R E P O R T   R E S U M E S

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A CURRICULUM DEVELOPMENT STUDY OF THE EFFECTIVENESS OF UPGRADING THE TECHNICAL SKILLS OF EDUCATIONALLY DISADVANTAGED UNION MEMBERS.

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A SECTION OF A JOB TRAINING PROGRAM CONSISTING OF THIRTY 10-HOUR JOB INSTRUCTION CURRICULUM MODULES WAS DEVELOPED FOR UPDATING AND UPGRADING THE TECHNICAL SKILLS OF ELECTRICAL MAINTENANCE EMPLOYEES. THIS JOB TRAINING PROGRAM WAS TRIED OUT IN CLASSES CONSISTING OF MAINTENANCE EMPLOYEES OF THE ELECTRICAL DEPARTMENTS IN A STEEL COMPANY. MEMBERS OF THE CLASSES WERE DIVIDED INTO 2 GROUPS OF 20 EACH. HALF OF THE TRAINEES IN EACH GROUP WAS LOANED AN ELECTRONIC TUTOR TO USE AT HOME. THE OTHER HALF STUDIED TEXT MATERIAL IN A NORMAL WAY WITHOUT ELECTRONIC TUTORS. A TEST WAS PREPARED AND USED AS PRETEST AND POST-TEST TO MEASURE THE MASTERY OF THE SUBJECT MATTER COVERED IN THE 30 CURRICULUM UNITS. THE CONCLUSIONS INDICATED THAT TRAINEES WHO HAD ELECTRONIC TUTORS ACHIEVED HIGHER ON ALL MEASURES. (RS)

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# A Curriculum Development Study of the Effectiveness of Upgrading the Technical Skills of Educationally Disadvantaged Union Members.

Author: Dr. Joseph S. Kopas

Project No. OEG 3-6-061484-0601
Project 6-1484

The Project Reported Herein was Supported by a Grant from the U. S. Department of Health, Education and Welfare Office of Education Bureau of Research - Division of Adult and Vocational Research.

11/28/66

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| PROJECT TITLE: | A Curriculum Development Study of the Effectiveness of Upgrading the Technical Skills of Educationally Disadvantaged Union Members |
| AUTHOR: | Dr. Joseph S. Kopas |
| PRINCIPAL INVESTIGATOR: | Frank Evans, Vice President<br>Negro American Labor Council |
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## SUMMARY OF PROJECT

(a) Grant Number

(b) Title — A Curriculum Development Study of the Effectiveness of Upgrading the Technical Skills of Educationally Disadvantaged Union Members

(c) Investigator — Frank Evans, Vice President

(d) Agency — Negro American Labor Council - Region IV, Cleveland, Ohio

(e) Duration — April 12, 1966 - October 30, 1966

(f) Objectives — To try out and test the practicality and effectiveness of a unique 10-hour job instruction curriculum module as a basis of development of a job training program for updating and upgrading the technical skills of industrial employees.

(g) Procedure — A section of a job training program consisting of thirty 10-hour job instruction curriculum modules was developed for updating and upgrading the technical skills of electrical maintenance employees. This job training program was tried out in classes consisting of maintenance employees of the electrical departments in a steel company.

Members of the classes were divided into two groups of twenty each, one half of the trainees in each group was loaned an electronic tutor to use at home. The other half studied the text material in a normal way without electronic tutors.

A test was prepared and used as pre-test and post-test to measure the mastery of the subject matter covered in the thirty curriculum units.

(h) Results and Conclusions — The members of the class who had electronic tutors to supplement their group instruction with individualized instruction achieved 27% better mastery of the subject matter in 1/3 less time. Their attendance was 14.2% better, their completion of the course 10% greater (20 as against 18) and 25% more enrolled in a subsequent advanced class.

(3) <u>TABLE OF CONTENTS</u>

(4) LIST OF TABLES, GRAPHS, ETC.

## (5) PROBLEM

There is currently a critical shortage of technically skilled workers in industry and business which in many urban centers provides up to 70% of gainful employment. The shortage is getting worse. By 1970 five million more skilled workers including technicians will be needed. Because of this urgent need, and because industry is one of the largest employers, the skill jobs it makes available, provide some of the best and most desirable employment opportunities for adults and for the socio-economically and educationally disadvantaged "unemployable" unemployed youth who are willing and able to qualify for entry jobs.

In the past, on-the-job training conducted by industry plus the experience gained from performing the job provided the necessary skilled manpower needed in industry. The higher level skilled jobs were filled by the more experienced and qualified senior employees. New recruits were employed for the job openings at the bottom of the job progression line. The only "unemployable" youth were the physically handicapped individuals. If more skilled manpower were needed, the job progression line was speeded up, and if less, it was slowed down.

Technological progress in industry has changed all this by adding new and more difficult to learn skills to today's job skill patterns. Furthermore, it has undermined and is continuing to undermine the current skills of employees. Throughout our nation key skill jobs in industry go begging or are poorly manned by senior employees not qualified to meet the changed and changing skill requirements of their jobs, thus losing the opportunity to advance, and clogging up the job progression system. The unemployed youth cannot gain employment in industry, a major employer of youth because the recruits cannot meet the upgraded employment requirements and because the entry and intermediate jobs are filled with employees many of them youth who are presently not qualified to move up the job skill progression ladder.

The job skill progression ladder must be unblocked and unclogged if it is to produce, as it has in the past, the necessary skilled personnel by starting with "unemployable" unskilled youth and ending with them as skilled senior employees.

This unclogging can be done by a well researched, developed, and piloted, upgraded and updated job-skill retraining program, which is professionally comparable in quality and effectiveness to the vocational training program available for in-school youth desiring skill training for gaining employment in industry. A training program for out-of-school youth and adults, employed and unemployed, employable and unemployable, has to be carefully designed to meet the conditions peculiar to the job environment in which the training must take place. It has to include these basic essentials of a sound on-the-job vocational training program, namely:

1. Courses - curriculum - teaching and learning aids that are job-oriented, job-directed and job-applied.
2. Personnel qualified to
   a. Develop and improve the job skill training program.
   b. Promote and interpret it.
   c. Administer it.
   d. Handle the instruction and coaching, and
3. Facilities for conducting the group training phase of the program adequately equipped and supplied with proper training and learning aids.

Industry and business has approximately 85% of its employees in three major job groupings. These three are:

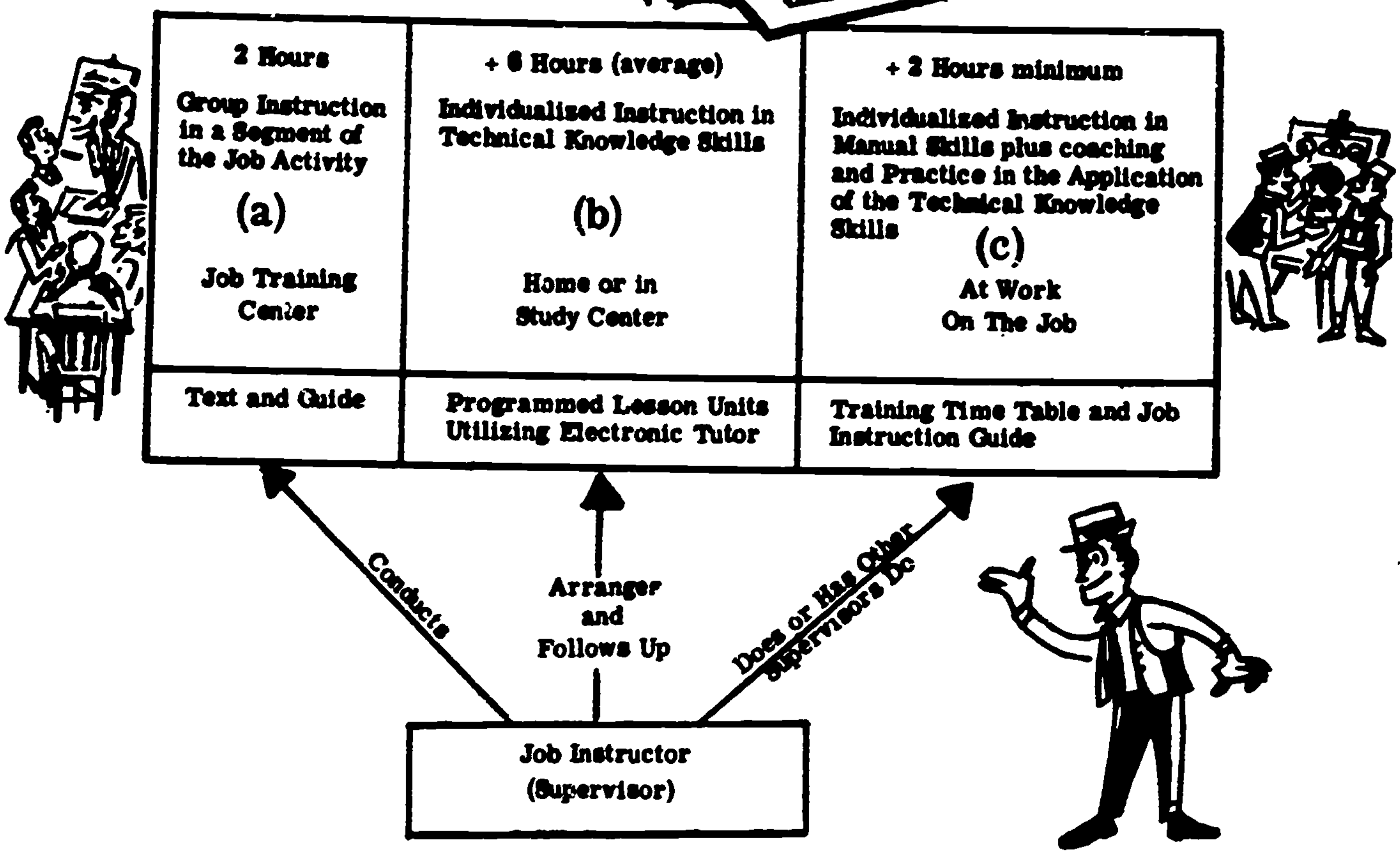
1. The job of constructing, installing and maintaining equipment.
2. The job of operating the equipment.
3. The job of managing the operation and maintenance of the equipment and supervising the personnel involved.

It is for these job groups that job oriented, job directed and job applied courses, curriculum, teaching and learning aids are urgently needed.

## (6) THE APPROACH

The curriculum is the heart of any well designed training program. The curriculum unit (module) developed and tested on a pilot basis in this project is described and illustrated in the following paragraphs. This description also explains (1) how the curriculum unit provides for group and individualized training and (2) how the training is conducted.

# A 10 HOUR JOB INSTRUCTION CURRICULUM MODULE




(a) Group training conducted by a qualified supervisor.

A logical segment of the job is studied and discussed. This discussion includes nature of the job activities or function, the best job practices experienced by members of the group, the problems normally met in performing these job skills, typical solutions and the technical knowledge or skills required to perform the activities in the light of changing job skill requirements.

(b) Individualized technical knowledge skill training guided and supervised by the instructor.

This constitutes the homework necessary to master the technical knowledge skills discussed in (a). The electronic tutor utilizing the programmed lesson material implements what was discussed in (a) and ties in with the application and use of the knowledge gained with (c), which is the on-the-job training phase.

(c) Individualized instruction and coaching by the supervisor.

This involves on-the-job training in the manual skills plus coaching in the application of the technical knowledge skills discussed in (a) and mastered in (b).

The most unique single feature of the proposed curriculum unit is the use of an electronic device designed to provide personalized instruction in the form of a constantly available tutor.

The heterogenity of the typical industrial training group with respect to formal training, technical aptitudes, age and work experience makes individualized instruction a highly desirable and necessary adjunct to group instruction.

Technical knowledge skills are currently the more critical job skills in industry. They can only be mastered by effective study. Studying is difficult for people and particularly for industrial employees because for them it is a part time activity (their job being their full time activity). Furthermore, they have many other pressing demands on their free time which places the study activity in a difficult competitive position.

## (7) OBJECTIVES

The primary purpose of the project is to test the practicality and effectiveness of utilizing an electronic tutor to provide employees with the additional individualized instruction they need to insure mastery of technical job knowledge. Acquiring this knowledge will help them to catch up and keep up with the job skill changes created by technological progress.

A secondary objective is to develop an effective and flexible curriculum module that will make maximum use of group and individualized instruction in a job training context.

Since the problems of studying and mastering knowledge are common to all educational programs, it was expected that any improved techniques forthcoming from this project would be beneficial to students generally.

## (8) PROCEDURE

The curriculum development phase of the project was subcontracted to the Human Engineering Institute Incorporated, a non-profit institution which is professionally qualified to undertake this assignment. The piloting phase was administered by the Negro American Labor Council with the help and guidance of the Human Engineering Institute.

a. General Design: Two industries, a steel company and a foundry company, cooperated in this step-wise job skill training and assisted in the tryout of the proposed curriculum approach to the development of job skill training.

   Employees performing electrical maintenance work constituted the trainee group in this pilot project. The course outline and first 30 curriculum units were developed.

   Precise evaluation devices acceptable to union and management alike were employed to identify and measure the technical knowledge and skill status of the participant in the several stages of the training program.

   Trainees in each class were divided into two groups. One group had available the use of the electronic tutor to assist them in mastering the technical knowledge covered in the curriculum. The other group studied the material in the normal manner.

   Measurements were made (1) prior to the training (2) during the training (3) following completion of the training. Other measures of the effectiveness of the training were also made including the amount of time devoted to study by the individual trainee, the degree of participation in class discussion, and the extent of application of technical knowledge to the job to the extent possible.

b. Schools: The existing Human Engineering Institute job training centers were used to conduct the training.

c. Participants: The two pilot groups, from a steel company consisted of supervisors and senior employees of electrical maintenance departments who voluntarily enrolled in the program in order to update and upgrade their job knowledge and skills. Instructors and coaches for the later expansion of this job training program will be drawn from this group.

d. Methods and Materials: The discussion technique was utilized in conducting the group instruction phase of the training program.

   The programmed lesson phase (utilizing the electronic tutor) and the on-the-job coaching phase constituted the individualized instruction portion of the curriculum activity.

The materials used in instruction included electrical measurement instruments, maintenance manuals from equipment manufacturers, specially developed texts, programmed lesson films and visual and educational aids of various types.

e. Time Schedule: The project was started April 13, 1966 and completed October 30, 1966.

## (9) THE DATA OBTAINED AND AN ANALYSIS OF THE RESULTS

### Comparative Data

| | Group A (with Didactor) | Group B (without Didactor) | Comparison of Group A with Group B |
|---|---|---|---|
| Number of Enrollees | 20 | 20 | - |
| Pre-Test Results | Range 16 - 63<br>Ave. 30.1 | 10 - 70<br>28.8 | + 1.3 |
| Post-Test Results | Range 80 - 100<br>Ave. 94.8 | 45 - 98<br>68.1 | 26.7 greater mastery of study material |
| Length of Time to Complete the Study Material | 24 weeks (self pacing) | 30 weeks (group paced) | 1/3 less time |
| Attendance in the Weekly Sessions | 87.8% | 73.6% | 14.2% better |
| Drop Outs | 0 | 2 | 10% less |
| Enrollment in Advanced Class | No. 20 of 20<br>% 100 | 16 of 18<br>87.5 | 12.5% greater<br>25% greater, if drop outs are included. |

## Results of Use of Didactor Survey

1. How much educational value have you received from your Didactor?

| | | |
|---|---|---|
| a. | Much more than I expected. | 50% |
| b. | About as much as I expected. | 45% |
| c. | Not as much as I expected. | 5% |
| d. | None. | 0% |

2. On the average, how many hours per week have you spent with your Didactor?

| | | |
|---|---|---|
| a. | 8 hours per week | 20% |
| b. | 6 hours per week | 45% |
| c. | 4 hours per week | 20% |
| d. | 2 hours per week | 10% |
| e. | Less than 2 hours. | 5% |

3. Did you find that the time you were spending with your Didactor increased every week?

| | | |
|---|---|---|
| a. | Increased every week. | 40% |
| b. | About the same. | 50% |
| c. | Followed no particular pattern. | 10% |

4. What is your opinion of the films that HEI has developed so far in your course?

| | | |
|---|---|---|
| a. | Too technical. | 10% |
| b. | Satisfactory. | 85% |
| c. | Too elementary. | 5% |

5. Do you feel that the Didactor films do a good job of supplementing or adding to the training which you are receiving in the classroom?

| | | |
|---|---|---|
| a. | Yes | 100% |
| b. | No. | 0% |
| c. | Undecided | 0% |

Comments:

"This is the first training program in which I had no fear of failing."

