTROLLED MAGNETIC PULSE SYSTEM.—A simplified wiring schematic for a transistor controlled magnetic pulse ignition system is shown in figure 10-71.

Many of the components comprising this system are essentially the same as those used in both the conventional and contact controlled systems. Note, however, that in this type of ignition system, no contact points are used. The ignition coil, which is similar in appearance to the conventional ignition coil, in reality is quite different electrically. The ignition coil for the transistor controlled magnetic pulse type ignition system has a different number of turns of wire in both its primary and secondary windings as compared with a conventional system, and the two types of coils are not interchangeable.

The magnetic pulse distributor is similar in external appearance to the conventional distributor and has some internal features that are the same. The centrifugal advance and vacuum advance mechanisms are the same in both units. However, the breaker cam, contact points, and condenser used in the conventional distributor are not used in the magnetic pulse distributor. In their place are a permanent magnet, a timer core, and a pickup coil. These units, which can be likened to the breaker cam, produce an alternating voltage when the distributor is in operation. This voltage is transferred to the electrical control section of the ignition pulse amplifier.

The ignition pulse amplifier functions as a set of contact points to interrupt the current in the primary circuit. The voltage developed by the distributor is increased by the pulse amplifier and then applied to the base of a transistor located in the control section. The control

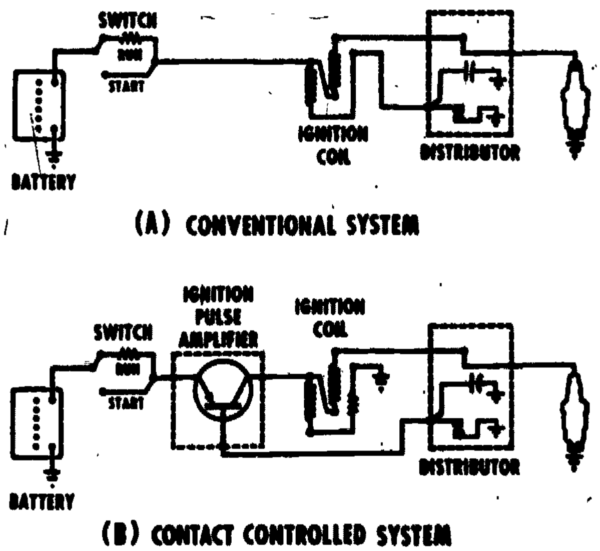

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Figure 10-70.—Comparison of conventional and contact controlled transistor ignition systems.

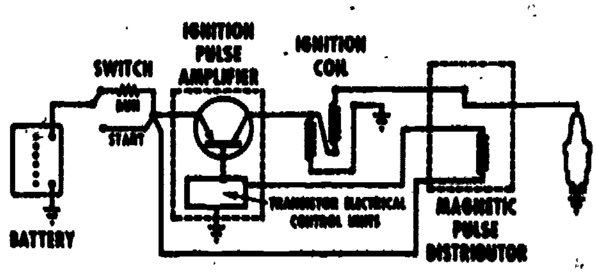

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Figure 10-71.—Transistor controlled magnetic pulse ignition system.

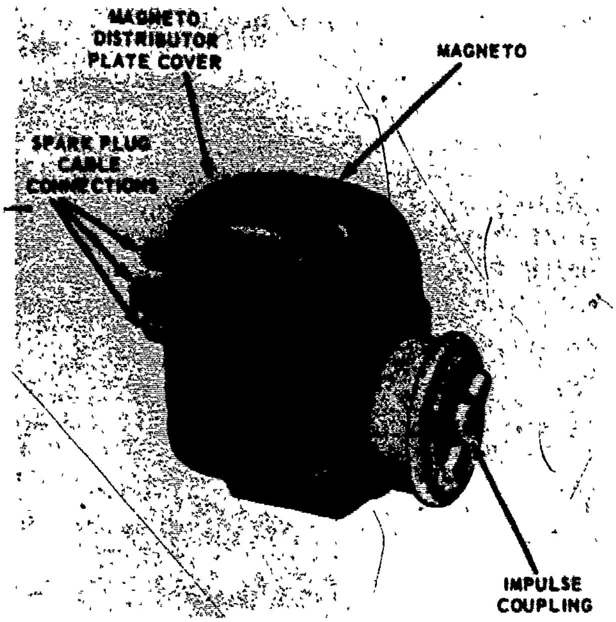

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Figure 10-72.—Magneto assembly.

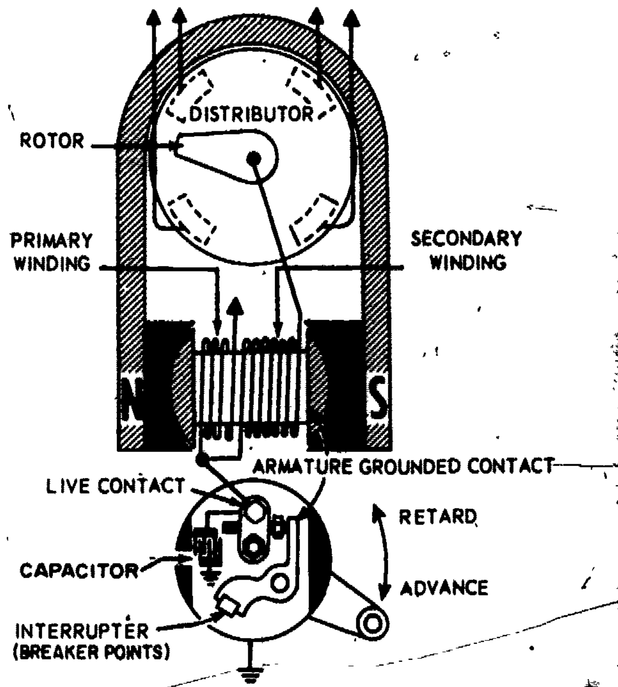

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Figure 10-73.—High-tension magneto circuits.

transistor acts as a switch and is controlled by the voltage applied to its base circuit. Other electrical control devices for the transistor are also located in the control unit.

For ease of understanding, the system's basic operation will be discussed. Assuming that the ignition switch is in the run position, current flows through the emitter-collector of the transistor and the primary winding of the ignition coil. Current flow in the primary winding builds up a magnetic field about both the primary and secondary windings just as it did in the conventional system.

When the magnetic pulse distributor generates a voltage in its winding, this voltage is carried to the electrical control portion of the ignition pulse amplifier. This voltage is amplified and used to increase the voltage on the base of the transistor to a value higher than that on the emitter, and the current flow through the ignition coil primary winding stops.

With no current flow in the primary ignition winding, the magnetic field within the coil collapses about the windings. The high voltage induced in the secondary winding is then impressed upon the secondary circuit to fire the spark plug. When the voltage reaches a sufficient value to jump the gap between the electrodes at the plug, a spark is created which ignites the air-fuel mixture in the cylinder of the engine.

The transistor, therefore, acts as the trigger to interrupt the primary circuit in order that secondary voltage can be produced. Since the transistor is capable of carrying more current than the contact points, more secondary output voltage is available at all engine speeds.

A transistor controlled magnetic pulse type ignition system is shown in figure 10-66.

MAGNETO SYSTEMS

The magneto (fig. 10-72) used for ignition is a self-contained unit. With the exception of the spark plugs and the wires leading to them, the magneto includes or substitutes for all the units usually found in the conventional battery ignition system. The magnéto provides electricity for ignition only. If the equipment requires lights and other electrically operated accessories, a battery and generator must be provided for this purpose. A number of methods are used for starting magneto equipped engines, such as handcrank, footcrank, pullrope, electric starter, etc.

Figure 10-73 shows a horseshoe magnet and the pole pieces that produce a magnetic field. The primary and secondary windings are wound on an armature which rotates within the magnetic field. As the armature revolves, an alternating current of low voltage is generated in the turns of the wire. When this current reaches its highest value, the breaker points open, and high-tension current is routed to the magneto distributor and

on an armature which rotates within the magnetic field. As the armature revolves, an alternating current of low voltage is generated in the turns of the wire. When this current reaches its highest value, the breaker points open, and high-tension current is induced in the secondary winding, as in the battery ignition system. The high tension current is routed to the magneto distributor and to the spark plugs in the proper firing order.

The magneto, a simple form of electric generator, produces its own current, thus eliminating the need of a battery in the ignition system.

Types of Magnetos

There are several types of automotive magnetos that differ in magnetic circuits and in the

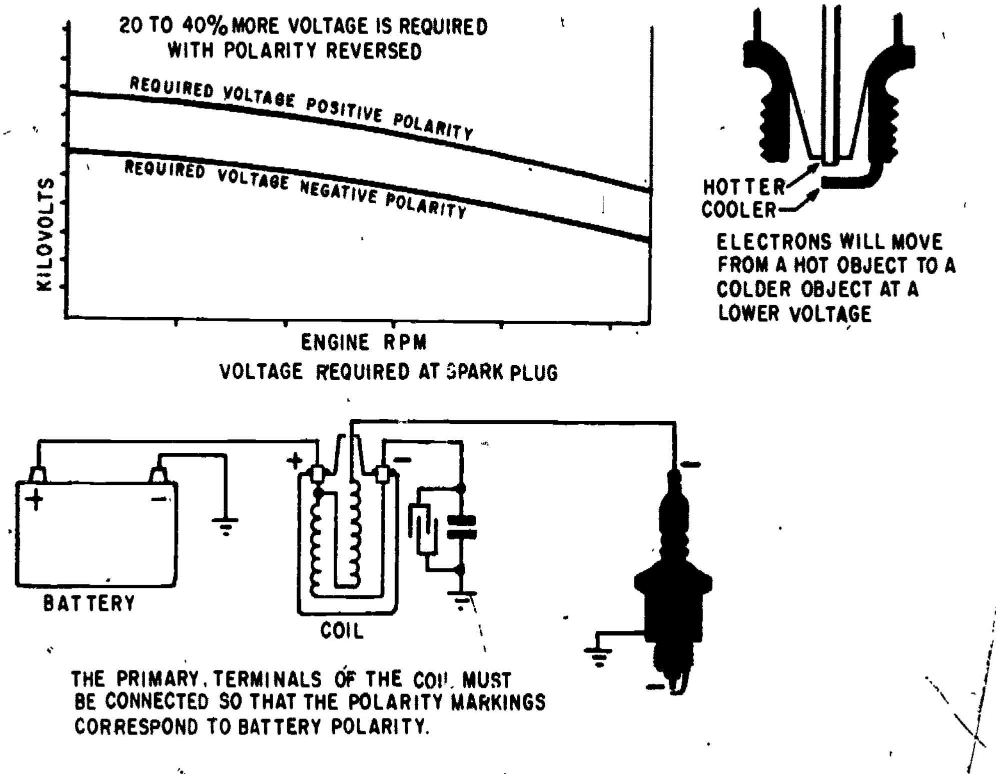

Figure 10-74.—Correct coil polarity and voltage flow for a negative grounded system.

way in which the low-tension current is induced. The rotating armature type magneto, just described, is the oldest and the one commonly used for automotive equipment. It generates low-tension current on the principle of rotating windings and a stationary field. In the induction type of magneto, the windings are stationary and the magnets rotate.

Coming-In Speed

The magneto must be turned at higher than a minimum speed to generate a primary current with enough strength to start the engine and keep it running. This speed differs with various types of magnetos, but the average is about 100 rpm, and is called the coming-in speed of the magneto.

In starting the engine, it is difficult to rotate the crankshaft fast enough to produce the coming-in speed of the magneto. An impulse coupling is used to obtain an initial starting current from the magneto.

Impulse Coupling

The impulse coupling is mounted between the magneto drive from the engine and the magneto-driven shaft. It consists of a spring and ratchet drive. When the engine is turned over by the handcrank, the spring in the device is wound up against a ratchet or trigger arrangement. As the piston reaches firing position, the trigger releases automatically. The spring, which is connected to the magneto-drive shaft, flips it with enough speed to produce current for one firing. The operation continues until the engine fires and starts to run. As the engine speed increases, the impulse coupling locks out and the magneto is driven normally.

MAINTENANCE

Many components of the conventional, the transistor, and the magneto systems previously discussed are inspected and tested in the same manner. However, some components of all type systems require special test equipment which is discussed in chapter 9 of this manual. To obtain specifications and information regarding the type of test equipment required and procedures for its use, reference must be made to the applicable maintenance manual for the equipment at hand.

Troubleshooting

Before making any test, conduct a thorough visual inspection of the ignition system.

BATTERY.—Check terminal posts and cables. Connections must be clean, tight, and free of corrosion.

PRIMARY WIRING.—Check for obvious damage such as broken wires, loose wires, frayed insulation, etc. All connections must be clean and tight.

IGNITION COIL.—Pull the high voltage lead out of the coil tower. Check the tower for signs of corrosion or burning. If it is corroded, clean with a round brush or sandpaper wound around a pencil. Examine the tower carefully for any sign of flashover (high voltage current leaving the intended path and jumping down, or around, directly to ground). Flashover can be caused by moisture or dirt on the coil exterior, a corroded tower interior, or by failing to have the high voltage lead pushed fully into the tower. If flashover has cracked the tower or left a burned path (carbon track), replace the coil.

Check for correct coil polarity—the coil must be connected into the primary circuit so that the positive and negative markings of the coil correspond to the battery connections. For example, in a negative grounded system, the negative terminal of the coil must be connected to the distributor where it is grounded through the breaker points. By connecting the coil in this manner, the center electrode of the spark plug assumes a negative polarity.

It takes less voltage to cause electrons to move from a hot to a cold surface, and since the center electrode of the plug is always hotter than the side (ground) electrode, current flow must be from the hot center electrode to the cooler side electrode. By giving the center electrode a negative polarity, current will flow in this manner, as shown in figure 10-74.

If the coil is connected so that polarity is reversed (spark plug center electrode positive), up to 40 per cent more voltage is required to fire the plugs. This could result in hard starting, missing, and eventual coil failure. Testing for correct coil polarity with the engine running is covered later in this chapter.

DISTRIBUTOR CAP.–Remove each spark plug lead (one at a time) from the cap. Check for corrosion, signs of burning, or flashover. Corrosion can be removed as previously described for ignition coils. If any sign of flashover is present, replace the cap. When the leads are replaced, insure that they are clean and are fully seated in the towers.

Remove the cap from the distributor and turn it upside down. If signs of burning, cracking, or flashover are present at the center contact or the spark plug terminal posts, the cap must be replaced. Check the spark plug terminal posts and the rotor tip for excessive scoring or burning. Mild scaling, caused by the high voltage jumping from the rotor to the terminal posts, can be removed by lightly scraping the terminal posts.

BREAKER POINTS.–With the ignition switch off, separate the points and check their condition; a dull, slate gray color is normal. If they have metal transfer (pitting) or are burned, they must be replaced. Breaker points must not be filed to correct pitting.

BREAKER CAM.–If the surface of the cam is rough or pitted, or the cam lobes show excessive wear, the cam must be replaced.

SECONDARY WIRING.–If the spark plug leads are oily or dirty, they must be cleaned. If signs of cracking, swelling, burning, or other damage are present, the leads must be replaced.

After making the visual inspection and correcting any defects that were noted, if the engine is still hard to start or will not start at all, the following tests can be made to locate the defects.

System Tests

Remove the secondary coil lead from the distributor cap and hold it approximately 3/16-inch from ground while cranking the engine, and observe the spark. A bright blue spark indicates proper operation of the primary circuit and the secondary winding of the ignition coil.

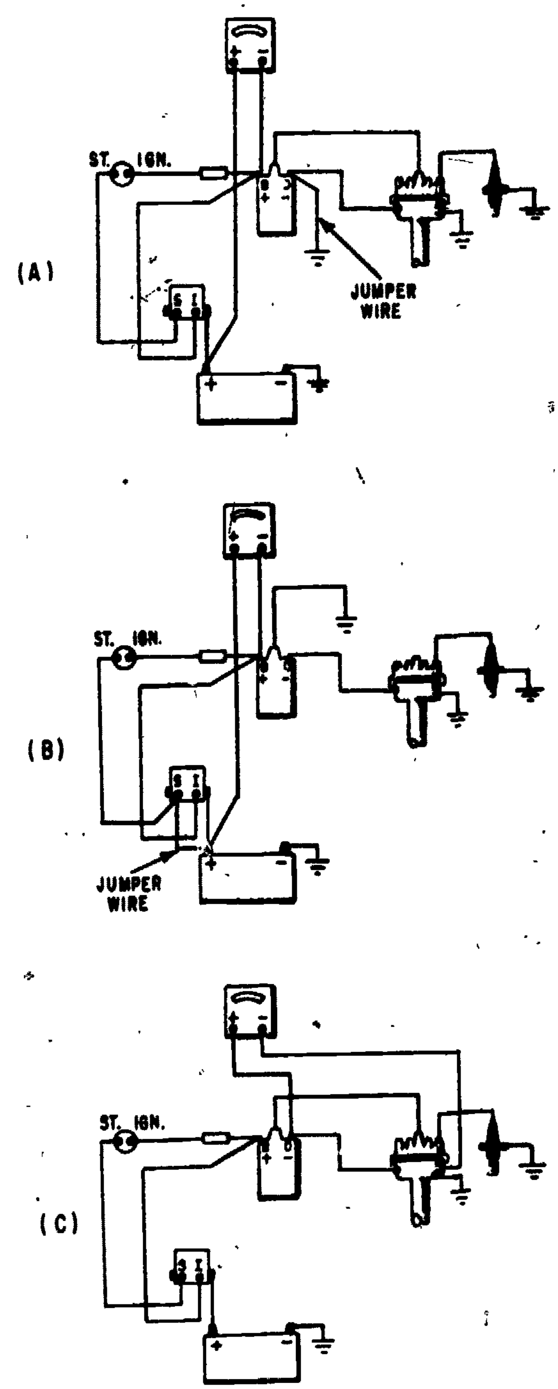

Figure 10-75.–Voltmeter connections for resistance tests of the primary circuit.

Troubleshooting can be limited to the distributor cap, rotor, spark plug leads, and spark plugs. A yellow spark indicates that the malfunction is in the primary circuit or the secondary winding of the ignition coil.

PRIMARY CIRCUIT TESTS.—Three basic voltmeter tests can be made to isolate high resistance areas or components in the primary circuit.

NOTE: The voltage readings and test connections used here are for a representative 12-volt, negative ground system. Always use the test specifications given by the manufacturer for any specific system.

Test 1. Battery to Coil Test.—Connect the voltmeter as shown in figure 10-75 (A). Connect a jumper wire from the distributor connection of the coil to ground.

With the ignition switch on and the points closed, voltage drop should not exceed 6.9 volts. If the drop exceeds 6.9 volts, a high resistance exists in the resistor, ignition switch, or the wiring between the battery and the coil. A drop of less than 4.5 volts indicates a shorted resistor.

Test 2. Starting Ignition Circuit Test.—Connect the voltmeter as shown in figure 10-75 (B). Remove the secondary coil wire from the distributor cap and ground the wire.

With the ignition switch off, crank the engine by placing a jumper wire from the battery positive post to the S terminal of the starter solenoid or relay. The voltage drop should not exceed 0.1 volt. If the drop exceeds 0.1 volt, a high resistance exists in the starter solenoid or relay contacts or in the wiring between the starter solenoid or relay and the coil.

Test 3. Coil to Ground Test.—Connect the voltmeter as shown in figure 10-75 (C).

With the ignition switch on and the points closed, the voltage drop should not exceed 0.1 volt. If the drop exceeds 0.1 volt, a high resistance exists either in the coil to distributor wire, the engine to frame ground strap, the distributor to engine mounting, the breaker plate to distributor housing mounting, or in the breaker points.

When the malfunction has been isolated to one area, continue with testing of that area, using the procedures discussed in chapter 9 of this manual to locate the defect.

If, after these tests have been made, the malfunction has not been located, remove the coil, resistor, and condenser and test separately using the appropriate test equipment discussed in chapter 9 of this manual.

SECONDARY CIRCUIT TESTS.—If preliminary testing indicates that the malfunction is in the secondary circuit, the defect can be located by making these tests:

Test 1.—Use a megger (discussed in chapter 9) and, following the instructions provided with it, test the distributor cap, rotor, and spark plug leads for insulation breakdown, cracks, or opens.

Test 2.—Remove and thoroughly examine the spark plugs. Figure 10-76 illustrates some types of fouling and damage that may be encountered.

A plug that exhibits any of the conditions shown in figure 10-76 except F,G, and H, may be reconditioned and reused. Reconditioning is covered later in this chapter. A plug exhibiting any of the conditions in F, G, or H, must be replaced, and the cause for the damage must be corrected.

Repair and Adjustment

The repairs and adjustments that are required on a battery ignition system are comparatively simple to perform, but in order to achieve good equipment performance and economic operation, care must be exercised and correct procedures followed.

DISTRIBUTOR.—Replacement of the breaker points can be accomplished with the distributor installed, but, generally, it is better to remove the distributor from the engine. This not only makes access to the breaker points easier, it also enables the ASE to inspect and, if necessary, repair other components of the distributor.

With the distributor cap removed, scribe a line across the junction of the distributor housing and the engine block, and one on the distributor housing in line with the center of the rotor contact strip. Disconnect the primary lead and, if used, the vacuum advance vacuum line. Remove the distributor holddown bolt and clamp and remove the distributor from the engine.

Clamp the distributor in a soft jawed vise, taking care not to damage the drive gear or housing.

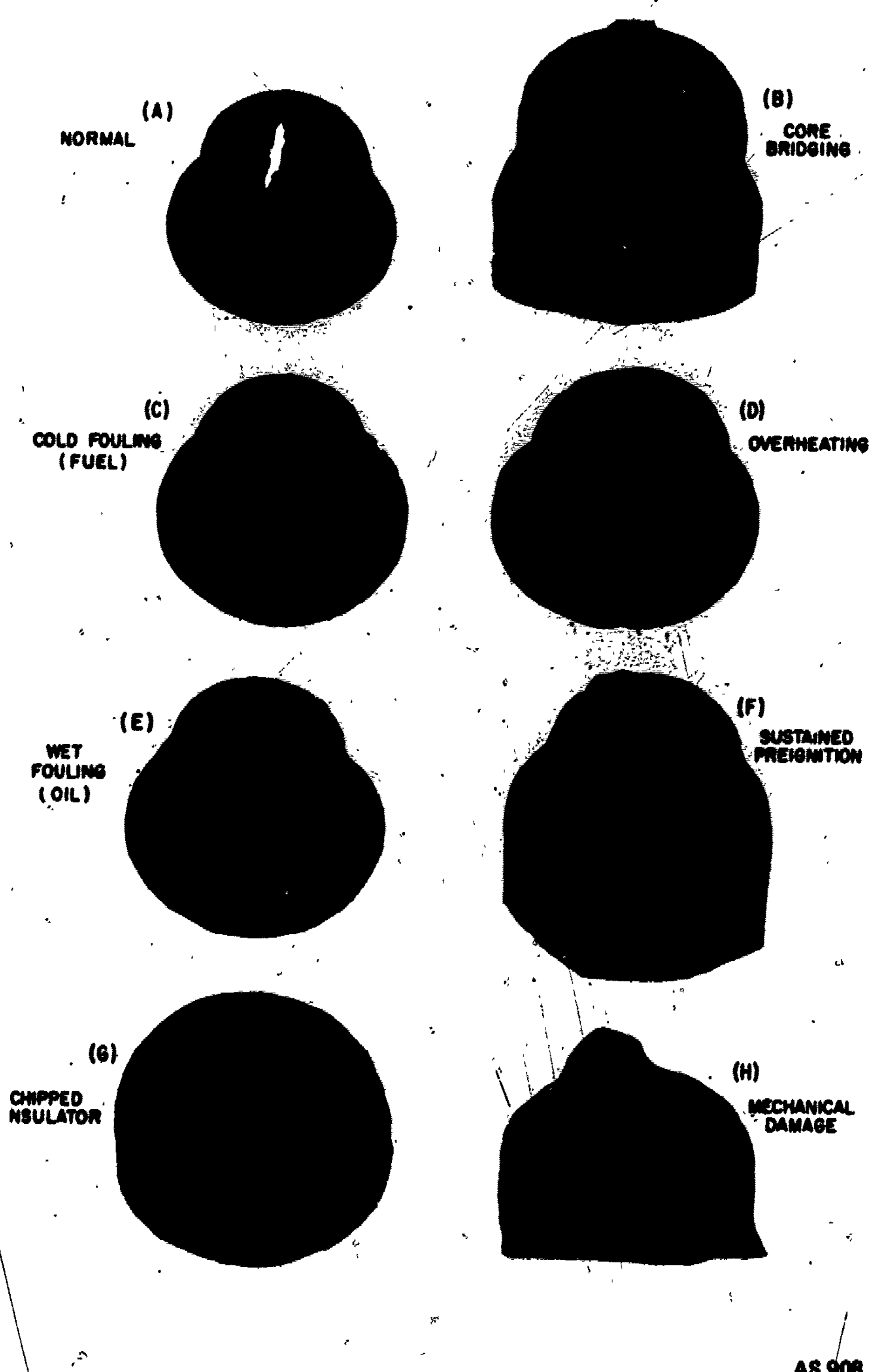

Figure 10-76.—Examples of spark plug appearances.

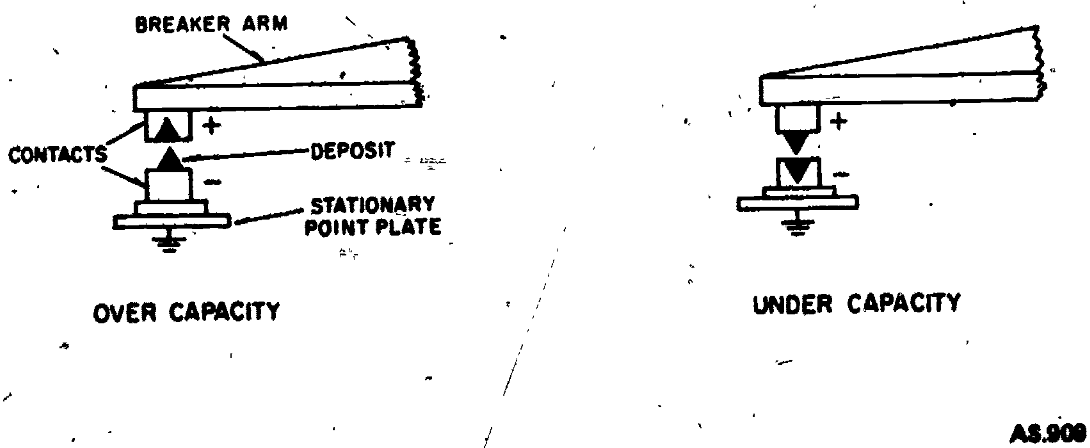

Figure 10-77.—Effects of incorrect condenser capacity.

Before attempting to remove the breaker points, with the distributor on or off the engine, stuff small rags in any hole or opening in the breaker plate through which small screws or nuts might fall, and note the location and position of the primary lead-in and condenser wires before disconnecting them.

Remove the used points, thoroughly clean the mounting area and the breaker cam, and install the replacement points.

Replacement of the condenser is generally accomplished at the same time the points are replaced. However, if the condenser is to be reused, it should be tested for capacity, resistance, and leakage, using a condenser tester of the type discussed in chapter 9 of this manual. If a new condenser is used, it should also be tested and the results compared to the manufacturer's specifications for the equipment at hand.

As shown in figure 10-77, a condenser of incorrect capacity will cause heavy arcing across the points, and metal transfer from one contact to the other.

With the points and the condenser installed, rotate the breaker cam until the points are closed, and check the alinement of the contacts. If both contacts are flat, the entire surface should contact at the same time. If both contacts are convex, or if one is flat and the other convex, contact should be in the center. If alinement is incorrect, bend the stationary contact bracket to provide correct alinement. Never attempt to aline the points by bending the movable arm.

Point gap (amount of opening between the contacts when the points are fully opened by the breaker cam) is critical and must be closely set. If the gap is too small, the points arc and burn; if the gap is excessive, saturation time for the coil is reduced and high speed missing occurs.

The gap for new points may be set initially with a feeler gage. This is done by turning the breaker cam until the point rubbing block is on the highest point of a cam lobe, and moving the stationary point plate until a feeler gage of the correct thickness (refer to manufacturer's specifications) is a snug fit between the contacts.

As shown in figure 10-78, used points cannot be gapped accurately with a feeler gage because the gage measures between the high spots while the actual point opening is much greater. Note that a .015 feeler gage is a snug fit, but the actual gap is .022. The correct method of obtaining the necessary accuracy for setting used points is to use a dwell meter.

Dwell, often called cam-angle, refers to the distance, in degrees of breaker cam rotation, that the breaker cam revolves from the time the points close until they are opened again (fig. 10-79). The dwell for any given set of breaker points is controlled by the point gap, so the two must be considered together.

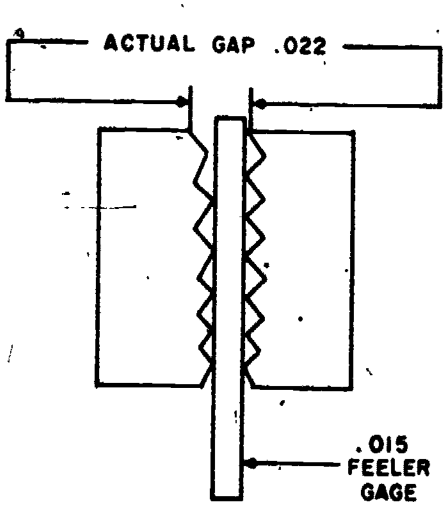

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Figure 10-78.—False setting given by feeler gage for used points.

As can be seen by referring to figure 10-79, if point gap is decreased, dwell increases; if point gap is increased, dwell decreases. Thus, point gap and dwell are indirectly proportional.

The use of a dwell meter to check and set points is covered later in this chapter.

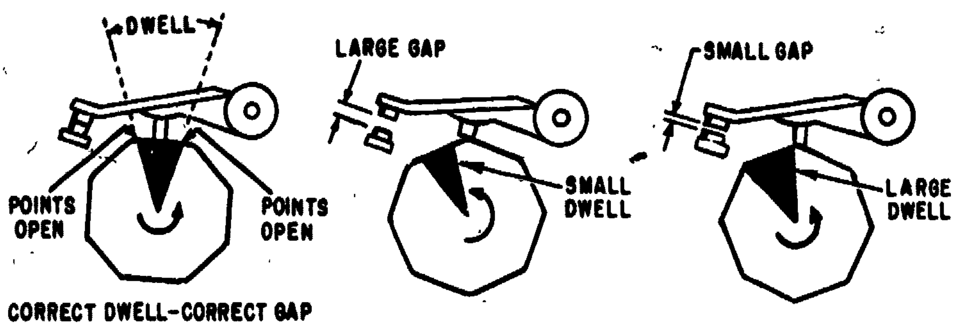
Once the point gap has been set, the breaker arm spring tension should be checked using an accurate ounce scale. If the pressure is excessive, rapid wearing of the rubbing block will cause the point gap to narrow, retarding the engine timing and increasing the dwell. Too low a pressure will cause the points to bounce, creating a high speed miss.

With the rubbing block positioned on the low point between cam lobes, hook the scale at the contact point edge. Pull at right angles to the movable arm and check the pressure just as the points separate, and compare to the manufacturer's specifications. If the pressure is incorrect, refer to the applicable maintenance manual for adjustment procedures. Insure that all wires are correctly connected and clear of all moving parts. Remove rags that were used to plug openings.

Apply a thin coat of high temperature grease to the breaker cam. Do not use engine oil or low temperature grease as it will be thrown off and onto the points. On distributors equipped with a felt wick type oiler under a lift-off type rotor, moisten with engine oil—3 to 5 drops. Lubricate the point pivot pin and bushing, the centrifugal advance mechanism, and, if required, the breaker plate bearing surfaces very lightly with engine oil. If an outside oiler is provided, apply 5 to 7 drops of engine oil.

CAUTION: Lubricate distributer parts sparingly to avoid getting it on the points because lubricant causes rapid burning of the points.

If a distributor test machine (discussed in chapter 9 of this manual) is available, it should be used to check the distributor for dwell, vacuum and centrifugal advance, point bounce,



AS.911
Figure 10-79.—Relationship of dwell and point gap.

bent shaft, worn bushings, worn breaker cam, etc.

If the distributor was marked before removal as previously indicated and the engine has not been cranked since the distributor was removed, installation is simple. Aline the rotor with the scribe mark on the distributor housing, aline the scribe marks on the housing and engine block, and insert the distributor. As the distributor drive gear meshes with the camshaft gear, the rotor will turn a small amount. Pull the distributor up far enough to disengage the gear and turn the rotor back far enough to compensate for the turning and push down again. When the housing is flush against the block, the scribe lines should be lined up. If they are, install the holddown bolt and clamp, and lock the distributor in place.

If the distributor will not bottom, do not attempt to force it down. The distributor shaft is not alined with the oil pump shaft slot or tang. Hold firm pressure on the distributor and crank the engine—when the shafts line up, the distributor will drop into place.

If the engine was cranked while the distributor was out, remove the number one spark plug and crank the engine until compression can be felt, and continue to turn the engine until the timing marks (located on the crankshaft vibration dampener or flywheel) are lined up with the stationary pointer. The engine is now ready to fire the number one cylinder. Aline the housing-to-block scribe marks and turn the rotor to aline with the number one spark plug tower on the distributor cap—points just starting to open. Insert the distributor and, as previously described, pull up and adjust for rotor movement as the gears mesh. When the installation is correct, the distributor will be fully bottomed, points just opening, and the rotor pointing to the number one spark plug tower on the distributor cap. This initial timing setting will suffice for starting the engine.

To time the engine to manufacturer's specifications, clean all the grease and dirt from the timing mark and reference pointer. Draw a chalk line over the timing mark to make it more visible. Connect the timing light to the high-tension lead of the No. 1 spark plug and the power leads to the power supply. Connect a tachometer, if available, to the primary circuit of the distributor. Warm the engine to normal operating temperature and adjust the idle speed. Aim the timing light flashes at the timing mark and reference pointer. If the timing mark and pointer do not line up, loosen the distributor and turn it in its mounting until the timing mark does aline with the pointer, then secure the distributor. Also check to see if the automatic advance mechanism is working. This is accomplished by keeping the timing light aimed at the timing mark and gradually increasing the engine speed. If the advance mechanism is working, the timing mark should gradually move away from the pointer. If the timing mark fails to move as the engine speed is increased, or if it hesitates and then suddenly jumps, the advance mechanism is not functioning properly and must be repaired.

A quick simple check for correct coil polarity can be made using an ordinary wooden pencil, as shown in figure 10-80.

Place a piece of rubber hose over the pencil to prevent the possibility of electrical shock. Remove any one of the spark plug wires; place the lead of the pencil between the spark plug wire and the plug. Start the engine and observe the spark—if it flares or has a yellow tinge on the wire side, polarity is reversed; if it flares or has a yellow tinge on the plug side, polarity is correct.

Point gap or dwell must be set before attempting to time the engine, as changing the gap will change the timing.

If used points are to be reused, or the gap setting is to be checked with the distributor installed, connect a dwell meter (following instrument manufacturer's instructions) and, with the engine idling, check the dwell. Compare the dwell reading with the manufacturer's specifications and, if incorrect, the point gap must be adjusted.

Remove the secondary coil lead from the distributor cap and ground it. Remove the distributor cap and rotor. With the dwell meter connected as before, crank the engine and adjust the points as necessary (while cranking) to obtain the correct dwell. Replace the rotor and distributor cap and reconnect the coil secondary lead. Start the engine and check the dwell—it should not have changed more than 3 degrees. If a greater change is noted, the distributor has worn bearings or a worn cam and should be removed for repair.

SPARK PLUGS.–When plugs receive periodic cleaning and gapping, they will function better and last longer.

Spark plug wires should be carefully removed by grasping them close to their terminals for the pull. Do not "jerk" them from the spark plug terminal. Loosen each plug one or two turns, then use low-pressure compressed air to blow out any dirt around the spark plug hole. This will prevent foreign matter from entering the cylinder

Remove the plugs, being sure that the gaskets (where used) are also removed. As the plugs are removed, keep them in order so that any peculiar condition of any plug can be related to a specific cylinder.

The plugs shown in figure 10-76 are some examples of plug conditions that may be encountered. The cause for each is discussed below.

(A) is from a mechanically sound engine, running at the correct temperature. Some deposits, light tan or gray in color, are present; but there is no evidence of burning. Some gap growth will have occurred, but not in excessive amounts.

(B) is from an engine having excessive combustion chamber deposits that shed off when normal combustion temperature was restored by the installation of new plugs. This is most prevalent in engines operated at slow speeds and in start-stop driving.

(C) is from a cold running engine. The deposits are unburned fuel.

(D) is from an engine that was running too hot due to over-advanced timing, or to cooling system blockage.

(E) is from an engine using excessive amounts of oil. The plug is drowned in oil that was bypassed through the rings or valve guides.

(F) is from an engine that had severe preignition (fuel charge being ignited by an overheated plug, piece of glowing carbon, hot valve edge, etc., before the spark plug fires), and the damage shown resulted from temperatures in the combustion chamber in excess of 2,700° F. The accompanying excessive combustion chamber pressures probably damaged other components of the engine also.

(G) is from an engine that was running normally. The damage was caused by the mechanic attempting to bend the center electrode.

(H) is from an engine which had some foreign object in the combustion chamber.

The plugs shown in (F), (G), and (H), cannot be reused, but the others can be reconditioned.

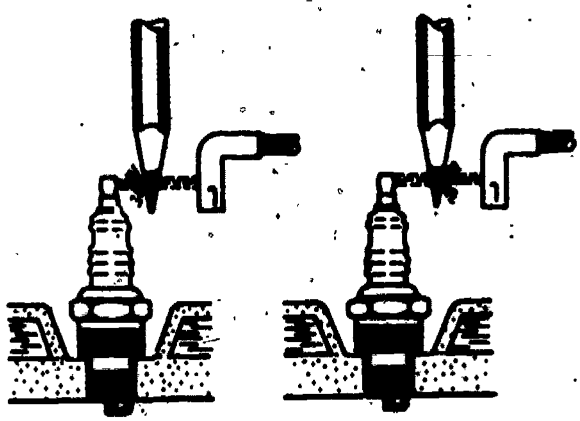


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Figure 10-80.–One method of checking coil polarity.

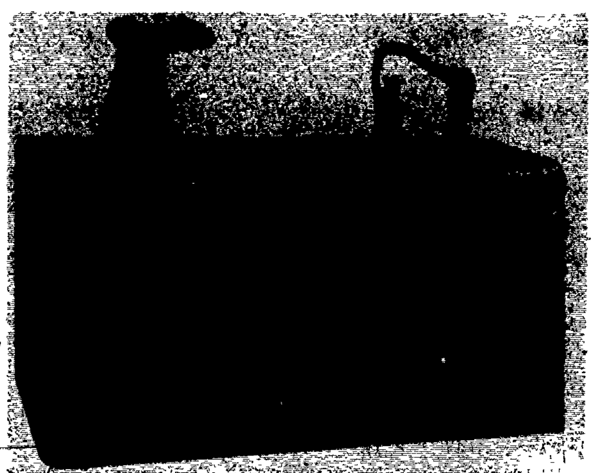

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Figure 10-81.–Spark plug cleaning and testing machine.

Before attempting to clean a plug, any oily deposits must be removed with an approved solvent. This is to prevent the cleaning material from being soaked and packed into the area around the center electrode insulator.

A machine of the type shown in figure 10-81 is used to clean (sand blast) and test the spark plugs.

Following the machine manufacturer's operating instructions, clean the plugs, blasting only long enough to remove the deposits. Prolonged blasting will damage the center electrode insulator.

Once cleaning is completed, the electrodes must be filed clean and square, as the machine blast will not clean this area. If the electrodes are not filed clean, the required voltage will still be high and the plug may misfire.

Using a fine cut point file, file the end of the center electrode flat. File the side electrode flat and the end square. This produces clean, sharp edges that improve plug performance. Remove only enough metal to clean and square the electrodes.

Using a round wire gage, not a feeler gage, set the gap to manufacturer's specifications by bending the side electrode.

Testing spark plugs outside the engine can be very misleading. There is no true relationship between firing a plug in compressed air at room temperature, which is the condition in the testing unit, and firing a plug in an operating engine. In the operating engine, voltages are higher, air-fuel mixtures are present, and the high temperatures in the cylinders aid ignition. If these factors are kept in mind, spark plugs can be successfully tested.

Do not discard plugs which show a bluish light just above the shell while they are being tested. This is a corona discharge caused by the presence of a high-tension field. It does not affect plug performance. Make sure the insulator is clean and dry before testing. If a spark comes through the insulator to the plug shell, it is an indication that the insulator is cracked. Sometimes this crack is hidden inside the shell where it cannot be seen. In many cases, movement of the insulator can be detected by hand pressure.

When replacing plugs, selection of the proper heat range is one of the most important considerations. The spark plug heat range best suited can be found by checking the manufacturer's manual, except in special cases where engine operation is abnormal. In special cases, or when the proper plug cannot be obtained, check with your supervisor to determine which is the best plug available for the particular engine.

Always use new gaskets, if gaskets are required, when installing spark plugs. The gasket performs two important functions—it maintains a gastight seal between the plug and its seat; and most of the heat absorbed by the insulator tip from the burning fuel in the combustion chamber passes through the gasket.

When installing spark plugs, use a torque wrench and tighten them to the torque specified by the engine manufacturer. If the gasket is not tightly seated, the spark plug will become overheated. If the gasket is flattened out too much, the shell may become distorted and damage the insulator.

WATERPROOF IGNITION SYSTEMS

Since many vehicles must operate under very wet conditions, it may be necessary to waterproof the ignition system. Waterproofing means that the system must be so watertight that the components continue to function normally even while totally immersed.

The distributor and ignition coil (fig. 10-82) are sealed in a common housing and enclosed by a common cover, This unit also has a means of ventilating the distributor, thus preventing condensation and the formation of harmful chemicals. Ventilation is accomplished by connecting two tubes to the distributor, one leading to the air cleaner (from which clean air can be obtained) and the other to the intake manifold. The intake manifold vacuum causes air to pass through the distributor from the air cleaner, thus keeping the distributor well ventilated.

The various leads in the ignition system are enclosed in a watertight conduit. This conduit prevents moisture from getting to the leads, thus preventing insulation deterioration from this cause. Repair and maintenance of waterproof ignition systems is similar to that on convention-

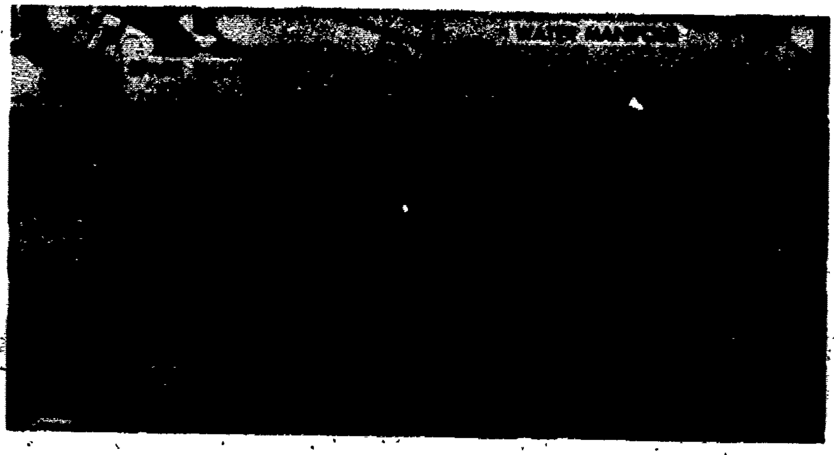

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Figure 10-82.—Waterproof ignition system.

al systems. The same tests and checks should be made, but in most cases special adapters for use on the waterproof connections are furnished with the test equipment. When replacing any connection on the waterproof system, make sure the gaskets and seals are in good condition, and that waterproof integrity is maintained.

LIGHTING SYSTEMS

The lighting system consists of all the lights necessary for an equipment to accomplish its assigned job, and includes control and protection devices for lighting circuits.

HEADLIGHTS

A cutaway view of a sealed beam headlight is shown in figure 10-83. In this type of light, the filament, reflector, and lens form a single unit. The unit is completely sealed so the reflector does not become tarnished and the light output is not seriously affected by age. The filament is correctly focused in relation to the lens and reflector by the manufacturer, and the alinement (aiming) is the only adjustment that can be made. Connection into the circuit is made by blade type connectors and a bayonet plug.

Two filaments are provided in the sealed beam unit—one provides an upper or high beam,

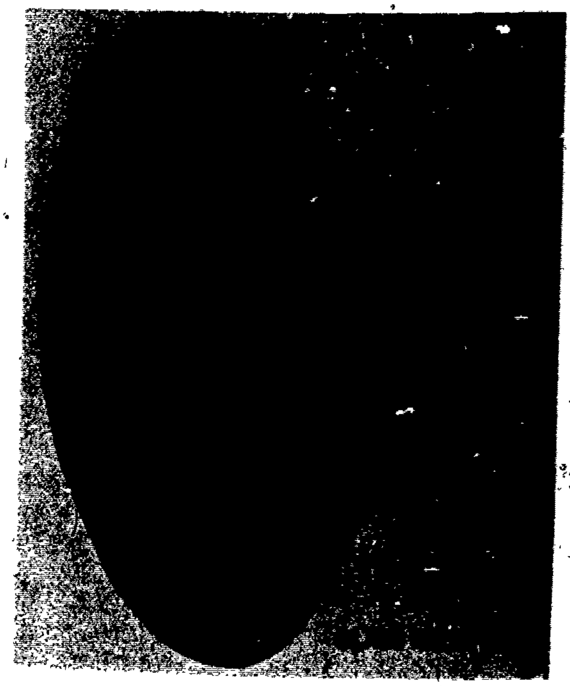

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Figure 10-83.—Cutaway view of a sealed beam headlight.

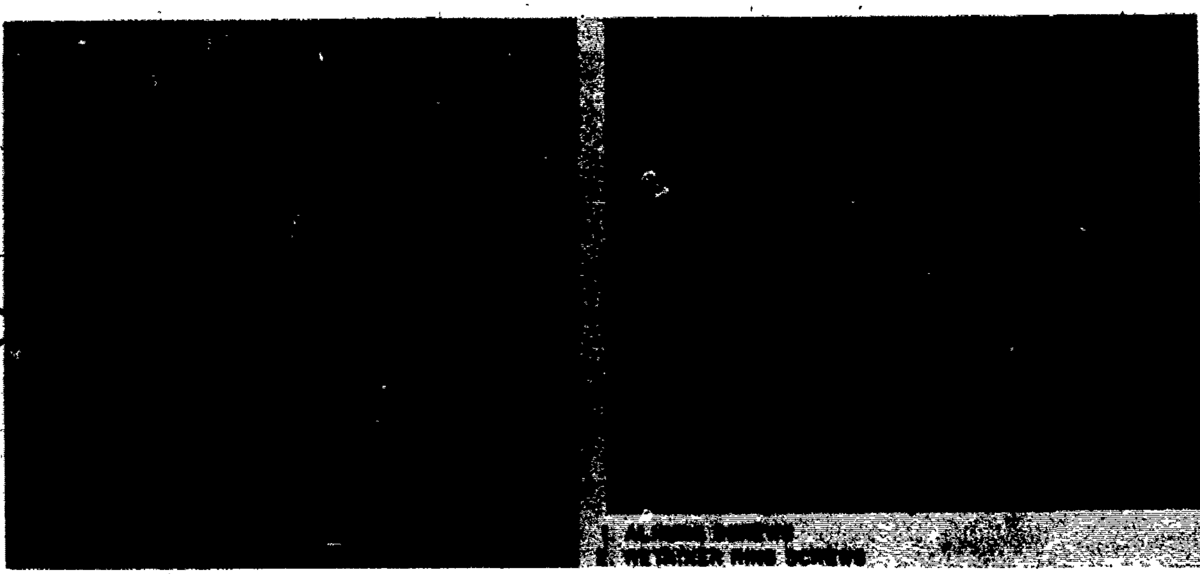

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Figure 10-84.—Sealed beam headlight installation.

and the other provides a depressed or low beam. When either filament burns out, corrective action requires that the whole unit be replaced. However, the sealed beam unit has a greater filament life expectancy than other types of bulbs, and requires no maintenance during its lifetime.

On some units of ground support equipment the headlights have only one filament, and instead of blade connectors for a bayonet plug, they have screws for connection of the leads.

Some modern equipment utilizes four headlights—two on each side. The inboard units have the numeral 1 embossed on the lens, and the outboard units have the numeral 2 embossed on the lens. The number 1 unit has only one filament and a two-blade connector; the number 2 unit has two filaments (as in the single unit described above) and a three-blade connector. When high beam is selected, the inboard unit provides a high intensity, far reaching beam, while the off-focus of the outboard units illuminates the area directly in front of the vehicle. When the lights are switched to low beam (dimmed), the inboard units are turned off and only the low beam filaments of the outboard units are used.

To aline the headlights, various types of special alinement equipment may be used. Always follow the equipment manufacturer's instructions for their use.

When replacement of a sealed beam unit becomes necessary, remove only the screws or springs holding the unit's retainer ring—do not move the alinement screws. (See fig. 10-84.)

MISCELLANEOUS LIGHTS

The bulbs (lamps) used in these lights will generally be of one of the types shown in figure 10-85—single contact, single filament; or double contact, double filament. Both types are provided with nibs to lock into bayonet sockets.

However, as some special purpose lightbulbs are in use, always replace a lightbulb with one of the same type, and if there is any doubt as to the type to be used, refer to the applicable maintenance manual to obtain the correct type.

Instrument Lights

Ordinarily, indirect lighting is used for the instrument lights which are on whenever the light switch is in any of the ON positions. Many vehicles are equipped with an instrument panel light switch so that the instrument panel lights can be dimmed or turned off when desired.

Parking Lights

The smaller lights used for parking are sometimes located immediately above or below the main headlights. Side lights sometimes serve as parking lights. The parking light switch is incorporated into the main light switch.

Taillights and Stoplights

Taillights and stoplights are ordinarily combined, with two lightbulbs contained in a single housing with a red lens. A larger lightbulb (about 15 candlepower) is used for the stoplight, and a smaller lightbulb (about 3 candlepower) is used for the taillight. Taillights and stoplights are sometimes enclosed in a single lightbulb having a double filament. Taillights are on whenever the light switch is in any of the ON positions.

Backup Lights

When a backup light is used, it is mounted so as to direct light to the rear of the vehicle. It is arranged and wired so that a switch turns it on when the gearshift lever is put into reverse position.

Spotlights

Spotlights are similar in construction to headlights (sealed beam). They are designed to project a beam for a great distance ahead and are constructed so that the light can be aimed by the vehicle operator. They are valuable for illuminating work or other areas in which the equipment is being used.

Blackout Lights

Blackout lights are used to enable a vehicle to move at night without being observed from the air. These lights provide sufficient illumination to enable units in a convoy to keep in line while progressing at slow speeds. Two blackout headlights, two blackout taillights, and a blackout stoplight are provided for this illumination. All other lights in the vehicle are off when the blackout lights are on. Blackout driving and rear marker lights are shown in figure 10-86.

SWITCHES

In most vehicle installations, the lighting circuits are arranged so that the headlights, parking lights, taillights, and instrument lights are controlled by one switch (main light switch), and the switch will be of either the push-pull type or push-pull with a rotary contact type. The rotary contact is a rheostat, actuated by rotating the switch knob, and is used to control the intensity of the instrument lights. These type switches, as shown in figure 10-87, have three positions—off, park, and head. Regardless of the type used, it is located on the instrument/control panel within easy reach of the operator.

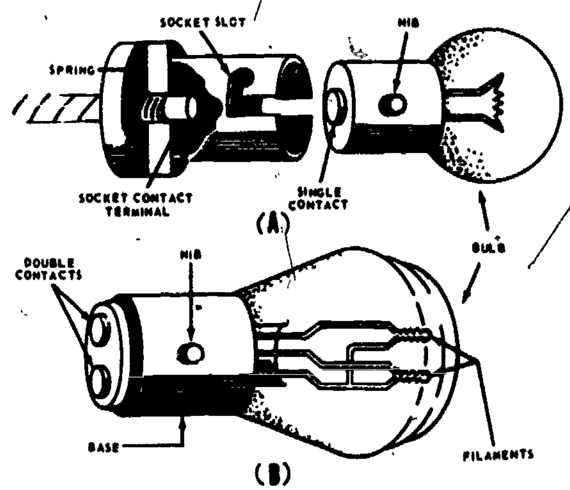

Figure 10-85.—Commonly used lightbulbs.

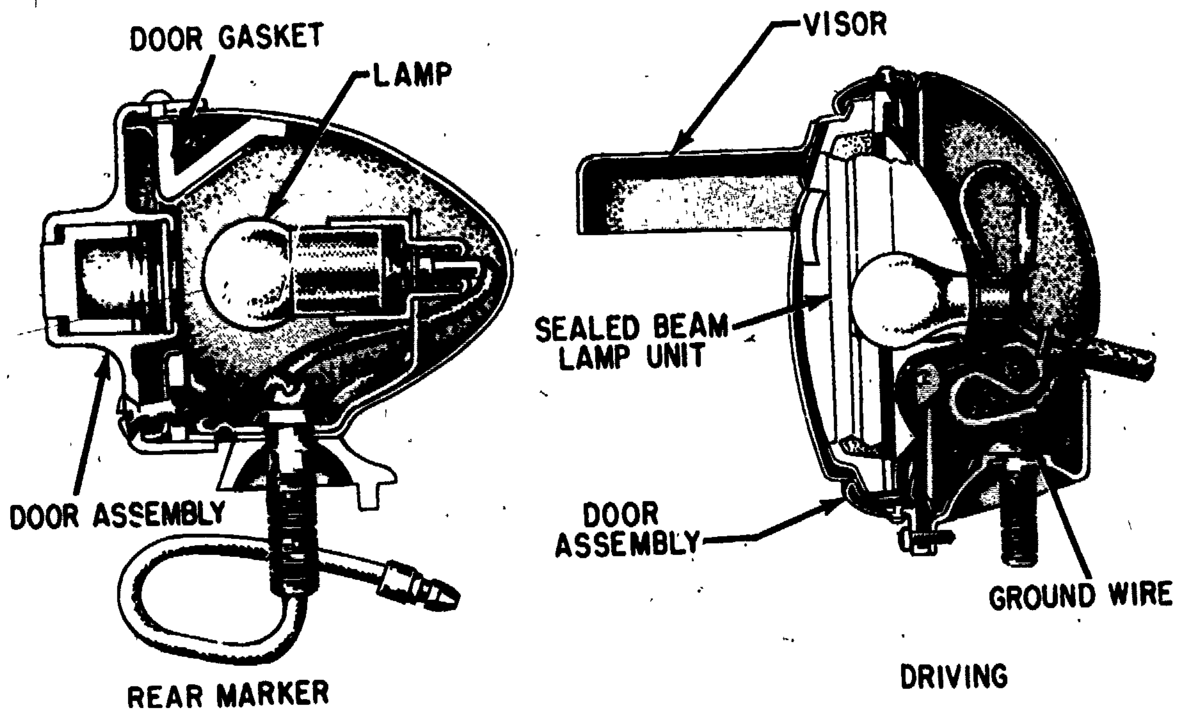

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Figure 10-86.—Rear marker and blackout driving lights.

Vehicles provided with blackout lights have a special blackout light switch which incorporates the operation of the service lights and blackout lights in one unit. This switch is shown in figure 10-88 with its connections to the various units in the lighting system. The plunger knob has three positions—OFF, BLACKOUT LIGHTS, and SERVICE LIGHTS. In its second or middle position, the switch turns the blackout lights on, keeping all other lights off. The plunger knob cannot be pulled out to its third position until the safety lock button is pushed in. This safety feature prevents any lights visible from above being accidentally turned on during a blackout. In the third position, with the plunger knob pulled all the way out, the service lights are on and operate normally as previously described. A trailer connection is provided to operate taillights on the rear of the trailer. These are on when the switch is in either the second or third position.

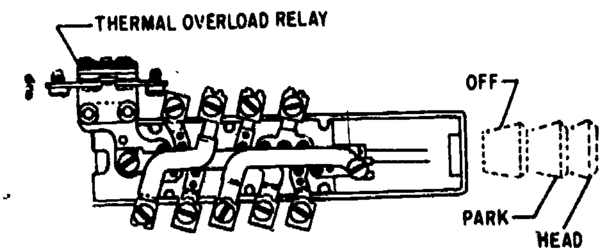

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Figure 10-87.—Main light switch.

Vehicles that are equipped with dual filament headlights are provided with a switch to allow the operator to select high or low beams (dimmer switch). It is a foot-operated pushbutton type, located on the floorboard.

The stoplights are controlled by a switch that is actuated whenever the vehicle's service brakes are applied. It may be located on the master cylinder mount brackets and actuated by mechanical linkage, or in the hydraulic system and actuated by hydraulic pressure.

RELAYS

Due to the limited voltage available in automotive lighting circuits, resistance of the wiring must be kept to a minimum to provide lighting of sufficient intensity. Some systems accomplish this by using heavy gage wire, and others accomplish this by using relays.

By placing the relay in such a position that only short runs of heavy gage wire is necessary, voltage loss in the wiring is reduced, the cost of the wiring is reduced, and since the main light switch and dimmer switch carry only low control current, voltage loss due to burned switch contacts is eliminated. Figure 10-89 shows a wiring diagram for a system using two relays—one for high beam and one for low beam. In some systems, these two relays are incorporated into one unit.

Another type of relay that is used in some automotive lighting systems is the current limiting relay. These are sometimes referred to as overload relays or circuit breakers, and can be found in two types—the thermal overload type that is incorporated as part of the main light switch, and the solenoid type that is mounted separately on the vehicle fire wall.

The construction and operating principles of relays are covered in chapter 8 of this manual.

FUSES

A fuse block is usually mounted behind the instrument panel, and contains fuses which provide protection for the miscellaneous lighting

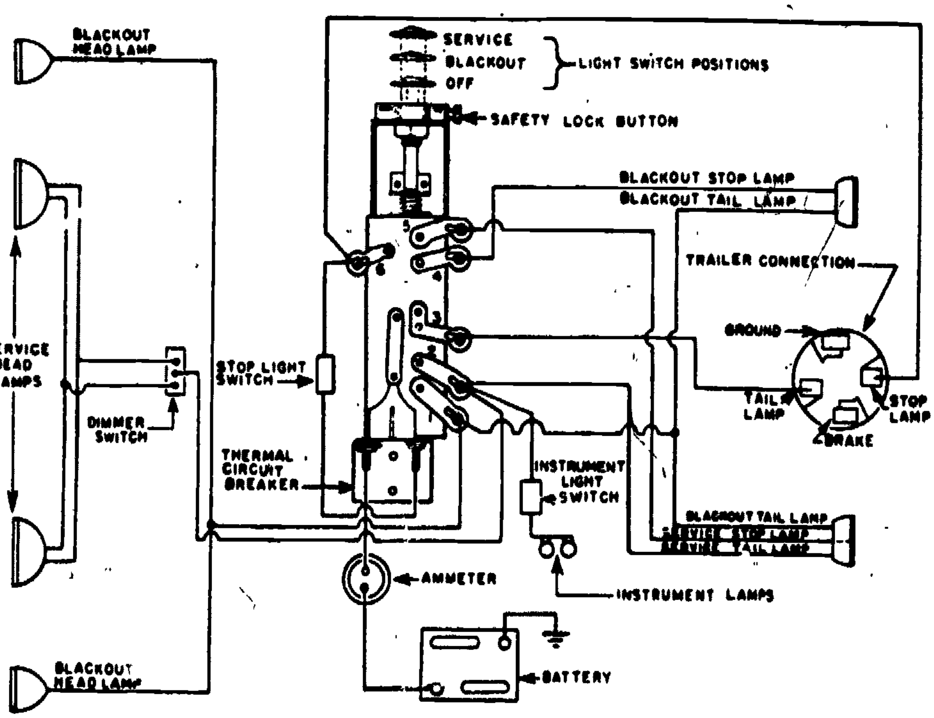

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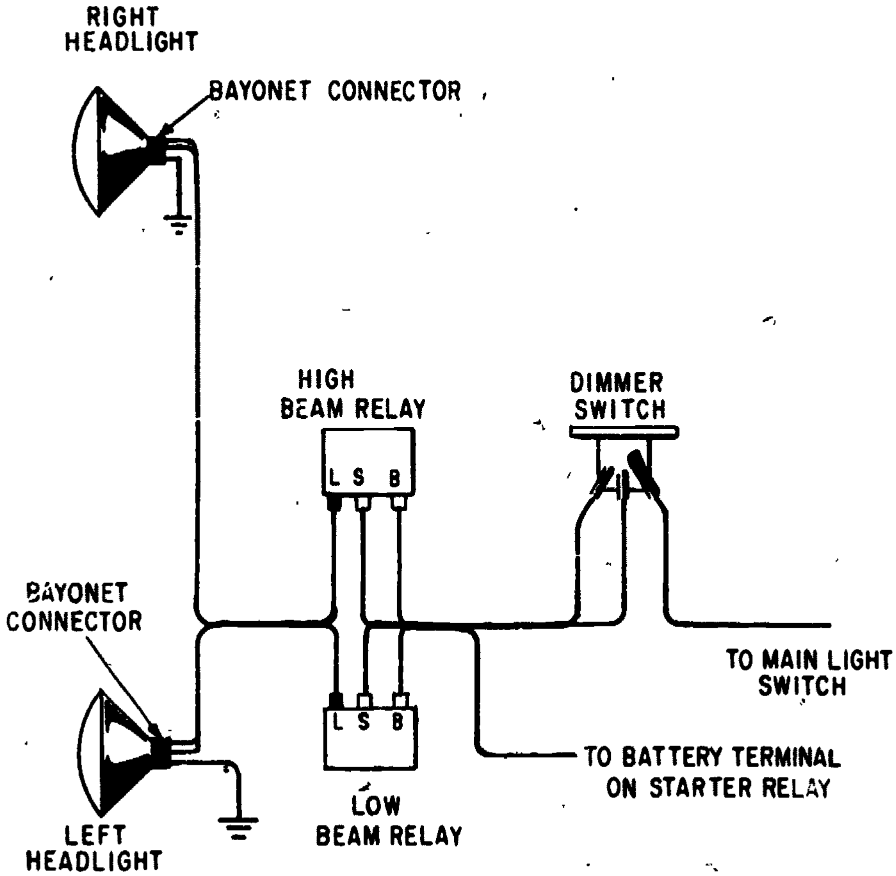
Figure 10-88.—Blackout light switch and connections.



WIRE SIZES:

RELAY-TO-HEADLIGHTS: 12 GAGE
RELAY-TO-DIMMER SWITCH: 16 GAGE
RELAY-TO-STARTER RELAY: 10 GAGE
DIMMER SWITCH-TO-MAIN SWITCH: 16 GAGE

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Figure 10-89.—Light relay wiring diagram.

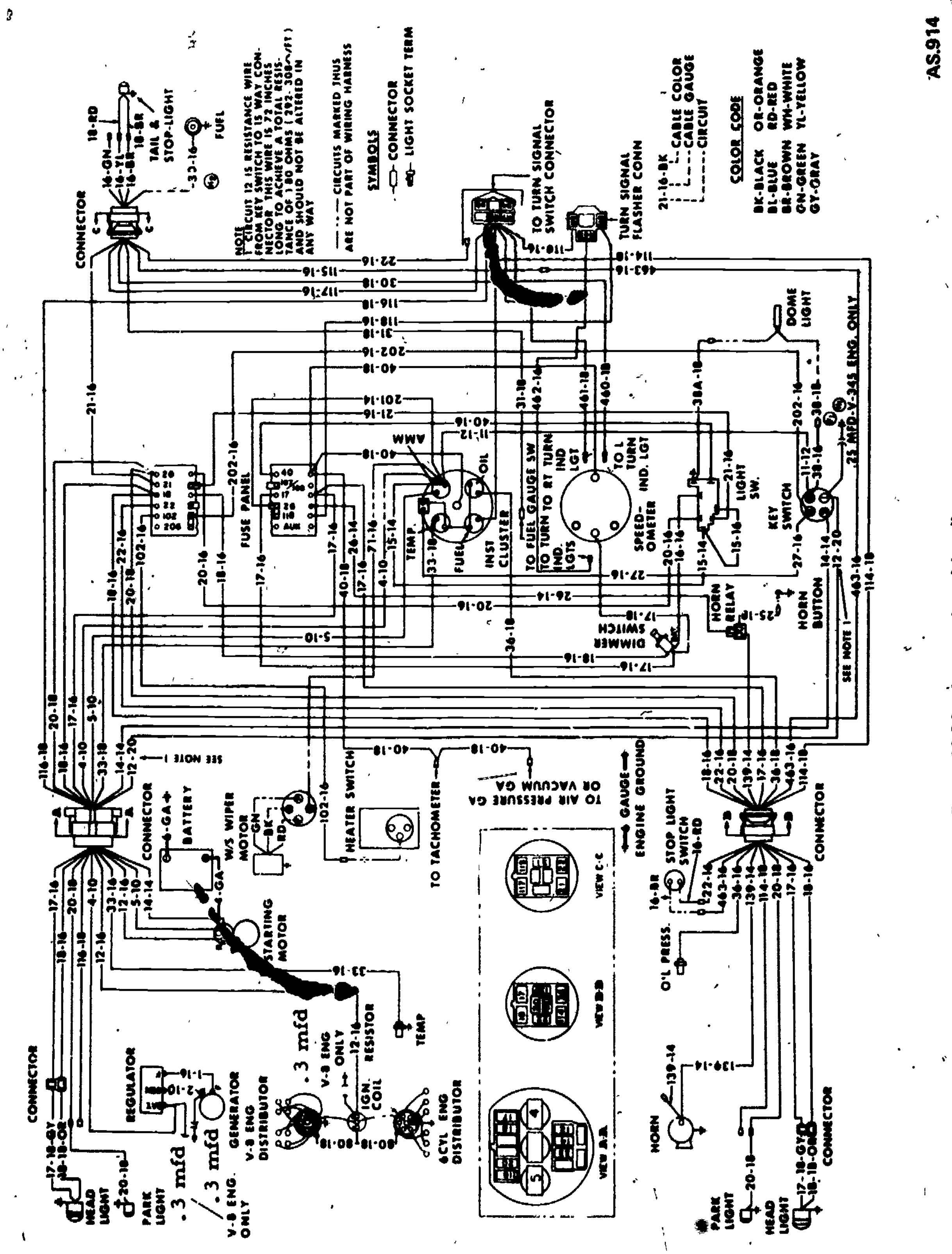

Figure 10-90.—Automotive wiring diagram.

circuits. Fuse construction and operation are covered in chapter 8 of this manual.

WIRING

Maintaining and repairing automotive vehicle electrical systems are among the many duties of the ASE. All vehicles are not wired in exactly the same manner; however, once the ASE thoroughly understands the wiring circuit of one vehicle, he should be able to trace an electrical circuit in any vehicle.

ELECTRICAL TROUBLES

Locating electrical troubles is the largest task in maintaining and repairing electrical systems. When the lights fail or the electric starter becomes inoperative, the ASE cannot always expect to find the trouble to be simply a dead battery or faulty generator. Many troubles are due to other causes, usually bare wires or poor connections.

Each piece of automotive equipment is provided with an operations and maintenance manual. The manual contains wiring diagrams which will aid in troubleshooting and repairing electrical systems. The diagrams show how the electrical units in the equipment are connected and the location of fuses and automatic switches.

Many diagrams show a color code for each wire in a particular circuit. The headlight circuit, for example, may have wires marked BK and G which would mean black wire and green wire. Wires in another circuit could be marked WR to indicate a white wire with a red tracer. Whether the diagram shows these designations or not, the ASE will find wires of the same color connecting units in an individual circuit. That is true, of course, if the original wire has not been replaced or improperly connected. Chapter 6 of this training manual gives a detailed explanation of uses of schematics and diagrams.

ONE- AND TWO-WIRE CIRCUITS

Tracing wiring circuits, particularly those connecting lights or warning and signal devices, can become a difficult task. Study the diagram in figure 10-90. Branch circuits that make up the individual systems have one wire to conduct electricity from the battery to the unit, and ground connections at the battery and the unit to complete the circuit. These are called one-wire circuits, or branches of a ground return system. The all-metal construction of automotive equipment makes it possible to use this system.

In automotive electrical systems with branch circuits that lead to all parts of the equipment, the ground return system saves installation time and eliminates the need for an additional wire from each electrical unit to complete the circuit.

A two-wire system requires two wires to complete the electrical circuit—one wire from the source of electrical energy to the unit, and another wire to complete the circuit from the unit back to the source of electric power. House wiring circuits are of this kind.

Two-wire circuits provide positive connections for lights and electric brakes on some trailers. The coupling between the trailer and the equipment, although made of metal and a conductor of electricity, has to be jointed to move freely. The rather loose joint or coupling does not provide the positive and continuous connection needed for a ground return system between the two vehicles.

When tracing electrical diagrams, always start from the source of electric power. Starting from the battery or a fuse junction block and following a circuit from one point to another often save time in looking for trouble.

The operation and maintenance manual, besides furnishing wiring diagrams, will also give information for the maintenance and repair of electrical units. Read these manuals—the information received from them, plus the basic principles that are contained in Basic Electricity, NavPers 10086 (Series), will be of great value.

PREVENTIVE MAINTENANCE

When working on an engine or doing other repair work, make it a habit to check wires in that part of the equipment. The ASE will learn a great deal about the electrical systems by doing so. The wiring diagrams tell only what circuits and units are in the equipment—not where they are placed nor how they are actually connected.

Electric current will flow in the path of least resistance, and if the resistance is too great, will not flow at all. Keep these facts in mind; they will help solve many of your problems in the maintenance of lighting systems. In figure 10-91, notice the method of grounding the battery to the vehicle frame. The short circuit illustrated in (A) shows what happens when the wire insulation wears through. Instead of current flowing through the filament of the light and then completing its circuit through the frame back to the battery, it takes the path of least resistance through the frame without going through the light. The light burns very dimly or not at all, and the battery becomes discharged. A short circuit of this kind could result in fire from overheated wires, or from sparks resulting from the bare wire making and breaking contact with the frame.

The open circuit caused by a loose connection as shown in (B) is common trouble in electrical systems. The expression open circuit is used not only when the wire connections are actually separated as in a switch, but also when the resistance in the wiring circuit is so great that no current can flow between the battery and the unit it operates. An example is rust or corrosion that forms or accumulates at a joint or wire terminal that may actually feel tight—the battery cable connection to the vehicle frame, for instance.

Wiring Harness

To prevent the possibility of chafing and loosening of wire terminals and connections caused by vibration and road shocks, insulated wires are, where possible, grouped together and protected by a nonmetallic tape or braid covering, sometimes called a wiring harness, as shown in figure 10-92. This is a typical wiring harness. The wires are grouped together and the branch circuits are divided to make connections with the various electrical units.

Wire Support and Protection

Wires in the electrical systems should be supported by cleats, clamps, or brackets at various points about the vehicle. When installing a new wire, be sure to keep it away from the hot engine parts which would scorch or burn the insulation. Wires passing through holes in metal members of the frame or body should be protected by rubber grommets or several turns of friction tape to prevent chafing or cutting on sharp edges.

Ground Connections

Make certain the ground return connections made to the chassis frame or engine are clean and tight. Where the engine or body is mounted on rubber or other insulating material, flexible bonding wires are used to connect the parts together. Pay particular attention to these areas as rust or corrosion may form at these connections, preventing the flow of current in the circuits even though the screws or bolts are tight.

FIELD AND SHOP REPAIR

Dependable operation of the electrical systems is the ASE's responsibility. Field maintenance is usually limited to minor repairs; all overhaul work on equipment is performed in the shop. In the shop, the electrical units are disassembled when major repairs require special tools and equipment.

Should electrical troubles be found in the field and corrective action is taken, do not make just a temporary repair, but do it right the first time; in this way the ASE will save time and gain the confidence of the drivers and operators. Should there be some question about other troubles, check your operation and repair manual and report what you have found to the supervisor in charge of the shop.

SAFETY

When working with electrical equipment there is one rule that must be strongly stressed—safety first. Whether working in the shop or on the line, prescribed safety procedures must be followed. The ASE must be aware of the many dangers that are associated with this type of work. Among the possible hazards of this work

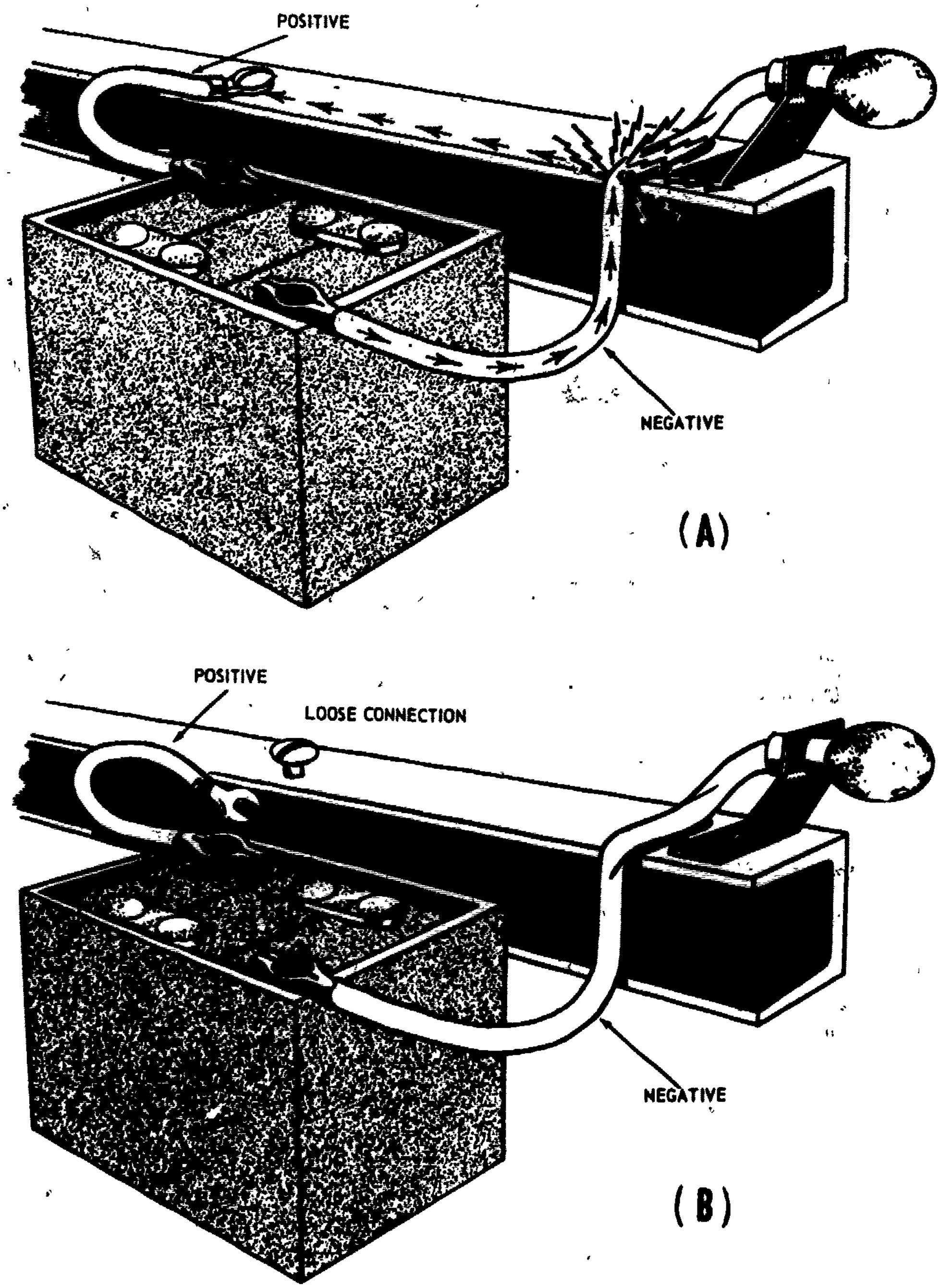

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Figure 10-91.—(A) Short circuit; (B) open circuit.

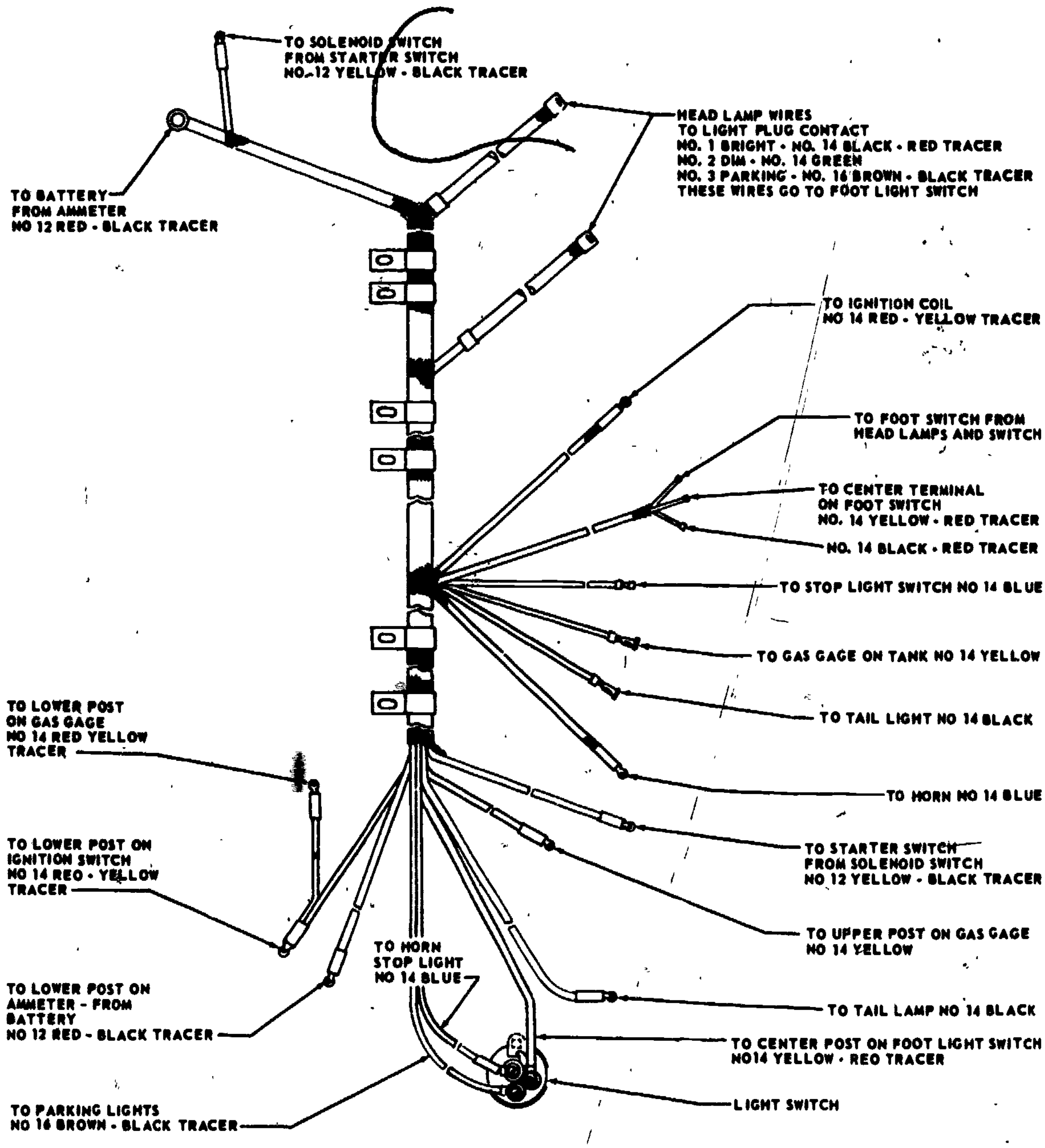

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Figure 10-92.—Automotive wiring harness.

are electrical fires and harmful gases, which are sometimes generated by faulty electrical and electronic devices. The most common danger encountered is that of the high voltages which are present in much equipment. Also, when working with ground support equipment, there is the possibility of falling from equipment, or of being burned by a jet blast.

Because of these dangers, the ASE should regard the formation of safe and intelligent work habits as being equal in importance to the development of his knowledge of electrical equipment. One of his primary objectives should be to become a safety specialist, trained in recognizing and correcting dangerous conditions, and in avoiding unsafe acts.

The safety precautions which apply to the work and duty of the ASE include those pertaining to working in and around support equipment in the electric or battery shop, precautions against electric shock and electric burns, and those which concern the proper use of handtools and small power tools. In addition to these, it is also necessary that the ASE know the authorized methods for dealing with fires of electric origin, for treating burns, and for giving artificial respiration to persons suffering from electric shock.

The Navy training courses Airman, NavTra 10307 (Series), and Standard First Aid Training Course, Nav Pers 10081 (Series), contain safety information with which the ASE should be familiar. It is recommended that he become acquainted or reacquainted with the sections of Airman that deal with safety as it relates to naval aviation. The Standard First Aid Training Course is designed as a basic reference in the field of first aid; since all naval personnel are required to possess a knowledge of the principles of first aid, become familiar with this training course.

ELECTRICAL FIRES

Electrical fires are extremely dangerous in automotive equipment. This is not because of the electrical shock danger, but because of the gasoline, diesel fuel, or oil that may ignite.

A short circuit in an automotive vehicle electrical system will not always cause a fire, but a fire can easily result from such a defect. By frequently inspecting, repairing, and maintaining the electrical system in the vehicle, the ASE helps prevent fires and electrical failures. Not only must he know how to prevent fires, he must also know what to do in case a fire gets started.

CAUTION: NEVER USE WATER ON ELECTRICAL OR PETROLEUM FIRES.

CHAPTER 11

AUTOMOTIVE ACCESSORIES

In early days of the automobile, only the ignition system depended on electricity for operation. As the automobile became more modern, the use of electricity was expanded to include many more items within the electrical system. Electricity is used to operate many automotive accessories such as heating and defrosting fans, direction signals, windshield wipers, and horns.

The ASE has the responsibility for maintenance and repair of automotive accessories. On some vehicles this might appear to be an overwhelming task; but by referring to diagrams and written information on the accessories it will be found they all operate on a few fundamental principles. A knowledge of these principles leads to an easier understanding of these accessories and how to service them. Before reading this chapter you should review the information on fundamentals of electricity in Basic Electricity, NavPers 10086 (Series).

INSTRUMENT ACCESSORIES

The instrument accessories are usually placed on a panel so that the instruments may be easily read by the operator. They inform the operator of the approximate speed, engine temperature, oil pressure, rate of charge or discharge of the battery, amount of fuel in the fuel tank, distance traveled, and the time. Certain controls are frequently mounted on the instrument panel, such as the throttle, choke, starter, heater, windshield wiper, and others.

AMMETER

The ammeter used on automotive equipment is somewhat simpler than the ammeter described in chapter 9 of this manual. The typical automotive ammeter (fig. 11-1 (A)) contains a steel armature mounted on the same shaft as the pointer. With no current flowing through the ammeter the permanent magnet holds the armature so that the pointer indicates zero.

When current flows, it produces a secondary magnetic field that bucks the magnetic field of the permanent magnet. The secondary magnetic field therefore acts on the pointer shaft, causing it to deflect so that the pointer moves away from zero.

The amount of deflection is determined by the strength of the secondary magnetic field, which is, in turn, determined by the strength of the current flow through the ammeter. When the current flows in one direction, for instance from the generator to the battery, the armature and pointer move around to indicate on the charge side. However, when the battery is delivering current to the electrical circuits, the pointer deflects to the other side of the scale, indicating discharge.

The ammeter is connected between the cutout relay (in the regulator) and the battery, and indicates the amount of current flowing to and from the battery. (See fig. 11-1 (B).) It does not give an indication of total generator output, because other circuits in the electrical system besides the battery are supplied by the generator, and this current does not flow through the ammeter.

NOTE: The ammeter is connected so that current from the battery to the starter motor does not flow through the ammeter when the vehicle engine is started. The starting motor may draw several hundred amperes during starting, and the range of the ammeter would be greatly exceeded.

FREQUENCY METER

The frequency meter is used for indicating the frequency of an a-c power generating system.