"I like this method of job training. It is great."

Comments (continued)

"I would like to spend more time on the Didactor in overcoming my lack of formal education."

"My children are also using the teaching machine and are getting better grades in their science courses."

"I think it's great to get individual instruction at my convenience and in privacy."

"I never thought I could learn so much electricity in as short a time."

"Boy! What an improvement in training. I hope it will continue."

"I wouldn't miss this kind of training for any money."

## (10) CONCLUSIONS, IMPLICATIONS AND RECOMMENDATIONS

As the comparative date indicates the performance and participation in the training program of the employees that had the advantage of both group and individualized instruction made possible by the new curriculum unit was significantly better.

The quantity and quality of their training was superior. These employees learned more in less time and participated to a greater degree. Furthermore, this approach to updating and upgrading the skills of electrical maintenance employees proved to be practical, helpful and acceptable both from the standpoint of the students (employees) and the instructors (supervisors).

Since 1955 the Human Engineering Institute has devoted its efforts to developing and conducting training programs designed to assist production and maintenance employees and their supervisors to catch up and keep up with the changes which technological progress is creating in their jobs.

Working in close cooperation with industry, HEI has been deeply involved in researching, developing and testing new and more productive methods and programs aimed at increasing the effectiveness of industry's total training effort.

The development of the Didactor -- an economical, all-purpose, automated tutor -- brought a new dimension of potential achievement to this endeavor.

The key element in this new program of updating and upgrading technical job skills is the unique 10 hour job instruction curriculum module. This concept combines the advantages of group and individualized instruction and utilizes the classroom, the home, and the job in a functionally organized training unit.

The implications of this curriculum approach goes beyond updating and upgrading the skills of employees. It makes possible a job training program that will (1) halt further erosion of present employees' job performance ability, repair the erosion that has already occurred and update their current job knowledge, thereby minimizing payroll waste; (2) help restore the morale, and improve the job security status of employees, especially older employees. It will also strengthen good management and employee relations, thus making it unnecessary for employees to seek help from other sources and to demand restrictive and penalizing action against industry, and (3) give the minority groups that have been discriminated against the best opportunity to acquire the ability to perform successfully the skilled jobs to which they want to aspire and from which they have the most to gain.

This type of a curriculum approach will prove effective in improving the quality and quantity of education in the vocational and academic areas of training.

(11) APPENDICES

(a) Job Skill Training Escalator - The Practical and Effective Answer to the Critical Shortage of Technically Skilled Personnel in Industry

(b) Electrical Maintenance -- Year I Units

(c) Electrical Maintenance -- Year II Units

(d) Electrical Maintenance -- Year III Units

(e) Electrical Maintenance -- Year IV Units

(f) Electrical Maintenance -- Didactor Films (Year 1)

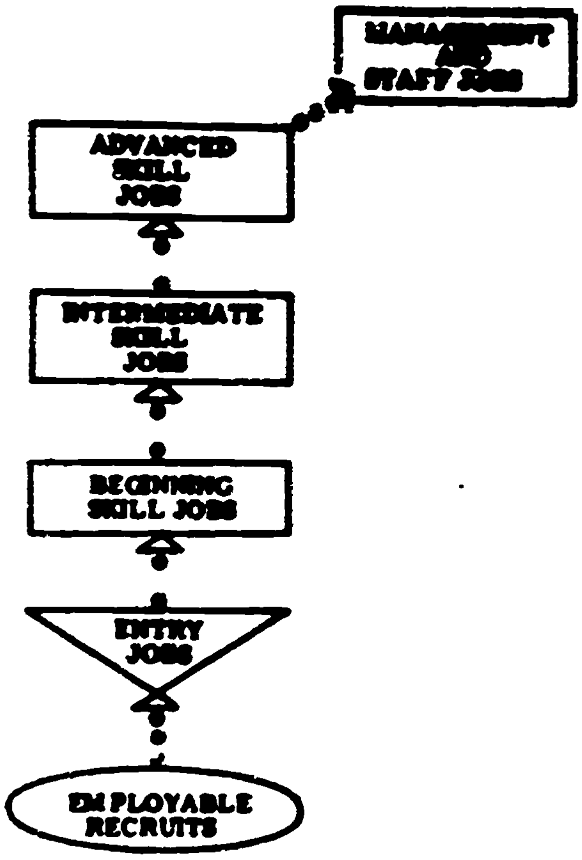
(g) Electrical Maintenance -- Vugraph Cells (Year 1)

(h) Didactor - 8-Frame Repro

(i) Pre-Test and Post Test on Effectiveness of Instruction by Film

(j) Accelerating and Improving Learning

Job Skill Training Escalator - The Practical and Effective Answer To the Critical Shortage of Technically Skilled Personnel In Industry



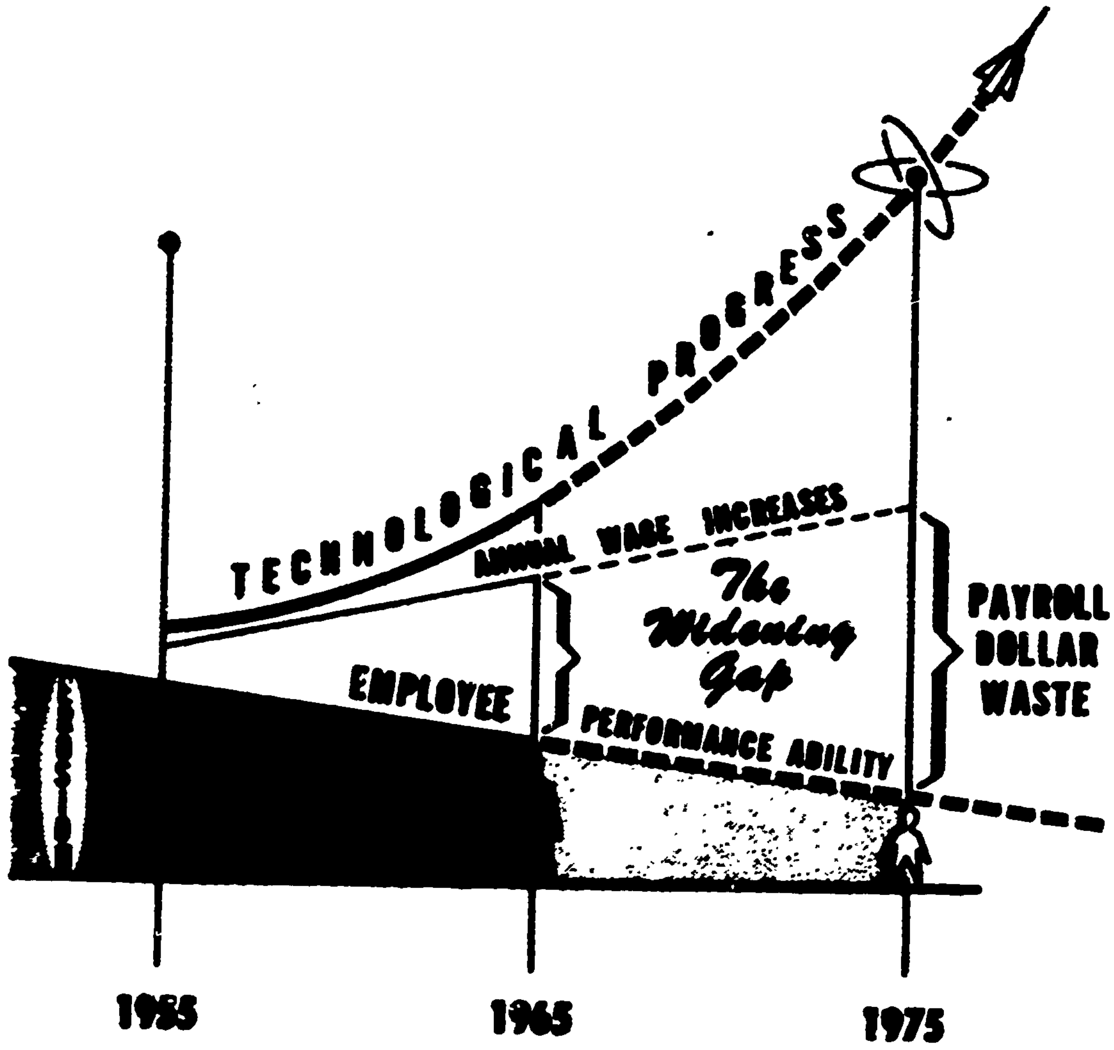

Prior to 1955 the top skill jobs in industry and business were filled by capable and qualified senior employees who took advantage of seniority, experience and job training, most of it informal. The skills needed to perform the jobs were largely manual and physical. The entry jobs were filled by recruits, mostly youth. The primary requirements for employment were physical competence and willingness to work. Educational and vocational requirements were secondary considerations and varied, depending on the availability and need for recruits. That is the reason there are so many "educationally disadvantaged" employees, especially senior employees, in upper level skill jobs, even illiterate.

The more capable and ambitious recruits would then bid for apprenticeship or trainee opportunities when they occurred, or they were placed on helper or trainee positions and thus acquired the beginning or basic skills in a job progression or craft.

Job rights to better paying, more secure, higher skilled jobs were exercised on the basis of seniority and were protected by seniority. The process of moving from the labor pool to the top skill job took time, usually a number of years, during which the employee had ample opportunity and time to acquire almost automatically skill by experience and on a hit-or-miss basis on-the-job training which was primarily informal.

During the war period in the early 1940's, when large numbers of skilled people were needed, this procedure produced them simply by speeding up and formalizing the on-the-job training. Unfortunately it was for these reasons that existing apprenticeships suffered a set back.

Minority groups, and the Negro in particular, were discriminated against in getting employment and in opportunities to move up the progression line. As a result there aren't as many Negroes in the lower levels of the progression line. If the job skills in industry and business remained the same, the Civil Rights Law would be the proper solution to the discrimination problem.

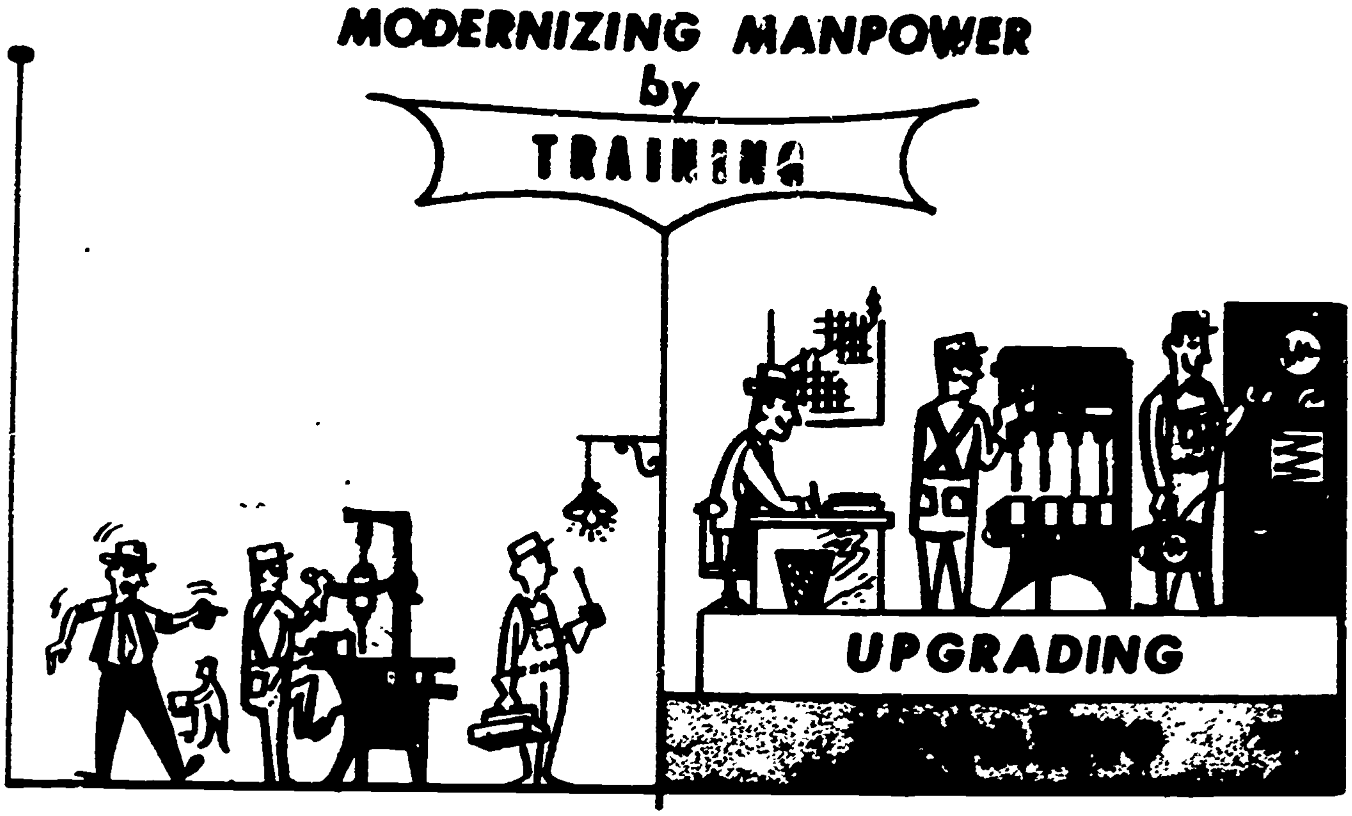



Dramatic technological advances in the last ten years have brought about rapid and extensive modernization of equipment, facilities and processes in industry. Companies have had no alternative but to modernize if they were to remain competitive. Moreover, there appears to be no end to the urgent need to modernize as the already fast pace of technological development continues to accelerate.

Technological progress has undermined very seriously the job performance ability of industry's current employees during the last ten years. During the same period annual wage increases have served to widen the gap between the pay which the employee receives and his diminishing ability to perform his technically changing job. The ever-widening gap is resulting in a tremendous waste of the payroll dollar.

This same erosion of employee competence has created in the minds of the workers--particularly the older ones--a demoralizing fear of losing their jobs. Of even greater concern to them is the fear of ultimate loss of their vocation. The results of these fears can readily be seen in the myriad of restrictive and penalizing clauses which are being inserted into labor agreements and government labor legislation at the insistence of the labor organizations. Unless industry finds a successful way to overcome this apprehension and the growing threat to their job security, employees will continue to exert even greater pressure on their unions and on government for protective action. Regardless of what action is taken, it is certain to be restrictive and costly to industry.

Technological progress and annual wage increases in one form or another will continue. In fact, technological progress will move forward at an even faster clip during the years just ahead. Therefore, the penalty to industry for further delay in action in modernizing its manpower will be even most costly than it is now. For some organizations this lack of action may even prove fatal.




1965

It becomes increasingly evident that industry cannot operate and maintain its technically modernized facilities with "obsolete" manpower. It must have capable supervisory, operating and maintenance technicians in increasing numbers. At present it does not have enough of them and for all practical purposes, there are none available and none in training. Worst of all, there is no effective plan currently in operation to train them.

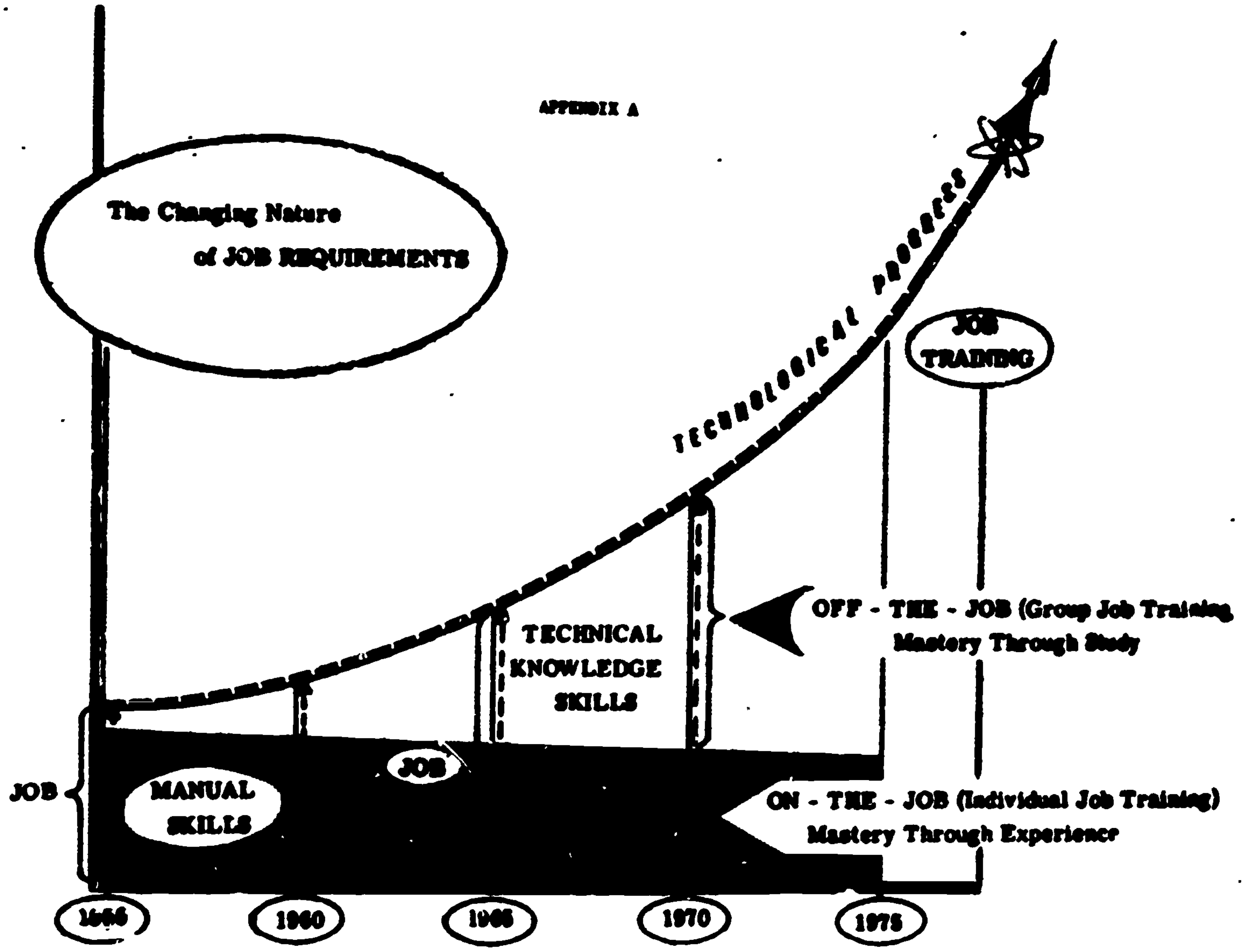
The changes in jobs and employment conditions that technological progress is creating will "scrap" and dump on the unemployment heap thousands of current employees along with the obsolete equipment they have been operating unless some practical, effective and economical method is found to help these employees as soon as possible catch up and keep up with the changes; updating and upgrading of employees must be done before they become unemployed for it is too difficult, too costly and too late to do it after they are unemployed.

This is particularly true with the thousands of older workers who have most to lose and are in the least favorable position to keep up with their technically changing jobs. They average 45 years of age, have had long service with their employers, are in key jobs, have good work records, and are too young to be retired and too old to start over again in a new, unrelated and unfamiliar vocation.

There needs to be developed and put into operation a mass program of updating and upgrading to modernize present industrial manpower. Technological progress makes obsolete not only equipment and facilities but manpower as well. It is relatively easy, although costly, to scrap obsolete equipment and replace it with up-to-date equipment. However, it is not only difficult, but practically impossible to scrap "obsolete manpower" and replace it with qualified manpower.

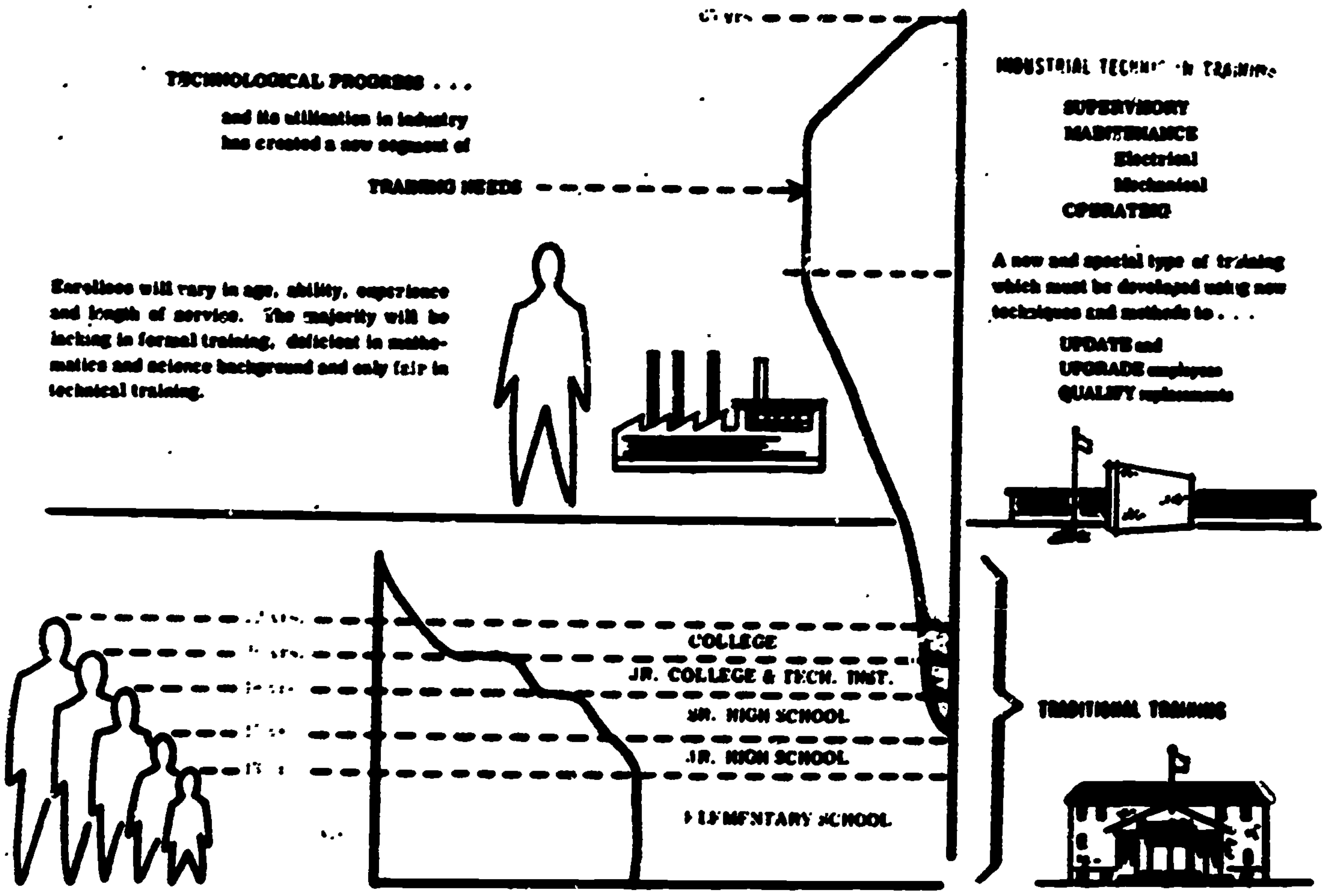
Therefore, the practical answer to this problem is for industry to modernize its manpower by means of an updating and upgrading program. Only by manning modern facilities with properly trained employees can industry realize the benefits of technological progress and obtain the necessary returns from the huge investment that modernization of equipment and facilities requires.

APPENDIX A




When a comparison is made of the job skills in 1955 with the job skills of 1965 it becomes evident that the 1965 job skills are not merely a change in the manual (hand skills) but consist of a significant and increasing addition of technical knowledge (head skills), and if we look to 1970 we can see that the technical knowledge skills will become a significantly larger proportion of the job skill mix. That means that employees in industry will not only need to catch up but keep up with their changing job requirements. To master these new technical knowledge skills a person must have a reasonably good grasp of the fundamentals of mathematics and science and must do considerable studying to master these skills. He cannot acquire them in the way he has been acquiring the manual skills through experience and practice. Hit-or-miss informal job training will no longer suffice as it has in the past in providing the job skills an employee needed. The job training program that will help employees acquire the technical knowledge skills must be updated and upgraded, expanded and formalized.

*Modernization of Manpower through a Unique and Special Program . . .*

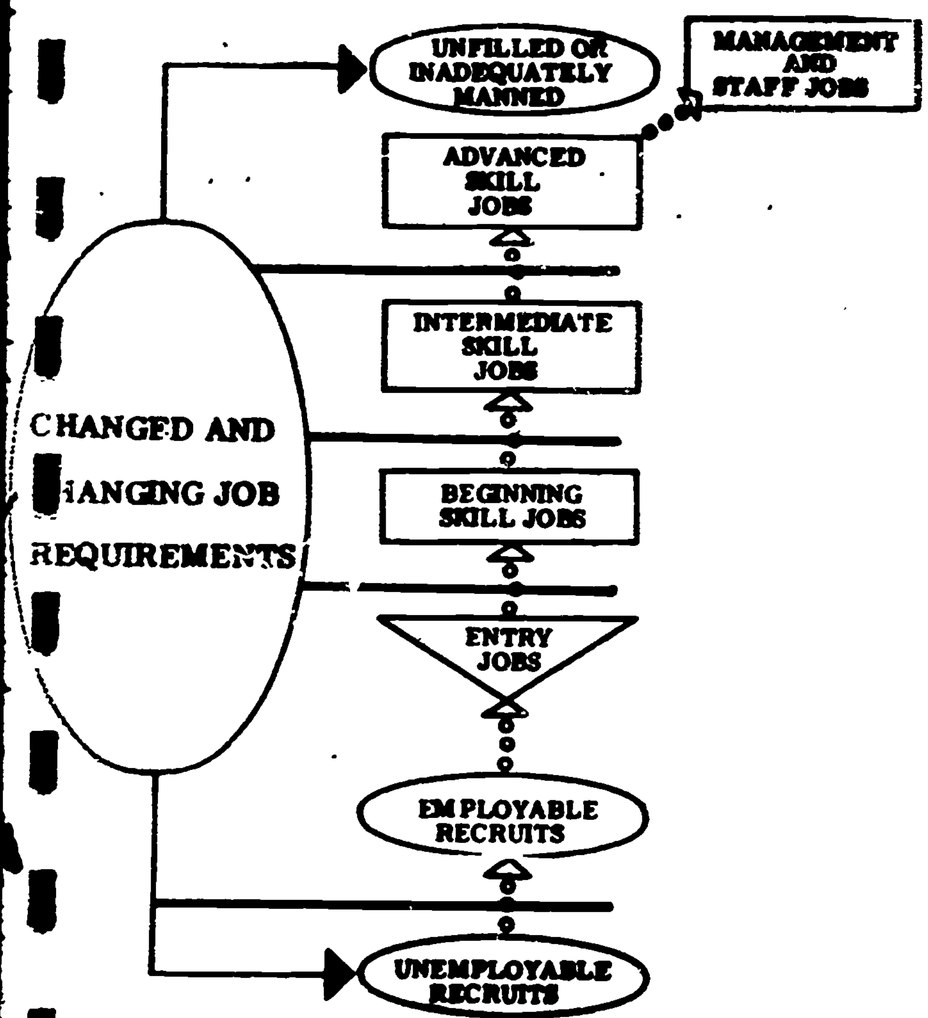



**The updating and upgrading of current supervisory, production and maintenance employees presents a challenging training problem because employees vary in age, ability, experience and length of service. Moreover, the majority are lacking in formal education, are deficient in mathematics and science, and are only fair in technical aptitude. For most of these employees the traditional technical training programs are ineffective, impractical and uninteresting. The most practical, most effective and most economical training programs for retraining individuals that are currently employed and for the unemployed in the labor market are training programs that are job oriented, job directed and job applied.**

**This will require new approaches to class formation, methods of teaching and selection and training of the instructors.**

**New text material; special educational and visual aids.**

**More effective follow-up and follow-through techniques to insure sound application of the training on the job.**




Since 1955 technological progress has ushered in a new job skill mix. As an employee aptly put it, "I don't have to work so hard now physically, but I have to use my head more."

Technical knowledge skills have been added to the normal manual skills. As a result, the job skill situation in industry and business today is radically different from what it was. These skill changes have already reached the point where new recruits are no longer able to meet the employment requirements, and the senior employee can no longer, through job experience and on-the-job training, acquire the skills needed in performing the top jobs in the job progression line.

As a result, there are a growing number of top skill jobs which are either unfilled or inadequately filled and a growing number of new recruits who are becoming unemployable and are therefore unemployed. The job progression line is logged up by employees who are unable to advance on the basis of seniority to the top skill jobs.

The seriousness of this situation is apparent when it is realized that what the new recruit needs to get employment under the upgraded educational requirements, the senior employee needs to maintain and continue his employment, that is, to keep from becoming unemployed. Both are disadvantaged educationally, with the senior employee, more so. Because of discrimination in education and for other obvious reasons the Negro is likely to have more of this so-called "educational disadvantage".

Percentage-wise, the largest number of unemployable youth are Negro.

The hard work ahead lies in the areas of training, education, and motivation of minority groups to overcome their educational disadvantage.

# *Who is the "Older Worker"*

THE SENIOR EMPLOYEE

Average Age - 45+ yrs.

Education 9th+ grade

Yrs. of Seniority 25+ yrs.

Yrs. of Work Experience 28+ yrs.

Out of School 31 years.