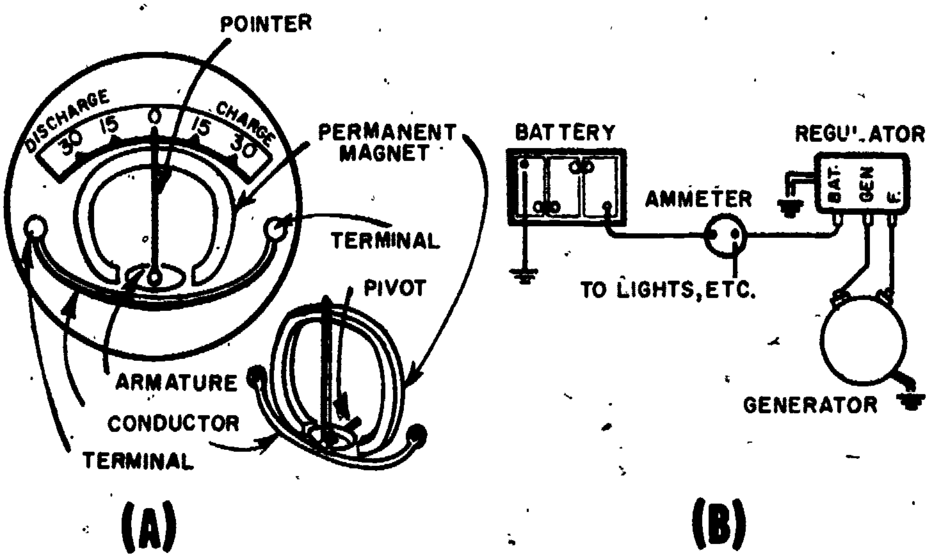

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Figure 11-1.—(A) Simplified automotive ammeter; (B) wiring diagram showing ammeter in the charging circuit.

There are two types of frequency meters used on support equipment—the vibrating-reed type and the moving-disc (pointer) type.

The theory of operation of both types of frequency meters is covered in detail in chapter 15 of Basic Electricity, NavPers 10086-B, and will not be discussed here. The frequency meters covered in Basic Electricity are designed for a frequency of 60 hertz and those on support equipment are designed for a frequency of 400 hertz, but the theory of operation is the same.

HOURMETER

Some support equipment requires servicing or maintenance after operating a certain amount of time. Hourmeters (fig. 11-2) are used to provide maintenance personnel with a means of determining when the equipment has operated a specific amount of time. With the information from the hourmeters and maintenance instructions, maintenance personnel can determine what maintenance is required and when to perform it.

There are two types of hourmeters commonly used on support equipment. These are the electrically driven (most common) and the mechanically driven types. The electrically driven type records elapsed time (clock hours), but the mechanically driven type records time after a certain number of functions have taken place. For example, the hourmeter may be designed to advance an hour after the crankshaft of an engine has completed as many revolutions as it normally would during an hour's operation.

Hourmeters may have a counter dial as shown in figure 11-2 (A), or a radial dial as shown in (B) and (C). The use of several different type dial configurations on hourmeters causes a great deal of confusion for many of the personnel who have the responsibility of reading the meters. Three different dial configurations are shown in figure 11-2. The meters are easy to read, but each meter must be observed very closely and considered individually. The second number from the right on the meter in (A) is in tenths; therefore, the meter indicates 143.75 hours. On many meters with this type dial, the first number on the right is in tenths (would be indicated on the dial of the meter); and if this were the case, this particular meter would be indicating 1,437.5 hours. At a quick glance, the hourmeters shown in (B) and (C) look the same, but from a closer examination it can be seen that identical hands traveling the same distance indicate different amounts of time. For example, on meter (B) when the large hand (outer scale) has traveled from "zero to one," 1 hour has passed, but on meter (C) 10 hours would have passed; therefore, determine how each dial is calibrated before taking a reading. Always read the scales in descending order. For example, on the meters shown in (B) and (C), read the inner scale first, middle scale second, and the outer scale last. On the meter in (B), the inner scale indicates 100 hours, the middle scale 30 hours, the outer scale 6 hours, and, putting them all together, the meter indicates 136 hours. The meter in (C) indicates 2,570 hours.

The purpose of the small hand located below the 9 on meters (B) and (C) is to indicate whether or not the meter is operating. Movement of the large hands cannot be detected by looking at the meter, but movement of the small hand can be detected easily with the eye.

START COUNTER METER

The start counter (fig. 11-3) is an electrically operated additive meter which is normally used to record the total number of complete starts of an engine since initial or overhaul installation. The start counter is only used on a few items of support equipment; however, it does provide valuable information on such items of equipment as gas turbine compressors on which the number of starts is of vital importance.

The start counter in figure 11-3 is shown mounted in the electrical control box of a GTC 85-73; however, it is also used on other items of support equipment. This start counter is provided with a plate incorporating four windows with dials showing through. The first dial on the right records starts in increments of even numbers, zero through eight, and any odd number between is indicated when the numbers stop at any intermediate point between any two even numbers. The second dial from the right records starts in tens, the third dial from the right records starts in hundreds, and the fourth dial from the right records starts in thousands. The

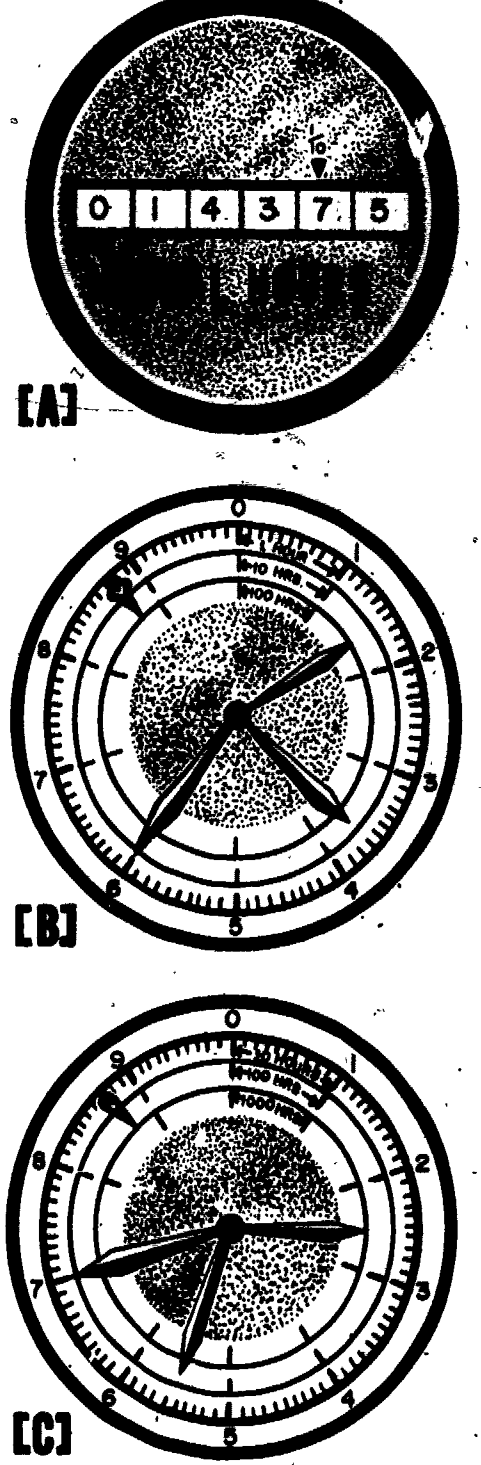

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Figure 11-2.—Hourmeters.

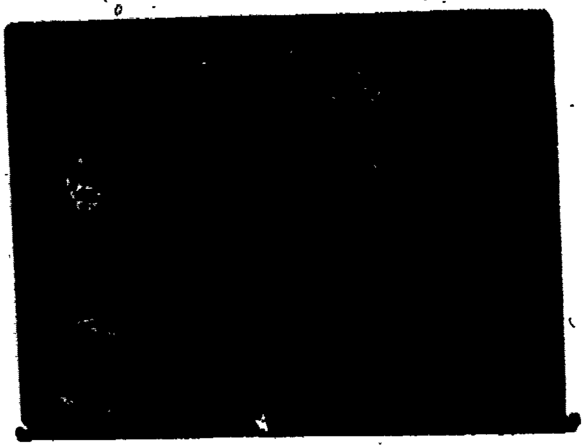

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Figure 11-3.—Start counter meter.

dials which record starts in tens, hundreds, and thousands show both odd and even numbers.

FUEL GAGE

Most fuel gages are electrically operated and are composed of two units—the gage mounted on the instrument panel, and the sending unit mounted on the fuel tank. The ignition switch is included in the fuel gage circuit so that the electrical fuel gage operates only when the ignition switch is on. Operation of the electrical fuel gages depends on either coil (magnetic) or thermostatic (bimetallic) action.

Coil Type

The electrical circuit for a fuel gage is shown in figure 11-4. The coil type gage is illustrated. Fuel level indications result from variations in the magnetic fields of two coils, which in turn cause the pointer to move. The rising or falling

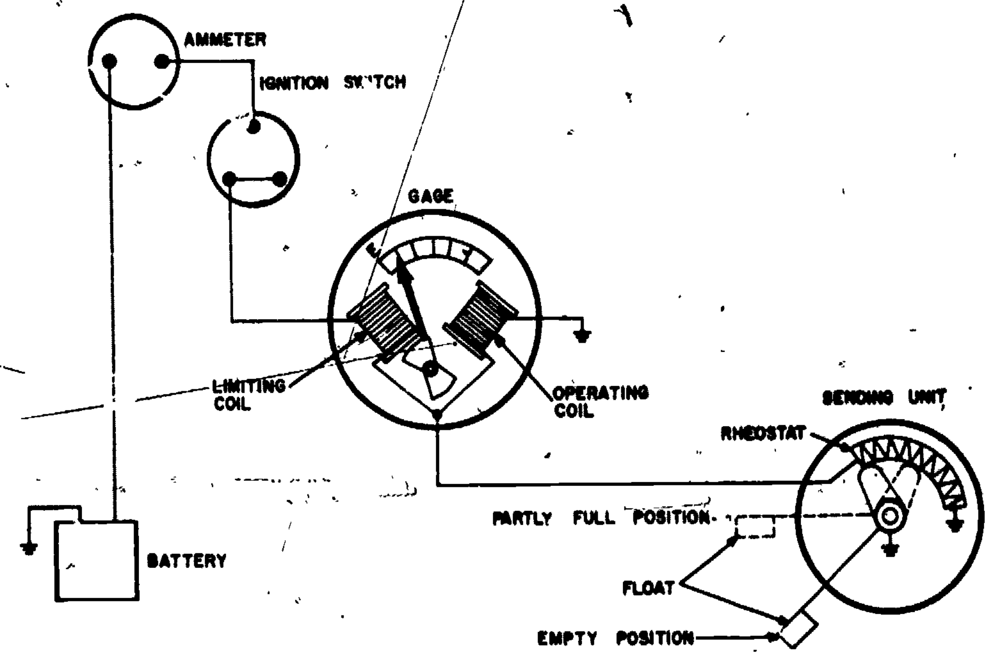

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Figure 11-4.—Coil type fuel gage circuit.

float in the fuel tank moves the arm of a rheostat or variable resistance, causing the magnetic fields to vary in the coils.

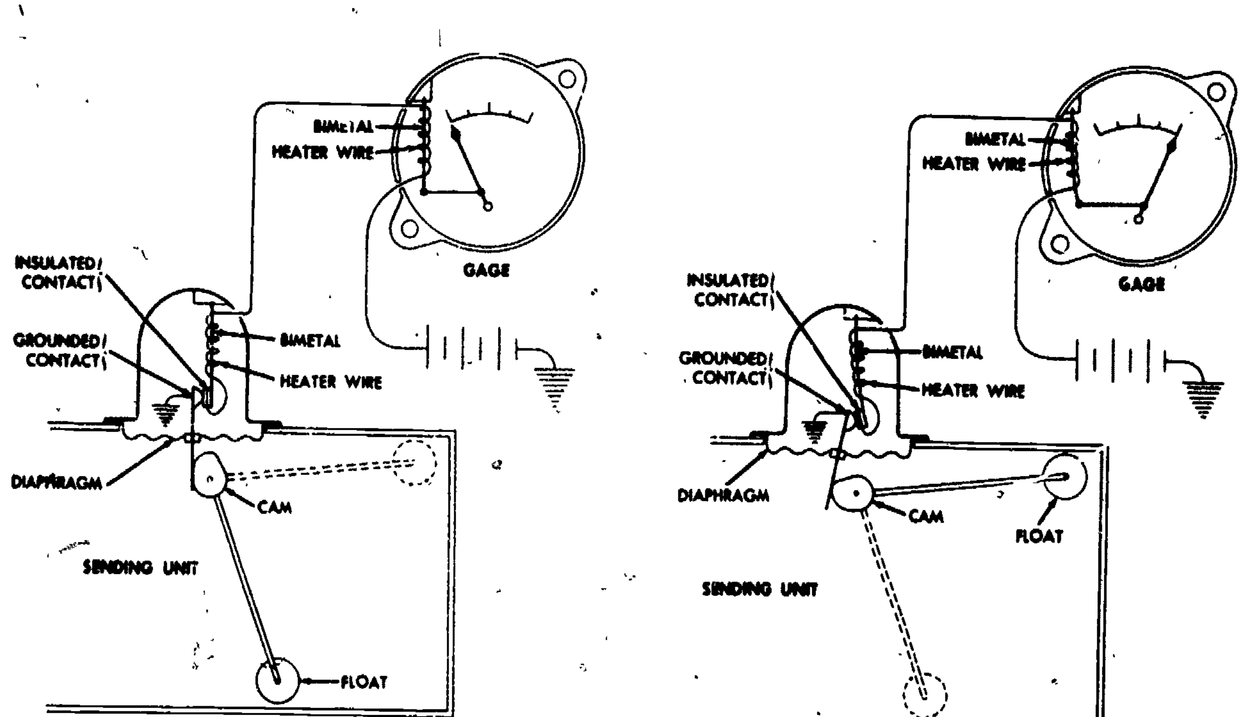
Current from the battery has parallel paths of flow through the rheostat of the sending unit and the operating coil of the gage. The parallel paths join at the common connection between the two coils of the gage, and current flows through the limiting coil, ignition switch, ammeter, and back to the battery.

When the fuel tank is empty, the grounded arm on the rheostat bypasses all the resistance in the sending unit and places a ground at the connection between the coils. All the current then flows through the limiting coil and, as a result, the indicating pointer is held at the empty position by the limiting coil.

If the fuel tank is partially full, the float of the sending unit rises on the surface of the fuel and moves the rheostat arm over the resistance element, increasing the resistance of the sending unit circuit. Current then passes through the operating coil and causes a magnetic pull on the pointer, overcoming some of the pull of the limiting coil.

When the tank is full, the sending unit circuit contains maximum resistance to the flow of current. The operating coil then receives its maximum current and exerts maximum pull on the pointer to give a full tank reading. As the tank empties, the operating coil loses some of its magnetic pull while the limiting coil still has approximately the same pull, so that the pointer is pulled toward a lower reading.

The type of gage consumes very little current, about one-eighth of an ampere. Since the operation of this gage depends on the difference in the magnetic effect between two coils, variations in the battery voltage will not cause an error in the gage reading.



(A) OPERATION WITH TANK EMPTY

(B) OPERATION WITH TANK FULL

AS.341

Figure 11-5.—Thermostatic type fuel gage circuit.

Thermostatic Type

The thermostatic electrical fuel gage has bimetal blades in both the gage and the sending unit. This type gage may also be used as a temperature or oil pressure gage by utilizing changes in temperature or pressure to operate the movable grounded contact in the sending unit.

hen the tank is empty and the float is down, as shown in (A) of figure 11-5, the two contacts in the sending unit are just touching. Current flows through the resistance heater wires of both gage and sending units, causing the bimetal blades to bend. Bending of the bimetal blade in the sending unit separates the contacts to break the circuit. The heater wire cools when the current stops flowing, and the bimetal blades return to their original position. Contact is again made, and the cycle of operation is repeated approximately every second. Opening and closing of the contacts produce an intermittent flow of current which does not heat the gage blade sufficiently to bend it, and the blade holds the pointer at the empty reading.

When the tank is full, the float is at the top and the cam takes the position shown in (B) of figure 11-5. In this position, the cam pushes the grounded contact against the insulated bimetal contact, bending the bimetal blade in the sending unit. Since the bimetal is then under a strain, the current must flow longer to bend it sufficiently to open the contacts. The longer flow of current causes a bending of the bimetal blade in the gage unit, pushing the pointer over to the full position.

The contacts open and close fast enough to give a steady reading by the pointer. The maximum current requirement for a full reading is less than one-fourth ampere. This type of gage is not affected by variations of battery voltage, and is compensated for outside air temperature variations.

OIL PRESSURE GAGE

The oil pressure gage indicates the oil pressure in the system. Usually, such gages are mounted on the instrument panel and are calibrated to read oil pressure in pounds per square inch.

Bourdon Tube

Bourdon tube type oil pressure gages are actuated by the pressure of air trapped above the oil in a very small copper tube connected from the gage to the lubricating system. Air pressure in the connecting tube is maintained by the oil pressure in the system. Operation of the gage itself is based on the use of the Bourdon tube (fig. 11-6), which is a flexible, semicircular metal tube, elliptically shaped in cross section, with one sealed end and one open end. The open end is connected to the pressure system; and as the pressure of gas or liquid within the tube increases, the tube tends to straighten. As the pressure decreases, the tube resumes its normal semicircular shape. By fixing the open end and allowing the sealed end to move freely, the "straightening" movement of the tube can be utilized to move a needle across a dial. A simple spring, gear, and lever arrangement serves to return the needle as the pressure is reduced and the tube resumes its shape.

Electrical Type

Some automotive vehicles are equipped with electrical type oil pressure gages. These gages may be either the balancing coil type (fig. 11-7) or the thermostatic type. The thermostatic type oil pressure gage operates very similarly to the thermostatic type fuel gage which was discussed previously.

In the balancing coil type system, a variable resistance is incorporated in the engine sending unit (fig. 11-7 (A)). Increasing oil pressure causes the diaphragm of the sending unit to become displaced (fig. 11-7 (B)). This increases the resistance, causing the right coil of the oil pressure gage to become stronger than the left coil. As a result, the armature and pointer swing to the right, indicating an increase in oil pressure. The opposite takes place with a decrease in oil pressure.

An absence of oil pressure during engine operation indicates a faulty oil system or inoperative oil pressure indicating system, and the engine should be stopped immediately. The trouble must be located and repairs made before the engine is restarted.

TEMPERATURE GAGE

Temperature gages, usually mounted on the instrument panel, are used to indicate the temperature of engine coolant, engine oil, transmission fluid, etc. Temperature gages are operated either electrically or by the Bourdon tube. The gages discussed in the following paragraphs where designed to indicate the temperature of engine coolant.

Bourdon Tube

When the principle of operation is the Bourdon tube, previously described, it is actuated by pressure conducted to it from a bulb which is screwed into the water jacket of the engine. The heat of the water affects the liquid in the bulb. This liquid vaporizes at a very low temperature and the gas flows through the capillary, a very small tube connecting the bulb to the gage. The greater the heat, the more vapor given off and the greater the pressure; thus, higher temperature is indicated on the gage.

Electrical Type

The electrical temperature gage (fig. 11-8) functions on much the same principle as the balancing coil type fuel gage and oil pressure gage.

The temperature gage consists of two coils at right angles to each other with an armature at the intersection of the coil axes. Connected to the armature is a pointer. Essentially, the sending unit is a resistor whose resistance varies inversely with the temperature of the engine. When the engine temperature is high, the sender's resistance is low; when the temperature is low, the resistance is high. On the low temperature side of the gage unit, the coil is connected directly across the battery. Thus, there exists a constant magnetic strength in that coil which attracts the armature and pointer to the low temperature side. However, the coil on the high temperature side is connected in series with the resistance of the sending unit, and across the battery. Since the sender's resistance varies with temperature, the coil's magnetic strength varies. More current flows when the resistance is low (high engine temperature) and so a stronger magnetic field is created. As engine temperature increases, the greater magnetic strength of the high temperature coil attracts the armature and pointer to a point of balance between the two sides. The scale is calibrated to the pointer movement.

AIR PRESSURE GAGE

An air pressure gage (for use with vehicles equipped with air or air-hydraulic brake systems) is employed to indicate air pressure in storage tanks. The air pressure gage operates on the Bourdon principle and utilizes a Bourdon tube. The gage face is marked in graduations of 30 psi, from 0 to 120; however, full system pressure is 100 psi. With the engine running, the air compressor governor cuts in at about 75 psi and the compressor builds up pressure to full (100 psi). The vehicle must not be driven until pressure is up to 60 psi. If, during operation, the air pressure buzzer sounds (when below 60 psi), the vehicle must be stopped until the malfunction has been located and corrected.

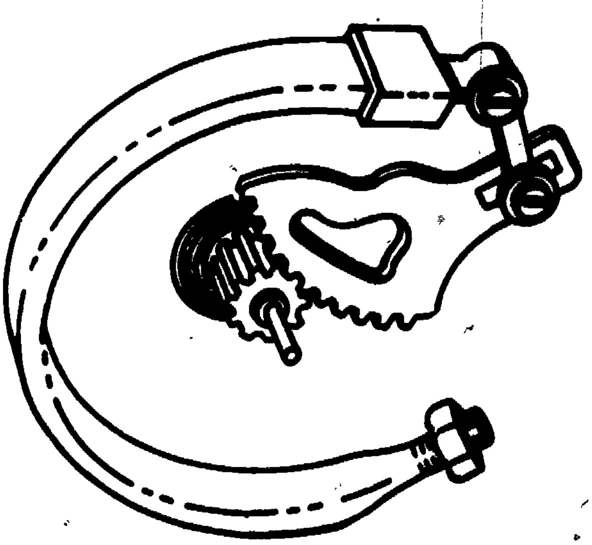


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Figure 11-6.–Bourdon tube.

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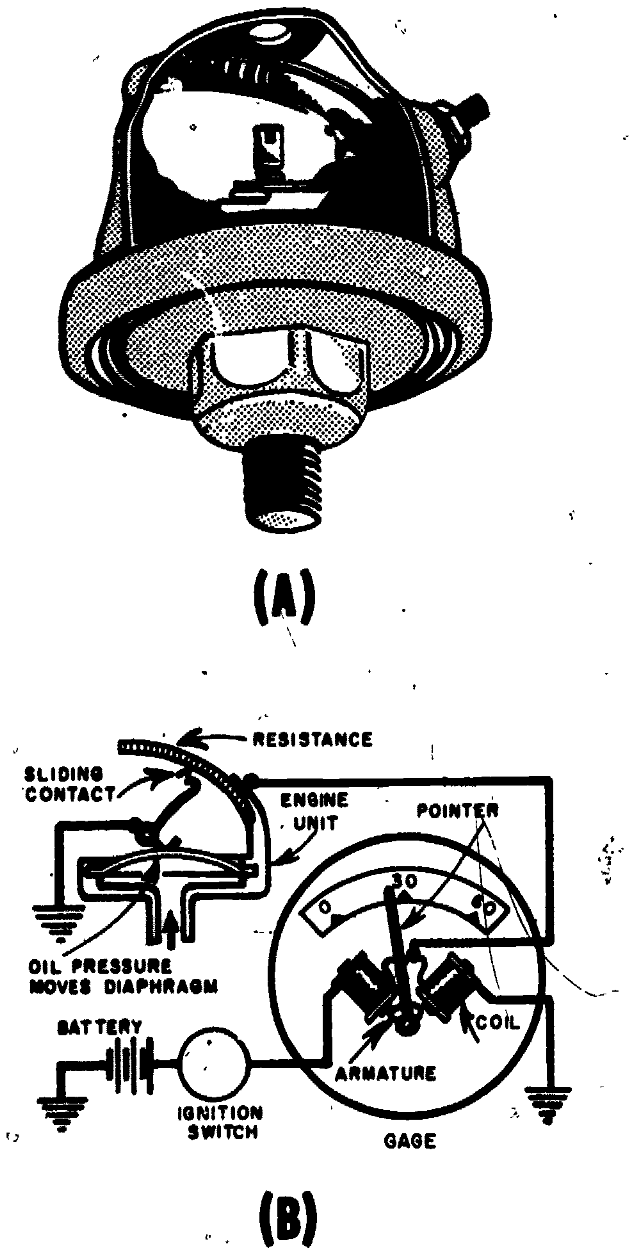

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Figure 11-7.—(A) Oil pressure sending unit; (B) schematic diagram of balancing coil oil pressure indicating system.

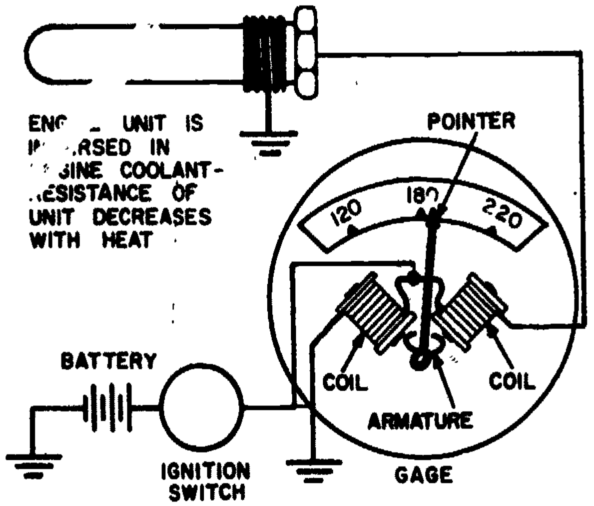

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Figure 11-8.—Electrical type temperature gage.

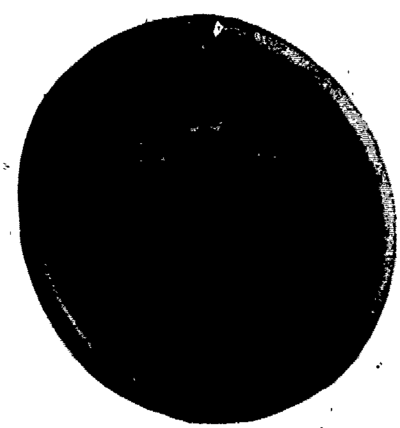

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Figure 11-9.—Speedometer.

SPEEDOMETER AND TACHOMETER

A speedometer (fig. 11-9) is used to indicate vehicle speed in miles per hour, and an odometer (frequently on the same instrument) records distance traveled. The speedometer may be driven either by a flexible shaft or by electrical

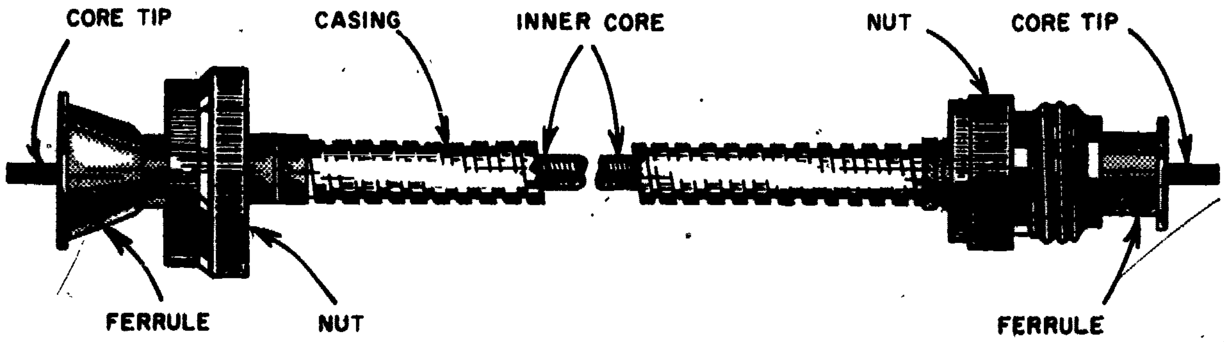

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Figure 11-10.—Speedometer and tachometer drive shaft.

means. The type using a flexible shaft has a set of gears in the vehicle transmission. This set of gears drives the flexible shaft and the flexible shaft, in turn, drives the rotating part of the speedometer and the gears of the odometer. The gears are designed for the particular vehicle model and take into consideration the tire size and rear axle ratio. The flexible shaft consists of an outer casing and an inner drive core. (See fig. 11-10.) The speedometer driven by electrical means is comprised of two separate units, a generator (or transmitter) and an indicator, connected by electrical wires.

The tachometer (fig. 11-11) is ordinarily used to indicate vehicle engine speed. It is similar to the speedometer, except that the face dial indicates revolutions per minute instead of miles per hour. The tachometer may be driven either by a flexible shaft or by electrical means. The type using a flexible shaft is driven, through the shaft, from the vehicle generator, camshaft, or distributor shaft. The tachometer driven by electrical means is comprised of two separate units, a generator (or transmitter) and an indicator, connected by electrical wires. An hourmeter is often incorporated in the tachometer to record operating time.

Operation of Speedometer and Tachometer

Even though the internal parts of the various instruments differ in construction and appearance, they all incorporate the same basic components and operate on the same principles. Operation of the speedometer and tachometer using the flexible shaft is discussed in the following paragraphs.

SPEED INDICATOR.—The speed-indicating portion of a speedometer (fig. 11-12) or tachometer of the magnetic type is operated by a permanent magnet being driven by a flexible shaft. Around this revolving permanent magnet is a stationary field plate. (Some instruments have a revolving field plate.) Between the magnet and field plate is a movable speed cup, with the indicating pointer attached to the end of the speed cup staff.

As the magnet revolves within the speed cup, it sets up a rotating magnet field which exerts a

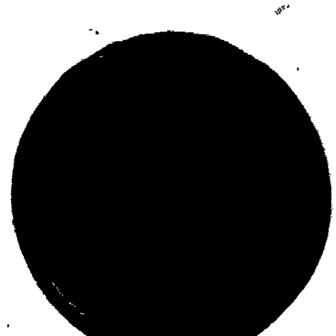

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Figure 11-11.—Tachometer.

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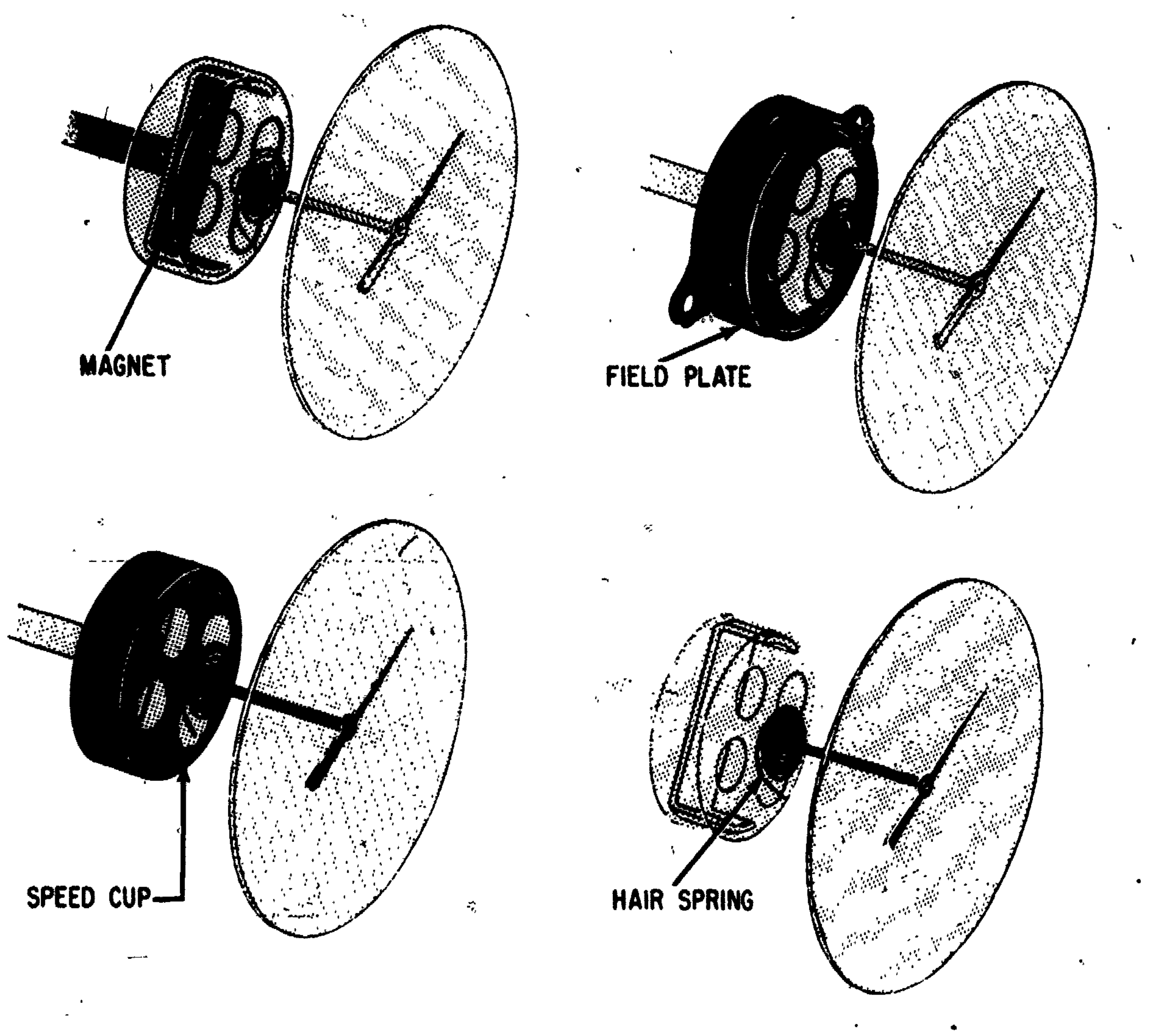

Figure 11-12.—Sectional view of indicating portion of the speedometer.

pull, or magnetic drag, on the speed cup, making it revolve in the same direction. Movement of the speed cup is retarded and held steady by a hairspring attached to the speed cup staff. The speed cup comes to rest at a point where the magnetic drag is balanced by the retarding force created by the hairspring. An additional function of the hairspring is to pull the pointer back to zero when the vehicle or engi. . stops.

There is no mechanical connection between the revolving magnet and the speed cup. As the speed of the magnet increases due to vehicle acceleration or (as in the case of a tachometer) to an increase in engine speed, the magnetic drag on the speed cup also increases and pulls the speed cup farther around, thus registering a faster speed by the pointer and face dial. The magnet's magnetic field is constant, and the amount of speed cup deflection is at all times proportional to the speed at which the magnet is being revolved.

TOTAL ODOMETER.—The total odometer (fig. 11-13 (A)) is driven through a series of gears originating at a spiral gear out on the magnet shaft. This gear, known as the first gear, drives an intermediate second gear and a third gear which is connected to a fourth gear at the odometer. The fourth gear turns the odometer through a series of star pinion gears inside the odometer dials, or figure wheels. The total odometer usually has five figure wheels, or dials, and is so constructed and geared that as any one wheel finishes a complete revolution it turns the next figure wheel to the left one-tenth of a revolution. Most models record to 99,999 miles, then automatically zero themselves.

TRIP ODOMETER.—The trip odometer (fig. 11-13 (B)) is also driven by the third gear, through the trip odometer drive gear and another gear at the trip odometer. The trip odometer usually has four figure wheels, and is so constructed that as any one figure wheel finishes a complete revolution, it turns the next figure wheel to the left one-tenth of a revolution. The figure wheel on the extreme right registers in tenths of a mile. Most models record to 999.9 miles, then automatically zero themselves. Also, they are usually equipped with a reset mechanism so that the mileage on the trip odometer can be reset as desired.

Electrical Type

Electrical type speedometers and tachometers utilize a small generator (transmitter) driven mechanically. The voltage produced causes a synchronous motor (receiver) in the indicator

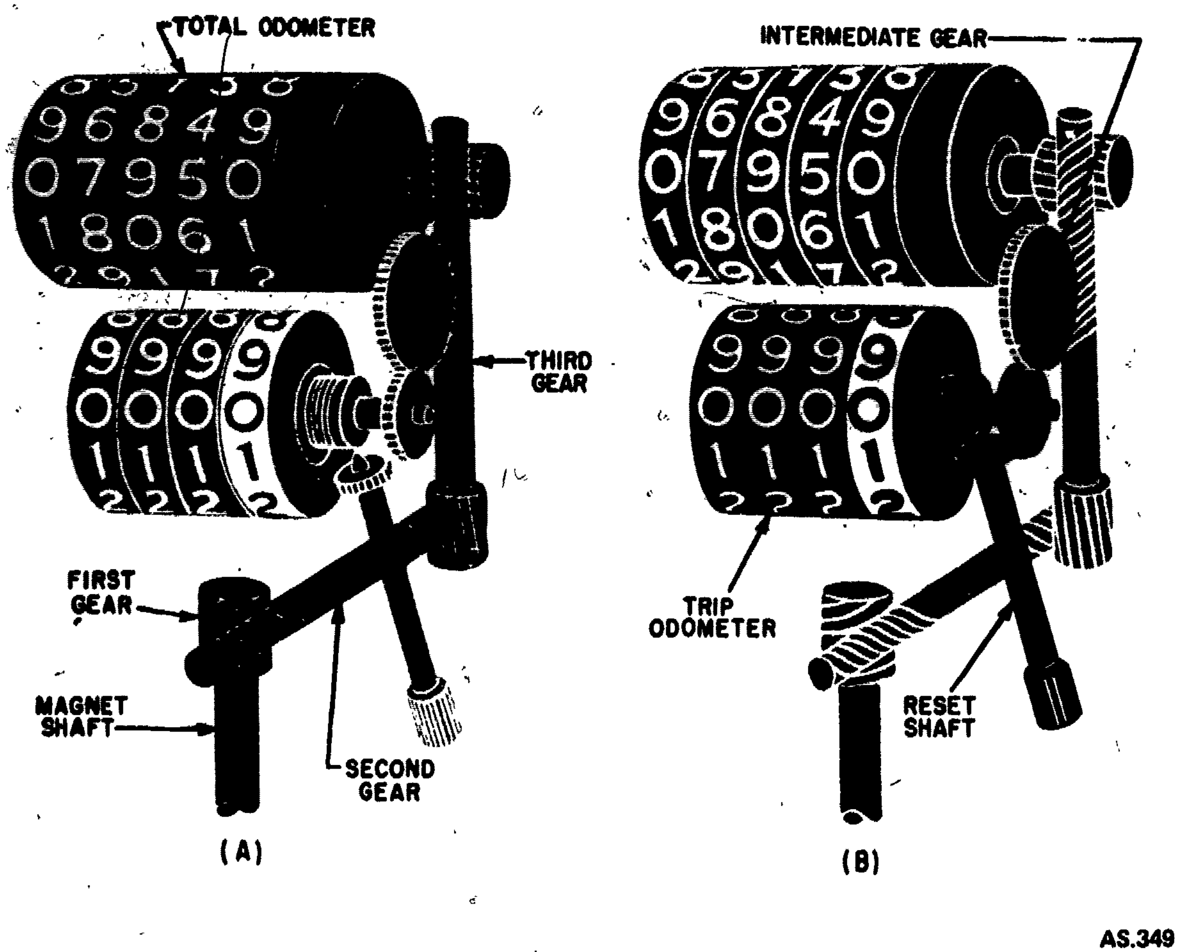

Figure 11-13.—(A) Total odometer; (B) trip odometer.

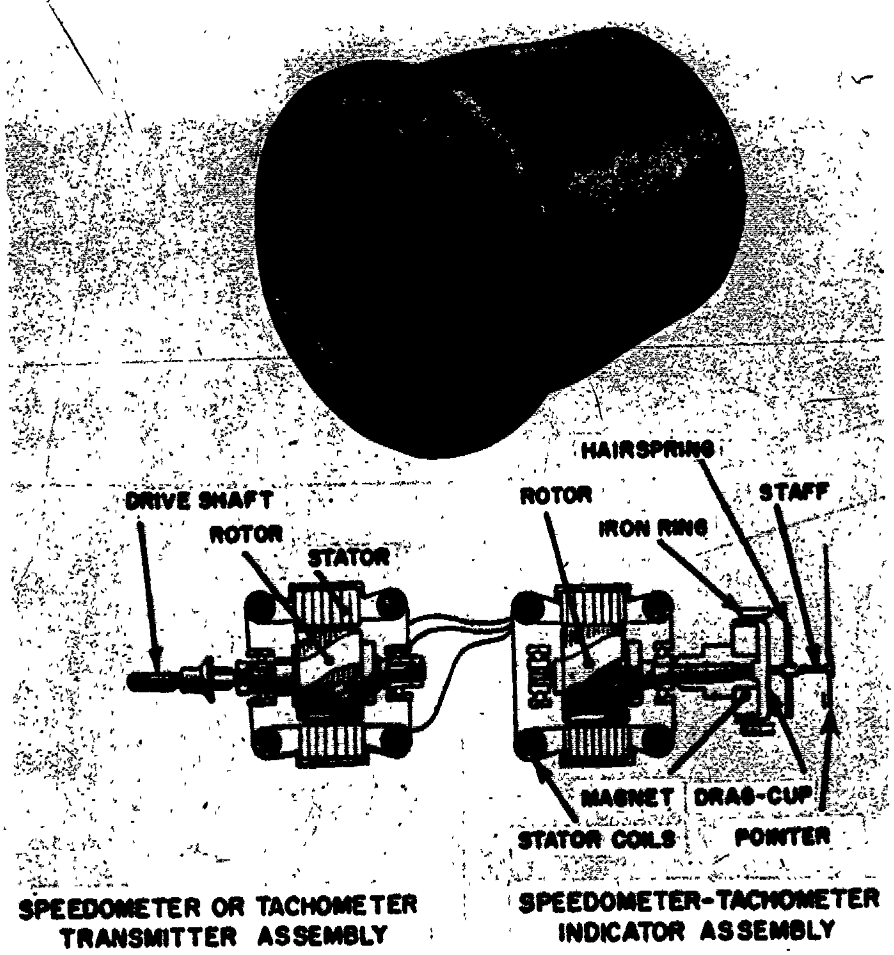

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Figure 11-14.—Electrical type speedometer-tachometer.

assembly to operate, thereby indicating vehicle and engine speed.

There may be several different arrangements or combinations of the electrical speedometer and tachometer. For instance, the speedometer and tachometer may be two completely independent systems, or there may be one transmitter and one receiver with a dual face, as shown in figure 11-14. If this instrument is used on a vehicle and driven by gears in the transmission, the tachometer will be inaccurate until a certain gear, normally high gear, is reached. Another arrangement involves two transmitters—one driven by the transmission for vehicle speed, and one driven by the engine for engine rpm. This type arrangement utilizes one indicator containing two receivers with independent pointers and dials. With this arrangement, both the speedometer and the tachometer are accurate in any gear.

The speedometer transmitter is driven from the final drive of the vehicle, usually the output shaft of the transmission. The tachometer transmitter is usually driven from an engine accessory drive, such as the ignition distributor drive. The output voltage of a transmitter is proportional to the speed at which it is driven; likewise, the speed of a receiver is proportional to the output voltage of the transmitter. The receiver speed determines the position of the pointer on the face of the indicator.

WARNING LIGHTS

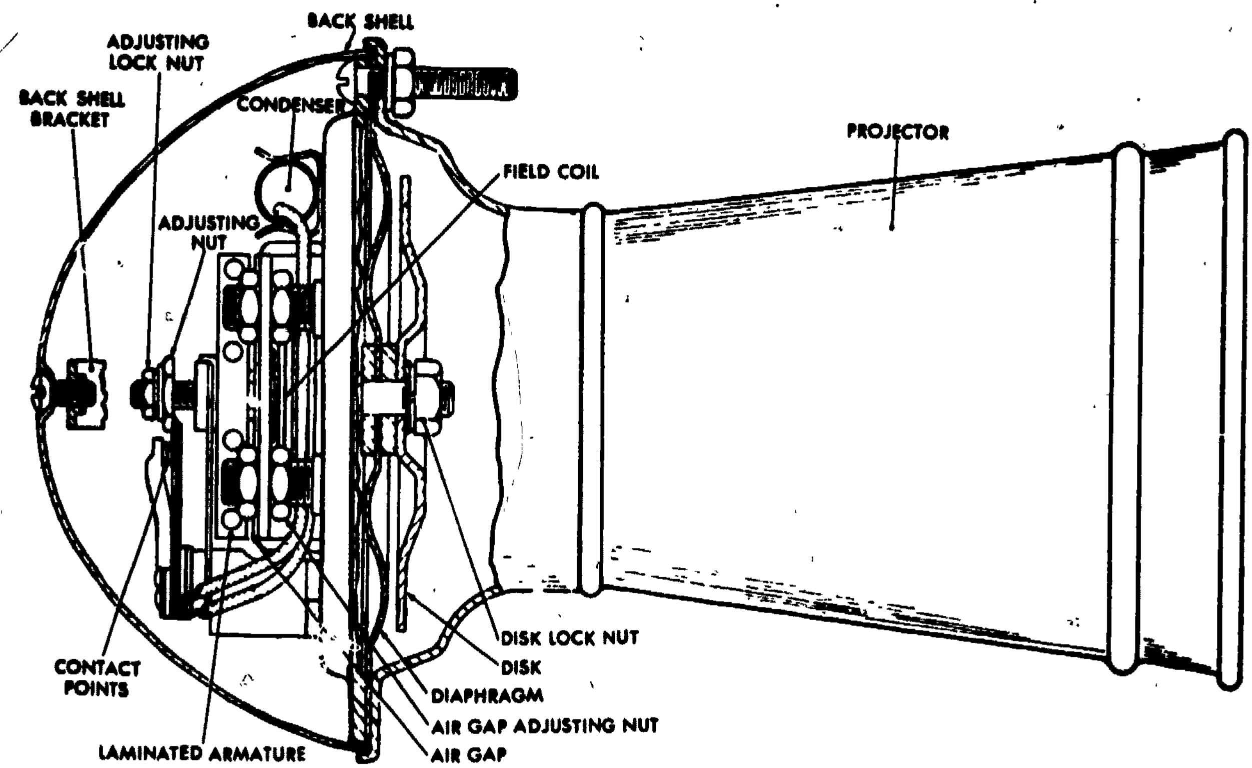
Some automotive manufacturers prefer a warning light system that indicates certain operating conditions, rather than a gage indicating system. The warning light is usually controlled by switches which may be operated by pressure, temperature, or mechanical linkage. The ASE may come in contact with vehicles that utilize either a warning light system, or a combination of warning light and gage systems.

NOTE: To provide a means of testing the warning lights, they are usually wired so that they illuminate when the ignition switch is placed in the starting position.

Temperature

Most late model vehicles utilize an engine temperature warning light (located on the instrument panel) in place of the conventional engine temperature gage. The warning light is wired in series with the ignition switch and the engine temperature sending unit. The sending unit provides ground for the warning lights when its contacts are closed. There are two systems for the temperature warning lights that are commonly used.

One of the systems contains a cold light (green) and a hot light (red). These lights are controlled by the engine temperature sending unit which has two sets of contacts, one set being normally closed for the cold light and one set being normally open for the hot light. The contacts are mounted on bimetal strips which



AS.351

Figure 11-15.—Electrical vibrator type horn.

cause them to open and close at predetermined temperatures. For example, when the engine is first started, the cold light comes on until the engine reaches normal operating temperature; then the cold light switch contacts open and the light goes off. This lets the operator know that it is safe to apply load to the engine which is then at normal operating temperature. Likewise, if the engine overheats, the hot light switch contacts close and the hot light comes on, warning the operator of the overheating condition.

The other system mentioned operates on the same principles but does not have a cold warning light. It has the hot warning light and an engine temperature sending unit with a single set of normally-open contacts. If the engine overheats, the contacts close and turn on the hot warning light.

Oil Pressure

The oil pressure warning light installed on some vehicles is also located on the instrument panel to indicate when the oil pressure is very low. The warning light is wired in series with the ignition switch. The oil pressure switch is located on the automotive engine.

The oil pressure switch contains a diaphragm and a set of contacts. When the ignition is turned on, the warning light should illuminate, because the light circuit is energized through the closed contacts in the oil pressure switch. When the engine is started, built-up oil pressure compresses the diaphragm, opening the contacts, thereby opening the circuit and causing the light to go out. The warning light is usually red in color, and indicates a bright "Oil" on the instrument panel.

Generator

Some vehicles utilize a generator warning light mounted on the instrument panel in place of the ammeter. The light indicates to the operator when the generator is charging the battery. The warning element is a panel-mounted window (usually red) behind which is mounted a small light bulb. The light comes on when the ignition is turned on and the generator is not charging. The circuit is completed from the ignition switch, through the light, to a terminal on the voltage regulator.

When the engine is started and the generator speed is increased to develop sufficient voltage, a relay within the voltage regulator closes, causing the main relay contacts to close. When the main relay contacts close, the generator warning is short circuited, causing the warning light to go out.

In another type of generator warning system, the warning light is connected in the circuit between the battery and generator output. When the generator begins to develop an output, it opposes the battery voltage to the generator warning light. As the differential between these two voltages decreases, the light goes out, indicating that the generator is on the line.

AUXILIARY ACCESSORIES

HORNS

The horn installed on automotive equipment is used as a warning device to pedestrians or crewmen of a moving vehicle. The horn is a magnetic switch (somewhat like a vibrating voltage regulator relay) which sets a diaphragm into rapid vibration when connected to the battery. Horns may be used in matched pairs so that a blended and more resonant signal is produced.

Operation

The most common type of horn (fig. 11-15) is the vibrator type. A winding is connected in series with a set of contacts within the horn; the contacts are closed when the horn is not energized.

When the external circuit to the battery is closed (by the horn pushbutton or horn relay), current flows through the contacts and winding. This causes the magnetic field to attract the armature of the coil to the winding core. The armature is mounted to the horn diaphragm so that movement of the armature causes a distortion of the diaphragm. The armature movement also operates the horn contact points that break the circuit.

When the contact points open, the magnetic field of the winding collapses, and the armature returns to its normal position as the distortion of the diaphragm is relieved.

When the contacts are closed again, a new surge of current induces magnetism in the coil and starts a second movement of the diaphragm. This cycle is repeated rapidly. Vibrations of the diaphragm within an air column produce the note of the horn.

Adjustment

Before making any adjustment, insure that the horn is properly grounded and there is correct voltage at the horn. To obtain a good sound from a horn, a minimum of 5.25 volts is required for the 6-volt horn, and a minimum of 11 volts is required for the 12-volt horn.

Tone and volume adjustments are made by loosening the adjusting locknut and turning the adjusting nut. This very sensitive adjustment controls the current consumed by the horn. Increasing the current increases the volume; however, too much current will make the horn sputter, and may lock the diaphragm.

Dual Horns

In dual horns, one horn having a low pitch is blended with another horn having a high pitch. These horns, although operated electrically, produce a sound closely resembling that of an air horn. The sound frequency of the low pitch horn is controlled by a long air column, and that of the high pitch horn by a short air column. The air column is formed by the projector and by a spiral passage cast into the base of the horn.

Most horns draw enough current to necessitate having a relay in the circuit. A horn circuit having a relay is shown in figure 11-16. By having a relay in the horn circuit, the contacts of the horn button (switch) are protected, and many more hours of trouble-free service are obtained than with a horn circuit that does not have a relay.

ELECTRICAL MOTORS

Electrical windshield wipers, heater fans, defroster fans, and other accessories are driven by small electrical motors. The amount of current drawn will depend on the particular motor and the load placed on the motor. The motors, with exceptions of the starter motor, should be connected to the ammeter so that any battery current used to run them is indicated by the ammeter. The construction and theory of operation of a-c and d-c motors are covered in detail in Basic Electricity, NavPers 10086 (Series).

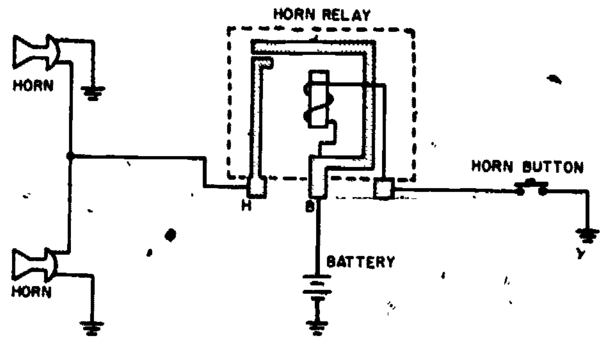


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Figure 11-16.—Dual horns and relay circuit.

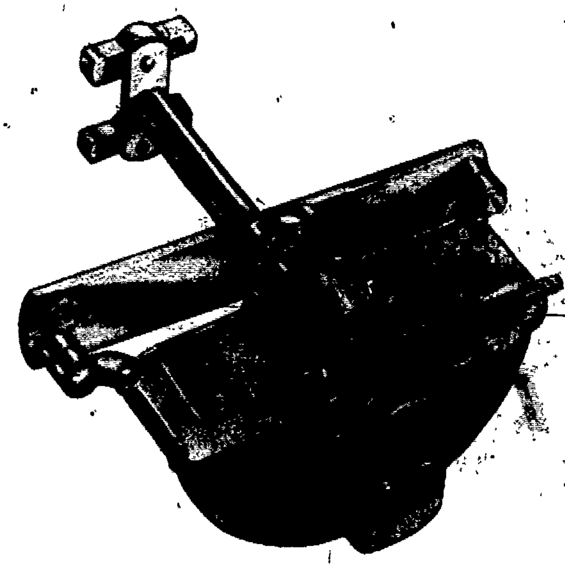

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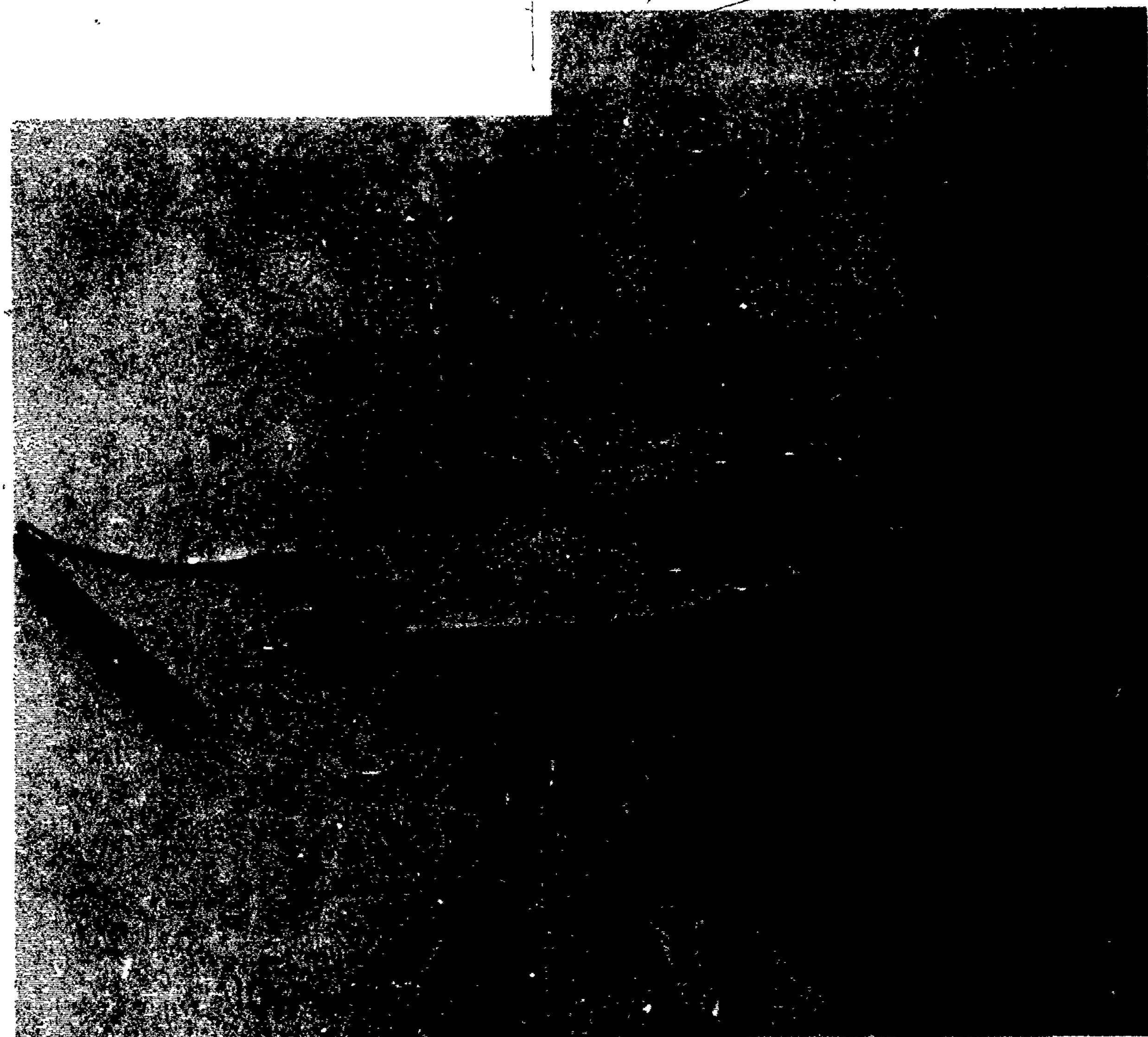
Figure 11-17.—Vacuum windshield wiper motor.



1. Wiper arm.
2. Wiper arm nut.
3. Pivot cover.
4. Mounting bracket.
5. Wiper blade.
6. Linkage.
7. Motor.
8. Pivot.
9. Circuit breaker.
10. Wiper switch.

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Figure 11-18.—Electrically operated windshield wipers.

WINDSHIELD WIPERS

The windshield wiper usually consists of a metal strip with a rubber insert attached to a rod that swings in an arc across the windshield, and the necessary mechanical linkage driven by either an electrically driven or a vacuum operated motor.

Vacuum

Vacuum operated windshield wipers (fig. 11-17) depend upon the vacuum in the intake manifold. The vacuum motor consists essentially of a piston within a cylinder. Valves, controlled by the piston position, alternately connect opposite ends of the piston cylinder to the intake manifold. In this way the piston is moved back and forth within the cylinder. Movement of the piston causes the operating shaft to oscillate, which, in turn, causes the windshield wiper blades to move in an arc back and forth across the face of the windshield.

Some automotive vehicles may be equipped with a single windshield wiper placed directly in front of the operator. In order to increase visibility and widen the range of vision, most modern vehicles are equipped with dual wipers. Most duel wiper systems are operated by one motor through suitable linkage.

Electric

Electrical-type windshield wipers (fig. 11-18) are usually driven by shunt or compound wound motors. The wipers may be driven in three different speeds—slow, medium, and fast.

To obtain satisfactory operation from electrical windshield wipers, it is essential that the motor, linkage, and drive pivots operate freely, otherwise operation may be noisy or complete failure may result.

A modern three-speed windshield wiper schematic is shown in figure 11-19. The system contains a compound type motor, a gearbox, and a relay.

The control switch has four positions—OFF, LO, MED, and HI. Wiper speed is controlled by increasing or decreasing the amount of current in the shunt field. At low speed, the motor has no external shunt field resistance, and maximum shunt field current flows. For medium speed, resistors R1 and R2 are connected in parallel with each other and in series with the shunt winding, thereby reducing the shunt field current. In high speed, only R1 is in series with the shunt field, resulting in maximum shunt field resistance, minimum shunt field current, and the least opposition to the series field. When the switch is placed in the "OFF" position, the motor continues to operate until a cam on the crank arm strikes a switch button (not shown), opening the circuit and placing the wiper in the park position.

Some windshield wiper systems have a windshield washing unit. The washers are energized by depressing a button which is part of the control switch. When the button is depressed, the washer relay coil is energized, placing the pump in operation.

HEATERS AND DEFROSTERS

Hot water heaters are part of the engine cooling system, since they circulate the cooling liquid from the engine through the heater radiator. The heater has an electrically driven

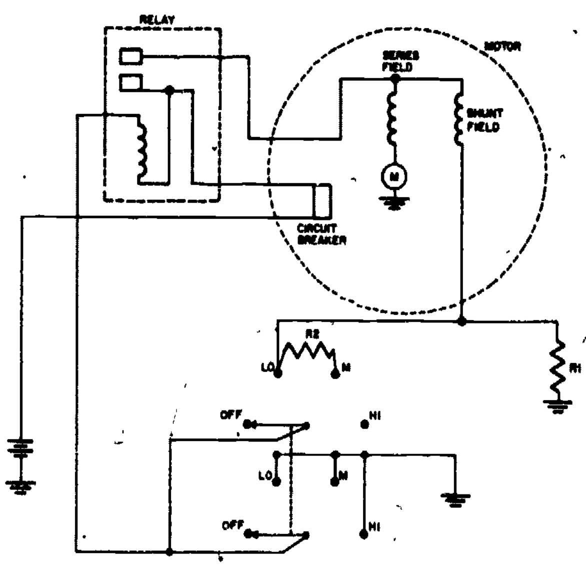

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Figure 11-19.—Schematic diagrams of a three-speed windshield wiper.

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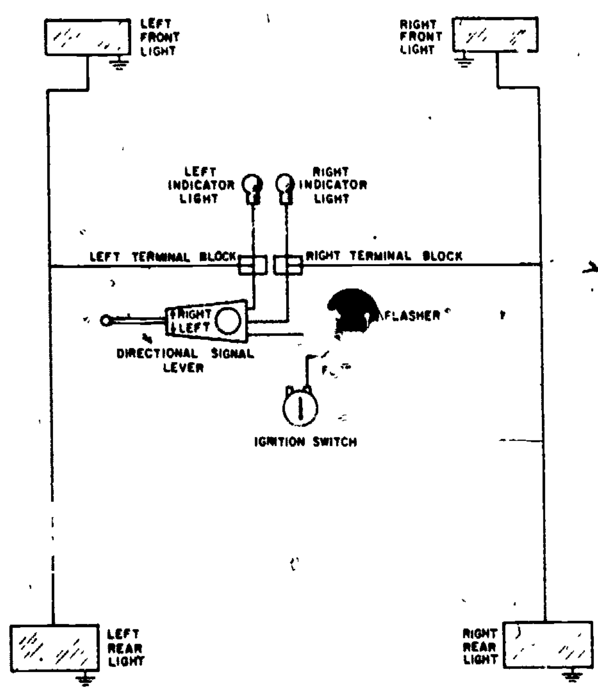

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Figure 11-20. -Pictorial diagram of a directional signal system.

fan which circulates air through the heater radiator so that the output air is warmed.

The defroster operates in a manner similar to the heater, usually deriving heat from the same heater radiator. The defroster, however, directs the flow of warm air against the windshield to prevent condensation or freezing of moisture.

The only service the heater will normally require is a periodic flushing out when the engine radiator is flushed. A defective heater fan motor is usually replaced by a new one; however, it is possible to replace bearings, armature, brushes, and certain other small parts under emergency conditions.

DIRECTIONAL (TURN) SIGNALS

The directional signals (fig. 11-20) permit the operator to signal his intention to make a right or left turn. The direction of turn is indicated by flashing lights on the front and rear, and sometimes on the side of the vehicle. The rear lights are red in color and part of the stoplight system; the front directional signals are usually white or amber in color. Both the front and rear lamps (bulbs) of the directional signal system normally contain a second filament which is used in the parking light system. Indicator lights are installed on the instrument panel of the vehicle to provide the operator with the following indications:

1. Direction of the turn.
2. Whether or not the directional signal switch lever has returned to the neutral position after completion of a turn.
3. The system is operating properly or improperly.

When the signal switch lever is moved in one direction or the other, a circuit is completed between the battery and the proper indicating lights. The connections are completed through a flasher, a device that opens and closes the circuit at proper intervals, thus providing a flashing signal. The flashing action is a result of heating a thermostatic element within the flasher. The wiring circuit of a representative stop-directional light signal system indicating a right turn with the brakes applied is shown in figure 11-21.

The directional signal switch (fig. 11-22) is located under the steering wheel. The lever is manually operated to indicate a turn, and when the turn is completed and the steering wheel is returned to the straight ahead position, the switch is unlatched and returned to neutral position. The return action is accomplished by means of a cam on the steering wheel hub and a trigger on the switch-lever plate. Directional signal levers automatically return to neutral after the turn has been made.

AUXILIARY POWER RECEPTACLES

Auxiliary power receptacles vary from vehicle to vehicle. In some applications, the auxiliary power receptacle is mounted near the equipment battery. The receptacle has two large pins; one pin is connected to the positive terminal of the battery, and the other pin is connected to the negative terminal.

The auxiliary power receptacle is used to obtain power from an external source for charging batteries, engine starting, and for operating other components on the vehicle.

The NC-5 and a few other power units provide convenience outlets (power receptacles) of a.c. and d.c. for use by the maintenance crews in performing their duties. In this application the power generating system of the vehicle provides power to the outlets. Through proper placement of switches, power can be obtained for test equipment, soldering irons, etc., so tests and repairs can be made without having to move to shop or hangar spaces.

RADIO (ELECTRONIC) INTERFERENCE AND INTERFERENCE SUPPRESSION

Any sparks created by the operation of electrical equipment (spark plugs, circuit breakers, coils, generators, regulators, magnetos, distributor assemblies), by a loose or dirty connection, or by chafing of metal to metal may cause interference with radio reception of nearby receivers. In addition, such sparks can disclose the location of the vehicle to sensitive electronic detectors. Since the units of electrical equipment are connected by a wire or a series of wires, as in an automotive ignition system, the wiring acts as an antenna to transmit the interference created by the spark into the air. The spark-producing unit causes the radiated energy to affect a wide band of frequencies on a radio receiver, with pronounced effects on certain frequencies.

Ignition Noises

When distributor breaker points are opened and closed by operation of the engine, the

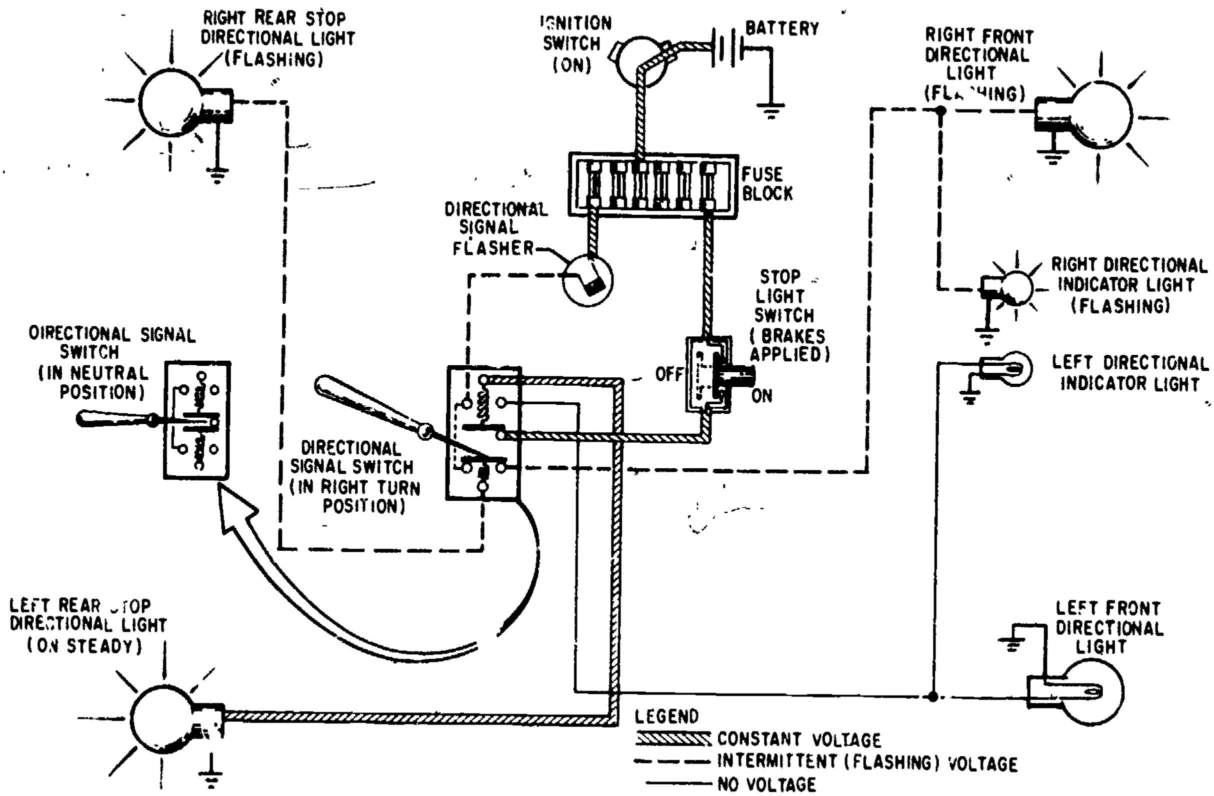


Figure 11-21.–A representative stop-directional light signal system indicating a right turn with the brakes applied.

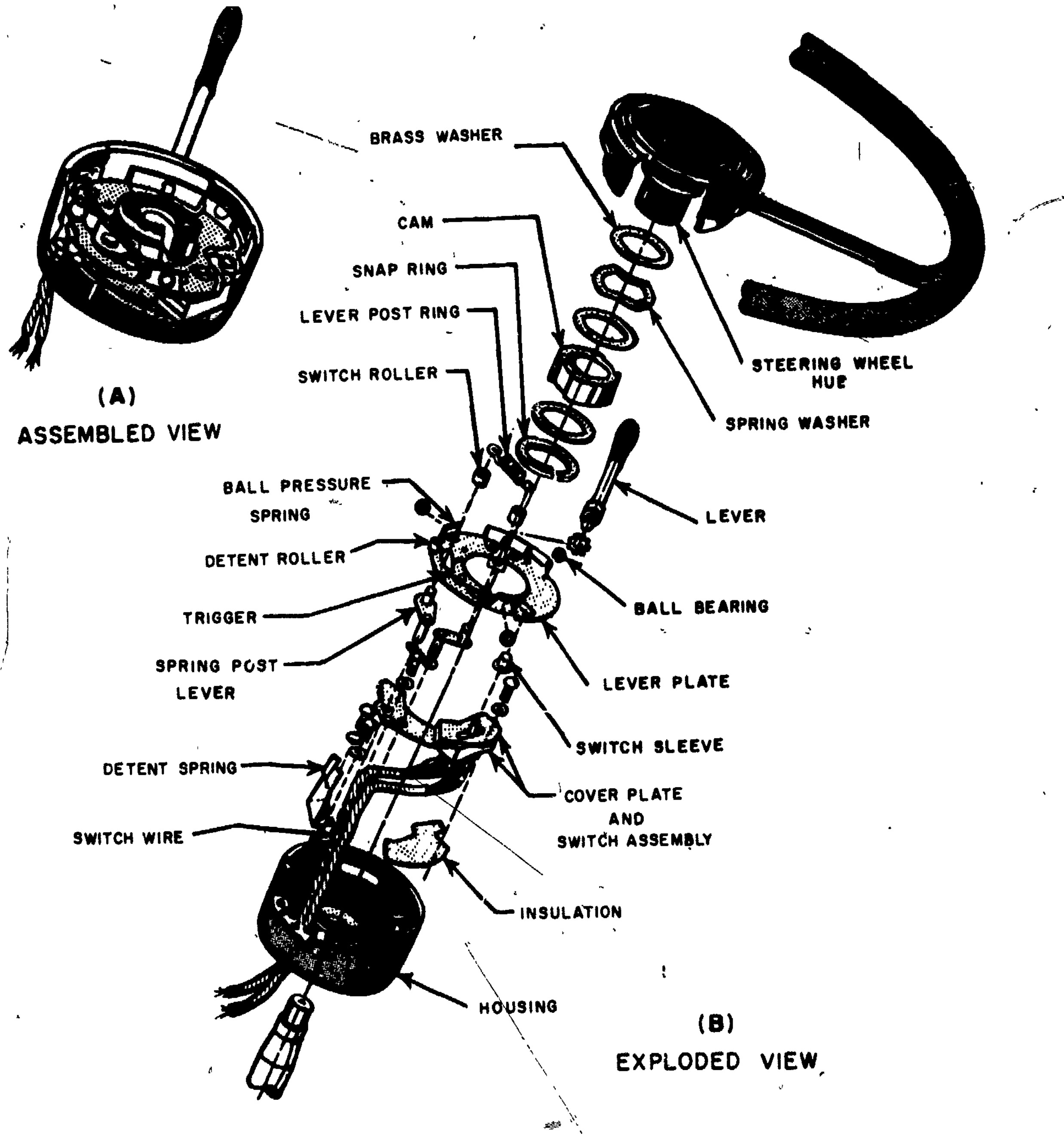


Figure 11-22.—A directional signal switch.

ignition coil produces a high voltage current which flows across the gap in the spark plug to cause ignition. The sparks at the plugs and those at the breaker points cause violent surges of current to flow in all wires involved in spark plug firing (fig. 11-23). Around each wire, a magnetic field builds up and collapses with each make and break of the circuit.

The resultant noise in the receiver from breaker points, distributors, or spark plugs is recognized by clicking sounds which vary in rapidity and intensity with the speed of the engine.

Generator Noises

With the generator in operation, there is some sparking between the brushes and commutator segments. Generators in good mechanical condition may exhibit some sparking, but this usually is not severe enough to cause radio interference. This type of sparking is increased by any of the mechanical defects listed below:

1. Brushes do not fit commutator.
2. Brushes worn more than one-half original length.
3. Incorrect brush spring tension.
4. Collection of oil or carbon particles around commutator.
5. Commutator worn out-of-round.
6. Generator loaded in excess of rated capacity.
7. Commutator segments burned or grooved.
8. High insulation between segments of commutator.

Sparking between the brushes and commutator segments may cause interference in nearby radio sets. This type of interference can be recognized by a roaring or whining noise that varies in pitch with the speed of the engine.

Body Noises

Body noises are produced by loose screws and bolts which allow various parts of the body to chafe against each other. This chafing produces static discharges which are a source of interference to radio receivers. Static charges caused by friction and induced charges from wiring on the vehicles are collected by the vehicle body.

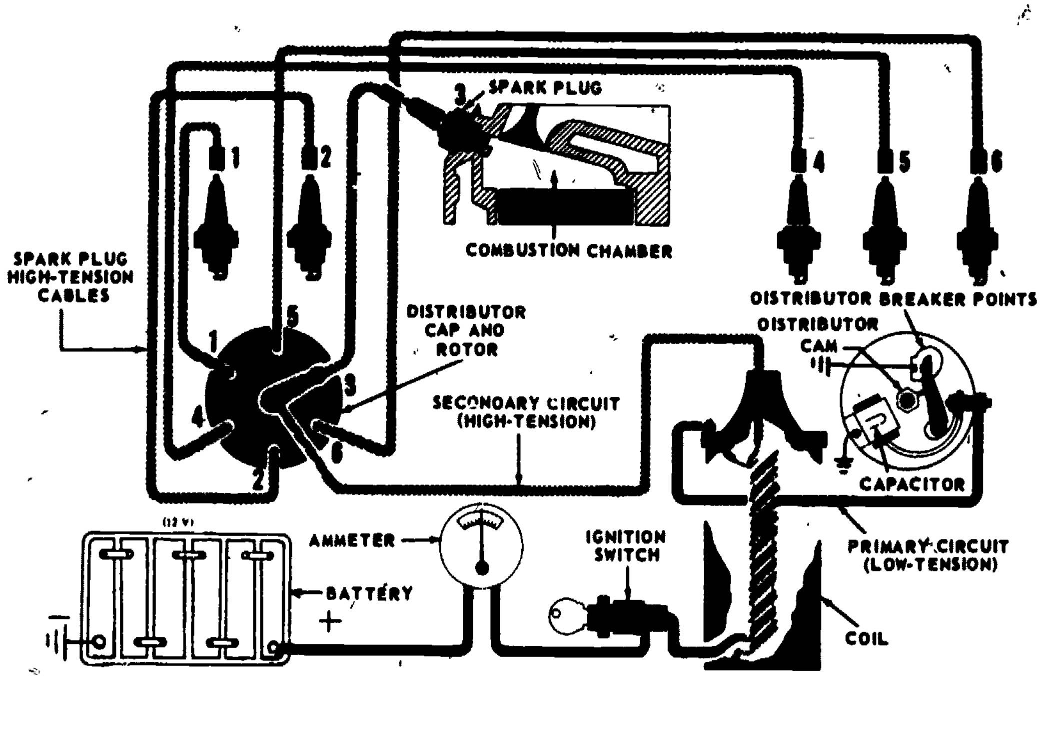


Figure 11-23.—Schematic of a representative battery ignition system.

These charges are retained by poorly grounded sections of the body until they build up to a sufficient value to jump to any well-grounded part of the vehicle. Each discharge causes a spark of sufficient intensity to create interference in a radio receiver.

Looseness in the hood, brackets, and bolts can cause considerable noise in a receiver. This type of disturbance is intermittent, varies in volume, and can be detected as a frying or snapping sound. It can be detected only when the vehicle is in motion, or, by moving the loose parts, it can be recongized as a scratching sound in a receiver.

Suppression Methods

Various methods are used to suppress radio interference caused by a vehicle:

1. Resistor-suppressors.
2. Capacitors.
3. Filters.
4. Bonding.
5. Shielding.

Application of one of the above methods is usually sufficient to adequately suppress the interference from any one source. However, in some instances it may be necessary to use a combination of these methods to obtain the desired amount of suppression.

RESISTOR-SUPPRESSORS.—These are normally installed in the secondary circuit of the ignition system. They may be in the form of a resistor built into the distributor rotor, distributor cap, spark plugs, or ignition leads, and at the present time the resistor type ignition leads are the most widely used type of suppressors. The resistor-suppressors are placed into the secondary circuit to reduce the intensity of electrical surges that occur in the circuit, and thus reduce the interference in electronic equipment. The resistance of the suppressors is high enough to control the electrical surges but not high enough to affect the operation of the engine.

CAPACITORS.—These are units of metal foils separated by paper insulation and protected by a metal case. The case is filled with an impregnating compound to keep moisture out. A wire connected to one side of the capacitor is provided for connection internally to the case.

Surges created in the wiring by sparks at the generator brushes, regulator, and gage contacts are not as strong as those produced by high-tension ignition circuits because the voltage is low, but they are strong enough to cause interference in a radio set. Resistor-suppressors cannot be used in these circuits because their resistance would reduce the low voltage current too much. However, capacitors may be used to dissipate these surges. They are attached to the circuit as near as possible to the point at which the spark occurs. The case of the capacitor is mounted on the metal frame of the unit causing interference, and the capacitor wire is connected to the terminal. A capacitor allows the interfering voltage to pass freely to ground (frame and body of vehicle), and at the same time prevents any loss of the useful direct current. Thus, the surges are conducted away from the wiring and cannot cause interference.

FILTERS.—An assembly made of a closely wound coil of heavy wire and one or more capacitors, all electrically connected together and mounted in a metal container, is called a filter. The capacitors act in the same manner described previously, and the coil of wire acts to block the interfering voltage from getting farther into the circuit. Filters are used in some generator, regulator, and low-tension ignition circuits.

BONDING.—This term is applied to the method of electrically connecting individual metal sections to each other and to the frame or body of the vehicle. Such bonding is necessary to provide an easy path to ground for static charges. Bonding is accomplished by internal-external toothed lockwashers, and by bond straps. The better the connection between metal parts, the greater is the effect in preventing interfering waves from being thrown off to affect radio reception.

SHIELDING.—This term is applied to the method of covering with a grounded metal shield all wiring carrying interfering voltages or surges. Woven metal conduit is used where flexibility is required, while solid conduit is used elsewhere. Units causing interference, such as spark plugs, ignition coil, distributor, and regulator, are enclosed in metal. This shielding does not reduce the intensity of the interfering surges, but prevents their radiation by providing a path to ground. While such shielding is effective in preventing the radiation of interfering waves, filters and capacitors are necessary to eliminate any interfering surges that would otherwise travel on the wires and affect the radio set through the power supply. Such filters and condensers are enclosed in metal boxes provided with means of attachment to the conduit which contains the connecting wires.

Suppression of radio interference is a task of utmost importance to the ASE. Any electrical interference in ground support equipment may result in improperly alined or tuned aircraft electronic equipment, which would greatly reduce the effectiveness of the aircraft. It behooves the ASE to be concerned and to become familiar with the problem of radio interference and how to eliminate it.

CHAPTER 12

POWER GENERATING EQUIPMENT

The electrical power requirements for starting and servicing modern aircraft are extremely high; even in aircraft equipped with batteries, and with the batteries fully charged, their capacity is not sufficient to withstand the heavy load of starting an aircraft engine or the power drain of prolonged operational ground checks.

The Navy has expended enormous amounts of time and money in the engineering of powerplants which are used for starting aircraft engines and for furnishing power for electrical and electronic circuits when performing operational ground checks.

NOTE: Batteries are not to be used to start aircraft reciprocating engines except in an extreme emergency. The purpose of an aircraft battery is to operate some of the instruments and the radio in case of a loss of generator power.

Although some theory is discussed in this chapter, the major intent is to acquaint the ASE with some of the most commonly used types of electric powerplants presently in service in the Navy. A general discussion of the electrical systems of each unit is given, tying together the major components which make up the particular powerplant.

Working with ground support equipment can be a very dangerous job unless the personnel understand and practice safety. Because of the potential dangers involved with electrical powerplants, assigned personnel should be extra cautious in operating and maintaining them.

MOBILE ELECTRIC POWERPLANTS

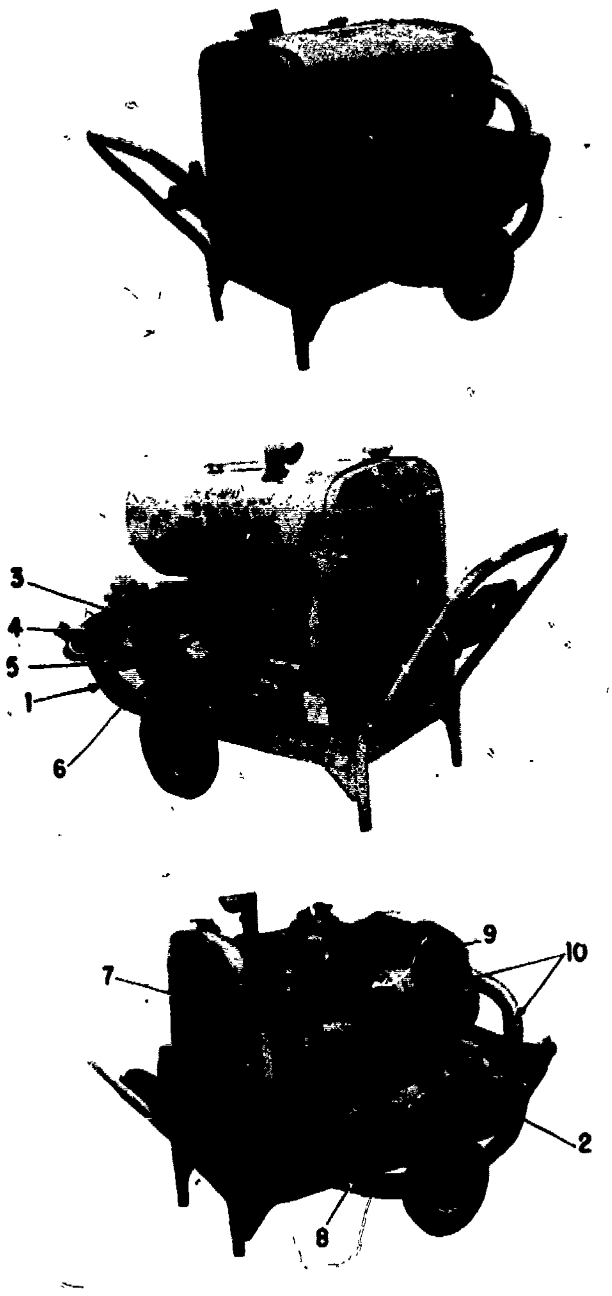
There are many and varied types of mobile electric powerplants (MEPP) available; some are designed for universal use, while others can be used only on specific aircraft. The ASE, therefore, should become familiar with the Index and Application Tables for Mobile Electric Powerplants, NavWeps 19-45-1. This manual contains technical data and general information and serves as a guide to various types and models of mobile and skid-mounted electric powerplants currently in service in the Navy.

E-APU

The model E-APU (fig. 12-1) produces d-c electrical power for starting aircraft reciprocating engines and for servicing aircraft electrical and electronic systems. This powerplant is a portable, self-contained unit consisting of a 4 cylinder, 4-stroke cycle, liquid-cooled gasoline engine which drives a standard aircraft generator through a system of four V-belts and a splined shaft.

The entire powerplant and the control box assembly, containing a voltage regulator, a reverse current relay, a voltmeter, and a switch assembly, are shock mounted on a 2-wheeled dolly. The unit is designed for portable duty where ease of movement is a prime factor. It may be easily converted for mounting in a stationary position simply by removing the handlebar, the wheels, and the axle assembly; or it may be suitably blocked up and bolted securely through four holes provided in the mounting rails—thus providing a permanent installation.

The engine is designed to operate at a maximum governed speed of 3,000 rpm; and the generator, running at 1.8 times engine speed, provides an output of 7.5 kw regulated to 28.5 volts d.c. Cooling air is provided through a blower and air duct arrangement to prevent the generator from overheating. (See fig. 12-1.) The electrical system wiring is arranged so that the reverse current relay (fig. 12-2) can be used as a



1. Power cable.
2. Control box.
3. Positive load terminal.
4. Equalizer.
5. Negative load terminal.
6. Oil Filter.
7. Magneto.
8. Generator.
9. Shielded ignition harness.
10. Cooling air ducts.

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Figure 12-1.—MEPP E-APU.

switch to motorize the generator when starting the engine. In some installations, the wiring is arranged so that the reverse current relay is bypassed during the motorizing operation. A standard 24-volt battery is an integral part of the powerplant.