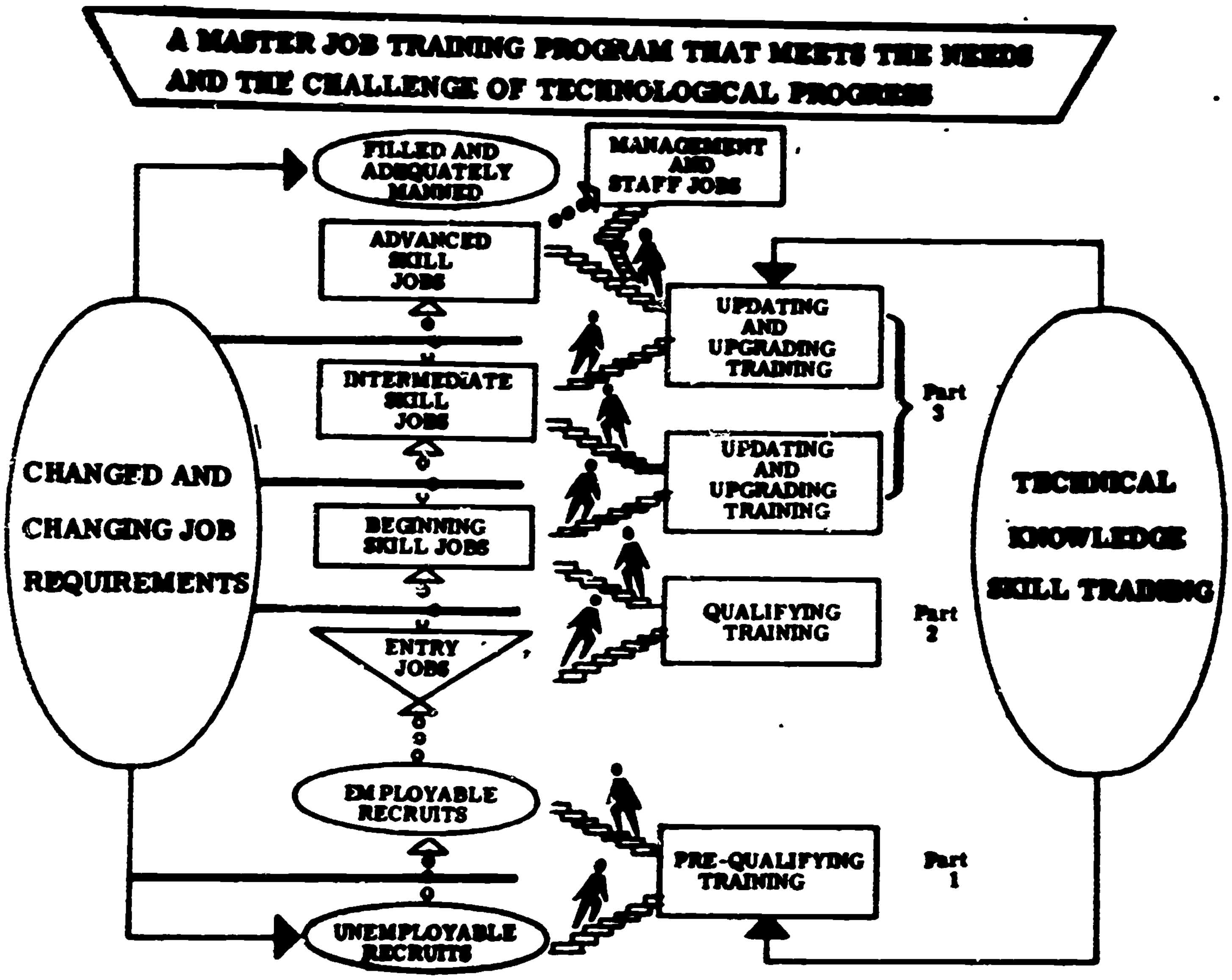
He may be a Supervisor, an Operator, or Maintenance man.

He has a key job at top of his job progression.

He has attained highest degree of
- Job Success
- Job Effectiveness
- Earning Power and Job Security

HE IS CURRENTLY THE PRIME VICTIM OF TECHNOLOGICAL PROGRESS WHICH HE DIDN'T ASK FOR, DIDN'T WANT, AND OVER WHICH HE HAS NO CONTROL.

- HE IS THE FIRST TO BE HIT, HAS THE MOST TO LOSE, AND IS IN THE LEAST FAVORABLE POSITION TO HELP HIMSELF.
- HE FINDS HIMSELF IN AN INESCAPABLE AND DESPERATE RACE BETWEEN OBSOLESCENCE AND RETIREMENT.
- TO COMPOUND HIS PROBLEM, HE FINDS THAT HIS COMPETITORS IN THIS RACE -- YOUNG MEN WHO ARE BETTER EDUCATED AND BETTER QUALIFIED -- ARE RECEIVING PREFERENTIAL TREATMENT.
- HE IS SEEKING HELP FROM HIS EMPLOYER, FROM HIS UNION, AND FROM HIS GOVERNMENT.
- UPDATING AND UPGRADING TRAINING IS HIS ONLY HOPE FOR THE FUTURE.
- HE NEEDS THIS TRAINING NOW - NOT AFTER HE IS UNEMPLOYED AND ON RELIEF.




The "unemployable" youth who wants employment in industry and who would have been employed by industry, if the job skill requirements had not been changed by technological progress:

(1) Needs a practical and effective occupationally-oriented job-directed and job-applied pre-qualifying training program to help him catch up with these changed entry job skill requirements, plus

(2) A beginning job skill qualifying training program to help him move into the job progression line and within it gain the opportunity for acquiring the additional skills, and

(3) Updating and upgrading training program that will help him to keep up with the changing job skill requirements, so that he can take advantage of the top skill job based on seniority and thereby protect his job rights and his continuity and stability of employment.

## A MASTER JOB TRAINING PROGRAM THAT MEETS THE NEEDS AND THE CHALLENGE OF TECHNOLOGICAL PROGRESS

**PART 3** ON-THE-JOB
UPDATING AND UPGRADING TRAINING PROGRAM

(A) JUNIOR AND SENIOR EMPLOYEES
1) MAINTENANCE SKILL TRAINING
2) PRODUCTION SKILL TRAINING
3) CRAFT SKILL TRAINING

(B) SUPERVISORY EMPLOYEES
MANAGEMENT SKILL TRAINING

**PART 2** ON-THE-JOB
QUALIFYING TRAINING PROGRAM

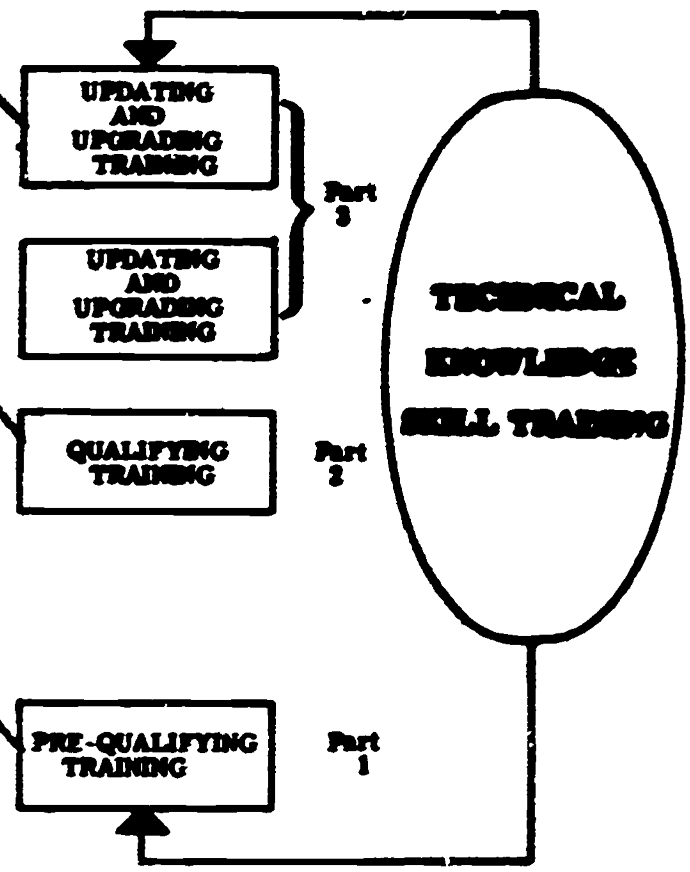
(A) PRODUCTION JOB LEARNERS
(B) MAINTENANCE JOB TRAINEES
(C) CONSTRUCTION CRAFT APPRENTICES

**PART 1** EMPLOYMENT PRE-QUALIFYING TRAINING PROGRAM

(A) VOCATIONAL ANALYSIS, GUIDANCE AND COUNSELING ESSENTIAL FOR THE DETERMINATION AND SELECTION OF AN OCCUPATIONAL OBJECTIVE.

(B) REFRESHER AND MAKE-UP OF BASIC EDUCATIONAL DEFICIENCIES, DEVELOPMENT OF SKILLS AND TOOLS OF LEARNING AND CREATION OF DESIRE FOR TRAINING AND FOR COOPERATION IN THE TRAINING PROGRAM.

(C) HIGH SCHOOL REFRESHER, COMPLETION OR EQUIVALENCY TRAINING AND PERSONAL DEVELOPMENT NECESSARY TO MEET ENTRY EMPLOYMENT AND SELECTION REQUIREMENTS OF THE OCCUPATIONAL OBJECTIVE.



# *The* Production and Maintenance *Employee*

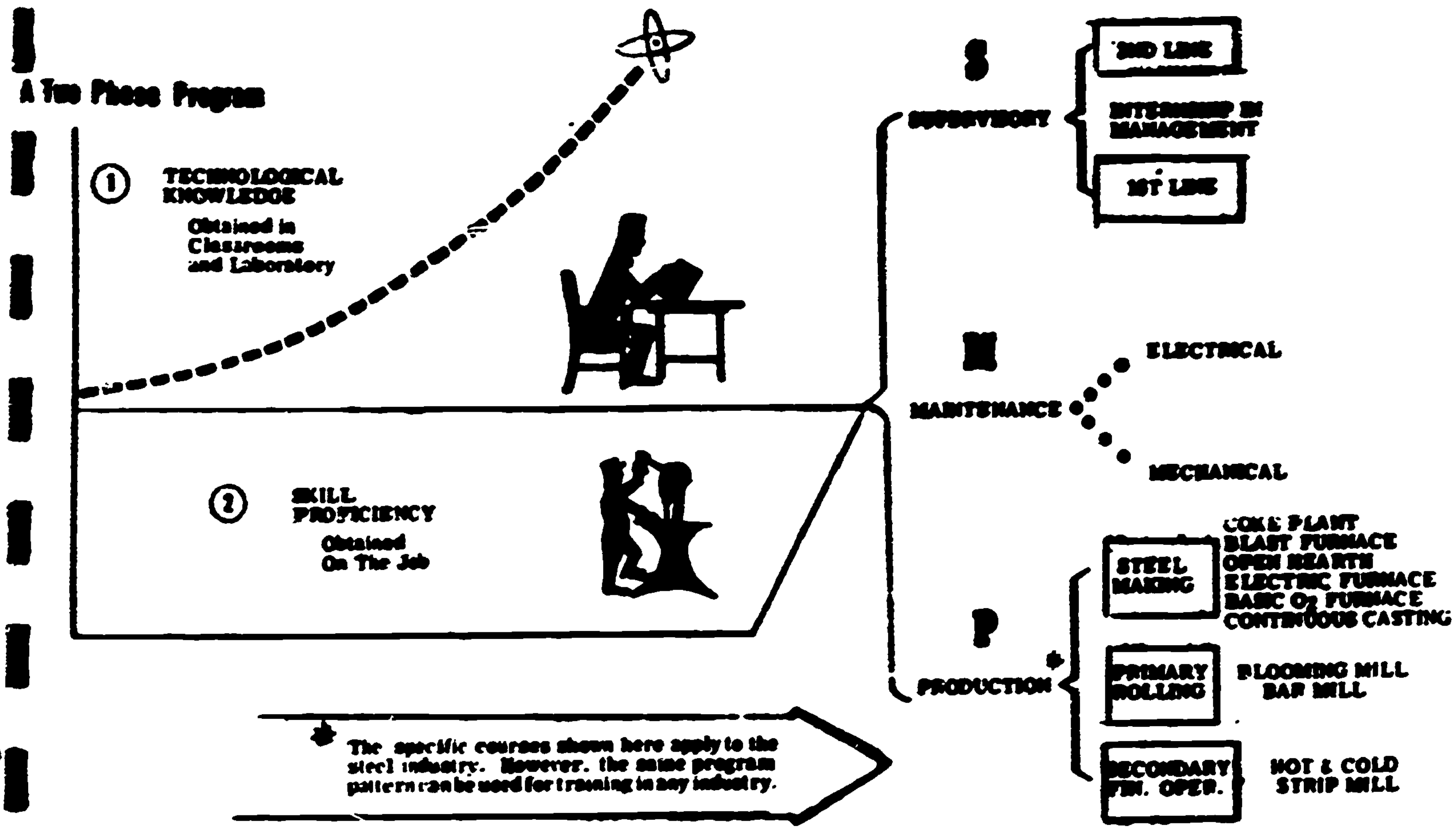
WANTS AND NEEDS TO UNDERSTAND HIS JOB BETTER TECHNICALLY; SO HE CAN DO MORE OF IT, AND DO IT BETTER.

# *The Supervisor*

WANTS AND NEEDS HIS EMPLOYEES TO UNDERSTAND THEIR JOBS BETTER TECHNICALLY; SO THEY CAN DO MORE OF THEIR JOB, AND DO IT BETTER.

# Supervisory, Maintenance & Production Employees

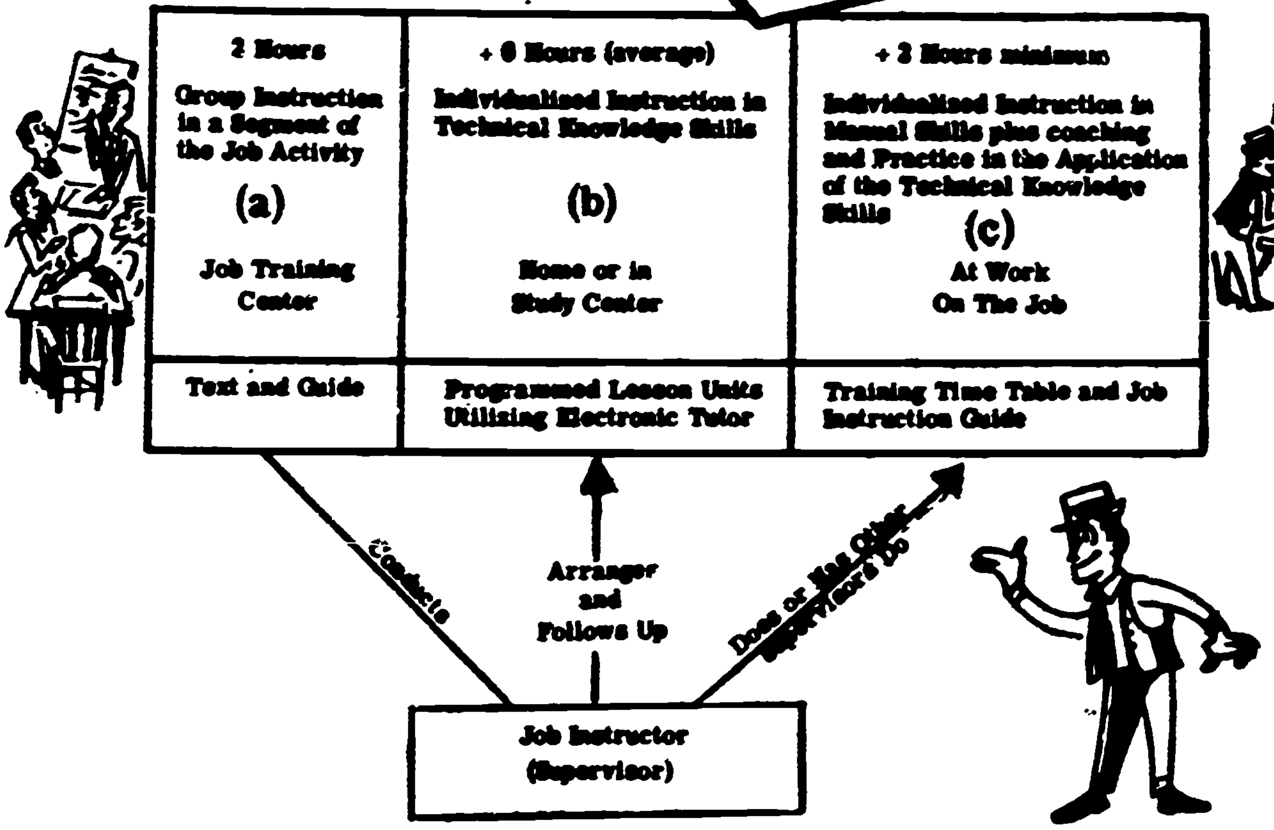
Three basic groups of updating and upgrading programs are provided to cover Operating employees, two for Maintenance workers, and two for Supervisory people. Extensive batteries of these programs have been developed and are "on the shelf.". Additional programs are being developed continuously and existing materials are under frequent review and revision to keep them up-to-date with technological changes and progress.