The voltage regulator and the voltmeter are located on the subbase mounted on the powerplant.

The engine may be started either manually or electrically. Manual starting is accomplished by pulling the starting cable in one rapid movement. To start the powerplant electrically, place the control switch in the START position. (This causes the generator to operate as a motor; as such, it turns the engine until it starts.) Release the control switch when the powerplant engine starts. After the engine warms up, place the control switch in the LOAD position to supply power to the battery and the external load.

NC-2A

The NC-2A (fig. 12-3) is a self-propelled diesel-engine-powered service unit. It is front-axle driven, steered by the two rear wheels, and readily maneuverable in congested areas. The front axle is driven by a 28-volt d-c, reversible, variable-speed motor, capable of propelling the unit up to 14 mph on level terrain, and the unit has a turning radius of approximately 11 feet.

The primary source of power is a 3-cylinder, water-cooled diesel engine which drives the a-c and d-c generators through a speed increasing transmission. All controls, both propulsion and electrical power, are available to the operator on three panels located in the front and to the right of the operator's seat.

The powerplant is designed for air transport and is provided with two tiedown rings each on the front and the rear bumpers. Forklift channels are located between the front and rear axles, providing safe lifting points for the unit.

A-c Generator

The a-c generator is an aircraft type, single bearing, synchronous, 120/208-volt, 400-hertz,

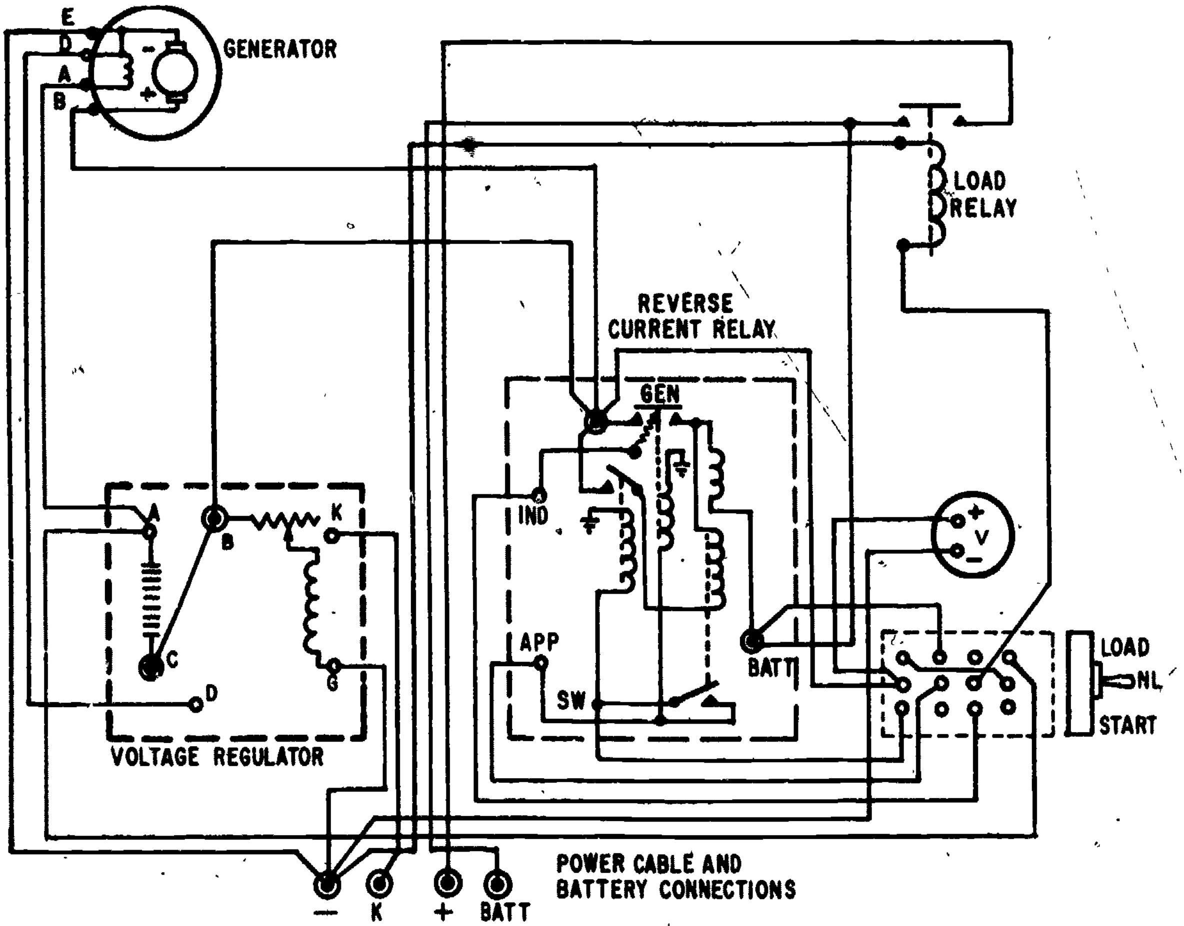

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Figure 12-2.—E-APU electrical generating system.

3-phase, 4-wire wye, brushless generator with an output of 30-kva at 6,000 rpm.

D-c Generator

The d-c generator is an aircraft type generator with an output of 28 volts and up to 500 amperes at a speed of 6,000 rpm.

Governors

The powerplant utilizes two electronic governors—the engine governor assembly and the drive control module assembly. The engine governor assembly monitors the output frequency of the a-c generator to control the engine speed. Speed control is accomplished by actuating the governor actuator motor, which adjusts the engine internal fuel control. With the START/DRIVE SERVICE POWER switch in the START/DRIVE position, the drive control module assembly controls the speed of the d-c motor by actuating the governor actuator motor, controlling the d-c generator output.

System Operation

The NC-2A system is broken down into four major circuits for ease of explanation, but it should be kept in mind that they are actually tied together and are interrelated. The following paragraphs describe the function and the operational sequence of various components and circuits of the NC-2A.

ENGINE STARTING CIRCUIT.–Refer to figure 12-4 for a simplified schematic of the starting circuit and to figure 12-5 for an illustration of the engine control panel. MASTER SWITCH CB4 must be closed, which will energize START CUTOUT RELAY K21, closing contacts B1 and B2. START/DRIVE-SERVICE POWER switch S29 must be in the START/DRIVE position prior to engine start.

Holding ENGINE START switch S14 in the start position energizes auxiliary start relay K20 and torque motor control relay K27. Start solenoid L1 is now energized through the closed contacts of relay K20, and starter motor B3 is energized through the closed contacts of solenoid L1. Fuel shutoff solenoid L3 is also energized, permitting free flow of fuel to the engine, and is held energized during unit operation through water temperature switch S11 and engine oil pressure switch S15.

The engine fuel control tube, which positions the fuel injector control racks, is connected to governor actuator motor B4 by means of the engine fuel rod. Battery voltage, reduced by resistor R9, drives the actuator motor to the injector full load position for engine starting through closed contacts A1 and A2 of relay K27.

After the engine fires, releasing ENGINE START switch S14 deenergizes relays K20 and K27, solenoid L1, and starting motor B3. Start cutout relay K21 is deenergized by voltage regulator VR3 when the engine reaches approximately 500 rpm. With the engine operating and relay K27 deenergized, control of the engine rpm is maintained by the governor actuator motor and the drive control module.

Should an overspeed condition occur during starting, or during unit operation, overspeed

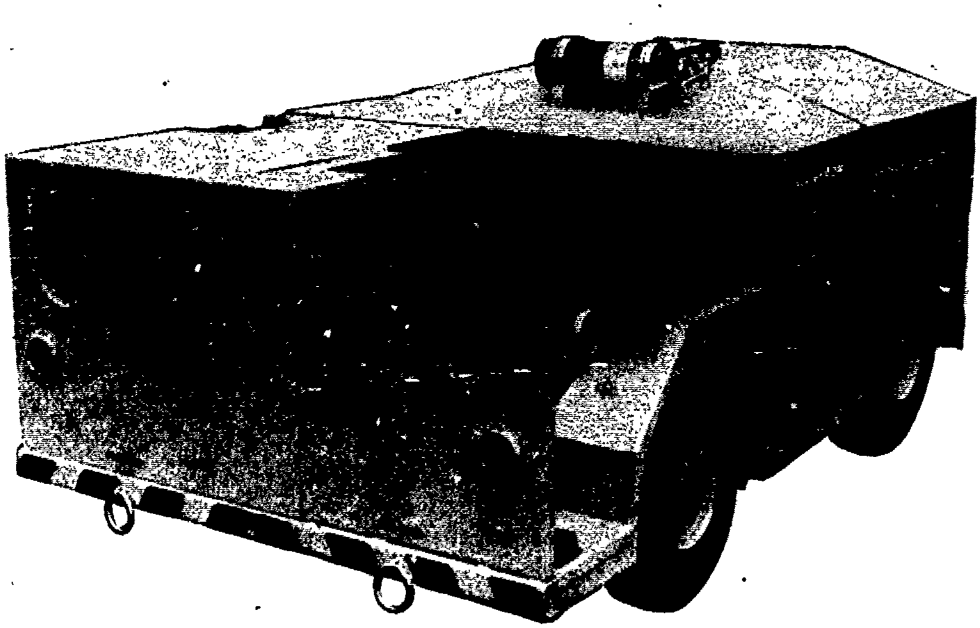

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Figure 12-3.–MEPP NC-2A.

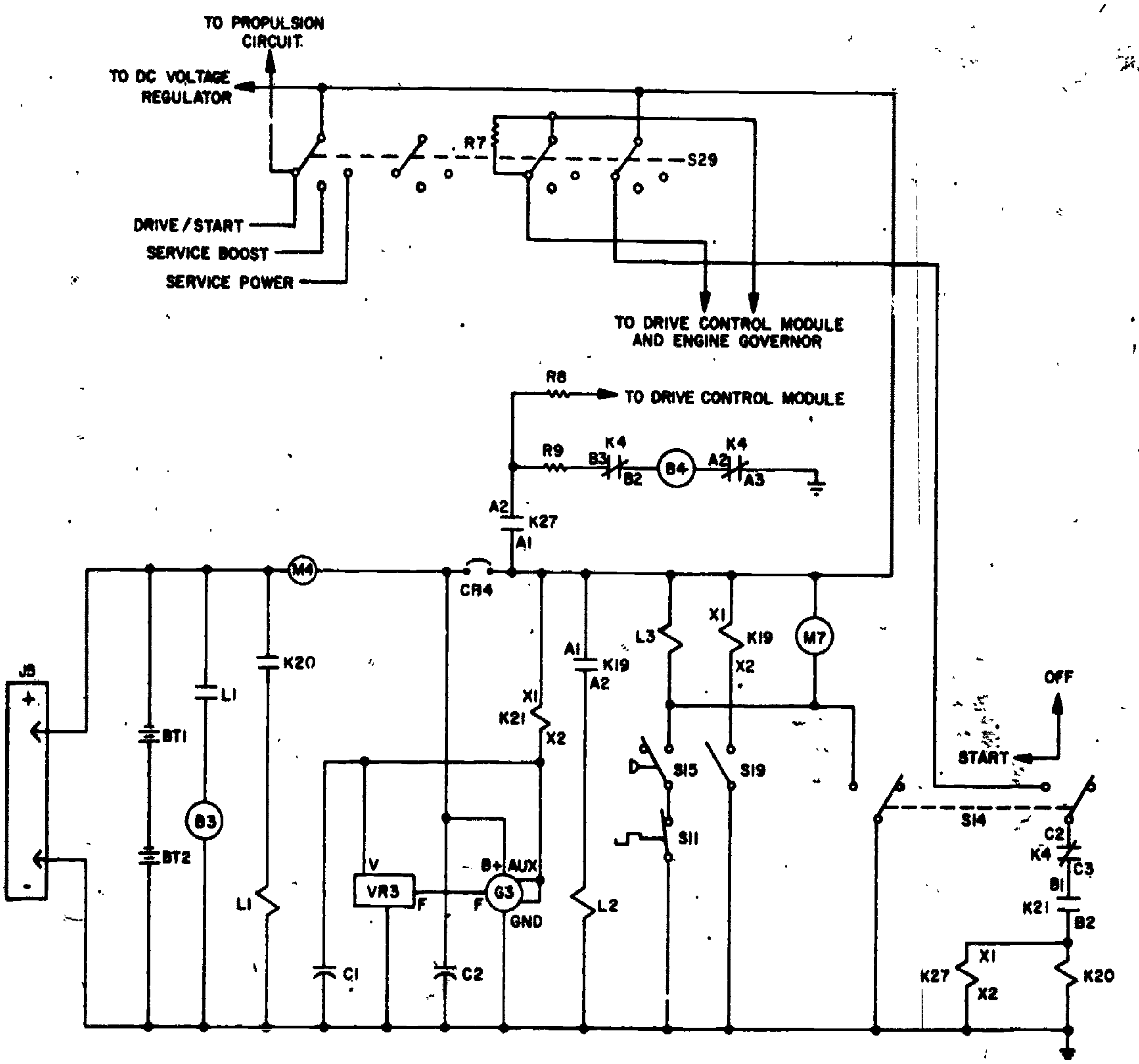

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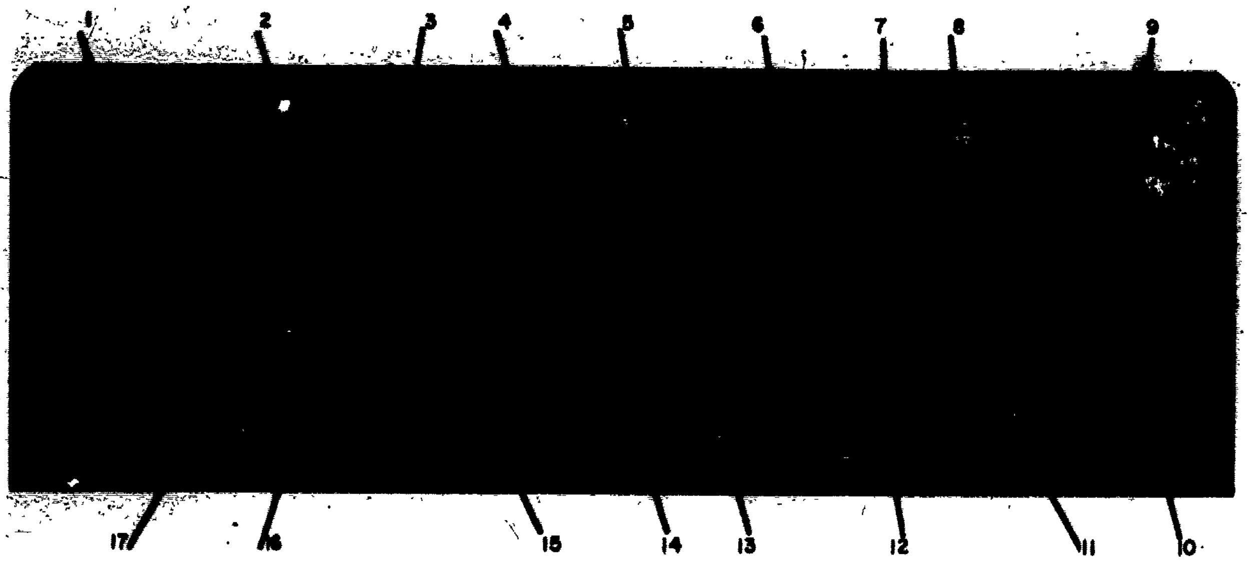
Figure 12-4.—Engine starting circuit.

switch S19 will close and energize air lockout relay K19. Air shutoff solenoid L2 is now energized through closed contacts A1 and A2 of relay K19. After an overspeed shutdown, air shutoff solenoid L2 must be manually reset before engine restart can be accomplished.

VEHICLE PROPULSION CIRCUIT.—Refer to figure 12-5 for an illustration of the engine control panel, and to figure 12-6 for a simplified schematic of the propulsion circuit. Prior to vehicle propulsion the following conditions must exist—engine must be operating, D-C POWER switch S5 in the OFF position, and START/DRIVE-SERVICE POWER switch S29 in the START/DRIVE position.

For forward operation, drive motor lockout relay K17 and forward control relays K13 and K14 must be energized. This is accomplished by placing VEHICLE MOTION switch S9 in the FWD position and depressing brake switch S7. Drive motor lockout relay K17 is now energized by battery voltage through limit switch S4, brake switch S7, and blocking diode CR5. Relay K17 is held energized during forward operation by battery voltage through START/DRIVE-SERVICE POWER switch S29, blocking diode CR6, and its own closed contacts B1 and B2. Battery voltage applied through switch S29, the closed contacts of K17, C1 and C2, the closed contacts of K18, A2 and A3, energizes relays K13 and K14 to close their contacts, A1 and A2, across the drive motor.

For reverse operation, VEHICLE MOTION switch S9 is placed in the REV position and brake switch S7 is again depressed, permitting reverse control auxiliary relay K18 and reverse control relays K15 and K16 to be energized. Contacts A1 and A2 of relays K15 and K16 are closed, directing d-c generator output voltage through the drive motor in the reverse direction.



1. Running time indicator.
2. Panel light.
3. Water temperature gage.
4. Oil pressure gage.
5. Panel light.
6. Battery ammeter.
7. Start/drive service.
8. Panel light.
9. Engine rpm indicator.
10. Gear box oil press light.
11. Low fuel light.
12. Engine start switch.
13. Master switch.
14. Circuit breaker reset button.
15. Intensity switch.
16. Panel lights-running lights switch.
17. Vehicle motion switch.

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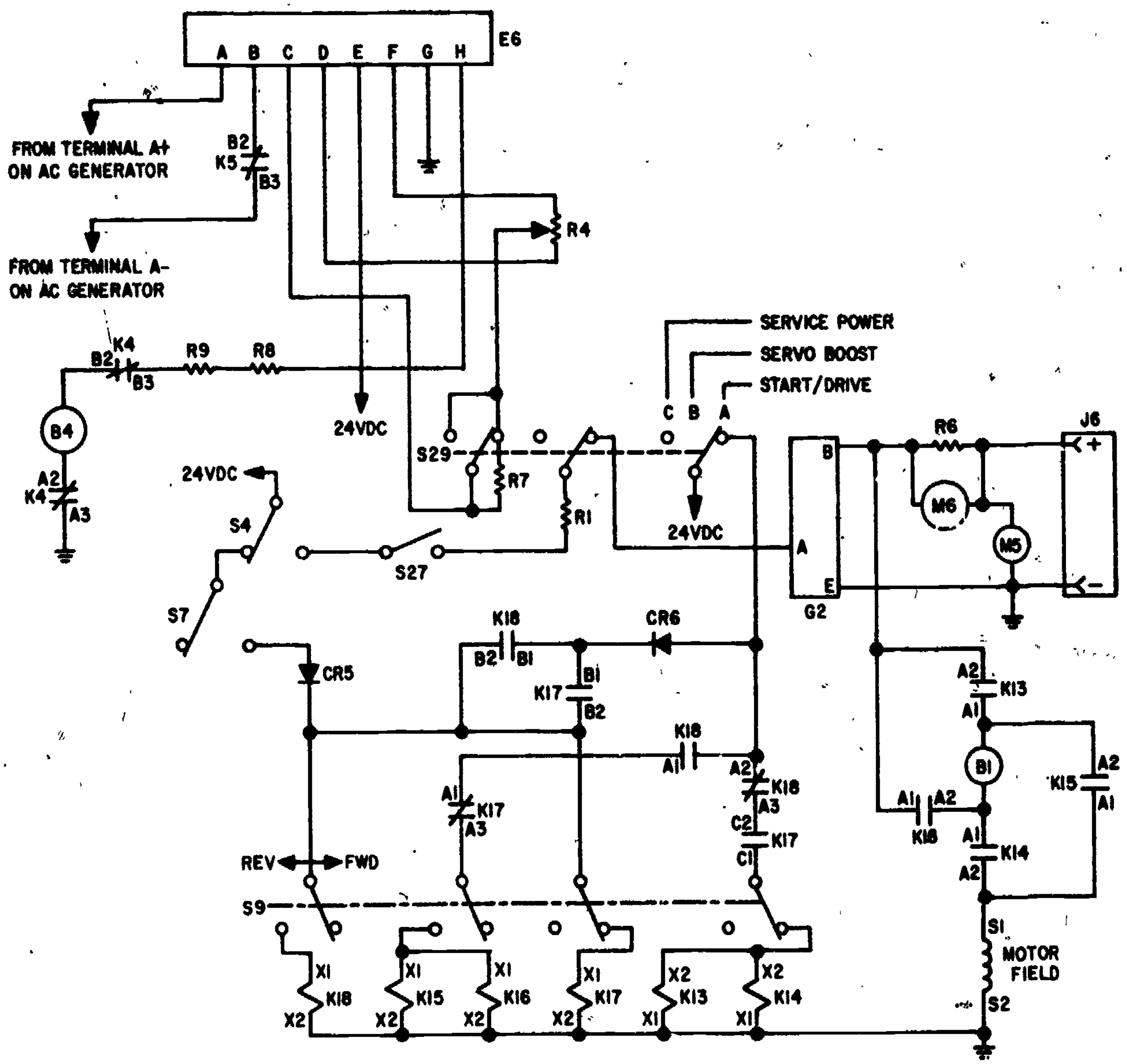
Figure 12-5.—Engine control panel.



AS.394

Figure 12-6.—Vehicle propulsion circuit.

During reverse operation, relay K18 is held energized by its own closed contacts B1 and B2.

Control of the powerplant speed during propulsion is the same for forward or reverse operation. Safety switch S27 must be held closed and the accelerator pedal must be depressed. With d-c voltage regulator VR2 isolated from the propulsion circuit, a control or biasing voltage must be induced across the field of the d-c generator to permit generator output. This is accomplished by depressing the accelerator pedal and closing limit switch S4. Battery voltage, reduced by speed regulating resistor R1, is induced across the d-c generator field through switch S29. The d-c generator output voltage, which energizes drive motor B1, is now controlled by engine speed, and involves accelerator rheostat R4, drive control module E6, and governor actuator motor B4. The higher the output voltage, the faster the powerplant moves.

Governor actuator motor B4 is connected to the engine fuel control rack and adjusts engine speed by controlling the amount of fuel injected into the engine. After initial engine start, the governor .tuator motor is held in the engine idle speed position by spring action. The governor actuator motor is actuated for engine control by variable output signals from drive control module E6 as rheostat R4 is repositioned by the accelerator pedal.

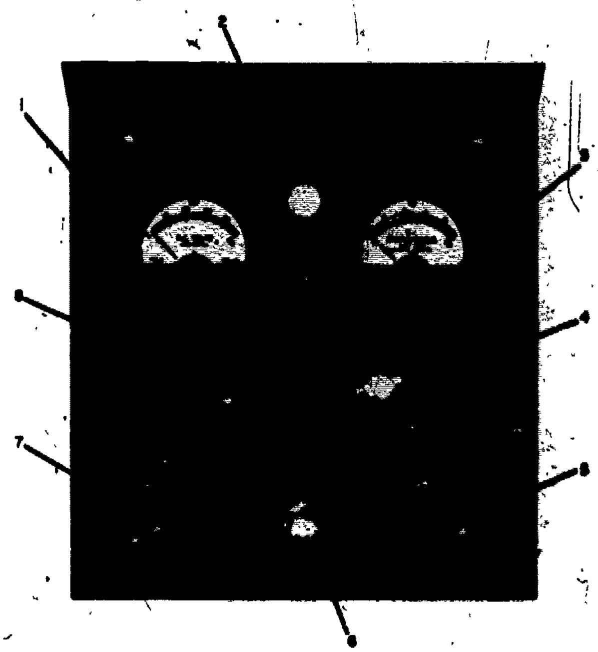
D-C POWER CONTROL AND DISTRIBUTION.–Refer to figure 12-7 for an illustration of the d-c control panel and to figure 12-8 for a simplified schematic of the d-c power control and distribution circuit. Prior to d-c power distribution, the engine must be operating, and START/DRIVE-SERVICE POWER switch S29, must be in the SERVICE POWER position.

Actuator control relay K4 and a-c generator control relay K5 are energized by battery voltage when switch S29 is placed in the SERVICE POWER position. Governor actuator motor B4 is now controlled by engine governor assembly E1 through the closed contacts of relay K4. The field of a-c generator G1 is connected to a-c voltage regulator VR1 through the closed contacts of relay K5. The engine governor assembly monitors the a-c generator output, sending controlling signals to the governor actuator motor to maintain engine rpm.

When D-C POWER switch S5 is placed in the D-C POWER position, field control relay K11 energizes, contacts B1 and B2 c. se, and the circuit is completed between d-c voltage regulator VR2 and the field of d-c generator G2. The battery voltage, reduced to approximately 1-volt d.c. by resistor R5, is fed through diode CR4 into the d-c voltage regulator at pin C to boost the residual magnetism of the generator and insures buildup of the output voltage. After the generator voltage has built up, GEN ON light DS20 illuminates and a 28-volt d-c signal is fed through diode CR3 into the voltage regulator at pin C. A loss of this signal will cause a d-c voltage shutdown.

After connecting the d-c cable to the aircraft, d-c power distribution is accomplished by pressing D-C SERVICE CABLE ON button S26, which energizes d-c output power relay K10, completing the circuit to d-c service output jack J6. D-C SERVICE ENERGIZED light DS19 will illuminate, indicating that relay K10 has energized and d-c power is available for distribution.

Overvoltage relay K25 is connected to the B+ output of the d-c generator. It senses any overvoltage not corrected by d-c voltage regulator VR2. When energized, the overvoltage relay, in turn, energizes lockout relay K12. Relay K12 then deenergizes field control relay K11, which removes the 28-volt d-c signal from the voltage regulator, and stops the generator output. Output



1. Generator voltmeter.
2. Panel light.
3. Generator ammeter.
4. Generator on light.
5. D-c service cable off button
6. D-c service cable energized light.
7. D-c service cable on button.
8. D-c power switch.

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Figure 12-7.–D-c control panel.

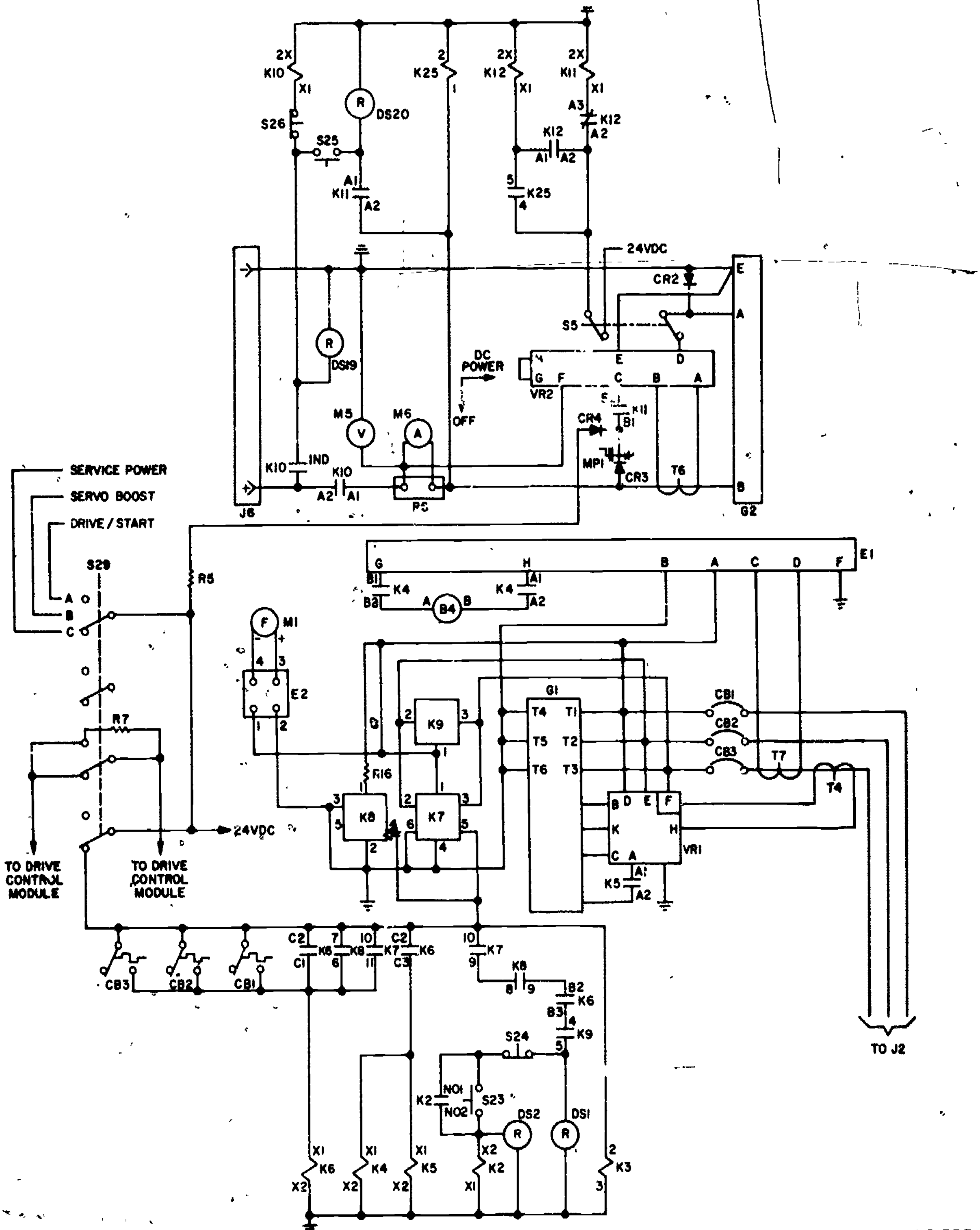


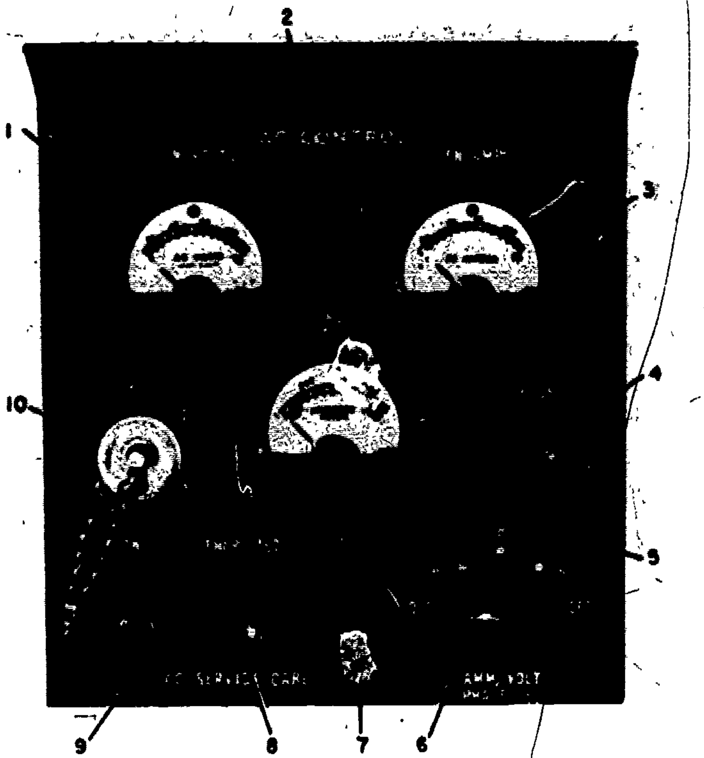
Figure 12-8.—D-c power control and distribution circuit.

power relay K10 will be deenergized it d-c servicing was in progress. After an overvoltage shutdown, relay K12 will remain energized until D-C POWER switch S5 is placed in the OFF position.

A-C POWER CONTROL AND DISTRIBUTION.–Refer to figure 12-9 for an illustration of the a-c control panel, and to figure 12-10 for a simplified schematic of the a-c power control and distribution circuit. Prior to a-c power distribution, the engine must be operating, and START/DRIVE-SERVICE POWER switch S29 must be in the SERVICE POWER position. Engine control is the same as described under d-c power control and distribution.

A-c power is controlled by a-c voltage regulator (VR1) in conjunction with time delay relay K3, over- and undervoltage relay K7, over- and underfrequency relay K8, a-c generator control relay K5, lockout relay K6, and circuit breakers CB1, CB2, and CB3.

NOTE: Relay K3 is a thermal time delay relay set to operate 5 to 10 seconds after voltage is applied to the coil. This time delay is incorporated in the circuit to allow protective relays K7 and K8 to reach their operating positions. When



1. Generator voltmeter.
2. Panel light.
3. Generator ammeter.
4. Generator on light.
5. Frequency meter.
6. Amp/volt phase selector switch.
7. A-c service cable off button.
8. A-c service cable energized light.
9. A-c service cable on button.
10. Test receptacle.

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Figure 12-9.–A-c control panel.

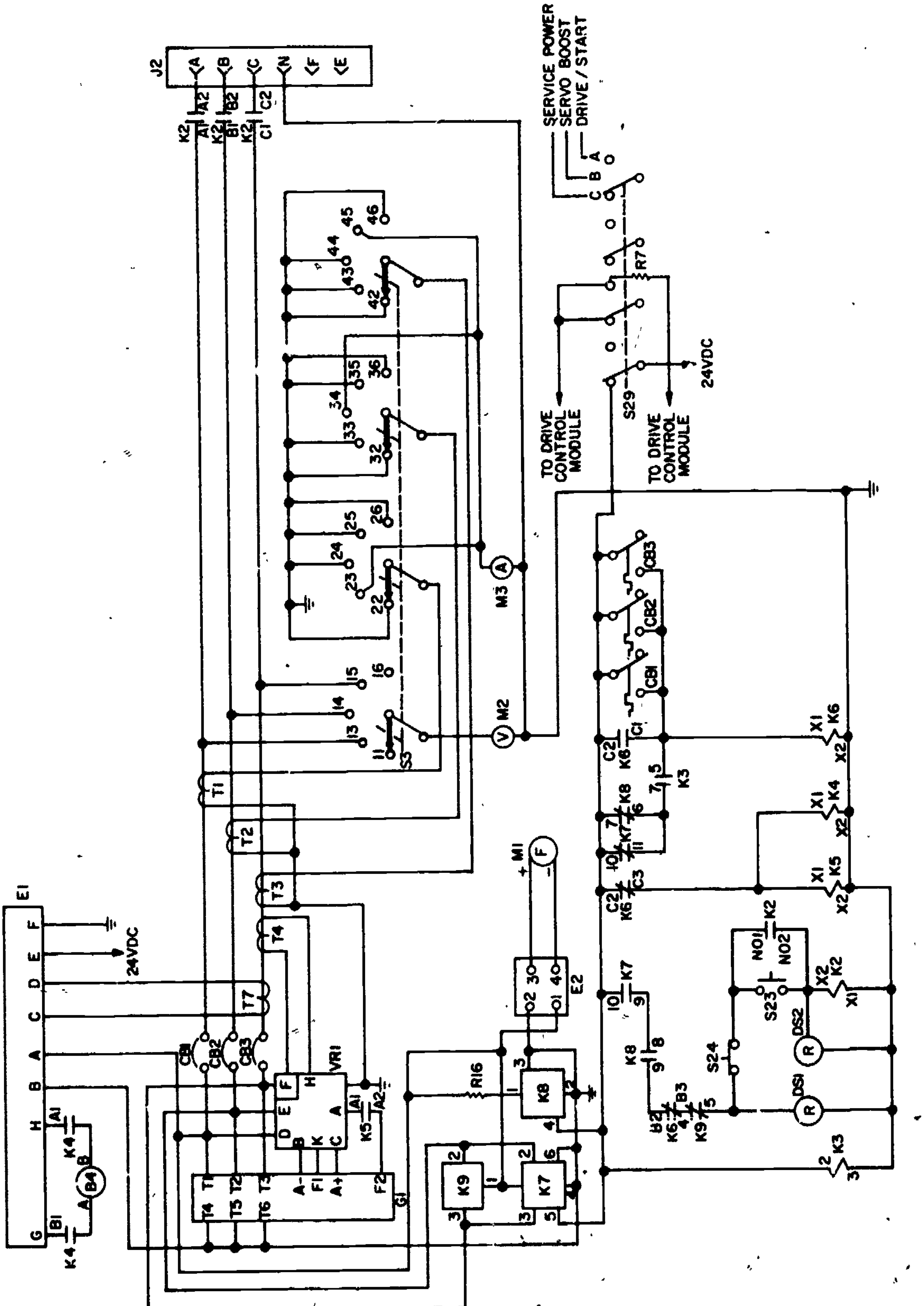

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Figure 12-10.—A-c power control and distribution circuit.

/ K3 is activated, contacts 5 and 7 will close, . mitting relay K6 to energize if either or both relays, K7 and K8, are deenergized due to a fault condition.

CAUTION: Approximately 30 seconds are required to cool the thermal control circuit within relay K3. Therefore, in the event of a fault, START/DRIVE-SERVICE POWER switch S29 should be placed in the SERVO BOOST or the START/DRIVE position and the engine permitted to idle. If the unit is operating properly, this amount of time is required prior to going into the SERVICE POWER position again.

With switch S29 in the SERVICE POWER position, a-c generator control relay K5 is energized through normally closed contacts C2 and C3 of relay K6, completing a-c generator G1 to a-c voltage regulator VR1 circuit. Relay K3 will not energize for 5 seconds. This time delay allows the a-c generator to reach rated voltage and frequency and prevents inadvertent tripping of over- and undervoltage relay K7 and over- and underfrequency relay K8 when going into the service power position. At rated voltage and frequency, relays K7 and K8 are energized, opening circuits to relay K6 and closing them to A-C SERVICE ON button S23 and A-C GEN ON light DS1.

After connecting the a-c cable to the aircraft, press A-C SERVICE ON button S23. Relay K2 energizes, completing the circuit to a-c service output connector J2. A-C SERVICE ENERGIZED ON light DS2 will light, indicating that relay K2 has energized and a-c power is available for distribution.

NC-7C

The NC-7C is powered by a V-8 gasoline engine, and contains two d-c generators, an a-c generator, a control console for control of the engine and both electrical power systems, and a propulsion system for moving the powerplant under its own power (fig. 12-11). Access doors are provided for the control console, engine compartment, battery compartment, cable stowage compartment, and tool compartment. A hand control unit is provided on the tow bar for controlling the unit during self-propelling operations. A fire extinguisher, readily accessible for emergency use, is mounted near the tow bar.

CAUTION: Do not move the powerplant by means of the self-contained propulsion mechanism while supplying power to an aircraft. Under no condition is the powerplant to be used as a prime mover for towing other equipment.

The self-propelling feature should be used only when moving from one aircraft to another or from the line to the hangar if the distance is not too great. For greater distances, the unit must be towed—towing speed is 20 mph.

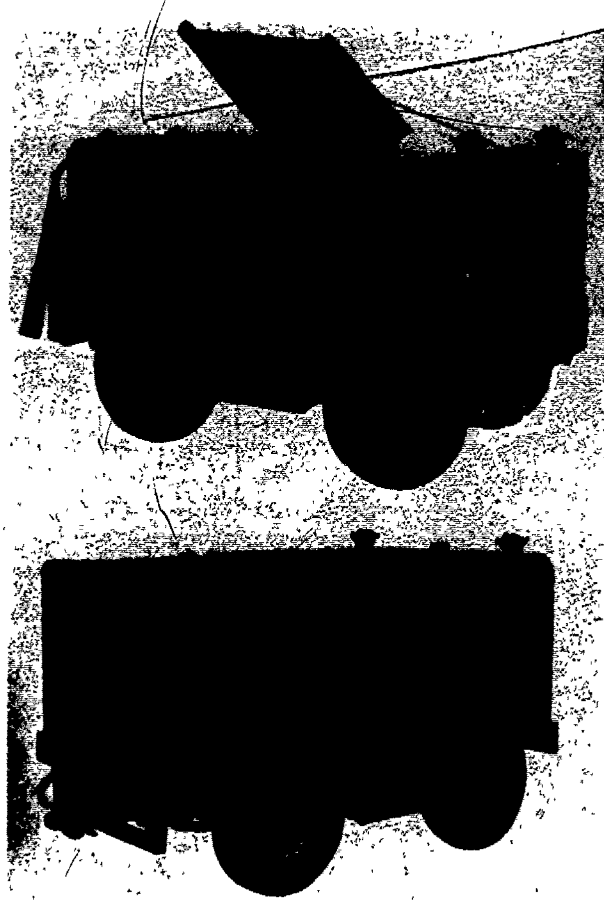

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Figure 12-11.—MEPP NC-7C.

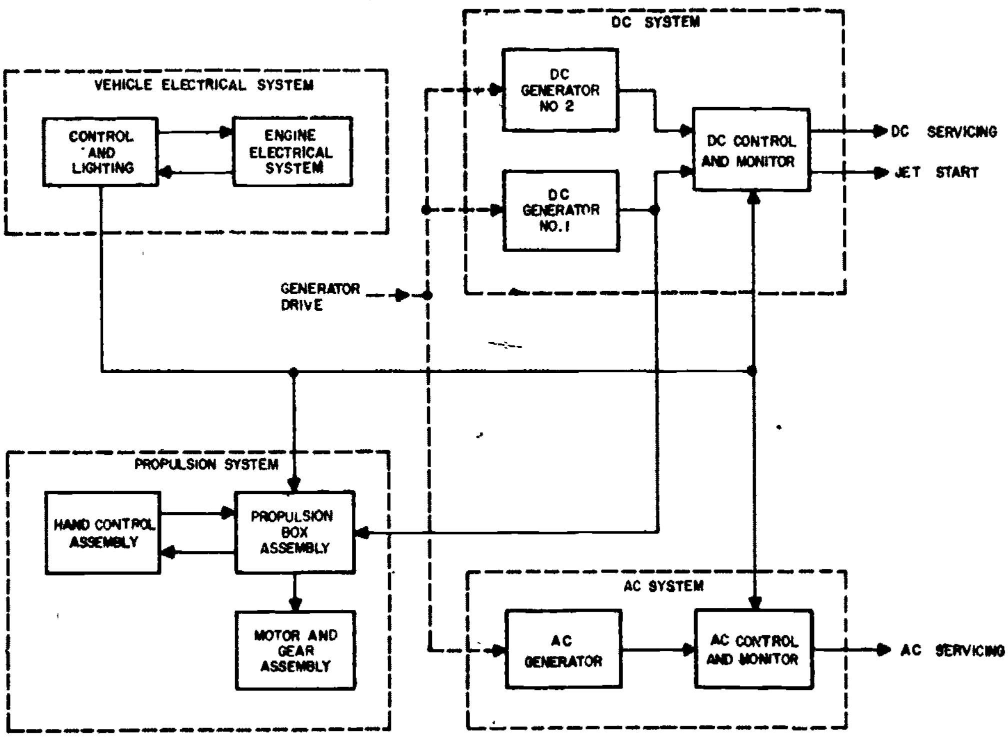

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Figure 12-12.—NC-7C power generating system block diagram.

D-c Power System

The outputs from the two d-c generators are used for jet starting and for servicing d-c components in aircraft. Also, an output from one of the d-c generators is used to power the self-propulsion system. The d-c generators are rated at 750 amperes continuous and 1,000 amperes intermittently.

Aircraft d-c servicing requires 28.5-volt d-c power, which is supplied by generator No. 1. (See fig. 12-12.) Both voltage and current are monitored and regulated. A carbon pile voltage regulator controls the output voltage and also provides current limiting of this generator. A voltage regulator coil and compensation coil act together to regulate the generator output voltage. The voltage regulator coil senses line voltage variations and compensates for them by varying the resistance of the carbon pile. The resistance variation changes the generator shunt field excitation, resulting in an output voltage correction. The current regulator coil varies the resistance of the carbon pile to provide a constant output current of 750 amperes for d-c servicing.

A-c Power System

The a-c electrical power system (fig. 12-12) provides 120/208-volt, 3-phase, 400-Hz power for servicing aircraft a-c components. The frequency developed by the a-c generator is maintained within limits by the use of a speed governor to control the speed of the gasoline engine in the powerplant. When the generator comes up to a predetermined speed, the centrifugal force contacts of the underspeed governor are closed and the exciter coil is connected into the generator circuit. The output voltage of the generator is controlled by a magnetic amplifier voltage regulator. The voltage regulator controls the exciter excitation, thus regulating the a-c generator field excitation and the output voltage of the generator. Output voltage and current are monitored by a volt-meter and ammeter for phases A, B, or C as desired. Current transformers provide ammeter-indicated current monitoring of each phase. In order to protect the current transformers from damaging current when they are not being used to monitor a phase, the transformer secondaries are shorted out. Current limiting fuses are used to carry a current of 87 amperes continuously, 130 amperes for 5 minutes, and 174 amperes for 5 seconds. Auxiliary a-c components are serviced by use of the 120-volt, 400-Hz convenience outlets.

NC-8A

The NC-8A (fig. 12-13) is a mobile, self-propelled unit used for servicing and starting rotary and fixed wing aircraft. It is powered by a 4-cylinder, two-stroke-cycle, diesel engine controlled by an electro-hydraulic governor.

This unit has one dual-purpose generator, capable of supplying both a-c and d-c power simultaneously. It consists of a d-c generator and a synchronous alternator enclosed in one housing (fig. 12-14). The mainshaft, connected to the engine by a driving disk (1), drives the a-c generator rotating field (4) and the d-c generator rotating armature (6). Field excitation for the generator is supplied by the vehicle battery. The

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Figure 12-13.—MEPP NC-8A.

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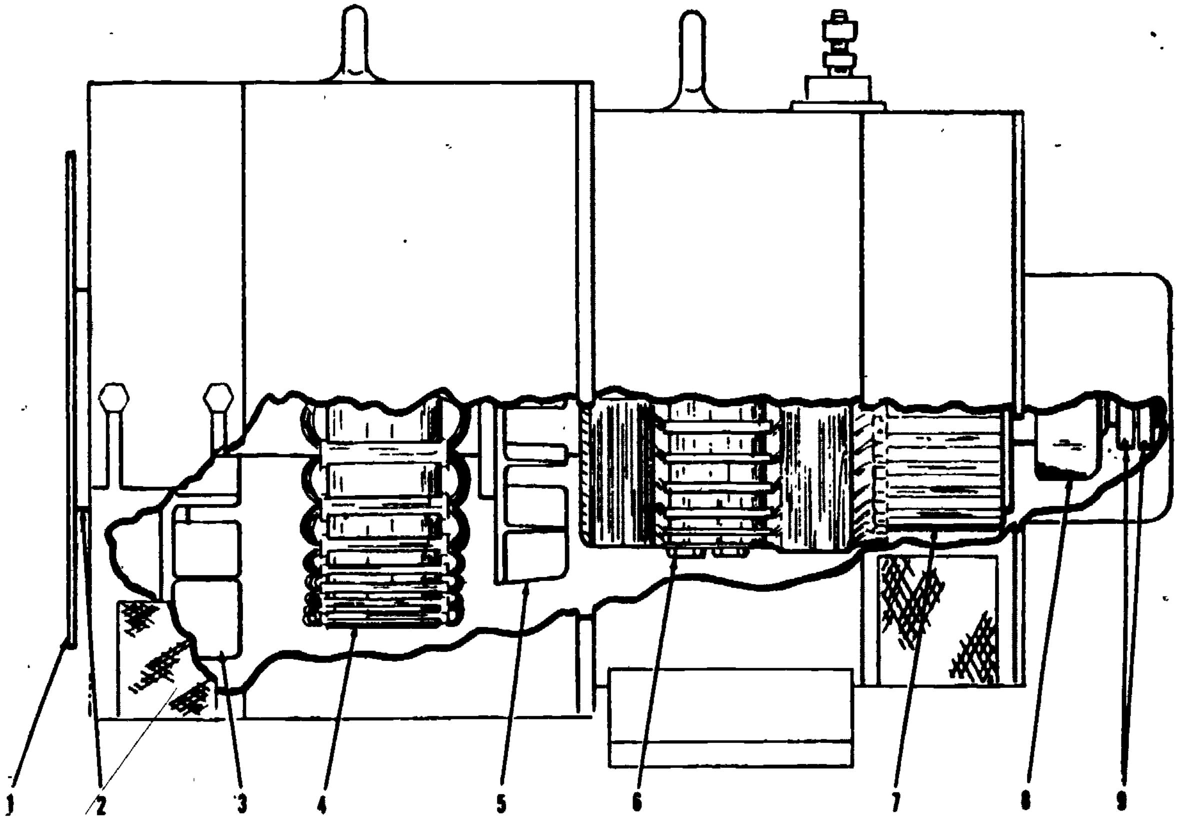

1. Driving disk.
2. Coupling hub.
3. A-c generator fan.
4. A-c generator field.
5. D-c generator fan.
6. D-c generator armature.
7. Commutator.
8. Bearing assembly.
9. Slip rings.

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Figure 12-14.—Cutaway view of an NC-8A generator.

generator is cooled by two internal fans (3 and 5) mounted on the mainshaft.

All engine controls and instruments are located directly in front of the operator, and controls and instruments for the generator are located to the operator's right.

Vehicle propulsion power is provided by a 28-volt, direct-current, reversible, variable-speed motor (fig. 12-15). The motor is connected to the rear wheels via an automotive type differential, and speed is controlled by a conventional foot-operated accelerator pedal. The direction of travel is controlled by a switch mounted on the instrument/control panel.

D-c Power System

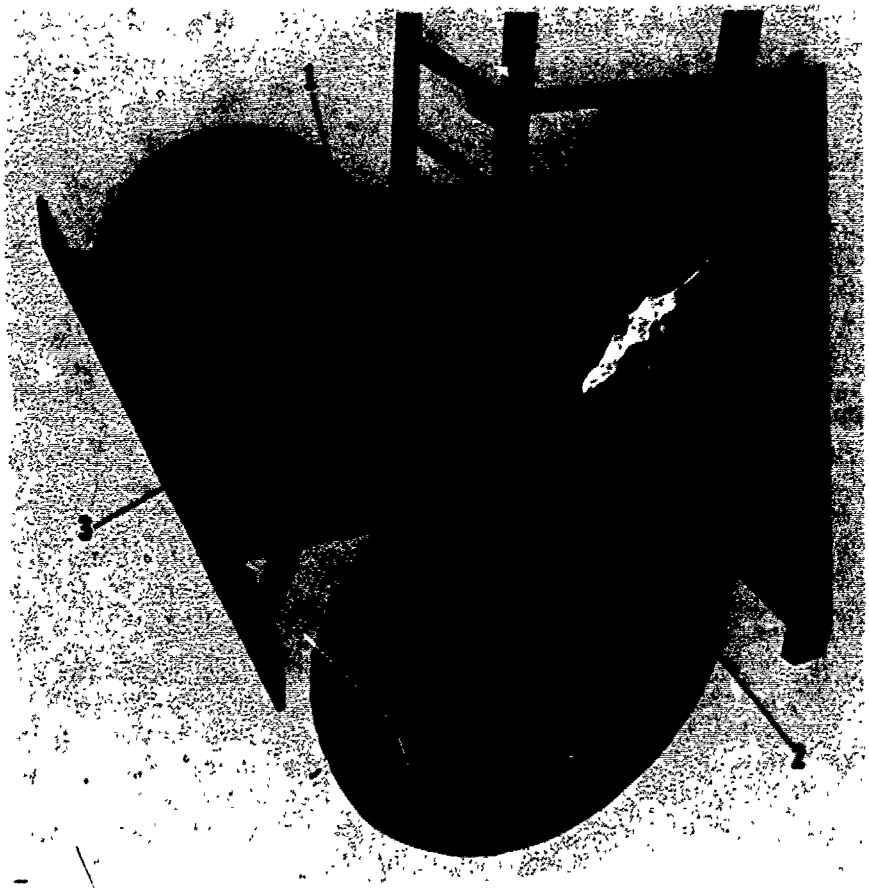
The d-c generator provides 28 volts, 500 amperes continuously, or 28 volts, 750 amperes intermittently.

When the mode selector switch is placed in the output power position, battery voltage is supplied to the d-c generator fields and to the engine governor. As the generator output increases to 28 volts, the regulator samples the output voltage and furnishes the proper amount of field excitation to maintain a constant 28 volts. When the rated output is reached, the operator connects the output to the load by closing the d-c cable switch, which energizes the d-c output load contactor. During load operation the output voltage tends to drop due to losses within the generator and the cable, but the voltage regulator compensates for these losses by increasing the field excitation.

A-c Power System

The a-c generator provides 120/208-volt, 3-phase, 400-Hz, 60-kva power when only the a-c power is being used. When both the d-c and the a-c power are used simultaneously, the a-c power is limited to 34 kw.

When the mode selector switch is placed in the output power position, the a-c generator



1. D-c drive motor.
2. Differential and gear drive.
3. Rear axle.

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Figure 12-15.—NC-8A self-propulsion package.

field is flashed by battery voltage. As engine rpm increases and the voltage output increases to 120/208 volts, the voltage regulator samples the generator output and provides bias for the exciter, which causes the exciter to maintain the generator field at a level to give a constant rated output. The electrohydraulic governor regulates the engine speed to maintain a constant frequency of 400 Hz. After the rated output is reached, the operator connects the output to the load by closing the a-c cable switch, energizing the a-c load contactor. During load operation, the generator output tends to drop due to armature drop and reaction, but the closed loop regulating system compensates for the power drop in the cables and the generator by increasing the field excitation.

Vehicle Propulsion and Control System

A d-c series traction motor converts the d-c generator output into mechanical power to drive the vehicle. With the mode selector switch set to the propulsion position, excitation to the d-c generator is kept constant at battery voltage level; and variation of vehicle speed is obtained by varying the input voltage to the motor. The vehicle operator depresses the accelerator pedal to vary the speed reference signal to the electrohydraulic governor. Varying this reference signal causes the governor to change engine speed, which, in turn, changes the generator output. The vehicle's direction is controlled by a relay circuit which reverses the polarity of the voltage delivered to the traction motor. A speed sensitive switch prevents changing the direction of travel at speeds greater than 3 miles-per-hour.

Protective System

This system is designed to prevent damage to the engine, the generator, the propulsion system, and the electrical systems as a result of a fault condition.

Circuit breakers provide overload protection for the a-c and d-c generators, and a-c and d-c load contactors provide line protection.

An integral part of the protective system is the fault locator with its associated relays and fault sensitive devices. The fault locator will automatically shut down or idle the engine, deactivate the generator, open the load contactors, and/or deactivate the propulsion system if a fault occurs. It is positioned on the generator control panel, and enables the ASE to determine which of the following conditions activated the fault locator's protective circuitry.

1. A-c over/undervoltage.
2. Over/underfrequency.
3. D-c overvoltage.
4. High engine coolant temperature.
5. Low fuel supply.
6. Low engine oil pressure.

A reset button is provided to return the fault locator circuitry to the operating condition after the malfunction has been corrected.

An overspeed switch and an air shutoff solenoid are provided to activate at 2,750 (± 50) engine rpm, causing a damper to restrict air flow to the engine, thus shutting it down.

NC-10B

The NC-10B (fig. 12-16) is a diesel-engine-driven unit designed for shipboard or shore station use. This unit supplies 90-kva, 120/208-volt, 3-phase, 400-Hz power for servicing, starting, and maintaining helicopters and jet aircraft. A portion of the electrical power generated is rectified to supply 28 volts d.c. at 750 amperes (1,000 amperes intermittent) for aircraft starting.

The powerplant is enclosed in a steel housing, fabricated in two sections which are easily removed for servicing the unit. Operating components are mounted on a 4-wheel trailer which is equipped with mechanical type internal expanding wheel brakes. The brakes may be set by a hand lever, and are set automatically when the tow bar is in the vertical position.

Double hinged doors provide access to the control panel, starting components, and three output power cables.

The plant's electrical system is protected from overload by output circuit contactors, circuit breakers, overvoltage and undervoltage relays, overfrequency and underfrequency relays, thermal overload relays, and fuses.

This unit is self-propelled, for movement between aircraft on the line, by two hydraulic wheel motors. The operator's control is located on the towbar. Hydraulic pressure is supplied by the hydraulic system which also provides pressure to operate the engine starter and the electrohydraulic governor's actuator system.

Power generation, both d-c and a-c, is controlled by the operator from the control panel located at the right front of the unit. The control panel (fig. 12-17) contains three functional groups of instruments–the a-c controls, the d-c controls, and the engine controls.

D-c Power System

The d-c power supply of the NC-10B is obtained from a 6-phase, full-wave transformer-rectifier, using 3-phase, 400-Hz, 120/208-volt generator output as a power source. The d-c output voltage is regulated by a two-stage magnetic amplifier circuit. The output d-c voltage range is 22 to 39 volts. The voltage is regulated within ± 1/2-volt at all loads up to 750 amperes. The maximum output is 750 amperes continuous duty, or 1,000 amperes on a 10-second-on, 20-second-off duty cycle.

Protective relays protect the power supply from current and voltage overloads. A cable is provided for connection of d-c power to aircraft, and a cable reel is provided for cable stowage.

A-c Power System

The NC-10B is equipped with an a-c generator which develops 90-kva, 115/200-volt, 3-phase,

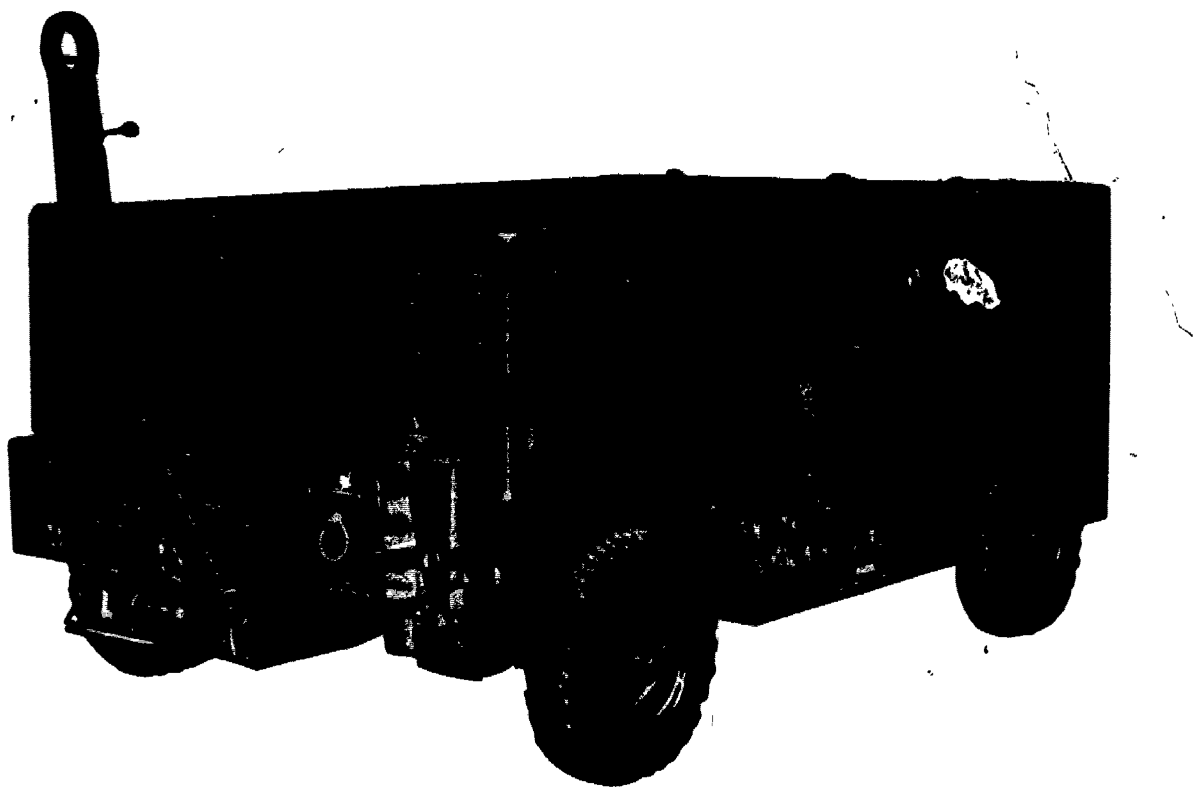

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Figure 12-16.–MEPP NC-10B.

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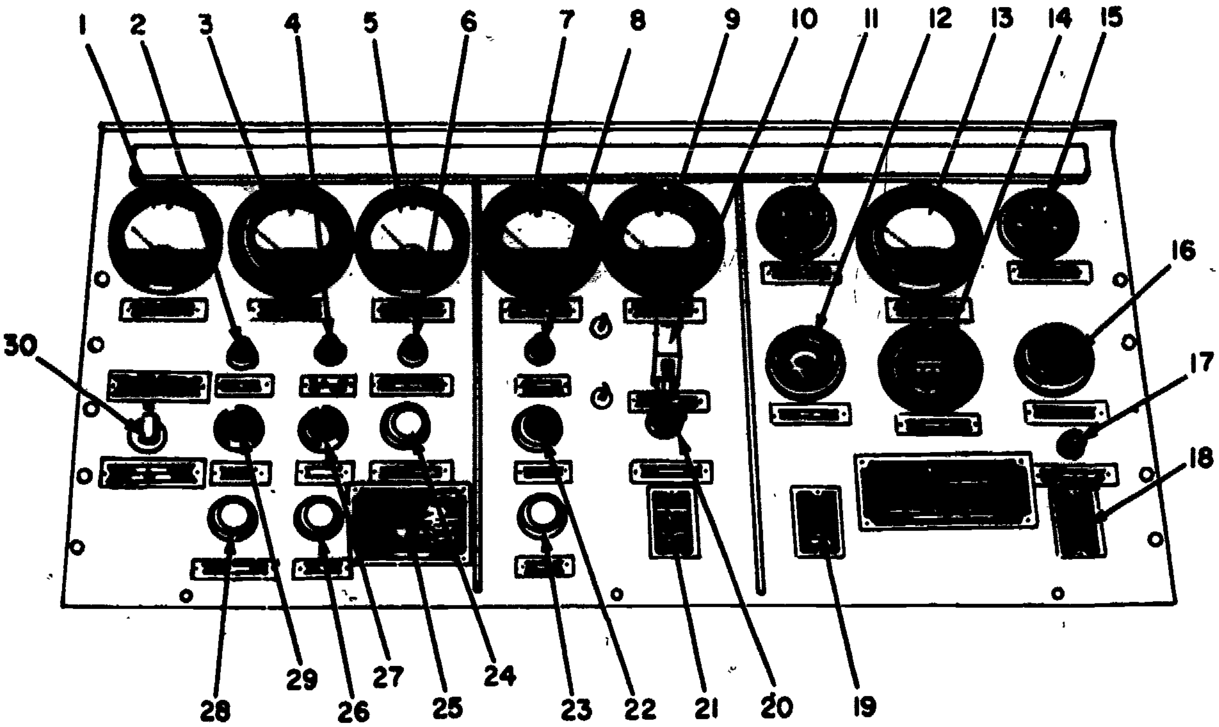

1. A-c output ammeter.
2. Indicating light, a-c output No. 1.
3. Frequency meter.
4. Indicating light, a-c output No. 2.
5. A-c voltmeter.
6. Indicating light, fault indicator.
7. D-c output ammeter.
8. Indicating light, d-c output.
9. D-c voltmeter.
10. Tail light switch.
11. Oil pressure gage.
12. Battery meter.
13. Tachometer.
14. Hourmeter.
15. Water temperature gage.
16. Fuel level gage, accumulator.
17. Indicating light, fluid pressure.
18. Governor switch.
19. Master switch.
20. Panel light switch.
21. D-c service-helicopter start switch.
22. D-c output ON switch.
23. D-c output OFF switch.
24. Fault reset switch.
25. Fault tracer switch.
26. A-c output No. 2 OFF switch.
27. A-c output No. 2 ON switch.
28. A-c output No. 1 OFF switch.
29. A-c output No. 1 ON switch.
30. Volt-ampere phase selector switch.

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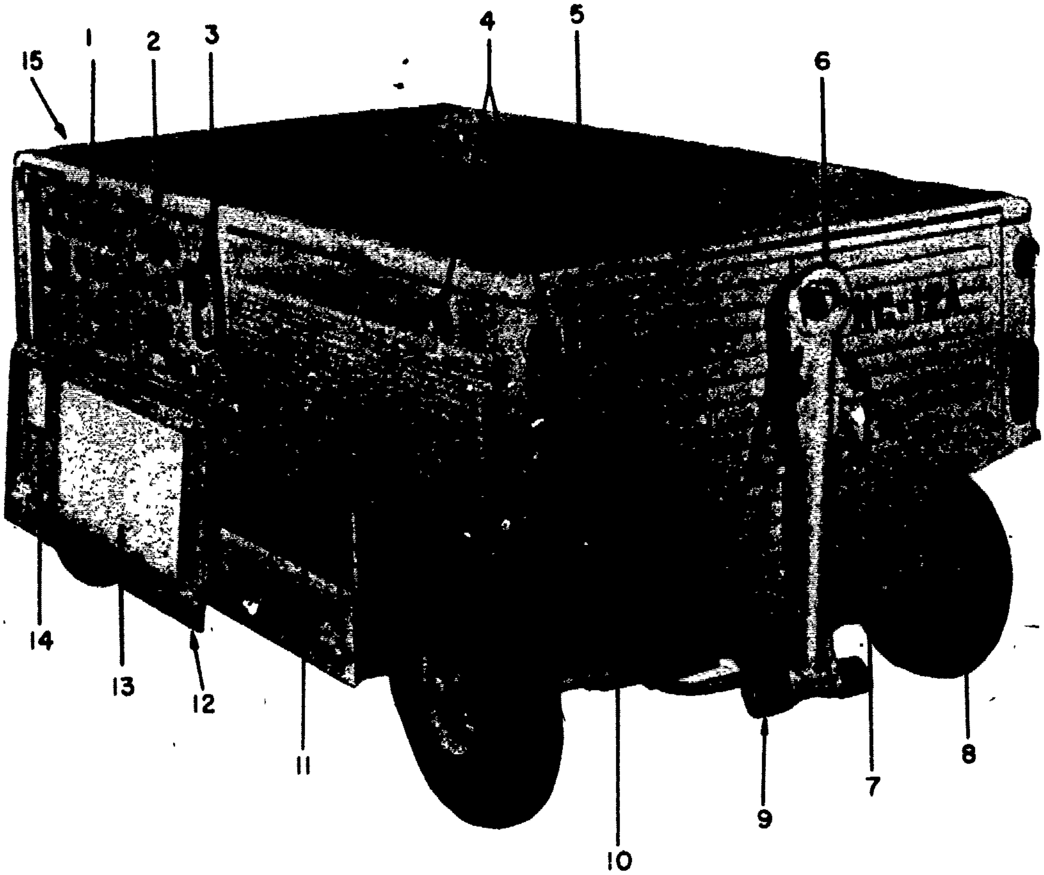
Figure 12-17.—NC-10B control panel.

4-wire, 400-Hz power when driven at 1,846 rpm. Generator field flashing and excitation are provided by a 24-volt battery. When the engine is running, excitation is supplied by a magnetic amplifier type voltage regulator.

The a-c voltage regulator is also a two-stage magnetic amplifier type. The regulator supplies total power to the a-c generator field circuit and regulates the output voltage within 1 percent no load to full load. The input power to the voltage regulator is 200 volts, 3-phase, 400-Hz. The a-c power system is protected from overload, overvoltage, undervoltage, and frequency variations by appropriate protective devices.

The a-c output voltage is applied to aircraft through two 30-foot cables which are contained



1. Electrical control panel.
2. Engine control panel.
3. Chain strap.
4. Safety reflectors.
5. Manual shutter control lever.
6. Tow bar.
7. Safety cable.
8. Parking brake lever.
9. Tow bar return springs.
10. Automatic shutters.
11. Output cable storage.
12. Control panels access door.
13. Schematic diagram encapsulation.
14. Lubrication diagram encapsulation.
15. Floodlight mounting location.

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Figure 12-18.—MEPP NC-12A.

on separate return reels having automatic ratchet stops. Collector rings and brushes within the reel hubs provide continuous electrical contact through the cables.

NC-12A

The NC-12A (fig. 12-18) is a fully enclosed, diesel-engine-driven, dual output powerplant. It provides a 120/208-volt, 3-phase, 400-Hz, 125-kva output, or 87.5-kva a-c power simultaneously with a 750-ampere, 28-volt d-c output. A d-c output of 950 amperes can be obtained intermittently when only the d-c power is being used.

The generator assembly consists of two brushless a-c generators and two brushless exciters, mounted on a common shaft and directly coupled to the engine. The NC-12A provides a d-c output by rectifying the output of one of the generators. The generator outputs are separately controlled—one by the a-c regulator, and the other by the d-c regulator.

The powerplant and its components are mounted on a 4-wheel trailer equipped with mechanical rear wheel brakes which are actuated by a hand lever, or by the spring-loaded tow bar. These units are not equipped with self-propelling features, and must be towed.

D-c Power System

The d-c power system consists of a housing assembly, a cooling fan assembly, two output bus bars, and a voltage regulator. Two output cables are attached to the unit at the two bus bars. The d-c voltage regulator assembly contains a transistorized voltage regulator circuit. (Theory of operation of this regulator is discussed in chapter 13 of this training manual.)

The output of the a-c generator is applied to a transformer-rectifier network which produces the necessary d-c output voltage, and the voltage regulator maintains the output at a constant level. A cooling fan assembly provides necessary cooling for the components of the d-c power system. The d-c output cable assembly consists of two 30-foot rubber insulated cables which are stowed in the cable stowage tray. The operating controls and the indicators for the d-c power supply are located on the power supply control panel (fig. 12-19).

A-c Power System

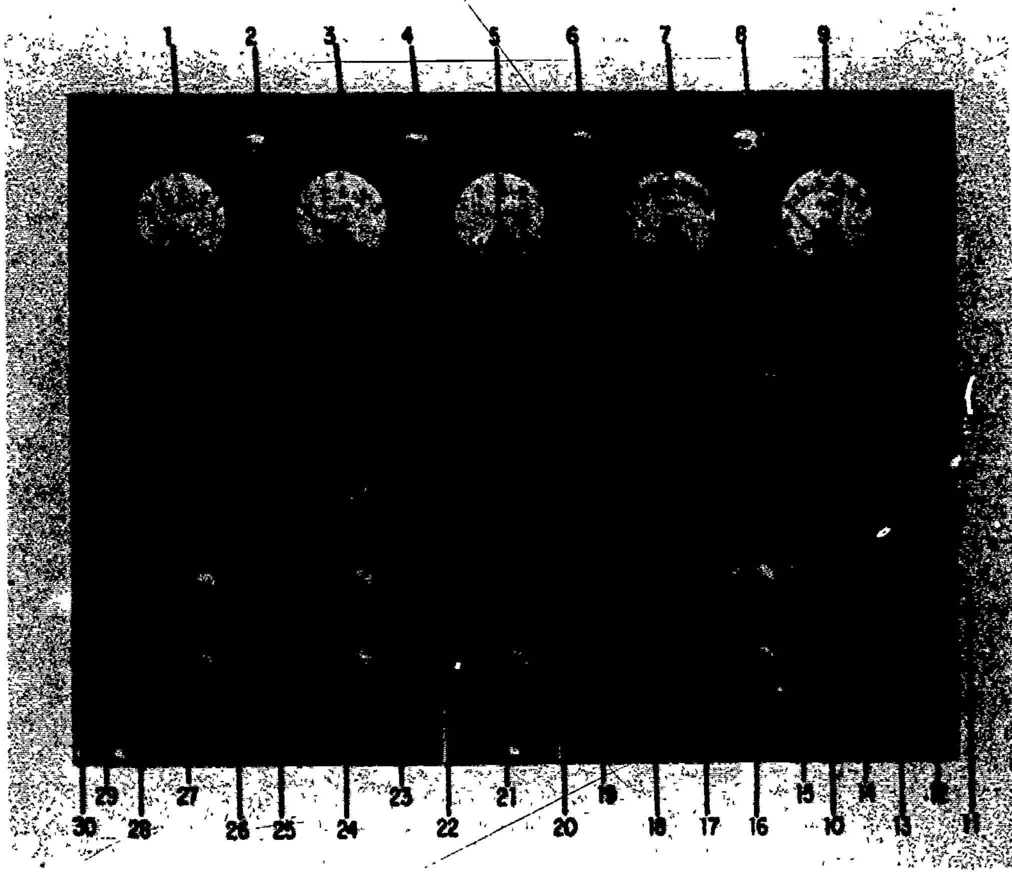
The a-c power system consists of a brushless generator, a voltage regulator, and the necessary protective devices. (See fig. 12-20.)

The generator exciter generates an a-c output which is rectified by a full-wave rectifier internally mounted in the generator and applied to the a-c generator. The generator then produces an a-c output. The voltage output of the generator exciter is regulated by the a-c voltage regulator in the a-c power supply. This regulator senses each phase of the generator output voltage and responds to the average of the 3-phase voltage. If the output voltage varies due to load fluctuations or varying engine performance, the regulator produces a compensating current flow in the generator exciter field which, in turn, causes a change in the exciter output with an ultimate correction in the a-c generator field current. This action continues until the generator output voltage settles at its original value.

The a-c output is also carried by two 30-foot cable assemblies. The controls and indicators for the a-c power system are located on the power supply control panel (fig. 12-19).

RCPT-105

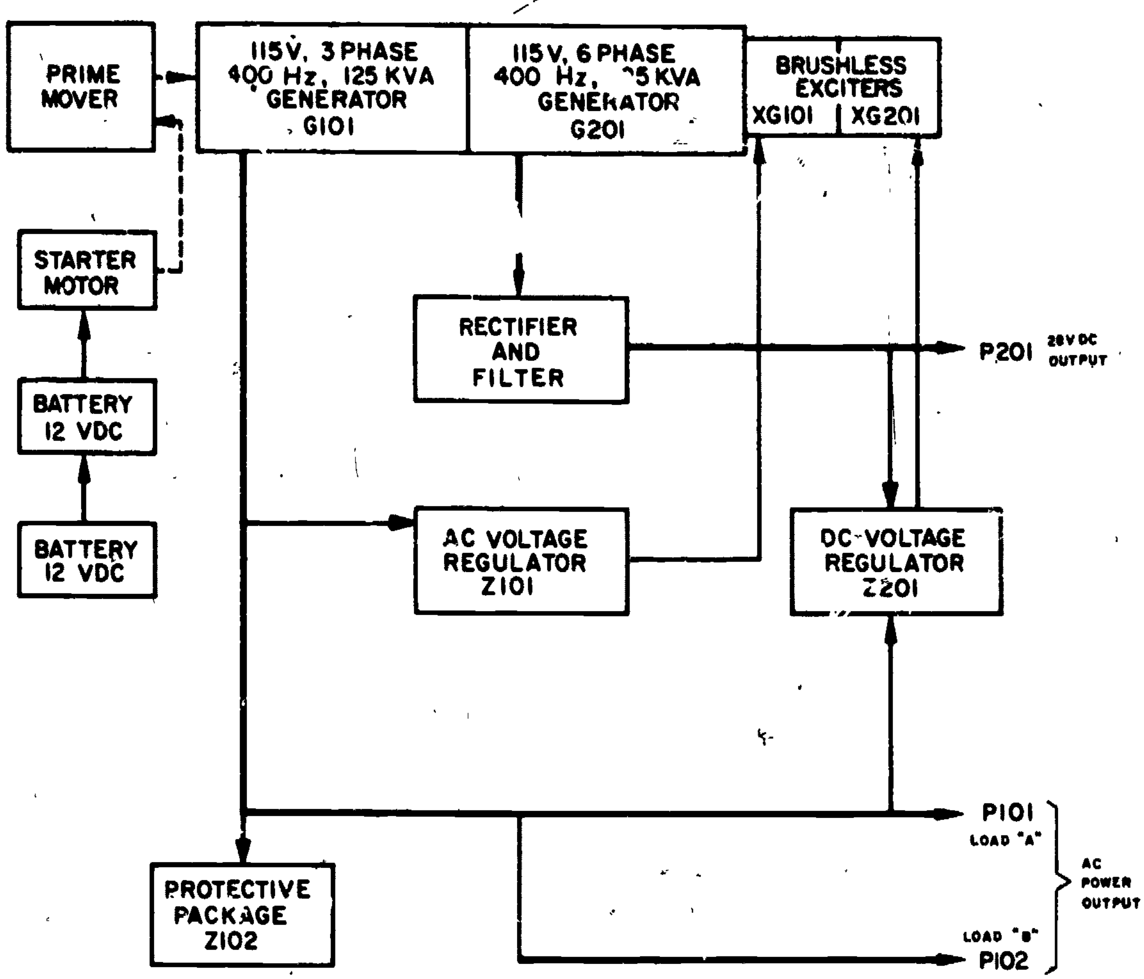
The RCPT-105 (fig. 12-21) is a gas-turbine-driven aircraft ground service unit, mounted in a low-silhouette, self-propelled trailer. The low silhouette design and the self-propulsion system enable the unit to be maneuvered in congested aircraft parking areas. It is completely self-contained—provides compressed air for starting the main engine, a-c and d-c electrical power for operation of aircraft components, and conditioned air for aircraft compartment cooling and pressure suit ventilation. All controls and instruments for the unit are grouped, by system, on one panel located at the right rear of the unit (fig. 12-22).



1. AMPERES A.C.
2. Panel lamp.
3. VOLTS A.C.
4. Panel lamp.
5. Frequency.
6. Panel lamp.
7. AMPERES D.C.
8. Panel lamp.
9. VOLTS D.C.
10. D.C. VOLT ADJ.
11. 10A fl.
12. 10A f2.
13. 10A f3.
14. 10A f4.
15. D.C. LOAD ON lamp.
16. D.C. LOAD OFF switch.
17. D.C. LOAD ON switch.
18. 24V DC floodlight receptacle.
19. 115 V. 400 Hz convenience outlet.
20. JET START- COPTER START switch.
21. FIELD FLASH switch.
22. A.C. VOLT ADJ.
23. LINE DROP TRANSF switch.
24. A.C. LOAD "B" OFF switch.
25. A.C. LOAD "B" ON switch.
26. Load "B" ON lamp.
27. A.C. LOAD "A" OFF switch.
28. A.C. LOAD "A" ON switch.
29. Load "A" ON lamp.
30. VM-AM SEL SW.

AS.331

Figure 12-19.—Power supply control panel.



AS.165

Figure 12-20.—Power system block diagram.

A-c Power System

The a-c power system produces a regulated 115/208-volt, 3-phase, 400-Hz, 60-kva output. The generator is mounted on the turbine engine accessory case and driven through a gear reduction at approximately 6,200 rpm. Excitation is provided by a d-c exciter that is integral with the a-c generator. Excitation current to the a-c generator fields is controlled by the a-c voltage regulator, which senses the difference in actual output voltage and a fixed reference voltage established within the regulator. The frequency is controlled by the engine rpm.

Protection for the a-c power system is provided by the generator lockout and anticycle relay, the cable contactor relay, the undervoltage lockout relay, the overvoltage relay, the underfrequency relay, the overload heater relays, and the undervoltage relay.

D-c Power System

The d-c power system rectifies a portion of the a-c generator output to provide d.c. for external use, and for battery charging and unit operation. A transformer-rectifier provides 28 volts at 150 amperes maximum.

Protection for the d-c system is provided by a circuit breaker located on the circuit breaker panel (fig. 12-23), and by a cable contactor. The circuit breaker panel also includes circuit breakers for the a-c and the d-c auxiliary circuits, the refrigeration control circuit, and the turbine engine control circuits. The circuit breaker panel is mounted directly below the control panel.

Propulsion System

The RCPT-105 is provided with a self-propulsion mechanism (fig. 12-24) for use in moving the unit over distances not to exceed 2,000 feet on a smooth, level surface. For greater distances, the unit must be towed. Power to operate the 28-volt d-c reversible drive motor, located on the rear axle, is provided by the unit's batteries. The operator controls are located on the towbar, and a time delay relay is used to keep the brakes applied for 4 seconds after the unit is stopped—this delay insures that the unit is completely stopped before changing direction of travel.

MOBILE MOTOR-GENERATOR SETS

Mobile motor-generator sets (MMG's) perform the same function as the mobile electric powerplants, but they are not self-contained and require an external source of electrical power for operation. The MMG's are primarily used in hangars on shore stations, or on the hangar decks of aircraft carriers where the running of an internal combustion engine would be objectionable,

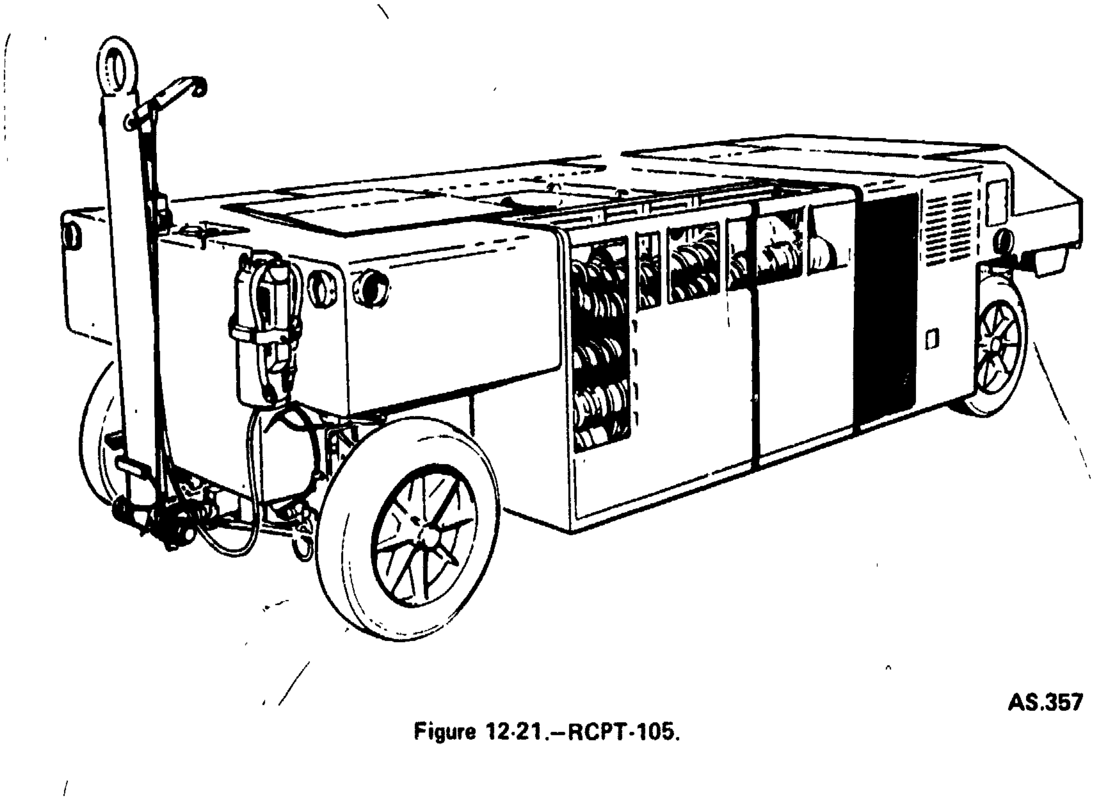


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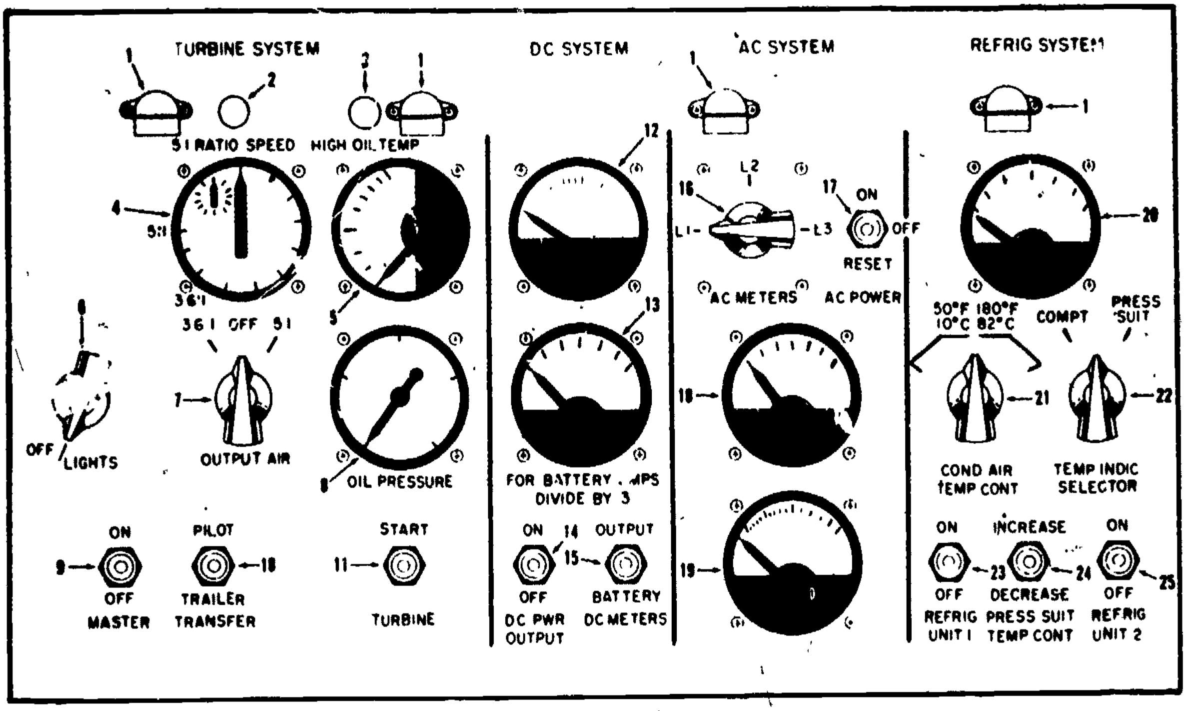
Figure 12-21.—RCPT-105.