In the case of job training programs the job naturally becomes the course and the knowledge and skills required to perform the job constitute the text material. Three basic jobs, namely (1) the job of managing the modernized equipment and facilities, (2) the job of operating the equipment effectively and (3) the job of maintaining the equipment adequately constitute work that approximately 85% of the personnel in industry perform. Therefore, by concentrating on these job activities only a relatively few basic job training courses are required and need to be developed.

A minimum of 1200 hour of individual and group instruction should be made available in each job updating and upgrading course to aid the employees in catching up and keeping up with the technical skill changes in their job.

# A 10 HOUR JOB INSTRUCTION CURRICULUM MODULE



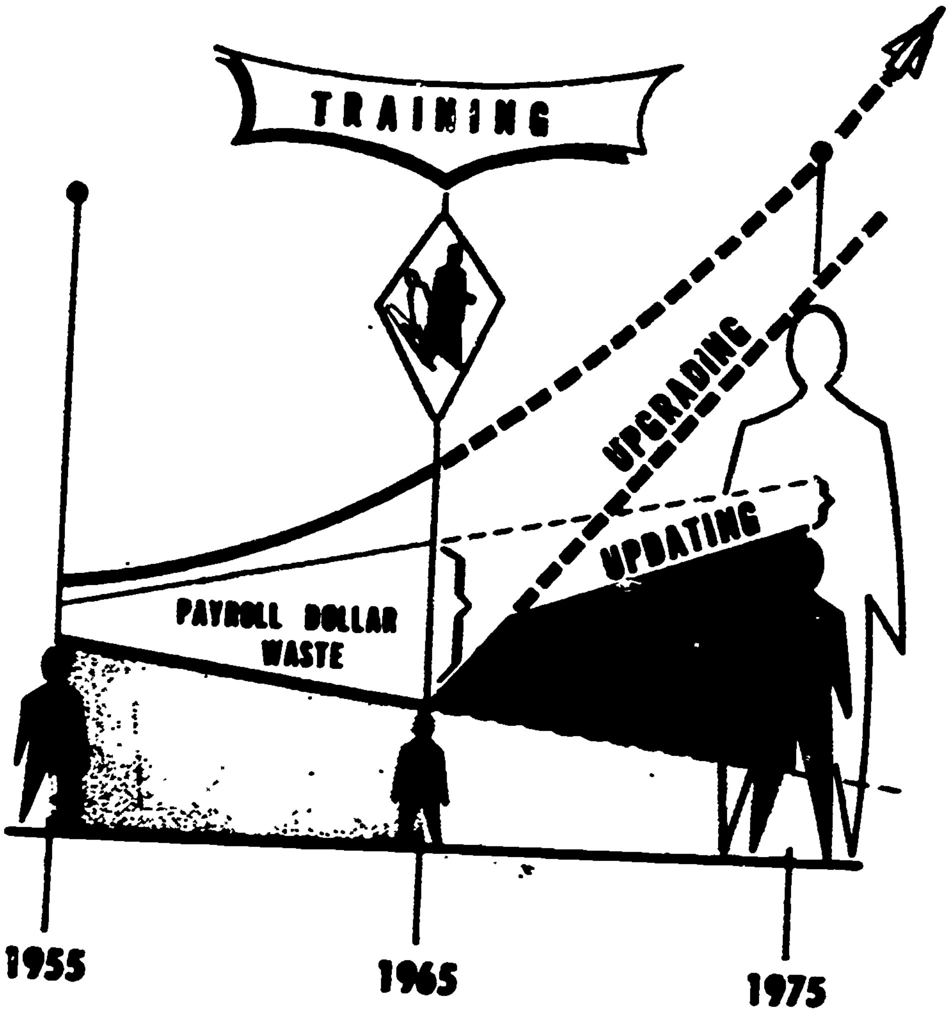

(a) Group training conducted by a qualified supervisor. A logical segment of the job is studied and discussed. This discussion includes nature of the job activities or function, the best job practices experienced by members of the group, the problems normally met in performing these job skills, typical solutions and the technical knowledge or skills required to perform the activities in the light of changing job skill requirements.

(b) Individualized technical knowledge skill training guided and supervised by the instructor.

This constitutes the homework necessary to master the technical knowledge skills discussed in (a). The electronic tutor utilizing the programmed lesson material implements what was discussed in (a) and ties in with the application and use of the knowledge gained with (c), which is the on-the-job training phase.

(c) Individualized instruction and coaching by the supervisor.

This involves on-the-job training in the manual skills plus coaching in the application of the technical knowledge skills discussed in (a) and mastered in (b).




A practical, effective and economical job training program will provide an ample supply of qualified supervisory, production and maintenance technicians which industry must have to manage, operate and maintain the equipment and facilities involved in its costly and growing modernization program.

It will put a halt to further erosion of present employees' job performance ability, repair the erosion that has already occurred and update their current job knowledge, thereby minimizing payroll waste.

It will help restore the morale, and improve the job security status of employees, especially older employees. It will also strengthen good management and employee relations, thus making it unnecessary for employees to seek help from other sources and to demand restrictive and penalizing action against industry.

It will also give the minority groups that have been discriminated against the best opportunity to acquire the ability to perform successfully the skilled jobs to which they want to aspire and from which they have the most to gain.

ELECTRICAL MAINTENANCE -- YEAR I

UNITS

As published for 1966-67

EM 1-1
5/6/66

YOUR ROLE AS AN ELECTRICAL MAINTENANCE MAN IN INDUSTRY

A. Introducing the maintenance man.
B. Keeping electrical equipment operating at peak performance.
C. Preventing trouble and insuring maximum life of equipment.
D. Repairing electrical equipment.
E. Doing the maintenance job safely.

EM 1-2
5/4/66

EXAMINING SOME BASIC ELECTRICAL IDEAS

A. Sources of power.
B. What is electricity?
C. Following the electric current.
D. Comparing voltage and pressure.
E. Controlling current flow with resistance.
F. The reasons for voltage drop.
G. The direction of current flow.

EM 1-3
5/12/66

CHANGING HEAT ENERGY INTO ELECTRICITY BY MAGNETISM

A. Getting acquainted with magnetism.
B. What magnets can do.
C. Exploring the magnetic field.
D. Investigating the nature of AC.
E. Understanding the basic forms of generators.

EM 1-4
5/11/66

ELECTRICAL RESISTANCE AND RESISTORS

A. What is resistance?
B. Factors controlling resistance.
C. Symbols and units.
D. Construction and properties.
E. Resistor color codes.
F. Maintaining power resistors.

6/27/66

EM 1-5
12/8/65

BECOMING BETTER ACQUAINTED WITH OHM'S AND KIRCHHOFF'S LAWS AND DC CIRCUITS

A. Fundamental principles of electricity.
B. Understanding Ohm's law.
C. Using Kirchhoff's law.
D. Series circuit analysis.
E. Parallel circuit analysis.
F. Power and energy.
G. Combination circuits and circuit simplification.

EM 1-6
12/17/65

THE GENERATION, TRANSMISSION AND DISTRIBUTION OF ELECTRICITY

A. Manufacturing and delivering electricity.
B. Using the transformer to change voltage.
C. AC plant distribution systems.
D. DC power becomes necessary.

EM 1-7
12/8/65

USING ELECTRICITY SAFELY AND EFFICIENTLY

A. Grounding equipment for safety.
B. Electricity costs money.
C. Maintaining plant electrical equipment.

EM 1-8
12/20/65

CHOOSING POWER TO SUPPLY MOTORS USED FOR LIFTING AND HANDLING MATERIALS

A. Why DC machinery is best suited to this work.
B. Converting AC to DC with generators.
C. Converting AC to DC with static units.
D. Individual power supplies lead to increased use of rectifiers.

EM 1-9
12/21/65

DIRECT CURRENT MOTORS IN MODERN INDUSTRY

A. Construction of DC motors and generators.
B. DC motor fundamentals.
C. Armature reaction and brush position.
D. The series motor.
E. The shunt motor.
F. The compound motor.

EM 1-10 12/22/65 — **VARIABLE VOLTAGE DC MOTORS AND GENERATORS**

A. Ohm's and Kirchhoff's laws and the DC motor.
B. Analyzing DC generator operation.
C. Power, torque, tension and speed fundamentals.
D. Adjustable generator voltage DC control systems.

EM 1-11 1/3/66 — **ROTATING AND MAGNETIC DC REGULATORS**

A. The Amplidyne rotating regulator.
B. The Rototrol rotating regulator.
C. Magnetic amplifier "package" drives.

EM 1-12 1/24/66 — **INTRODUCING ALTERNATING CURRENT AND ROTATING FIELDS**

A. Ohm's and Kirchhoff's laws applied to AC circuits.
B. Inductance and capacitance.
C. Introducing AC motors.
D. Rotating magnetic fields.

EM 1-13 1/13/66 — **SINGLE PHASE AC MOTORS**

A. Split phase motors.
B. Other single phase motors in industry.
C. Motor maintenance pays big dividends.

EM 1-14 1/17/66 — **RESISTANCE, AND INDUCTANCE AS CIRCUIT ELEMENTS**

A. Alternating current fundamentals.
B. Resistance as an AC and DC circuit element.
C. Inductive effects on DC.
D. Inductive effects on AC.

EM 1-15 1/19/66 — **CAPACITANCE IN AC AND DC CIRCUITS**

A. Capacitive effects on DC.
B. Capacitive effects on AC.
C. Types of capacitors.

EM 1-16
2/8/66

SERIES AC CIRCUIT FUNDAMENTALS

A. Vectors and right triangles.
B. The series-resistance-inductance circuit.
C. The series-resistance-capacitance circuit.
D. Resistance, inductance and capacitance in series.

EM 1-17
2/3/66

PARALLEL AC CIRCUIT FUNDAMENTALS

A. The parallel resistance-inductance circuit.
B. The parallel resistance-capacitance circuit.
C. Resistance, inductance and capacitance in parallel.

EM 1-18
2/9/66

LEARNING TO READ THE ELECTRICAL LANGUAGE

A. The electrical alphabet -- symbols.
B. Abbreviations and definitions.
C. Types of electrical diagrams and their purposes.

EM 1-19
3/2/66

MEASURING ELECTRICAL QUANTITIES -- A MAINTENANCE ESSENTIAL

A. DC meter fundamentals.
B. AC meter fundamentals.
C. Moving iron instruments.
D. Electrodynamometer instruments.
E. Using Ohmmeters.

EM 1-20
3/7/66

REDUCING THE VOLTAGE FOR DISTRIBUTION WITH SINGLE PHASE TRANSFORMERS

A. Transformer principles.
B. Construction features.
C. Preventive maintenance.

EM 1-21
3/14/66

CONNECTING SINGLE PHASE TRANSFORMERS

A. Transformer connections.
B. Auto transformers.
C. Instrument transformers.

Electrical Maintenance -- Year I
Units

EM 1-22
3/10/66

USING THREE PHASE POWER IN INDUSTRY

A. Why three phase?
B. Three phase voltages and currents.
C. The three phase "Y" or star connection.
D. The three phase triangle or delta connection.
E. Three phase transformers and loads.
F. Installing and maintaining transformers.
G. Troubleshooting three phase systems.

EM 1-23
3/16/66

UNDERSTANDING DC MOTOR CONTROLS

A. Starting, accelerating, reversing and stopping.
B. Controlling with the shunt field.
C. Armature voltage ~~and resistance~~ control.
D. Variable voltage control.
E. Speed, torque and tension regulators.
F. Troubleshooting DC motor drives.

EM 1-24
4/14/66

INDUSTRY'S WORKHORSE -- THE SQUIRREL CAGE INDUCTION MOTOR

A. Motors and rotating magnetic fields.
B. Single phase motors.
C. Speed and torque relations.
D. Multi-speed motors.
E. Troubleshooting squirrel cage motors.

EM 1-25
6/8/66

THE WOUND ROTOR INDUCTION MOTOR

A. Adding resistance to the rotor circuit.
B. Speed and torque.
C. Manual controls.
D. Automatic controls.
E. Maintaining wound rotor motors.

EM 1-26
6/7/66

SYNCHRONOUS MOTORS IN INDUSTRY

A. Construction and operating principles.
B. Changing the field strength.
C. Starting methods.
D. Power factor correction.
E. Maintenance and troubleshooting.

EM 1-27
12/31/65

**MOTOR PROTECTION AND BASIC MOTOR CONTROLS**

A. What are motor controls?
B. Why motors overheat.
C. Current type protectors.
D. Temperature type protectors.
E. Basic motor control circuits.
F. Give your controls a break.

EM 1-28
1/4/66

**PERFORMING MOTOR AND CONTROL MAINTENANCE EFFICIENTLY AND SAFELY**

A. Using troubleshooting charts and maintenance check lists.
B. AC and DC motor check lists.
C. AC and DC motor and motor starter check lists.
D. Industrial control check lists.
E. Twenty-one electrical safety rules.

EM 1-29
4/18/66

**USING VACUUM TUBES IN INDUSTRY -- ELECTRICITY IN A BOTTLE**

A. Introducing electronics and its historical background.
B. Tubes are control valves.
C. Diodes: vacuum tube rectifiers.
D. Triodes: adding the control grid.
E. The basic vacuum tube amplifier.

EM 1-30
3/28/66

**TETRODES, PENTODES, AND GAS TUBES**

A. Tetrodes and pentodes
B. Basic phototube operations.
C. Electronic power tubes: thyratrons, ignitrons, and mercury pool rectifiers.