1. Panel light.
2. 5:1 ratio indicator lamp.
3. High oil temperature indicator lamp.
4. Tachometer.
5. Turbine engine exhaust gas temperature indicator.
6. Panel light control.
7. Output air selector switch.
8. Oil pressure indicator.
9. Master switch.
10. Transfer switch.
11. Turbine engine start switch.
12. D-c voltmeter.
13. D-c ammeter.
14. D-c power output switch.
15. D-c meter transfer switch.
16. Phase selector switch.
17. A-c power switch.
18. A-c voltmeter.
19. A-c ammeter.
20. Conditioned air temperature indicator.
21. Air temperature control.
22. Temperature indicator selector switch.
23. Refrigeration switch (refrigeration unit No. 1).
24. Pressure suit temperature control switch.
25. Refrigeration switch (refrigeration unit No. 2).

AS.359

Figure 12-22.—Control panel.

and where external power is readily available.

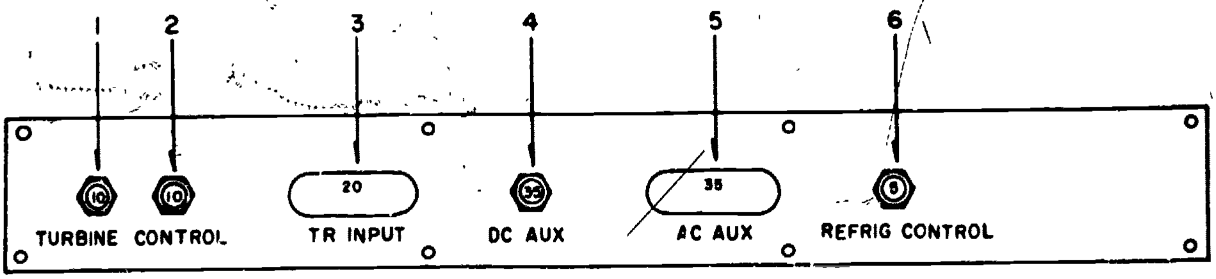
MMG-2

The MMG-2 (fig. 12-25) is physically quite small and very compact. It is a trailer mounted electric motor-driven generator set used to provide 120/208-volt, 400-Hz, a-c power, and 28-volt d-c power for use in ground maintenance, calibration, and support for all fighter/interceptor type aircraft equipment.

The motor generator assembly contains a 3-phase a-c, synchronous, 1,200-rpm motor, an a-c exciter, and an a-c generator. The motor, exciter, and generator are combined in a single common-shaft, two-bearing assembly. The motor and the a-c generator are brushless, rotating field types with the field winding wound on the shaft, and the armature winding mounted on the inside of the housing. The exciter is a brushless, rotating a-c type with the armature winding wound on the shaft, and the stationary field winding mounted on the inside of the housing. The exciter delivers its output to a shaft-mounted, 3-phase, silicon rectifier assembly. A cooling fan is mounted on the rotor shaft between the motor and the generator field windings. The leading particulars for the MMG-2 are listed in table 12-1.

D-c Power System

The d-c power supply (fig. 12-26) is mounted on the rear of the trailer assembly, and is regulated to supply 500 amperes at 28 volts within the range of 27.5 and 28.5 volts for any steady state load from no load to full load. The power supply consists of a magnetic amplifier assembly, a cooling fan assembly, a power transformer assembly, a transistorized voltage regulator, and a filter capacitor and overload regulator, and a filter capacitor and overload relay assembly. All components are mounted on a steel frame assembly. The magnetic amplifier assembly contains 12 saturable magnetic amplifiers and 12 silicon controlled rectifiers. The rectifiers are mounted in heavy copper plates, which function as the primary conductors. An input power change board, mounted above the power transformer, contain 18 screw type terminals and 3 sets of strapping bars. The strapping



1. Turbine control circuit breaker.
2. Turbine control circuit breaker.
3. Transformer-rectifier input circuit breaker.
4. D-c auxiliary service circuit breaker.
5. A-c auxiliary service circuit breaker.
6. Refrigeration control circuit breaker.

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Figure 12-23.—Circuit breaker panel.

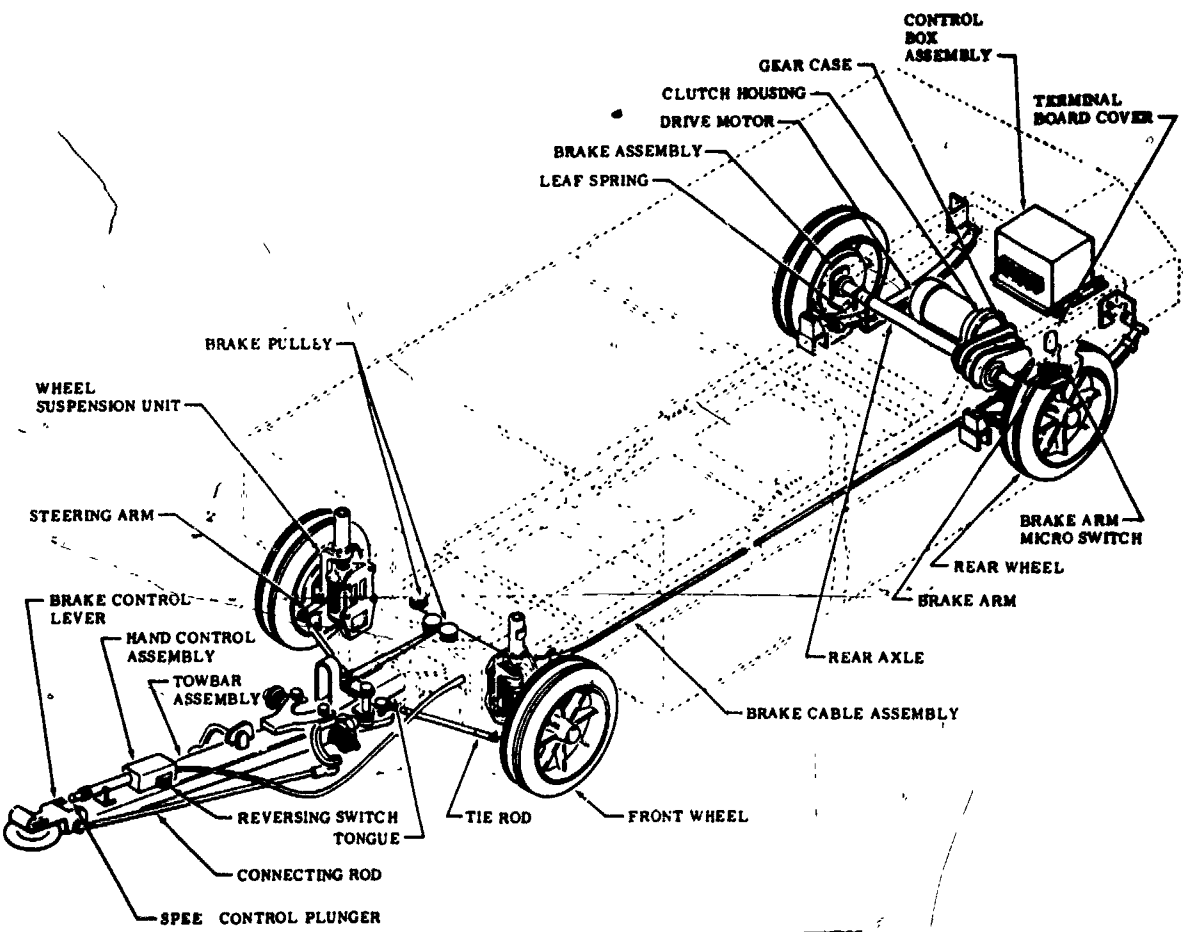

Figure 12-24.—Propulsion system.

bars are used to strap between the terminals for 440-volt a-c or 220-volt a-c operation.

A-c Power System

Figure 12-27 is a simplified block diagram showing the relationship of the circuits of the mobile motor generator. Input a-c power is applied to the contacts of a-c start control relays K1 and K2, and to control transformer T9. Transformer T9 steps the voltage down to 120 volts for application to the relay circuits. Input a-c power is also applied to reverse phase relay

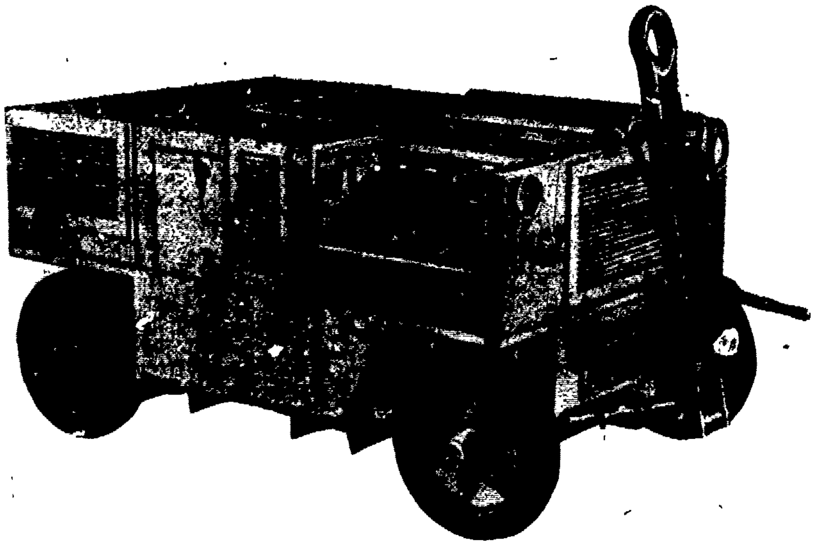

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Figure 12-25.—MMG-2.

K8. If the phase connections of the input a-c power source are incorrect for proper operation of synchronous motor (A1) B1, reverse phase relay K8 energizes and, in turn, energizes reverse phase control relay K15. When relay K15 energizes, it disables a-c start control relays K1 and K2, thus preventing synchronous motor (A1) B1 from being started. When momentary contact MOTOR ON START switch S2 is depressed, the switch applies energizing power to relays K1, K2, and K3.

Energizing relays K1 and K2 applies operating power to the stator windings of motor (A1) B1, and the motor generator assembly shaft starts to rotate. Time-delay relay K3 provides approximately 5 seconds time delay to allow the reverse phase circuit to operate in the event of improper phase connections. At the end of the time-delay period, relay K3 energizes time-delay relay K18 and a-c voltage regulator control relay K5. Relay K18 provides approximately 5 seconds time delay to allow motor (A1) B1 time to reach operating rpm.

At the end of the time-delay period, relay K18 closes the circuit through the normally closed contacts of a-c voltage fault protection relay K6, frequency fault protection relay K7, and A/C LOAD OFF switch S3 to normally open A/C LOAD ON switch S4. When A/C LOAD ON switch S4 is depressed, it energizes

Table 12-1.—MMG-2 leading particulars

Item	Characteristics
A-c output	30-kva, 120/208v a-c, 400-hertz, 3-phase, 4-wire, 0.8-power factor
D-c output	28v d-c, 500-ampere
A-c voltage regulation	± 1 percent
D-c voltage regulation	± 0.5-volt
Voltage modulation	Within ± 1/4 percent
Frequency regulation	± 1 percent
Frequency modulation	± 1 percent
Input power required	220v or 440v a-c, 3-phase, 3-wire, 60-Hz
Motor	1,200-rpm, 6-pole, 3-phase, 3-wire, 220v or 440v a-c, 60-Hz
Operating temperature range	-40° C (-40° F) to +50°C (+122°F)
Weight	2,680 pounds
Overall dimensions:	
Height	32 inches
Width	44 inches
Length	78 inches
Volume	57 cubic feet

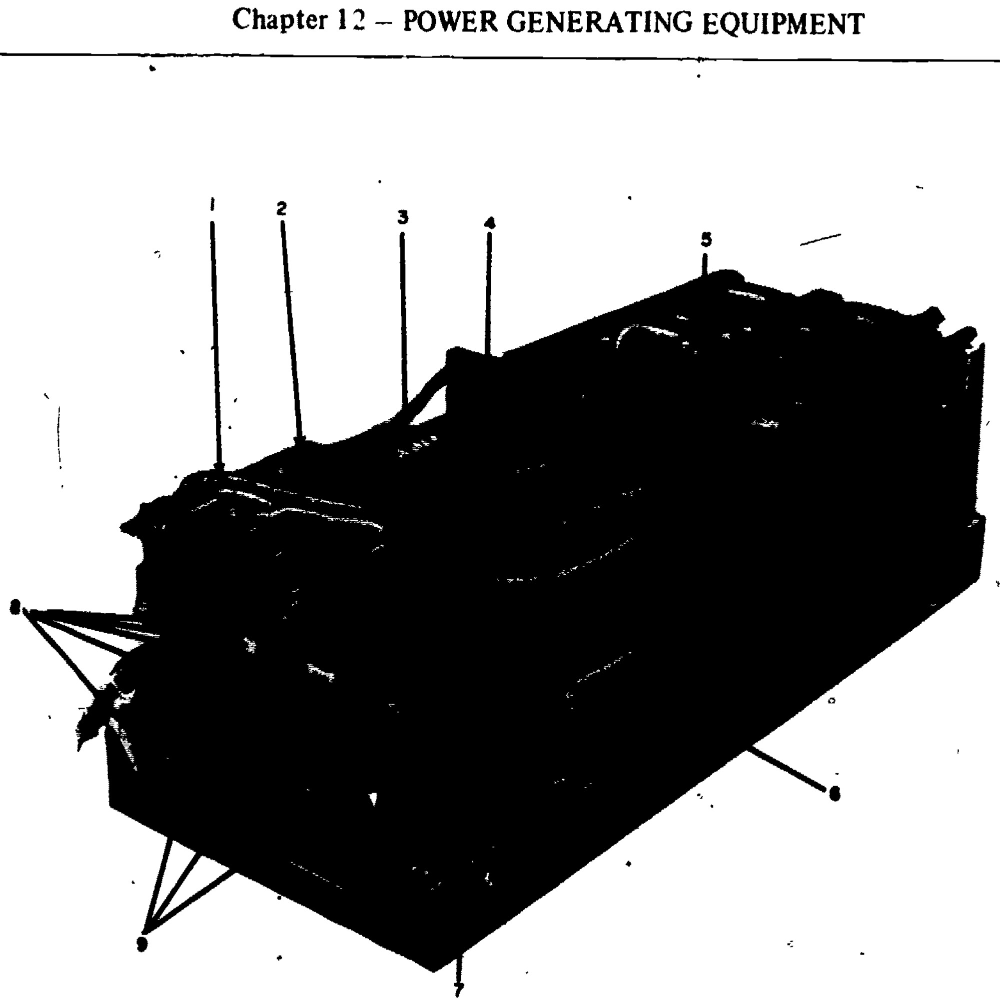
a-c output control contactor K4. Contactor K4 then connects output a-c power through overload relays F2A, F2B, and F2C to a-c output cable assembly W2. When relay K5 energizes, it connects a-c input power to a-c voltage regulator VR1. During operation, FREQ. METER M3 constantly monitors and provides a visual indication of the a-c output frequency. VM-AM SELECTOR switch S8 may be set to apply individual line-to-neutral voltages to A/C VOLTMETER M1, and individual line currents to A/C AMMETER M2. INPUT VOLTMETER M5 provides a constant visual indication of the a-c input voltage.

RX-400

The RX-400 (fig. 12-28) provides 120/208-volt, 3-phase, 400-Hz a-c power, and 28-volt d-c power for use in ground maintenance, calibration, and support of aircraft equipment. The motor generator power supply contains two output channels. Channel 1 provides 60-kva, 120-volt a-c line-to-neutral, 208-volt a-c line-to-line. Channel 2 provides 60-kva, 120-volt a-c line-to-neutral, 208-volt a-c line-to-line, or 28-volt d-c at a maximum d-c load of 2,000 amperes–either a.c. or d.c., but not both at the same time.

The motor generator power supply consists of a canopy assembly, a control panel installation, a rectifier housing assembly, an output control and stabilizing panel assembly, a motor generator assembly, an a-c regulator panel assembly, a current transformer panel assembly, a trailer assembly, and miscellaneous electrical parts. A fire extinguisher is bracket mounted on the front right-hand side of the unit. Two a-c output cable assemblies, a d-c output cable assembly, and an a-c input cable assembly are provided. One a-c output cable assembly and the a-c input cable assembly are stowed in a cable stowage box on the right-hand side of the trailer assembly. The second a-c output cable assembly and the d-c output cable assembly are stowed in a cable stowage box on the left-hand side of the trailer assembly.

The motor generator power generating system contains two output channels. (See fig. 12-29.) Channel 1 generates regulated 120/208-volt a-c, 3-phase power at 400 Hz. Channel 2 generates



1. Terminal board assembly.
2. Input change board.
3. Control transformer.
4. Fan assembly.
5. Magnetic amplifier assembly.
6. Base assembly.
7. Capacitor mount assembly.
8. Capacitors.
9. Overload relays.

AS.408

Figure 12-26.—D-c power supply.

regulated 120/208-volt a-c, 3-phase power at 400 Hz, or regulated 28-volt d.c. The motor generator assembly used in the power generating system consists of two alternators and an electric motor mounted on a single shaft. The electric motor is a 3-phase, synchronous 1,200-rpm motor utilizing a rotating field with fixed armature windings. During the starting phase of operation, the 60-Hz signal from the external source is rectified for use in the alternator field buildup circuits. The field buildup circuit then supplies initial excitation voltage to the fields of both

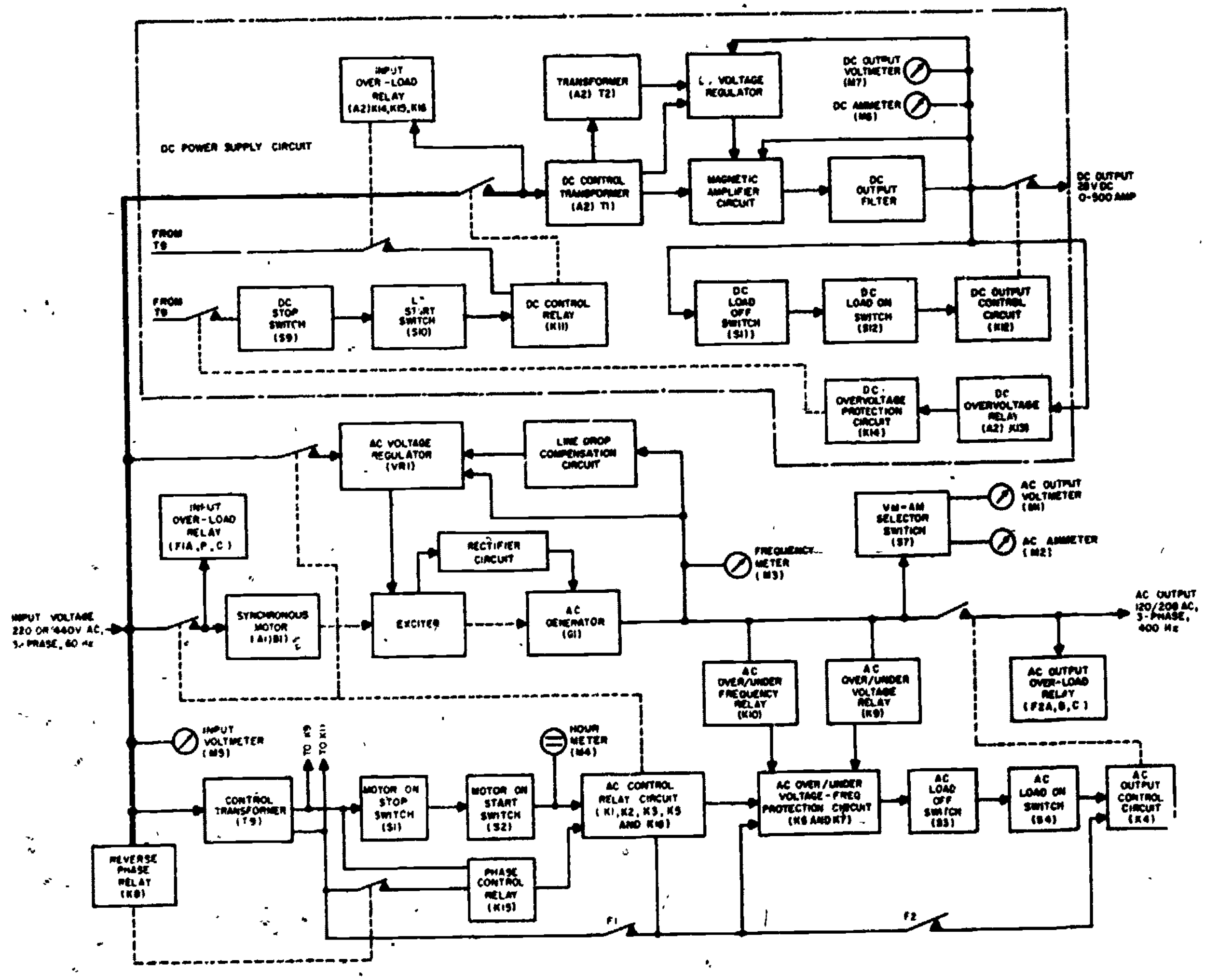


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Figure 12-27.—MMG-2 block diagram.

alternators. When the alternator output reaches a level of approximately 90 volts, the field buildup circuit is automatically disconnected from the alternator field circuit, and field excitation voltage is supplied from the voltage regulator in each channel.

The voltage regulator in each channel is a feedback circuit which samples the a-c output current and voltage from the alternator, and provides d-c excitation voltage to the alternator field circuit. The voltage regulators allow the output of the alternators to build up to 208

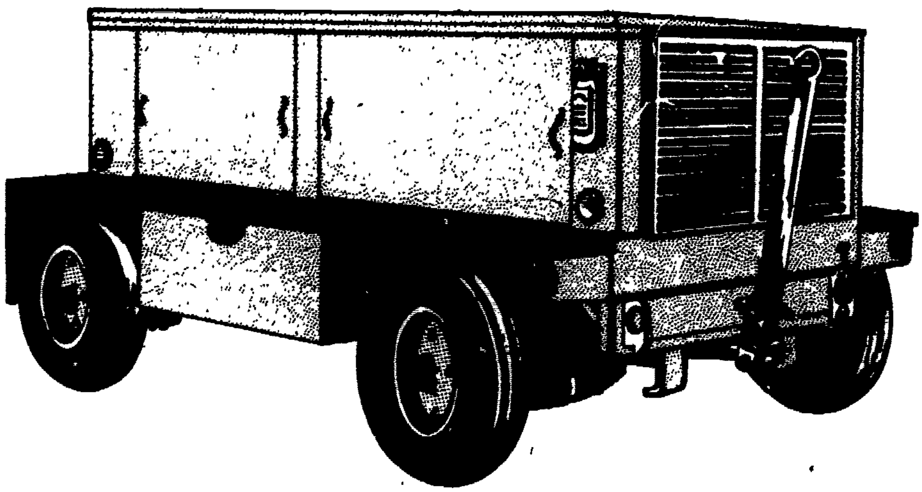

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Figure 12-28.—MMG RX-400.

volts a.c., and then maintain the output at this level. If the alternator output varies due to load fluctuations or engine performance, the voltage regulator produces a compensating current flow in the alternator field circuit which results in correction of the alternator output. If the a-c output increases above the 208-volt level, the voltage regulator proportionately decreases the d-c excitation voltage applied to the alternator field circuit. This action automatically decreases the a-c output voltage of the alternator. If the output decreases below the 200-volt, output level, the voltage regulator proportionately increases the d-c excitation voltage applied to the alternator field, which atuomatically increases the a-c output from the alternator. This action continues until the alternator output settles at the 208-volt output level.

Channel 2 may be used to supply either 120/208-volt a.c., or 28-volt d.c.; it will not supply both a-c and d-c power at the same time. Output circuit breaker CB31 is mechanically interlocked with d-c output circuit breaker CB41—both circuit breakers cannot be in the ON position at the same time. When channel 2 is used for d-c operation, feedback voltage to the voltage regulator is supplied from the d-c output circuit through relay CR33, and the a-c voltage output from the alternator No. 2 drops to approximately 90 volts.

The a-c output voltage for channel 1 may be monitored by voltmeter VM21. Selector switch VS21 is used to select any channel 1 line-to-neutral voltage for monitoring. The a-c output current for channel 1 may be monitored by ammeter AM21. A current sensing transformer (CT1, CT2, or CT3) senses the output current for each phase. Selector switch AS21 is used to select any line for monitoring the current on ammeter AM21.

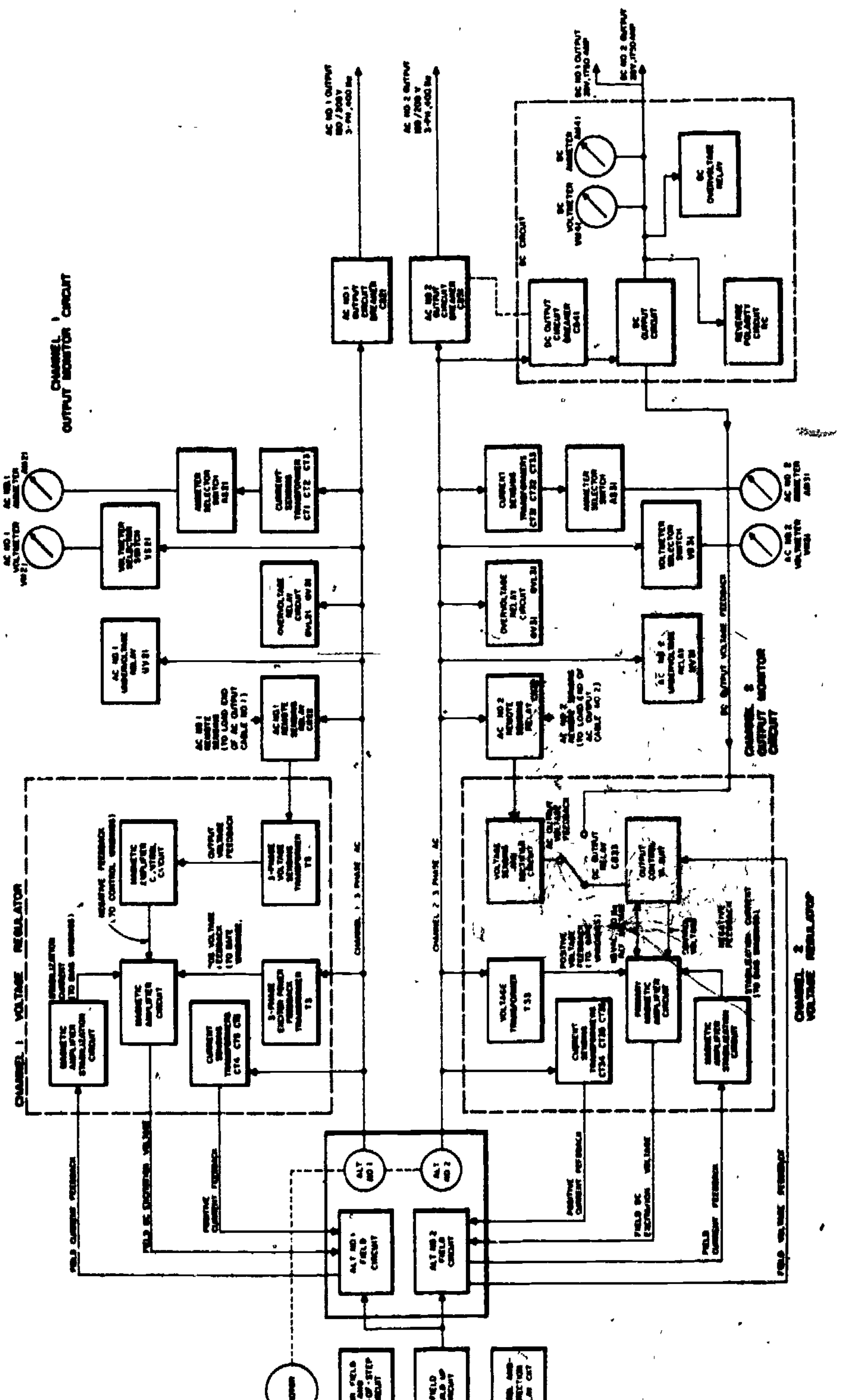

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Figure 12-29.—Power generating system block diagram.

The a-c output voltage for channel 2 may be monitored by voltmeter VM31. Selector switch VS31 is used to select any channel 2 line-to-neutral voltage for monitoring. The a-c output current for channel 2 may be monitored by ammeter AM31. Again, a current sensing transformer (CT31, CT32, or CT33) senses the output current in each phase. Selector switch AS31 is used to select any line for monitoring the current on ammeter AM31.

The d-c output voltage for channel 2 is continuously monitored by voltmeter VM41, and the d-c output current for channel 2 is continuously monitored by ammeter AM41.

For a detailed description of operation of the RX-400, consult NW-19-45-282.

CHAPTER 13

POWER GENERATING SYSTEMS

Power generating systems vary in type, size, capacity, and number of generators, depending upon the demands made upon the powerplant. A system may consist of one dual-purpose, a-c—d-c generator (NC-8A); one a-c generator and a rectifier (NC-10B); two a-c generators and a rectifier (NC-12A); one a-c and one d-c generator (NC-2A); or one a-c and two d-c generators (NC-7C).

D-C GENERATORS

A d-c generator is a rotating machine that converts mechanical energy into electrical energy. This conversion is accomplished by rotating an armature, which carries conductors, in a magnetic field, thus inducing an emf in the conductors. In d-c generators the armature is the rotating member and the field is the stationary member. A mechanical force is applied to the shaft of the rotating member to cause the relative motion. Thus, when mechanical energy is put into the machine in the form of a mechanical force or twist on the shaft, causing the shaft to turn at a certain speed, electrical energy in the form of voltage and current is delivered to the external load circuit.

The power source used to turn the armature is commonly called a PRIME MOVER. Many forms of prime movers are in use, such as steam turbines, diesel engines, gasoline engines, electric motors, and steam engines. Mobile electric powerplants containing d-c generators are usually driven by gasoline or diesel engines. Figure 13-1 shows a typical prime mover.

D-c generators used in MEPP's differ somewhat in design, because they are built by a number of manufacturers. All, however, have the same general construction and operate similarly. Figure 13-2 shows a representative d-c generator.

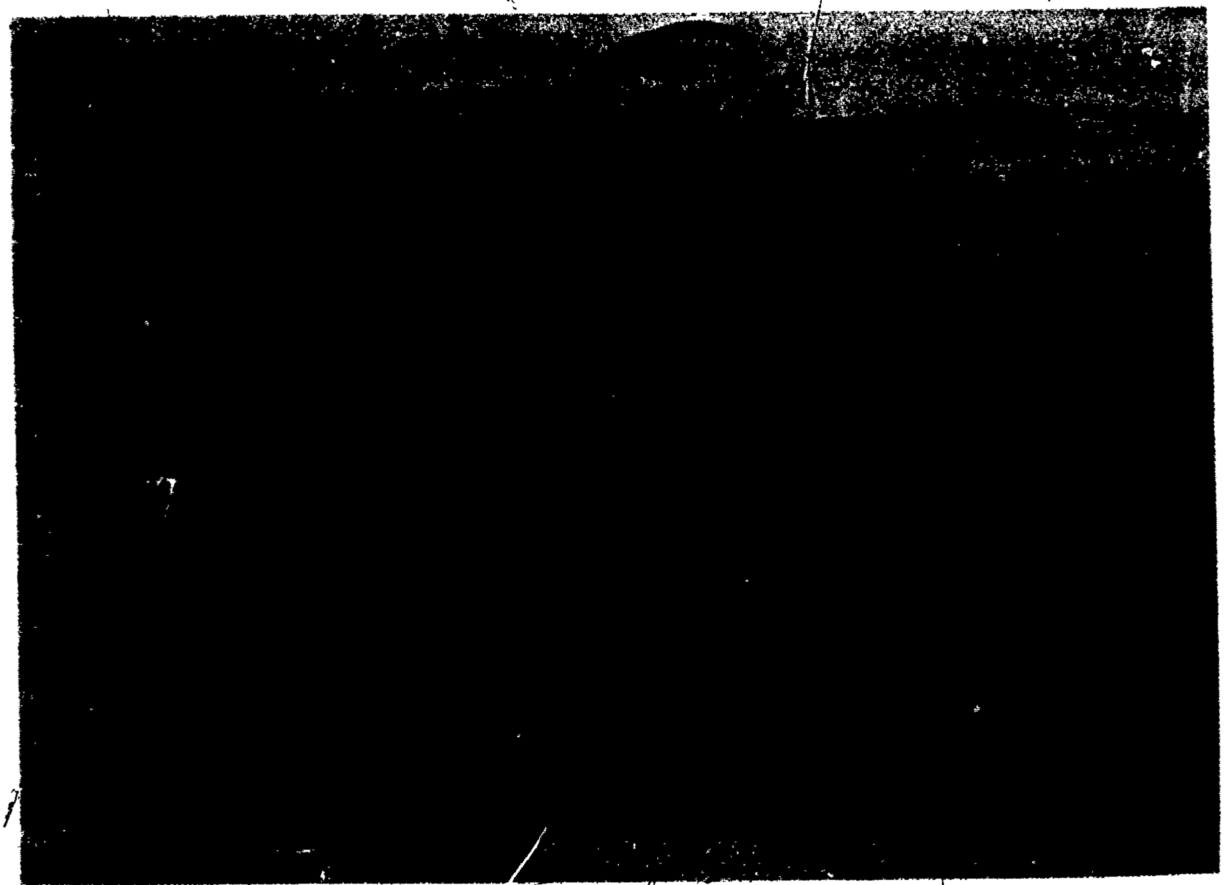
TYPES AND RATINGS

The d-c generator most commonly used in MEPP's is the 28-volt compound type machine; that is, the series field is connected in series with the armature and the shunt field is in parallel. (See fig. 13-3.) The high-output generators also employ commutating poles (interpoles) and/or compensating windings. These are employed to produce good commutation (minimize brush sparking) by counteracting the self-induced emf in the coil undergoing commutation and by opposing field distortion due to armature reaction.

Commutating-pole windings and/or compensating windings are connected in series with the load (fig. 13-3); hence, all load current flows through them. These windings are series elements of the generator's output circuit.

Current Range

The d-c generators on MEPP's are designed for a wide range of current capabilities. Generators used on small type MEPP's, such as the Waukesha E-APU, have a maximum current range of 300 amperes. Larger MEPP's, such as the NC-2A and NC-7C, use d-c generators rated as high as 500 to 750 amperes continuous duty, 1,000 amperes intermittently. The ASE should consult the applicable manual for the proper current ranges of the generator he is maintaining. Caution should be exercised, because some d-c generators must not be operated intermittently at 1,000 amperes for a period exceeding 1 minute on and 1 minute off for 30 minutes operation. This must be followed by 30 minutes at no load.



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1. Primary fuel filter.
2. Air inlet housing.
3. Engine block.
4. Valve cover cap.
5. High coolant temperature shutdown switch.
6. Water temperature transmitter.
7. Fan.
8. Alternator-rectifier.
9. Secondary fuel filter.
10. Starter.
11. Oil level dipstick.
12. Fuel pressure switch.
13. Filter.
14. Oil pressure transmitter.

Figure 13-1.—Typical prime mover.

Two d-c generators are not usually mounted on one MEPP, however, the NC-7C uses the output from two d-c generators for jet starting and d-c servicing. Also, an output from one of the d-c generators is used to power the propulsion system of the powerplant.

Speed Range

D-c generators on MEPP's are designed to operate within different speed ranges. The speed range is that range of speed in which a generator must be operated in order to obtain rated

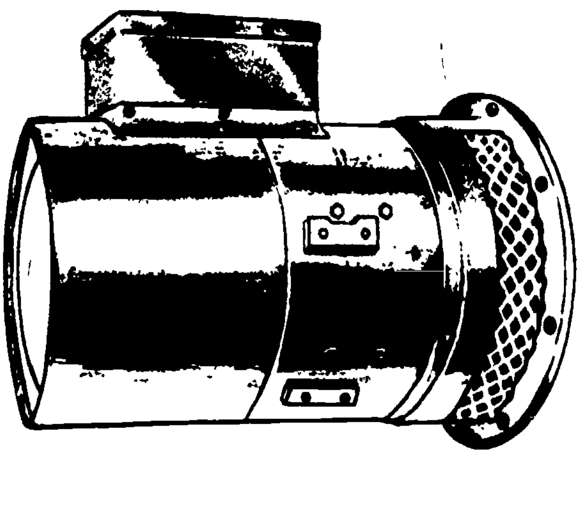

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Figure 13-2.—Representative d-c generator.

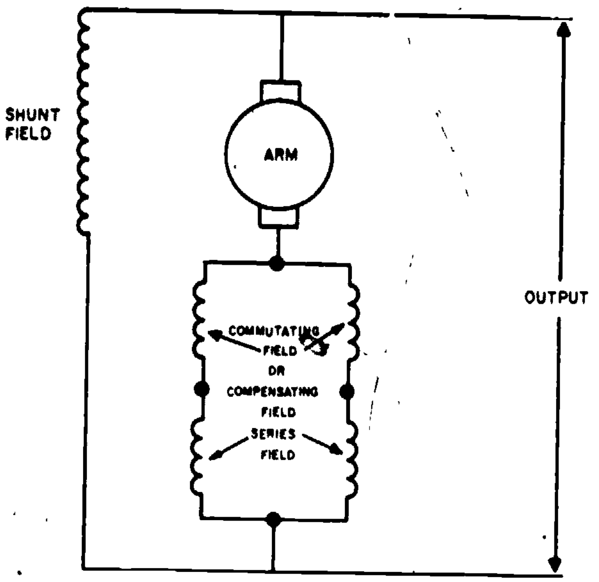

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Figure 13-3.—Internal connections of a compound generator.

generator output; that is, rated voltage at all values of load current within the current range of the generator. The speed range for an E-APU is approximately 3,000 rpm, and the generator speed is controlled by the engine governor.

The speed range for the NC-7C d-c generators is approximately 3,500 rpm and is also governor controlled.

Rectifiers

Rectifiers, in conjunction with a stepdown transformer, or with a special, low-voltage, a-c generator, supply 28-volt d-c power on powerplants utilizing an a-c generator to supply the d-c service power.

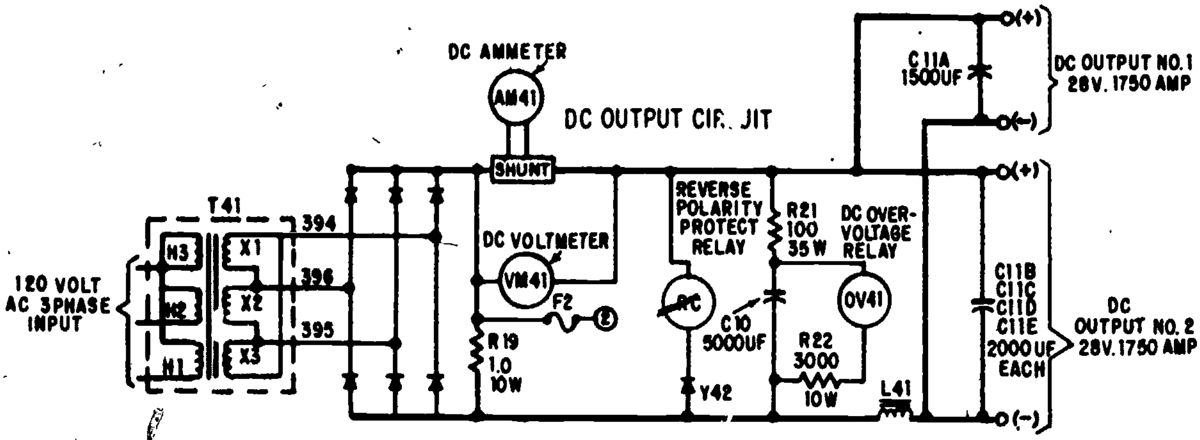
Figure 13-4 (A) shows a wiring schematic of a rectifier system used with a stepdown transformer to reduce the 120-volt a-c input voltage to approximately 30 volts a.c., which is then rectified to provide 28-volt d-c service power. (B) shows a wiring schematic of a rectifier system used with a special, low-voltage, a-c generator.

FACTORS AFFECTING GENERATOR POWER OUTPUT

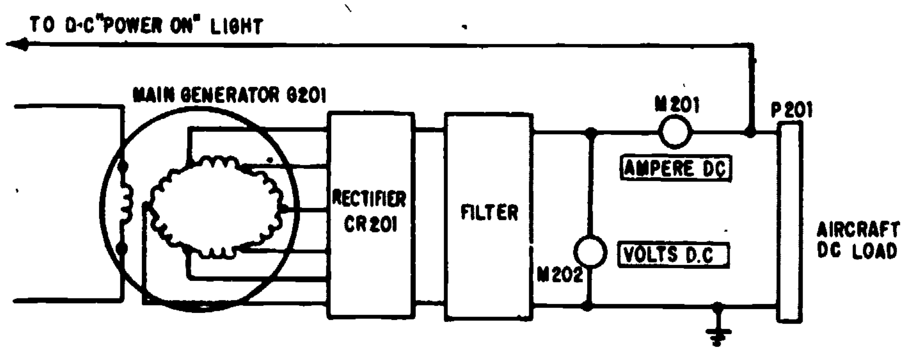
A high-speed generator can produce more power for a given size than a low-speed machine. This is possible because less wire in series is necessary to produce a given voltage in the high-speed generator. Since a shorter length of wire is necessary, a larger size wire can be used, thus increasing the current capacity of the generator.

Due to the large amounts of current which MEPP generators deliver, cooling may become a problem. Most of the generators on MEPP's are cooled by integral built fans. The ASE should always make certain the generator is not overheating. The amount of heat which a given volume of air can remove from a generator is determined by the density of the air; the less the density, the less heat removed. If the temperature of the generator is allowed to rise too high, the insulation may become damaged.

The voltage, current rating, and speed range of generators are usually found on a metal nameplate secured to the generator frame. If this information cannot be found on the generator, refer to the manufacturer's manual.



(A) RECTIFIER AND STEPDOWN TRANSFORMER



(B) RECTIFIER AND SPECIAL LOW-VOLTAGE A-C GENERATOR

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Figure 13-4.—Wiring schematics of rectifier systems. (A) Rectifier and stepdown transformer; (B) rectifier and special, low-voltage, a-c generator.

MAINTENANCE

Generator failures or apparent failures are due to a variety of causes. Before removing a generator that is not delivering its rated voltage or current, determine that the trouble is not caused by a fault in the control, feeder, or regulating circuits or units.

Major repairs such as rewinding of armatures and field coils are done at the depot maintenance activity. Minor troubleshooting for opens, shorts, and grounds of field coils and armatures is discussed in chapter 10 of this training manual.

The ASE will encounter very little trouble with d-c power generating systems if inspections and maintenance are scheduled and performed in accordance with manufacturer's or other applicable manuals.

Table 13-1 is a typical troubleshooting chart for d-c generators. It contains many of the probable causes and remedies for troubles commonly found on d-c generating systems.

Table 13-1.—D-c generator troubleshooting chart

Probable cause	Remedy
Failure To Build Up Voltage	
Open field resistor	Repair or replace resistor.
Open field circuit	Check coils for open and loose connections. Replace the defective coil or coils. Tighten or solder loose connections.
Absence of residual magnetism in a self-excited generator.	Flash the field.
Dirty commutator	Clean or dress commutator.
High mica	Undercut mica.
Brushes not making proper contact	Free, if binding in holders. Replace and reseat if worn.
Newly seated brushes not contacting sufficient area on the commutator.	Run in by reducing load and use a brush-seating stone.
Armature shorted internally, or to ground	Remove, test, and repair or replace.
Grounded or shorted field coil	Test, and repair or replace.
Shorted filtering capacitor	Replace.
Open filter choke	Replace.
Broken brush shunts or pigtails	Replace brushes.
Output Voltage Too Low	
Prime mover speed too low	Check speed with tachometer. Adjust governor on prime mover.
Brushes not seated properly	Run in with partial load, use brush-seating stone.
Commutator is dirty or film is too heavy	Clean, or if film is too heavy, replace brushes with a complete set of proper grade.
Field resistor not properly adjusted	Adjust field strength. Tighten all connections. Make shim adjustment.
Reversed field coil or armature connection.	Check and connect properly.

Table 13-1.—D-c generator troubleshooting chart—Continued

Probable cause	Remedy
Output Voltage Too High	
Prime mover speed too high	Check speed with tachometer. Adjust governor on prime mover.
Faulty voltage regulator	Adjust or replace.
Armature Overheats	
Overloaded	Check meter readings against nameplate ratings. Reduce load.
Excessive brush pressure	Adjust pressure or replace tension springs.
Couplings not alined	Aline units properly.
End bells improperly positioned	Assemble correctly.
Bent shaft	Straighten or replace.
Armature coil shorted	Repair or replace armature.
Armature rubbing or striking poles	Check for bent shaft, loose or worn bearings. Straighten and realine shaft. Replace bearings, tighten pole pieces, or replace armature.
Clogged air passages (poor ventilation)	Clean equipment.
Repeated changes in load of great magnitude. (Improper design for the application)	Generator should be used with a steady load application.
Unequal brush tension	Equalize brush tension.
Broken shunts or pigtails	Replace brushes.
Open in field rheostat	Repair or replace rheostat.
Field Coils Overheat	
Shorted or grounded coils	Repair or replace.
Clogged air passages (poor ventilation)	Clean equipment.
Overload (compound generator)	Check meter reading against nameplate rating. Reduce load.

Table 13-1.—D-c generator troubleshooting chart—Continued

Probable cause	Remedy
Sparking at Brushes	
Overload	Check meter readings against nameplate ratings. Reduce load.
Brushes off neutral plane	Adjust brush rigging.
Dirty brushes and commutator	Clean brushes and commutator.
High mica	Undercut mica.
Rough or eccentric commutator	Resurface commutator.
Open circuit in the armature	Repair or replace armature.
Grounded, open- or short-circuited field winding.	Repair or replace defective coil or coils.
Insufficient brush pressure	Adjust or replace tension springs.
Brushes sticking in the holders	Clean holders. Sand brushes.

TESTING

Operational testing of d-c generators is required when a generator has been removed and/or repairs such as brush replacement, disassembly, and reassembly have been completed. Generally after reassembly the d-c generator is placed on the drive pad of the MEPP.

A typical testing procedure is as follows:

1. If new brushes have been installed, run the generator for 20 to 30 minutes with no load to permit the brushes to seat.
2. Place an external load of less than 330 amperes on the generators.

NOTE: The external electrical load banks are discussed in chapter 9 of this training manual under "Test Equipment."

3. If operation is satisfactory, stop the engine and replace the generator brush covers.
4. Reposition the d-c shunts.
5. Replace all panels and door assemblies and secure them properly.
6. Adjust the generators to rated output.

Testing procedures for d-c generators will vary; therefore, the ASE should consult applicable manuals to conduct these tests properly. It is beyond the scope of this training manual to discuss all methods used in testing of d-c generators.

D-C VOLTAGE REGULATORS

D-c voltage regulators are used to maintain a substantially constant generator voltage despite variations in generator speed and load conditions. They also equalize generator load in installations involving two or more generators. These units are essentially automatic generator field rheostats that maintain a constant output voltage by controlling the generator field current.

CARBON-PILE VOLTAGE REGULATOR

The carbon-pile regulator employs a stack of carbon washers (carbon pile) for the variable resistance element which controls the generator field current. When the stack of carbon washers is compressed, the resistance is at a minimum. As the pressure is released, the resistance increases. The resistance of the carbon stack is automatically varied by the action of an electromagnet coil and the spring tension of the movable armature assembly.

Operating Principles

Figure 13-5 (A) is a simplified schematic diagram of a d-c carbon-pile voltage regulator. When the generator armature first begins to rotate, the wafer spring holds the carbon stack under maximum compression (low resistance) so that the voltage produced by the generator's residual magnetism causes sufficient current flow in the generator field windings. If the carbon stack remained compressed, the generator voltage would rise in proportion to the armature speed and would soon exceed the recommended line voltage. However, the electromagnet coil (potential coil) is connected across the main line of the power supply system and any increase of line voltage causes an increase of current flow in the electromagnet coil. The magnetic force set up by the coil opposes the armature spring and proportionally reduces the compression on the carbon stack, increasing the resistance.

The carbon stack, being in series with the generator shunt field, reduces the flow of current through the generator field coils. In accordance with a previous adjustment, a balance point is then reached between the action of the armature spring and the magnetic pull of the coil to maintain the proper amount of field current in the generator for correct line voltage. This line voltage is then automatically maintained irrespective of generator variations in speed and load. Figure 13-5 (B) shows a more complete schematic which includes an equalizer circuit that is used when generators are connected in parallel. This is explained later.

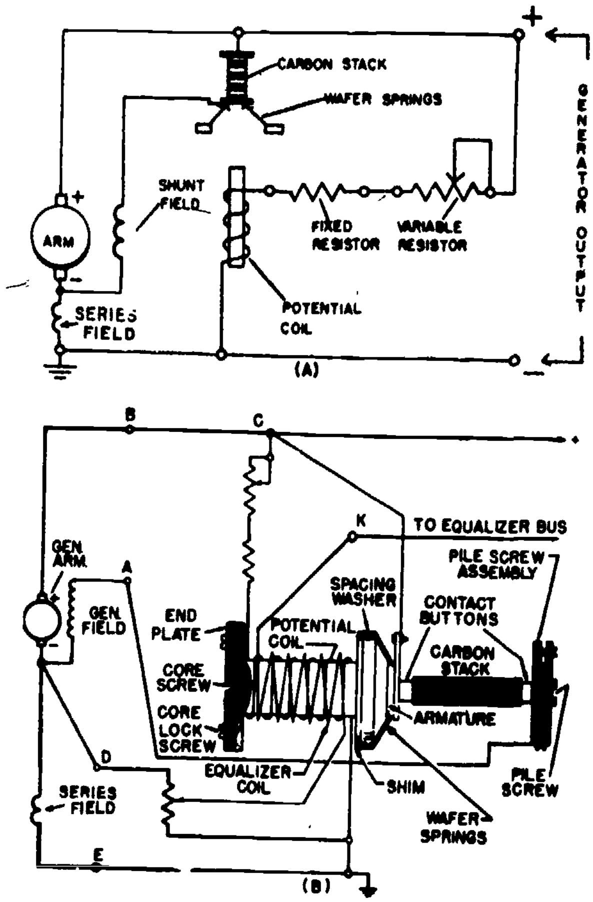

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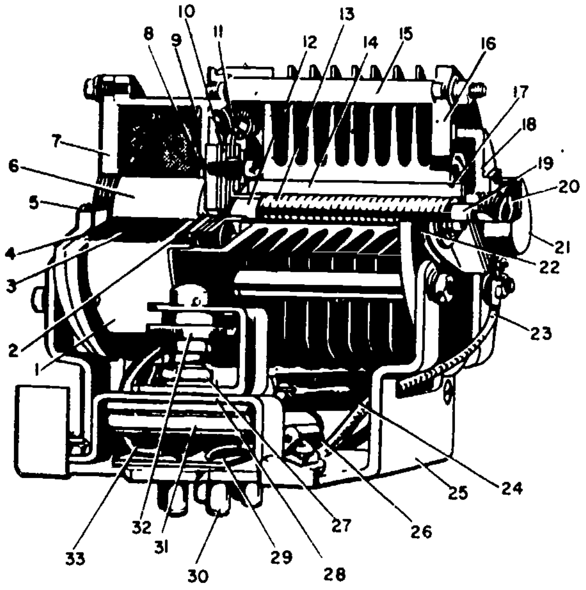
Figure 13-5.—Schematic diagram of a d-c carbon-pile voltage regulator.

Figure 13-6 shows a cutaway view of a typical carbon-pile voltage regulator. The major parts of this regulator are described in the following paragraphs.

The carbon washers are enclosed in a ceramic tube to insulate them from the frame. They are normally under compression (low resistance) between the pile screw contact plug and the contact plug of the armature. The number and the type of washers vary with the different regulators. Some employ all washers of the same thickness, while others have "scrambled" stacks made up of alternately thick and thin carbon washers.



1. Magnet case.
2. Armature stop shim.
3. Electromagnet coil.
4. Paper packing washer.
5. Core locking screw.
6. Magnet core.
7. End plate.
8. Temperature compensating ring.
9. Coil clamping spring.
10. Diaphragm armature assembly.
11. Ferrule.
12. Contact button.
13. Carbon pile.
14. Pile tube.
15. Stud.
16. Pile housing.
17. Tube lock.
18. Pile adjusting screw bracket.
19. Contact button.
20. Pile adjusting screw.
21. Cap.
22. Mica insulator.
23. Lead assembly.
24. Tubular resistor.
25. Base.
26. Stabilizer resistor.
27. Rheostat mounting nut.
28. Clip and bracket assembly.
29. Insulator.
30. Terminal contacts.
31. Rheostat.
32. Adjusting nut assembly.
33. Sliding arm.

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Figure 13-6.—Cutaway view of a d-c carbon-pile voltage regulator.

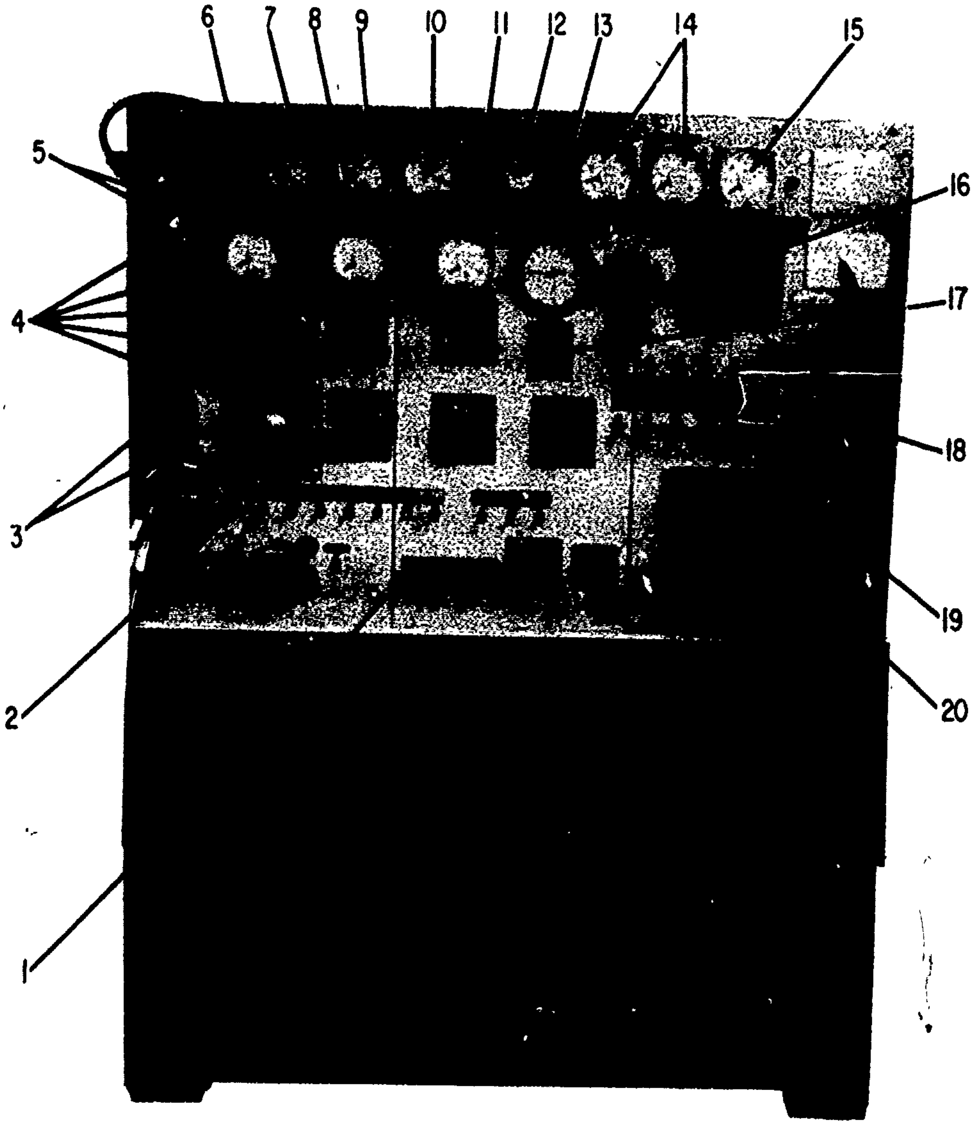
The resistors in series with the electromagnet coil consist of one fixed resistor and one variable resistor. The variable resistor (rheostat) is necessary to adjust the line voltage when installing the regulator, since test stand lead resistance usually varies from that on the MEPP. The fixed resistor has the greater resistance and therefore causes the greater voltage drop and dissipates the most heat. This permits the use of a smaller rheostat which provides for a finer adjustment of the current flow in that circuit. A spring clip engages a knurled flange on the adjusting nut assembly to prevent accidental change of the rheostat setting. The resistance winding of the rheostat is contacted by a sliding arm.

The core screw forms the electromagnet core and is made of soft iron. It is screwed into the end plate and held in place by core locking screws.

The temperature compensating metallic ring which encircles the magnetic core is in contact with the inside wall of the magnet case. This ring enables the regulator to maintain a steady generator voltage for the regulator's range of operating temperatures. The resistance of copper wire increases with an increase in temperature and decreases with a decrease in temperature. As a result, changes in regulator temperature cause changes in the resistance of the magnet coil winding; thus the magnetic flux induced by the coil, which links the armature and the core, is changed. This variation in flux, if not compensated for, causes a change in the magnetic attraction of the core for the armature and produces excessive drift in the generator voltage.

The temperature compensating ring has a magnetic reluctance (opposition to the passage of magnetic flux) which varies directly with temperature. With an increase in regulator temperature, the reluctance of the magnetic path between the magnet case and the core is increased and a greater proportion of the magnetic flux induced by the magnet coil links the core and armature. With a decrease in temperature, the reluctance of the magnetic path between the case and core is decreased and a greater proportion of the induced flux is short-circuited around the armature. As a result, the magnetic flux linking the armature is reduced.

The temperature compensating ring counteracts the effect of temperature on the flux linking the core and armature. As a result, the



1. A-c voltage regulator terminal.
2. A-c generator load switches.
3. D-c generator input.
4. A-c generator input.
5. Meter link terminals.
6. Single-phase wattmeter.
7. Single-phase ammeter.
8. Three-phase wattmeter.
9. Three-phase ammeter.
10. High-low frequency meter.
11. A-c voltmeter.
12. Frequency meter.
13. Pressure gage.
14. D-c ammeters.
15. D-c voltmeter.
16. Voltage regulator pad.
17. Phase sequence indicator.
18. Load disconnect switch.
19. D-c generator load switches.
20. Relay pad.

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Figure 13-7.—Electric power equipment test assembly, model 7085.

tendency of the regulator to drift with changes in temperature is reduced.

The finned pile housing radiates the heat developed during regulator operation. Their terminal contacts extending through holes in the base provide for circuit connections, making connections with contact blades in the shock-mounted base.

There are many different variations in the design of the carbon-pile regulator just described, but they use the same basic principles of operation. Therefore, the ASE should study and learn these principles well, in order that he may have a better understanding of any carbon-pile regulator which he has to service and maintain.

Adjustment

The following adjustment procedure is typical for most carbon-pile regulators. However, each model has its own peculiarities and the proper procedure for each model will differ slightly. The following procedure is to be used only as an example and does not represent test procedures for every regulator in service.

EQUIPMENT REQUIRED.—It is preferable to use the same type of generator for adjusting the regulator that will be used with the regulator in service. However, satisfactory regulator adjustment can be obtained by using any d-c generator having the same or a higher capacity than the one to be used with the regulator in service; that is, a regulator adjusted on a 400-ampere generator will usually work well on a 200-ampere generator, but the reverse is not true.

The test assembly shown in figure 13-7 and test stand shown in figure 13-8 are recommended for testing and adjusting this type of voltage regulator. Other comparable equipment may be used but may necessitate a modification of testing procedures. This test equipment will normally be found in the Ground Support Equipment Shop or the Aviation Electric Shop of an Intermediate Maintenance Activity (IMA) or an activity of a higher level of maintenance. It can be used for testing and adjusting several of the components mentioned in this chapter.

To correctly adjust the regulator for the 27.7 volts required, the voltmeter being used must be capable of producing a readable measurement with an accuracy of 0.1 volt. A recently calibrated and carefully handled PX-14 or similar voltmeter will meet these requirements. The voltmeter on the test assembly cannot be read as accurately as the PX-14.

A pair of headphones are needed to check the stability of the regulator. A phone jack is provided on the electrical test assembly for connecting the headphones.

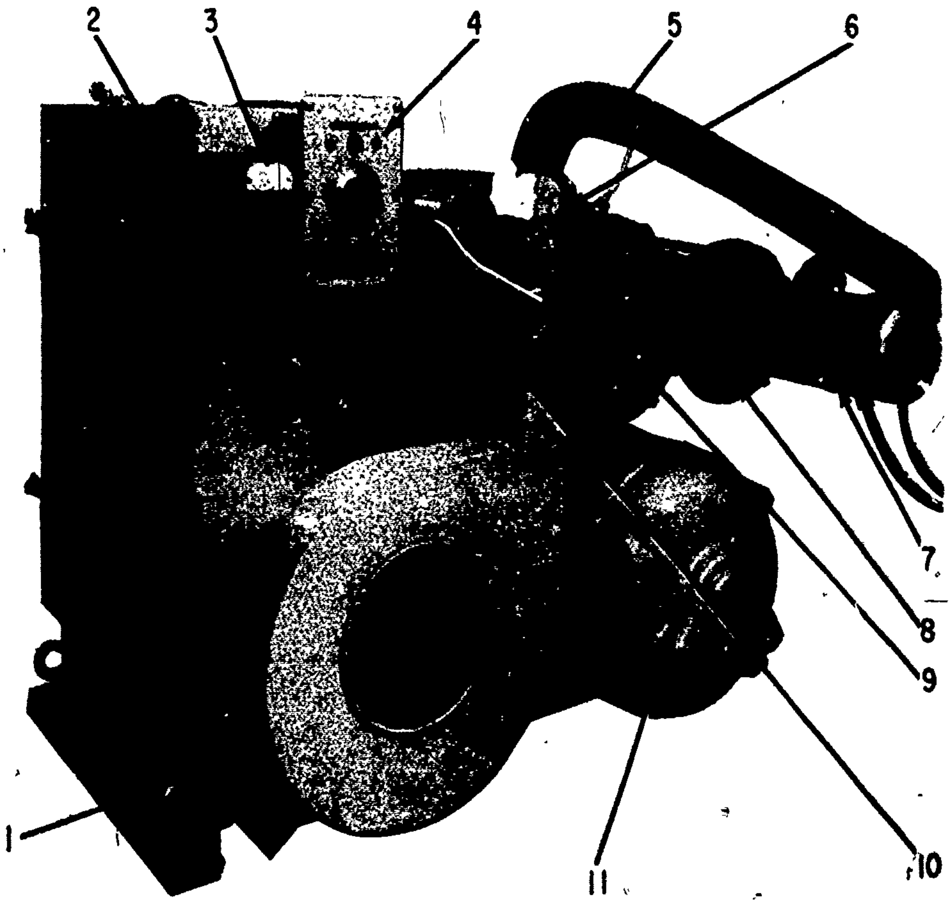
CHARACTERISTIC CURVE.—A typical pile screw characteristic curve is shown in figure 13-9. Point A is the first peak of generator voltage as the pile screw is turned inward (clockwise) from a full-out position. Point B is the proper adjustment point, a point near A where the full-load voltage and the no-load voltage of the generator are the same.

CAUTION: Point D can be obtained on a regulator of this type that has a full-load and no-load voltage of the same value at 27.7 volts. If a regulator pile screw is adjusted for point D and the regulator is installed in an MEPP, excessive generator voltage may be experienced with a temperature change in the regulator. Point D is the improper adjustment point—avoid adjusting here. Point C is shown because it is desirable to check on the condition of the regulator at this point. Do not shock-load the regulator with the pile screw near point C on the curve.

PROCEDURES FOR TESTING AND ADJUSTING. Procedures for testing and adjusting must be accomplished in the following sequence:

1. Connect the equipment as shown in figure 13-10. Make certain that the proper size wire is used and that all connections are clean and tight.

2. Connect the POS lead of the PX-14 voltmeter to terminal B of the voltage regulator base, and the NEG lead to terminal G. This connects the voltmeter across the generator output.



1. Blower fan housing.
2. Start-stop pushbuttons.
3. Tachometer indicator.
4. Speed sensitive master control station.
5. Flexible airhose.
6. Pitot tube.
7. Test generator.
8. Generator mounting bracket, 60-cycle input.
9. Generator mounting bracket, 60-cycle input.
10. Blast gate.
11. Varidrive motor.

Figure 13-8.—Generator test stand, type MA-1. AE.115

CAUTION: Terminals A and B of the voltage regulator base are near each other. A short from A to B will cause excessively high generator voltage. Be sure not to short these two terminals with the POS lead of the voltmeter.

3. Inspect the regulator for wiring discrepancies, such as wires too long or too short, wires not routed properly, wires chafed or overheated, cold-solder joints, and other items that might cause failure.

4. Make sure that the four screws holding the magnet case to the frame are tight.

5. Measure the coils, resistors, and rheostat for proper resistance values. If the regulator parts are not within the range of resistances given in the Overhaul Instructions Manual, repair the regulator or return it for overhaul.

6. Set the voltage regulator rheostat to its mechanical midposition.

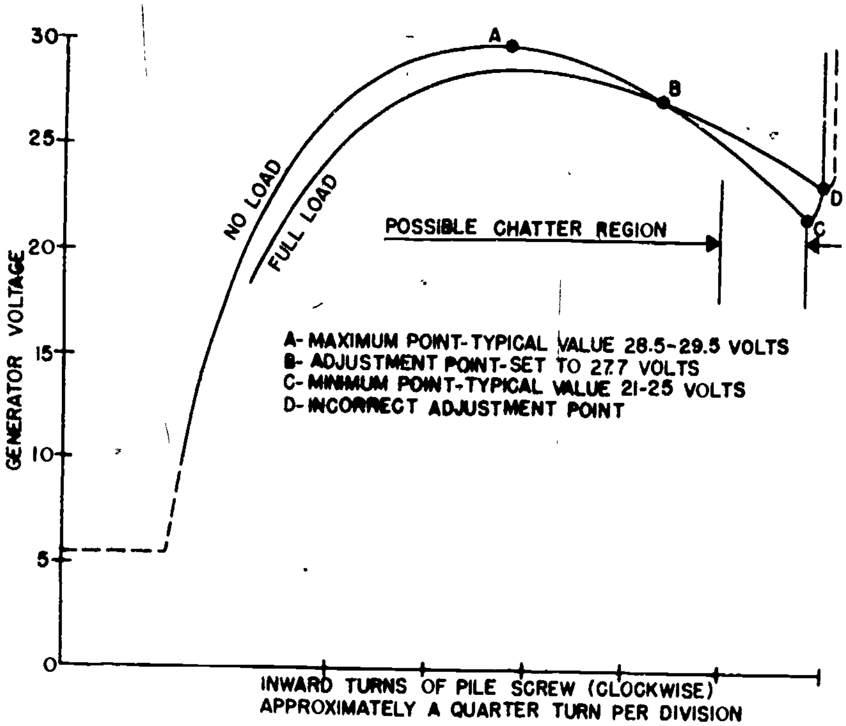


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Figure 13-9.—Typical pile screw characteristic curve.

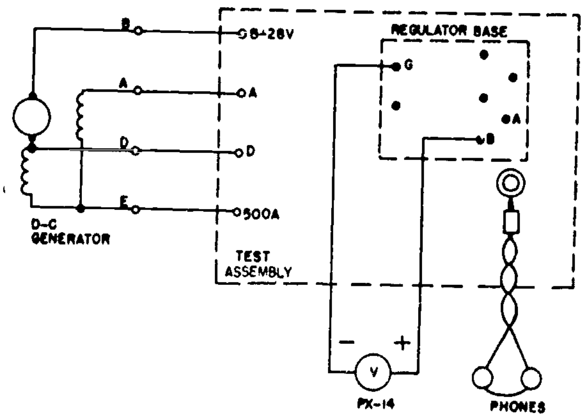

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Figure 13-10.—Test wiring diagram.

7. Mount the regulator on the base provided on the test assembly.

8. Set all switches and links on the test assembly to their proper positions. See the Operation and Service Instruction Manual, NavAer 17-15BA-517, to determine the proper settings of the switches and links.

9. Turn the pile screw out (counterclockwise) until pressure is relieved and the screw turns freely.

10. Start the cooling fans for the load bank.

11. Start the generator and bring it up to 4,500 rpm. The generator voltage shown on the PX-14 voltmeter should be less than 10 volts. If not, the carbon pile is too long and one washer should be removed. Recheck for a generator voltage of less than 10 volts.

12. Increase the generator speed to 8,000 rpm.

13. Turn the pile screw in (clockwise) slowly. The generator voltage will rise to a maximum at

point A on the characteristic curve (fig. 13-9). The voltage at point A should be between 28 and 30 volts.

14. Continue to turn the pile screw slowly in a clockwise direction until the generator voltage falls about 1 volt below point A. This is the approximate position of point B.

15. Fully load and unload the generator to determine point B, the point where the full-load and no-load voltages are the same. If the full-load voltage is lower than the no-load voltage, turn the pile screw in; if it is higher, turn the pile screw out.

16. When point B is established, loosen the magnet locking screw and turn the core screw in (clockwise) slightly if the generator voltage is higher than 27.7 volts. If the generator voltage is below 27.7 volts, turn the magnet body (core screw) out (counterclockwise) slightly. Tighten the magnet locking screws uniformly, making certain to establish point B at 27.7 volts with the magnet locking screws tight. (NOTE: In this procedure, 27.7 volts is specified as the voltage to which the regulator should be adjusted. The varying effects of climatic and operating conditions will sometimes dictate a change in this setting.)

17. Set the test assembly d-c voltmeter circuit selector switch to the PILE V position.

18. Reduce the generator speed, with no load on the generator, to approximately 3,500 rpm; then adjust the speed until the pile voltage is 13 volts. Allow the generator to operate at this speed for 15 minutes to bring the regulator up to operating temperature

19. Turn the test assembly d-c voltmeter circuit selector switch to the INVERTER INPUT or GEN V position.

20. Increase the generator speed to 8,000 rpm.

21. To detect instability, listen carefully on the headphones while shock-loading (applying and removing full load to the generator) the regulator. A stable regulator produces a humming noise or steady roar. A rapid series of popping noises indicates instability. If the regulator is unstable, replace the carbon-pile stack and readjust the regulator.

22. With the generator at 8,000 rpm, turn the pile screw in (clockwise) until voltage reaches its minimum, point C.

23. Note the voltage at point C and calculate the voltage difference between points B and C. This voltage difference is normally 3 to 6 volts. If it is less than 0.7 volt, return the regulator to be overhauled.

24. Return the pile screw setting to point B. CAUTION: The pile may chatter near point C, therefore, pass through this region as quickly as possible to prevent damage to the carbon-pile disks. Do not shock-load the regulator near point C as this may induce chattering.

25. Establish the exact position of the pile screw for point B by checking the full-load and no-load regulated voltage at 8,000-rpm generator speed. Readjust the magnet body, if necessary, to the 27.7-volt value for point B. Make sure the magnet locking screws are tight.

26. Record the no-load and full-load voltages at 4,500, 6,000, and 8,000 rpm. The regulated voltage should remain between 27.2 and 28 volts for these speeds. If the voltage does not remain between these limits, turn the pile screw in slightly and recheck.

27. Increase the generator speed from 4,500 to 8,000 rpm without shock-loading, then note the generator voltage.

28. Shock-load the regulator several times and note the no-load voltage. The difference between these two readings should not be greater than 0.3 volt. If it is greater, replace the carbon disks and check the insulation tube for cleanliness and cracks.

29. With the generator at 6,000 rpm, note the regulated voltage. Press the EQUALIZER TEST button on the test assembly. The regulated voltage should drop a few volts. If the voltage does not change, check for an open equalizer circuit. If the voltage rises, check for reversed equalizer connections.

30. With the generator running at no load and 6,000 rpm, move the rheostat through its travel to determine if it will adjust the regulated voltage from 26 to 30 volts. If not, check the resistance of the rheostat for proper value.

31. After this check, set the rheostat for a generator voltage of 27.7 volts no load at 6,000 rpm.

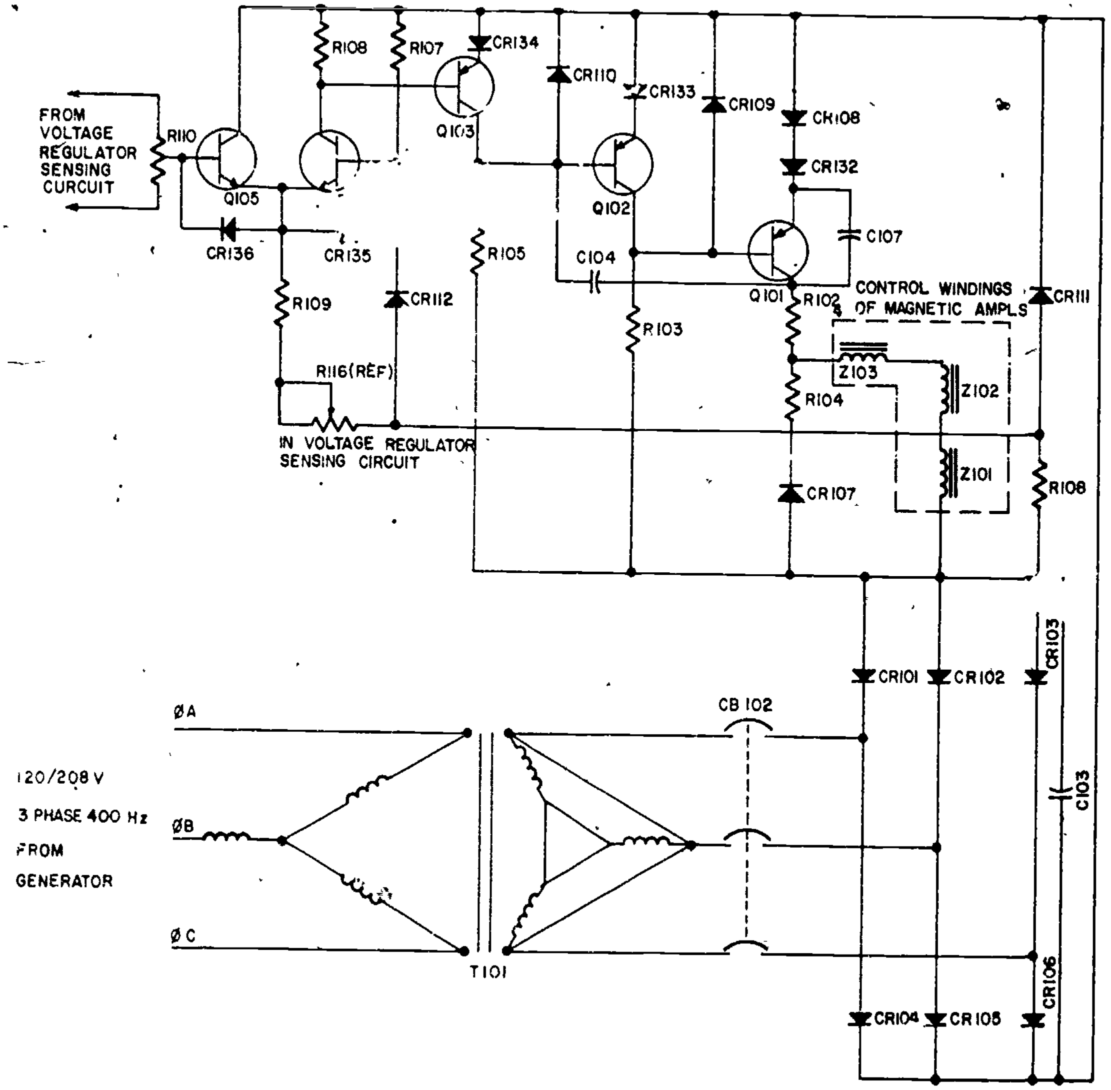

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Figure 13-11.--D-c transistorized voltage regulator.

TRANSISTORIZED VOLTAGE REGULATOR

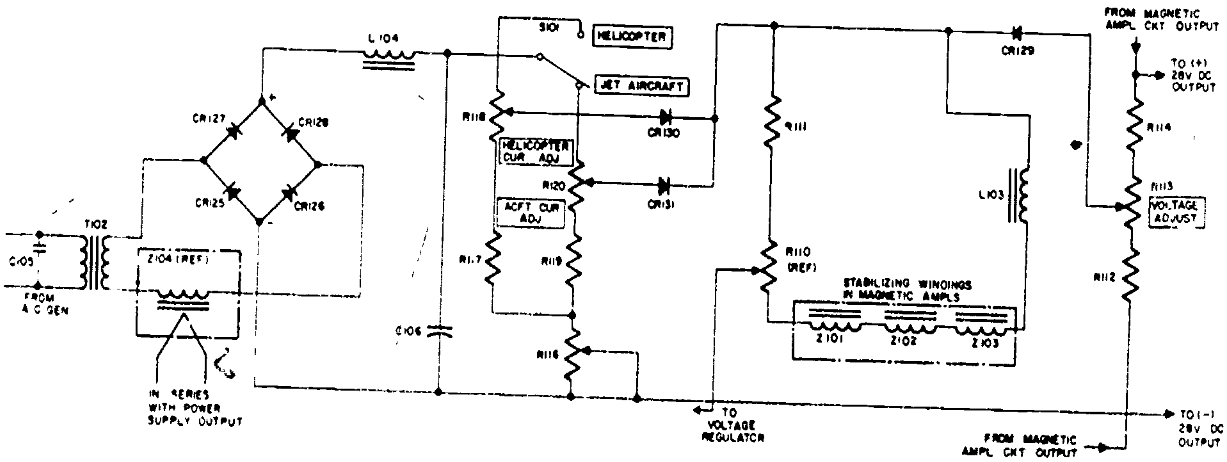
This d-c voltage regulator is referred to as a transistorized regulator because transistors are combined with magnetic amplifiers to provide regulation. One of the many outstanding features of this regulator as well as some of the a-c voltage regulators discussed later in this chapter is that they have no moving parts. The particular d-c voltage regulator (fig. 13-11) under discussion is used on the NC-12, but similar regulators are used on other modern MEPP's. If the ASE does not understand the theory of transistors and magnetic amplifiers it behooves him to refer to the appropriate chapters of Basic Electronics, NavPers 10087 (Series), and Basic Electricity, NavPers 10086 (Series).

As mentioned earlier, the NC-12 has only one large a-c generator for supplying large amounts of a-c and d-c power to external electrical loads. A three-phase full-wave rectifier and filter is used to change a portion of the a.c. to d.c. The d.c. must be regulated, so a d-c transistorized voltage regulator is used. This type d-c voltage regulator provides the d-c control signal for the control windings of the magnetic amplifier. The regulator controls the output voltage and maintains it at a constant level, even if the input voltage to the magnetic amplifier varies, or a change in load current occurs. The d-c voltage regulator operates as a switching device with a varying duty cycle in a manner identical to the a-c transistorized voltage regulator discussed later in this chapter.

D-c Voltage Regulator Input Sensing Circuit

The d-c voltage regulator input circuit (fig. 13-12) senses changes of output voltage from both the a-c generator and the magnetic amplifier. Transformer T102 provides a constant a-c voltage. A voltage divider network composed of resistors R112, R113, and R114 provides the sensing voltage from the output of the magnetic amplifier. The output of transformer T102 is applied to a bridge rectifier composed of crystal diodes CR125 through CR128. Current transformer Z104 is connected in series with the output of transformer T102. Transformer Z104 produces an output proportional to the amount of current flow in the d-c output lines which is out of phase with the output of transformer T102. With an increase of d-c output current, the voltage input to the bridge rectifier increases. The rectified voltage from the bridge rectifier is filtered in inductor L104 and capacitor C106. Depending upon the position of HELICOPTER-JET AIRCRAFT switch S101, the rectifier voltage will appear across a voltage divider network composed of variable resistor R116 and either resistors R117 and R118 or resistors R119 and R120.

Under constant output voltage conditions, the voltage that appears at the input to the voltage regulator keeps the voltage regulator biased to the center of its operating curve. Changes in either the d-c output lines or the a-c generator are coupled through crystal diode CR129 and appear at the input of the voltage regulator through resistor R111 and variable resistor R110. The voltage regulator will then correct for the change in voltage and keep the d-c output



AS.371

Figure 13-12.—D-c voltage regulator input sensing circuit.

voltage constant. An increase of current flow in the d-c output lines will create a voltage drop across the output cables. This voltage drop is compensated for by the voltage regulator sensing circuit. Since the output voltage from transformer Z104 is out of phase with the output voltage from transformer T102, an increase of current flow in the output cables decreases the voltage drop across variable resistor R116. The effect is the same as if the d-c output voltage had dropped. The voltage regulator corrects for a decrease in output voltage and increases the output voltage from the magnetic amplifier. The stabilizing windings of the magnetic amplifiers Z101, Z102, and Z103 are energized whenever a change in voltage occurs at the other windings in the magnetic amplifiers. The action of the magnetic amplifiers is the same as any transformer. With an a-c signal applied to one of its windings, a transfer of power occurs. In this case, the a-c signal is developed whenever a change of output voltage occurs. The stabilizing windings receive the transfer of power and present this output to the voltage regulator. The voltage regulator, in turn, corrects for the change of voltage in the winding of the magnetic amplifiers and damps out any oscillations that may occur.

D-C CIRCUIT PROTECTION

With the incorporation of high capacity power generating systems in MEPP's, accompanying problems of protecting the MEPP and the aircraft electrical system from a number of possible fault conditions occurred. Such conditions include shorts in power cables and improper system voltage. A discussion of some of the d-c protection devices follows.

OVERVOLTAGE RELAY

The d-c electrical power generating systems of modern MEPP's are equipped with protective devices (overvoltage relays) for prevention of damage which might result from excessive voltage. If the generator produces an overvoltage (a condition which sometimes occurs momentarily due to power surges), the overvoltage relay will automatically open the field circuit of the generator. The upper limit of voltage is usually set at 31 to 33 volts. The overvoltage unit consists of two relay coils—the TRIP coil and the RESET coil. When the overvoltage condition occurs, the trip coil is energized and the field circuit of the generator is thus opened. The relay may be reset by placing the generator control switch in the RESET position. This energizes the reset coil of the overvoltage relay, closing the generator field circuit again; but the generator will not operate until its control switch is returned to the ON position. If the circuit trips a second time, further operation of the generator should not be attempted until the trouble has been investigated.

UNDERVOLTAGE RELAY

Some d-c power generating systems utilize an undervoltage relay for protection of the d-c electrical system. The undervoltage relay is used in a number of different ways to perform this task and is usually used with one or more relays or other components to perform a particular task when an undervoltage condition exists. It is the voltage sensing device (set to close and open at certain voltages) and is the control for the other components.

The undervoltage relay can be used in the control circuit of the main relay that connects the generator to the load (aircraft, etc.). When the MEPP is operated the generator does not come on the line if there is an undervoltage condition, because the undervoltage relay senses the low voltage and does not close. With the undervoltage relay open there is no power to the control circuit of the main relay and it remains open. But if the generator voltage is of the proper value the undervoltage relay closes, sending power to the control circuit of the main relay, which closes and places the generator on the line. During operation if the output voltage decreases below that for which the undervoltage relay is set, the undervoltage relay will open. This removes power from the main relay which opens and removes the generator from the line.

If the power requirement for the particular load is critical, the undervoltage relay may be designed so that a set of contacts could close when the relay is deenergized. This would send power to the main relay of an alternate or standby power supply, placing it on the line.

REVERSE-CURRENT RELAY

The reverse-current relay is an automatic switch installed in the power supply system between the generator and the battery.

When the generator voltage is above battery voltage, the relay closes, connecting the battery to the generator. When the generator is stopped or its voltage output is below battery voltage, the reverse current from the battery causes the relay to open, thus preventing battery discharge.

The reverse-current relay shown in figure 13-13, although it has limited use in mobile power equipment, will be used to illustrate the basic principles of reverse-current relay operation. This fixed voltage type relay is still widely used in battery charging work as well as in automotive and small MEPP applications.

The reverse-current relay employs a potential coil and a series coil wound on the same core to actuate the relay contacts. When the generator armature begins to rotate, current flows through both the potential and the series coils. As the generator voltage increases, the current through these coils increases. The fluxes produced by these coils are additive. When the generator voltage reaches about 26.5, the current through the coils produces adequate flux to close the relay contacts. This permits current to flow to the battery and to other loads. All of this current must pass through the series coil. This load current produces additional magnetism which aids in holding the relay contacts firmly closed. The contacts remain closed as long as the generator is supplying current to the load.

When the engine speed is decreased, the generator voltage is decreased. When the generator voltage becomes lower than the battery voltage, current flows from the battery to the generator (reverse current). The direction of current flow through the potential coil remains the same. The magnetism produced by the reverse current through the series coil opposes that of the potential coil, and the contacts open, disconnecting the generator from the load. The relay closing voltage is adjusted by changing the armature spring tension.

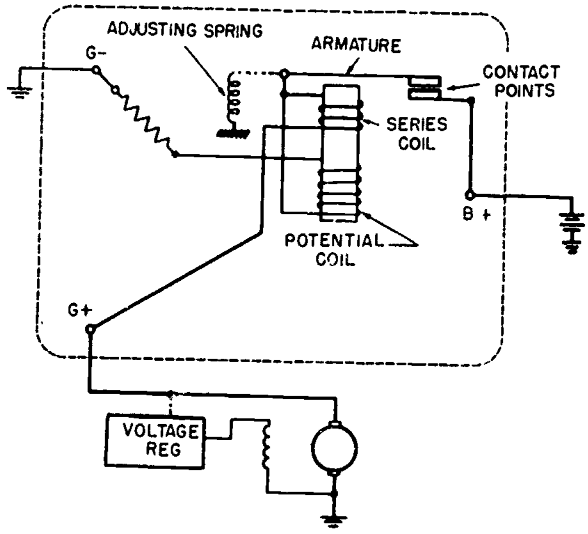


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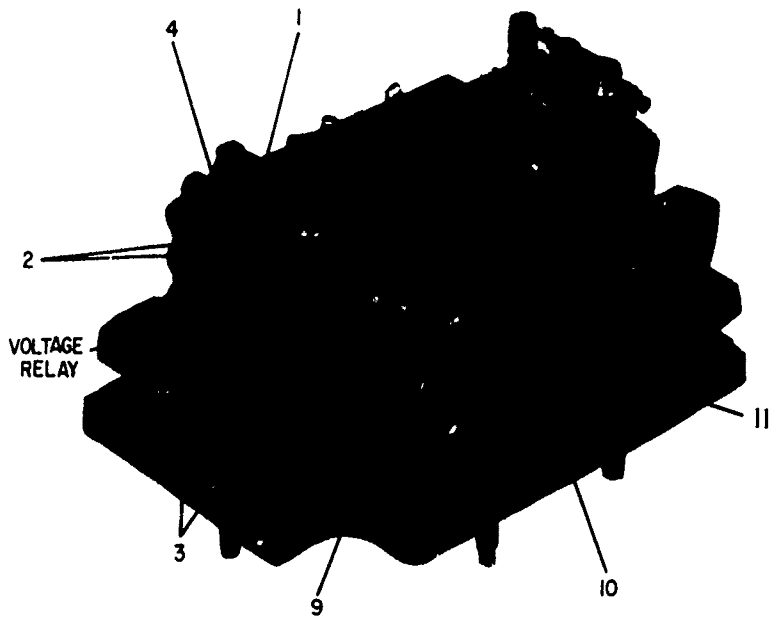
Figure 13-13.—Internal connections of a reverse-current relay.

Differential Reverse-Current Relay

The differential voltage type reverse-current relay measures the difference between generator voltage and the system voltage, and prevents operation until a predetermined voltage difference exists. Hence, the system voltage may vary over a wide range without objectionable chatter when the differential voltage type reverse-current relay is used.

The following paragraphs discuss the details of construction and the principles of operation of the AN3025-300 (type A-700A) differential voltage generator control relay.

The differential type reverse-current relay, as illustrated in figure 13-14, prevents reverse current in excess of 25 amperes from flowing from the battery of an aircraft or MEPP to the generator of an MEPP. The differential voltage type of relay prevents this reversal of current by automatically disconnecting the generator from the battery or electrical system when the generator's voltage drops below the voltage of the



1. Permanent magnet armature.
2. Pole faces.
3. Relay frame.
4. Spring.
5. Permanent magnet armature.
6. Coils.
7. Series coil.
8. Movable contacts.
9. Magnetic frame.
10. Movable core.
11. Core rod.

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Figure 13-14.—AN-3025-300 (type A-700A) differential voltage generator reverse-current relay.

battery or that of the system. The reverse-current relay will automatically reconnect the generator to the battery or electrical system when the generator's output voltage exceeds that of the battery or electrical system.

The relay may also be used as a starting contactor, as well as a reverse-current relay, for the E-APU which is started by applying battery voltage to the generator.

The voltage relay (fig. 13-14 (A)) consists of a permanent magnet armature (1) pivoted between the pole faces (2) of the relay frame (3). Because the armature is a permanent magnet, the relay will not operate unless the voltage applied to the coil is of the correct polarity.

The relay coil has approximately 480 ohms resistance and is designed to close its contacts between 20 and 24 volts if the generator builds up in the correct direction. If the generator is faulty and builds up reverse voltage, the relay will not close.

A spring (4) is attached to the armature so that the voltage relay will open when the voltage drops to 18 volts.

The differential relay (fig. 13-14 (B)) is similar in construction to the voltage relay and also uses a permanent magnet armature (5). The only difference between these relays is that the differential voltage relay has two coils. These are wound in opposite directions so that one coil instead of a spring will return the armature.

One of these coils (6) is wound with fine wire. It has a resistance of approximately 5 ohms and is designed to close the relay when the voltage

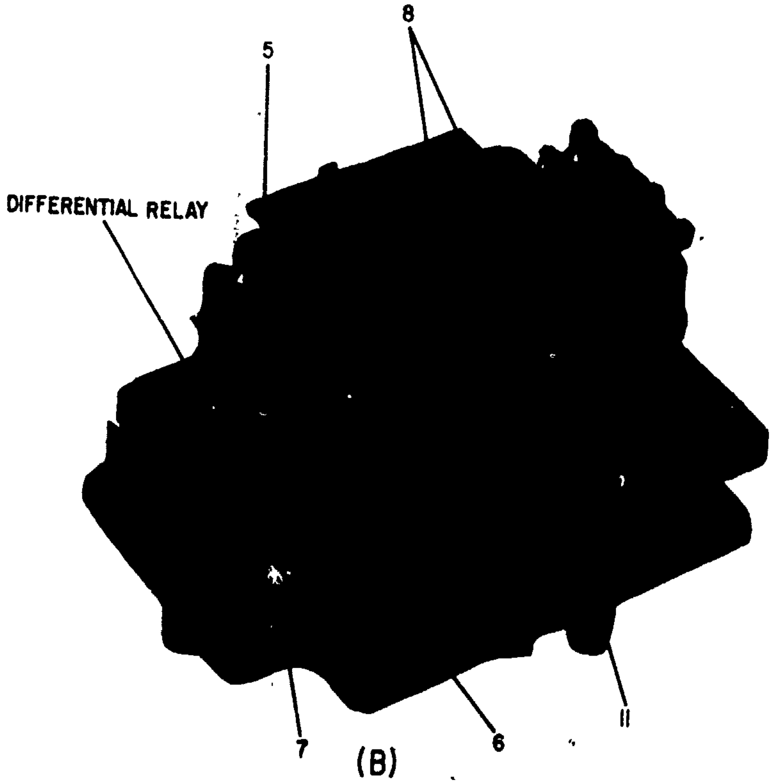


Figure 13-14.—AN-3025-300 (type A-700A) differential voltage generator reverse-current relay—Continued. AE.171

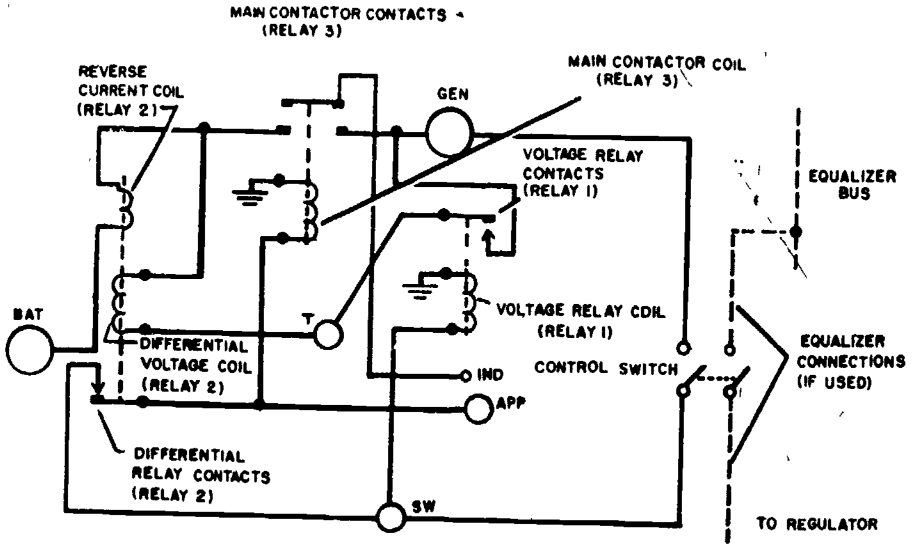
difference between the generator and bus is greater than 0.35 to 0.65 volt, and the generator voltage is greater than the bus voltage.

The series coil (7) is a current coil arranged to open the relay when the current is between 16 and 25 amperes and in a reverse direction flowing from the system to the generator.

The contactor is a solenoid type switch and consists of a coil, magnetic frame (9), and movable core (10). When voltage in excess of 10 volts is applied to the coil, the plunger is attracted by the magnetic frame. As the plunger moves up in the coil, the movable contacts (8), which are attached to the core rod (11), close the circuit and connect the generator to the system. These main contacts are rated at 300 amperes. The contacts will remain closed until reverse current opens the differential voltage relay, which opens the contactor coil circuit and permits the main contacts to open.

PRINCIPLES OF OPERATION.—The heart of this device is the polarized differential relay. This is an electromagnetic switch with a permanent-magnet armature. The opening and closing of this armature is, therefore, dependent upon the direction of current flow in the coil.

The sequence of operation is explained in figure 13-15. When the generator voltage reaches approximately 22 volts, the polarized voltage relay (1) will close if the generator control switch is closed. This energizes the fine wire coil of the polarized differential relay (2) which is connected across the main contacts. At this time these main contacts are in the open position. The voltage on the coil of relay (2) is now the difference between generator voltage and that of the system, or battery voltage. When this voltage reaches a value between 0.35 and 0.65 volt and is of the correct polarity (generator voltage must be higher than the system voltage), the differential



AE.172

Figure 13-15.—Schematic wiring diagram, AN-3025-300 (type A-700A) generator reverse-current relay.

relay coil magnetizes the associated iron core material and trips the differential relay contact. This contact closes the circuit between the generator output and the coil of the main contactor, energizes the contactor coil, and closes its normally open contacts joining the generator to the system. The closing of the main contactor shorts out the differential voltage coil (2); however, its contacts will remain closed because of the magnetic attraction of the permanent-magnet armature.

During operation, if the generator voltage drops below the value of the system voltage, current will flow through the generator to the system. This action attempts to drive the generator as a motor. The reverse current flows through the reverse-current coil. When its value reaches from 16 to 25 amperes, the resulting magnetic field in the core of the differential relay forces the pivoted permanent-magnet armature to open the differential relay contacts. This opens the circuit containing the coil of the main contactor, and thus its contacts open which, in turn, disconnects the generator from the system. As the generator voltage decreases to 18 volts, the voltage relay (1) will open.

By referring to figure 13-15, it can be seen that this reverse-current relay also serves as a generator relay. Opening the generator control switch will deenergize both the voltage relay (1) and the main contactor relay(3) which disconnects the generator from the system. Closing the switch will likewise connect the generator to the system.

Testing

Reverse-current relays must be bench tested when there are indications that they are operating improperly in the MEPP's. The procedure to be used when testing the AN-3025-300 (type A-700A) cutout, using a test stand, is given as a typical example. The circuit shown in figure 13-16 is used in this presentation. Connect the relay into the circuit, as shown in the figure, without removing the cover.

The procedures for operating and testing a reverse-current relay are given under the appropriate headings.

DIFFERENTIAL VOLTAGE AND REVERSE-CURRENT OPERATION.–

1. Set all switches in the OFF position.
2. Operate the generator on the test stand at about 4,000 rpm.
3. With SW1 in position 1, adjust the generator voltage by means of R1; the field rheostat, so that the generator voltage is about 1 volt less than the battery voltage. Generator and battery voltage readings are obtained on V3 by placing SW5 in the 1 or 2 position.
4. With SW2 in position 1 and SW4 closed, place SW3 in position 2 and slowly increase the generator voltage by means of R1. When the relay operates, the voltage indicated on V2 will go to zero. The differential voltage is the reading just before V2 goes to zero, and should be between 0.35 and 0.65 volt.
5. SW3 must be set in the open position before performing the next test.
6. To measure the reverse current, slowly decrease the generator speed until the relay opens. This current is read at A1 and should be between 16 and 25 amperes. This will be the reading just before the reading on A1 returns to zero.
7. Leave the differential relay contacts in the open position.

TESTING VOLTAGE RELAY.–

1. Set all switches in the OFF position. Operate the generator at about 4,000 rpm.
2. The differential relay contacts must be in the open position.
3. Set SW2 in position 1, SW5 in position 1, and SW1 in position 1, and slowly raise and lower the voltage by means of R1. The closing voltage should be between 20 and 24 volts and is read on V3 when the relay operates. The opening voltage should be above 18 volts.
4. The contactor will not close with this switching arrangement, so it will be necessary to connect an ohmmeter from GEN terminal to T test terminal to indicate when the contacts have

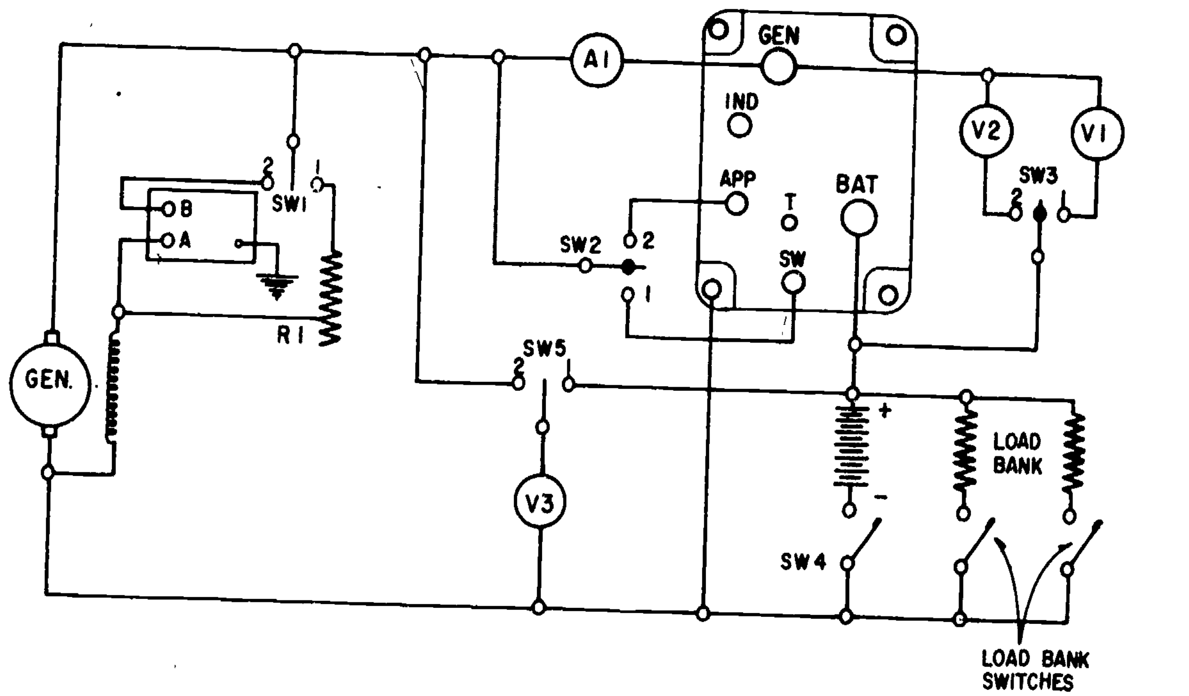


Figure 13-16.–Test circuit (using test assembly).

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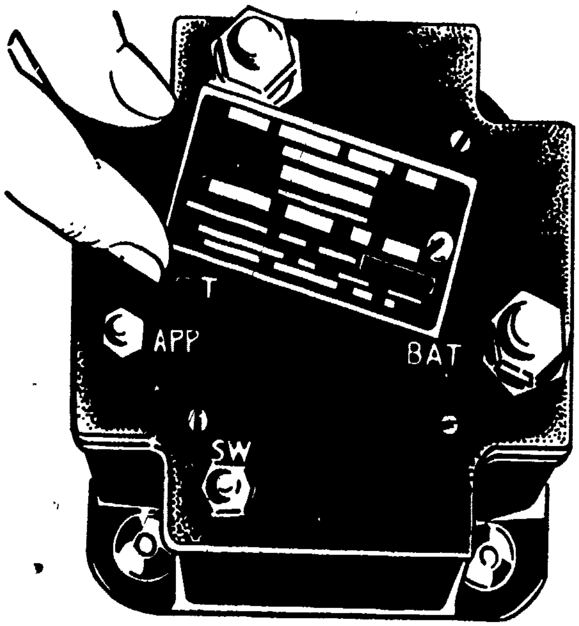


AE.174
Figure 13-17.—Location of test terminal T.

closed. Remove the nameplate and make a connection to terminal T (fig. 13-17) by means of a No. 6-32 screw, one-half inch or longer, screwed into the tapped hole at T.

5. After testing, remove this screw and replace the nameplate.

TESTING CONTACTOR.—

1. Set all switches in the OFF position.
2. Make the test before the coil has become heated.
3. Make the test with the four mounting holes flat on the table. The position of the relay will have some effect on this operating voltage even though the relay may be mounted on the MEPP in any position.
4. Operate the generator at about 4,000 rpm.
5. With SW4 and SW3 open and SW1 in position 1 and SW2 in position 2, vary the voltage by means of R1 until the contactor closes and opens. It should close between 14 and 15 volts, and open below 5 volts.

MEASURING MILLIVOLT DROP.—

1. Set all switches in the OFF position.
2. Operate the generator at about 5,500 rpm. Set SW1 in position 2, SW2 in position 1, SW3 in the open position, and SW4 closed.
3. Adjust the regulator to 27.7 volts.
4. Close the load bank switches until 300 amperes are indicated on A1.
5. Place SW3 in position 1 and read the millivolt drop on V1. This should be less than 100 mv.

NOTE: Place SW3 in the open position before permitting the relay to open.

The differential relay contacts should be left in the open position after completing tests. Otherwise, serious damage to the relay will result if it should be installed in an MEPP having a generator of reversed polarity. To open these contacts, operate the relay in the normal manner.

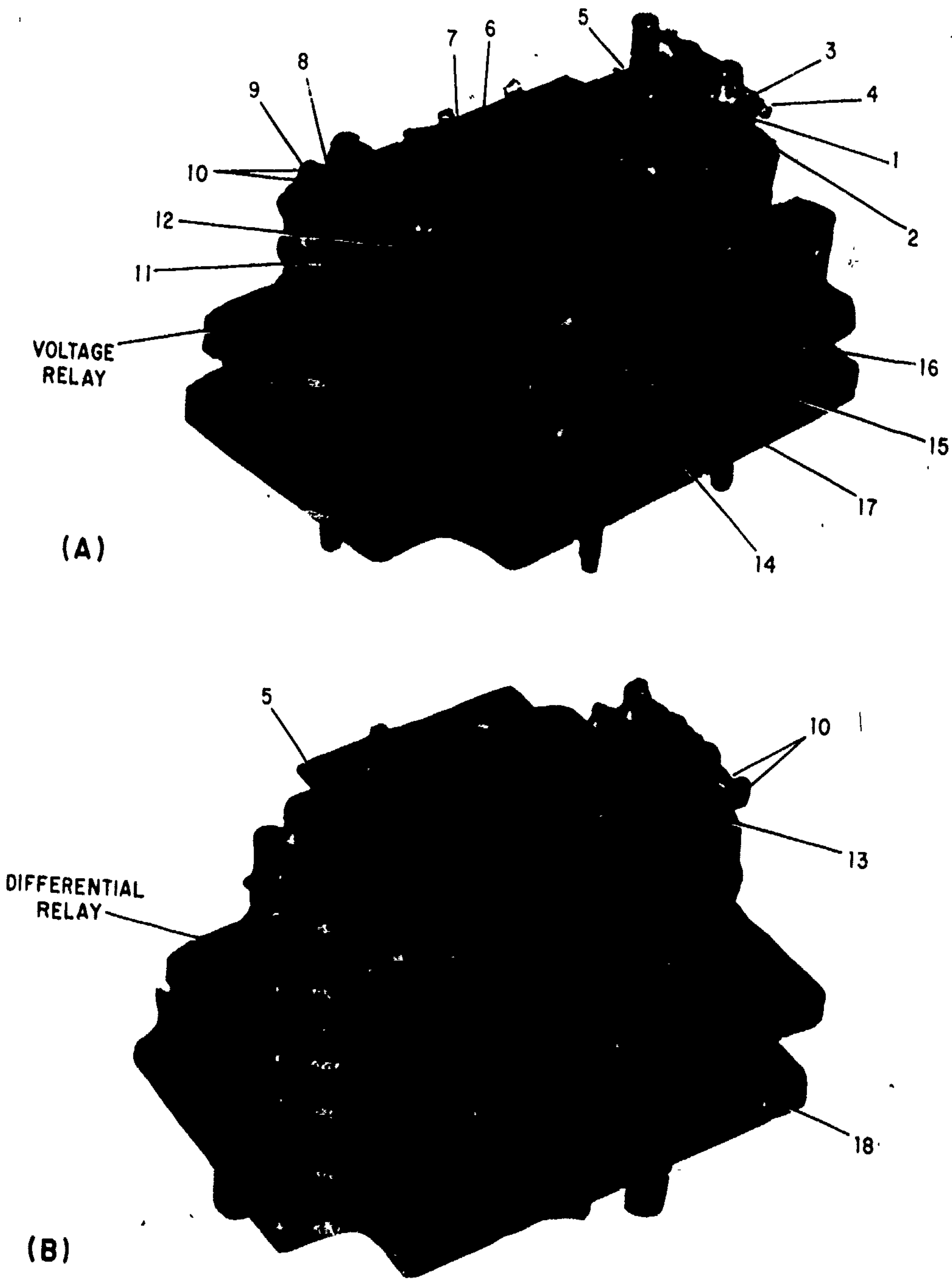
As a result of these tests, you should be able to determine if the relay is only out of adjustment or if it needs repairs.

Adjusting

In order to adjust the reverse-current relay, it must be connected to a test panel as for testing. The steps for adjusting are as follows:

DIFFERENTIAL VOLTAGE RELAY (fig. 13-18 (A) and (B)).—

1. To set the closing differential voltage, loosen locknut (1) and adjust screw (2) (clockwise to lower the voltage or counterclockwise to raise the voltage) until the relay closes between 0.45 and 0.55 volt. Lock adjust screw (2) with locknut (1).
2. To set the opening differential voltage, loosen locknut (3) and adjust screw (4) (clockwise to lower the voltage or counterclockwise to raise the voltage) until the relay opens between 0.33 and 0.36 volt. (Contact screw (5) is set and locked so that when the relay is closed the contacts would engage for at least one-half turn if screw (5) were backed out.) Lock adjust screw (4) with locknut (3).



1. Locknut.
2. Screw.
3. Locknut.
4. Screw.
5. Screw.
6. Screw.
7. Locknut.
8. Spring.
9. Spring screw.
10. Locknuts.
11. Screw.
12. Locknut.
13. Screw.
14. Gap.
15. Locknut.
16. Movable core.
17. Notch.
18. Locknut.

Figure 13-18.—Reverse-current relay adjustment points. AE.176

VOLTAGE RELAY.

1. Adjust screw (6) until the relay armature gaps are equal. Lock with nut (7).

2. Adjust spring (8) by means of spring screw (9) and nuts (10) until the relay closes at 23.5 volts. Locknuts (10). Increasing tension of spring (8) will raise both the closing and opening voltage; decreasing tension will lower both voltages.

3. To change the opening voltage only, adjust screw (11) until the relay opens at 18.5 volts. (Silver-tipped contact screw (13) is set and locked so that when the relay is closed the contacts will remain closed for at least one-half turn if screw (13) were backed out.) Lock screw (11) with nut (12).

MAIN CONTACTOR.

1. The gap (14) between the core rim and the frame should be adjusted to 0.093 inch. This gap represents the total movable core travel. To adjust this gap, loosen locknut (15) and screw movable core (16) in or out. The core can be held while locking and tightening nut (15) by inserting a 3/32-inch rod or drill through notch (17) in the shoulder of the core into a matching hole in the frame.

2. The contact overtravel (amount the core moves after contacts touch) should be adjusted to approximately 0.020 inch. This adjustment is made by loosening locknut (18), making the adjustment, and then tightening the locknut. If the overtravel is too great, the contacts will not be "pulled in" by 15 volts, and a correct adjustment should be made.

Troubles and Remedies

It is general practice to replace rather than to repair differential relay units in the field. Procedure, however, is guided by the type of repair required and the availability of replaceable units, as well as repair facilities. Table 13-2 will prove helpful in servicing and maintaining reverse-current relays.

A-C GENERATORS

Many generators range in size from the relatively tiny tachometer instrument generator used on the automotive vehicle tachometer system to the 125,000 volt-ampere machines used on the NC-12 and NC-12A mobile electric powerplants. Regardless of weight, shape, or rating, practically all of these generators have certain characteristics in common.

1. The a-c output is taken from a set of stationary windings (stator).

2. The a-c generator field (rotor) is a rotating magnetic field with fixed polarity.

3. Voltage control, when used, is accomplished by controlling the strength of the rotating magnetic field.

4. The frequency of the output voltage is controlled by controlling the speed or rotation of the rotating magnetic field.

Some types of a-c generators now in use completely eliminate brushes. The single-phase a-c generator, used extensively in the past and not as advantageously as the 3-phase a-c generator, has advantages over the d-c generator.

The ASE should be familiar with the principles of operation of a-c generators so that complex systems may be more easily understood. The basic principles and methods of calculating for such factors as speed and induced voltage power are discussed in Basic Electricity; however, a brief review of a-c generators is given in the following paragraphs.

A simplified pictorial diagram of a single-phase a-c generator is illustrated in figure 13-19. In comparison, figure 13-20 shows a typical a-c generator as it actually appears when separated into its major assemblies.

EXCITATION

Effective control of the generated voltage can be maintained by controlling the strength of the magnetic field through which the conductors are moving. The strength of the magnetic field is regulated by a voltage regulator. The current which generates this magnetic field, called the exciting current, is supplied either by an auxiliary d-c generator (called the exciter) or by a rectifier. This exciter (fig. 13-20) is usually

Table 13-2.—Reverse-current relay troubleshooting chart

Trouble	Probable cause	Remedy
Voltage relay will not close.	Improperly connected or faulty generator. Relay coil open or leads broken. Relay improperly adjusted. Chips on the permanent magnet.	Check connections and generator voltage and polarity. Replace coil. Readjust. Clean out chips.
Voltage relay will not open.	Broken or damaged return spring. Relay improperly adjusted. Chips on permanent magnet.	Replace spring. Readjust. Clean out chips.
Differential relay will not close but voltage relay closes.	Open coil or broken coil lead. Voltage relay contacts not touching. Chips on magnet. Improperly adjusted.	Replace coil. Clean and readjust voltage relay contacts. Clean out chips. Readjust.
Differential relay will not open.	Chips on magnet. Improperly adjusted.	Clean out chips. Readjust.
Contactor will not close but voltage relay and differential relay are closed.	Differential relay contacts do not touch. Coil open or leads broken. Excessive friction on moving core. Core rod bent.	Clean and readjust. Replace coil. Replace stationary core assembly. Replace core rod.
Contactor will not open but differential relay is open	External short circuit between SW and APP terminals. Core rod bent. Contactor contacts out of adjustment.	Correct short circuit. Replace core rod. Readjust contacts.

mounted on the same shaft as the a-c generator. When a rectifier is used, it changes the a-c output of the a-c generator into d.c., which is fed back to the field, via the voltage regulator.

The present military specification for a-c generators states that no source of excitation or preenergization should be required other than that supplied by the generator and/or regulator. To meet this requirement, direct-connected d-c generator exciter units are integrated into the a-c generators.

Any rotary generator requires a prime moving force (1), (fig. 13-19), to rotate the a-c field and exciter armature. This rotary force is transmitted to the generator through the rotor drive shaft and is usually furnished by a combustion engine, air or gas turbine, or electric motor. The exciter shunt field (2) creates an area of intense magnetic flux between its poles. When the exciter armature (3) is rotated in the exciter field flux, voltage is induced into the exciter armature windings. The exciter unit is nothing more than an ordinary d-c generator. The exciter output commutator and brushes (4) connect the exciter output directly to the a-c generator field input sliprings and brushes (5). Since these

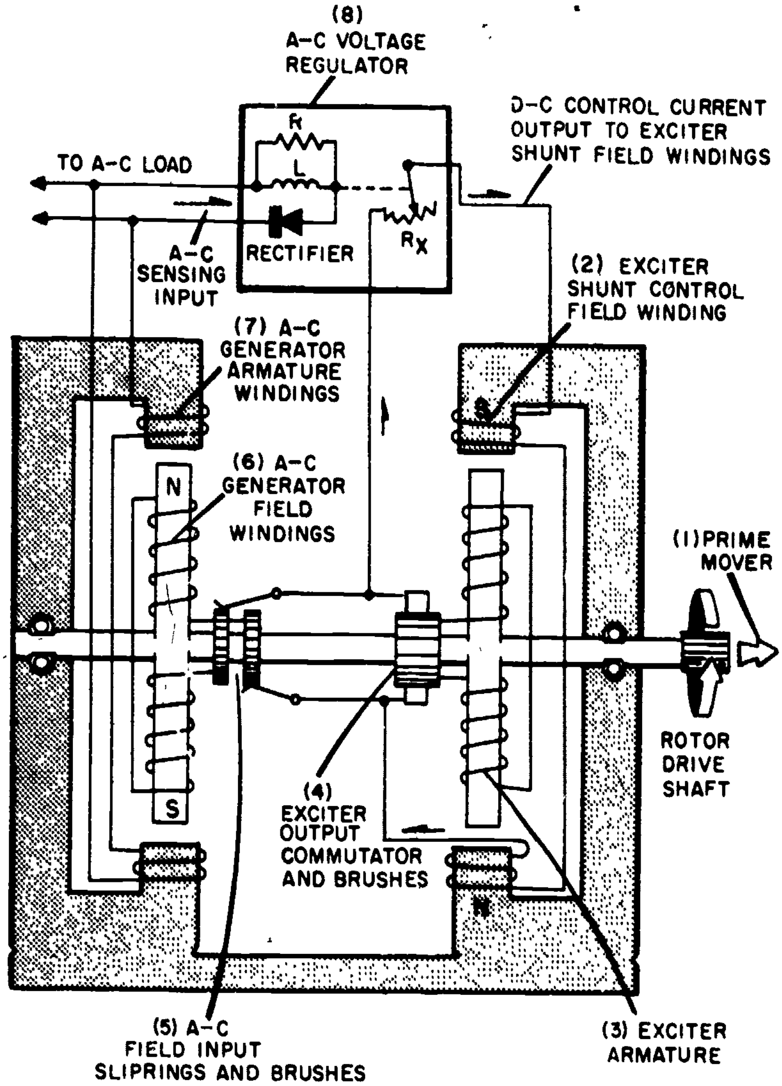
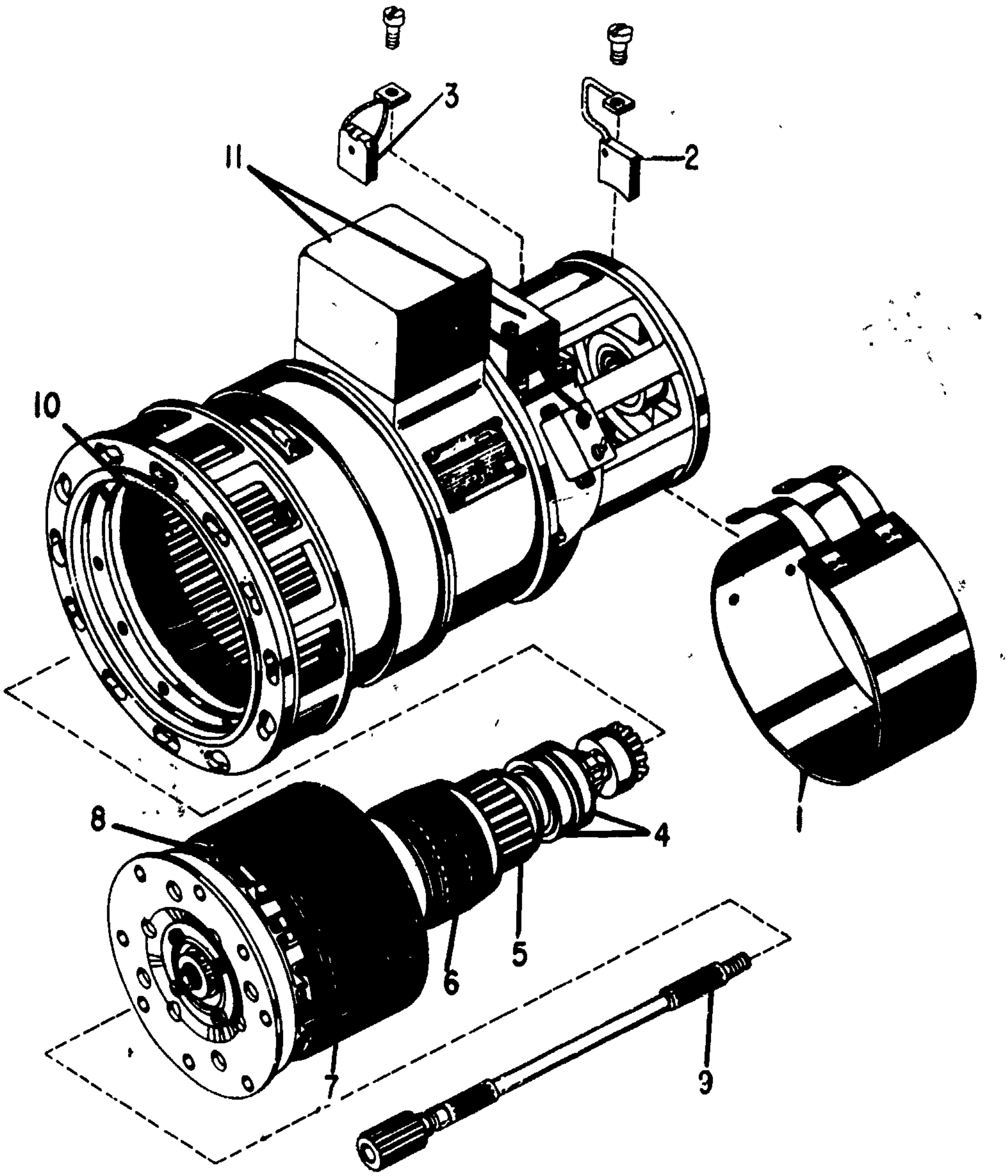


Figure 13-19.—Simplified a-c generator. AS.372

sliprings, rather than a commutator, are used to supply current through the a-c generator field (6), current will always flow in only one direction through these windings. Thus, a fixed polarity magnetic field is maintained at all times in the a-c generator field windings. When the a-c generator field is rotated, its magnetic flux is passed through and across the a-c generator armature windings (7). Remember, a voltage is induced if a conductor is stationary and a magnetic field is passed across it, or if the field is stationary and a conductor is moved through it.

SINGLE-PHASE A-C GENERATOR

The single-phase a-c generator is finding less application in a-c power systems that demand large amounts of a-c power. However, the ASE may come in contact with this type generator in some of the equipments which he maintains. Basic Electricity covers the detailed theory of operation of most single-phase a-c generators. An exception (the inductor type) is discussed in the following paragraphs.



1. Cover assembly.
2. Collector ring brush.
3. Exciter brush.
4. Collector rings.
5. Exciter commutator.
6. Exciter armature.
7. A-c generator rotating field.
8. Fan.
9. Spindle.
10. A-c armature.
11. Terminal blocks.

Figure 13-20.—Typical a-c generator. AS.373

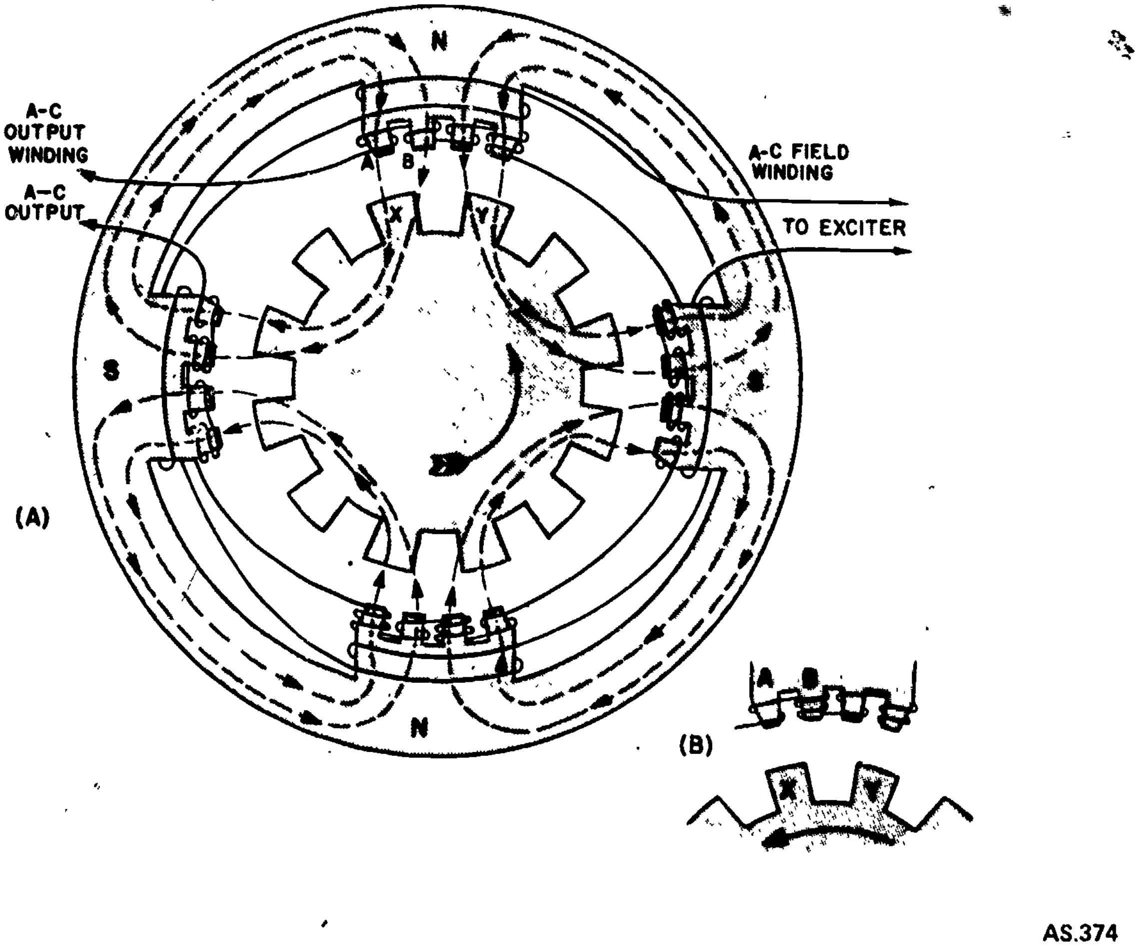


Figure 13-21.—Schematic of an inductor type single-phase a-c generator.

Inductor Type

Figure 13-21 shows the schematic of an inductor type single-phase a-c generator. In a-c generators of this type, the armature coils are stationary in the magnetic field. The rotor has no coils, only projections. The rotation of these projections past the armature coils causes the magnetic flux (magnetic lines of force) enclosed by the armature coils to pulsate periodically. This generates in the armature coils a pulsating (a-c) voltage having a frequency proportional to the speed. As in the case of a d-c generator, the voltage depends on the saturation characteristics of the flux paths (iron and airgap), the field current, and the speed. Unlike a d-c generator, which can supply its own shunt-field current, the field current for an a-c generator must be supplied by some other source, either an exciter or the d-c section of an a-c/d-c generator.

As in the case of a d-c generator, the voltage of an inductor a-c generator increases with field current, but only up to a certain point. In an inductor a-c generator, excessive field current saturates the iron, reducing the magnitude of the flux pulsations and the voltage; that is, if the field current is increased beyond a certain point, the voltage will decrease instead of increase. The inductor a-c generator has inherently high reactance (inductive reactance), which means that an unusually large increase in field current would be required to maintain its voltage if a load were applied directly to its terminals. To provide for additional field current without danger of over-saturation would mean increased size and weight. Consequently, the positive reactance (inductive reactance) of the generator itself is partially compensated by the insertion of negative reactance (capacitive reactance) in the armature circuit in the form of a 10 to 15 microfarad capacitor.

The a-c generator shown in figure 13-21 has two windings in the stator - the a-c field winding, and the a-c output winding. The a-c field winding is connected across the d-c output. Rotation of the d-c armature thus produces a flow of direct current through the a-c field coils which produces a magnetic field in the magnetic circuit of the a-c stator. As the rotor turns, the reluctance of the magnetic circuit through the coil cores and rotor teeth varies, causing a variation in the flux. This change in the magnitude of the flux through the coil cores induces the voltage in each coil.

For example, as the rotor tooth X approaches coil A (fig. 13-21 (A)), the flux through coil core A will increase while that through coil core B will decrease. The voltage induced in coil A, therefore, is opposite to that induced in coil B. To make these voltages additive, the coils are connected as shown. As the rotor continues to rotate, tooth X will move away from coil A and tooth Y will approach coil B (fig. 13-21 (B)). This causes the flux to decrease through coil core A and increase through coil core B. This produces induced voltages opposite to those induced with the rotor in the position shown in figure 13-21 (A). Thus, an a-c voltage is induced in each coil. All coils are influenced simultaneously by the rotor teeth as described for coils A and B.

The a-c voltage is maintained constant by an a-c voltage regulator which automatically adjusts the alternator's field current with changes in generator speed and a-c load.

THREE-PHASE A-C GFNERATOR

Present military specifications require that the basic a-c power generating systems for servicing aircraft have an output of 120/208 volts. These voltages are obtained by designing the generator to produce 120 volts per winding and connecting the windings to form a wye system as shown in figure 13-22 (A). When so connected, the voltage between the neutral wire and any one of the phase wires or lines—that is, the line-to-neutral voltage—will be 120 volts. The line-to-line voltage in a wye-connected system equals 1.73 times the line-to-neutral voltage, and

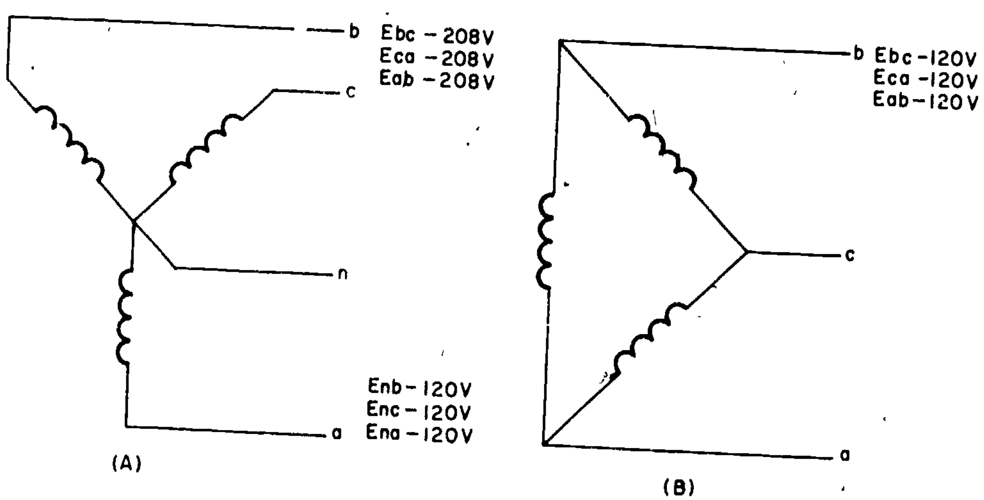


Figure 13-22.—Wye-delta voltage relationships.

AS.375

in this case is 1.73 times 120, or 208 volts. (NOTE: Refer to Basic Electricity, NavPers 10086 (Series) for basic information on 3-phase circuits.)

By comparing the circuits ((A) and (B) of fig. 13-22), it can be determined that a distinct advantage of the wye over the delta system is that two voltages are available from a wye-connected system; however, the delta system is used for supplying power to certain aircraft instruments. The lower voltage of the wye system may be applied by connecting a load between a line and neutral, the higher voltage by connecting a load line to line across two phase coils.

When a load is connected line to neutral, the voltage generated by a single-phase winding in the generator will appear across it. Because this is the lower of the two voltages, the current will be correspondingly lower and will flow through the load and only that phase winding across which the load is connected.

When a load is connected line to line, two phase windings will be in series across it. The vector sum of the two generated voltages will be applied and will equal 1.73 times the voltage of a single phase, as stated previously. Because the power is proportional to the product of current and voltage, the higher voltage will require less current for the delivery of an equal amount of power. With the higher of the two voltages and an equal current flow, power will increase by a factor of 1.73, the factor by which the voltage increased. Obtaining increased power by increasing voltage instead of current allows the use of smaller current-carrying conductors in both the distribution system and the generator; this makes the system lighter in weight, less costly, and more adaptable for supplying power to a wide variety of loads.

In the 4-wire grounded neutral system, the neutral wire is connected to the frame which, in this case, constitutes ground. The 3-phase wires are then connected to the 3-phase power receptacle. The convenience outlets are connected line to neutral, and they supply single-phase power for such items as test equipment and soldering irons.

The line-to-line voltage found in a 3-phase, wye-connected system is the vector sum of the voltages generated by two separate phase windings. Because a phase difference of 120° exists between the two generated voltages, they will reach their peak amplitudes at different times and consequently must be added vectorially, not directly.

The a-c generator on the NC-12 provides 125-kva of 3-phase power at 120/208 volts, 400 Hz with a 75-percent lagging power factor when rotated at 1,846 rpm.

This a-c generator has an integral d-c exciter which provides the excitation for the rotating field. The exciter generates d-c power which is fed through its own shunt field as well as to the rotating field of the generator. Regulation of the a-c output voltage is accomplished by varying the external resistance in series with the exciter shunt field, thereby controlling the exciter output and consequently the rotating field input which, in turn, determines the a-c output voltage.

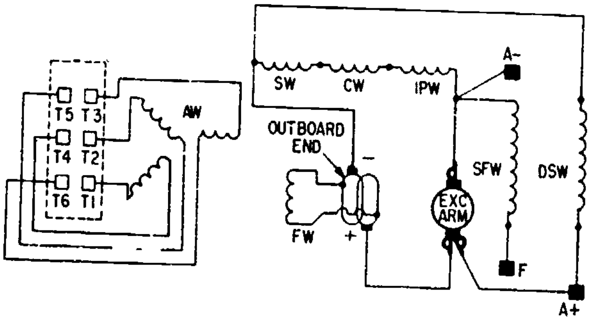
The collector rings, exciter armature, rotating field, and a fan are mounted on the same shaft which is supported between two bearings. This shaft is driven by a flexible drive spindle which mates directly in the engine-drive spline. The fan provides ventilating air for cooling of the generator.

The stationary member of the generator is made up of the a-c armature and the d-c exciter field. Both a-c and exciter terminal boards are mounted so that they are easily accessible. All brush rigging is located on generator and is protected with a brush cover. Slotted-hole type mounting provides for ease in attaching to the engine pad. Capacitors connected between the exciter armature terminals and ground suppress radio noise.

The a-c generator rotating field has 12 poles with adjacent poles being of opposite polarity. One cycle per revolution is produced by each pair of poles; thus, 6 cycles are produced per revolution. The output frequency of the generator varies in direct proportion to the engine-drive speed. The internal wiring diagram of a typical a-c generator is shown in figure 13-23.

BRUSHLESS A-C GENERATOR

A modern concept in the generation of a-c voltage is being utilized in current MEPP's. This



AS.377

1. SFW—exciter shunt-field winding.
2. AW—a-c generator armature winding.
3. FW—a-c generator field winding.
4. SW—exciter series winding.
5. CW—exciter compensating winding.
6. IPW—exciter interpole winding.
7. DSW—exciter differential shunt winding.

Figure 13-23.—Internal wiring diagram of an a-c generator.

concept eliminates the need for brushes in the a-c generator. Traditionally, brushes and commutators or sliprings have been the chief deterrent in extending the time between overhauls of a-c generators.

The development of a practical brushless generator has eliminated the brush problem. The time between scheduled removals of generators has been doubled by the use of brushless generators. It is predicted that this time period will be increased in the future.

The theory of the brushless generator is not new. The lack of a small rectifier that could withstand the electric current and rotational stresses caused the delay between the drawing board and the production of a brushless generator. The development of a silicon diode that is small, rugged, and has sufficient current capabilities allowed the development of a practical brushless generator.

Brushless Generator Theory

A brushless generator is shown in schematic form in figure 13-24. It is comprised of three

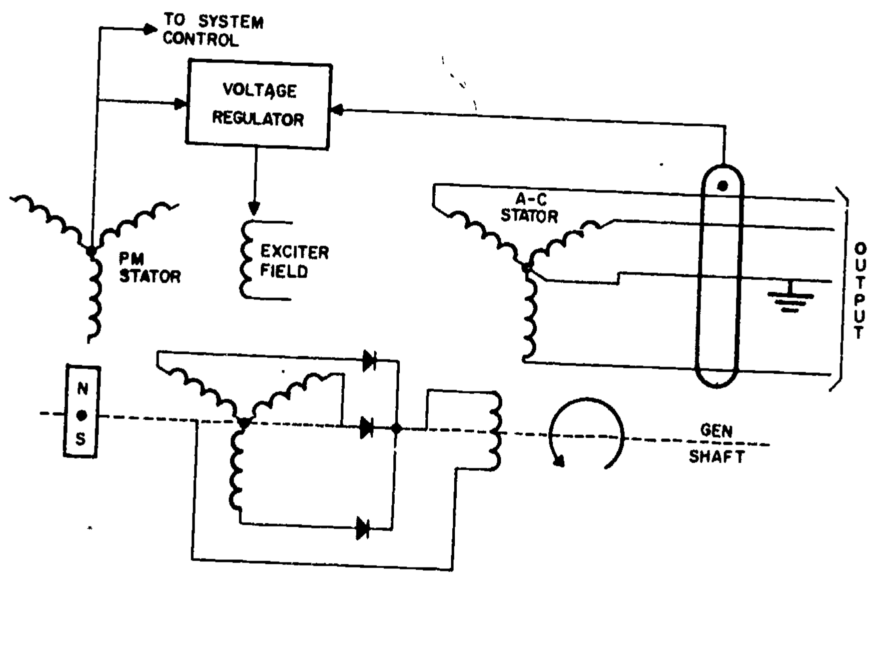


Figure 13-24.—Diagram of a brushless a-c generator excitation system.

AS.378

main sections—the permanent magnet (PM) generator, the exciter-and-rectifier assembly, and the main a-c generator. Each of these sections has two parts—the rotating and the stationary. The only connections between the rotating and stationary parts are working airgaps in each of the three sections (no brushes).

The speed of operation of the brushless generator is limited to a narrow range (plus or minus 5 percent). The newer electrical a-c generators are driven by constant-speed drive units or constant-speed engines. In most of the newer MEPP's, the generator's operating speed is held to within 1 or 2 percent of the generator's nominal speed. Most brushless generators are driven at a speed to produce a 400-Hz output.

Permanent Magnet Generator

The PM generator section consists of a permanent magnet rotor and a 3-phase or single-phase stator, depending on the particular model. The PM generator is a simple, highly reliable source of power. The power generated by the PM generator is used for excitation, for operation of the electrical power control relays, and for operation of the electrical protective system. Since the PM generator operates at a constant speed, its output voltage is constant and completely independent of the main generator's output. The PM generator will deliver power during a failure of the main generator. This arrangement provides positive control of the main generator. The PM generator insures that a source of power is available for buildup of the exciter and main generator; therefore excitation is not dependent on a residual flux being present in the generator or exciter. The PM generator excitation system has been designed to operate transistors at their optimum voltage, thus avoiding exposure of the transistors to the harmful transient voltages present during fault or load-switching conditions of the main generator system.

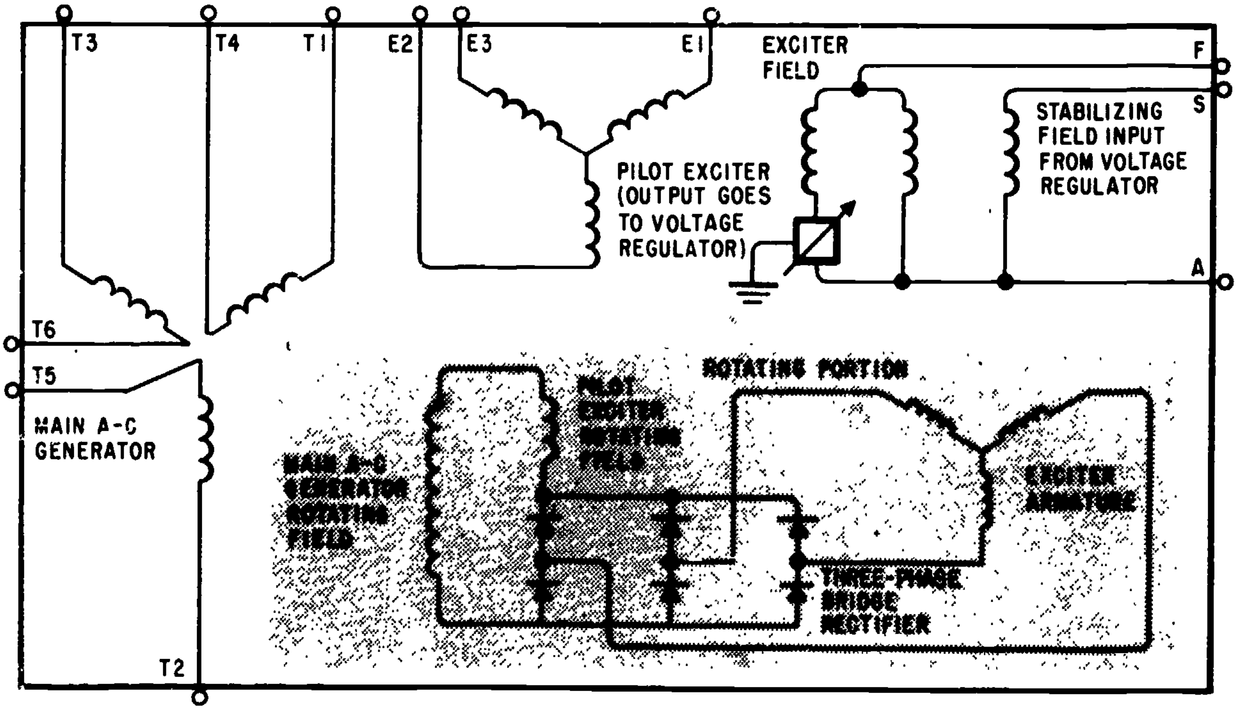


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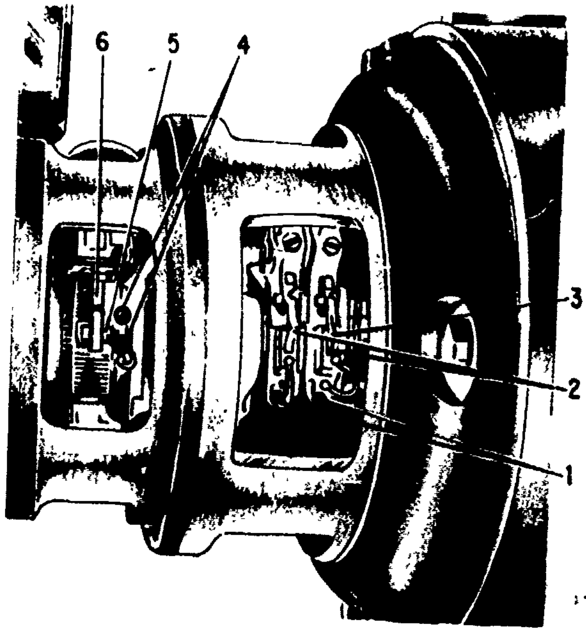
Figure 13-25.—Schematic of a brushless a-c generator.

In summary, the PM generator section of a brushless generator is a simple, reliable source of power. The PM generator makes the brushless generator a completely self-contained unit that does not depend on an external source of power for buildup or excitation during operation.

Another type of brushless a-c generator is shown in figure 13-25. This generator consists of a pilot exciter, an exciter, and the main generator. Utilizing an integral exciter with a rotating armature that has its a-c output rectified for the main d-c field, which is also rotating, eliminates the necessity of brushes. The pilot exciter is an eight-pole, a-c generator.

The pilot exciter field is mounted on the main generator rotor shaft and is connected in series with the main generator field. The pilot exciter armature is mounted on the main generator stator. The a-c output of the pilot exciter is supplied to the voltage regulator, where it is rectified and controlled, and is then impressed on the exciter field winding to furnish excitation for the generator. The exciter is a small a-c generator with its field mounted on the main generator stator and its 3-phase armature mounted on the generator rotor shaft. Included in the exciter field are permanent magnets mounted on the main generator stator between the exciter poles. The exciter field resistance is temperature compensated by a thermistor. This aids regulation by keeping a nearly constant resistance at the regulator output terminals. The exciter output is rectified and impressed on the main generator field and pilot exciter field.

Rectification of the exciter output is accomplished by utilizing a 3-phase, full-wave bridge rectifier consisting of six high-temperature silicon rectifiers mounted in the rotor shaft of the main generator. The exciter stator has a stabilizing field which is used to improve stability and to prevent voltage regulator overcorrections for changes in generator output voltage. The generator is 3-phase, 4-wire, wye-connected with ground neutrals. By using an integral a-c exicter, the necessity for brushes within the generator has been removed. The a-c output of the rotating exciter armature is fed directly into the 3-phase, full-wave rectifier bridge located inside the rotor shaft. The d-c output from the rectifier bridge is fed to the main a-c generator rotating field. Voltage regulation is accomplished by varying the strength of the a-c exciter stationary fields. Polarity reversals of the a-c generator are eliminated and the minimization of radio interference is accomplished by the absence of brushes.



1. Screw and washer.
2. Generator brush spring.
3. Generator brush.
4. Screw and washer.
5. Exciter brush.
6. Exciter brush spring.

AS.380

Figure 13-26.—A-c generator brushes.

MAINTENANCE

The Service and Repair Instructions Manual usually contains troubleshooting charts or tables to aid the ASE in locating and eliminating a-c generator troubles quickly. Before attempting troubleshooting, consult the applicable manual for detailed instructions. Table 13-3 is a typical troubleshooting chart for a-c generators.

When it becomes necessary to install new brushes (fig. 13-26), the following procedure is recommended:

Table 13-3.—A-c generator troubleshooting chart

Trouble	Probable Cause	Remedy
Generator runs at rated speed but delivers no voltage.	Circuit breaker in generator control open.	Reset circuit breaker.
	Exciter not generating caused by defective brushes.	Replace and reseat brushes.
	Exciter not generating caused by defective windings.	Repair windings.
	Defective suppression capacitor on filters.	Replace capacitor in collector and shield or replace filter in filter box on exciter.
	Generator field circuit open caused by defective brush connections or faulty brush contact.	Tighten brush connections. Reset brush contact on sliprings.
	Direction of generator rotation incorrect.	Change drive to obtain proper generator rotation.
	Improper operation of voltage regulator circuit.	Replace defective components.
	Short, ground, or open circuit in generator windings.	Repair Generator windings.
Generator temperature excessive.	Overload on generator.	Reduce generator load.
	Excessive field excitation caused by defective overload circuit breaker.	Replace defective overload circuit breaker in generator control.
	Excessive field excitation caused by defective connections or defective generator windings.	Repair or replace defective components.
	Restricted ventilation	Remove obstructions from air passages.

Table 13-3.—A-c generator troubleshooting chart—Continued

Trouble	Probable cause	Remedy
Exciter temperature excessive.	Poor exciter connections.	Tighten or repair connections.
	Restricted ventilation.	Remove obstructions from air passages.
	Overload on exciter.	Replace defective overload breakers and/or regulators.
	Short, ground, or open circuit in exciter windings.	Repair windings or replace exciter.
Bearings are overheated.	Bearing lubrication deteriorated.	Replace bearings.
	Bearings worn.	Replace bearings.
	Bearings misalined.	Install bearings and end shields properly.
Excessive noise.	Bearings peened or worn.	Replace bearings.
	Foreign matter in generator.	Remove foreign matter. Replace defective components.
	Excessive vibration.	Mount generator properly.
Brushes spark.	Worn brushes.	Replace brushes.
	Exciter brush spring tension too low.	Replace exciter brush springs.
	Generator brush spring tension too low.	Replace generator brush springs.
	Rough, pitted, or worn commutator or collector rings.	Repair or replace defective components.
	Short, ground, or open circuit in exciter armature or short circuit in commutator.	Repair or replace defective components.
Failure to build up voltage.	Loss of residual magnetism.	Momentarily flash control field from d-c source.
	Loose or missing connections in exciter load circuit.	Tighten or replace connections.
	Defective circuit breaker.	Replace circuit breaker.

Table 13-3.—A-c generator troubleshooting chart—Continued

Trouble	Probable cause	Remedy
	High resistance in exciter load circuit.	Tighten circuit connections or replace defective circuit breaker.
Exciter output goes to maximum.	Reversed polarity of exciter.	Momentarily flash field from d-c source.
	Defective radio noise filter.	Replace defective components.
	Exciter not functioning as an amplidyne caused by open brush rigging cross connector.	Replace defective rigging and reset.
	Improper regulator operation.	Adjust regulator, replace if defective.
	Open control field in exciter.	Repair or replace defective component.

Pull the brush springs back only as far as necessary to allow removal of the old brushes; this may be easily accomplished by using a hook made of stiff wire. Attach the brush pigtails of the new brushes to the proper connections and secure the pigtails electrically. Insert the brushes in the brush holders. After the new brushes have been installed, steps must be taken to remove the old commutator film, fit the new brushes, and establish a new film.

TESTING

The testing of field coils, armatures, and commutators for a-c generators is the same as for d-c generators which was discussed previously.

The presentation of detailed test procedures for individual a-c generators is beyond the scope of this training manual and, as procedures will vary for each a-c generator, the ASE must refer to the operation and service instructions for the unit to be tested and the operation and service instructions for the load bank to be used. For detailed, step-by-step procedures for complete testing of a particular a-c system.

A-C VOLTAGE REGULATORS

The essential function of the voltage regulator is to use the a-c output voltages as a sensing influence to control the amount of current the exciter may supply to its own control field. A drop in the output a-c voltage causes a rise in the exciter control field current. A rise in the output a-c voltage causes a drop in the exciter control field current. These latter two characteristics are caused by actions within the voltage regulator and are common to resistive (carbon-pile) and magnetic types of a-c voltage regulators. All types of regulators perform the same functions, but accomplish them through different operating principles.

CARBON-PILE A-C VOLTAGE REGULATOR

The operating principles of a carbon-pile a-c voltage regulator are identical to those employed in the d-c type of regulator; that is, the strength of the magnetic field of a potential coil controls the compression of a carbon pile. The resistance of the carbon pile is thus controlled by the amount of voltage applied across the potential coil. In the d-c regulator, the potential coil is connected through a resistance directly to the d-c voltage to be controlled. The a-c regulator potential coil cannot be connected in such a direct manner because the alternating magnetic field would be practically useless for purposes of voltage regulation. This problem is solved by making a full-wave rectifier a part of the basic regulator.

Figure 13-27 is a simplified schematic of a single-phase a-c voltage regulator. Some of the a-c line voltage (a-c generator output) is connected across terminals B and G In series with terminals B and G is a 500-ohm voltage-dropping variable resistor, a 150-ohm voltage-adjusting potentiometer, and a rectifier. The potential coil is connected across the d-c terminals of the rectifier. Any change in a-c voltage results in a change in direct current through the coil, thus causing a change in carbon-pile compression. The same effects may be caused by moving the potentiometer setting. However, the most significant relation to understand is that any change in the a-c voltage applied across terminals B and G causes a corresponding change in resistance between terminals A and D (carbon-pile compression). Thus, by connecting the carbon-pile resistance in series with the exciter shunt control field, the current through that field is controlled indirectly by the value of line a-c voltage.

A simplified drawing of an a-c generator and its controlling regulator is shown in figure 13-28.

A complete sequence of what happens when a change occurs in the generator's a-c output is: Assume that a heavy load has been placed on the system. The resultant decrease in voltage across terminals T1 and T2 causes a decrease in the voltage at terminals B and G on the voltage regulator. This same decrease in a-c voltage also

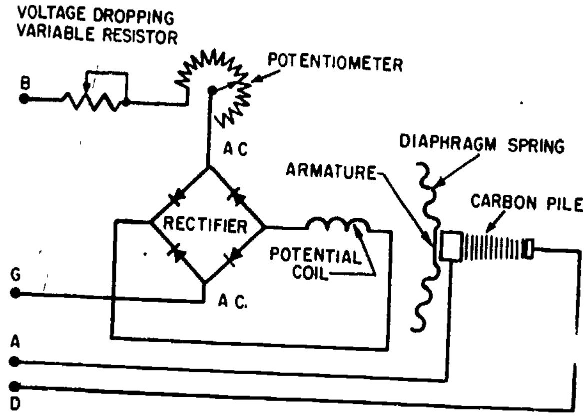


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Figure 13-27.—Simplified schematic of a single-phase a-c voltage regulator.

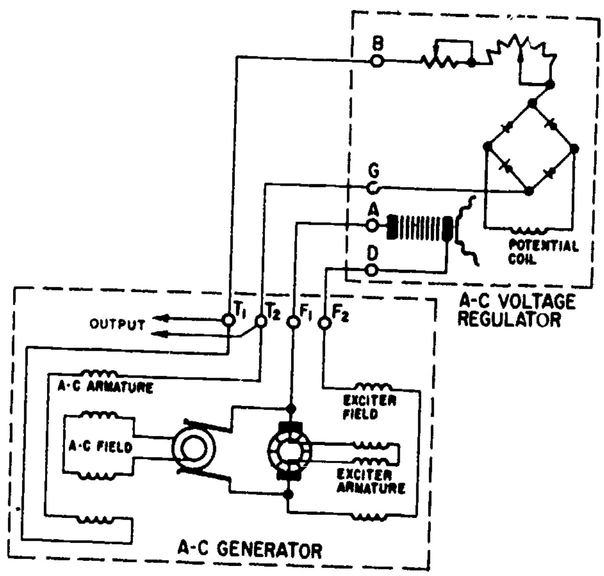

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Figure 13-28.—A-c generator and regulator.

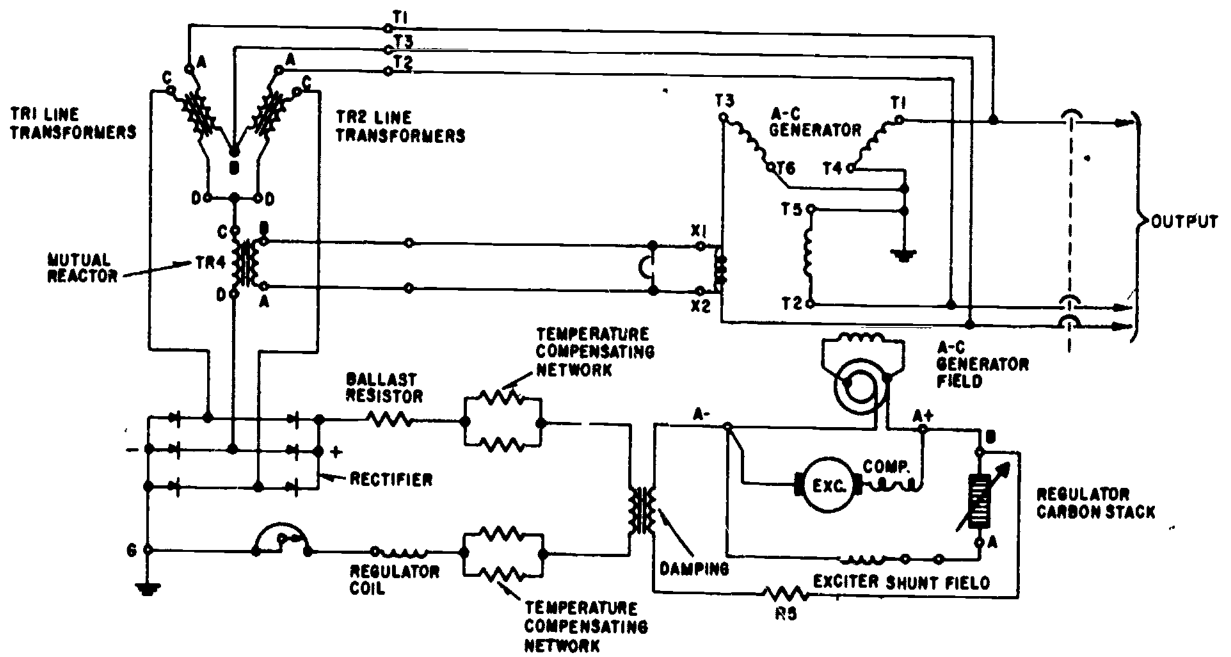

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Figure 13-29.—Schematic of a 3-phase a-c voltage regulator.

occurs across the regulator rectifier; this causes a decrease of current through the potential coil. As the potential coil current decreases, the strength of its magnetic field also decreases. The resultant partial release of magnetic "pull" acting on the iron armature allows the diaphragm spring to press the iron armature slightly tighter against the carbon pile.

Increased pressure on the pile improves the quality of contact between the individual carbon washers which comprise the pile. The result is a decrease in resistance of the pile. When the pile resistance decreases, pile current increases.

This pile current flows from the exciter armature output brush through terminal F1, through the carbon pile, back through terminal F2, then through the exciter shunt control field, and finally returns to the exciter armature. When the pile current (exciter field current) increases, the exciter control field is made strong and a greater voltage is induced into the exciter armature. The increased exciter output voltage causes an increased current through the a-c generator field. As the a-c generator field is made stronger, a greater a-c voltage is induced into the a-c armature windings. The a-c voltage, across terminals T1 and T2, is then raised back to the proper level. Should the load be decreased, the regulator would react in a manner to keep the output constant.

The construction and theory of operation of single-phase and 3-phase regulators are essentially the same. However, the associated equipment for a 3-phase regulator is more complex. Figure 13-29 shows the electrical schematic for the 3-phase a-c carbon-pile voltage regulator.

MAGNETIC AMPLIFIER REGULATOR

The magnetic amplifier type a-c voltage regulator has wide use on MEPP's. The ASE is required to understand and maintain the magnetic amplifier type regulator, sometimes referred to as the static a-c voltage regulator. As the word static indicates, there are no moving mechanical parts in the entire regulating mechanism (except for exciter control relays).

A simplified generator and magnetic amplifier type voltage regulator are shown in figure 13-30. The magnetic amplifier (L1) is shown wound on a three-legged iron core. The two outer (field) windings are connected to phase T1 of the generator and through full-wave rectifier to the buck windings located in the generator. The control winding for the amplifier is wound on the center leg of the iron core and is connected in the center leg of the bridge circuit. The bridge circuit is composed of resistors (R1, R2, R3, R4, and R5), a rectifier (CR3), a control winding, and two voltage regulator tubes. After a regulator tube fires it maintains a constant 150-volt drop. Due to the characteristics of the tubes only one will conduct and the other is used as a backup in case of failure of the operating tube. The bridge circuit senses any change in the generator output voltage, and this change is impressed across the control winding of the amplifier. The amplifier controls the amount of current flow through the buck windings. Current flow through the buck windings will always be in the same direction due to the action of full-wave rectifier (CR2). The buck and boost windings are wound on the same pole pieces but the magnetic field set up by the buck windings is always in opposition to the magnetic field set up by the boost windings. The pole pieces on which the windings (buck and boost) are wound retain

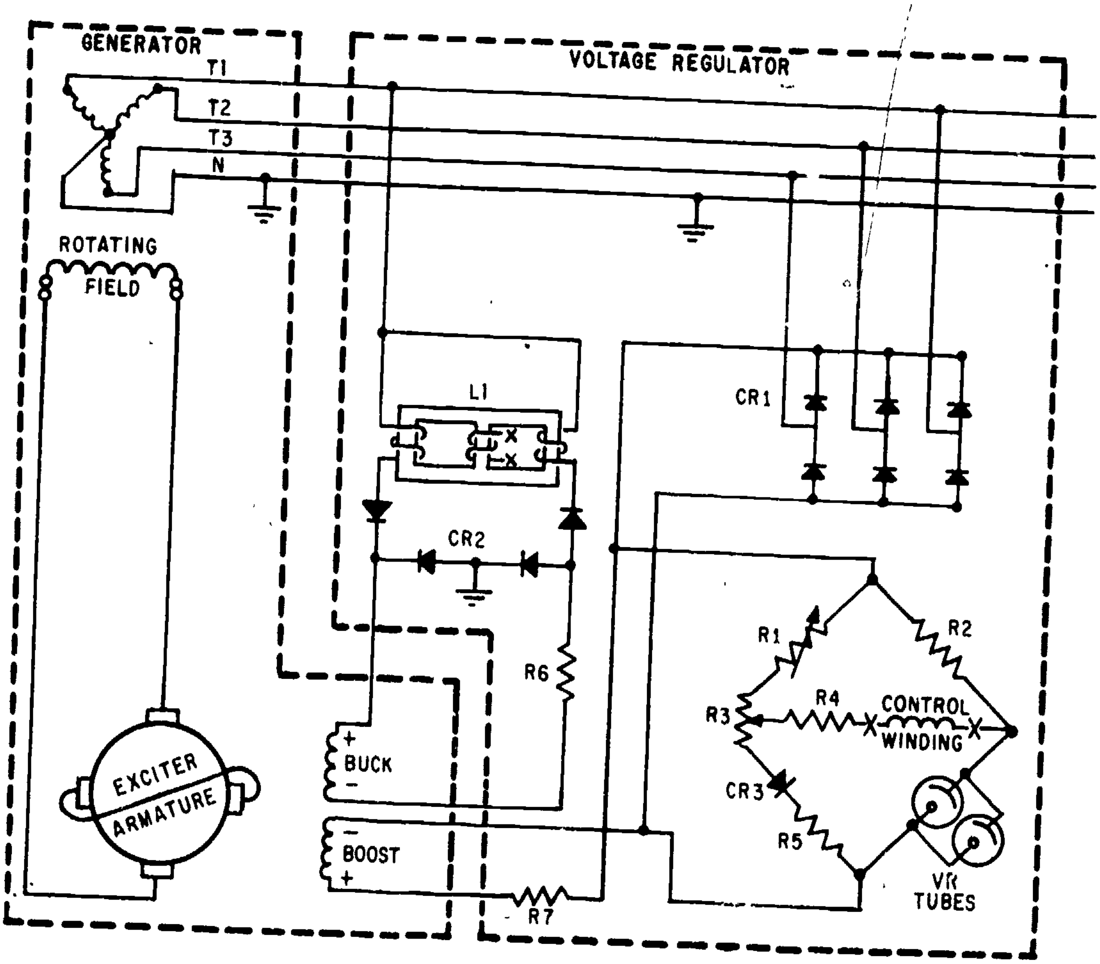

Figure 13-30.—A-c generator and magnetic amplifier type voltage regulator. AS.385

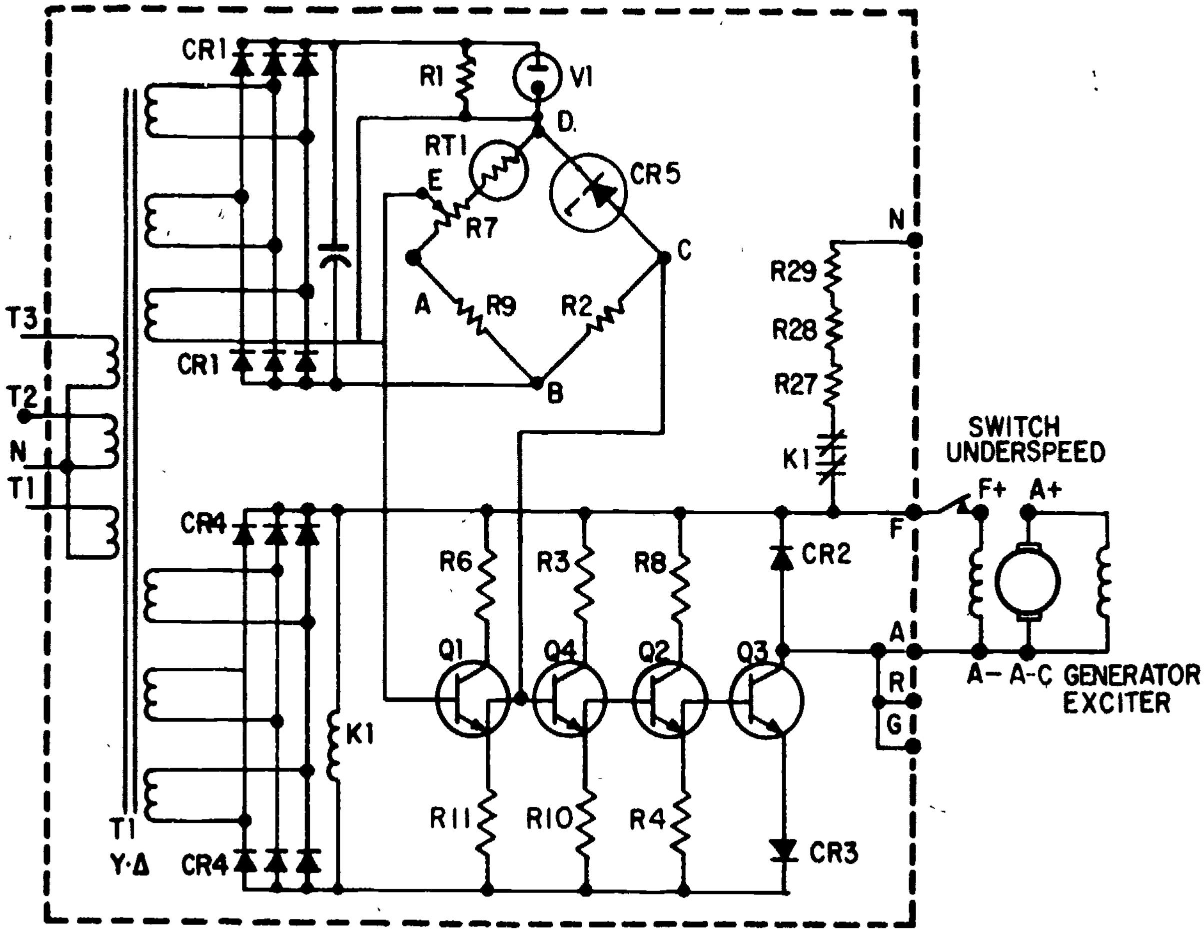

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Figure 13-31.—Transistorized a-c voltage regulator.

some magnetism for initial buildup of the exciter generator. Then, a portion of the a-c generator output is rectified by the full-wave rectifier (CR1) and, as a result, current flows through the bridge circuit and the boost windings. The boost windings aid the residual magnetism in the pole pieces for a complete buildup of the exciter generator, which causes the output voltage of the a-c generator to go up to the value for which the voltage regulator is set.

Operation

The exciter armature and rotating field are mounted on the same shaft. When the shaft is turned the exciter armature cuts the magnetic field set up by the residual magnetism in the pole pieces. Voltage is induced into the exciter armature, causing current to flow through the rotating field. The rotating magnetic field cuts the stator windings of the a-c generator, inducing a voltage into the windings. A portion of the generator output is rectified and impressed across the bridge circuit and the boost windings. This causes current to flow through the boost windings, providing a stronger magnetic field for the exciter armature to cut. This cycle continues until the output voltage reaches the value for which the regulator is set.

As the generator comes up to regulated voltage, one of the voltage regulator tubes will fire and maintain a constant 150-volt reference voltage for the bridge circuit. Current flows through the center leg of the bridge circuit (control winding), driving the magnetic amplifier toward saturation (decreasing inductance). This causes the current in the magnetic amplifier field windings to increase. This same current flows through the buck windings, causing a stronger magnetic field in opposition to the magnetic field set up by the boost windings. When the generator voltage reaches the value for which the regulator is set, there will be a proper balance between the buck and boost windings to maintain this voltage.

When a load is placed on the generator the output voltage will decrease. The voltage across the bridge circuit and the control winding will decrease. This decreases control winding current, driving the magnetic amplifier away from saturation, increasing inductance, and decreasing amplifier field current and buck winding current. The strength of the buck field decreases, giving an overall stronger magnetic field. The exciter armature cuts the stronger magnetic field, inducing more voltage, increasing rotating field current, and increasing generator voltage to the value for which the regulator is set. When a load is removed from a generator, just the opposite takes place, but in the same order as when a load was placed on the generator.

A-C TRANSISTORIZED VOLTAGE REGULATOR

The a-c output of the generator is fed to the voltage regulator where it is compared to a reference voltage, and the difference is applied to the control amplifier section of the regulator. (See fig. 13-31.) If the output is too low, field strength of the a-c exciter generator is increased by the circuitry in the regulator. If the output is too high, the field strength is reduced.

The power supply for the bridge circuit is CR1, which provides full-wave rectification of the 3-phase output from transformer T1. The d-c output voltages of CR1 are proportional to the average phase voltages. Power is supplied from the negative end of CR1 through point B, R2, point C, Zener diode (CR5), point D, and to the parallel hookup of V1 and R1. Takeoff point C of the bridge is located between resistor R2 and the Zener diode. In the other leg of the reference bridge, resistors R9 and R7 and the temperature compensating resistor RT1 are connected in series with V1 and R1 through points B, A, and D. The output of this leg of the bridge is at point E.

As voltage changes occur (for example, if the generator voltage lowers), the voltage across R1 and V1 (once V1 starts conducting) will remain constant, leaving the total voltage change occurring across the bridge. Since the voltage across the Zener diode remains constant (once it starts conducting), the total voltage change occurring in that leg of the bridge is across resistor R2. In the other leg of the bridge, the voltage change across the resistors will be proportional to their resistance values.

Therefore, the voltage change across R2 is greater than the voltage change at point E. If the generator output voltage were to drop, point C would be negative with respect to point E. Conversely, if the generator voltage output were to increase, the polarity of the voltage between the two points would be reversed.

The bridge output, taken between points C and E, is connected between the emitter and the base of transistor Q1. With the generator output voltage low, the voltage from the bridge is negative to the emitter and positive to the base. This is a forward bias signal to the transistor and the emitter-to-collector current therefore increases. With the increase of current, the voltage across emitter resistor R11 increases. This, in turn, applies a positive signal to the base of transistor Q4, increasing its emitter-to-collector current and increasing the voltage drop across the emitter resistor R10.

This gives a positive bias on the base of Q2, which increases its emitter-to-collector current and increases the voltage drop across its emitter resistor R4. This positive signal controls output transistor or Q3. The positive signal on the base of Q3 increases the emitter-to-collector current.

The control field of the exciter generator is in the collector circuit. Increasing the output of the exciter generator increases the field strength of the a-c generator, and this increases the generator output.