ELECTRICAL MAINTENANCE -- YEAR II

UNITS

As published for 1966-67

EM 2-1
5/9/66

CONTROLLING SPEED, TORQUE AND POWER WITH DC MOTORS

A. Review - DC motor Fundamentals
B. Terms and Relationships to Remember
C. What kind of Control Do We Need?
D. Understanding the Elementary Ward Leonard Control
E. Learning How Variable Voltage Control Operates

EM 2-2
5/11/66

SYNCHRONOUS AND INDUCTION MOTOR DRIVES

A. Synchronous Motor Drives
B. Squirrel Cage Induction Motor Drives
C. Which Drive Motor Shall We Use?
D. Starting Large AC Drive Motors
E. Updating Variable Voltage DC Drives

EM 2-3
5/18/66

UNDERSTANDING INDUSTRIAL CONTROL WITH SCHEMATIC DIAGRAMS

A. Using Electrical Roadmaps
B. Reading Schematics Which Show How DC Motors Are Controlled
C. Tracing the Squence of Operation of a DC Motor Control
D. DC Adjustable Voltage Control with Motor-Generator Sets

EM 2-4
5/12/66

REGULATING VARIABLE VOLTAGE SYSTEMS WITH THE ROTOTROL

A. What Is the Rototrol?
B. Basic Rototrol Circuits
C. Applications of the Rototrol
D. Rototrol Field Marking and Identification
E. Voltage Regulating Circuits
F. The Current Limit Rototrol

EM 2-5
5/16/66

ROTOTROL APPLICATIONS

A. Voltage and Speed Regulation
B. Current and Power Regulation
C. Other Applications

9/1/66

Electrical Maintenace -- Year II
Units

EM 2-6
5/16/66

VARIABLE VOLTAGE DC CONTROL WITH THE AMPLIDYNE ROTATING AMPLIFIER

A. Amplidyne for Automatic Control
B. Amplidyne Operation
C. Voltage Control Circuit
D. Speed Control Circuit
E. Amplidyne in the Metal Industry
F. Amplidyne Maintenance
G. Polarity Determination
H. Terms to Remember

EM 2-7
5/17/66

VARIABLE SPEED DRIVES USING AC SUPPLY POWER

A. Reviewing Our Knowledge of Variable Speed Drives
B. Magnetic Slip Couplings
C. Adjustable Frequency AC Drives
D. The Brush Shifting Polyphase Shunt Motor (SCHRAGE)
E. Low Power Adjustable Speed AC Drives

EM 2-8
5/18/66

CONVERTING AC TO DC WITH STATIC RECTIFIERS

A. The Half Wave Rectifier
B. The Full Wave Center Tapped Rectifier
C. The Single Phase Bridge Rectifier
D. Polyphase Rectifers

EM 2-9
5/19/66

METALLIC AND SEMICONDUCTOR RECTIFIERS

A. Metallic or Dry Plate Rectifiers
B. Silicon and Germanium Rectifiers
C. The Controlled Avalanche Silicon Diode Rectifier
D. Using Rectifiers for Arc and Surge Suppression

EM 2-10
5/22/66

THE SATURABLE REACTOR CONTROL AND AMPLIFIER

A. Reviewing Magnetic Fundamentals
B. The Series Resistance-Variable Inductance Circuit
C. The Swinging Choke -- A Saturable Reactor
D. Adding the DC Control Winding
E. Improving the DC Control Winding
F. Saturable Reactor Applications

EM 2-11
5/20/66

MAGNETIC AMPLIFIERS

A. Development of Magnetic Amplifiers
B. Self-Saturation and Internal Feedback
C. Adding the Bias and Feedback Windings
D. Circuits and Symbols
E. Magnetic Amplifiers have Good and Bad Points
F. Core Materials

EM 2-12
5/26/66

TRANSMITTING MECHANICAL MOTION WITH ELECTRICAL GEARING - THE SYNCHRO

A. Synchro Motors and Generators
B. Synchro Differential Motors and Generators
C. Synchro Control Transformers
D. Other Types of Control Synchros
E. The Power Synchro System

EM 2-13
5/25/66

USING YOUR MOST IMPORTANT TOOLS -- INSTRUMENT AND METERS

A. Basic DC Meters
B. Basic AC Meters
C. Measuring Current Flow with Ammeters
D. Measuring Electrical Pressure with Voltmeters
E. Measuring Resistance with Ohmmeters
F. The Multimeter and Meter Sensitivity
G. Measuring Insulation Resistance
H. Other Types of Testers

EM 2-14
5/27/66

MEASURING HIGH CURRENT, VOLTAGE AND POWER

A. Using Shunts with DC Ammeters
B. Using Mulitpliers with DC Voltmeters
C. Instrument Transformers for High Current and Voltage AC Measurements
D. Operation, Care and Maintenance of Meters

Electrical Maintenance -- Year II
Units

| | | |
|---|---|---|
| EM 2-15<br>6/9/66 | BECOMING FAMILIAR WITH VACUUM TUBE VOLTMETERS AND THE OSCILLOSCOPE | |
| | A. Errors with Voltmeters and Multimeters<br>B. Other Troubles with the Multimeter<br>C. Using The Vacuum Tube Voltmeter<br>D. The Cathode Ray Oscilloscope<br>E. Understanding the Scope Controls<br>F. Applications for the Scope | |
| EM 2-16<br>6/13/66 | ACHIEVING PRECISE CONTROL WITH ELECTRONICS | |
| | A. Fundamentals of Vacuum Tubes<br>B. How Diodes and Simple Rectifiers Operate<br>C. How Triodes and Simple Amplifiers Operate<br>D. The Three Basic Amplifiers<br>E. How the Tetrode and Pentode Improve the Amplifier<br>F. Transducers Provide the Input Signals to the Amplifier | |
| EM 2-17<br>6/16/66 | UNDERSTANDING BASIC TUBE TYPE RECTIFIERS | |
| | A. Single Phase Rectifiers and Vacuum Tubes<br>B. Gas Filled Tubes and Polyphase Rectifiers<br>C. Polyphase Rectifier Circuits<br>D. Comparison of Tube Type and Solid State Rectifiers and Amplifiers | |
| EM 2-18<br>7/7/66 | SUPPLYING DC FOR LOW POWER ELECTRONIC CIRCUITS | |
| | A. Transformerless or AC/DC Power Supplies<br>B. Voltage Doublers<br>C. Voltage Multipliers<br>D. Safety in Electronic Work<br>E. Maintenance of Electronic Equipment | |
| EM 2-19<br>7/6/66 | REMOVING THE RIPPLE WITH FILTERS | |
| | A. The Need for Filters<br>B. Using Inductance as A Filter<br>C. Using Capacitance as A Filter<br>D. The Resistance-Capacitance Filter<br>E. Choke Input Filters<br>F. Capacitor Input Filters<br>G. The Swinging Choke | |

Electrical Maintenance -- Year II
Units

EM 2-20
8/2/66

ELECTRONIC VOLTAGE REGULATORS

A. Voltage Regulation
B. Voltage Dividers and Bleeders
C. Voltage Regulators
D. Glow Tube Regulators
E. Vacuum Tube Voltage Regulators
F. Zener Diode Voltage Regulators
G. The Constant Voltage Transformer
H. The Complete Electronic Power Supply

EM 2-21

THE THYRATRON AND OTHER HOT CATHODE GAS FILLED TUBES

A. The Phanotron or Hot Cathode Diode
B. The Thyratron or Gas Filled Triode
C. DC and AC Bias Controls
D. Phase Shift Control
E. Shield Grid Thyratrons
F. Thyratron Applications

EM 2-22

THE IGNITRON AND OTHER MERCURY POOL TUBES

A. Mercury Arc Rectifiers
B. The Ignitron
C. The Excitron
D. Ignitron Circuits and Applications
E. Ignitron Maintenance and Troubleshooting

EM 2-23

PHOTOELECTRIC "EYES" FOR INDUSTRY

A. Photoelectric Effects and Sensors
B. Photomultiplier Tubes
C. Basic Phototube Circuits and Amplifiers
D. Basic Photoelectric Control Circuits
E. Photoelectric Control of Thyratrons
F. Industrial Photoelectric Control Applications
G. Phototransistors - Solid State "Eyes"

EM 2-24

AUTOMATIC CONTROLS , INDICATORS AND RECORDERS

A. Basic Control Systems and Terminology
B. Types of Automatic Controls and Controllers
C. Basic Inductors and Recorders.

Electrical Maintenance -- Year II
Units

EM 2-25 THE BROWN "ELECTRONIK" CONTINUOUS BALANCE POTENTIOMETER

A. The Continuous Balance System
B. The Amplifier
C. The Balancing Motor

EM 2-26 THE TRANSISTOR INTRODUCES A NEW AGE IN ELECTRONIC CONTROL

A. Semiconductors and Electronic Control
B. Semiconductor Fundamentals
C. The Junction Diode
D. How Transistors Work
E. Schematic Symbols
F. Semiconductor Maintenance

EM 2-27 SEMICONDUCTOR PRINCIPLES

A. Introducing the Atom
B. Conductors and Insulators
C. Semiconductors

EM 2-28 SEMICONDUCTORS AND JUNCTION DIODES

A. Adding Impurities or Doping
B. N-Type and P-Type Junctions and Diode Rectifiers
C. Zener and Avalanche Diodes
D. Junction Diode Ratings

EM 2-29 TRANSISTOR FUNDAMENTALS

A. Birth of the Transistor
B. NPN Junction Action
C. PNP Junction Action
D. Basic Circuits

EM 2-30 WORKING WITH TRANSISTORS

A. Biasing and Stabilization Techniques
B. Coupling and Neutralization Methods
C. Thermal Characteristics, Heat Sinks and Life Expectancy

PRELIMINARY TOPICAL OUTLINE

ELECTRICAL MAINTENANCE -- YEAR III

| CODE | UNIT TITLE AND SECTION HEADINGS |
|---|---|
| EM 3-1 | GETTING BETTER ACQUAINTED WITH DC CIRCUITS<br>A. Working with resistors in series and parallel<br>B. Solving network problems<br>C. Efficient use of DC power<br>D. Inductors and capacitors in DC circuits |
| EM 3-2 | UNDERSTANDING AC CIRCUITS<br>A. How inductors and capacitors act in AC circuits<br>B. Solving AC circuit problems<br>C. Correcting power factor<br>D. Advantages of AC systems |
| EM 3-3 | DC MOTORS AND CONTROLS<br>A. Series, shunt, and compound motors<br>B. Speed, torque, and current relationships<br>C. Popular speed control methods<br>D. Maintaining DC machinery |
| EM 3-4 | AC MOTORS AND CONTROLS<br>A. Important AC motor characteristics<br>B. Speed, torque, and current relationships<br>C. Popular speed control methods<br>D. Maintenance needs of AC machines |
| EM 3-5 | ELECTRICAL MAINTENANCE MEASUREMENTS<br>A. DC power measurements<br>B. AC power measurements<br>C. Using "meggers"<br>D. Checking grounds -- accidental and intentional |
| EM 3-6 | RENEWING OUR KNOWLEDGE OF ELECTRONICS<br>A. Fundamentals of common vacuum tubes<br>B. Important gas tube characteristics<br>C. Phototubes and other devices |

5-5-66

Preliminary Topical Outline
Electrical Maintenance -- Year III

| CODE | UNIT TITLE AND SECTION HEADINGS |
| --- | --- |
| EM 3-7 | USING VACUUM TUBE AMPLIFIERS<br>A. Class A, B, and C amplifier operation<br>B. Important industrial electronic circuits<br>C. Maintenance of vacuum tube equipment |
| EM 3-8 | VACUUM TUBES IN MODERN ELECTRONICS -- ON THE WAY OUT?<br>A. Are transistors taking over?<br>B. Vacuum tubes vs. solid state<br>C. The vacuum tube fights for life<br>D. A look at the future |
| EM 3-9 | THE SATURABLE REACTOR -- PRINCIPLES AND APPLICATIONS<br>A. What is it and how does it work?<br>B. Typical industrial control circuits<br>C. Limitations |
| EM 3-10 | THE MAGNETIC AMPLIFIER -- AN IMPROVED SATURABLE REACTOR<br>A. Renewing basic principles<br>B. Typical applications<br>C. Summarizing the good and bad points<br>D. How to maintain magnetic amplifiers |
| EM 3-11 | THE MAGNETIC PRE-AMPLIFIER<br>A. Why use pre-amplifiers?<br>B. Typical applications in modern control<br>C. Advantages and disadvantages |
| EM 3-12 | THE CUTLER HAMMER ULTRAFLEX "M" MAGNETIC AMPLIFIER DC MOTOR DRIVE<br>A. Sections of the DC drive system<br>B. How does the system work?<br>C. Maintaining the system |

Preliminary Topical Outline
Electrical Maintenance -- Year III

| CODE | UNIT TITLE AND SECTION HEADINGS |
|---|---|
| EM 3-13 | THE NEED FOR BETTER SENSORS AND TRANSDUCERS<br>A. How the control problem is changing<br>B. Sensors or transducers?<br>C. Getting useful electrical control signals |
| EM 3-14 | HOW DO MECHANICAL TRANSDUCERS WORK?<br>A. How to measure distance<br>B. Speed measuring systems<br>C. Pressure sensing devices<br>D. Weight measurement techniques<br>E. How force, torque, and tension are measured |
| EM 3-15 | ELECTRICAL TRANSDUCERS -- THE KEY TO AUTOMATION<br>A. Resistance, inductance, and capacitance devices<br>B. Electronic, ionic, electrokinetic, and light transducers<br>C. Thermal, piezoelectric, and radiation devices<br>D. Semiconductors -- a promising new group of transducers |
| EM 3-16 | PRACTICAL APPLICATIONS OF TRANSDUCERS<br>A. Measuring and controlling temperatures<br>B. The measurement and control of product size<br>C. Force measurement and control<br>D. Working with electrical and magnetic properties |
| EM 3-17 | SEMICONDUCTORS AND SOLID STATE ELECTRONICS<br>A. Renewing semiconductor principles<br>B. The PN junction -- a basic building block<br>C. Using PN junctions in other solid state devices |
| EM 3-18 | SEMICONDUCTOR DIODES AND THEIR MANY FUNCTIONS<br>A. Rectifying and clamping diodes<br>B. Breakdown diodes for voltage regulation<br>C. The unusual tunnel diode<br>D. Photodiodes, thermistors, and multilayer devices |

Preliminary Topical Outline
Electrical Maintenance -- Year III

| CODE | UNIT TITLE AND SECTION HEADINGS |
|---|---|
| EM 3-19 | SEMICONDUCTOR DIODE APPLICATIONS<br>A. Rectifier and voltage multiplier circuits<br>B. Voltage regulation and contact protection<br>C. Simplifying circuits with tunnel diodes<br>D. Photodiode and thermistor uses in industrial control |
| EM 3-20 | THE TRANSISTOR -- THE MODERN ELECTRONIC MIRACLE<br>A. Reviewing transistor fundamentals<br>B. Comparing NPN and PNP transistors<br>C. Biasing and coupling methods<br>D. Protecting transistors from heat damage |
| EM 3-21 | TRANSISTOR TYPES AND THEIR MANY USES<br>A. Germanium and its applications<br>B. Where should silicon transistors be used?<br>C. Other important transistors in common use |
| EM 3-22 | UNDERSTANDING BASIC TRANSISTOR AMPLIFIERS<br>A. The common emitter circuit<br>B. The common base circuit<br>C. The common collector circuit |
| EM 3-23 | SEMICONDUCTORS VS TUBES AS SIGNAL AMPLIFIERS AND POWER CONVERTERS<br>A. Tubes vs semiconductors for industrial control<br>B. Comparing tube and solid state amplifiers<br>C. Comparing tube and solid state power converters |
| EM 3-24 | DIODE AND TRANSISTOR SWITCHING<br>A. Using transistors in logic circuits<br>B. Diodes in logic circuits<br>C. Learning to use logic symbols |

Preliminary Topical Outline
Electrical Maintenance -- Year III

| CODE | UNIT TITLE AND SECTION HEADINGS |
|---|---|
| EM 3-25 | SPECIAL SEMICONDUCTOR APPLICATIONS IN INDUSTRY |
| | A. Small servo motor drives<br>B. Instrument circuit applications<br>C. Circuit surge protection<br>D. Commutating diodes and other power circuit uses |
| EM 3-26 | THE NEWEST ELECTRONIC SKILL -- SEMICONDUCTOR MAINTENANCE |
| | A. Checking for correct use<br>B. Care in handling<br>C. Protection from electrical damage<br>D. Testing in the field and in the shop |
| EM 3-27 | OTHER SEMICONDUCTORS AND THYRISTORS |
| | A. Uses of unijunction transistors<br>B. The field effect transistor and impedance matching<br>C. The growing family of thyristors<br>D. Future thyristors |
| EM 3-28 | INDUSTRIAL APPLICATIONS OF THYRISTORS |
| | A. Solving the overvoltage protection problem<br>B. Using light activated thyristors<br>C. Simplifying circuits with solid state switching |
| EM 3-29 | THE SCR -- GIANT OF THE THYRISTORS |
| | A. Learning how the SCR works<br>B. Using SCR's for power conversion<br>C. Improving drive systems with SCR's<br>D. Building solid state inverters with SCR's |
| EM 3-30 | SILICON CONTROLLED RECTIFIERS -- TODAY AND TOMORROW |
| | A. The growth and popularity of SCR's<br>B. Overcoming the early application problems<br>C. The breakthrough in powering large drive systems<br>D. The bright future for the SCR |

PRELIMINARY TOPICAL OUTLINE

ELECTRICAL MAINTENANCE -- YEAR IV

| CODE | UNIT TITLE AND SECTION HEADINGS |
|---|---|
| EM 4-1 | RENEWING OUR ABILITY TO USE THE LAWS OF ELECTRICITY |
| | A. Reviewing DC circuit fundamentals<br>B. Inductors and capacitors in DC circuits<br>C. Using vectors to understand AC circuits<br>D. Inductors and capacitors in AC circuits |
| EM 4-2 | THE IMPORTANCE OF AC CIRCUITS |
| | A. Series and parallel AC circuits<br>B. DC vs AC power circuits<br>C. Why is power factor important?<br>D. Advantages of polyphase power systems<br>E. How do phase shift circuits work? |
| EM 4-3 | WORKING WITH TRANSFORMERS |
| | A. Transformer characteristics<br>B. Distribution and control transformer connections<br>C. Auto transformers<br>D. AC voltage regulators<br>E. Instrument transformers |
| EM 4-4 | IMPORTANT AC MOTORS |
| | A. Squirrel cage induction motors<br>B. Wound rotor induction motors<br>C. Synchronous motors<br>D. Handling AC motor maintenance |
| EM 4-5 | DC MOTOR DRIVE SYSTEMS -- MAINSTAY OF MODERN INDUSTRY |
| | A. Practical speed control methods<br>B. Adjustable voltage DC drives<br>C. Series vs shunt motors<br>D. Shunt motor speed control by field weakening<br>E. Using armature resistance to get shunt motor speed control<br>F. Speed control by variable voltage<br>G. The problem of speed regulation |

5-5-66

Preliminary Topical Outline
Electrical Maintenance -- Year IV

| CODE | UNIT TITLE AND SECTION HEADINGS |
|---|---|
| EM 4-6 | MODERN TRENDS IN AC DRIVE SYSTEMS<br>A. What lies ahead in speed control systems?<br>B. The magnetic amplifier improves speed control systems<br>C. The SCR teams up with the magnetic amplifier<br>D. The SCR works alone |
| EM 4-7 | AC DRIVE SYSTEMS -- TODAY AND TOMORROW<br>A. Corepak replaces the DC drive motor<br>B. Other methods for using AC drive motors<br>C. Modern variable frequency AC drives<br>D. Power inverter systems |
| EM 4-8 | VACUUM AND GAS TUBES<br>A. Vacuum tube amplifiers<br>B. Gas tube operation<br>C. Vacuum tubes and thyratrons in industrial control<br>D. Troubleshooting tube circuits |
| EM 4-9 | SEMICONDUCTORS AND TRANSISTORS<br>A. Use of semiconductor diodes<br>B. Reviewing transistors and their uses<br>C. Special transistors and their applications |
| EM 4-10 | UNDERSTANDING THE SILICON CONTROLLED RECTIFIER<br>A. How does the SCR work?<br>B. Definitions symbols and terminology<br>C. Understanding SCR characteristics<br>D. Disadvantages<br>E. The many uses of the SCR |
| EM 4-11 | USING SCR UNITS IN INDUSTRIAL CONTROL<br>A. Combining SCR's and magnetic amplifiers<br>B. Applying the buck -- boost magnetic amplifier to SCR control<br>C. Basic SCR power circuits<br>D. Typical SCR package units |

Preliminary Topical Outline
Electrical Maintenance -- Year IV

| CODE | UNIT TITLE AND SECTION HEADINGS |
|---|---|
| EM 4-12 | SCR MOTOR CONTROLS AND CIRCUIT PROTECTION<br>A. Basic SCR rectifier motor controls<br>B. Electronic gating circuits<br>C. Industrial motor controls<br>D. Circuit protection for semiconductors |
| EM 4-13 | THE SCR ULTRAFLEX "M" MOTOR CONTROL SYSTEM<br>A. Upgrading the magnetic amplifier system<br>B. Comparing the SCR and magnetic amplifier versions of ultraflex<br>C. Differences in operating characteristics<br>D. Differences in maintenance |
| EM 4-14 | SOLID STATE INVERTER POWER AND CONTROL CIRCUITS<br>A. What are inverters and how do they work?<br>B. Power applications<br>C. Control circuit uses<br>D. Maintenance problems |
| EM 4-15 | OTHER USEFUL THYRISTORS<br>A. The triac simplifies AC switching<br>B. Unidirectional and bidirectional signal diodes<br>C. Gate controlled devices<br>D. Light activated devices |
| EM 4-16 | THYRISTOR APPLICATIONS<br>A. Speed control<br>B. Timing applications<br>C. Improved pulse generators<br>D. Troubleshooting |
| EM 4-17 | SOLID STATE LOGIC -- A BASIC TOOL FOR AUTOMATION<br>A. Why use solid state logic?<br>B. Solid state logic vs relay circuits<br>C. How do logic elements work? |

Preliminary Topical Outline
Electrical Maintenance -- Year IV

| CODE | UNIT TITLE AND SECTION HEADINGS |
|---|---|
| EM 4-18 | IMPORTANT INDUSTRIAL LOGIC SYSTEMS<br>A. Cutler-Hammer DSL non-inverting logic systems<br>B. Westinghouse Prodac logic systems<br>C. General Electric transistorized static control systems |
| EM 4-19 | GETTING ACQUAINTED WITH SOLID STATE LOGIC<br>A. Can we use Boolean algebra?<br>B. Truth tables -- another useful tool<br>C. Diode logic circuits<br>D. Practical English Logic Circuits |
| EM 4-20 | NOR LOGIC SYSTEMS<br>A. Why NOR logic?<br>B. Performing the basic logic functions with NOR elements<br>C. How to count with NOR's<br>D. Typical NOR logic system applications<br>E. Maintenance of NOR logic systems |
| EM 4-21 | THE GENERAL ELECTRIC DIRECTO-MATIC I AND II CONTROL SYSTEMS<br>A. Directo-matic I hardware<br>B. Understanding Directo-matic I circuits<br>C. Directo-matic II -- a new generation of process controls<br>D. Reading Directo-matic II diagrams |
| EM 4-22 | AUXILIARY COMPONENTS AND OTHER LOGIC DEVICES<br>A. Auxiliary components in logic systems<br>B. Solid state counters and information storage units<br>C. Glow tube indicators and switches |

Preliminary Topical Outline
Electrical Maintenance -- Year IV

| CODE | UNIT TITLE AND SECTION HEADINGS |
| --- | --- |
| EM 4-23 | GETTING ACQUAINTED WITH COMPUTERS<br>A. What is a computer?<br>B. Types of computers<br>C. Analog computer operations<br>D. Digital computer opeartions |
| EM 4-24 | HOW A DIGITAL COMPUTER ADDS AND SUBTRACTS<br>A. Binary arithmetic<br>B. Counter and storage circuits<br>C. Basic adder circuits<br>D. How an adder can subtract |
| EM 4-25 | COMPUTER ARITHMETIC CIRCUITS AND MEMORY UNITS<br>A. Digital multiplication and division<br>B. Core type memory units<br>C. Drum type memory units<br>D. Tape type memory units |
| EM 4-26 | COMPUTER MAINTENANCE TECHNIQUES<br>A. Module packaging methods<br>B. Maintenance tools and procedures<br>C. Special maintenance test circuits<br>D. Printed circuit repair techniques |
| EM 4-27 | QUALITY CONTROL AND INSPECTION TRANSDUCERS<br>A. Introduction to nondestructive testing transducers<br>B. Eddy current testing for surface defects<br>C. Ultrasonic flaw detectors<br>D. Dye penetrant inspection methods |
| EM 4-28 | RADIATION TRANSDUCERS<br>A. Why use radiation?<br>B. How can we use radiation?<br>C. Typical industrial uses<br>D. How to work safely near radiation equipment |

Preliminary Topical Outline
Electrical Maintenance -- Year IV

| CODE | UNIT TITLE AND SECTION HEADINGS |
|---|---|
| EM 4-29 | TELEMETERING SYSTEMS |
| | A. What is telemetering? |
| | B. Popular types of telemetering systems |
| | C. Pulse systems |
| | D. Frequency systems |
| | E. Other useful systems |
| EM 4-30 | ELECTRICAL MAINTENANCE -- A JOB WITH A FUTURE |
| | A. What have you learned? |
| | B. Using your new tools |
| | C. Your job in 1982 |
| | D. Keeping up to date |
| | E. Meeting the future confidently |

## ELECTRICAL MAINTENANCE -- YEAR I
## DIDACTOR FILMS
As published for 1966 - 67

| | | |
|---|---|---|
| EM 1-1D<br>9/65 | MAINTAINING MAGNETS IN INDUSTRY | Magnetism -- lines of force -- right hand rule -- storing magnets -- weakening magnets -- magnet maintenance -- electromagnets-- magnetic fields -- ampere turns -- strength of electromagnets -- residual magnetism. |
| EM 1-2D<br>9/65 | MAGNETIC CONTROL EQUIPMENT | Care and maintenance of contactors and relays -- overvoltage and coil life -- undervoltage and sluggish operation -- parts of an electromagnet-- uses -- electric circuits and current -- comparing gallons per minute to amperes -- voltage -- ohms -- rheostats. |
| EM 1-3D<br>9/65 | OHM'S LAW I | Current -- how voltage is generated or induced -- the armature -- producing a flow of electricity -- electron flow -- resistance -- ohms -- circuits -- circuit diagrams -- external and internal circuits -- open or broken circuits -- grounds -- shorts. |
| EM 1-4D<br>10/65 | OHM'S LAW II | Ohm's law triangle -- series circuits and parallel circuits -- power -- series-parallel circuits -- circuit problems and formulas. |
| EM 1-5D<br>12/65 | BECOMING BETTER ACQUAINTED WITH KIRCHHOFF'S LAWS AND DC CIRCUITS | The voltage law -- checking switches -- the current law -- series resistance and current -- series circuit voltages -- parallel current division -- three branch parallel circuit -- parallel resistors -- equal resistors -- equivalent resistance -- combination circuits and circuit simplification. |

8-30-66

EM 1-6D
12/65

**GENERATION, TRANSMISSION AND DISTRIBUTION OF ELECTRICITY**

Generators -- limitations of DC generators -- AC generators -- transformers -- transmission line losses -- transformers -- induction in transformers -- mutual flux -- ampere turns -- right hand rule -- counter voltage -- exciting current -- Lenz's law -- distribution systems.

EM 1-7D
12/65

**USING ELECTRICITY SAFELY AND EFFICIENTLY**

Grounding for safety to equipment and personnel -- neutral system grounding -- effects of ground placement on windings -- grounding conductors and grounded conductors -- overcurrent protection -- National Electric Code -- electricity and cost -- watthours -- demand charges -- power factor charges -- lubricants and over lubrication -- insulation life -- insulation checks -- distribution panels -- transformer maintenance.

EM 1-8D
12/65

**CHOOSING POWER TO SUPPLY MOTORS USED FOR LIFTING AND HANDLING MATERIALS**

Speed, torque and horsepower control with DC motors -- shunt, series, and compound types -- schematics -- changes in load and effect -- advantages and disadvantages -- armature current and Ohm's law -- converting AC to DC with generators -- right hand rule -- loading generators -- over and under-compounding -- converting AC to DC with static units -- rectifiers -- polyphase rectifiers.

EM 1-9D
12/65

**DC MOTORS IN MODERN INDUSTRY**

Left hand motor rule -- torque -- speed -- exchange of torque for speed -- horsepower -- counter voltage -- speed related to counter voltage and magnetic field strengh -- commutating poles -- series motors -- advantages and disadvantages -- shunt motors and speed control -- reversing motors.

EM 1-10D
12/65

**VARIABLE VOLTAGE DC MOTORS AND GENERATORS**

Kirchhoff's laws -- input power and efficiency -- starting DC motors -- locked rotor currents -- effect of speed increases on line current -- horsepower -- torque -- tension -- power and torque relationships -- Ward Leonard control -- direction of rotation of the motor -- motors and generators -- amplification of control power.

EM 1-11D
1/66

## ROTATING AND MAGNETIC DC REGULATORS

Amplidynes -- load current -- flux -- excitation power -- using right angle flux -- Amplidyne amplifiers -- armature excitation -- control fields -- Rototrols -- saturation curve and air gap line -- voltage output and field current -- Rototrol regulators -- stabilization -- magnetic amplifier rectifier drives -- Cutler-Hammer Ultraflex M -- adjusting rectifier input -- adjusting output and controlling impedance.

EM 1-12D
1/66

## INTRODUCING AC AND ROTATING FIELDS

Frequency -- AC generators -- effective and peak values -- counter or back voltage -- opposition to AC current flow -- capacitance and capacitors -- current flow in capacitors -- AC voltages applied to capacitors -- frequency effects -- induction motors -- single phase types -- rotor slip -- two phase rotating fields -- using capacitors and resistors for starting.

EM 1-13D
1/66

## SINGLE PHASE AC MOTORS

Split phase types -- resistance split phase auxiliary starting windings and centrifugal switches -- capacitor start split-phase starting torque and line current -- split capacitor types -- shaded pole motors -- AC-DC series motors -- repulsion motors -- repulsion-induction motors -- repulsion start induction motors.

EM 1-14D
1/66

## RESISTANCE AND INDUCTANCE AS CIRCUIT ELEMENTS

Types of voltage -- wave forms -- sine waves -- flux lines -- simple alternators -- induced voltage -- frequency -- measuring sine wave quantities -- root-mean-square values -- resistance in AC circuits -- inductive effects on DC -- closing and opening DC circuits -- current rise and fall in inductive circuits -- inductive effects on AC -- self-induction and counter voltage -- factors affecting self inductance -- inductive reactance -- inductive phase relationships.

EM 1-15D
1/66

## CAPACITANCE IN AC AND DC CIRCUITS

Capacitive effects on DC -- resistance, inductance and capacitance -- difference between capacitance and inductance -- capacitors, plates, dielectrics -- units -- charging a capacitor -- current through a capacitor -- retained charges -- discharging a capacitor -- factors affecting capacity -- capacitors in series -- the resistance-capacitance series circuit -- checking capacitors with an ohmmeter -- capacitive reactance -- vectors.

EM 1-16D
2/66

## SERIES AC CIRCUIT FUNDAMENTALS

Vectors -- right triangles -- electrical trigonometry -- sines and cosines -- series impedance -- series resistance-inductance circuits -- resistive and reactive characteristics -- impedance diagrams -- power factor -- series resistance-capacitance circuits -- phase relationships -- resistance -- inductance and capacitance in series -- resonance.

EM 1-17D
2/66

## PARALLEL AC CIRCUIT FUNDAMENTALS

Resistance-inductance circuits -- Ohm's law -- current vector diagrams -- Kirchhoff's laws -- power vector diagrams -- power in (R-L) circuits -- resistance-capacitance circuits -- power in (R-C) circuits -- resistance -- inductance and capacitance in parallel -- reactive currents -- (C-L) tank circuits -- parallel resonance -- frequency effects -- power factor correction.

EM 1-18D
2/66

## LEARNING TO READ THE ELECTRICAL LANGUAGE

Schematic diagrams -- electrical details -- block diagrams -- wiring and cabling diagrams -- layout diagrams -- drafting rules -- ASA symbol standards -- common symbols -- what different symbols mean -- importance of symbols.

EM 1-19D
3/66

## MEASURING ELECTRICAL QUANTITIES -- A MAINTENANCE ESSENTIAL

DC meter fundamentals -- DC microammeters and milliammeters -- shunts -- swamping resistors -- applying Ohm's law to ammeter shunts -- high DC measurements -- meter accuracy -- AC meter fundamentals -- AC rectifier meters -- compensation -- full wave rectification -- measuring both AC and DC -- disadvantages of shunts in AC circuits -- hysteresis -- electrodynamometer instruments -- uses -- Ohmmeters.

EM 1-20D
2/66

**REDUCING THE VOLTAGE FOR DISTRIBUTION WITH SINGLE PHASE TRANSFORMERS**

Principles -- energy transfer and varying magnetic flux -- induction and transformers -- construction -- inducing voltage -- mutual flux -- ampere turns -- counter voltage -- right hand rule -- copper and core losses -- eddy current -- residual magnetism -- magnetizing current -- voltage regulation -- KVA rating -- insulation -- Inerteen and Askarel.

EM 1-21D
2/66

**TRANSFORMER PRINCIPLES**

Functions of transformers -- ratios -- induction principles -- ampere turns -- exciting current -- relationship between flux and load -- impedance -- counter voltage -- Lenz's law and induced voltages -- current and voltage in relationship to turns -- additive and subtractive polarity -- parallel and series connected transformers.