To prevent exciting the generator when the frequency is at a low value, there is an underspeed

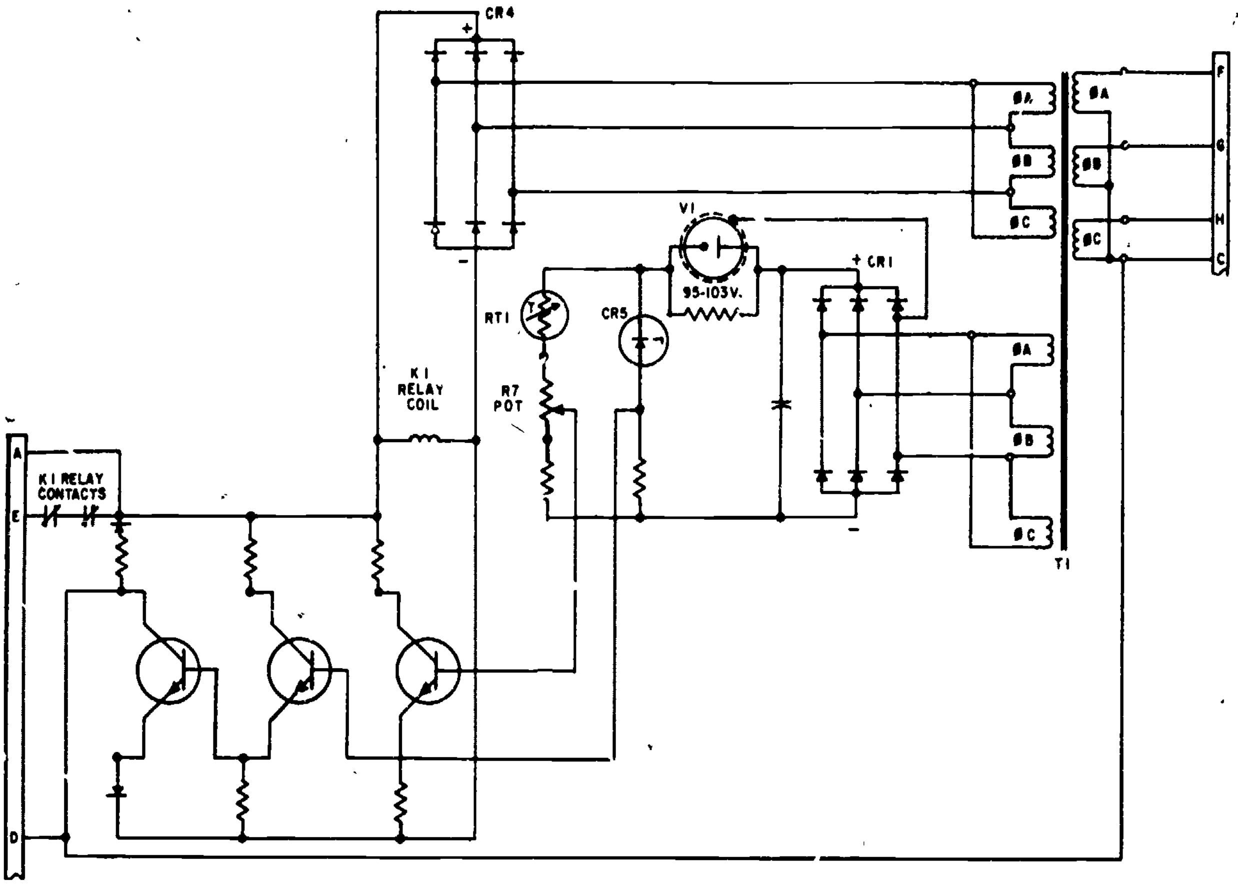

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Figure 13-32.—Transistorized a-c voltage regulator schematic.

switch located near the F+ terminal. When the generator reaches a suitable operating frequency, the switch closes and allows the generator to be excited.

Resistors R27, R28, and R29 are connected in series with the normally closed contacts of relay K1. Relay K1 is connected across the power supply (CR4) for the transistor amplifier. When the generator is started, electrical energy is supplied from the 28-volt d-c bus to the exciter generator field to "flash the field" for initial excitation. When the field of the exciter generator has been energized, the a-c generator starts to produce and, as its output voltage increases, relay K1 is energized, opening the "field flash" circuit.

A similar type of transistorized voltage regulator (fig. 13-32) operates by sensing the voltage existing on the lines, amplifying the changes in this signal and varying the average current supplied to the field winding of the integral exciter. The voltage regulator consists of a sensing circuit with input rectifiers, a temperature compensated Zener diode reference and error detecting bridge, and a three-stage transistor amplifier. The output of the bridge circuit is a voltage inversely proportional to the difference between the generator voltage and the regulator set voltage and is referred to as the error signal.

The output of the 3-phase a-c generator is supplied through transformer T1 in the regulator to provide isolation from the generator and to deliver correct utilization voltages. The output of the transformer is then passed through the full-wave bridge rectifier (CR1) to obtain a direct voltage to supply the comparison circuit. The output of the rectifier is proportional to the average of the three line voltages and is applied to the voltage reference and error detecting bridge. This voltage is then compared to the constant voltage present across the Zener diode (CR5), and a means of telling whether the generator is too high or too low is achieved. Potentiometer R7 permits adjustment to the desired voltage. The low (V1) serves to increase the sensitivity of the voltage reference and error detecting bridge. Thermistor RT1 provides temperature compensation in the comparison circuit to offset the effects of changes in the other elements of the circuit resulting from temperature variations so that a nearly constant voltage is held.

The output voltage of the error detecting bridge has a sawtooth wave shape due to the ripple resulting from the semifiltered 3-phase rectifier supply. This sawtooth voltage is applied to the input of the first stage of the three-stage transistor amplifier, and with the second and third stages being overdriven, an essentially square wave output is obtained. The effect of the error detecting bridge output is to modulate the width of the pulses that are being passed through the amplifier so that the output current to the shunt field of the integral exciter is varied by varying the width of the square wave pulses.

The power for operating the three-stage transistor amplifier is supplied through the full-wave bridge rectifier (CR4) from transformer T1. Obtaining the amplifier power supply in this manner requires special consideration since there are times when excitation is required and no voltage is available to supply the amplifier. Such conditions exist during initial buildup of system voltage from rest, and during 3-phase short circuit on the generator. A control relay (K1) connected across the full-wave bridge rectifier (CR4) overcomes these obstacles since, with the relay deenergized, the exciter is self-excited. When the generator voltage is approximately 90 volts line to line, the voltage across CR4 is sufficient for the control relay (K1) to pick up, removing the self-excited field circuit, and the exciter shunt field is then supplied from the voltage regulator as a separately excited machine. No feedback network or stabilizing transformers are necessary in this voltage regulator due to the absence of phase shift and the fast response characteristics of the transistor type amplifier.

A-C CIRCUIT PROTECTION

This MEPP, like most high capacity power generating equipment, has a system for sensing fault conditions in both voltage and frequency. The sensors used to detect fault conditions on this equipment are located in a PROTECTIVE PACKAGE. The sensors in the protective package sense overvoltage, undervoltage, overfrequency, and underfrequency conditions. When one or more of these conditions exist, control relays are energized, cutting off the output voltage supply. The operating limits for a-c voltage and frequency are: voltage, 90-125 volts; frequency, 380-420 Hz.

A typical protective package (fig. 13-33) contains four silicon-controlled rectifiers (SCR) to control out of limits detection. The SCR15, SCR16, SCR22, and SCR24 are controlled by different monitor circuits, but the conduction of any one of the four completes the current path necessary to energize relay K116, thereby cutting off the output voltage. (See fig. 13-34.) The SCR can conduct only when the proper voltage is applied to the input gate. The input gate voltage required to fire the SCR is 0.2 to 2.5 volts.

The voltages necessary to operate the protective package are brought in through J103. (See fig. 13-33.) Pin M is d-c ground and pin N is 24v d.c. Zener diode CR8 and diodes CR9 through CR11 are connected across the d-c input to reduce the d-c voltage to 13.5 volts, for use in the detection circuits. The three phase a-c voltage is applied through pins F (phase C), J (phase B), E (phase A), and L (a-c neutral). All phases are stepped down to 20 volts a.c. Phase B is also transformer coupled into the frequency monitor circuits.

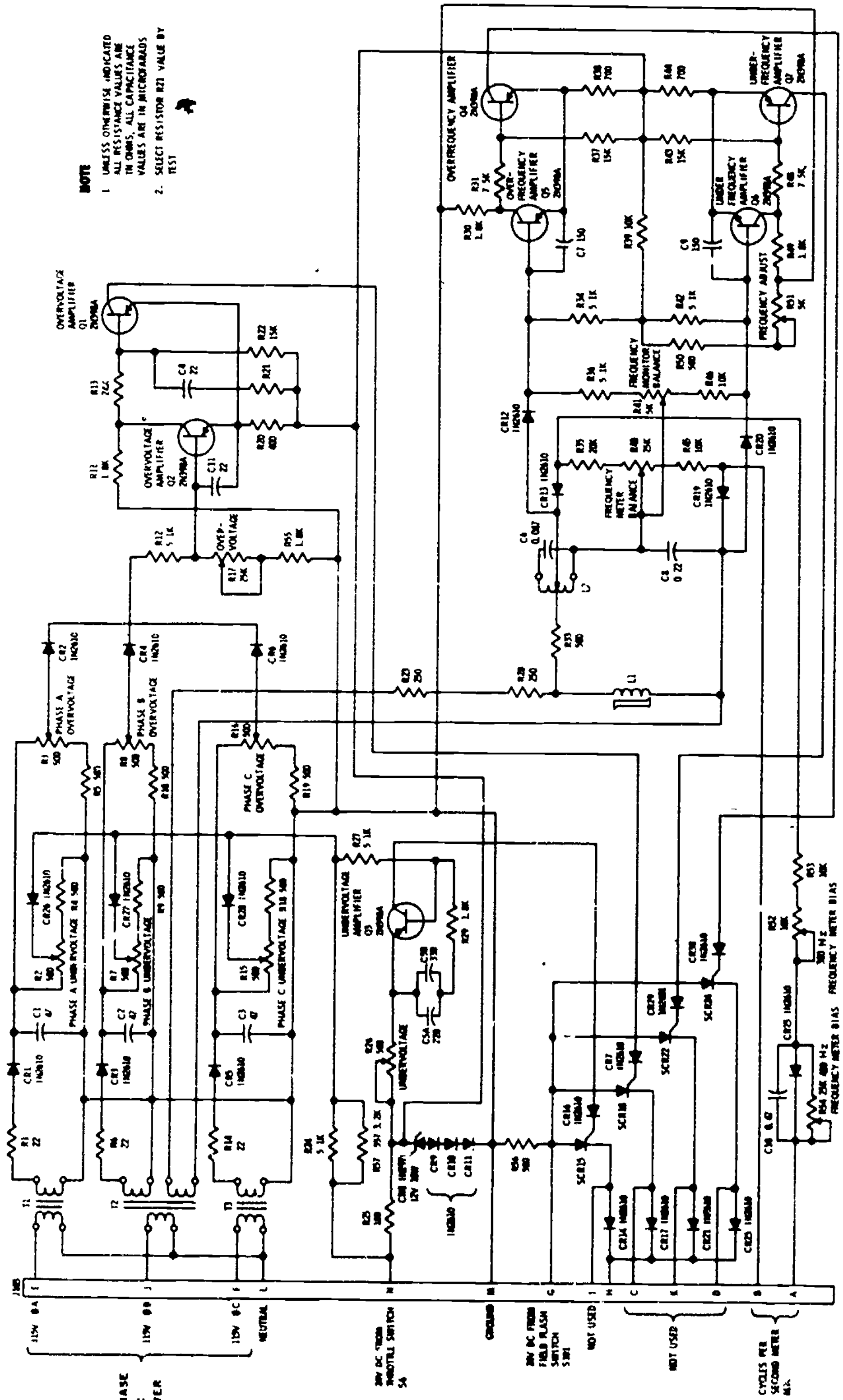

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Figure 13-33.—Protective package diagram.

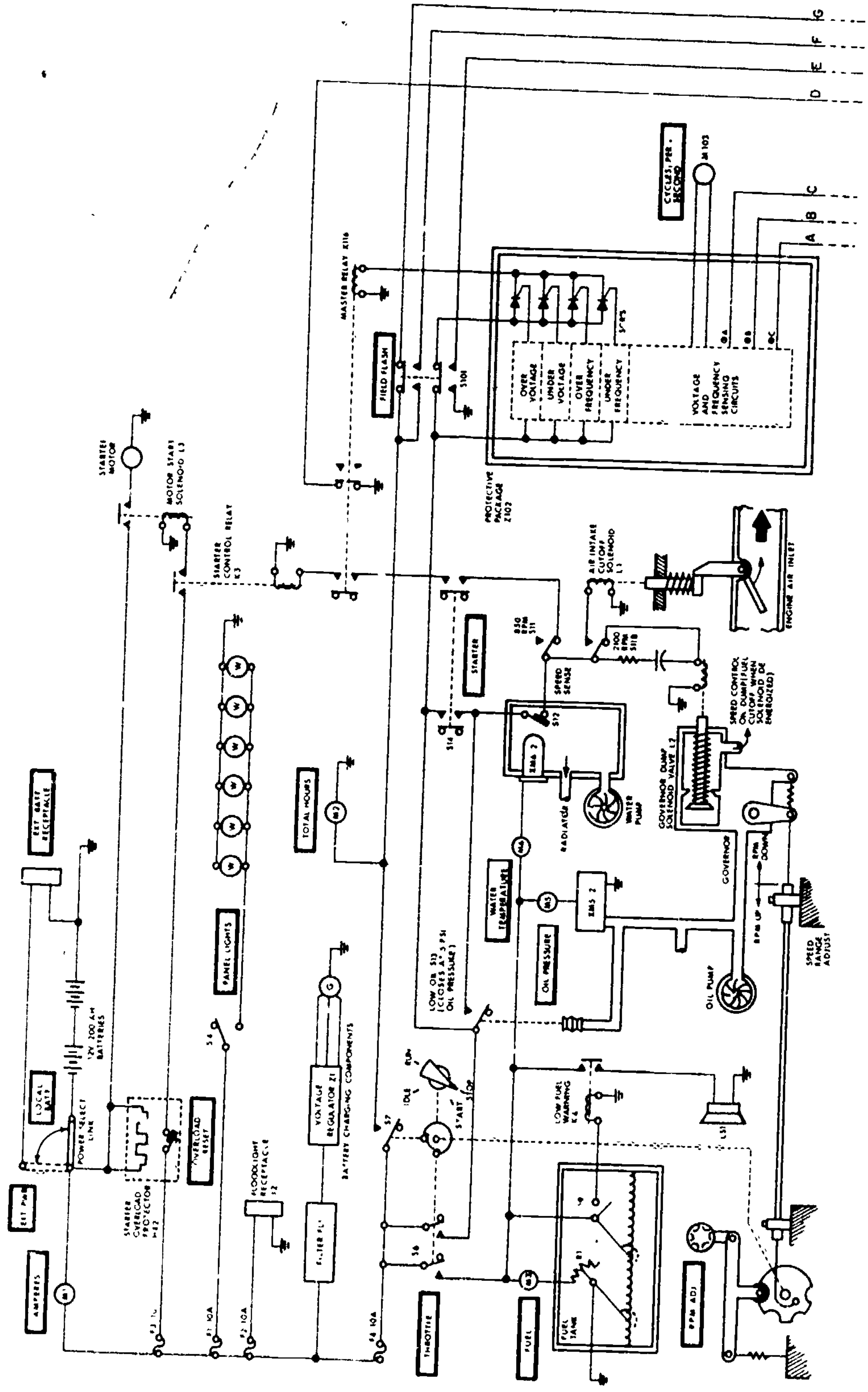

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Figure 13-34.—Simplified schematic diagram.

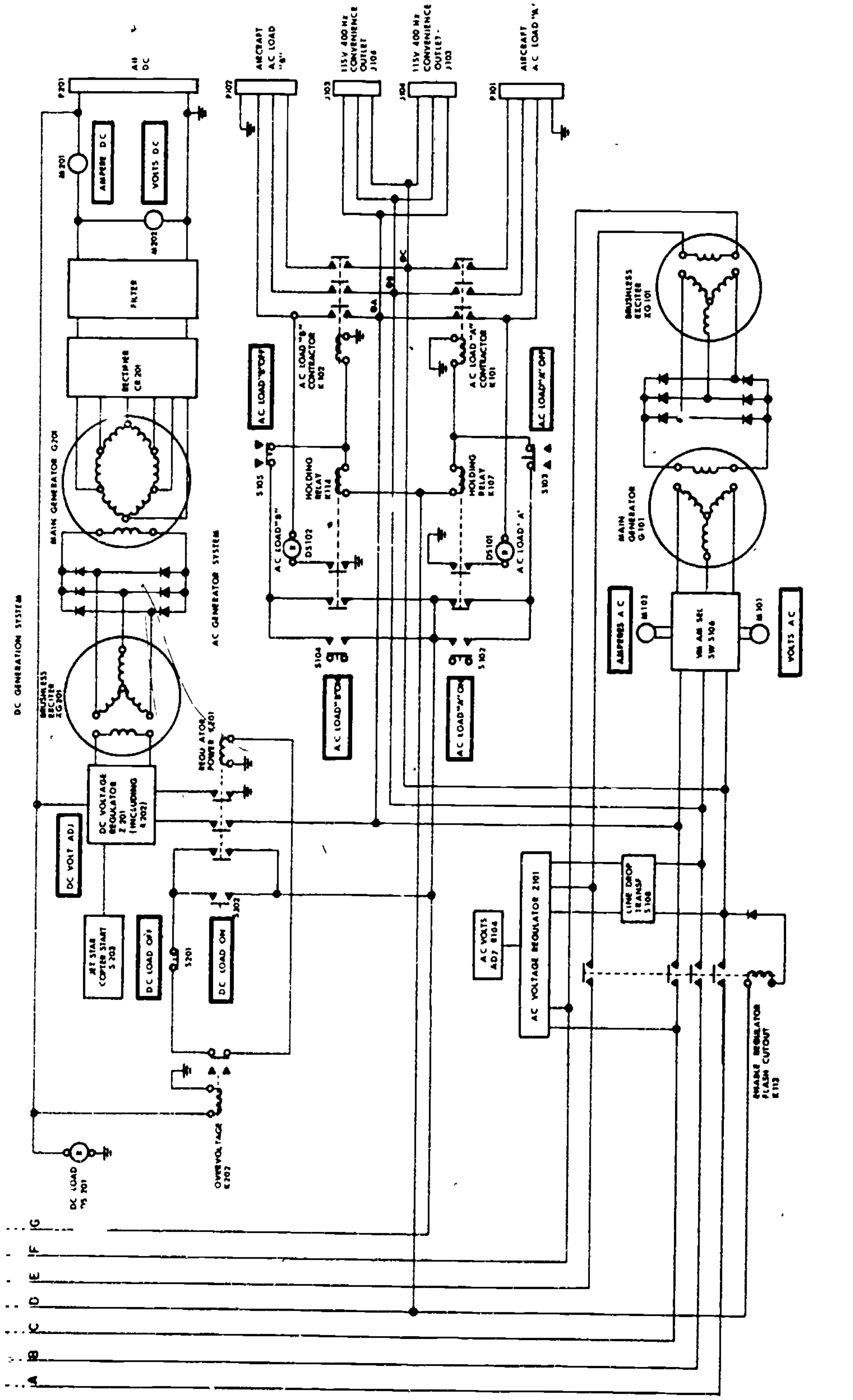

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Figure 13-34.—Simplified schematic diagram—Continued.

UNDERVOLTAGE

The undervoltage transistor Q3 controls the gate input voltage to SCR15. Potentiometers R2, R7, and R15 are set for approximately 15 volts d.c. The three potentiometers are diode isolated from each other. R26 is used to set the bias point for Q3. The emitter of Q3 is biased negative with respect to the base. Since the base is connected to all three a-c phases, a decrease in voltage in any phase will cause the base to become negative with respect to the emitter and Q3 will conduct. This applies a positive potential to the gate of SCR15. SCR15 will conduct, sending current flow out pin H of J103 to the relay K116, disabling the output contactors of the a-c and d-c generators.

OVERVOLTAGE

Transistors Q1 and Q2 (fig. 13-34) control operation of the overvoltage circuit. Rectifier power from the 3-phase transformer is adjusted by potentiometer R17 so that in the stable condition, Q2 is conducting and Q1 is cut off. When an increase in voltage is felt across any phase, an increase in potential is felt at the base of Q2, cutting it off. When Q2 cuts off, a negative potential is felt at the base of Q1, with respect to the emitter, and Q1 conducts. When Q1 conducts, it applies a positive potential to the gate of SCR18, causing it to conduct, thereby energizing relay K116. Relay K116 disables the output contactors of the a-c and d-c generators, thereby cutting off the output voltages.

UNDERFREQUENCY AND OVERFREQUENCY

The frequency monitoring circuitry (fig. 13-33) consists of an overfrequency and an underfrequency circuit. The 115 volts a.c. is applied to the frequency circuits from transformer T2, phase B. Direct-current voltage is applied to the transistors from Zener diode CR8. The frequency circuitry consists of transistors Q4 and Q5 (overfrequency), transistors Q6 and Q7 (underfrequency), a tuned tank circuit, and a frequency meter control circuit. Most of the a-c voltage is dropped across R23 and R28 before being applied to the tank circuit. The tank circuit consists of L1, L2, R33, C6, and C8. The tank circuit is resonant below 400 Hz. Therefore, at 400 Hz there is some current flowing through the tank. Current flow through the tank is used to change the bias in the underfrequency and overfrequency circuits, also to power the frequency meter. The frequency control circuits are connected across the tank circuit by CR13, CR19, and R40 is used to adjust the frequency meter to 400 Hz when the a-c output is 400 Hz.

In the stable frequency condition, transistors Q5 and Q6 are conducting, and transistors Q4 and Q7 are cut off. R41 is adjusted for a large bias potential at 400 Hz; therefore, a relatively large frequency variation is required to overcome this bias. Assume an overfrequency condition (425 Hz) exists. This will cause sufficient current flow through the tank circuit to change the bias potential of R41, thus cutting off Q5. When Q5 cuts off, a negative potential is developed at the base of Q4 with respect to the emitter. Q4 will conduct, causing SCR24 to conduct, cutting off the generator output. Just the opposite happens with an underfrequency condition. Current flow through the tank circuit lessens; R41 bias potential cuts off Q6 causing Q7 to conduct, and SCR22 energizes relay K116, cutting off the output of the a-c and d-c generators. (See fig. 13-34.)

PHASE SEQUENCE

Another a-c fault that may be encountered on the MEPP's and bears consideration is improper phase sequence. The normal phase sequence of the MEPP's and aircraft's a-c generator is ABC; therefore, if the sequence of the MEPP's a-c power was BAC, it must not be allowed to enter the aircraft's electrical circuitry. Improperly phased voltages applied to the aircraft electrical systems could cause serious damage to the 3-phase instruments, motors, and servomechanisms by trying to reverse their rotations. This damage, aside from twisting, breaking, and binding, could result in overheating and fire.

The most common cause of improper phase sequencing of MEPP equipment is replacement of the a-c MEPP aircraft power cable. If any two of the output cable leads were improperly connected at the MEPP a-c generator terminals, the phase sequence would in effect be reversed. Therefore, any time the a-c power cable is replaced and/or the possible cause of a trouble is phase sequencing, the receptacle end of the power cable should be checked with a phase sequence indicator such as is provided on electrical load bank testers.

The phase sequencing protector devices are normally contained in the aircraft. The phase sequencing protector contains a phase sequence-sensitive relay that will not allow external a-c power from an MEPP to be applied to the aircraft's electrical system unless it is of the proper phase sequence.

POWER AND POWER FACTOR

In a d-c circuit, power is computed by the equation, $P = EI$; that is, watts equals volts times amperes. Thus, if 1 ampere flows in a circuit at a pressure of 200 volts, the power is 200 watts. The product of the volts and the amperes is the TRUE POWER in the circuit.

In an a-c circuit, a voltmeter indicates the effective voltage and an ammeter indicates the effective current. The product of these two readings is called the APPARENT POWER. Only when the a-c circuit is made up of pure resistance is the apparent power equal to the true power. When the impedance of the circuit is either inductive or capacitive, the current and voltage are not exactly in phase, and the true power is less than the apparent power. The true power may be obtained by a wattmeter reading. The ratio of the true power to the apparent power is called the POWER FACTOR, and is equal to true power divided by apparent power.

It is desirable that equipments utilizing a-c power have as near a unity power factor load as practicable. This improves the efficiency of power distribution by reducing the line current and I^2R losses. Most a-c loads are somewhat inductive, resulting in a lagging power factor. Power factor correction may be accomplished by connecting a capacitor of the proper capacitance in parallel with the circuit. The connection should be made as close to the inductance load as possible.

The nonenergy component of the current in the inductive branch is 180° out of phase with the capacitive current. These currents circulate between the capacitor and inductive load and do not enter the line. The vector sum of capacitor current and total inductive load current is equal to line current. The line current is now in phase with the applied voltage to the parallel combination of the inductive load and capacitor. This reduction in line current reduces line loss and increases the efficiency of transmission.

Information on power factor and power factor correction may be found in Basic Electricity, NavPers 10086 (Series), under the heading "Power and Power Factor."

WYE, DELTA, AND OPEN-DELTA SYSTEMS

Most 3-phase distribution systems utilize either the wye or delta connection. The voltage and current relationships of these systems were covered previously in this chapter.

An advantage of a delta connection system is that if one winding of the power source becomes inoperative, it may be disconnected and the system can still operate at 57.7 percent of capacity. But in a wye connection, if one winding of a 3-phase system is damaged or disconnected, it is not possible to operate the system. When power is distributed in this manner, it is known as an open-delta system. For a detailed description of open-delta operation, refer to Basic Electricity, NavPers 10086 (Series), under the heading "Three-Phase Connections."

The principal reasons for using a wye-connected distribution system are that two different voltages are obtainable from the same source; an economy in transmission results because the line voltage is 1.73 times greater than the phase voltage, and the line current is equal to phase current. Thus, the line losses are reduced, and the efficiency of transmission is improved.

POWER SYSTEMS

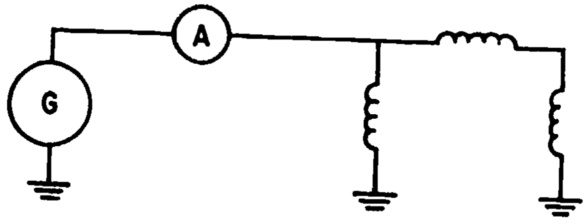
Most current MEPP's, such as the NC-10 and NC-12, are designed to furnish extremely large amounts of power for modern aircraft. Present-day generators on MEPP's are of such capacity that they are capable of providing power for the full load of one aircraft; however, there may be exceptions to this on some installations; for example, two patrol type aircraft may be furnished power simultaneously from one MEPP. Since power requirements of aircraft vary, the power system of the MEPP also varies. Most MEPP a-c power systems provide one or more sources of 120/208 volts 3-phase and 120 volts single-phase. Many of the MEPP's also provide 28 volts d.c., which is usually obtained by rectifying a portion of the a-c generator output on the later models. The type distribution system depends largely upon the requirements of the aircraft which the MEPP is designed to service.

GROUNDED SYSTEMS

Almost all of the electrical and electronic circuits the ASE works with are of the grounded type. This means that one leg of the circuit is connected to a common conductor, such as the earth, or to a structural member (frame) of the powerplant. When the grounded leg of the circuit is connected to a good electrical conductor, this conductor may serve as one leg of the circuit; thus, no separate conductor is needed for this leg of the circuit.

Figure 13-35 shows a simple grounded system. Even though the grounds are shown at different points, the potentials at these points are essentially the same since they are connected to a common conductor.

The 3-phase a-c generator is most commonly connected in what is called 4-WIRE WYE. In this system the common connection for the phases called NEUTRAL is connected to ground. There is also a 3-WIRE WYE, accomplished by connecting one of the phases to ground, usually the B phase. If this system is used, care must be taken to insure that all 3-phase equipment has the same phase grounded. Another method of connecting the



AE.190

Figure 13-35.—Grounded system.

phases is called DELTA. In this system, a common connection of two of the phases is grounded. Figure 13-36 shows the grounding of the 3-phase systems.

In the d-c systems the negative (-) side of the circuit is usually connected to ground (determined by the way the power supply is connected).

Any wire that completes the circuit to the ground network for an equipment is designated with the letter N. Any wire so designated may come in contact with ground at any point without causing malfunction of the equipment.

The grounded type circuit is advantageous since it reduces overall weight by using fewer conductors. This results in a reduction in cost and space requirements. Other advantages are that troubleshooting is simplified to some extent and the impedance of the ground return path is

AE.191

Figure 13-36.—Grounding of 3-phase systems. (A) 3-wire wye; (B) 4-wire wye; (C) delta.

lower than that of a run conductor. The disadvantages of a grounded system are as follows: First, short circuits will result when a bare spot on any ungrounded conductor of the system touches ground; and second, where circuits of different potentials and frequencies are using a common ground, there is the possibility of one circuit feeding into another. This trouble is more pronounced in electronic circuits.

UNGROUNDED SYSTEMS

The term ungrounded system means that the circuit is in no way connected to ground; thus, all conductors are run from the power source to the loads. Circuits of this type are often referred to as being above ground. The ungrounded system has the following advantages: It prevents one circuit from feeding into another; no malfunction of equipment will occur should one conductor become accidentally grounded; and the circuits are completely insulated from each other. The system has the disadvantage of adding more weight because it requires more conductors than the grounded system. This results in added cost and space requirements.

MEPP GOVERNORS

When an electrical load is placed on the generator of an MEPP, the prime mover speed will decrease; likewise, when the load is removed, the prime mover speed will increase. In a d-c generating system, the prime mover has to drive the generator within a certain speed range (depending on particular generator) to maintain the required voltage, even though the system has a voltage regulator. In an a-c generating system speed is far more critical because it also determines the output frequency. Likewise, some engines will overspeed unless some means is used to regulate the speed. A manual type throttle is ineffective because of the varying electrical loads. It is for these reasons all MEPP's use some type of automatic governor.

There are several different types of governors. For instance, the governors may be mechanical, hydraulic, electrical, electronic or combinations of governors mentioned. The governors normally control engine speed by controlling quantity of fuel or the fuel-air mixture and the magnetic field in the electric motor-driven MEPP's.

The ASM 3 & 2 Manual, NavPers 10315 (Series), contains information on governors that will be of interest to the ASE. The governors may be the responsibility of the ASM or the ASE, but on most of the more modern MEPP's it is a joint responsibility.

ELECTRICAL SAFETY PRECAUTIONS

Insofar as is practicable repair work on energized circuits should not be undertaken. When repairs on operating equipment must be made because of emergency conditions, or when such repairs are considered to be essential, the work should be done only by experienced personnel, and if possible, under the supervision of the senior petty officer of the ASE shop. Every known safety precaution should be carefully observed. Ample light for good illumination should be provided; the worker should be insulated from ground with some suitable nonconducting material such as several layers of dry canvas, dry wood, or a rubber mat of approved construction. The worker should, if possible, use only one hand in accomplishing the necessary repairs. Helpers should be stationed near the main switch or the circuit breaker so that the equipment can be deenergized immediately in case of emergency. A man qualified in first aid for electric shock should stand by during the entire period of the repair.

HIGH-VOLTAGE PRECAUTIONS

Personnel should never work alone near high-voltage equipment. Tools and equipment containing metal parts should not be used in any area within 4 feet of high-voltage circuits or any electric wiring having exposed surfaces. The handles of all metal tools, such as pliers and cutters, should be covered with rubber insulating tape. (The use of plastic or cambric sleeving or of friction tape alone for this purpose is prohibited.)

Before touching a capacitor which is connected to a deenergized circuit, or which is disconnected entirely, short-circuit the terminals to make sure that the capacitor is completely discharged. Grounded shorting prods should be permanently attached to workbenches where electrical devices are regularly serviced.

Do not work on any type of electrical apparatus with wet hands or while wearing wet clothing, and do not wear loose or flapping clothing. The use of thin-soled shoes with metal plates or hobnails is prohibited. Safety shoes with nonconducting soles should be worn if available. Flammable articles should not be worn.

When working on electrical or electronic apparatus, you should first remove all rings, wristwatches, bracelets, and similar metal items. Care should be taken that the clothing does not contain exposed zippers, metal buttons, or any type of metal fastener.

Warning signs and suitable guards should be provided to prevent personnel from comming into accidental contact with high voltages.

LOW-VOLTAGE PRECAUTIONS

Most people never realize the dangers of low-voltage electric shock. These hazards are ever present, and it is surprising how dangerous they can be. Defective handtools and improper usage can be corrected, but some hazards will always exist. An awareness of their existence seems to be the answer. In general, beware of any voltage.

The Navy Training Courses, Airman, NavPers 10307 (Series), and Standard First Aid Training Course, NavPers 10081 (Series), contain safety information with which you should be familiar. It is recommended that you acquaint or reacquaint yourself with the sections of Airman that deal with safety as it relates to naval aviation. The Standard First Aid Training Course is designed as a basic reference in the field of first aid; since all naval personnel are required to possess a knowledge of the principles of first aid, you should become familiar with this training course.

The ASE should also become familiar with the contents of Department of the Navy Safety Precautions for Shore Activities, NAVSO-P-2455.

CHAPTER 14

GAS TURBINE ENGINES

Although the ASE is not responsible for the maintenance of an entire engine and its mechanical systems, he must have a basic knowledge of the engine and mechanical systems so as to operate this equipment safely when performing maintenance on the engine's electrical system. He is required to be able to operate gas turbine engines such as those found in jet engine starting units. This chapter is intended to acquaint the ASE with the safe and proper operation of these units so that he will be able to perform the maintenance for which he is responsible.

Gas turbine engines of the type used in jet engine starting units provide pneumatic power in the form of compressed bleed air for operation of large-class pneumatic equipment. This equipment includes aircraft main engine starters, air-conditioning systems, and other types of compressed air consumers requiring air at relatively low pressure but in high volume.

There are many types and configurations of gas turbine engines used in the Navy; however, because of their similarity in construction and operation, only one is discussed in this chapter.

PNEUMATIC POWER GAS TURBINE ENGINE MODEL GTC85-72

This engine, normally referred to as a unit, consists of a two-stage, centrifugal flow compressor directly coupled to a radial, inward-flow, single stage turbine.

There are several different configurations of the GTC85-72 in use with the major difference being the type of enclosure installation that is used. Two of these configurations are shown in figure 14-1.

ENGINE SECTIONS

The engine is comprised of three sections, each section being designed as a separate assembly, so that any section can be repaired or replaced individually. Also, as the engine does not use a long, one piece main shaft, balance and alinement problems are kept to a minimum. These three sections are shown separated in figure 14-2.

Accessory

The accessory section consists of a gear reduction drive coupled directly to the compressor shaft through a special type drive shaft. It provides mounting pads and drives for the starter, centrifugal switch assembly, oil pump assembly, generator, and the fuel pump and control unit.

Compressor

This section provides the compressed air for combustion, engine cooling, and pneumatic power. The first and second stage impellers are mounted on and driven by a common shaft. The ends of the shaft are splined internally to receive the drive shafts which connect the compressor shaft to the accessory drive shaft and the turbine shaft to the compressor shaft. The compressor section is enclosed by a sheet metal plenum chamber with the oil cooler radiator mounted over the air intake.

Turbine

This is the section in which all the power required to drive the compressor and accessories in produced. A single stage turbine wheel is used with a ring of fixed nozzles surrounding its outer

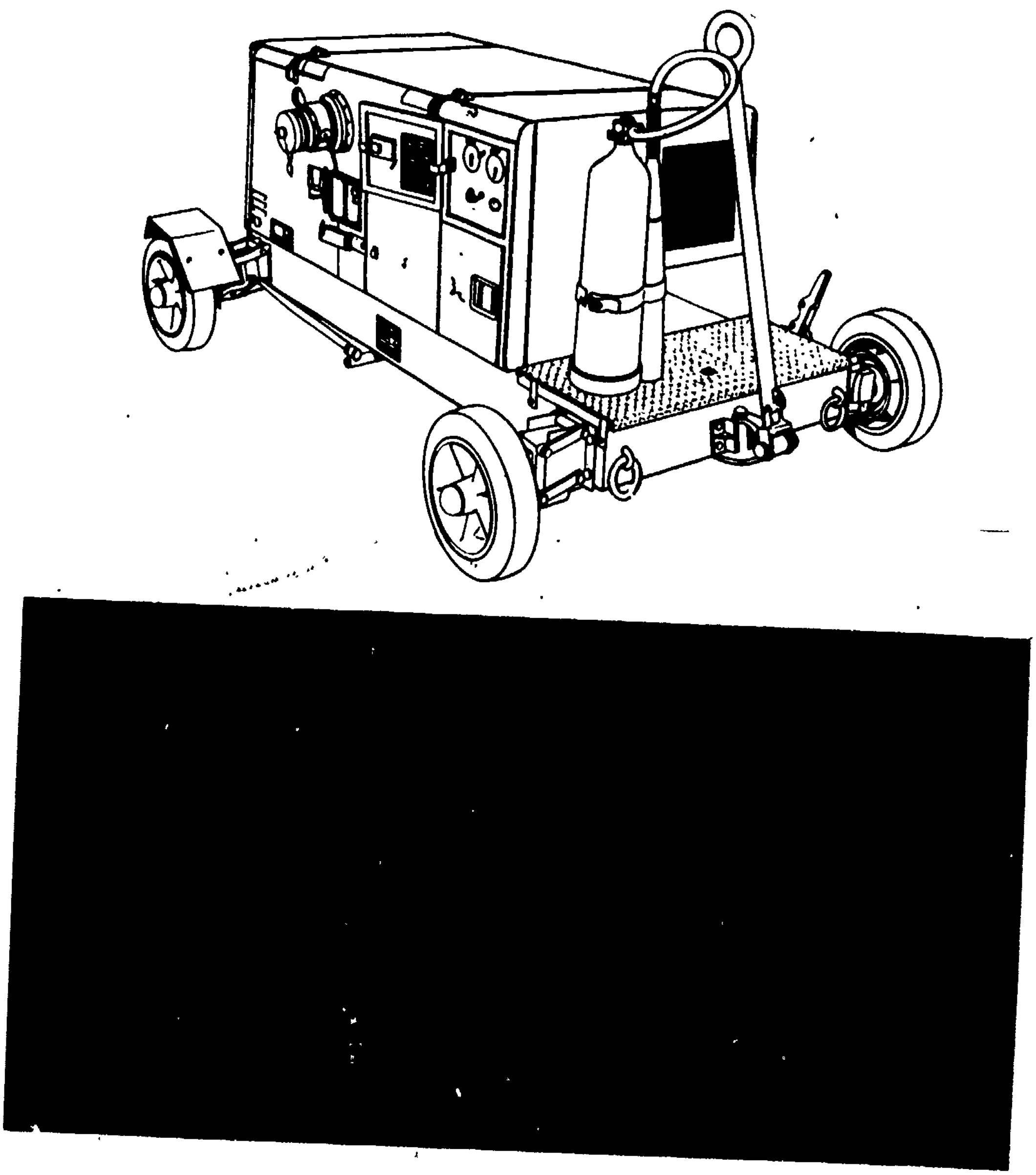
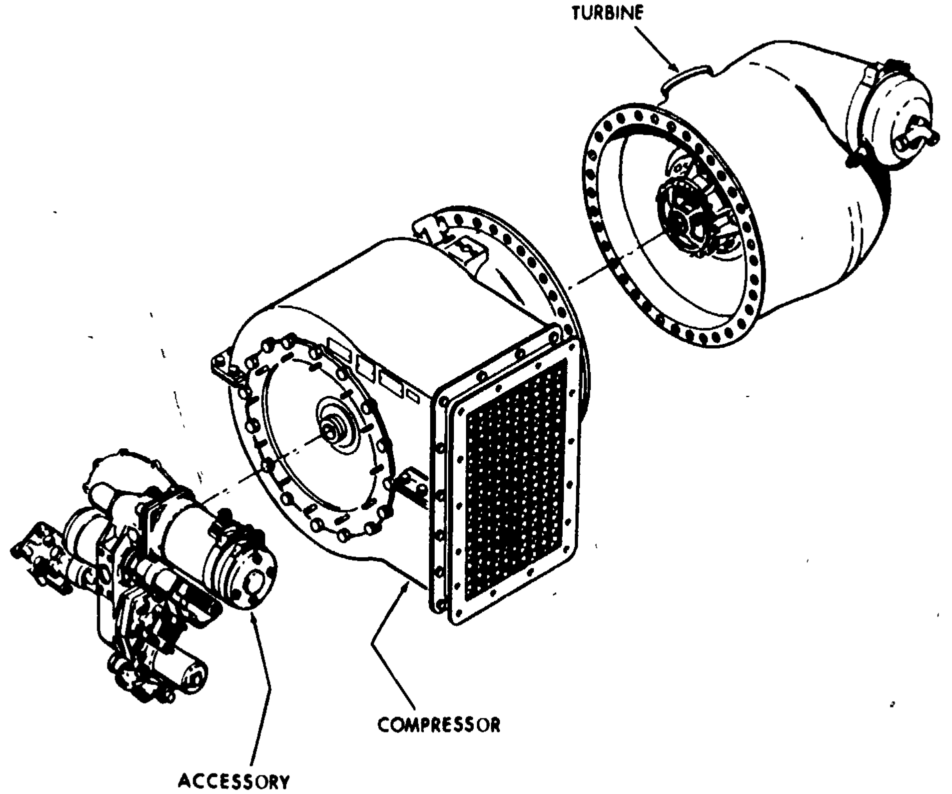


Figure 14-1.–Enclosure installations. AS.915



AS.413

Figure 14-2.—Engine sections.

circumference. A single combustion chamber provides the high velocity gas flow which is directed to the nozzle ring by an assembly called the torus. The turbine section is enclosed by a sheet metal plenum chamber on which the unloading air shutoff (load) valve is mounted. It is from this plenum chamber that the bleed air is obtained to support pneumatic loads.

ENGINE AIRFLOW

See figure 14-3. Rotation of the compressor creates a low-pressure area at the inlet side of the unit. This draws air through the oil cooler into the first stage compressor plenum chamber (air supply chamber). Note that the first stage of the compressor is constructed with a dual-entry; this is necessary to provide the large volume of air that is required for engine combustion and cooling and for supplying pneumatic power. As air is drawn into the first stage of the compressor, tremendous velocity is imparted to it by the first stage impeller. The air is then directed into the first stage diffuser where it is slowed down and its pressure increased (first stage compression) to approximately 18 psi. It is then directed through interstage du s into the second stage of the compressor and tremendous velocity is again imparted to it by the second stage impeller. It is then directed into the second stage diffuser where it is slowed down and its pressure further increased (second stage compression) to approximately 37 psi. From the second stage compressor, the air is directed through a set of deswirl vanes where, as the term deswirl implies, the air is straightened out into a smooth flow as it enters the turbine plenum chamber. Approximately 75 percent of the air entering the turbine plenum chamber is used to support combustion and for combustion chamber cooling while the remaining 25 percent is available as bleed-air for operation of pneumatic equipment. When no air is being bled from the engine, this 25 percent provides additional engine cooling, enabling the engine to operate at reduced temperature under no-load conditions.

Air enters the combustion chamber, via small holes or perforations in the flame tube or liner, where it is combined with fueld and burned. The result of the burning of the fuel is the rapid expansion of the burning gases and creation of a high velocity, high energy, exhaust gas flow. This gas flow is collected in an assembly, referred to as the torus, and directed through a nozzle ring surrounding the turbine wheel and onto the blades of the turbine wheel at the proper angle to drive it. The high velocity, high energy exhaust gas flow drives the turbine (hence the term gas turbine) at a very high rate providing the power to drive the compressor and accessories and to support pneumatic loads. After passing through the turbine blades the exhaust gases (still hot) pass out the tailpipe to the atmosphere.

SYSTEMS

Before the ASE attempts to operate a gas turbine engine or to perform any maintenance on it, he must have a knowledge of the different

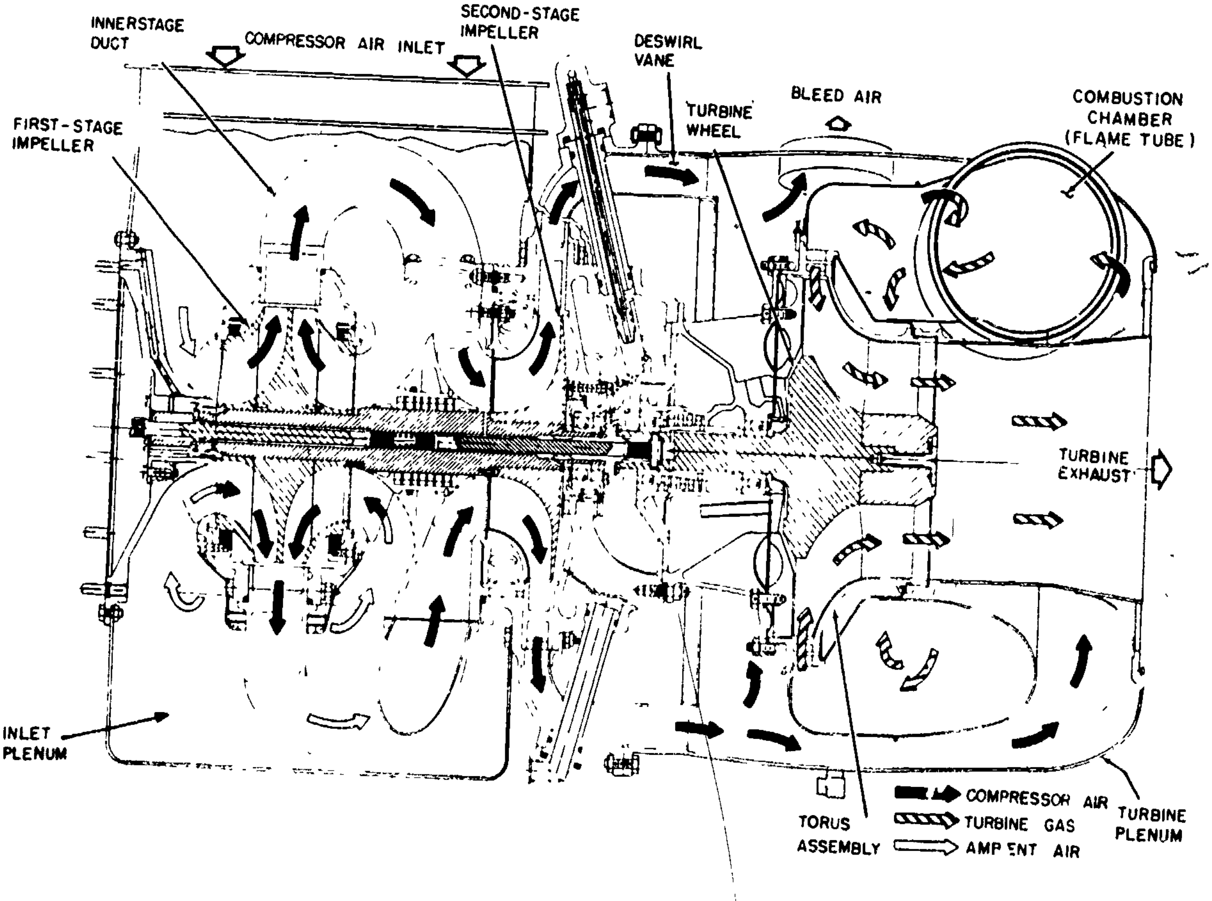
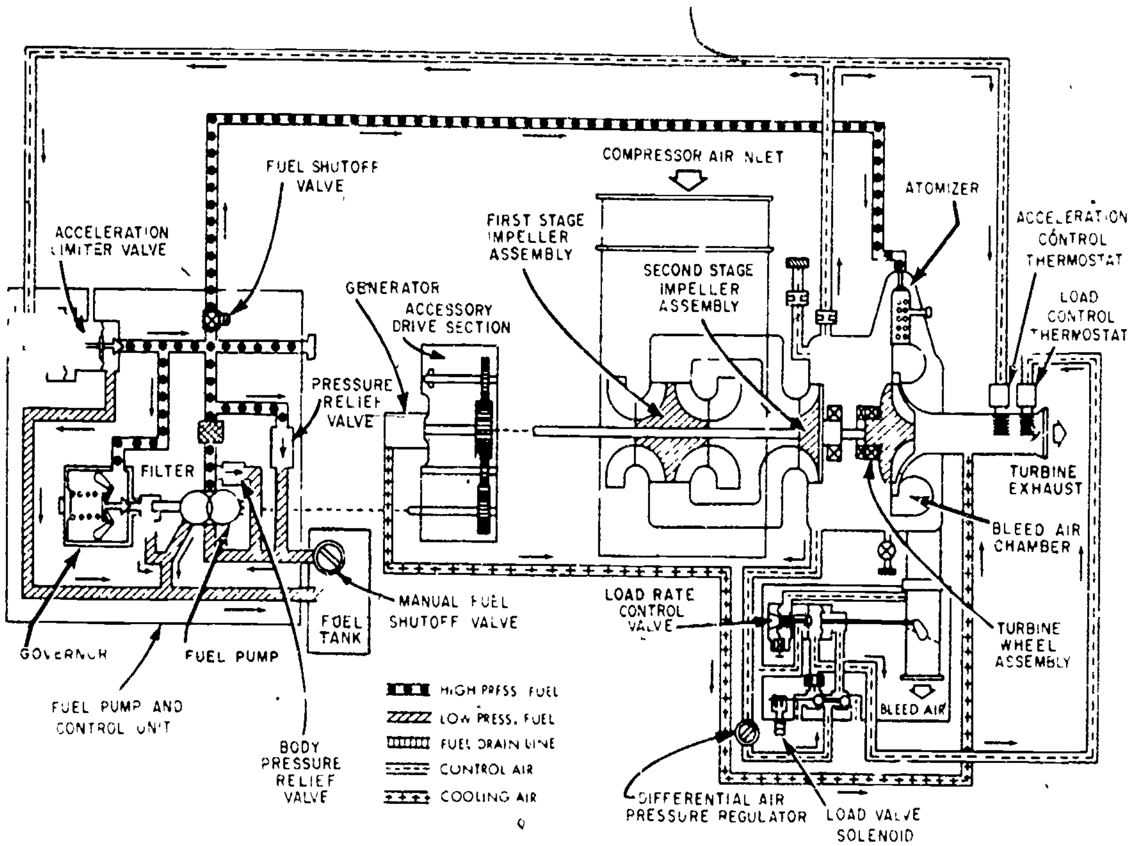


Figure 14-3.—Engine airflow. AS.414



AS.415

Figure 14-4.—Fuel and bleed-air control system.

systems and the function performed by each as the systems are interconnected and dependant on each other. These systems, fuel and bleed-air control, lubrication, and electrical, are discussed in the following paragraphs.

Fuel and Bleed-Air Control

(See fig. 14-4.) This system functions automatically to maintain a near-constant turbine operating speed under varying conditions of load and to control the amount of bleed-air supplied by the engine. The system consists of electromechanical and pneumatic components with connecting plumbing and wiring. The principal components of the system are a fuel pump and control unit, an acceleration stabilizer and adjustable orifice assembly, a fuel atomizer assembly, an acceleration control thermostat, an unloading air shutoff (load) valve, and a bleed-load control thermostat.

FUEL PUMP AND CONTROL UNIT. The fuel pump and control unit incorporates the fuel pump, acceleration limiter (bypass) valve, a flyweight-type (mechanical) governor, and a fuel solenoid valve.

The acceleration limiter valve consists of a check valve actuated by two diaphragms—one controlled by fuel pressure and the other by a combination of spring pressure and compressor discharge (control) air pressure. It is called a bypass valve because it is designed to control fuel flow to the atomizer assembly by bypassing a portion of the fuel delivered by the fuel pump back to the fuel tank in relation to compressor discharge air pressure. As engine rpm increases and compressor discharge air pressure increases, less fuel is bypassed and more is delivered to the atomizer assembly. The acceleration limiter valve controls fuel flow during starting and acceleration up to approximately 95 percent of governed engine rpm.

The mechanical governor begins to function as engine rpm reaches approximately 95 percent. Enough centrifugal force is applied to the flyweights at this point to allow the governor to begin bypassing fuel, in conjunction with the acceleration limiter valve. The combined bypass action of the acceleration limiter valve and the governor allow just enough fuel to reach the atomizer assembly to maintain governed engine rpm.

The fuel solenoid valve is of the normally closed type. It admits or shuts-off fuel flow to the atomizer assembly in response to electrical control system operation.

ACCELERATION STABILIZER AND ADJUSTABLE ORIFICE ASSEMBLY.-The acceleration stabilizer and adjustable orifice assembly consists of a normally open solenoid valve and an adjustable air bleed installed in the control air line between the acceleration limiter valve and the acceleration control thermostat. Its purpose is to control and stabilize the rate of acceleration by bleeding control air pressure off the acceleration limiter valve. Bleeding off a portion of the air pressure from the acceleration limiter valve causes the valve to bypass more fuel, decreasing the rate of acceleration. The solenoid is energized during starting (up to 35 percent of governed engine rpm) and when the load switch is actuated, causing the acceleration limiter valve to close and bypass no fuel. This provides the increased fuel flow required at these times to support engine operation.

FUEL ATOMIZER ASSEMBLY.-The fuel atomizer assembly is a dual orifice type and is mounted on the combustion chamber cap assembly. A flow-divider valve directs all fuel at low pressure to the small orifice which provides proper atomization of the fuel during starting. As engine rpm increases and fuel pressure increases, the flow divider valve actuates to permit combined flow to both orifices.

ACCELERATION CONTROL THERMOSTAT. The acceleration control thermostat is mounted in the engine tailpipe. It consists of a spring-loaded-closed, ball check valve, actuated by exhaust gas temperature (EGT). It is connected to the acceleration limiter valve by a control air line. The thermostat acts to override control of fuel flow by dumping all the control air pressure from the acceleration limiter valve if EGT exceeds a specified limit during acceleration.

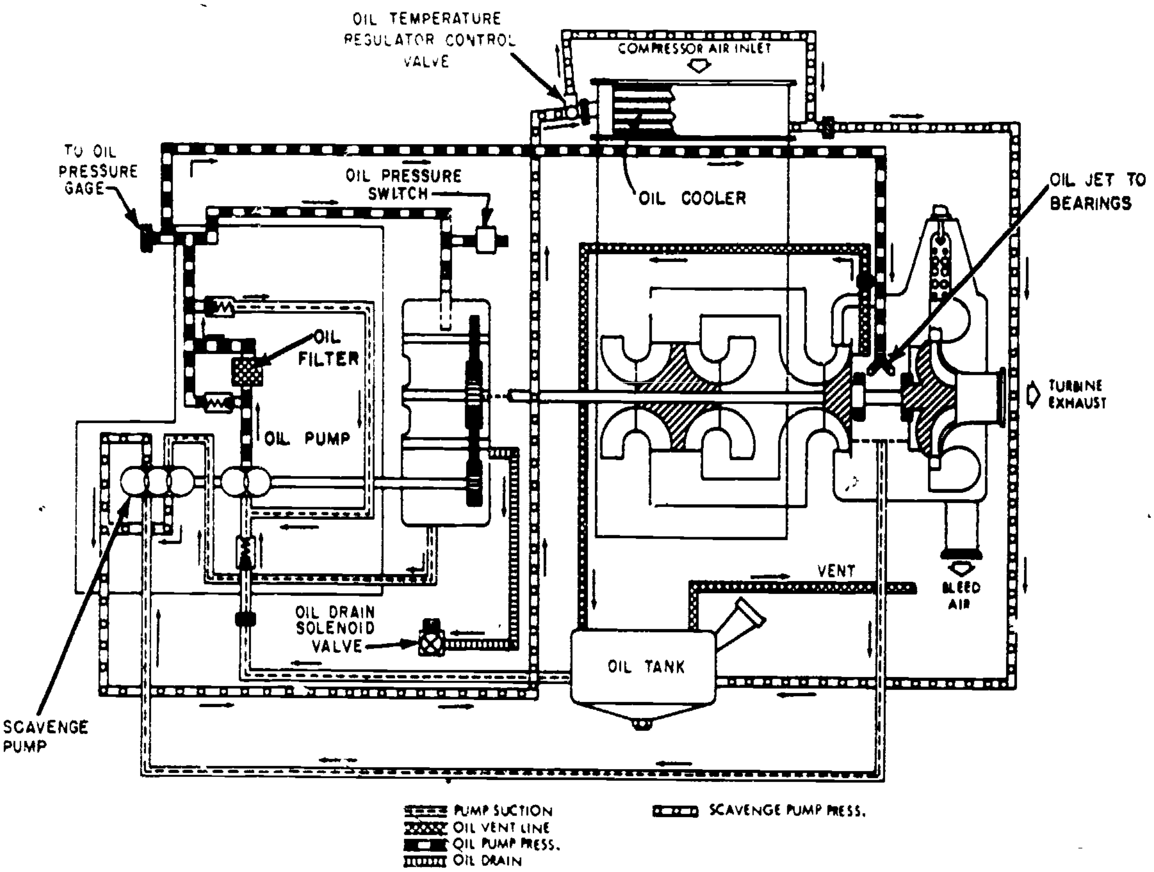
UNLOADING AIR SHUTOFF VALVE.- The unloading air shutoff (load) valve assembly consists of a normally closed solenoid valve, a normally closed butterfly valve, and two diaphragms. It functions to control the amount of air that is bled from the engine in relation to EGT. If too much air is being bled off (overloading), action of the bleed-load control thermostat allows the butterfly valve to close sufficiently to regulate bleed-air flow without causing engine shutdown or loss of engine speed.

BLEED-LOAD CONTROL THERMOSTAT.-The bleed-load control thermostat is mounted in the engine tailpipe. It has the same construction as the acceleration control thermostat and is connected to the load valve by a control air line. It functions to control the bleed-load in relation to EGT. At a specified temperature, the thermostat valve opens and bleeds control air pressure from the actuator diaphragm of the load valve. This reduction in control air pressure allows the butterfly valve to modulate, thereby maintaining the maximum permissible bleed-load on the engine and preventing overloading.

Lubrication

The lubrication system is very simple, but, because of the temperatures and rpm at which the unit operates, positive feed oil pressure for lubrication and cooling must be provided. The system includes a pressure and scavenge pump, an oil filter, an oil temperature regulator, an oil cooler, and an oil tank. (See fig. 14-5.) Oil under pressure is supplied to all gears, shafts, and bearings. After the oil has been used, it collects in the common sump between the compressor and turbine assemblies and in the sump of the accessory section and is then returned, by the scavenge pump, to the oil tank.

If the temperature of the oil is such that it requires cooling, it is routed through the oil



AS.416

Figure 14-5.—Lubrication system.

cooler. Cooling is accomplished by compressor inlet air flowing around the tubes of the oil cooler. If the temperature of the oil is not great enough to require cooling, a bypass valve in the temperature regulator routes the oil directly to the oil tank, where it is again pumped through the engine. The unit is provided with an oil pressure actuated switch which prevents starting of the engine until oil pressure builds up sufficiently to close the switch. Also, if oil pressure is lost during operation, this switch will function to shut down the engine. Sometimes, the oil pump will require priming to provide oil pressure at time of starting.

Electrical

The electrical system provides the means for starting, operating, and stopping the engine. It is a 26±2 volt d-c system which may be operated from a battery or an external power source, such as a mobile electric powerplant.

The electrical system has two groups of components engine mounted and enclosure mounted. The engine group is the same for all installations but the enclosure group will vary as to type of components and circuitry. A typical electrical system schematic is shown in figure 14-6.

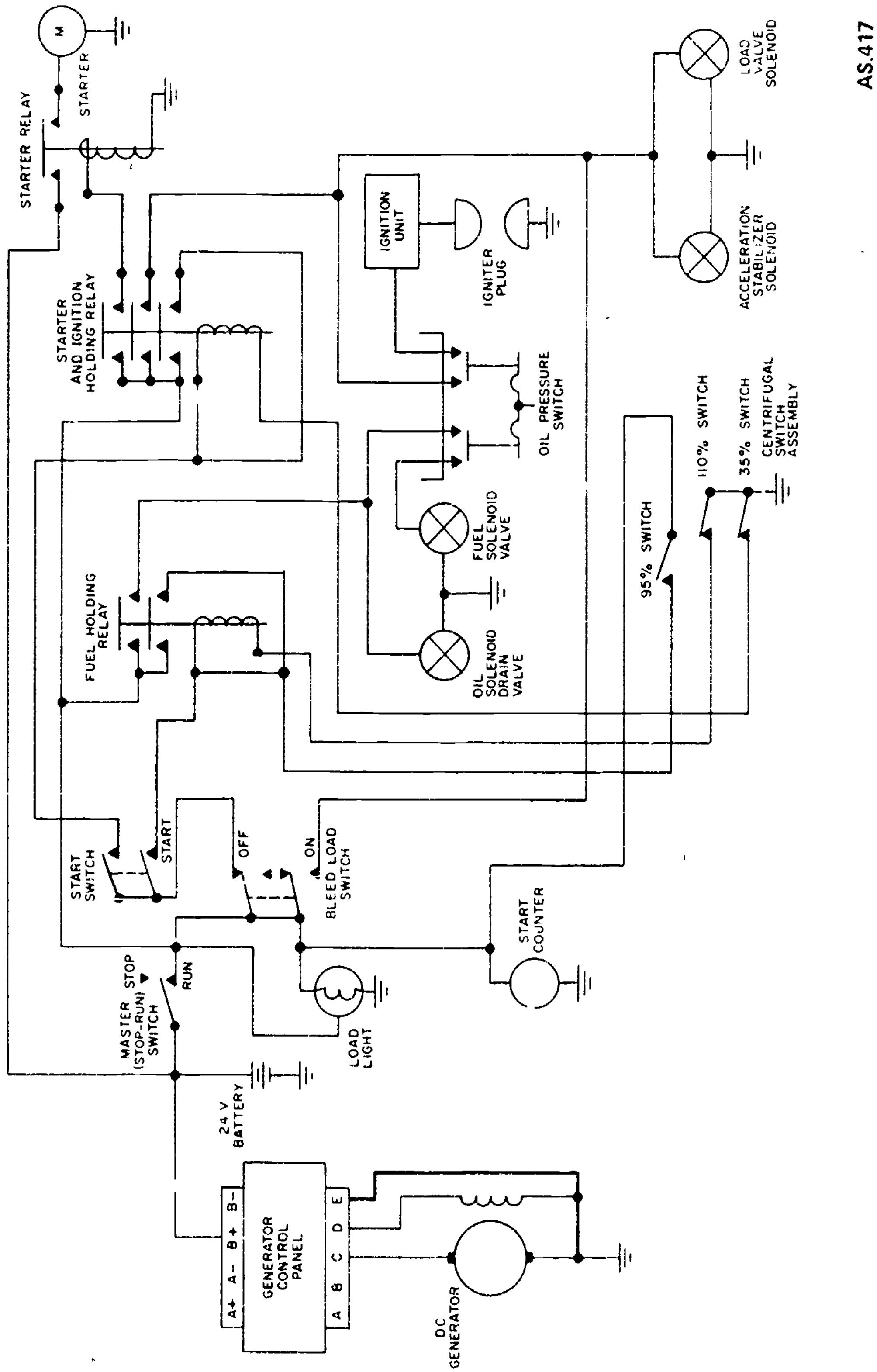


Figure 14-6.—Electrical system.

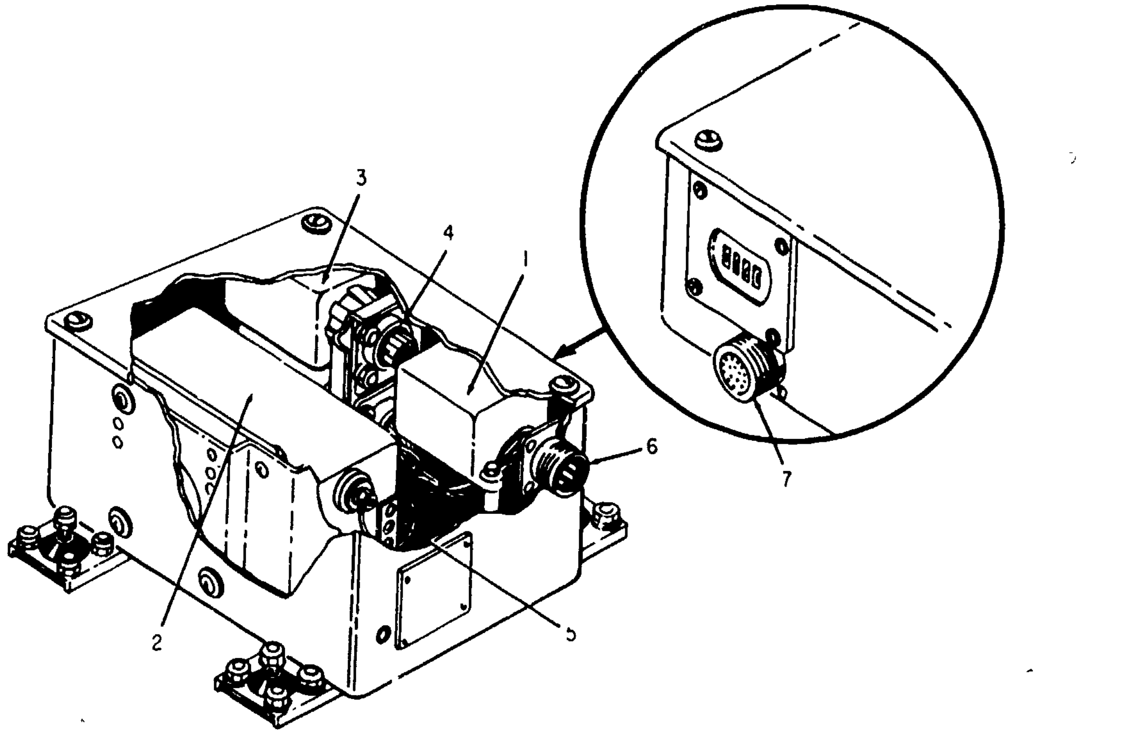


Figure 14-7.—Electrical control box.

AS.916

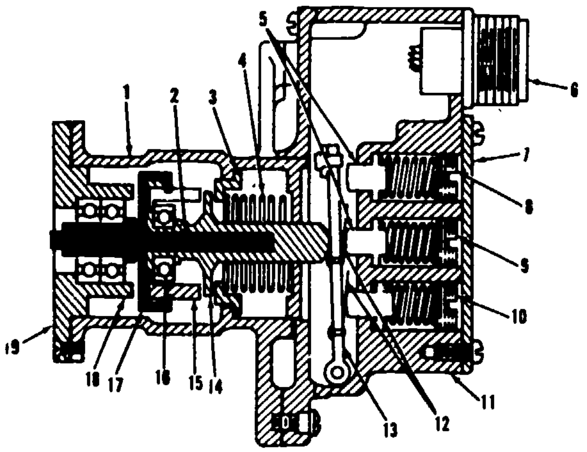
The components of the engine group are the electrical control box, ignition system, generator, starter, centrifugal switch assembly, oil drain solenoid valve, fuel solenoid valve, acceleration stabilizer solenoid valve, and the load control valve solenoid valve.

ELECTRICAL CONTROL BOX.-Electrical control of the engine is maintained through the electrical box. (See fig. 14-7.) It houses the starter and ignition holding relay, fuel holding relay, ignition unit, and the start counter. The starter and ignition holding relay and the fuel holding relay, when energized, provide power to the circuits they control and also to their own coils for a holding action. The ignition unit provides the high-tension current to the igniter plug. Operation of the start counter is covered in chapter 11 of this manual.

IGNITION SYSTEM. The gas turbine engine ignition system is very simple in construction and operation. The entire system consists of the igniter (spark unit) located in the combustion chamber, a section of high-tension ignition lead, and the ignition unit located in the electrical control box. The ignition unit provides the high-energy voltage source. This is accomplished by a step-up transformer which charges internal storage capacitors. The storage capacitors are then discharged across a booster coil arrangement and the high voltage is applied to the igniter. After the engine has started and a flame is established in the combustion chamber, the ignition system is deenergized since burning is constant once a successful start has been accomplished.

NOTE: The voltage to the igniter is dangerously high (near 40,000 volts); therefore, caution must be observed when maintenance is performed on the ignition system. Always make certain that the capacitors are fully discharged before removal or checking components of the ignition system.

GENERATOR AND STARTER ASSEMBLIES.- The generator, driven by the accessory drive gear section, is a continuous-duty unit rated at 12 amperes and 28 volts. Cooling of the generator is provided by air drawn through cooling inlet holes in the generator housing through the generator, into a cooling outlet tube, and into the turbine exhaust. Control of the generator and the circuits associated with it is the function of the voltage regulator and reverse current relay. These units and a noise filter are located in the generator control panel. The starter unit operates on a 24- to 28-volt power supply; power for operation of the starter may be provided by a battery or may be supplied from an alternate external 28-volt source. The starter is provided with a friction and inertia type clutch mechanism which allows automatic initial engagement, and disengagement is accomplished when the speed of the accessory drive is exceeded. Starter motor current is cut off at 35 percent of engine speed.



1. Housing.
2. Centrifugal switch shaft.
3. Spring sliding retainer.
4. Compression spring.
5. Push rod.
6. Receptacle.
7. Access plate.
8. Adjusting screw.
9. Adjusting screw.
10. Adjusting screw.
11. Switch cover.
12. Leaf spring.
13. Switch actuating lever.
14. Lever actuator.
15. Governor flyweight.
16. Ball bearing.
17. Fulcrum flyweights.
18. Overspeed switch bearing carrier.
19. Mounting flange.

AS.419

Figure 14-8.—Centrifugal switch assembly.

CENTRIFUGAL SWITCH ASSEMBLY. The centrifugal switch assembly (fig. 14-8), through the operation of a set of flyweights, controls the sequence of operation of the electrical system. As the flyweights are caused to move outward by centrifugal force, three switches are actuated by an actuating lever. The first to operate is the 35 percent switch which deenergizes the starter and ignition holding relay. The second to operate is the 95 percent switch which energizes the ready-to-load light, load switch circuit, and the start counter. The last switch to operate the 110 percent switch, operates at from 105 to 110 percent and is a safety device to protect the engine from overspeed. When this switch operates, the fuel holding relay is deenergized and the engine stops.

The principal components of the enclosure group are a starter relay, generator control panel, and an engine control panel. The engine control panel provides the operating controls and instruments for monitoring engine operation.

SYSTEM OPERATION.--(Refer to fig. 14-6.) With the master (stop-run) switch in the run position, power is available to the start switch, through the load switch in its off position, the test circuit of the load light, the contacts of the fuel holding relay, and the contacts of the starter and ignition holding relay. Depressing the momentary contact start switch energizes the coils of the fuel holding and the starter and ignition holding relays. The fuel holding relay energizes the oil solenoid drain valve, the fuel side of the oil pressure switch, the normally open 95 percent switch, and its own coil. Ground for the fuel holding relay coil is through the normally closed 110 percent switch. The starter and ignition holding relay energizes the starter relay, acceleration stabilizer solenoid, load valve solenoid, ignition side of the oil pressure switch, and its own coil. Ground for the starter and ignition holding relay is through the normally closed 35 percent switch. The starter relay energizes the starter motor which begins rotating the engine. At about 5,000 rpm, rising oil pressure closes the oil pressure switch, energizing the fuel solenoid valve and the ignition unit. Combustion is initiated and the engine begins to accelerate under the combined drives of the starter and combustion until approximately 15,000 rpm (35 percent) is reached. At this time the 35 percent switch opens the ground circuit to the coil of the starter and ignition holding relay, causing it to open. This action deenergizes the starter relay, ignition unit, acceleration stabilizer solenoid, and the load valve solenoid. The engine continues to accelerate and as approximately 42,000 rpm (95 percent) is reached, the 95 percent switch closes, energizing the load light (indicating that a load may now be applied), start counter, and the circuit to the load switch. The engine is loaded by placing the load switch in the on position. This energizes the load valve solenoid and the acceleration stabilizer solenoid. If at any time the engine speed reaches 105 to 110 percent, the 110 percent switch opens, opening the ground circuit to the coil of the fuel holding relay, causing it to open. This action deenergizes the fuel solenoid valve, and the bleed-load valve circuit. Fuel flow to the engine is stopped, the load valve closes, and the engine is shut down.

OPERATION

In the operation of any gas turbine compressor unit, the ASE must first become completely familiar with the proper operating procedures. No one should attempt to operate these equipments until he has had an operational checkout by a qualified and authorized operator. The actual operation of gas turbine compressors is simple, however, they are powerful pieces of equipment and must be treated accordingly. The following safety precautions must be strictly enforced to prevent possible personnel injury or equipment destruction:

1. Before starting and during operation, keep the area around the compressor air inlet clear of personnel, loose gear, and debris. Although the turbine engine of the unit is small, as compared to an aircraft engine, it consumes great quantities of air and can be very dangerous.

2. The exhaust gas from this equipment is exactly like that of the engine in an aircraft HOT and exits from the unit at a terrific velocity. Therefore, personnel must avoid this area and make sure that the exhaust is not directed onto anything which the heat or the velocity of these gases would damage.

3. A third danger which lurks hidden in equipment of this type may not be quite as evident as the two previously discussed. This danger is in the area of the plane-of-rotation of the high-speed compressor and turbine assemblies. There have been times when a turbine blade has been thrown out of the turbine. At the speeds which the turbine turns, the blades become like rifle bullets. These areas are marked clearly with red painted stripes. Never stand in the planes so marked.

4. Always wear sound attenuators when working on or near this equipment while it is operating, since the noise level is very high and will cause loss of hearing. The use of the sound attenuators cannot be overstressed. Remember, the high-frequency component of the noise generated by this equipment can and often does cause permanent damage to the auditory system.

Preoperational Inspection

The Preoperational Maintenance Requirements Cards require a thorough visual inspection of the unit and it should be remembered that these are the minimum requirements prior to starting. All accessories, wiring, tubing, ducts, and fittings are inspected for security and mounting. Check the entire unit for evidence of fuel or oil leakage; if leakage is detected do not attempt a start, as a serious fire may result.

The compressor intakes and the turbine exhaust ducts must be inspected for foreign material or other obstructions. Check for the proper oil level in the oil tank; replenish as required. Check for adequate fuel supply and for security of fillercaps and connections.

All instruments must be checked for zero or normal indication as appropriate, and for fogged or broken glass. On indicators which have range-marks, check for the marks being in the correct location. The bleed air connection is checked for obstructions and the bleed airhose in inspected for torn shielding and for holes; the hose clamps are also checked for security at this time.

The battery must be inspected for security of the clamp assembly and terminals. Connect the battery and check for a minimum reading of 24 volts. (Inspection of the battery electrolyte and specific gravity is a special inspection performed at 7-day intervals.) A fire extinguisher must always be available if the unit is to be started. In the case of the trailer-mounted enclosure, the fire extinguisher is mounted in a special mounting and must be included in the preoperational inspection. The fire extinguisher is checked for proper mounting and for security of the seal.

Starting

After the preliminary checks and inspections have been completed, the following steps are performed: (1) manual fuel valve OPEN; (2) stop-run switch RUN, and (3) bleed-load switch OFF. Then momentarily press the start switch to the START position.

CAUTION: If difficulty is encountered in starting, do not exceed the duty cycle of the starter 1 minute ON, 4 minutes OFF.

When starting a new or overhauled unit, or if the oil lines have been disconnected, the oil primer button must be pressed as the unit is started; release the button when the unit lights off. Normal governed speed should be reached within 15 to 20 seconds. When 95 percent governed speed is reached, the load light should glow and the load may then be applied if desired by placing the bleed-load switch in the ON position.

Shutdown

EMERGENCY. Stop the engine immediately by depressing stop-run switch to the STOP position if any of the following conditions are observed.

1. No oil pressure within 10 seconds after the start circuit is energized.
2. If the turbine discharge temperature exceeds 677° C (1,250° F) for a period greater than 5 seconds, or if the temperature exceeds 649° C (1,200° F) continuously under any operating condition.
3. If ignition failure occurs (flame-out), to prevent fuel accumulation in the turbine section.

NORMAL. The unit requires a 1-minute operating period under no-load prior to stopping in order to allow for a gradual cooling off. After the 1-minute cooling-off period, place stop-run switch in the STOP position. When the turbine stops turning, turn the manual fuel shutoff valve OFF. The unit should be checked visually for any discrepancies and fuel and oil levels.

If any discrepancies exist, take the necessary steps to have them corrected so the unit will be ready for use when it is needed again. Disconnect and stow the air hose, etc., disconnect the battery, and secure the access panels.

MAINTENANCE

The calendar Maintenance Requirements Cards are used in the maintenance of all the gas turbine compressors. The maintenance as outlined on these cards provides the minimum requirements necessary to maintain the equipment, and is a normal function of the Intermediate maintenance activity. The cards do not contain the instructions for repair, adjustment, or means of rectifying defective equipment, and local conditions may require modification of the inspections as to depth and frequency.

Because field level maintenance is limited, most of the maintenance which will be performed on these units can be expected to occur at the Intermediate maintenance level. Major repairs to these units which require complete disassembly and the use of specialized shop testing and calibration equipment are to be performed in an overhaul activity only.

The operating (using) organization has the responsibility of complying with the Daily and Preoperational Maintenance Requirements Cards. These cards contain minimum requirements that must be met before the unit can be used.

Troubleshooting

At the intermediate maintenance level, the ASE may expect to be a part of a troubleshooting/maintenance crew. This crew will probably consist of a senior AS and at least one each of the three service ratings (ASE, ASH, ASM). When a malfunctioning unit is received, a troubleshooting crew is assigned to locate the trouble, make the necessary repairs, and return the equipment to an operational status.

A guide to common engine malfunctions, their probable causes, and an appropriate remedy is provided in the maintenance section of the Maintenance Instructions Manual. Table 14-1 presents a section of the type troubleshooting information that is found in the manual and is used in conjunction with the gas turbine engine analyzer. These tables do not cover all of the possible malfunctions, but should be used as a guide when performing corrective maintenance.

In table 14-1, the appropriate portion of the Maintenance Instructions Manual is referenced when specific step-by-step instructions are to be followed. One such reference is given in the last entry in the table.

Maintenance as set forth in the Calendar Maintenance Requirements Cards is to be performed at an Intermediate level maintenance activity. The reason of course is that this equipment is a precision unit that requires special tools and testing devices which are not available at the lower levels of maintenance. The areas where the work is performed have special requirements as to cleanliness and power availability. The determining factor which governs the intervals between maintenance performed is the number of engine starts.

At time of engine replacement, the crew will be required to operate a hoist or some type of chain fall when hoisting the unit out of its enclosure, placing it in a shipping container, and installing a new unit in the enclosure. There is no specific hoisting device included in the instructions given in the maintenance requirements cards; therefore, the crew leader will normally assume the responsibility for selecting a type of hoisting device that will allow this operation to be performed with maximum safety. Removal and installation of these units demand an alert crew; each step of the removal or installation procedure must be performed in strict accordance with the instructions provided in the appropriate manual or as outlined in the maintenance requirements cards for the type unit being maintained.

The special lifting adapter, which is supplied with the unit, may not be replaced with a substitute. These adapters are made for use with the specific unit, and substitution could cause imbalance during hoisting, or may be the cause for the unit to be dropped, with possible injury to a crewmember, or damage to the unit.

General Cleaning Procedures

Electrical parts may be cleaned with a soft cloth dampened in solvent of the type specified only. When using a solvent the technician must be sure to keep the area well ventilated, clear of any source of ignition, and avoid breathing the fumes. A clean, dry, soft-bristle brush may also be used. Metal parts and tube assemblies may be cleaned by dipping the part in solvent when required, then drying thoroughly with clean compressed air. Air, fuel, or oil passages in removed components may be blown clean with compressed air, but care must be exercised to direct the airblast away from personnel and equipment.

Electrical Repair and Adjustment

The items for which the ASE is basically responsible are the electrical components which provide the control of the unit. The maintenance responsibility for which he is specifically charged is the replacement of the major electrical components such as the starter, generator, ignition assembly parts, etc. After any major part has been replaced, or if the component was removed, repaired, and replaced, the unit must be subjected to a performance check. During the performance testing procedure, some adjustments may be necessary to cause the unit to function properly. Because of the nature of the equipment there are few adjustments which may be made without the use of special calibration equipment. Some minor adjustments are allowed to be made, but normally the gas turbine engine analyzer is required to perform the calibration adjustments correctly.

The gas turbine engine analyzer was described and discussed in chapter 9 of this manual. Since

Table 14-1. Troubleshooting information

Trouble	Probable cause	Remedy
No response from starter when start switch is pressed.		
No lights on. IGN TEST inoperative.	External power supply defective.	Check voltage across battery terminals or from either BENCH jack or anlayzer to ground.
		Minimum 14 volts required. Check external power circuit and circuit breakers; repair or replace as required.
	Stop switch open.	Check for voltage between power source and pin A of external electrical connector. If no voltage, repair or replace stop switch.
No lights on. IGN TEST operative.	Bleed-load switch on.	Check load switch position.
	Start switch or bleed-load switch failure.	Check for voltage between start switch poles to ground. If no voltage, replace bleed-load switch; if voltage, replace start switch.
STARTER light off.	Starting and ignition holding relay defective.	Check relay for continuity. Replace if required.
RELAY light on.	Centrifugal switch 35 percent switch open.	Replace centrifugal switch assembly (paragraph 4-79).

NOTE: The gas turbine engine analyzer is to be used with table 14-1.

the operation of this test equipment is quite complex, and requires adherence to a specific step-by-step procedure, no attempt is made to discuss the calibration adjustments requiring the use of the analyzer. Some of the repairs and adjustments which may be made without the use of the analyzer are described briefly in the following paragraphs.

CAUTION: Adjustments on all equipment should be made step-by-step according to the technical publications for the specific type and model of equipment as many adjustments are critical and if not properly made will endanger the lives of personnel and cause damage to the equipment.

GENERATOR ADJUSTMENT. The generator may be adjusted for proper output and for end play. End play adjustment requires a special measuring gage and installation or removal of shims (washers) at the end of the armature shaft to obtain the proper end play. Generator output is adjusted on the engine while at a no-load governed speed. Also, if the generator brushes have been replaced, a period of run-in time is usually required to seat the brushes. The adjustment of the generator output is made through the generator control panel. The output should fall within the range of 28 to 28.8 volts, and charging current indicated on the meter should be 5 amperes.

GENERATOR CONTROL PANEL ADJUSTMENT. With the unit running and voltage regulator at operating temperature the output voltage should be $28.4 \pm .4$ volts. If voltage is out of tolerance the generator control panel must be adjusted Procedures for adjusting the generator control panel should be observed as follows.

Stop engine. Remove cover from generator control panel. Connect negative lead of a voltmeter to ground. and the positive lead to the terminal or reverse current relay marked GEN.

Start engine. When the voltage regulator has come up to operating temperature and the voltage has stabilized, adjustment is made through hole in top of generator control panel. If adjustment cannot be made, shut the engine down, and first check for loose or broken wires. The next step is to make continuity and resistance checks of the generator. These are made at the connector plug coming from the generator. This plug is illustrated in figure 14-6. The first reading is made across pins C and D; the reading should be approximately 2.8 ohms. A higher resistance indicates internal wire failure. If normal resistance is obtained, move the meter leads to read across D to E; resistance here should be 5 to 7 ohms. The next check is across pins C to E; a resistance of 1 ohm should be indicated. A high resistance here indicates a bad commutator or brushes.

If during the time the engine is running, the voltmeter reads 28 volts and the ammeter reads 0 amperes, the ammeter portion of the meter has failed. If the voltmeter reads less than 15 volts or does not indicate at all, the meter movement has failed. There are other tests which may be made on the generator; however, generators and their maintenance in general were discussed in previous chapters.

CENTRIFUGAL SWITCH ADJUSTMENT.– The centrifugal switch is adjusted as follows: (refer to fig. 14-8 for this adjustment) Remove the access plate (item 7) and adjust the appropriate screw. The 35 percent switch setting is altered by adjustment of item 10, and the 95 percent switch setting is altered by adjusting screw 9. If an adjustment has been made to either the 35 percent or the 95 percent switches, the overspeed switch (item 8) will now require adjustment. The engine will shut down at a no-load governed speed of approximately 100 percent if either the 35 percent or the 95 percent switch settings have been reduced. To compensate for this, turn the overspeed switch adjusting screw clockwise to increase the overspeed switch setting For the reverse situation adjust screw 8 counterclockwise to decrease the overspeed switch setting.

All repair, replacement, and cleaning operations must be performed in accordance with current approved standards. Parts such as plumbing lines, electrical wiring, and connectors are to be replaced with an identical new part. Prior to disconnection of any cable, line, or other part, tags should be installed for identification at final assembly. When parts are installed, all nuts and/or bolts are to be tightened according to standard torque values unless otherwise specified.

CHAPTER 15

AIR-CONDITIONING SYSTEMS

Mobile air conditioners are primarily designed to remove the heat produced by operating electronic equipment and to reduce the humidity within electronic equipment spaces while the aircraft is undergoing maintenance, thereby limiting the ambient (encompassing) temperature and humidity within the aircraft to the level specified for the equipment.

Air conditioning encompasses more than the transfer of heat from one place to another. Although it is usually thought of as a lowering of temperature, air can be conditioned by cooling, heating, filtering, or dehumidifying. Modern mobile air conditioners are designed to accomplish all these to condition air for electronic equipment spaces within naval aircraft.

Mobile air conditioners are referred to as mechanical refrigeration systems because mechanical means are used to circulate a refrigerant through a closed system to accomplish heat transfer.

Basically, the purpose of all refrigeration systems is heat transfer. To understand the basic principles of refrigeration, a definite understanding of the relationship of heat, temperature, and pressure is mandatory.

TERMINOLOGY

In the study of refrigeration and air conditioning, it is essential that the meaning of certain terms, as they are applied to refrigeration and air conditioning, be understood. The terms listed and defined here apply to any refrigeration or air-conditioning system of the mechanical type.

1. BRITISH THERMAL UNIT (Btu). The amount of heat required to produce a temperature change of 1° F in 1 pound of water at sea level pressure.

2. CHANGE OF STATE. The change of any matter from one state (solid, liquid, or vapor) to another.

3. COMPRESSION. The act of increasing the pressure and temperature of a substance by decreasing its volume.

4. CONDENSATION. The process by which a vapor changes state to a liquid when heat is removed from the vapor, or when pressure is increased on the vapor.

5. CONDUCTION. Heat transfer from molecule to molecule within a substance or between two substances that are in physical contact with each other.

6. CONVECTION. Heat transfer through some easily circulated medium (usually liquid or vapor). As the medium moves, it carries with it its contained heat energy, which is then transferred to the surroundings.

7. CYCLE. The complete course of operation of a refrigerant, from starting point back to starting point, in a closed refrigeration system.

8. DEHUMIDIFY. To reduce the quantity of water vapor in a given space.

9. EVAPORATION. The process by which a liquid changes state to a vapor when heat is added to the liquid, or when pressure is decreased on the liquid.

10. HEAT. A basic form of energy which is transferred by virtue of a temperature difference. Heat always flows from a hot object to a cold object, and the greater the temperature difference, the faster the flow. Heat cannot be manufactured or destroyed—only transferred.

11. HEAT OF CONDENSATION. The latent heat given up by a substance as it changes state from a vapor to a liquid.

12. HEAT OF FUSION. The latent heat absorbed as a substance changes state from a solid to a liquid.

13. HEAT OF VAPORIZATION The latent heat absorbed by a substance as it changes state from a liquid to a vapor.

14. LATENT HEAT. Heat applied to, or removed from, a substance which causes a change in the physical state of the substance, but not in its temperature

15. LOAD. The amount of heat imposed upon a refrigeration system in a specified amount of time, or the required rate of heat transfer, expressed in Btu per hour.

16. PRESSURE. Force per unit area, measured in pounds per square inch; pressure is directly proportional to temperature.

17. REFRIGERATION TON. The transfer of heat at a rate of 288,000 Btu in 24 hours (12,000 Btu in 1 hour).

18. SENSIBLE HEAT. Heat applied to, or removed from, a substance which causes a change in the temperature of the substance, but not in its state.

19. SUPERHEAT. Heat added to a vapor above the boiling point of the liquid which produced the vapor. The vapor and the liquid must be separated before the vapor can be superheated.

20. TEMPERATURE. A measure of the heat intensity or concentration of heat (thermal energy) in a body or substance, measured in degrees.

21 VACUUM. Any pressure less than atmospheric pressure.

22. VAPOR. Gaseous form of any substance. Vapor condenses very readily to a liquid state under small changes of temperature or pressure, or both. It may be said to be very close to the liquid state, although it is a vapor.

REFRIGERANTS

A refrigerant is a substance that can easily be changed from a liquid state to a vapor state. Ideally, it is a substance having a low boiling point and the capability to absorb and carry heat at a low temperature, and to transfer this heat to a cooling medium, either air or water, as it condenses.

Most refrigerants in use today require comparatively low pressures in the system; thus equipment does not require heavy construction, and leaking tendencies are reduced to a minimum.

In order to prevent confusion and to provide for standardization among users, all refrigerants are assigned numbers rather than trade names, and are referred to as refrigerant 12, refrigerant 22, etc.

The two most commonly used by the Navy, refrigerant 12 and refrigerant 22, will be discussed in this manual.

REFRIGERANT 12

Research for the perfect refrigerant resulted in R-12; it approaches that ideal more than any other so far discovered. Its chemical name and symbol, dichlordiflurommethane (CCl_2F_2), indicate that R-12 contains one part carbon, two parts chlorine, and two part fluorine.

At atmospheric pressure, R-12 boils at -12.66° F, and its latent heat of vaporization at atmospheric pressure is about 72 Btu per pound; that is, as R-12 changes state to a vapor at atmospheric pressure, it absorbs 72 Btu per pound.

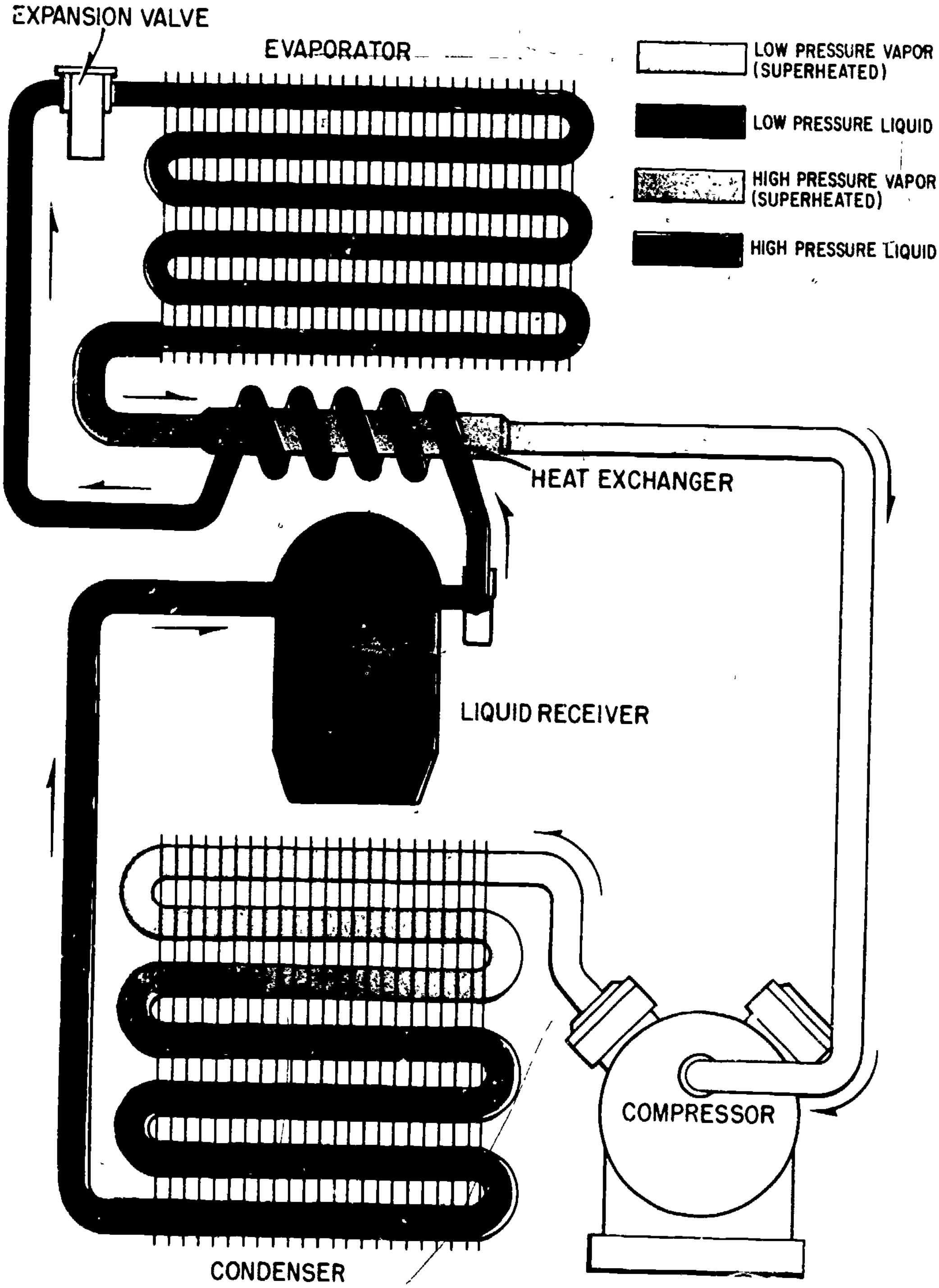
Some of the advantages of R-12 are:

1. It is nonflammable, nonexplosive, and noncorrosive.
2. Its vapor is nontoxic.
3. At the low pressure point of its cycle, it operates at pressures slightly above atmospheric pressure, thus minimizing the possibility of air entering the system.
4. At the high pressure point of its cycle, pressure is comparatively low, allowing the use of lightweight equipment.

REFRIGERANT 22

R-22, like R-12, is a member of the fluorinated hydrocarbon family. Its chemical name and symbol, monochlorodifluoromethane, ($CHClF_2$), indicate that R-22 contains one part carbon, one part hydrogen, one part chlorine, and two parts fluorine.

At atmospheric pressure R-22 boils at -41° F, and its latent heat of vaporization is about 92 Btu per pound. This capability to absorb great amounts of heat, combined with its low boiling



AS.421

Figure 15-1.—Fundamental refrigeration cycle.

point, makes R-22 a very good refrigerant for use in systems of high capacity and very low temperatures, such as refrigerators, freezers, and modern compact air conditioners.

R-22 requires higher pressures in its cycle than R-12 and, consequently, slightly heavier construction of system components. With this exception, all of the advantages associated with R-12 also apply to R-22.

One inherent disadvantage which is shared by both of these refrigerants is the capacity to absorb water, making the use of chemical driers mandatory to prevent freezeups of the expansion valves.

REFRIGERATION CYCLE

The refrigeration cycle is divided into two pressure sections, the high pressure side and the low pressure side. The dividing lines between these two pressure areas are the compressor and the thermal-expansion valve, as shown in figure 15-1.

As the refrigerant flows through the system, it assumes four different and distinct states.

1. Low-pressure vapor.
2. High-pressure vapor.
3. High-pressure liquid.
4. Low-pressure liquid.

As shown in figure 15-1, the high side starts as the pistons in the compressor compress the vapor and force it out through the compressor discharge valves. As the pressure of the vapor is increased, its temperature is also increased, thereby becoming superheated vapor.

When the hot, high-pressure vapor leaves the compressor, it flows directly to the condenser coil.

The hot vapors from the compressor enter the condenser at the top. Cooling air is circulated over the condenser coil by the condenser fan. As the refrigerant cools, giving up the latent heat of condensation to the condenser tubes where it is transferred to the cooling air by conduction, it changes state into a liquid and drains through an outlet fitting in the bottom of the condenser. As the liquid passes through the bottom set of tubes, its temperature is lowered below the condensing temperature. This is known as subcooling. Subcooling of the refrigerant increases the capacity of the unit by allowing the refrigerant to absorb a greater amount of heat before reaching the point of vaporization.

From the condenser coil, the high-pressure liquid refrigerant flows to the liquid receiver, which acts as a reservoir for the liquid refrigerant and forms a liquid seal on the liquid line to prevent backflow when the unit is shut down.

After leaving the receiver, the high-pressure liquid refrigerant flows to the thermal expansion valve. As the refrigerant is metered and passes through the thermal expansion valve, it undergoes a change in pressure, becoming a low-pressure liquid. This is the beginning of the low-pressure side of the system. As pressure on the refrigerant is decreased, its boiling point is correspondingly decreased.

The low-pressure liquid then enters the evaporator coil. At the evaporator coil, heat is transferred by conduction from the air to be conditioned to the coils of the evaporator and then to the liquid refrigerant within the evaporator, thus beginning a change of state of the liquid refrigerant into a vapor. The heat absorbed by the refrigerant within the evaporator is known as the latent heat of vaporization. The refrigerant is now a mixture of liquid and vapor and continues through the evaporator, absorbing more heat, and changing all the liquid to vapor. The change of state is now complete and the vapor will be superheated as it passes on through the evaporator.

After leaving the evaporator, the low-pressure, superheated vapor is returned to the suction side of the compressor, completing the cycle.

This cycle is repeated as long as the compressor is operating. As can be seen from the description just given, the basic refrigeration or air conditioning cycle is compression, condensation, expansion, and evaporation. The flow in a basic system is from the compressor, through the condenser coil, to the receiver, through the expansion valve, through the evaporator coil, and back to the compressor.

MAJOR COMPONENTS

Compressor

Compressors used in refrigeration and air conditioning units have but one purpose to withdraw the heat-laden refrigerant vapor from the evaporator and compress the vapor to such an extent that it will, by cooling only a few degrees, liquify in the condenser. The design of the compressor depends upon the application and type of refrigerant used in the system. There are three types of compressors, classified according to their principle of operation reciprocating, rotary, and centrifugal. (See fig. 15-2.)

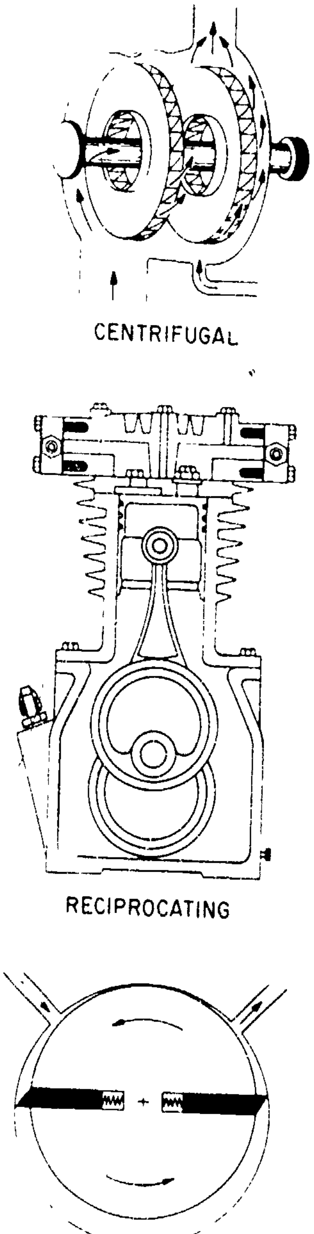
The function of the compressor is the same for all three types, but the mechanical means used to accomplish this function differ considerably. The only type discussed in this manual is the reciprocating, since this is the type used on the mobile air conditioners the ASE is required to troubleshoot and maintain.

Reciprocating compressors used in air conditioning and refrigeration are designated as either open, semihermetic, or hermetic.

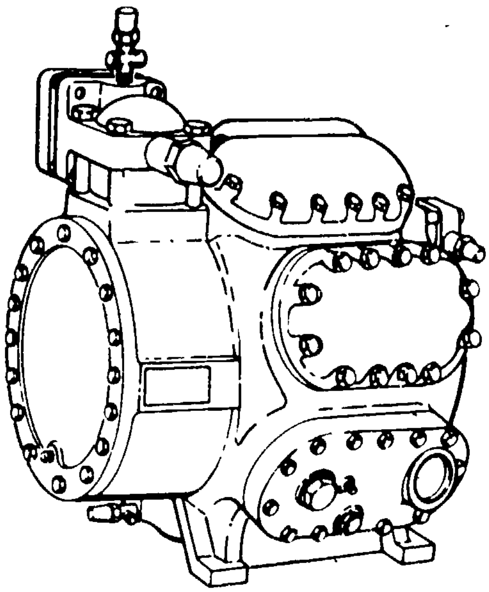
The open type of compressor (fig. 15-3) is driven from an external power source through "V" belts, gears, or a flexible coupling, and is used on mobile air conditioners which are powered by a gasoline or diesel engine.

The semihermetic type compressor (fig. 15-4) is a motor-compressor combination enclosed within a common housing. It is provided with access plates and can be serviced in the field if necessary. It is capable of maintaining a larger volume of refrigerant flow than an open type of the same size because it and its electric driving motor operate on a common shaft and at the same speed. This type compressor, in multi-cylinder versions (4 or 6), is used on mobile air conditioners that are electrically powered.

The hermetic type compressor (fig. 15-5) is a motor-compressor combination encased within a gastight, welded casing that cannot be opened for servicing except in refrigeration component overhaul shops. This type is used on refrigerators, freezers, window air conditioners, or any small unit.



AS.916
Figure 15-2.—Compressor types.



AS.917
Figure 15-3.—Reciprocating open compressor.

The operation of all reciprocating compressors is basically the same. The piston is actuated by a connecting rod attached to a crankshaft which is turned by the driving force. As the piston moves down toward its lowest position, a low-pressure area is formed within the cylinder. As indicated in figure 15-6 (A), the suction (intake) valve opens when the pressure within the cylinder becomes less than the pressure in the suction line leading to the cylinder. When the intake valve opens, the cylinder is filled with low-pressure refrigerant vapor.

As the piston moves upward, (fig. 15-6 (B)), the intake valve closes when the pressure within the cylinder becomes greater than the pressure in the suction line. As the piston continues its upward travel, the discharge valve opens when pressure within the cylinder becomes greater than the pressure in the discharge line, and the compressed refrigerant vapor is discharged to the high-pressure side of the system.

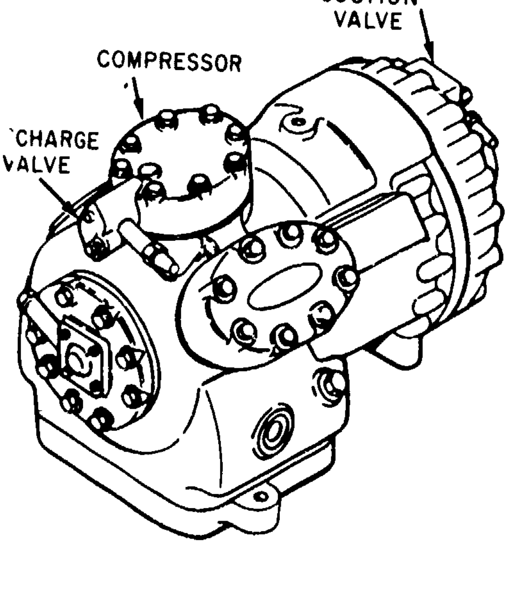
Reciprocating compressors are lubricated either by pressure from an oil pump or by splash as the crankshaft turns in the oil in the crankcase of the compressor.

Condenser

The purpose of the condenser in a refrigeration system (fig. 15-1) is to convert the hot refrigerant vapor from the compressor into a liquid state, making it ready for use again in the evaporator. The condenser accomplishes this by removing heat from the hot vapor, causing it to condense at the pressure existing in the high-pressure side of the system.

There are two general types of condensers, the air-cooled and the water-cooled.

The air-cooled condenser (fig. 15-7) utilizes a flow of ambient (surrounding) air through the coils of the condenser to provide a cooling effect. Maximum condenser surface is obtained by closely spaced fins on the coils. The coil and fin arrangement is similar to that of an automobile radiator.



AS.918
Figure 15-4—Reciprocating semihermetic compressor.

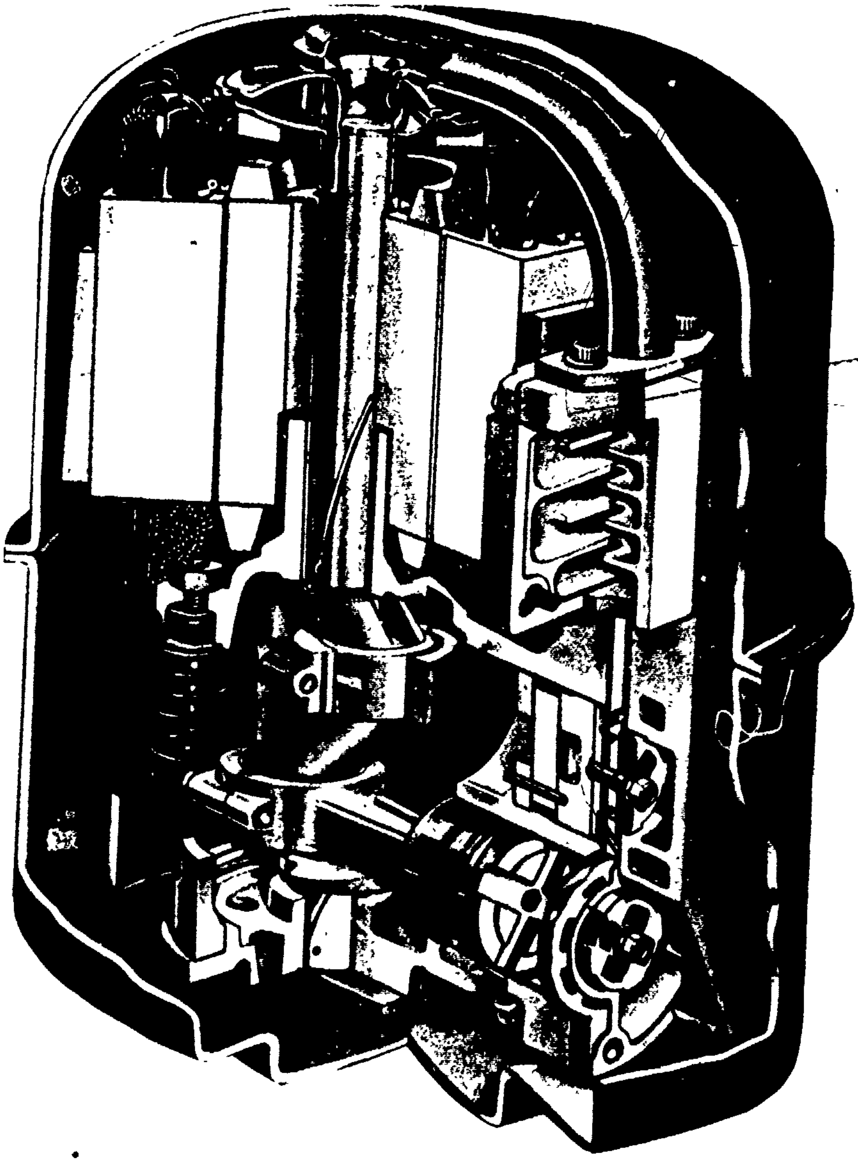


Figure 15-5.—Reciprocating hermetic compressor AS 919

Maintenance of air-cooled condensers used on mobile air conditioners is relatively minor, consisting of keeping the coil and fins free of dust and dirt. This should be done with care so as not to bend or damage the coil and fins.

Receiver

The receiver (fig. 15-1) is installed to collect the liquid refrigerant as it leaves the condenser.

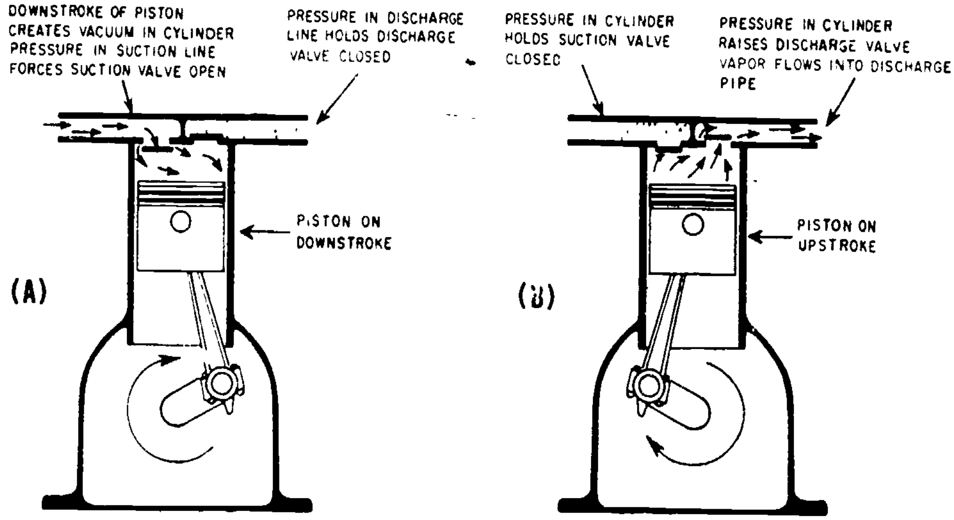


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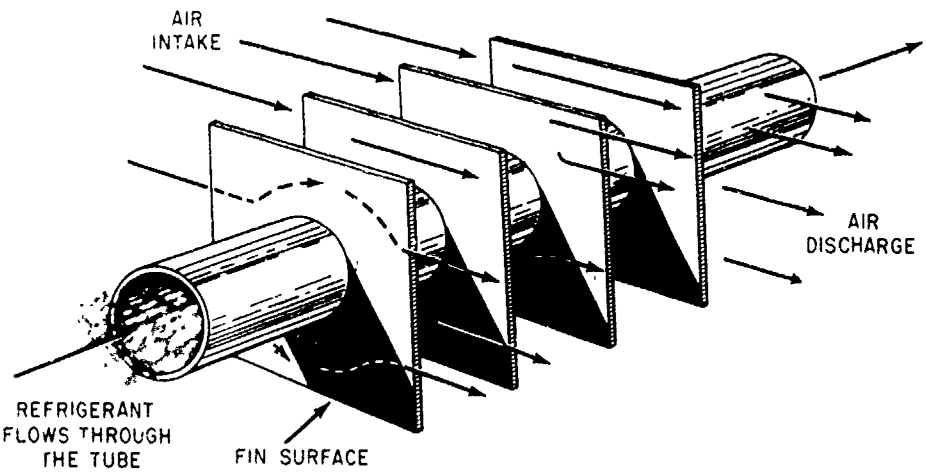
Figure 15-6.—Operating cycle of a reciprocating compressor.



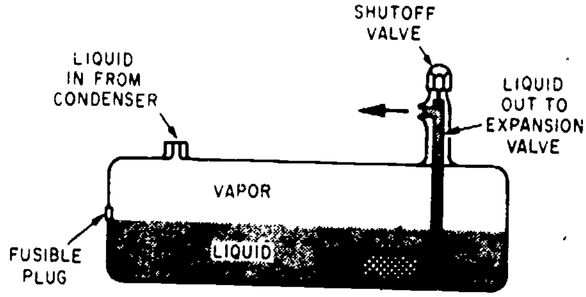
AS.423

Figure 15-7.—Construction detail of air-cooled condenser.

It serves as a reservoir for the refrigerant and maintains a liquid seal on the liquid line to the expansion valve.

Receivers (fig. 15-8) are designed to be large enough to hold the complete charge of refrigerant required for the unit to operate. They are equipped with shutoff valves on the inlet and outlet lines to permit maintenance personnel to pump the unit down (entrap all refrigerant in the receiver) when work is being done on another component of the system. With the shutoff valves closed, no loss of refrigerant occurs.

Some receivers are equipped with liquid sight glasses to show liquid level during operation. The receiver is normally about 1/3 full during operation.



AS.920
Figure 15-8.—Refrigerant receiver.

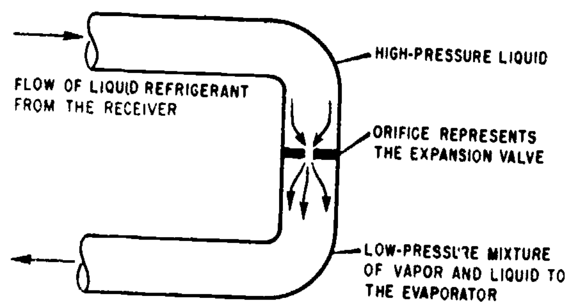
Expansion Valve

The function of the expansion valve (fig. 15-1), also referred to as a metering device, is to change the high-pressure liquid into a low-pressure liquid as it enters the evaporator, and to regulate the flow of liquid refrigerant into the evaporator to insure the correct quantity of refrigerant flow to keep the evaporator operating at maximum efficiency without overloading the compressor. The action of the valve is similar to a spray nozzle in that the liquid refrigerant enters the evaporator as a mist or spray.

Many different types of metering devices are in use in air conditioning systems today. The basic types are automatic expansion valves, thermostatic expansion valves, and capillary tubes. Regardless of the complexity of design of any particular device, the principle involved is the same as that shown in figure 15-9. When a gas or liquid is forced through a small opening, the pressure decreases and the gas or liquid expands.

The thermostatic valve is the type of expansion valve used on mobile air conditioners, so it is the one discussed in this manual.

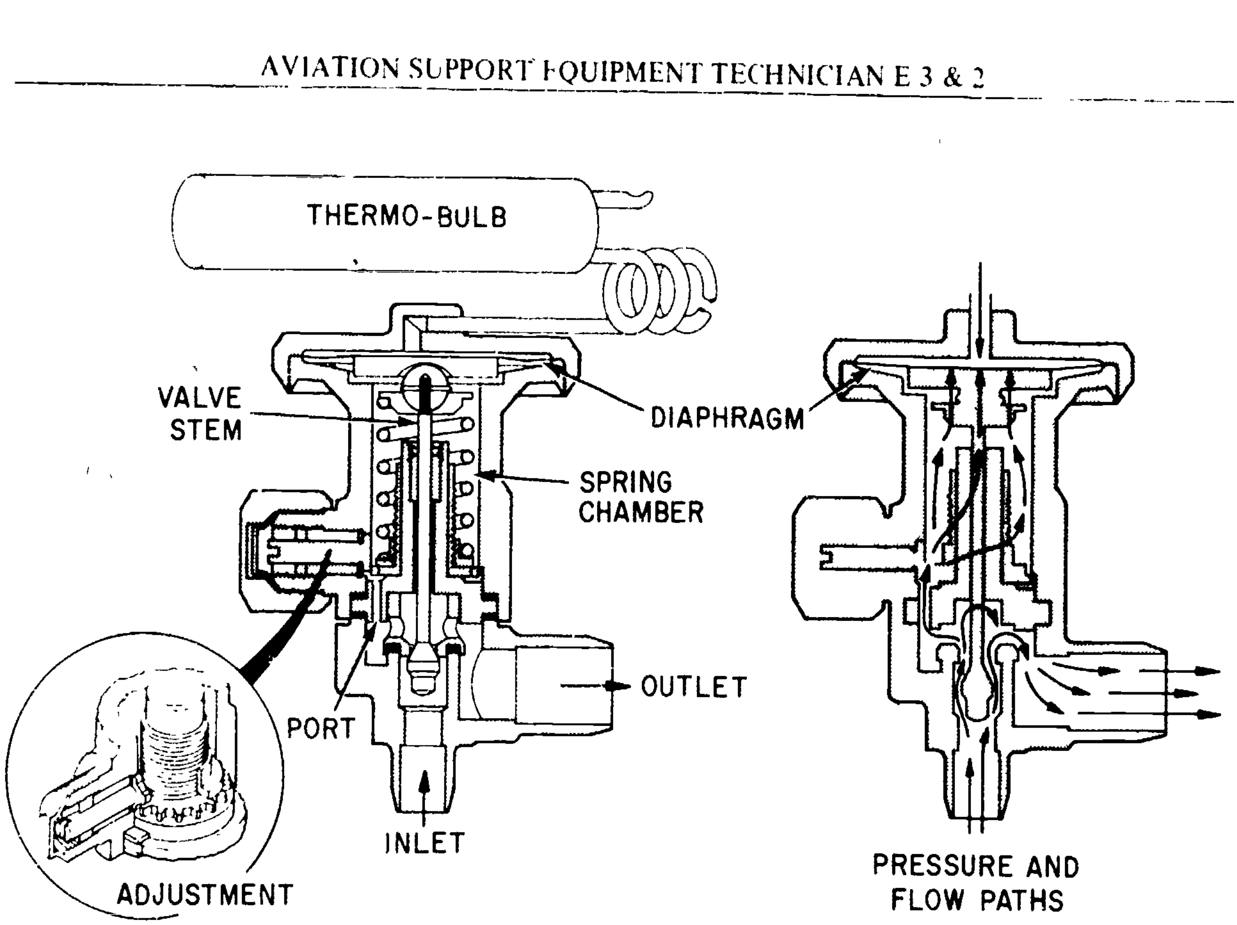
The thermostatic expansion valve (fig. 15-10) consists essentially of a diaphragm connected by a small tube to a temperature sensitive bulb attached to the refrigerant tubing at the discharge side of the evaporator The bulb is filled



AS.426
Figure 15-9.—Expansion valve principle.

with the same refrigerant as that used in the system. Connected to the diaphragm, inside the valve housing, is the valve and spring.

The thermostatic expansion valve insures that the amount of refrigerant which enters the evaporator is in proportion to the rate of evaporation of the refrigerant. Thus, the expansion valve regulates refrigerant flow in proportion to refrigerant evaporation. The rate of evaporation of the spray or mist is dependent upon the rate of heat absorption from the air passing through the evaporator. The liquid refrigerant enters the evaporator in the form of a low-pressure mist or spray. Because heat is absorbed by the mist as it travels through the evaporator the mist changes to a vapor and, when all the liquid is changed to a vapor, any additional heat that is absorbed by the vapor is called superheat. By the time the



AS.921

Figure 15-10.—Thermostatic expansion valve.

refrigerant leaves the evaporator, all of it should be in the superheated vapor form.

In figure 15-11 a thermostatic expansion valve is shown with the evaporator for a typical cooling unit operating at 37 psi suction (low-side) pressure. The refrigerant moving through the coil absorbs heat from the air outside the coil until, at point B, it has absorbed sufficient latent heat for complete vaporization. At this point, all the liquid has vaporized. Any additional heat now absorbed from the air raises the temperature of the vapor, but the pressure remains at 37 psi because this is the suction pressure of the compressor. By the time the vapor reaches the thermal bulb, point C, it has been superheated according to the thermal expansion valve setting; in the figure, an additional 10° F has been absorbed.

SUPERHEAT REGULATION. The temperature of the refrigerant within the thermal bulb is 50° F, the same as the temperature of the suction vapor at this point. The pressure within the thermal bulb, and consequently on the diaphragm within the thermal expansion valve, is 46.7 psi (P1). This pressure tends to push the diaphragm down, opening the valve from the receiver. Opposing this force is the 37 psi (P2) exerted against the bottom of the diaphragm by the vapor at the inlet of the evaporator coil. A spring pressure of 9.7 psi (P3) added to 37 psi (P2) holds the valve in equilibrium at 10° F superheat.

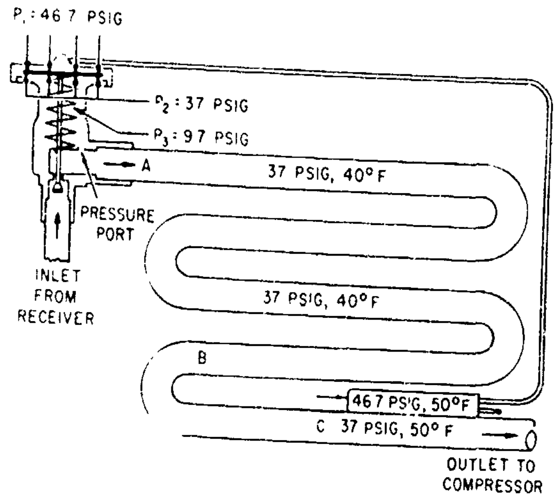
If an increase in load occurs, the superheat in the suction vapor increases, causing the thermal bulb temperature and pressure to increase, exerting a greater pressure on the top of the diaphragm. This causes the valve to open further, allowing an increase in the flow of refrigerant to the evaporator to restore superheat to the 10° setting of the valve.

If a decrease in load occurs, the superheat decreases and the pressure in the thermal bulb decreases. Evaporator inlet pressure plus spring pressure tend to close the valve, reducing the flow of refrigerant sufficiently to maintain the superheat at 10°.

Evaporator

The evaporator (fig. 15-12) is a bank or coil of thin-walled tubing mounted in a block of thin metallic fins. It is here that the refrigerant absorbs heat. The evaporator coil is cooled by the refrigerant absorbing heat from the tubing, then the air to be cooled is directed over the cold coil, and cooling of the air is accomplished.

HEAT REMOVAL.—As the warm air is passed over the outside of the evaporator coils, heat is transferred from the air to the refrigerant through the fins and metal walls of the coil. Heat is transmitted from the warm air to the fin surfaces, to the circular pipe, and then to the refrigerant. The heat applied to the outside of the tube causes the refrigerant to boil. As a result of boiling, the liquid changes into a vapor, but remains at the same low pressure. This vapor is then drawn back to the suction side of the compressor. Also, as the warm humid air comes into contact with the cold coil, moisture in the air is condensed and drips down off the evaporator.



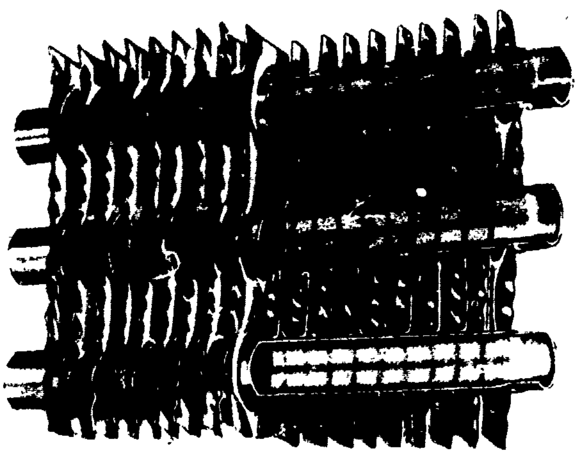
AS.922
Figure 15-11.—Superheat action in an evaporator.

ACCESSORY COMPONENTS

There are various accessories that can be added to the major components to provide either simplified maintenance or increased efficiency without changing the function of the refrigeration system.

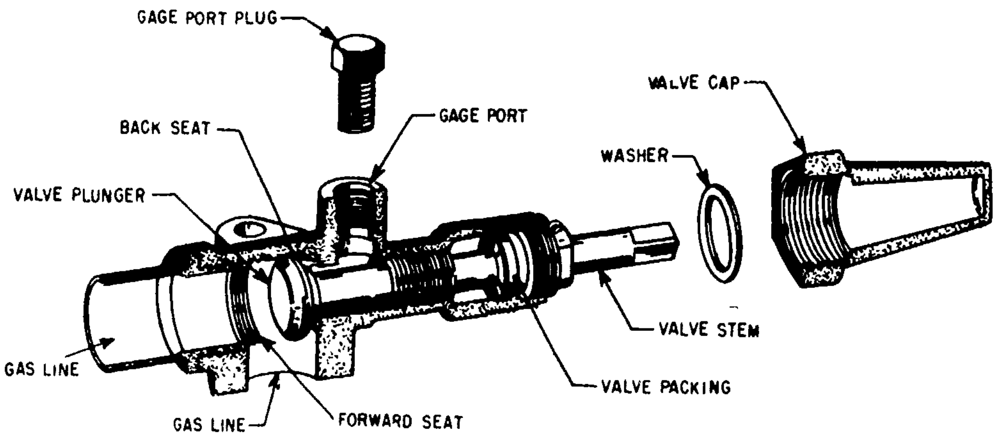
Service Valves

Service valves, referred to as head and suction valves, are provided for charging the system and for use during some maintenance operations. The head valve is mounted on the high-pressure port of the compressor, and the suction valve is mounted on the low-pressure side. Construction of the valves and their method of operation are identical. (See fig. 15-13.) However, they differ in size, use, and placement.



AS.431
Figure 15-12.—Construction detail of an evaporator.

The valve cap for a compressor service valve contains a gasket which forms a refrigerant-tight fit between valve cap and valve body. The valve cap and gasket must be removed to position the valve plunger. The valve plunger can be positioned in the forward seated, back seated, or cracked position. Always use the wrenches



AS.432

Figure 15-13.—Service valve.

provided with the air conditioner for adjusting the service valves.

To forward seat a service valve (fig. 15-13), turn the valve stem clockwise as far as it will go. This puts the plunger to the left and tight against the forward seat, and stops gas flow at this point.

To back seat a service valve, turn the valve stem counterclockwise as far as it will go. The valve plunger is now to the right and tight against the back seat. The gasline is now completely open.

To crack a service valve, first back seat and then turn the valve stem one-fourth turn clockwise. This moves the valve plunger slightly to the left, and allows gas to flow into the gage port.

To install a pressure gage in a service valve, back seat and remove the gage port plug; then insert the gage and crack the service valve so the gage will read.

Never operate the compressor with the head service valve forward seated. This condition blocks the output of the compressor and causes the pressure of the compressor to build up sufficiently to become dangerous to personnel. Also, the compressor will almost certainly suffer damage.

Vibration Eliminators

Vibration eliminators absorb and remove inherent vibration in copper tubing caused by floating components. They are constructed of an accordion-like, phosphorous bronze tube with copper fittings at each end to facilitate joining with the system tubing. The accordion-like folds in the material are called convolutions.

On some air-conditioning systems, a simple loop is made in the refrigerant tubing itself. The loop permits vibrations to be absorbed in the extended length of tubing.

Liquid Line Sight Glass

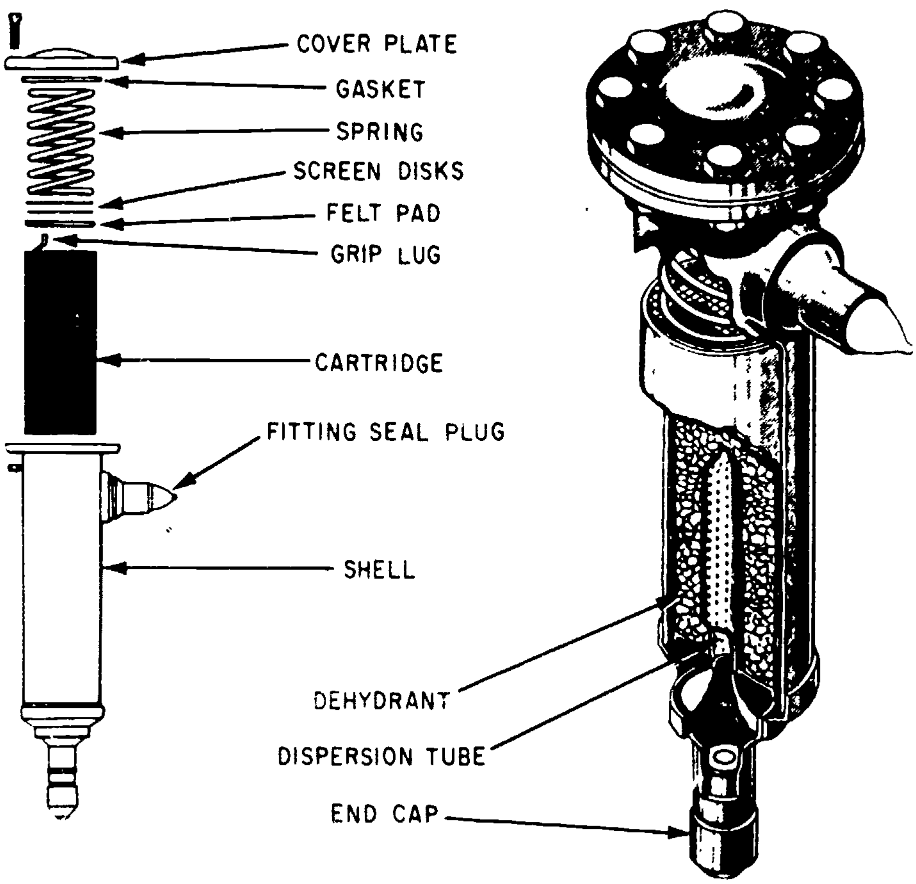
The sight glass is a visual indicator used to visually determine the condition of the refrigerant entering the thermal expansion valve. The sight glass is located on the inlet side and close to the thermal expansion valve as possible. The appearance of the refrigerant passing through the sight glass should be clear. If the sighting indicates a cloudy or milky appearance, the level of refrigerant is low. The milky appearance is caused by tiny refrigerant vapor bubbles mixed with the liquid refrigerant.

Receiver Valve

The receiver valve, referred to as the king valve, is located on the output side of the receiver tank. This valve is used when it is necessary to trap the refrigerant in the receiver and condenser lines.

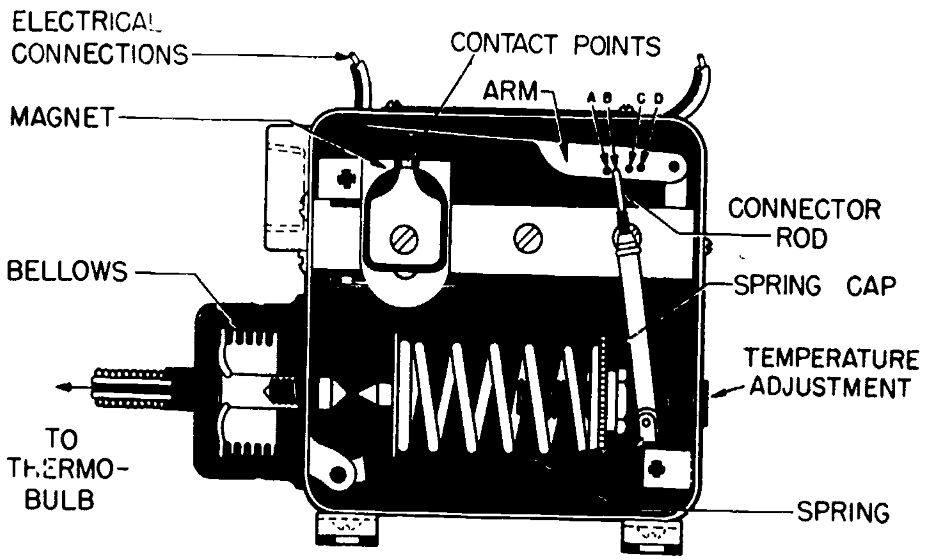
Heat Exchanger

The heat exchanger (fig. 15-1) provides for an increase in system efficiency by transferring heat from the hot, liquid (flowing from the receiver to the evaporator) to the cooler suction vapor (flowing from the evaporator to the compressor). Because of this heat transfer, the liquid refrigerant enters the evaporator at a lower temperature, allowing it to absorb more heat-per-pound of refrigerant. This heat transfer also insures that the vapor flowing to the compressor from the evaporator contains no liquid (which would damage the compressor).



AS.923

Figure 15-14.—Drier-strainer (Dehydrator).



AS.924

Figure 15-15.—Thermostat.

Heat exchangers can be constructed in several ways a small liquid line enclosed within a larger suction line; a small liquid line wrapped around a larger suction line; or the liquid and suction lines being placed side by side and physically connected together by clamps or solder.

Drier-Strainer (Dehydrator)

The drier-strainer (fig. 15-14), also called a dehydrator, is employed to remove foreign matter and water from the system. Foreign material which would clog small openings, and water which would freeze in the expansion valves, are trapped and held here The drier-strainer is located in the liquid line between the receiver and the evaporator, and consists of a replaceable cartridge of activated alumina or silica gel enclosed in a metal container.

Upon inspection, if the drier strainer feels cooler than the liquid line entering the drier, the indication is that the drier is clogged and the liquid refrigerant is vaporizing in the drier. In this situation, the drier cartridge must be removed and replaced.

CONTROLS

Controls of an air-conditioning unit may be classified into two distinct types operating and safety. Operating controls maintain the desired conditions, while the safety controls prevent damage to the equipment.

Operating Controls

The operating controls of an air-conditioning system may be simple or complex, depending upon the design and use of the system. Some of the operating controls are manually controlled by the operator, while others are automatic and operate in response to changes in temperature or pressure.

THERMOSTAT. A thermostat is a device which automatically regulates temperature. Thermostats used on mobile air conditioners, similar to the one shown in figure 15-15, consist of a capillary tube filled with a volatile liquid, a bellows, and a set of electrical contacts.

The thermostat contacts are connected to a solenoid valve circuit, and the capillary tube bulb is placed in the discharge airflow immediately downstream of the evaporator. As the temperature of the discharge air rises, the liquid in the capillary tube expands and exerts a pressure on the bellows. This causes the contacts to close, energizing the solenoid coil which opens the valve so liquid refrigerant can flow to the expansion valve.

When the desired temperature of the discharge air is reached, a reverse of the above action occurs. The liquid in the capillary tube contracts, the contacts open, the solenoid valve closes, and the flow of refrigerant to the expansion valve is stopped.

SOLENOID VALVES.- Solenoid valves, similar to the one shown in figure 15-16, are used in mobile air conditioners to control the flow of refrigerant at various points in the system.

These valves are of two types, normally open or normally closed, but regardless of type or use, construction and function of the valves are essentially the same.

In the normally closed type, when the circuit to the solenoid coil is completed, the coil energizes and pulls the valve off its seat, opening the valve passage. When the circuit to the solenoid coil is opened, the coil deenergizes and spring pressure pushes the valve into its seat, closing the valve passage.

In the normally open type, operation is the reverse of the operation of the normally closed type. When the solenoid coil is energized, the valve is closed, when the solenoid coil is deenergized, the valve is open.

CIRCUIT CONTROLS.-Controls for the various circuits of an air-conditioning unit may vary from simple toggle switches to remote controlled contactor relays. These devices may be used for actuating fans, lights, motors, or for checking various circuits while troubleshooting a defective system. Switches used for maintenance work are called service switches.

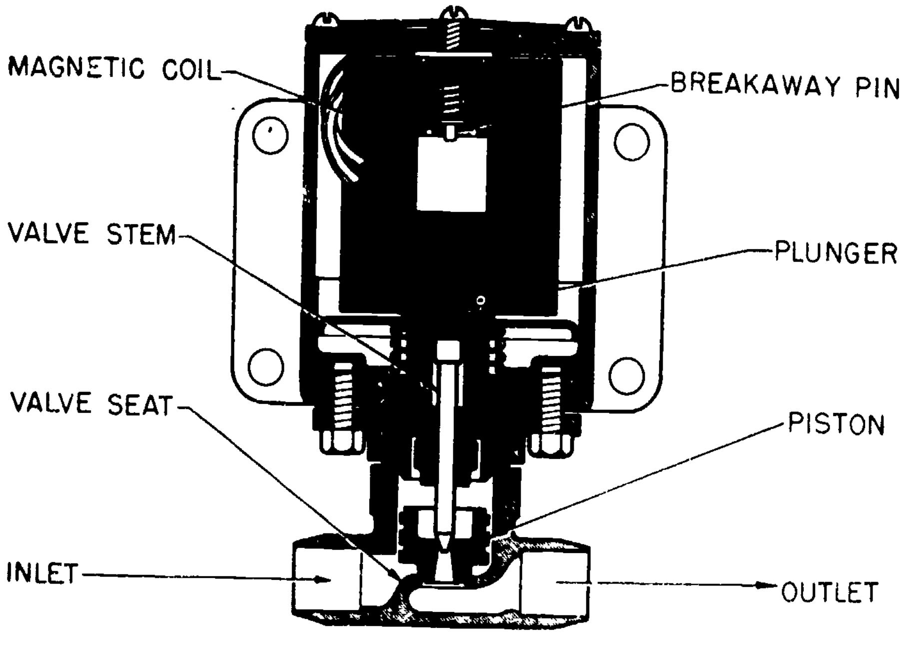
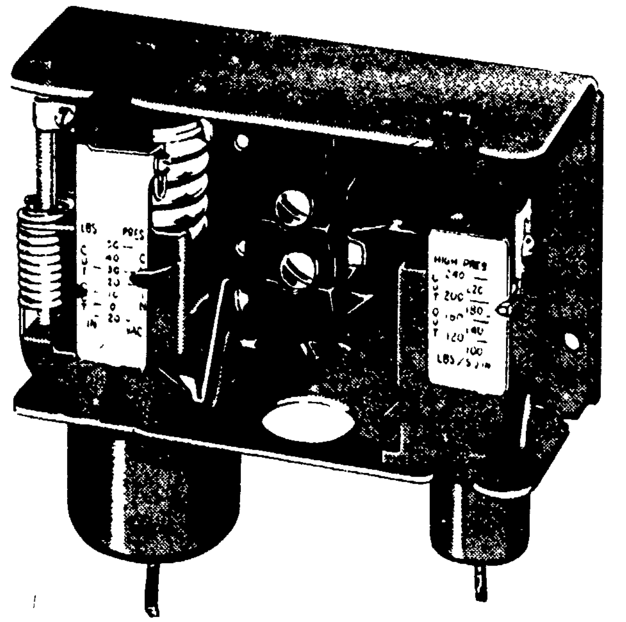


Figure 15-16 —Solenoid valve.



AS.434
Figure 15-17.—High- and low-pressure cutouts.

Safety Controls

Sufficient safety devices are installed in air-conditioning systems to prevent bodily injury to operating personnel and damage to system equipment or equipment and spaces receiving the conditioned air.

FUSIBLE PLUG.—The fusible plug is provided to prevent excessive buildup of refrigerant pressure within the confined area of the equipment. The refrigerants commonly used today will act in accordance with the normal liquid/gas laws, whereby increasing temperature causes increasing pressure. Should the air-conditioning equipment be in close proximity to a fire, a positive method of releasing vapor and liquid must be provided to prevent the buildup of excessive pressure within the system. The fusible plug is usually located at the inlet connection of the receiver tank. When excessive external heat is present, due to fire or other similar causes, the plug melts, allowing the refrigerant gas to escape from the system. This reduction of gas pressure prevents possible rupture or explosion of the equipment.

HIGH- AND LOW-PRESSURE CUTOUTS.—High- and low-pressure cutout switches are incorporated in refrigeration units to control the operation of the compressor. The pressure control prevents the discharge pressure of the compressor from building up beyond a reasonable limit, and suction pressure of the compressor from falling below the safe limit.

The control unit illustrated in figure 15-17 contains controls for both the high- and low-pressure gases. In some installations the high- and low-pressure controls are mounted in separate units; however, their operation is essentially the same.

DUCT AIR PRESSURE SWITCH. The duct air pressure switch is designed to shut down the entire unit if an overpressure condition occurs in the conditioned air discharge duct. The pickup tube for the duct pressure switch is located in the discharge air plenum chamber.

MOBILE AIR CONDITIONER (NR-2B)

The NR-2B mobile air conditioner (fig. 15-18) is a mobile, trailer-mounted, electrically powered, self-contained air conditioner. It requires a 440-volt, 3 phase, 60-Hz power supply for operation of the compressor motor, fan motors, and the control circuits.

The NR-2B has a cooling capacity of 7 tons with a discharge air temperature of 50° F in the cooling mode of operation, and of 90° F in the dehumidification mode of operation. It will operate in a temperature range of 0° F to 110° F at altitudes up to 5,000 feet.

The NR-2B is designed to provide cooling, ventilation, dehumidification, and filtration of air for electronic equipment. The unit is intended for, but not limited to, use for air conditioning aircraft cabins and equipment compartments.

The NR-2B utilizes a semihermetic, six-cylinder compressor, with refrigerant R-22 used as the heat transfer medium.

Two tube and fin type evaporators and a single condenser are used in the unit. Air flow for the evaporators is provided by a positive displacement blower, and air flow for the condenser is provided by two axial type fans.

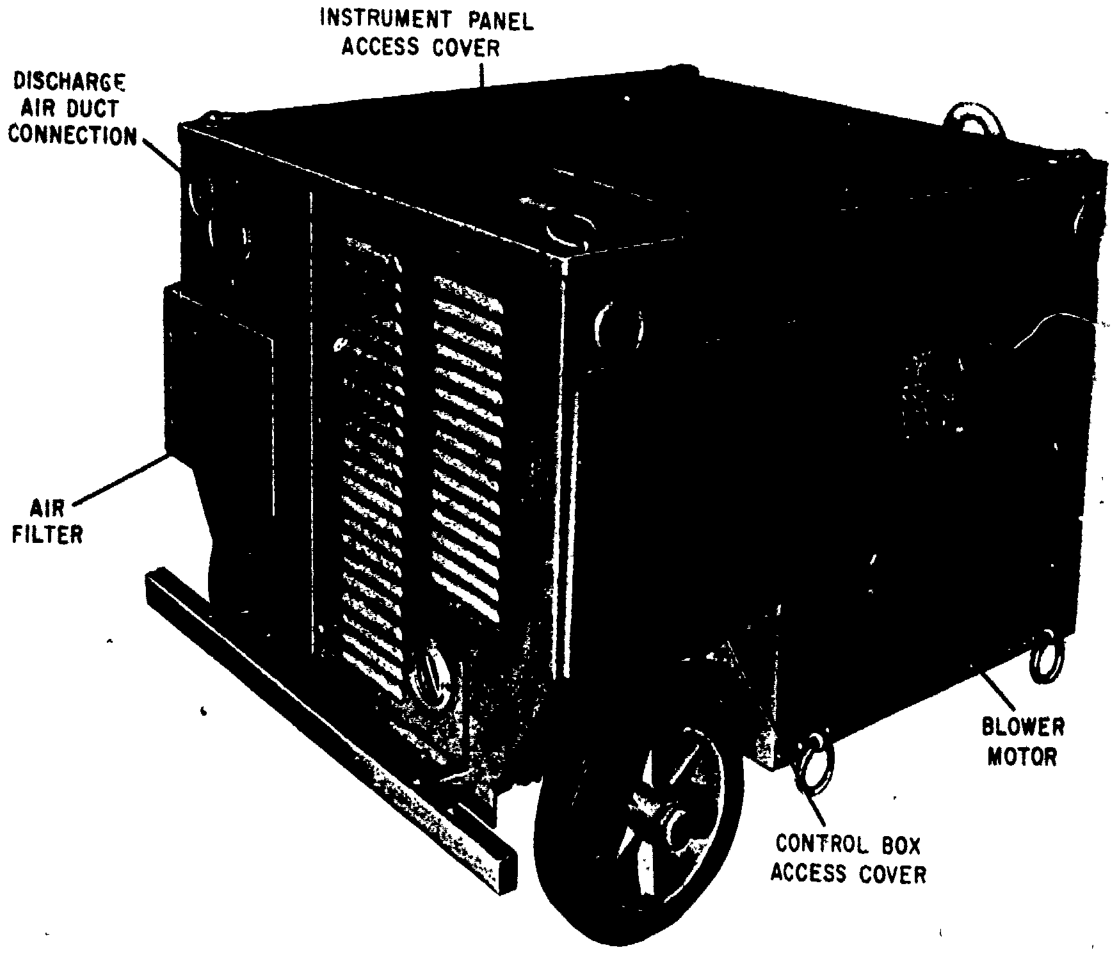
SYSTEM OPERATION

The NR-2B is composed of 3 major systems - electrical, refrigerant, and airflow. (See figures 15-19, 15-20, and 15-21.)

Inasmuch as the electrical and refrigerant systems are interconnected and depend upon each other for operation, they will be discussed together.

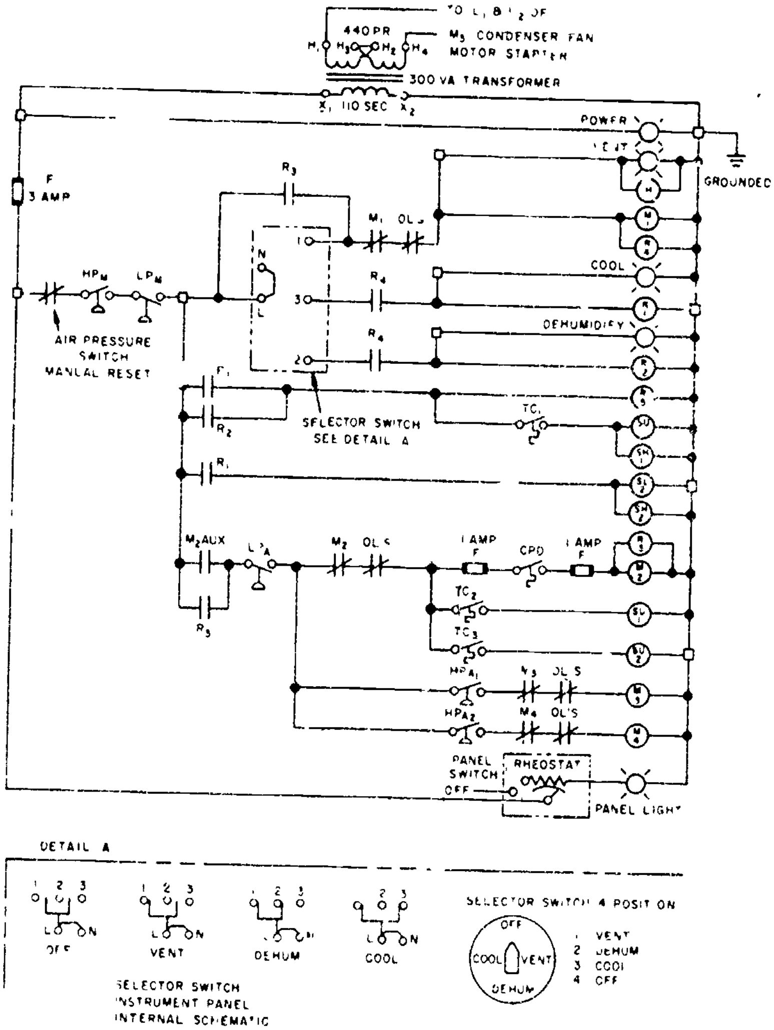
Electrical/Refrigerant Systems

Operation and control functions require 440-volt, 3-phase, 60-Hz power which is supplied to the unit via a power cable connected at the upper right front of the unit. This power is protected by a 60-ampere circuit breaker which also functions as a master power switch. A 300-VA transformer is used to lower the voltage



AS.926

Figure 15-18.—NR-2B mobile air conditioner.



LEGEND

- M_1 —— BLOWER MOTOR STARTER HOLDING COIL
- M_2 —— COMPRESSOR STARTER HOLDING COIL
- M_3 & M_4 - CONDENSER FAN MOTOR STARTER HOLDING COIL
- HP —— HIGH PRESSURE SWITCH M - MANUAL A - AUTOMATIC
- LP —— LOW PRESSURE SWITCH M - MANUAL A - AUTOMATIC
- R —— RELAY R_1 - COOL, R_2 - DEHUMIDIFY R_3 - COMPRESSOR SAFETY, R_4 - MOTOR INTERLOCK, R_5 - PUMP DOWN
- SL —— SOLENOID LIQUID 1 - PRECOOL, 2 - AFTERCOOL
- SH —— SOLENOID HOT GAS 1 - PRECOOL 2 - AFTERCOOL
- SU —— SOLENOID COMPRESSOR UNLOADER 1 & 2 STAGES
- T —— TEMPERATURE CONTROL TC_1 - PRECOOL ENTERING AIR, TC_2 & TC_3 UNIT - LEAVING AIR
- F —— FUSE
- OL —— MOTOR THERMAL OVERLOAD
- CPD —— COMPRESSOR INTERNAL PROTECTIVE DEVICE
- H —— HOUR METER ELAPSE TIME

AS.927

Figure 15-19.—NR-2B electrical system schematic.

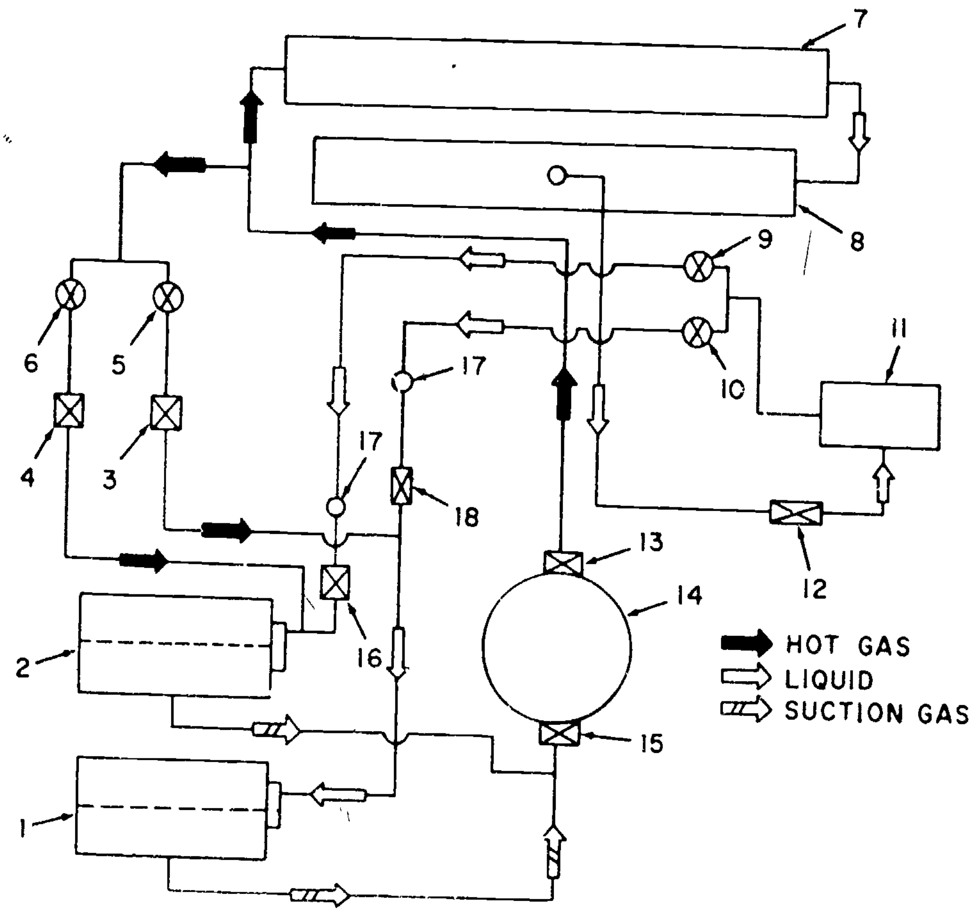


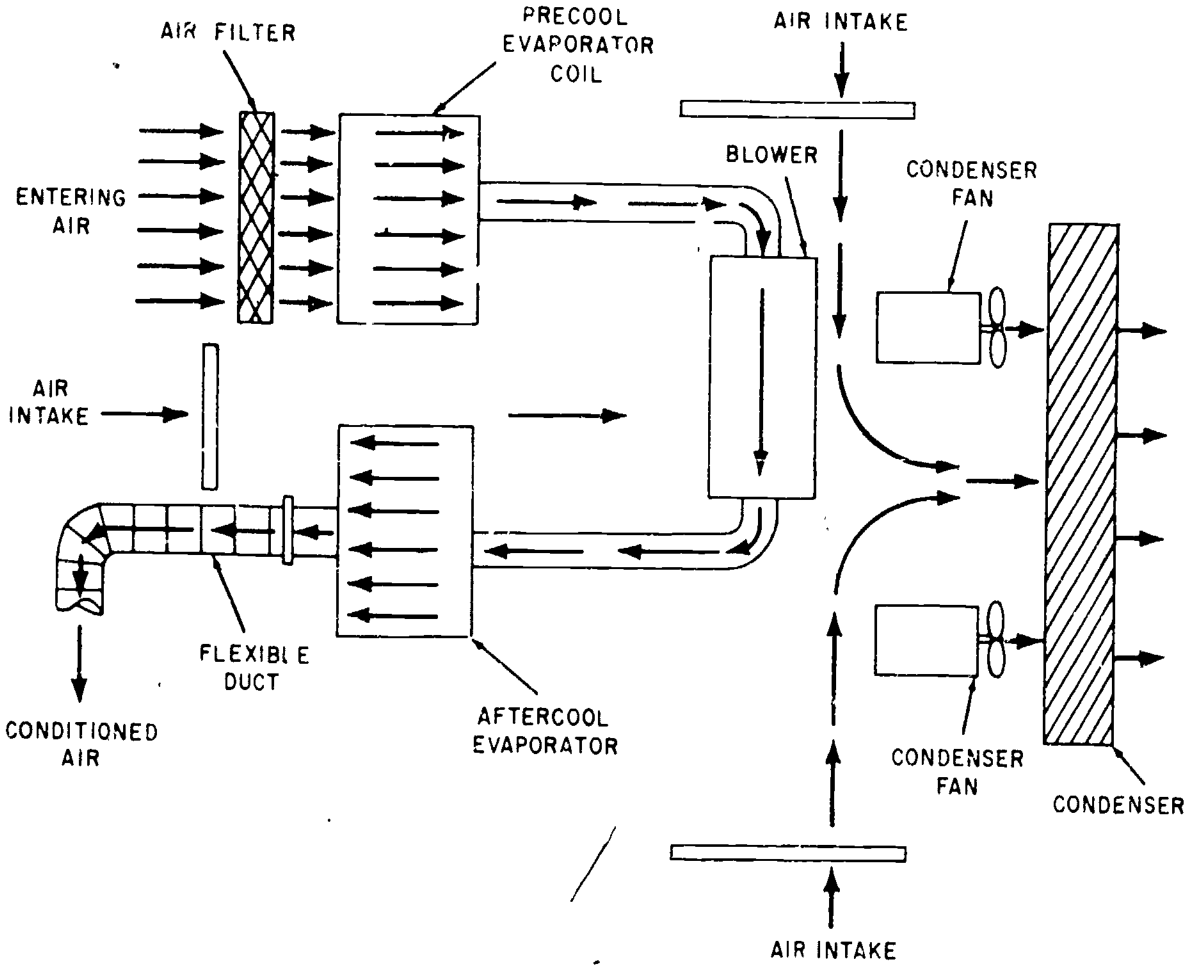
Figure 15-20.—NR-2B refrigerant system schematic. AS.928

from 440 volts a.c. to 110 volts a.c. for control and instrument operation, while the full 440 volts is applied to the motor contactors (starters).

Placing the circuit breaker (fig. 15-22) in the ON position connects power to the circuits and illuminates the power on light. The refrigerant/electrical functions are started by placing the selector switch in the COOL or DEHUM position.

COOLING MODE. The cooling mode is initiated when the selector switch is set to the cool position (fig. 15-19). The compressor motor is started by closing cooling relay (R1) and compressor motor starter (M2). The cooling circuit is completed through the high- and low-pressure cutout switches (HP and LP), compressor safety relay (R3), motor interlock relay (R4), and pumpdown relay (R5). The cool circuit light illuminates. T' blower motor starter (M1) contacts close, starting the blower motor, and the two condenser fan motor starters (M3 and M4) energize, starting the fan motors.

With the compressor operating (fig. 15-20), the superheated refrigerant vapor leaves the compressor (14) through the compressor



AS.929

Figure 15-21.—NR-2B air flow schematic.

discharge valve (13) and is delivered to the condenser (7).

Condensing airflow is provided by the condenser fans (fig. 15-21). The two fans are controlled by compressor discharge pressure through switches HP_{A1} and HP_{A2}, figure 15-21. If the discharge pressure falls below 160 psi, one of the fans will be cut out to decrease the amount of condensing, raising compressor discharge pressure. If the discharge pressure falls below 140 psi, the second fan will be cut out. As the entering air temperature rises, compressor discharge pressure increases and, because more condensing is required, the fans return to operation - one at 220 psi discharge pressure and the other at 240 psi discharge pressure.

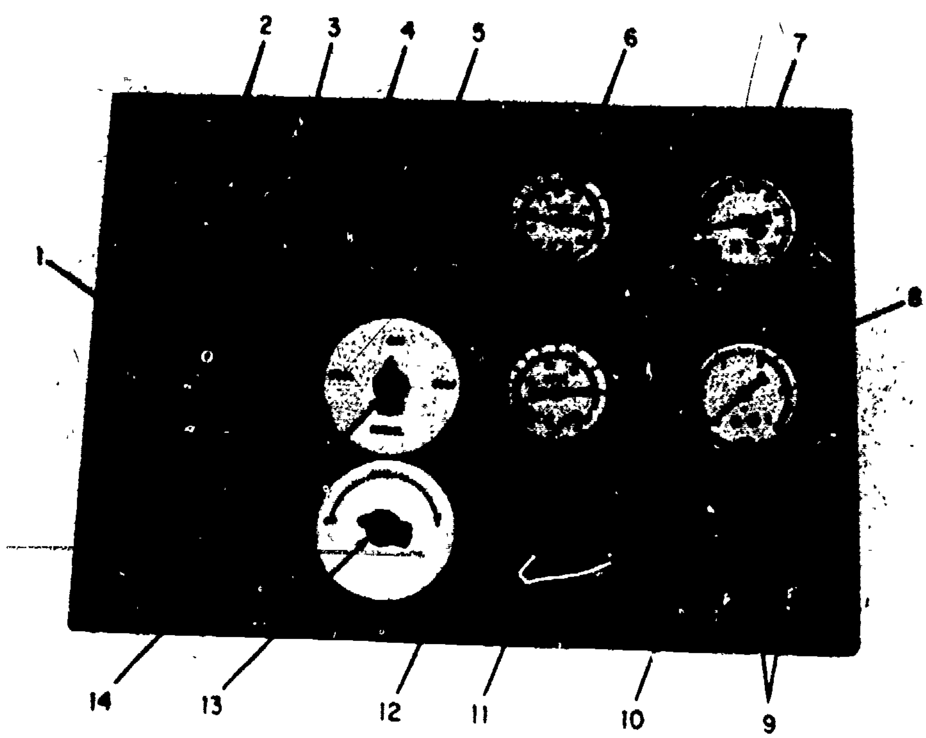
NOTE: Compressor discharge and suction pressures are monitored on gages mounted on the instrument panel (fig 15-22).

The superheated refrigerant vapor is changed to a liquid in the condenser This liquid is stored in the receiver (8, fig. 15-20) and from the receiver the liquid passes through the filter-drier (11). From the filter-drier the liquid passes through the precool and aftercool refrigerant solenoid valves (9 and 10) and sight glasses (17). The two expansion valves (16 and 18) meter the liquid into the two evaporators (1 and 2). From the evaporators, the suction vapor returns to the compressor through the compressor suction valve (15).

As the air to be conditioned flows through the fins of the precool evaporator, it is lowered in temperature as required by the setting of the precool thermostat (TC1, fig. 15-19). If the entering air temperature is sufficiently low and no precooling is required, the thermostat (TC1) will open its contacts, deenergize the precool refrigerant solenoid valve (9, fig. 15-20), and stop the flow of refrigerant to the precool evaporator.

Temperature of the conditioned air leaving the aftercool evaporator is controlled by a two-stage switch (TC2 and TC3, fig. 15-19). When the temperature of the conditioned air drops below the control setting, TC2 opens and deenergizes one unloader solenoid (SU1, fig. 15-19). This stops compression on one bank of pistons in the compressor and cuts down compressor capacity. As the temperature drops further, TC3 opens and deenergizes the second unloader solenoid (SU2, fig 15-19) to further decrease compressor capacity.

DEHUMIDIFICATION MODE. See figure 15-19. When the selector switch is placed in the dehumidify position, the dehumidify circuit light illuminates. Operation of the refrigerant system is the same as explained above except that the cool relay (R1) deenergizes, closing the aftercool refrigerant solenoid valves and



AS.930

Figure 15-22.—NR-2B instrument/control panel.

stopping refrigerant flow through the aftercool evaporator

The air to be conditioned enters and flows through the fins of the precool evaporator where the temperature is lowered to the setting of the thermostat (1CT), and the moisture content is lowered by condensation of moisture on the cool evaporator tubes. The air is then compressed in the blower. Compression causes the air to be heated to the dehumidification temperature, after which it is delivered to the conditioned space at approximately 90° F.

VENTILATION MODE. When the selector switch is placed in vent position, the vent light illuminates. Due to the holding action of the pumpdown relay (R5, fig 15-19), the refrigerant system continues to operate for a period of time when switched from cool or dehumidification modes to the vent mode. With the refrigerant solenoid valves closed (9 and 10, fig 15-20), the compressor attempts to evacuate the low-pressure side of the system. When low side pressure drops below 25 psi (pumpdown completed) the low-pressure cutout switch (LPS, fig 15-19) opens the circuit to the compressor motor starter halting the compressor.

Airflow System

See figure 15-21. Ambient air enters the unit through a 50-micron air filter and passes through the precool evaporator where its temperature and moisture content are lowered. The air is then drawn through flexible ductwork into the positive displacement blower.

As the air is compressed in the blower, its temperature rises, but the moisture content remains unchanged. Air at 3 psi enters the aftercool evaporator and is cooled to the final temperature and moisture content. Air leaves the unit and is delivered to the conditioned space through a 4-inch diameter 25-foot length of flexible duct. Conditioned air temperature and pressure are monitored on gages mounted on the instrument panel (fig 15-22). A duct air pressure switch stops operation of the unit if air pressure in the discharge duct exceeds 5.0 psi. (See fig 15-19.)

Two axial-flow propeller type fans are used to move the air across the condenser. Air is drawn through expanded metal panels on the sides and a louvered panel at the rear of the unit, and is discharged through the condenser at the front of the unit. Each fan is directly coupled to its drive motor.

TROUBLESHOOTING

Not all of the possible troubles that might be encountered in conjunction with the NR-2B can be covered here; however, table 15-1 lists the troubles most likely to be encountered, probable causes for each trouble, and the remedy.

MAINTENANCE

Maintenance data for the air conditioner includes information for servicing, testing, adjusting, and lubricating. Applicable safety precautions and first aid information are also included. For more maintenance information, refer to the Operation and Service Instructions for the NR-2B mobile air conditioner.

Safety Precautions

The precautions presented here must be observed in order to prevent injury to personnel working on or in the immediate vicinity of any air-conditioning unit while maintenance is being performed on the unit.

1. Suitable eye protection must be used when handling refrigerants.
2. Never heat a refrigerant drum with a torch or any other open flame.
3. When repairing a refrigerant system, always blow out any residual refrigerant before attempting to heat the pipe or tubing.
4. Never put liquid refrigerant into a compressor suction line.
5. Inspect all charging lines for brittleness and condition of the couplings prior to use.
6. Do not allow liquid refrigerant to come into contact with the skin.
7. If a large refrigerant spill occurs, ventilate the space immediately.

Table 15-1.—Troubleshooting

Trouble	Possible cause	Remedy
Panel light fails to illuminate.	Defective lamp.	Replace lamp.
	Defective PANEL LIGHT switch	Replace switch
	Defective panel light.	Replace panel light.
	Defective wiring.	Check and repair wiring
Circuit light(s) fail to illuminate.	Defective lamp(s).	Replace lamp(s).
	Defective SELECTOR SWITCH.	Replace switch.
	Defective light(s).	Replace light(s).
	Defective wire	Check and repair wiring.
Unit cuts out on high pressure	High pressure cutout switch tripped.	Reset switch.
	High pressure cutout switch improperly set.	Adjust switch setting.
	High pressure switch defective.	Replace switch.
Compressor fails to start	High or low pressure cutout tripped.	Reset switch.
	Defective high or low pressure cutout.	Replace switch.
	Compressor motor starter tripped.	Reset motor starter.
	Defective motor starter.	Replace motor starter.
	Defective relay.	Replace relay.
	Defective wiring	Check and repair wiring.
	Defective compressor	Repair or replace compressor.

Table 15-1. - Troubleshooting - Continued

Trouble	Possible cause	Remedy
DISCHARGE PRESSURE gage indicates less than 200 psi	Refrigerant charge low as indicated by bubbles in sight glass	Test system for leaks, then add refrigerant as required.
	Defective hot gas bypass solenoid valve.	Replace solenoid valve.
	Defective gage.	Replace gage.
	Defective compressor or unloader.	Repair or replace compressor.
DISCHARGE PRESSURE gage indicates higher than 365 psi.	Condenser coil clogged or obstructed.	Clean coil.
	Overcharge of refrigerant.	Bleed small amounts of refrigerant from suction valve through a charging line until pressure is normal.
	Defective gage.	Replace gage.
	Defective compressor.	Repair or replace compressor.
	Receiver shutoff valve closed.	Open valve.
SUCTION PRESSURE gage indicates zero psi.	Receiver shutoff valve closed.	Open valve.
	Defective gage.	Replace gage.
	Defective compressor.	Repair or replace compressor
SUCTION PRESSURE gage indicates less than 40 psi.	Air filter dirty.	Clean air filter
	Evaporator coil frosted, blocking airflow.	Turn off unit and allow ice to melt.

Table 15-1. Troubleshooting Continued

Trouble	Possible cause	Remedy
	Low refrigerant charge	Add refrigerant
	Filter-drier clogged	Replace filter drier core
	Expansion valve defective	Repair or replace expansion valve
	Hot gas bypass valve not functioning properly.	Adjust valve. Replace valve if necessary.
	Blower not operating properly	Repair or replace blower.
Suction pressure higher than normal.	Hot gas bypass valve set too high	Adjust bypass valve
	Discharge pressure too high.	Refer to (6 above).
	Expansion valve not operating properly.	Adjust expansion valve.
	Defective compressor.	Repair or replace compressor.
Blower not operating.	Air pressure switch tripped.	Reset switch.
	Defective air pressure switch.	Replace switch.
	Defective blower motor	Replace blower motor
	Defective wiring	Check wiring in unit and repair as necessary
	Defective blower.	Repair or replace blower.

Table 15-1.—Troubleshooting—Continued

Trouble	Possible cause	Remedy
Unit will not start	Air pressure switch tripped	Reset switch.
	High- or low-pressure switch tripped.	Reset switches as necessary.
	3-amp fuse blown.	Replace fuse
	Defective relay.	Replace relay
Compressor will not start.	Pressure switch tripped	Reset switch
	Defective relay	Replace relay.
	Compressor motor starter tripped.	Reset motor starter.
	Defective motor starter.	Repair or replace motor starter
	Compressor internal thermostat switch tripped.	Allow compressor to cool. Switch will reset.
	1-amp fuse blown.	Replace fuse.
	Defective compressor	Repair or replace compressor
Condenser fan motors will not start	Pressure switches open	Allow discharge pressure to reach switch settings.
	Pressure switches not operating properly	Adjust switches. Replace switches if necessary
	Fan motor starter(s) tripped	Reset motor starter(s).
	Defective motor starter(s)	Repair or replace motor starter(s).

Table 15-1 —Troubleshooting—Continued

Trouble	Possible casue	Remedy
System will not pumpdown	Defective receiver shutoff valve	Replace shutoff valve.
	Defective pumpdown relay.	Replace relay.
	Defective pressure switch.	Replace pressure switch.
	Solenoid valves will not close.	Repair or replace solenoid valves.
Compressor will not unload.	Conditioned air two-stage switch not set properly.	Adjust switch.
	Defective switch.	Replace switch
	Defective unloader solenoids.	Replace solenoids.
	Defective wiring.	Repair or replace wiring.

First Aid Treatment

If liquid refrigerant comes into contact with the skin, a serious injury will result. Such injury must be treated as if the skin were severely frostbitten or frozen. Flush the area with clean water and seek medical attention immediately. If liquid refrigerant comes into contact with the eyes, flush with clean water and, again, seek medical attention immediately.

Servicing

Some of the more common servicing tasks are mentioned here for background information.

AIR FILTER SERVICING. The intake air filter is of the permanent, washable type and can be cleaned as follows.

1. Open the air filter box and remove the filter.
2. Inspect the filter for damage or deterioration, and replace if necessary.
3. Wash the filter with dry cleaning solvent (Federal Spec. P-D-680) and flush with hot water.
4. Allow the filter to dry thoroughly and then oil lightly with general purpose lubricating oil (Federal Spec. W-L-820B or equivalent).
5. Reinstall the filter in the unit and close the filter box.

LEAK TESTING. Oily film deposits around piping connections and valve bonnets are an indication of refrigerant loss. Leaks may be detected by use of a Halide torch or an electronic leak detector, as outlined below.

1. Open the access doors, remove the access panels, and remove the top of the unit to gain access to the refrigerant lines and tubes.
2. Operate the air conditioner.
3. Pass the exploring tube of a Halide torch or the probe of an electronic leak detector over all refrigerant fittings, couplings, and valves.
4. Mark all spots where leaks are found.

5. Before attempting to repair any leaks, pumpdown the refrigerant system (Refer to the Operation and Service Instructions for pumpdown procedure.)

6. Repair all leaks detected.

7. Refer to the Operation and Service Instructions for procedures for pressure testing and dehydrating the system.

DRIER-STRAINER (DEHYDRATOR) SERVICING. Replace the drier-strainer cartridge as follows.

1. Refer to the Operation and Service Instructions and pumpdown the system

2. Remove the left side panel.

3. Remove the six bolts securing the cap on the drier case, and remove the cap.

4. Remove the cartridge from the case and install a new cartridge.

5. Replace the case cap.

6. Refer to the Operation and Service Instructions and evacuate and dehydrate the system

7. Leak-test the drier-strainer at the cap as previously described.

CHAPTER 16

CORROSION PREVENTION AND CONTROL

Modern ground support equipment is dependent upon the structural soundness of the metal from which it is fabricated. The greatest threat to the structural integrity of the equipment is corrosion of the metal. With higher strength demands being made of metals and the closer tolerances of safety demanded, these equipments would rapidly become inoperative without regular anticorrosion attention.

Corrosion endangers support equipment by reducing the strength and changing the mechanical characteristics of the materials used in its construction. Materials are designed to carry certain loads and withstand given stresses as well as to provide an extra margin of strength for safety. Corrosion can weaken the structure, thereby reducing or eliminating the safety factor. Replacement or reinforcement operations are costly and time consuming, and reduce usage. Corrosion in electronic, electrical, and automotive systems often causes serious malfunctions which reduce the effectiveness of the equipment, and often destroys it completely.

Material presented in this chapter has been compiled from a variety of sources and has necessarily been greatly condensed. As with other training manuals, no maintenance procedures should be initiated which are based solely on information contained herein.

A thorough comprehension of the dangers of corrosion, the ability to recognize the various types of corrosion, and the development of the skills necessary to cope with them should be included in the objectives of every maintenance training program. The ASE will find that corrosion prevention and control frequently turns out to be an all-hands evolution. In his day-to-day work he can improve the quality of corrosion prevention and control by observing precautions outlined herein when working on ground support equipment. Careless handling of tools and equipment, scuffing of feet, etc., can result in damage to protective finishes leaving an area unprotected from corrosion. Even a fingerprint on any unprotected surface will cause corrosion and etching of the metal. This chapter will also be invaluable to the ASE in preventing corrosion.

CORROSION

Metal corrosion is the deterioration of metal when combined with oxygen to form metallic oxides. This combining is a chemical process which is essentially the reverse of the process of smelting the metals from their ores. Very few metals occur in nature in the pure state. For the most part, they occur naturally as metallic oxides. The refining processes generally involve the extraction of relatively pure metal from its ore and the addition of other elements (either metallic or nonmetallic) to form alloys.

After refining, regardless of whether or not alloyed, base metals possess a potential or tendency to return to their natural state. However, potential is not sufficient in itself to initiate and promote this reversion. There must also exist a corrosive environment, in which the significant element is oxygen. It is the process of oxidation—combining with oxygen—that causes wood to rot or burn and metals to corrode.

Prevention and control of corrosion is dependent upon maintaining a separation between susceptible alloys and the corrosive environment. This separation is accomplished in various ways. An intact coat of paint provides corrosion protection. Sealants are used at seams and joints to prevent entry of moisture into vital areas, preservatives are used on unpainted areas of working parts, and shrouds, covers, caps, and other mechanical equipment provide varying

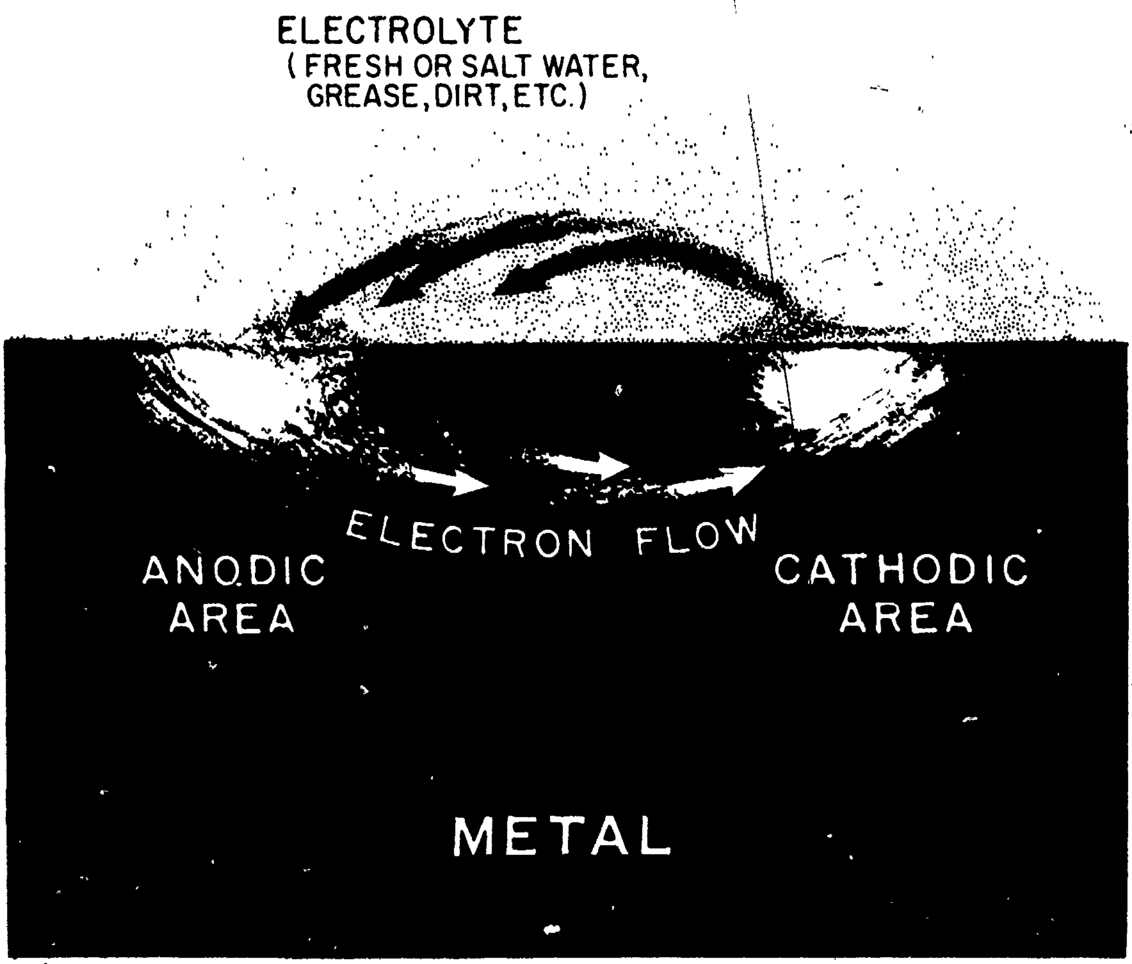


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Figure 16-1.—Simplified corrosion cell.

degrees of protection from corrosive media. None of these, however, provide 100 percent protection paint is, subject to oxidation and decay through weathering; sealants may work out by vibration or else be eroded by rain and windblast. Preservatives at best offer only temporary portection when used on operating support equipment, and the mechanical coverings are subject to improper installation and neglect.

CAUSES

Prevention and control of corrosion begins with an understanding of the causes and nature of this phenomenon. Corrosion is caused by electrochemical or direct chemical reaction of a metal with other elements. In the direct chemical attack, the reaction is similar to that which occurs when acid is applied to bare metal.

Corrosion in its most familiar form is a reaction between metal and water and is electrochemical in nature.

In the electrochemical attack, metals of different electrical potential are involved and they need not be in direct contact. When one metal contains positively charged ions and the other negatively charged ions and an electrical conductor is bridged between them, current will flow as in the discharge of a dry cell battery. In electrochemical corrosion, the conductor bridge may be any foreign material such as water, dirt, grease, or any debris that is capable of acting as an electrolyte. The presence of salt in any of the foregoing media tends to accelerate the current flow and hence speed the rate of corrosive attack.

Once the electrolyte has completed the circuit (fig. 16-1) the electron flow is established within the metal in the direction of the negatively charged area (cathode), and the positively charged area (anode) is eventually destroyed. All preventive measures taken with respect to corrosion prevention and control are designed primarily to avoid the establishment of the electrical circuit, or secondly, to remove it as soon as possible after establishment before serious damage can result.

Electrochemical attack is evidenced in several forms, depending upon the metal involved, its size and shape, its specific function, atmospheric conditions, and the type of corrosion-producing agent (electrolyte) present. There are many forms of metals deterioration resulting from electrochemical attack about which a great deal is known. But despite extensive research and experimentation, there is still much to be learned about other more complex and subtle forms. Descriptions are provided later in this chapter for the more common forms of corrosion.

Since there are so many factors which contribute to the process of corrosion, selection of materials by the manufacturer must be made with weight versus strength as a primary consideration and corrosion properties as a secondary consideration. However, close attention during design and production is given to heat treating and annealing procedures, protective coatings, choice and application of moisture barrier materials, dissimilar metals contact, and access doors and plates. Every logical precaution is taken by the manufacturers to inhibit the onset and spread of corrosive attack.

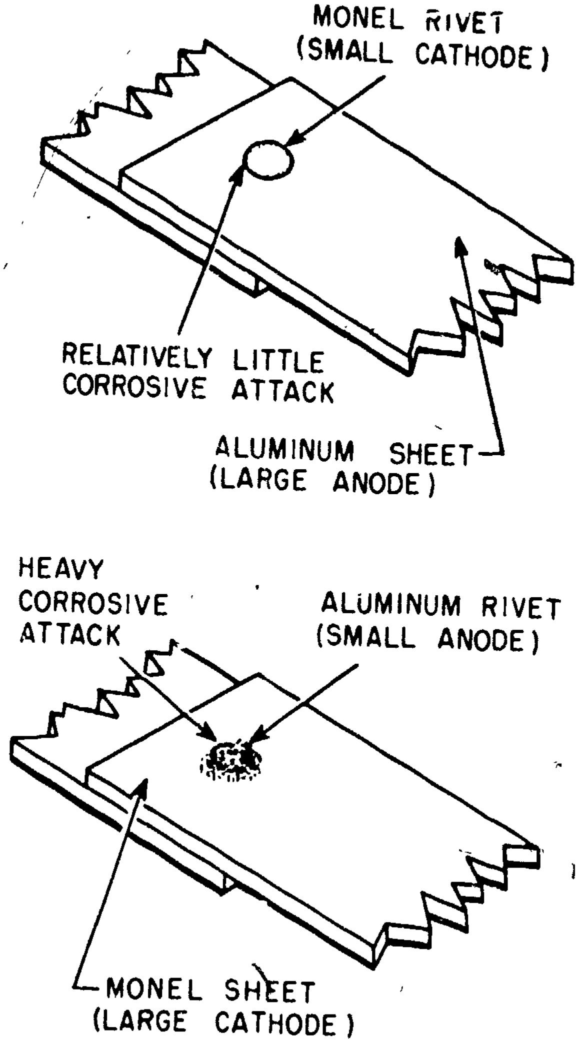


Figure 16-2.—Effects of area relationships in dissimilar metal contacts.

There are many factors that affect the type, speed, cause, and the seriousness of metal corrosion. Some of these corrosion factors can be controlled, others cannot. Preventive maintenance factors such as inspection, cleaning, and painting and preservation are within the control of maintenance personnel. Preventive maintenance offers the most positive means of corrosion deterrence.

The electrochemical reaction which causes metal to corrode is a much more serious factor under wet, humid conditions. The salt in sea water and in the air is the greatest single cause of corrosion. Hot climates speed the corrosion process because the electrochemical reaction develops fastest in a warm solution, and warm moisture in the air is usually sufficient to start corrosion if the metals are uncoated. As would be expected, hot dry climates usually provide relief from constant corrosion problems. Extremely cold climates produce corrosion problems if a salt atmosphere is present. Melting snow or ice provides necessary water to begin the electrochemical reaction.

Another corrosion factor is in the relationship between dissimilar metals. (See fig. 16-2.) When two dissimilar metals are used where possible contact may develop (if the more active metal is small, compared to the less active one), corrosive attack will be severe and extensive if the insulation should fail. If the area of the less active metal is small compared to the other, corrosive attack is relatively slight.

TYPES AND RECOGNITION

One of the greatest problems involving corrosion control encountered by maintenance personnel is the recognition of corrosion products when they occur. The following paragraphs provide brief descriptions of several types of corrosion and the characteristics by which they may be recognized.

Direct Surface Attack

The surface effect produced by reaction of the metal surface to oxygen in the air is a uniform etching of the metal. The rusting of iron and steel, the tarnishing of silver, and the general dulling of aluminum surfaces are common examples of surface attack. On aluminum surfaces, if such surface attack is allowed to continue unabated, the surface will become rough and eventually frosted in appearance.

Galvanic or Dissimilar Metals

Galvanic corrosion is the term applied to the accelerated corrosion of metal caused by dissimilar metals being in contact in a corrosive medium such as salt spray or water.

Dissimilar metal corrosion is usually a result of faulty design or improper maintenance practices which result in dissimilar metals coming in contact. It is usually recognizable by the presence of a build-up of corrosion at the joint between the metals. For example, aluminum and magnesium materials riveted together in equipment form a galvanic couple if moisture or contamination is present. When aluminum pieces are attached with steel bolts or screws, galvanic corrosion can occur around the fasteners.

All manufacturers utilize a variety of separating materials such as plastic tape, sealant, primer, washers, lubricants, etc., to keep these metals from coming in direct contact and thus keep corrosion to a minimum. It is imperative that these separating materials remair intact or are replaced, restored, or repaired as necessary throughout the life of the equipment.

Since some metals are more active than others, the degree of attack will depend on the relative activity of the two surfaces in contact. In any case, the more active or easily oxidized surface becomes the anode and corrodes. In plated metal, the possibility of dissimilar metal corrosion becomes a factor only if there are defects in the plating which allow moisture penetration and subsequently the forming of a galvanic cell.

Pitting

The most common effect of corrosion on aluminum and magnesium alloys is called pitting. It is due primarily to variation in grain structure between adjacent areas on the metal surface in contact with a corrosive environment. Pitting corrosion is first noticeable as a white or gray powdery deposit, similar to dust which blotches the surface. When the superficial deposit is cleaned away, tiny pits or holes can be seen in the surface. They may appear as relatively shallow indentations or deep cavities of small diameter. Pitting may occur in any metal, but it is particularly characteristic of aluminum and magnesium.

Intergranular

Intergranular corrosion is an attack on the grain boundaries of some alloys under specific conditions. During heat treatment, these alloys are heated to a temperature which dissolves the alloying elements. As the metal cools, these elements combine to form compounds; and if the cooling rate is slow, they form predominantly at the grain boundaries. These compounds differ electrochemically from the material adjacent to the grain boundaries and can be either anodic or cathodic to the adjoining areas, depending on their composition. The presence of an electrolyte will result in attack of the anodic area. This attack will generally be quite rapid and can exist without visible evidence.

As intergranular corrosion progress to the more advanced stages, it reveals itself by lifting up the surface grain of the metal by the force of expanding corrosion products occurring at the grain boundaries just below the surface. This advanced attack is referred to as EXFOLIATION, and its recognition by corrosion personnel and immediate action to correct such serious corrosion is vital. The insidious nature of such an attack can seriously weaken structural members before the volume of corrosion products accumulate on the surface and the damage becomes apparent.

Metal that has been properly heat-treated is not readily susceptible to intergranular attack; however, susceptibility can develop from localized overheating, such as could occur from welding, fire damage, etc.

Whenever intergranular corrosion is evident or suspected, it should be immediately brought to the attention of senior personnel who can initiate appropriate action.

Crevice Attack or Concentration Cell

Concentration cell corrosion is actually a form of pitting corrosion which is caused by the difference in concentration of the electrolyte or the active metal at the anode and cathode. When there is concentration differences at two different points in an entrapped pool of water or cleaning solution, anodic and cathodic areas may result, and the anodic area will be attacked. Figure 16-3 illustrates the theory of concentration cell corrosion. This type of attack is generally detected where there are crevices, scale, surface deposits, and/or stagnant water traps. This type corrosion is controlled and prevented by keeping areas clean by eliminating the possibility of water accumulation, by avoiding the creation of crevices during repair work, and by using approved sealants and caulking compounds to eliminate existing voids which may become water traps.

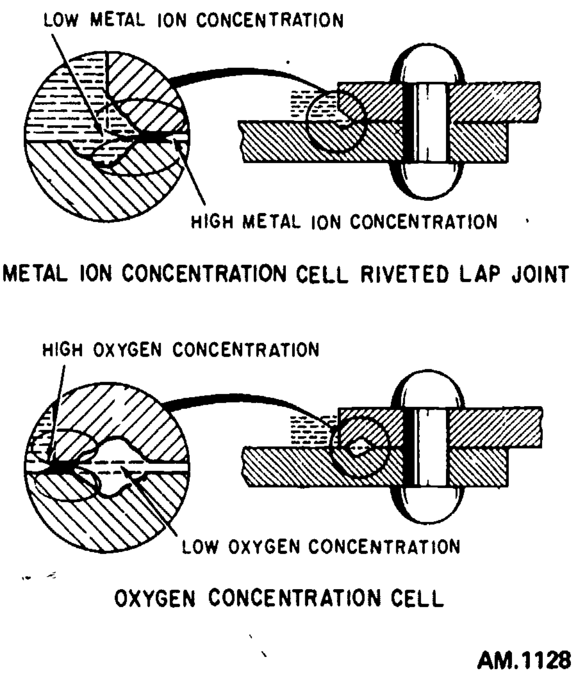


Figure 16-3.—Concentration cell corrosion.

Fretting

Fretting corrosion is a limited but highly damaging type of corrosion caused by a slight vibration, friction, or slippage between two contacting surfaces which are under stress and heavily loaded. It is usually associated with machined parts, such as the area of contact of bearing surfaces, two mating surfaces, and bolted or riveted assemblies. At least one of the surfaces must be metal. In fretting corrosion, the slipping movement at the interface of the contacting surface destroys the continuity of the protective films that may be present on the metallic surface. This action removes fine particles of the basic metal. The particles oxidize and form abrasive materials which further agitate within a confined area to produce deep pits. Such pits are usually so located as to increase the fatigue failure potential of the metal. Fretting corrosion is evidenced at an early stage by surface discoloration and by the presence of corrosion products in any lubrication present. Lubrication and securing the parts so that they are rigid are the most effective measures to prevent this type of corrosion.

Stress

Stress corrosion, evidenced by cracking, is caused by the simultaneous effects of tensile stress and corrosion. Stress may be internal or applied. Internal stresses are produced by nonuniform deformation during cold working, by unequal cooling from high temperatures during heat treatment, and by internal structural rearrangement involving volume changes. Stresses set up when a piece is deformed, those induced by press and shrink fits, and those in rivets and bolts are examples of internal stresses. Concealed stress is more important than design stress, especially because stress corrosion is difficult to recognize before it has overcome the design safety factor. The magnitude of the stress varies from point to point within the metal. Stresses in the neighborhood of the yield strength are generally necessary to promote stress corrosion cracking, but failures have occurred at lower stresses.

Fatigue

Fatigue corrosion is a special kind of stress corrosion and is caused by the combined effects of corrosion and stresses applied in cycles to a part. (NOTE: An example of cyclic stress is the alternating loads to which the reciprocating rod on the piston of a hydraulic, double-acting actuating cylinder is subject. During the extension stroke a compression load is applied and during the retracting or pulling stroke, a tensile or stretching load is applied.) Damage from fatigue corrosion is greater than the combined damage of corrosion and cyclic stresses if the part was exposed to each separately. Fracture of a metal part due to fatigue corrosion generally occurs at a stress far below the fatigue limit in a laboratory environment, even though the amount of corrosion is unbelievably small. For this reason, protection of all parts subject to alternating stress is particularly important wherever practical, even in environments that are only mildly corrosive.

Filiform

Filiform corrosion is threadlike filaments of corrosion known as underfilm. Metals coated with organic substances, such as paint films, may undergo this type of corrosion.

Filiform corrosion occurs independent of light, metallurgical factors in the steel, and bacteria, but takes place only in relatively high humidity, 65 to 95 percent. Although the threadlike filaments are visible only under clear lacquers or varnishes, they also occur with some frequency under opaque paint films. Filiform corrosion can occur on steel, zinc, aluminum, magnesium, and chromium plated nickel.

Microbiological

Micro-organisms contained in sea water can be introduced into fuel systems by contaminated fuel. These fungus growths attack the sealing material used on fuel tanks. Under certain conditions, they can cause corrosion of aluminum probably by aiding in the formation of concentration cells. Residues resulting from biological growth tend to clog fuel filters, and coat fuel capacity probes, giving erroneous fuel quantity readings.

CORROSION PREVENTION

It was mentioned earlier in this chapter that base metals possess a potential or tendency to return to their natural state (metallic oxides). However, potential is not sufficient in itself to initiate and promote this reversion. Therefore, a very good way to prevent corrosion due to bad weather is, when possible, keep ground support equipment in a hangar, hangarbay, or other shelter. If the equipment not in use cannot be kept out of bad weather, protect it from the elements by closing all doors and installing protective panels and covers. If the equipment is being used, have it closed up as much as is practicable. But keep in mind, certain doors and panels must be open during operation of some equipment.

Cleaning and lubrication are two very important measures to use in the prevention of corrosion in ground support equipment. Methods of cleaning and lubrication of specific equipment are included in the chapters discussing the particular equipments. This section discusses the various Naval Air Systems Command authorized cleaning and lubricating materials available to the ASE.

ELECTRICAL COMPONENTS

One of the problems the ASE will have to cope with is the corrosion of light fixtures. Such conditions as salt spray and a salt-laden atmosphere cause rapid deterioration of fixtures. Unless metallic surfaces are protected by plating or similar noncorrosive surface, rapid corrosion may result. Fungus is a problem in hot, humid environments and usually takes the form of mildew and rot decay. Fungus growth can be easily eliminated by proper cleaning with available solvents.

Cloudy lamp lenses and reflectors are usually signs of air leaks around the lens. When relative humidity is excessive, it becomes a major problem and may cause electrical breakdowns. A high humidity, coupled with temperature fluctuations with periods of wetting and drying, causes physical distortion, decomposition, electrolysis, electromechanical corrosion, and cracks and fusion.

When inspecting lamps and lighting fixtures, necessary steps must be taken to combat corrosion. Use sealants and gaskets on all lighting assemblies and fixtures that require them. Keep all lamp lenses and reflectors clean and highly polished. When replacing burned out lamps and/or lighting assemblies, replacement parts which are identical in all respects with the original must be used. This will insure proper service and long life.

Battery compartments are highly corrosive areas. Fumes from overheated battery electrolyte are difficult to contain and will spread to all adjacent internal cavities causing rapid corrosive attack on unprotected surfaces. If the battery installation includes an external venting system, proper inspection and maintenance is of uppermost importance to keep the system operating properly. Cleaning and neutralization of acid deposits can be accomplished by using a solution of sodium bicarbonate and fresh water. Battery compartments should be painted with an acid resistant paint, and battery posts and connections should be greased lightly with vaseline to keep corrosion to a minimum.

When starters and/or generators are removed for corrosion prevention or treatment, work should be performed in a clean, dry, well-ventilated area.

Clean all nonelectrical parts by immersion in a solvent conforming to federal specifications. Do not use a wire brush or metal wool at any time. Blow out internal passages carefully with filtered compressed air. Electrical parts must be cleaned by wiping with a lint-free cloth moistened with a solvent conforming to Federal Specification P-S-661B.

Circuit breakers, contact points, and switches are extremely sensitive to moisture and corrosive attack and should be inspected for these conditions as thoroughly as design permits during routine checks. If design features hinder examination of these items while in the installed condition, advantage should be taken of component removals for other reasons with careful inspection for corrosion required before reinstallation. Treatment of corrosion in electrical and electronic components should be done only by or under the direction of personnel familiar with the function of the unit involved, as conventional corrosion treatment may be detrimental to some units.

CLEANING

Cleaning is one of the most important steps in the preparation of unpainted surfaces for stowage or for the application of protective coatings. Cleaning also is important in reconditioning contaminated and deteriorated surfaces prior to lubrication. If contaminants remain on the surfaces of equipment, the best lubricants or preservatives and the best methods of protection and preservation for standby stowage may be rendered ineffective. Corrosion and contamination may cause faulty operation of the equipment or deterioration beyond reclamation.

Only cleaning materials which meet Naval Air Systems Command specifications may be used on ground support equipment. Navy approved cleaning materials are compounded to accomplish definite results and are made available only after complete testing and actual field acceptance. All cleaning materials are inspected and tested before acceptance and delivery to the supply activities. Cleaning agents commonly used for maintenance cleaning are included in the following categories.

Solvents

Solvents are liquids which dissolve other substances. There are a great number of different solvents; but for cleaning purposes, organic solvents are most often used. Some solvents are chlorinated. When solvents contain more than 24 percent by volume of chlorinated materials, they must be kept in specially marked containers. Care must be taken to insure that solvents do not escape into the work spaces.

All personnel working with or near chlorinated solvents should be particularly careful to avoid breathing the vapors. While the vapors from some solvents are more toxic than others, prolonged breathing of the fumes can be injurious to health.

In addition to the breathing hazard associated with solvents, they also present varying degrees of fire and explosion hazards. Solvent cleaners having a flashpoint greater than 105° F are relatively safe under normal ambient temperatures. Solvents having flashpoints below 105° F require explosion proofing of equipment and other special precuations. (The flashpoint is the temperature at which the first flash from the material is seen, as an open flame is passed back and forth over a sample of flammable liquid being heated in a cup.)

Another hazard associated with solvents, and to a certain extent with all cleaning materials, is the effect on the surface or material being cleaned. Some solvents will deteriorate rubber, synthetic rubber, asphaltic coverings, etc. This is such an important consideration that it must always be taken into account when selecting cleaning materials. It may do a good job in removing dirt, grease, oil, exhaust gas deposits, etc., but may also damage the object being cleaned or soften and ruin otherwise good paint coatings.

DRYCLEANING SOLVENT.—Type I is commonly known as Stoddard solvent and has a flashpoint slightly above 105° F. Type II has a flashpoint of 138° F and is intended for shipboard use. These drycleaning solvents are a liquid petroleum distillate and are used as a general all-purpose cleaner for metals, painted surfaces, and fabrics. They may be applied by spraying, brushing, dipping, and wiping.

MINERAL SPIRITS.—This is another liquid petroleum distillate which is used as an all-purpose cleaner for metal and painted surfaces, but is not recommended for fabrics. Mineral spirits may be applied by spraying, brushing, dipping, and wiping.

ALIPHATIC NAPHTHA.—This is an aliphatic hydrocarbon product used as an alternate compound for cleaning acrylics and for general purposes that require fast evaporation and no remaining film residue. It may be applied by dipping and wiping. Saturated surfaces must not be rubbed vigorously due to the highly flammable nature of the naphtha.

AROMATIC NAPHTHA.—This is a petroleum aromatic distillate used as a bare-metal cleaner and for cleaning primer coats before applying lacquer. It will remove oil, grease, and light soils.

SAFETY SOLVENT.—Methyl chloroform is intended for use where a high flashpoint and less toxic solvent than carbon tetrachloride is required. It is used for general cleaning and grease removal of assembled and disassembled components in addition to spot cleaning, but should not be used on painted surfaces. It may also be applied by wiping, scrubbing, or booth spraying. The term Safety Solvent is derived from the high flashpoint of the solvent and is easier to say and remember than methyl chloroform. Many later issue maintenance manuals label safety solvent as Trichloroethane, 1,I,1.

CORROSION PREVENTIVE, FINGERPRINT REMOVER, MIL-C-15074B.–This compound is intended for use in removal of fresh fingerprints and perspiration deposits. It is designed to suppress corrosion that may develop as a result of fingerprint residue.

THINNER, CELLULOSE NITRATE DOPE AND LACQUER.–In addition to its intended purpose of thinning dope and lacquer, this material is used for the spot removal of lacquer and primer deposits remaining after paint stripping operations, especially along seams and edges, which will interfere with refinish paint operations. Also, it may be used for removal of oil, grease, and light soils from bare metal. This solvent is applied with wiping rags or soft bristle brushes over small areas at a time.

METHYL ETHYL KETONE (MEK).–This material is used as a cleaner for bare-metal surfaces. It does not mix to any great extent with water but is a thinner for lacquers. It is applied with wiping cloths or soft bristle brushes over small areas at a time.

Emulsion Cleaners

Emulsion cleaners differ from solvent cleaners in their action on contaminants to be removed. With solvents, the contaminants go into solution with the cleaning material. Emulsion cleaners tend to disperse contaminants except sand, etc., into tiny droplets which are held in suspension in the cleaner.

Emulsion cleaners must be used with precaution since some are flammable and toxic and, like solvents, may damage paint or other finishes.

CLEANING COMPOUND SOLVENT, GREASE EMULSIFYING, TYPE I.–This is a liquid agent containing soap and solvent. It is nonphenolic. (See Type II which follows.) This compound is used for cleaning bare metal and all painted metal and wood surfaces. It is a heavy-duty cleaner for removal of oil, grease, atmospheric films, industrial films, mud, sand, and soils of all types. It is also used for removal of paralketones and similar corrosion preventive compounds.

Both types (I and II) of this compound must be mixed with Stoddard Solvent or mineral spirits prior to use. A ratio of 1 part compound to 3 to 9 parts of solvent is recommended. Heavy soils require the heavier concentration. The heavy concentrations clean best when the ambient temperature is high.

For best results this compound should be sprayed on the dry surface and then brushed thoroughly. Moist or water-wetted surfaces reduce the emulsion action. It can be used for hand wipedown or hand scrubbing on small areas. Regardless of the method of application, the emulsion compound and loosened soil should be thoroughly flushed away with high-pressure fresh water.

CLEANING COMPOUND, SOLVENT, GREASE EMULSIFYING, TYPE II.–This is a liquid emulsifying compound containing phenolic materials. (Phenolic materials are obtained from the distillation of many organic substances such as wood, coal, etc., and from coal tar. The popular name for the phenols is carbolic acid.) Due to the acid content and type of cleaning for which designed, its use is very limited. Type II cleaning compound is designed for the heaviest, toughest cleaning jobs, but its acidity renders it harmful to many materials.

CLEANING COMPOUND, WATER EMULSION.–This is a liquid emulsifying agent containing soap and water, which is used in solution with 4 to 20 parts fresh water for the heavy-duty removal of oil, grease, industrial films, mud, sand, and soils of all types. It is also used in the removal of chalking formed on epoxy surfaces. This material is applied by spray or brush to cold, wet surfaces, brushed lightly and, after 10 to 15 minutes dwell time, thoroughly flushed with fresh water. Dwell time should be reduced 2 to 3 minutes on hot surfaces to avoid drying and streaking.

Soaps and Detergent Cleaners

There is a variety of materials available in this category for mild cleaning use. In this section, only some of the more commonly used materials are discussed.

CLEANING COMPOUND, TYPE I (POWDER) AND TYPE II (LIQUID).—These soaps are used in general cleaning of painted and unpainted surfaces for the removal of light-to-medium soils, operational films, oils, and grease. They are safe to use on all surfaces, including fabrics, leather, and transparent plastics.

CLEANING COMPOUND, WATERLESS.—This cleaning compound is intended for use on painted and unpainted surfaces in heavy-duty cleaning operations under conditions where fresh water for rinsing is not readily available or where freezing temperatures do not permit the use of water. It is a relatively nontoxic, noncorrosive, stable, nonflowing gel, and its detergent properties enable it to serve as an agent for the removal of grease, tar, wax, carbon deposits, and exhaust stains. This cleaner is applied with a dampened cloth or sponge except in freezing weather when a dry applicator should be used.

Mechanical Cleaning Materials

Mechanical cleaning materials such as abrasive papers, polishing compounds, polishing cloths, wools, wadding, etc., are available in the supply system for use as needed. However, their use must be in accordance with directions supplied with the material if damage to finishes and surfaces is to be avoided.

ALUMINUM OXIDE PAPER.—Aluminum oxide paper (300 grit or finer) is available in several forms and is safe to use on most surfaces since it does not contain sharp or needlelike abrasives which can embed themselves in the base metal being cleaned or in the protective coating being maintained. The use of carborundum (silicon carbide) papers as a substitute for aluminum oxide paper should be avoided. The grain structure of carborundum is sharp, and the material is so hard that individual grains can penetrate and bury themselves even in steel surfaces.

POWDERED PUMICE.—The material is similar to Bon Ami, which may also be used. The pumice is used as a slurry with water and is applied to the surface of most metals with clean rags and bristle brushes.

IMPREGNATED COTTON WADDING.—Cotton which has been impregnated with a cleaning material is used for the removal of exhaust gas stains and for polishing corroded aluminim surfaces. It is also used on other metal surfaces to produce a high reflectance.

ALUMINUM METAL POLISH.—Aluminum metal polish is used to produce a high-luster, long-lasting polish on unpainted aluminum-clad surfaces. It is not used on anodized surfaces as it will remove the oxide coating.

ALUMINUM WOOL.—Three grades of aluminim wool—coarse, medium, and fine—are stocked for general abrasive cleaning of aluminum surfaces.

LACQUER RUBBING COMPOUND, TYPE III.—For the removal of engine exhaust, and minor oxidation, lacquer, rubbing compound, Type III, may be used. Heavy rubbing over rivet heads or edges where protective coatings may be thin should be avoided as the coverings may be damaged most easily at these points.

Chemical Cleaners

Chemical cleaners must be used with great care. The danger of entrapping corrosive materials between layers of metal and at seams counteracts any advantages in their speed and effectiveness. All materials used must be relatively neutral and easy to remove. It is important that all residues from this type cleaning be removed. Soluble salts from chemical surface treatments such as chromate acid or dichromate treatment will liquify and promote blistering in the paint coatings.

PHOSPHORIC-CITRIC ACID MIXTURE.—This chemical surface cleaner is available in Types I and II. Type I is a ready-to-use prepackaged mixture. Type II is a concentrate which must be diluted with mineral spirits or water as required. The mixture is applied to the surface to be cleaned with a soft brush, rag, or sponge, using a circular brushing motion in order to loosen the surface film. After a 15-minute dwell time, this acid mixture should be thoroughly flushed from the cleaned surface with fresh water.

BICARBONATE OF SODA.–This material, commonly known as baking soda, should always be available to neutralize acid deposits as well as to treat acid burns from chemical cleaners and inhibitors. All battery holders, battery compartments of automotive vehicles, and electric powerplants are generally cleaned with this agent. It can also be used to clean tarnished silver contacts by placing the silver-coated part in contact with magnesium metal and submerging the two in a solution of baking soda and salt.

AMMONIUM HYDROXIDE.–In addition to baking soda, ammonium hydroxide also may be used as a neutralizing agent for acid in battery compartments and elsewhere. Treated areas should be rinsed thoroughly with fresh water after use.

Cleaning Equipment

Cleaning not only requires the use of correct cleaning materials, but also the use of proper equipment to produce efficient and satisfactory results. A specific cleaning area should be prepared and equipped for performing cleaning operations.

The choice of equipment depends upon several factors, such as the amount of cleaning that is regularly performed, the type of equipment that is being cleaned, the location of the activity, and the availability of facilities such as air, steam, and electricity.

Some of the equipment available for cleaning are pressure tank sprayers, high-pressure cleaning machines, immersion tanks, and industrial vacuum cleaners.

In addition to the equipment mentioned above, other items such as hoses, spray guns, brushes, sponges, and wiping cloths are required for cleaning. These items are procured through regular supply channels.

Items of personal protection such as rubber gloves, rubber boots, goggles, and aprons should be worn when necessary to protect the clothing and eyes from fumes and splashings of caustic materials.

Cleaning Precautions

Observe the following precautions to prevent damage to equipment which has been or is to be cleaned:

1. When equipment with unpainted metal surfaces has been cleaned and dried prior to applying preservatives, do not handle except by mechanical means or when wearing clean canvas or rubber gloves. Avoid touching cleaned and dried surfaces with bare hands, as perspiration is extremely corrosive. If, under emergency conditions, it becomes necessary to handle equipment with bare hands, remove the resultant fingerprints by the method set forth in the cleaning section of this chapter.
2. Handle equipment coated with preservatives by mechanical means only. If the preservative coating is abraded, restore the affected area after handling.
3. Clean metal surfaces tend to corrode in a short time. Apply preservatives as soon as possible after cleaning. If application of preservatives is delayed, coat the metal surfaces with a preservative lubricating oil until the specified preservative can be applied.
4. Slight changes in the temperature and humidity of the surrounding air may cause condensation of water on metal surfaces. When applying preservatives or lubricants to metal surfaces, maintain the temperature of the surface above the dewpoint of the ambient atmosphere, to prevent condensation and retention of water, which causes corrosion under the protective film.
5. Remove water condensed on the equipment or treat the equipment with a water-displacing compound before application of preservatives. If cleaning is performed out of doors under adverse weather conditions, shelter the operation with canvas or tarpaulins.
6. Process disassembled equipment indoors.
7. Avoid trapping cleaning materials within the equipment. Take special care to avoid contact of cleaning materials with optical surfaces, dials, electrical contacts, and painted surfaces.

8. Do not use immersion cleaning on any equipment containing nonmetallic materials, unless they will not be affected by the cleaners, or are masked for protection.

9. Do not use alkaline solutions such as those of soda ash, trisodium phosphate, or metasilicate for cleaning equipment with extremely close tolerances or highly finished surfaces.

10. Do not clean the following metals in alkaline solutions, unless the solution is specified for such purposes: Aluminum, aluminum aloys, zinc, tin, terne, and lead.

11. Do not use acid or alkaline solutions to clean equipment having bolted or riveted assemblies, when there is a possibility of trapping cleaning solution between joined members. The solutions or their residues may cause corrosion and damage paint coatings. Do not allow organic materials to remain in contact with oxidizers.

12. Prepare acid cleaning solutions accurately, as excess acid may attack copper, brass, bronze, steel, and other metals.

13. Do not allow organic solvents to remain in contact with rubber, electrical insulation, or organic coatings.

LUBRICATION

Lubrication is generally considered to be for reduction of friction and to aid in dissipation of heat; however, many lubricants are specifically compounded for the purpose of corrosion prevention.

The corrosion-inhibiting properties of a lubricant are almost equal in importance to its lubricating properties. In some applications it may be necessary to reduce lubrication quality to obtain better protection against corrosion. Many metal parts are subject to corrosion when exposed to moist air. The application of oil or grease to a metal surface tends to protect it from air and moisture, thus retarding corrosion. It is essential that a lubricant selected for this purpose be one that will remain on the surfaces to be protected under adverse conditions of pressure and temperature, and be formulated so as to retard or prevent the formation of corrosive substances. Many of the lubricants discussed in this chapter contain corrosion inhibitors and other additives to improve stability and other properties.

Corrosion, particularly that resulting from continuous exposure to a marine environment, is a problem of major importance. Equipment which is in temporary stowage or standby condition must also be protected. In many instances, it is essential that equipment be protected in such a way that its return to active service will require only a minimum of change, such as removal of preservatives. Greases containing corrosion inhibitors are often used as preservatives because they possess lubricating qualities and need not be removed from the equipment when it is reactivated.

Lubricants

Lubricants for ground support equipment are selected on the basis of the following desired characteristics:

1. Maximum reduction of friction between the surfaces involved.
2. Corrosion inhibiting quality.
3. Stability over a wide range of temperatures.
4. Ability to withstand high pressures.
5. Nonvolatility at operating temperatures.
6. High resistance of oxidation and consequent formation of acids, gums, sludges, and carbon.
7. Resistance to emulsification.
8. Maximum resistance to contamination under the environmental conditions of the particular application.

Although various lubricants are described herein and certain properties listed, the applicable specification should be consulted and all properties and characteristics of the material reviewed prior to its selection for a specific application.

It is not feasible to cover all the lubricants available to the fleet in this course. However, lubricants that are most commonly used by the ASE are discussed.

PETROLEUM-BASE LUBRICATING OILS.—Petroleum-base lubricating oils or mineral oils refined from petreleum are composed mainly of hydrocarbons. The important properties of the oils are viscosity, viscosity index, pour point, resistance to deterioration, and retardation of corrosion. Viscosity depends largely on the fraction of petroleum selected. Certain additives are used to improve properties such as viscosity index, pour point, stability (oxidation resistance), and corrosion prevention. Oils containing corrosion inhibitors should be used where standby storage and continued exposure are involved.

SYNTHETIC OILS.–Synthetic oils, composed largely or entirely of synthetic materials, provide satisfactory lubrication and corrosion prevention under conditions where petroleum-base lubricants are unsuitable. It should be noted that synthetic oils have a greater deteriorating effect on rubber materials, certain insulators, and organic coatings than petroleum-base oils. Before substituting synthetic lubricants for other synthetic lubricants or for petroleum-base lubricants, be certain that they will not have a rapid deteriorating effect on rubber or other organic materials which the lubricant contacts.

GREASES.–Greases are mixtures of oils and soaps or other thickening agents. The oils may be petroleum base, synthetic, or mixtures of these. Greases with synthetic oils are used in applications where the requirements are such that petroleum-base oils are not adequate. It is to be noted that greases with synthetic oils have a greater deteriorating effect on rubber materials, certain insulators, and organic coatings than those with petroleum oils. Soaps of metals such as sodium, calcium, lithium, or lead may be used. The soap helps to retain the lubricant on surfaces and in places where it might otherwise leak, drain, or be thrown off. Greases are sometimes used to provide a water or dirt seal. The preferred greases are those which pass salt spray and copper corrosion stability tests. Some greases contain additives to increase their load-carrying capacity.

The consistency, plasticity or flow characteristics under pressure, and other properties of a grease depend on the types and proportions of oils and thickening agents. Greases containing lithium or sodium soaps generally have higher dropping points than those containing other soaps and are therefore more suitable for use at higher temperatures. Calcium-soap grease is used where the highest water resistance is required. Generally, the sodium-soap greases are not water resistant and should not be used in such applications unless the water-resistance property is controlled by the specification. Lithium-soap greases are used in many applications because of their high degree of stability over a wide temperature range and their excellent preservative properties.

The texture (fibrous, smooth, or buttery) of a grease depends principally on the nature of the thickener used. A mixture of calcium and lead-based soaps is often used to obtain specific properties such as high load capacity.

There are many types of grease available to the ASE for use on ground support equipment. However, before selecting a grease for use on a particular piece of equipment, refer to the instructions covering the equipment for the grease that is specified for use.

OIL, PRESERVATIVE, HYDRAULIC EQUIPMENT.–This oil is used in the preservation of hydraulic systems and components, and is similar in appearance to, but is not interchangeable with, operating hydraulic oil. Therefore, before using operating hydraulic oil (MIL-H-5606) or this preservative oil (MIL-H-6083) for any purpose, the specification number should be checked to ascertain that the correct oil is being used. The preservative oil contains oxidation and rust inhibitors, viscosity improver, and antiwear agents. Hydraulic parts and components being turned in for screening and repair are flushed and drip drained with MIL-H-6083 oil prior to being forwarded.

Designed primarily for hydraulic components, this oil may be used on any bare surface that needs protection. For example, operating hydraulic oil, MIL-H-5606, will protect a steel panel immersed in water for only about 48 hours while the same metal panel, coated with MIL-H-6083 hydraulic oil, will show 100 percent protection for a period of 30 days or more.

LUBRICATING OIL, GENERAL PURPOSE, PRESERVATIVE MIL-L-644.–There are several different types of lubricating oil, some of which contain preservatives. In order to be absolutely sure that the proper oil is used in a given situation, each must be identified with its specification number. The specification number for the oil discussed in this section is MIL-L-644.

MIL-L-644 was compounded for lubrication and protection of systems whenever a water-displacing, low temperature, lubricating oil is required. Many manufacturers recommend this oil for use in external piano type hinges as it will force out and take the place of any water entrapped between the hinge pin and the tangs.

LUBRICATING OIL, GENERAL PURPOSE, LOW TEMPERATURE.—This general purpose oil (specification number MIL-L-7870) is interchangeable with MIL-L-644 oil and recommended over MIL-L-644. It is suitable for use anywhere that a general purpose lubricating oil with low temperature, low viscosity, and corrosion-preventive properties is required.

Application may be by brush, spray, dip, or general squirt can. It is not necessary to remove before reoiling or for inspection.

LUBRICATING OIL, PRESERVATIVE, MEDIUM, MIL-L-3150.—This is a mineral base, medium grade lubricating oil with inhibitors for the protection of ferrous and nonferrous metals.

MIL-L-3150 is intended for use in preserving some equipments for periods of 30 days or more. Equipments preserved with this material must be cleaned and relubricated before use. The lubricant can be readily removed with Stoddard Solvent P-S-661.

It may be applied by the brush, dip, or spray method in temperatures above 20° F.

Lubrication Instructions

For proper lubrication of the various components of ground support equipment, such as bearings, sliding parts, linkages, and gearing, follow the lubrication charts and instructions furnished for the particular equipment or for the general type of equipment. The charts and instructions are revised frequently, and it is important that the latest revision be used, as the applicable manuals accompanying the equipment do not necessarily agree with the current lubrication instructions and charts.

LUBRICANT CONTAMINATION.—Prevention of either accidental or deliberate contamination of lubricants and fluids used in ground support equipment is of great importance. Foreign materials such as dirt, metal particles, and water may render equipment inoperable or cause severe wear or damage. Even minute foreign particles can affect adjustment or cause faulty operation of delicate instruments. The following precautions should be strictly observed:

1. All surfaces, fittings, oil and grease cups, and applicators, such as grease guns, oilcans, pressure lubricators, spray guns, spatulas, and brushes should be thoroughly cleaned before using.

2. Containers of lubricants and fluids should be kept tightly closed when not in use and should be carefully protected against entrance of foreign materials when opened.

3. Material which is suspected of being contaminated, because of its unusual appearance should not be used unless close examination reveals that it is free of solid particles, or tests show it to be in conformance with the requirements of the applicable specification.

4. Workshop or shipboard locations where lubrication or preservation is carried on should be kept clean and orderly.

PRESERVATION

Suitable protection against corrosive attack is achieved essentially by placing a barrier between the cleaned surface that is to be protected and any possible source of moisture. During manufacture or overhaul, protective barriers such as electroplate, paint, or chemical surface treatment are provided. Surfaces that cannot be so treated, and in some instances the treated surfaces themselves, must be covered with special corrosion-preventive compounds. The protection these compounds give is effective only if no moisture, dirt, or active corrosion is present on the treated surface. It is essential, therefore, that the equipment be thoroughly clean and dry before a preservative compound is applied. It is also necessary that an unbroken film of preservatives be applied in as moisture-free an atmosphere as practicable.

Compounds alone do not provide complete protection. Tapes, barrier paper, and sealing devices must also be used to seal off openings which, if allowed to remain open during longtime stowage, would permit the entry of moisture and dirt. To provide additional protection against corrosion, a complete moisture barrier is sometimes provided. Internal areas that have been sealed off are dehydrated by installing desiccants (moisture absorbents) to remove entrapped moisture unless the cavity is protected with a vapor corrosion inhibitor. When any areas cannot be sealed adequately, provision must be made for ventilation and moisture drainage.

When certain ground support equipment is not being used regularly, its components are required to be preserved. The type of oil or other protective treatment which is to be applied subsequently depends upon the anticipated period of idleness.

In maintenance of metal surfaces, preservation means supplementing the protection already present, or providing temporary protection to damaged areas, by the use of various protective coatings and barrier materials. A brief description of some of the more common materials used in preservation is included in the following paragraphs.

Compound, Corrosion-Preventive, Solvent Cutback

This material is familiarly known as "paralketone." It is supplied in four grades for specific application. All grades of this compound may be applied by brush, dip, or spray. They may be easily removed with Stoddard Solvent or mineral spirits. These materials are designed for cold application. Prior to use of this solvent cutback material, the specification should always be checked to ascertain that the correct grade is chosen for the specific application.

Grade 1 forms a dark, hard-film, opaque cover. Its general use is limited because of the difficulty in removing aged coatings and also because of the hiding power of the material when it is applied over corroded areas. This material is used only where maximum protection against salt spray is required.

Grade 2 is a soft-film, grease type material that can be used on most operating parts. Its chief disadvantage is the fact that it may be washed off under direct exposure to salt water or may be removed by inadvertent wiping. It protects under relatively severe conditions and, given adequate maintenance and touchup as necessary, can be used for most maximum protection requirements.

Grade 3 is a very light, water-displacing preservative, with the ability of penetrating under surface water and forming a protective film on the metal. This material is most effective in treatment of equipment or components after direct exposure of critical surfaces to water or firefighting chemicals, or for internal protection of water-carrying systems. This grade itself offers only limited protection for short periods of time and must be supplemented by frequent maintenance or heavier materials as soon as practicable.

Grade 4 preservative forms thin, semitransparent films through which identification data can usually be read. It also sets up relatively dry to the touch so that preserved parts may be easily handled. This grade has proved particularly effective in protecting wheel well areas and other exposed surfaces where film transparency is required and moderate protective characteristics can be tolerated. The main disadvantages of this material are that it is easily removed by water spray and requires replacement at 1-month intervals under severe exposure conditions.

These preservatives are designed for hot application and are available in two classes—Class 1 (hard film) and Class 3 (soft film). Both consist of corrosion inhibitors in petroleum. They are removed with Stoddard Solvent or mineral spirits. Where a hard film is not necessary, Class 3 should always be used as it is easier to apply and remove yet renders the same degree of protection. Class 1 is generally used for longtime indoor protection of highly finished metal surfaces. Class 3 is used to provide protection of metal surfaces such as antifriction bearings, pistons, and other bright metal surfaces.

Class 1 must be heated to 170° to 200° F before applying by brush or dip. For brushing Class 3 material, it must be between 60° and 120° F, and for dipping, between 150° and 180° F.

Packaging and Barrier Materials

WATER-VAPORPROOF BARRIER MATERIAL.–This material is a laminated metal foil barrier that has good water-vapor resistance and can be used for protection of acrylics during cleaning, and for necessary packaging of removed components and accessories being returned to overhaul. It is heat sealable with a soldering or clothes iron.

POLYETHYLENE PLASTIC FILM.–This barrier material is used for the same purposes as the metal foil barrier material and is much less expensive. It is, however, not puncture resistant. The plastic film is heat sealable only with special equipment.

POLYETHYLENE COATED CLOTH.–Cloth of this type is used to a greater extent in ground support equipment covers. Its use is preferred over the plastic film material for general shrouding because of its greater tear and puncture resistance.

TAPE, FEDERAL SPECIFICATION PPP-T-6, TYPE I, CLASS 1.–This pressure-sensitive tape is used for closure of small openings and for direct contact use on noncritical metallic surfaces. The tape has moderate water-vapor resistance, which is generally adequate for maintenance use. The main disadvantage of this tape is that some cloth-backed materials have not been preshrunk, and tape closures tend to pull loose when exposed to high humidity conditions.

Stowage of Lubricants and Related Materials

Lubricants and related materials may be stowed for long or short periods before use. Although they are relatively stable, they are not inert, and proper stowage methods are important.

Many factors contribute to the deterioration of materials in stowage. The nature of their constituents makes them more or less susceptible to chemical and physical changes, which are accelerated by elevated temperatures, humidity, exposure, and the presence of certain catalysts. Principal physical changes are separation and contamination.

Oxidation is the most common chemical reaction in stowed materials. It occurs when the material is exposed to air, particularly moist air, and is accelerated by high temperatures and the presence of certain catalysts. Materials containing soluble additives may deteriorate by decomposition or precipitation of the additive. These and other ch[illegible]ges can produce such harmful subs[illegible]ids, gases, water, insoluble gum, and sludge. Animal and vegetable oils are generally more susceptible to chemical change than mineral oils.

Physical changes include separation of oils from the soap component in greases, and separation of insoluble additives from the parent material in oils. These changes may not be as serious as chemical changes, since thorough mixing may restore the material to a usable state.

Rain, melted snow, and water vapor in the atmosphere can contaminate materials which are exposed or improperly sealed. Water vapor trapped in the container prior to sealing can condense when the ambient temperature drops.

Generally, containers used to package materials supplied under specification requirements are suitable for stowage purposes. The effects of overheating, insufficient ventilation, and proximity to dangerous materials must be considered when handling and stowing lubricants and related materials. Good housekeeping in handling and stowage areas should be stressed at all times.

All stowage areas should have foundations of steel, concrete, or adequately treated wood. Facilities for proper drainage should be provided at all times.

Containers, when stowed, should be handled carefully to avoid breakage. If they are stacked, overloading of the lower ones should be avoided, as this may open seams and permit loss of material. To prevent accumulation of water [illegible] their upper ends, drums should be stowed on their sides.

Containers from which material is occasionally being drawn should be kept tightly closed when not in use and should be stowed with the bung or outlet in the up position and securely tightened. Solvent containers should be kept out of the sun and away from heat at all times.

Lubricants and related materials should be segre ted from explosives and other dangerous materials.

Before cont e stowed, inspect for corrosion, leak complete closure of all plugs, caps, and covers. Remove all corrosion and repaint the affected areas.

During stowage, inspect containers frequently for leakage and corrosion. If tests indicate that the contents of leaking containers are in satisfactory condition, the materials should be transferred immediately to serviceable containers. Remove and destroy leaky containers.

Inspect stowage areas for adequate drainage, foundations, and properly placed undamaged tarpaulins. Correct immediately all deficiencies found during inspection.

Vapors from oils, greases, solvents, and similar products are flammable. When combined with air in certain concentrations, they may form explosive mixtures which can be ignited easily by a spark, open flame, or lighted cigarette. To prevent accumulation of flammable vapors, stowage areas must be properly ventilated. To safeguard against fire and explosion, display warning signs prominently, keep oil-fire extinguishing equipment available, and keep interiors of stacks open to permit entry of firefighting equipment. Use spark-enclosed forklift trucks only.

Flammable materials such as oils, greases, and solvents, packed in metal containers or overpacked in fiberboard or wood boxes, are best protected when stowed in special nonflammable buildings. A temperature range of 40° to 80° F is the most desirable for stowage.

Vapors from lubricants and related materials may frequently have a toxic effect on the human system. Take every precaution to prevent excessive concentrations of such vapors in the air.

When space is limited, it may be necessary to stow lubricants and related materials in a general stowage warehouse. In this case, use end bays whenever possible.

If the lack of indoor stowage facilities necessitates stowing materials outdoors, protect containers from the weather with tarpaulins or sheds to reduce the likelihood of contamination by water. When tarpaulins are used, lash them in place securely and position them so that air is free to circulate around the containers.

PAINTING

The ASE will not be required to involve himself in extensive painting projects, since the ASH has the basic responsibility for painting. However, he may be called upon to aid in the preparation of the surfaces to be painted and may even perform small painting jobs where a paint touchup is all that is necessary as part of a corrosion-prevention program. Therefore, painting is discussed very briefly and is pointed toward paint touchup.

Surface Preparation

Effectiveness of any paint finish and its adherence to the surface depend on the careful preparation of the surface prior to painting. First, all loose paint must be brushed off, and curled or flaky edges must be removed if good adhesion is to be attained. The touchup paint should overlap the existing good paint surface. The touchup materials will not adhere to glossy finishes and the rough edge of the area being painted may chip away unless it is smoothed. To break the glossy finish and to feather (smooth out) the edges for overlap, scuff-sand with abrasive paper of the appropriate type, depending upon the type of surface being repaired. This paper should be a fine abrasive material, or a pumice slurry in water may be used in its place. The sanded pattern should provide about a one-half inch overlap for the new paint. After the abrasive operation is completed, wash the area with fresh water to remove all abrasive residues.

Next, all sanded areas and exposed baremetal surfaces are wiped down with light mineral spirits solvent or alcohol, followed by a washing with detergent. Remove any loosened seam sealants in the area to be touched up and replace as necessary; this includes securing any loose rubber seals. The area to be painted is then outlined with masking tape and masked with masking paper to protect adjoining surface areas from overspray and excessive paint buildup.

CORROSION REMOVAL

Corrosion removal operations and methods vary considerably, and are dependent mainly upon the type material of which the equipment is constructed. Approved methods of corrosion removal for several types of metal are described briefly in the following paragraphs. The use of chemicals for treatment of metal corrosion is discussed in the next section, and painting to prevent corrosion is described in the last section.

REMOVAL FROM ALUMINUM

There are three types of aluminum surfaces insofar as corrosion removal is concerned. They are clad, anodized, and exfoliated.

Clad Aluminum Surfaces

Pure aluminum has considerable corrosion resistance compared to aluminum alloys, but has little or no structural strength. It has been learned that an extremely thin sheet of pure aluminum laminated onto each side of an aluminum alloy sheet improves the corrosion resistance with little impairment of strength. The trade name of this aluminum laminate, as originated by the Aluminum Company of America, is "Alclad." From this trade name has derived the adjective "clad" and the verb "cladding." Not all sheet aluminum is clad, especially those alloy sheets from which small brackets, gussets, fittings, etc., are made. The pure aluminum is very soft and the fabrication processes would severely damage or destroy the clad surfaces.

To remove corrosion from clad surfaces the corroded areas should be hand polished with household abrasives such as Bon Ami or Ajax, or with a specification metal polish, MIL-P-6888. The specification polish effectively removes stains and produces a high-gloss, lasting polish on unpainted clad surfaces. If a surface is particularly difficult to clean, Compound, Cleaner and Brightener, Aircraft Surfaces, Type II (specification MIL-C-5410), may be used. Mixed 50-50 percent with solvent or mineral spirits, this compound used before polishing will shorten the time and lessen the effort necessary to get a clean surface. During both the foregoing polishing and brightening operations, care must be taken to avoid unnecessary mechanical removal of the protective clad layer and the exposure of more susceptible, but stronger, aluminum alloy base.

If there is any superficial corrosion present, it should be treated by wiping down with an inhibitive material such as the Chemical Surface Films for Aluminum Alloys, available under specification MIL-C-5541. Allow the solution to remain on the corroded area for 5 to 20 minutes, and then remove the excess by wiping the surface dry with clean cloths. If the alclad material is to be used in the unpainted condition, it may now be overcoated with an approved wax which is of the waterproof, solvent type. If the treated alclad surface is to be painted, no wax is used, and the paint pretreatment is applied instead.

Anodized Aluminum Surfaces

Anodizing is the most common surface treatment of nonclad aluminum alloy surfaces. The aluminum alloy sheet or casting is the positive pole in an electrolytic bath in which chromic acid or other oxidizing agent produces an aluminum oxide film on the metal surface. Aluminum oxide is naturally protective, and anodizing merely increases the thickness and density of the natural oxide film. When this coating is damaged in service, it can only be partially restored by chemical surface treatments. Therefore, any processing of anodized surfaces, including corrosion removal, should avoid unnecessary destruction of the oxide film.

Aluminum wool, aluminum wire brushes, or fiber bristle brushes are the approved tools for cleaning anodized surfaces. The use of steel wool, steel wire brushes, or harsh abrasive materials on any aluminum surfaces is prohibited. Producing a buffed or wire brush finish by any means is also prohibited. Otherwise, anodized surfaces are treated in much the same manner as other aluminum finishes.

Exfoliated Surfaces

Exfoliation is a separation along the grain boundaries of metal and is caused by intergranular corrosion. More severe procedures must be observed when intergranular corrosion is present. The mechanical removal of all corrosion products and visible delaminated metal layers must be accomplished in order to determine the extent of destruction and to evaluate the remaining structural strength of the component. Metal scrapers, rotary files, and other necessary tools are used to assure that all corrosion products are removed and that only structurally sound aluminum remains. Inspection with a 5- to 10-power magnifying glass, or the use of dye penetrant, will aid in determining if all unsound metal and corrosion products have been removed. When complete removal has been attained, any rough edges should be blended or smoothed out even though this involves the removal of more metal. Grinding, where required, can best be accomplished by using rubber base wheels into which tiny particles of aluminum oxide abrasives have been impregnated.

Chemical treatment of exposed surfaces is applied in the same manner as for any other aluminum surface.

REMOVAL FROM IRON AND STEEL

The most practical means of controlling the corrosion of steel is the complete removal of the corrosion products (rust) by mechanical means. Except in highly stressed steel surfaces, the use of abrasive papers, small power buffers and buffing compounds, hand wire brushing, and steel wool are all acceptable cleanup procedures. It is a recognized fact, however, that in any such uses of abrasives, residual iron usually remains in the bottom of small pits and other surfaces. As a result, a part once rusty usually corrodes again, and more easily than it did the first time.

There are approved methods for converting active iron rust to phosphates and other protective coatings; however, most of these procedures require shop installed equipment and are therefore impractical in the field. Another disadvantage of chemically inhibiting iron rust is the danger of entrapping these chemicals in installed assemblies where thorough flushing is difficult, thereby causing far more corrosion than was originally present.

Stainless Steel Alloy Surfaces

When processing corroded stainless steel surfaces in the field, the following precautions must be considered:

1. Stainless steel surfaces are never wire brushed under any conditions.

2. If removal of heat scale is necessary, the part should be removed and sent to the nearest depot maintenance activity for the proper chemical treatment.

3. In some cases, stainless steel components may be cleaned by light blasting with 100-mesh garnet or the equivalent at a pressure not to exceed 40 psi; however, this requires special equipment that is not generally available in the field.

REMOVAL FROM MAGNESIUM

Magnesium corrosion reprotection involves the maximum removal of corrosion products, the partial restoration of surface coatings by chemical treatment, and a reapplication of protective coatings.

After cleaning the surface and stripping the paint, if any, as much of the corrosion products as possible should be broken loose and removed using a stiff bristle brush. Steel wire brushes, carborundum abrasives, or steel cutting tools should not be used.

The corroded area is treated liberally with a solution of chromic acid and battery electrolyte. The solution is worked into pits and crevices by brushing the area while still wet, again using a bristle rather than a metal brush. After the chromic acid solution has remained in place from 5 to 20 minutes, the excess should be wiped off with a damp cloth. If any excess solution is allowed to dry on any painted surfaces, the paint film will be ruined. As soon as the surfaces are dry after the damp cloth wiping, the original protective paint scheme should be restored.

Cadmium-Plated Surfaces

As stated previously, cadmium platings are still offering sacrificial protection even when they show mottling ranging from white to brown to black on their surfaces. This discoloration should never be removed for appearance sake alone. Not until the characteristic color peculiar to corrosion of the base metal appears should steps be taken.

Corrosion present should be removed by rubbing lightly with stainless steel wool. Under no circumstances should a wire brush, stainless or otherwise, be used on cadmium plated surfaces as these will remove more plating than corrosion. After the corrosion has been removed, the affected area should be swabbed with a chromic acid solution and, after 30 to 60 seconds, rinsed with clean fresh water and dried with clean cloths or low-pressure compressed air. The part is then ready for a protective paint coating.

SOURCES OF INFORMATION

One of the biggest problems in corrosion prevention and control is knowing what materials to use, where to find them, and the limitations applicable to their use. Materials used should be those covered and controlled by military specifications. Corrosion prevention and control information pertaining to materials, methods, and techniques is scattered throughout many directives and instructions. The following is a list of sources of information that should be used as a reference in every unit's technical library or in the ground support equipment shop. Although these publications are intended primarily for corrosion prevention and control on aircraft and weapons systems, most of the information is also adaptable for aviation support equipment.

1. Aircraft Maintenance Cleaning Manual, NavWeps 01-1A-506.
2. Corrosion Control for Aircraft, NavWeps 01-1A-509.
3. Corrosion Preventive Compounds for Protection of Naval Weapons Systems, NavWeps 01-1A-518.
4. Chart-Chemical Materials for Naval Weapons Systems-Maintenance and Overhaul Operations, NavWeps 07-1-503.
5. Toxicity, Flashpoint Flammability of Chemicals, NavWeps 07-1-505.
6. Preservation of Naval Aircraft, NavWeps 15-01-500.

SAFETY

Safety must be strongly stressed in the stowing, handling, and using of chemicals in corrosion prevention and control. Some of these chemicals are very toxic and highly flammable. Injury and death to personnel and damage and destruction to buildings and equipment will result if these chemicals are not used properly. Before attempting to use the cleaning materials, you should become thoroughly familiar with them. Check the appropriate manuals and other written materials for this information and, if there are any questions, discuss them with the supervising petty officer.

APPENDIX I

FORMULAS

Ohm's Law for D-C Circuits

$$I = \frac{E}{R} = \frac{P}{E} = \sqrt{\frac{P}{R}}$$

$$R = \frac{E}{I} = \frac{P}{I^2} = \frac{E^2}{P}$$

$$E = IR = \frac{P}{I} = \sqrt{PR}$$

$$P = EI = \frac{E^2}{R} = I^2R$$

Resistors in Series

$$R_T = R_1 + R_2 + \ldots$$

Resistors in Parallel

Two resistors

$$R_T = \frac{R_1 R_2}{R_1 + R_2}$$

More than two

$$\frac{1}{R_T} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} + \ldots$$

RL Circuit Time Constant

$$\frac{L \text{ (in henrys)}}{R \text{ (in ohms)}} = t \text{ (in seconds), or}$$

$$\frac{L \text{ (in microhenrys)}}{R \text{ (in ohms)}} = t \text{ (in microseconds)}$$

RC Circuit Time Constant

R (ohms) x C (farads) = t (seconds)

R (megohms) x C (microfarads) = t (seconds)

R (ohms) x C (microfarads)
= t (microseconds)

R (megohms) x C (micromicorfarads)
= t (microseconds)

Capacitors in Series

Two capacitors

$$C_T = \frac{C_1 C_2}{C_1 + C_2}$$

More than two

$$\frac{1}{C_T} = \frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3} + \ldots$$

Capacitors in Parallel: $C_T = C_1 + C_2 + \ldots$

Capacitive Reactance: $X_C = \frac{1}{2\pi fC}$

Impedance in an RC Circuit (Series)

$$Z = \sqrt{R^2 + (X_C)^2}$$

Inductors in Series

$L_T = L_1 + L_2 + \ldots$ (No coupling between coils)

Inductors in Parallel

Two inductors

$$L_T = \frac{L_1 L_2}{L_1 + L_2} \text{ (No coupling between coils)}$$

More than two

$$\frac{1}{L_T} = \frac{1}{L_1} + \frac{1}{L_2} + \frac{1}{L_3} + \ldots \text{ (No coupling between coils)}$$

Inductive Reactance

$$X_L = 2\pi fL$$

Q of a Coil

$$Q = \frac{X_L}{R}$$

Impedance of an RL Circuit (Series)

$$Z = \sqrt{R^2 + (X_L)^2}$$

Impedance with R, C, and L in Series

$$Z = \sqrt{R^2 + (X_L - X_C)^2}$$

Parallel Circuit Impedance

$$Z = \frac{Z_1 Z_2}{Z_1 + Z_2}$$

Sine-Wave Voltage Relationships

Average value

$$E_{ave} = \frac{2}{\pi} \times E_{max} = 0.637E_{max}$$

Effective or r. m. s. value

$$E_{eff} = \frac{E_{max}}{\sqrt{2}} = \frac{E_{max}}{1.414} = 0.707E_{max}$$
$$= 1.11E_{ave}$$

Maximum value

$$E_{max} = \sqrt{2}\,(E_{eff}) = 1.414E_{eff} = 1.57E_{ave}$$

Voltage in an a-c circuit

$$E = IZ = \frac{P}{I \times P.F.}$$

Current in an a-c circuit

$$I = \frac{E}{Z} = \frac{P}{E \times P.F.}$$

Power in A-C Circuit

Apparent power: $P = EI$

True power: $P = EI\cos\phi = EI \times P.F.$

Power Factor

$$P.F. = \frac{P}{EI} = \cos\phi$$

$$\cos\phi = \frac{\text{true power}}{\text{apparent power}}$$

Transformers

Voltage relationship

$$\frac{E_p}{E_s} = \frac{N_p}{N_s} \text{ or } E_s = E_p \times \frac{N_s}{N_p}$$

Current relationship

$$\frac{I_p}{I_s} = \frac{N_s}{N_p}$$

Induced voltage

$$E_{eff} = 4.44 \times BAfN \times 10^{-8}$$

Turns ratio

$$\frac{N_p}{N_s} = \sqrt{\frac{Z_p}{Z_s}}$$

Secondary current

$$I_s = I_p \times \frac{N_p}{N_s}$$

Secondary voltage

$$E_s = E_p \times \frac{N_s}{N_p}$$

Three-Phase Voltage and Current Relationships

With Wye connected windings

$$E_{line} = \sqrt{3}(E_{coil}) = 1.732E_{coil}$$

$$I_{line} = I_{coil}$$

With delta connected windings

$$E_{line} = E_{coil}$$

$$I_{line} = 1.732I_{coil}$$

With wye or delta connected winding

$$P_{coil} = E_{coil}I_{coil}$$

$$P_t = 3P_{coil}$$

$$P_t = 1.732E_{line}I_{line}$$

(To convert to true power multiply by $\cos\phi$)

Resonance

At resonance

$$X_L = X_C$$

Resonant frequency

$$F_o = \frac{1}{2\pi\sqrt{LC}}$$

Series resonance

$$Z \text{ (at any frequency)} = R + j(X_L - X_C)$$

$$Z \text{ (at resonance)} = R$$

Parallel resonance

$$Z \text{ (at any frequency)} = \frac{Z_1 Z_2}{Z_1 + Z_2}$$

$$Z_{max} \text{ (at resonance)} = \frac{X_L X_C}{R} = \frac{X_L{}^2}{R} = QX_L$$

$$= \frac{L}{CR}$$

Band width

$$\Delta = \frac{F_o}{Q} = \frac{R}{2\pi L}$$

Tube Characteristics

Amplification factor

$$\mu = \frac{\Delta e_p}{\Delta e_g} \text{ (} i_p \text{ constant)}$$

$$\mu = g_m r_p$$

A-c plate resistance

$$r_p = \frac{\Delta e_p}{\Delta i_p} \text{ (} e_g \text{ constant)}$$

Grid-plate transconductance

$$g_m = \frac{\Delta i_p}{\Delta e_g} \text{ (} e_p \text{ constant)}$$

Decibels

NOTE: Wherever the expression "log" appears without a subscript specifying the base, the logarithmic base is understood to be 10.

Power ratio

$$db = 10 \log \frac{P_2}{P_1}$$

Current and voltage ratio

$$db = 20 \log \frac{I_2 \sqrt{R_2}}{I_1 \sqrt{R_1}}$$

$$db = 20 \log \frac{E_2 \sqrt{R_1}}{E_1 \sqrt{R_2}}$$

NOTE: When R_1 and R_2 are equal they may be omitted from the formula. When reference level is one milliwatt

$$dbm = 10 \log \frac{P}{0.001} \text{ (when P is in watts)}$$

Synchronous Speed of Motor

$$\text{r.p.m.} = \frac{120 \times \text{frequency}}{\text{number of poles}}$$

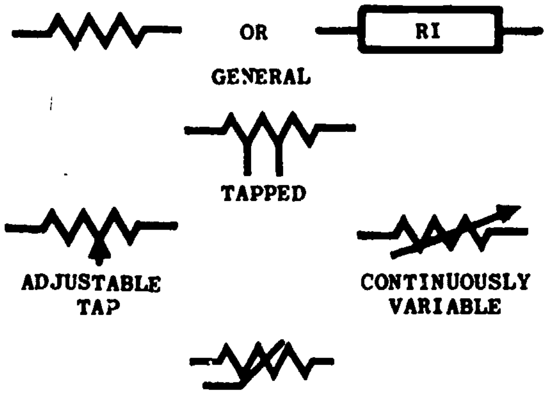
Comparison of Units in Electric and Magnetic Circuits

	Electric circuit	Magnetic circuit
Force.	Volt, E, or e. m. f.	Gilberts, F, or m. m. f.
Flow.	Ampere, I	Flux, Φ, in maxwells
Opposition.	Ohms, R	Reluctance, $\mathcal{R}$
Law.	Ohm's law, $I = \frac{E}{R}$	Rowland's law, $\Phi = \frac{F}{\mathcal{R}}$
Intensity of force	Volts per cm. of length.	$H = \frac{1.257IN}{L}$, gilberts per centimeter of length
Density.	Current density--for example, amperes per cm.^{2}	Flux density—for example, lines per cm.^{2}, or gausses

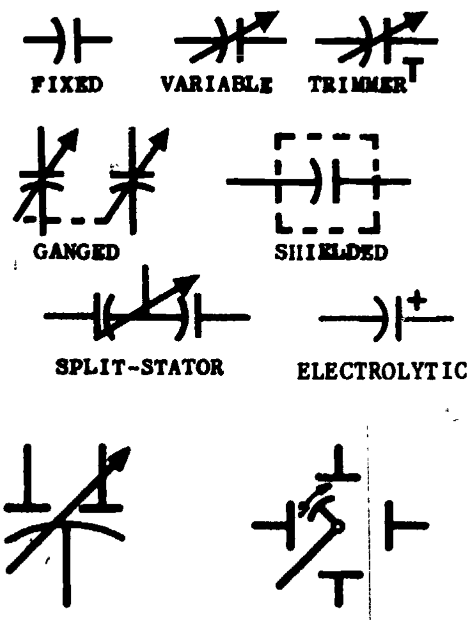
APPENDIX II

ELECTRICAL AND ELECTRONIC SYMBOLS

RESISTORS

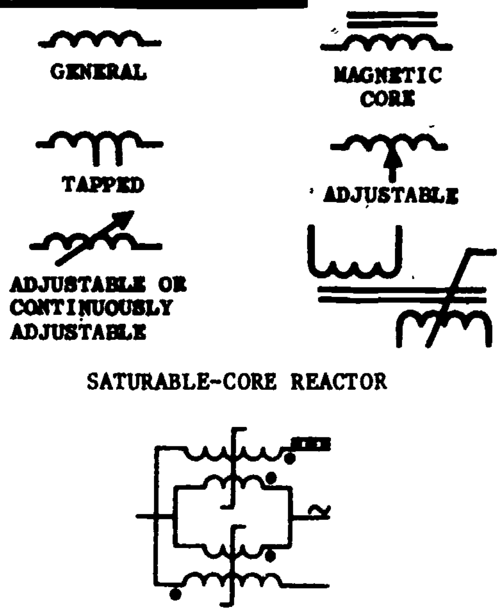


CAPACITORS



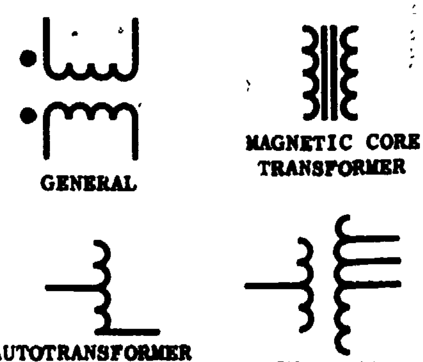
(WHEN CAPACITOR ELECTRODE IDENTIFICATION IS NECESSARY, THE CURVED ELEMENT SHALL REPRESENT THE OUTSIDE ELECTRODE IN FIXED PAPER-DIELECTRIC AND CERAMIC-DIELECTRIC CAPACITORS, THE MOVING ELEMENT IN VARIABLE AND ADJUSTABLE CAPACITORS, AND THE LOW POTENTIAL ELEMENT IN FEED-THROUGH CAPACITORS.)

INDUCTIVE COMPONENTS



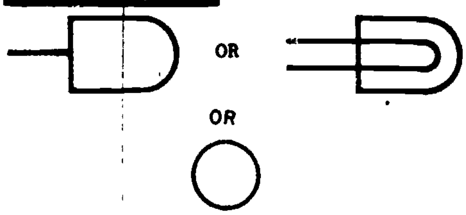
(POWER WINDINGS ARE DRAWN WITH THREE SCALLOPS OR LOOPS, CONTROL WINDINGS WITH FIVE. AN INCREASE OF CURRENT ENTERING THE END OF THE CONTROL WINDING MARKED WITH A DOT CAUSES AN INCREASE IN THE POWER OUTPUT.)

TRANSFORMERS

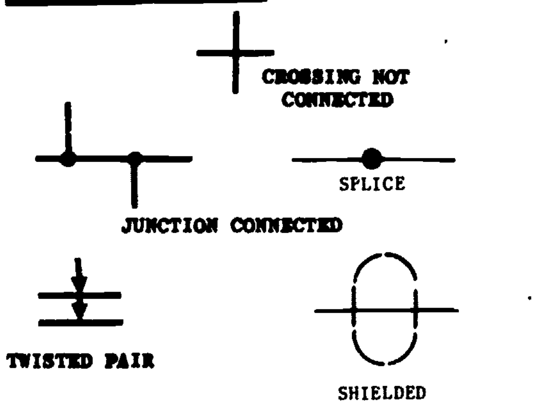


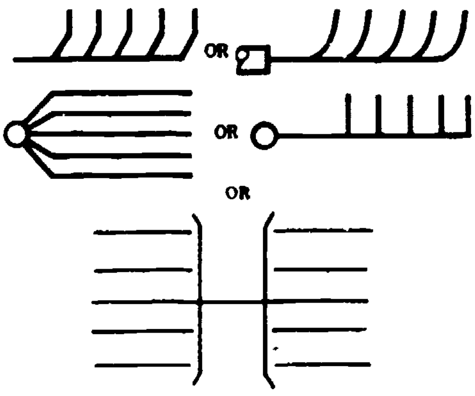
(A DOT, REPRESENTING INSTANTANEOUS POLARITY, MAY BE PLACED NEAR ONE END OF EACH COIL OR WINDING SYMBOL.)

INDICATOR LAMP

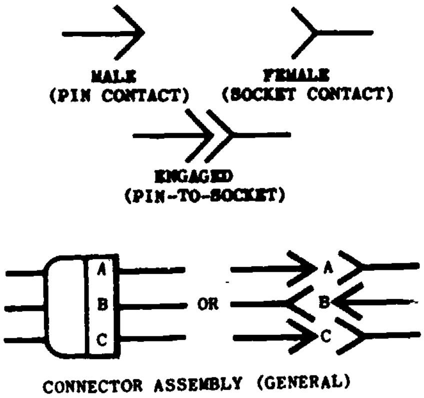


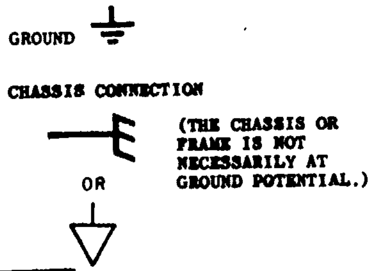
MAY HAVE APPLICABLE IDENTIFICATION FOR CIRCUIT USAGE OR COLOR.

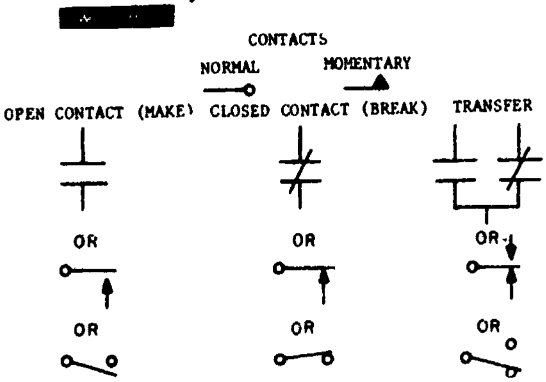




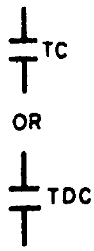
GROUPING LEADS.--(BEND IN LINE INDCIATES WHERE OTHER END OF LEAD CAN BE FOUND.)





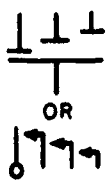


TIME CLOSING (TC) OR TIME-DELAY CLOSING (TDC)



MAKE-BEFORE-BREAK

TIME SEQUENTIAL CLOSING

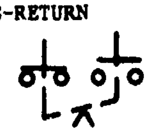


PUSHBUTTON, MOMENTARY OR SPRING-RETURN

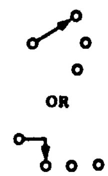
CIRCUIT CLOSING (MAKE)

CIRCUIT OPENING (BREAK)

TWO-CIRCUIT, MAINTAINED OR NOT SPRING-RETURN

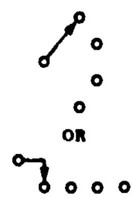


SELECTOR OR MULTIPOSITION SWITCH

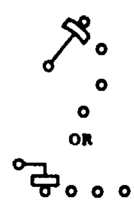


THE POSITION IN WHICH THE SWITCH IS SHOWN MAY BE INDICATED BY A NOTE OR DESIGNATION OF SWITCH POSITION.

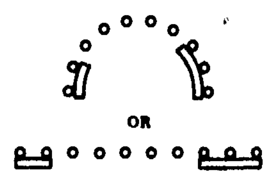
BREAK-BEFORE-MAKE, NONSHORTING (NONBRIDGING) DURING CONTACT TRANSFER



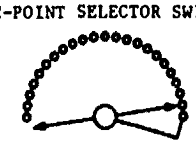
MAKE-BEFORE-BREAK, SHORTING (BRIDGING) DURING CONTACT TRANSFER



SEGMENTAL CONTACT

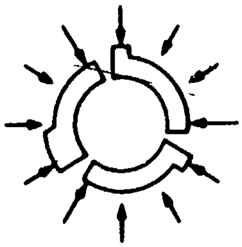


22-POINT SELECTOR SWITCH

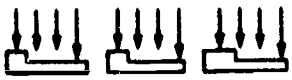


ROTARY (SECTION-, DECK-, OR WAFER-TYPE) SWITCH.

VIEWED FROM END OPPOSITE CONTROL KNOB OR ACTUATOR UNLESS OTHERWISE INDICATED. FOR MORE THAN ONE SECTION, THE FIRST SECTION IS THE ONE NEAREST CONTROL KNOB OR ACTUATOR. WHEN CONTACTS ARE ON BOTH SIDES, FRONT CONTACTS ARE NEAREST CONTROL KNOB.



OR



TEMPERATURE-ACTUATED SWITCH

CLOSES ON RISING TEMPERATURE

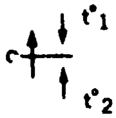
OR

OPENS ON RISING TEMPERATURE

OR

THERMOSTAT

TRANSFER, WITH INTENDED CENTRAL-OFF (NEUTRAL) POSITION



(THE t° SYMBOL WILL BE SHOWN OR BE REPLACED BY DATA GIVING THE NOMINAL OR SPECIFIC OPERATING TEMPERATURE OF THE DEVICE.)

IF CLARIFICATION OF DIRECTION OF CONTACT OPERATION IS NEEDED, A DIRECTIONAL ARROW MAY BE ADDED. THE ARROWHEAD WILL POINT IN THE DIRECTION OF RISING TEMPERATURE OPERATION. A DIRECTIONAL ARROW WILL ALWAYS BE SHOWN FOR CENTRAL-OFF (NEUTRAL) POSITION DEVICES.)

FLASHER
SELF-INTERRUPTING SWITCH

OR

LIMIT SWITCH, DIRECTLY ACTUATED, SPRING RETURNED

NORMALLY OPEN

NORMALLY OPEN-HELD CLOSED

NORMALLY CLOSED

NORMALLY CLOSED-HELD OPEN

BATTERIES

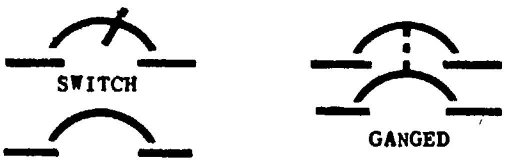
ONE CELL MULTICELL TAPPED MULTICELL

(LONG LINE IS ALWAYS POSITIVE)

CIRCUIT PROTECTORS

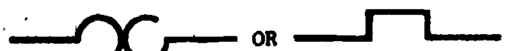
FUSE

CIRCUIT BREAKERS

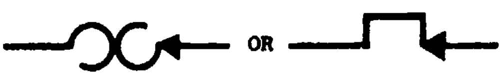


PUSH PULL OR PUSH

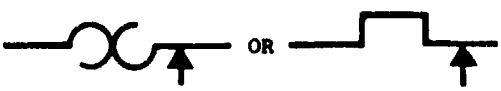
THERMAL ELEMENTS

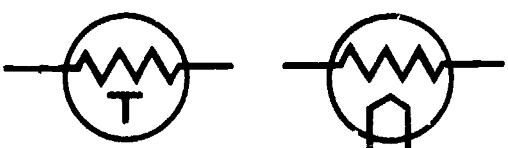


THERMAL RELAY WITH NORMALLY CLOSED CONTACT.



FLASHER; THERMAL CUTOUT





THERMISTOR

WITH INTEGRAL HEATING ELEMENT

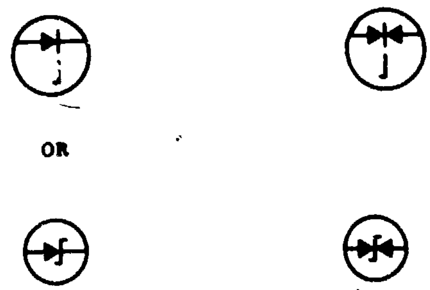
TEMPERATURE-MEASURING THERMOCOUPLE (DISSIMILAR METAL DEVICE)

SEMICONDUCTOR DEVICES

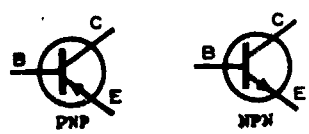
ELECTRON FLOW IS AGAINST THE ARROW.

UNIDIRECTIONAL DIODE; VOLTAGE REGULATOR

BIDIRECTIONAL DIODE



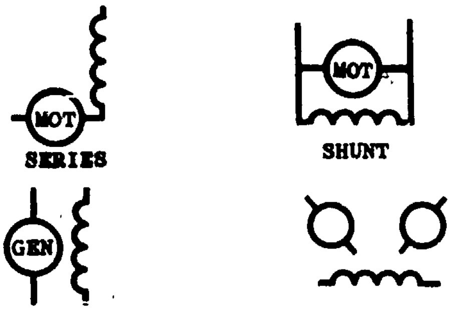
TRANSISTORS



ROTATING MACHINES

MOTOR GENERATOR

TYPES OF WINDINGS



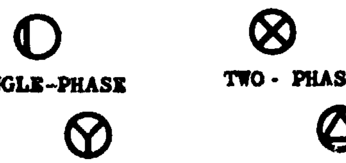
SERIES

SHUNT

SEPARATELY EXCITED

DYNAMOTOR

WINDING SYMBOLS



SINGLE-PHASE

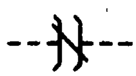
TWO-PHASE

THREE-PHASE (WYE)

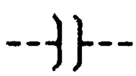
THREE-PHASE (DELTA)

CLUTCH/BRAKE

ENGAGED



DISENGAGED



METERS

A	AMMETER
AH	AMPERE-HOUR METER
CRO	OSCILLOSCOPE
DB	DB (DECIBEL) METER AUDIO LEVEL/METER
DBM	DBM (DECIBELS REFERRED TO 1 MILLIWATT) METER
F	FREQUENCY METER
μA OR UA	MICROAMMETER
MA	MILLIAMMETER
OHM	OHMMETER
PF	POWER FACTOR METER
PH	PHASEMETER
PI	POSITION INDICATOR
REC	RECORDING METER
SY	SYNCHROSCOPE
t°	TEMPERATURE METER
TT	TOTAL TIME METER ELAPSED TIME METER
V	VOLTMETER
VA	VOLT-AMMETER
VAR	VARMETER
W	WATTMETER
WH	WATTHOUR METER

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