EM 1-22D
3/66

**USING THREE PHASE POWER IN INDUSTRY**

Three phase distribution -- advantages -- efficiency, reliability, and maintenance -- generating three phase voltages -- vectors -- Y connections -- voltages and currents in the Y system -- advantages -- delta connections -- voltages and currents in the delta system -- Y and delta connections -- applications -- three phase transformers and loads -- three phase operation with single phase transformers -- construction -- connections -- phasing transformers -- installing, maintaining, and trouble-shooting transformers -- three phase motor connections -- checking for grounds.

EM 1-23D
3/66

**UNDERSTANDING DC MOTOR CONTROLS**

Controlling with the shunt field -- varying armature voltage, armature circuit resistance and field flux -- stabilized shunt motor control -- field weakening -- speed-torque relationships in field weakening -- response of field weakened motors -- armature voltage control -- horsepower and torque relationships -- combined field and armature control -- adjustable voltage control.

EM 1-24D
4/66

**THE SQUIRREL CAGE MOTOR -- INDUSTRY'S WORKHORSE**

DC motor fundamentals -- magnetic forces -- rotor-stator -- squirrel cage induction motor -- magnetic induction -- speed and torque -- multi-speed motors -- single phase and polyphase power supplied to AC motors -- starting induction motors splitting the single phase voltage.

EM 1-25D
6/66

**THE WOUND ROTOR INDUCTION MOTOR**

Squirrel cage motors -- adding resistance to the rotor circuit -- variable rotor resistance -- comparing with standard squirrel cage motors -- advantages and disadvantages -- speed and torque.

EM 1-26D
5/66

**POWER FACTOR**

Types of AC current -- power factor -- actual pow and apparent power -- power in AC circuits -- power related to voltage and current -- power in reactive circuits -- average power factor -- poor power factor -- voltage regulation and operating costs -- using synchronous motors to correct lagging power factor.

EM 1-27D
5/66

**MOTOR PROTECTION**

Fuses -- types and application -- elements of a fuse -- how fuses work -- fuse holders -- why fuses blow -- renewable fuses -- avoiding poor contact -- AC motor controllers -- three phase motor control circuits -- reduced voltage starters overload and undervoltage protection -- safety factors in control circuits.

EM 1-28D
6/66

**SAFETY AND ELECTRICAL MAINTENANCE**

Becoming part of an electrical circuit -- nerve shock and burns -- the most dangerous current path and how to avoid it -- factors that increase shock -- safety tips on checking circuits -- safety switches, tie-up tags, and insulation resistance -- why grounding is important -- tips on testing equipment -- removing fuses -- working around motors and switchboards -- safety equipment -- three wire grounding type cords and receptacles -- artificial respiration.

EM 1-29D
4/66

**VACUUM TUBE FUNDAMENTALS**

Electron theory -- cathode and anodes -- thermionic emission -- function of diodes -- simple rectifiers.

EM 1-30D
5/66

**TRIODES, TETRODES AND PENTODES**

Difference between diodes and triodes -- the grid and its function -- how triodes work and what they do -- grid bias -- tetrodes -- screen grids -- secondary emission -- suppressor grids -- pentodes -- advantages and disadvantages.



2

ELECTRICAL MAINTENANCE -- YEAR I

VU-GRAPH CELLS

As published for 1966-67

EM 1-1

1. Lines of magnetic force. Incorporates a magnet and metal filings.
2. Magnetic effects; magnetic forces.
3. Rod moving through a magnetic field.
4. Magnetized and demagnetized metal bars.
5. Magnetic brake -- construction.
6. Motor on; motor off -- magnetic brake.
7. Cutaway view -- crane magnet.
8. Exploded view -- crane magnet.

EM 1-2

1. Fleming's right hand rule -- I.
2. Fleming's right hand rule -- II.
3. Lines of magnetic force -- crane manget.
4. Strength of an electromagnet -- amperes, turns relation.
5. A typical relay.
6. Hoist contacts -- schematic.

EM 1-3

1. Water flow compared to current flow -- I.
2. Water flow compared to current flow -- II.
3. Water flow compared to current flow -- III.
4. Water flow compared to current flow -- IV.
5. Ohm's law triangle.

EM 1-4

1. Power law triangle.
2. Simple series, parallel, and compound circuits.
3. Schematic symbols of resistors.

EM 1-5

1. Shunt, series and compound fields.

6/30/66

EM 1-6

1. Cross section -- coil in a magnetic field.
2. Left hand generator rule.
3. Transformers and symbols.
4. Resulting fields and currents due to mutual induction.
5. DC generator showing coil positions for one revolution.
6. Single loop wire in a magnetic field.

EM 1-7

(NO CELLS)

EM 1-8

1. Rectifiers compare to switches.

EM 1-9

1. The left hand motor rule.
2. Torque -- on a current carrying coil; on conductors in a motor armature.

EM 1-10

(NO CELLS)

EM 1-11

1. Conventional shunt generator.
2. DC shunt generator, reduced excitation.
3. Amplidyne generator, full load current and voltage restored.

EM 1-12

1. Calculation of effective and average values of an AC sine wave.
2. Induced field in rotor conductors of squirrel cage motor.
3. Construction, squirrel cage rotor.

Electrical Maintenance -- Year I
Vu-Graph Cells

EM 1-13

1. Electric motor enemies.
2. Pictorial view and schematic of a shaded pole motor.
3. Electrical schematic of a repulsion motor.

EM 1-14

1. Polarity of induced voltage and current.
2. Elementary two pole AC generator showing a single turn coil.
3. Current -- time relationships in resistance and inductance circuits.
4. Adjustable phase relationship demonstrator.

Also applicable: EM 1-2 (1), EM 1-2 (2).

EM 1-15

1. Capacitor charging action in DC circuits.
2. Discharging a capacitor in a DC circuit.
3. Capacitor and schematic symbol.

Also applicable: EM 1-14 (4).

EM 1-16

1. Becoming better acquainted with the right triangle.
2. Two methods of drawing a vector diagram.
3. Four basic vector diagrams for a series inductance resistance circuit.
4. Reactance curves for a series (R-L-C) circuit.

Also applicable: EM 1-14 (4).

EM 1-17

1. Resistance -- inductance power vector diagram.
2. Total current and impedance in an (R-L-C) circuit.

EM 1-18

1. Typical block diagram of a motor and control.
2. Typical large induction motor control circuit.

Electrical Maintenance -- Year I
Vu-Graph Cells

## EM 1-19

1. Voltmeter with internal resistance shunted.
2. Electrodynamometer, used as voltmeter, ammeter and wattmeter.

## EM 1-20

1. Simple transformer with open circuited secondary.
2. Simple transformer with load applied to secondary.
3. Relationship of magnetizing current to voltage.

## EM 1-21

1. Three common single phase transformer connections.
2. Typical autotransformer with current and voltage supplying load at 50 percent supply voltage.
3. Typical connections: Instrument transformers and instruments for single phase measurement.

## EM 1-22

1. Three phase voltage shown pictorially and with vectors.
2. Generation of three phase voltage.
3. Y connected voltages.
4. Current flow in delta connected system.

## EM 1-23

1. Shunt motor with adjustable control resistances.
2. Adjustable voltage controller -- manually operated rheostats.
3. Acceleration of a DC shunt motor.
4. Dynamic braking circuit for a DC motor.
5. A magnetic controller for automatic starting.

## EM 1-24

1. Shaded pole motors.
2. Synchronous motors.

Electrical Maintenance -- Year I
Vu-Graph Cells

EM 1-25

1. Diagrams of wound rotor motor circuits.
2. Speed and torque characteristics of the wound rotor motor.

EM 1-26

1. Construction of a synchronous motor.
2. Torque developed by the synchronous motor.
3. Interlocking the stator and rotor magnetic fields.

Also applicable: EM 1-24 (2).

EM 1-27

1. Functions of a motor control.
2. An elementary motor control.

EM 1-28

1. Setting brush contact and checking for high mica.
2. Motor bearing lubrication systems.
3. Lubrication of ball type motor bearings.
4. Life and hard times of a brush holder.

EM 1-29

1. Schematics of 11 different vacuum tubes.
2. Explanation of symbols used for tube structure.

EM 1-30

1. Typical tetrode circuit.
2. Typical pentode circuit.
3 Elementary phototube circuit.

0

EM 1-26D
5/26/66.

POWER FACTOR

Human Engineering Institute — Minn. State Dept. of Ed. Vocational Education

Press A 1 — Check to see that timer if OFF

---

1

In this Didactor film you will be given information on POWER FACTOR. Usually there will be a question at the end of the information. This question will ask about information that you have read before.

If the question is answered correctly, you will go on to new information and a question on the information you have just read.

Press A 1-1

1

---

1-1

If the question is answered incorrectly, you will go back to read the past information which you need for this question (and an old question which you have already answered correctly).

For example: This film covers ________. (choose one)

A. power factor 2
B. AC motors 1
C. DC motors 1

1

---

2

OK.

Since you answered that question correctly, you are on your way to new material. If you answered it incorrectly, you were sent back to read the title again before getting here. That's how most of this film will work.

If you answer a question incorrectly, you will________.

1-1 A. go forward.
3 B. go backward.
1-1 C. stand still.

1

---

3

POWER FACTOR

AC motors need current for field magnetization. This magnetizing current can come from the source of current supply. The magnetizing current then flows through the motor field and back to the supply without doing any useful work. It only magnetizes the field.

If you answer questions correctly, you________________.

4 A. go on to new material.
2 B. go back to old material.
2 C. don't go anywhere.

1

---

4

On the other hand, the power current produces electrical energy, most of which is converted by the motor into useful work. Thus - an AC motor needs a total current made up of the magnetizing current and the power current.

How much useful work does the magnetizing current perform?

3 A. One-half as much as the power current.
5 B. None.
3 C. As much as the power current.

1

---

5

Power factor is a measure of the usefulness of the current. It is a ratio equal to the power current divided by the total current supplied to a system.

Thus, power factor = $\frac{\text{power current}}{\text{total current}}$

How much useful work does the power current perform?

6 A. All.
4 B. None.
4 C. One-half as much as the magnetizing current.

1

---

6

FINDING POWER-- In a DC circuit, we can find the power by multiplying the volts times the amperes. The answer is power, in watts. (W = E x I)

We said that power factor was equal to______________.

7 A. $\frac{\text{power current}}{\text{total current}}$
5 B. power current x total current
5 C. power current ÷ total current

1

8

1

For AC circuits that are in phase, we can find power the same way we did for a DC circuit.

Power in a DC circuit and power in an in-phase AC circuit equals ______________.

A. volts x watts.
B. volts x amperes.
C. volts x ohms.

1

When voltage and current are out of phase in an AC circuit, the actual power used equals volts times amperes times the power factor.

Thus, actual power used = volts x amperes x power factor. What does power in an in phase AC circuit equal?

7 A. watts x amperes
7 B. volts x amperes
7 C. volts x watts

1

10

A certain AC circuit draws a current of 5 amperes. The voltage is 240 volts, and it is in phase with the current. What is the power used?

10 A. 120 watts
11 B. 1200 watts
10 C. 48 watts

1

10

Your answer was not correct.

We said the power in an in-phase AC circuit is found by multiplying the voltage (240 volts) by the current (5 amperes).

$$\begin{array}{rl} 240 & \text{volts} \\ \times\, 5 & \text{amperes} \\ \hline 1200 & \text{watts of power} \end{array}$$

Remember: this works for DC and for in phase AC circuits.

Press A 11

1

11

OK.

Here is a problem using an out-of-phase AC current. The power factor is 0.5. The circuit draws a current of 5 amperes at 240 volts. What is the total power used?

13 A. 600 watts
12 B. 1200 watts
12 C. 48 watts

1

12

Your answer is not correct.

Remember the solution for power in an out-of-phase AC circuit?

Power = volts x amperes x power factor.

In this problem, voltage = 240 volts; current = 5 amperes; and power factor = 0.5.

Using the formula: Power = 240 x 5 x 0.5 or 1200 x 0.5

$$\begin{array}{r} 1200 \\ \times 0.5 \\ \hline 600.0 \end{array}$$ or 600 watts total power used.

When you understand this example, Press A 13

1

13

OK.

There are other ways to find power factor.

Take a voltmeter and an ammeter reading. Multiply these two readings together. Their product is called "apparent power".

Now take a wattmeter reading. This shows actual or "true" watts. To find the power factor, divide the actual watts by the "apparent power".

$$PF = \frac{\text{watts}}{\text{apparent power}}$$

Press A 14

1

14

Apparent power is also called volt amperes. That's because the voltmeter and ammeter readings are multiplied together.

Volt amperes is usually abbreviated as VA.

What does the power factor equal?

15 A. True watts + apparent power.
15 B. True watts x apparent power.
15 C. True watts ÷ apparent power.

1

15

We said to find the power used in an out-of-phase AC circuit, we use this formula:

power = volts x amperes x power factor.

We can simplify this by saying that power being used is found by multiplying the power factor and the apparent power.

Thus, power = apparent power x power factor.

Apparent power is also called ________________.

14 A. reactive volt amperes
14 B. watts
16 C. volt amperes

1

16

Thus, two formulas for power used in an out-of-phase AC circuit are:

power = volts x amperes x power factor

and power = apparent power x power factor

The power factor depends on the relative amounts of resistance, inductance and capacitance in a circuit.

Power factor varies between one and zero.

Press A 17

1

17

When current and voltage are in phase, the power factor equals one. When current and voltage are out of phase, the power factor is less than one.

The power factor varies from ________ to ________.

16 A. one, infinity.
16 B. zero, infinity.
18 C. one, zero.

1

18

REVIEW

How much useful work does the power current perform?

19 A. One-half as much as the magnetizing current.
19 B. None.
20 C. All.

1

19

Your answer is incorrect.

In the beginning we said that an AC motor needs a total current made up of the power current and a magnetizing current.

The magnetizing current does no work - it just magnetizes the field.

The power current, on the other hand, does all the useful work in addition to supplying all circuit losses.

Press A 20

1

20

OK.

How is the "apparent power" in a circuit found?

21 A. By a wattmeter reading.
22 B. By multiplying the circuit voltage by the circuit amperes.
21 C. By multiplying the circuit voltage by the circuit amperes and the circuit power factor.

1

21

Your answer is not correct.

A wattmeter reading shows "true" or actual watts.

Apparent power is found by multiplying the circuit voltage by the circuit amperes. The answer is in volt amperes, which can be shortened to VA.

And, by multiplying the apparent power by the power factor in an out-of-phase circuit, we can find the power used.

Press A 22

1

22

OK.

When the current and voltage in a circuit are in phase, the power factor is ________________.

24 A. one
23 B. zero
23 C. 0.5

1

23

Your answer is not correct.

When the current and voltage in a circuit are in-phase, the power factor is one.

When current and voltage in a circuit are out-of-phase, the power factor is less than one.

Press A 24

1

24

The review shows that you are doing well.

Now we will go on to some pictorial representations called power curves.

If you would like to review the material just covered (before going on), Press A. 3

To go on to power curves, Press B. 26

X-C 25

1

25

You made an incorrect answer for one or more of the review questions. This shows that the material covered so far should be reviewed. Try to read carefully. Look for ideas that are new to you.

Press A. (The Didactor will take a few moments to find the correct place).

3

1

26

OBTAINING A POWER CURVE

Under any phase condition, the instantaneous power is equal to voltage times the current at that instant.

A curve can be made of these instantaneous voltage and current values. From these curves another curve can be made showing the value of instantaneous power through the complete cycle. Look at the power curve in Plate I of the Didactor Reference Sheet. Read the explanation; then Press A. 27

2

27

Look at Plate I again. Notice that the power is positive in both halves of the cycle, even though the voltage and current are both negative for half the cycle.

The product of two negative quantities is always a positive quantity. Thus, the product of a negative voltage times a negative current is positive power.

Power at any instant equals voltage times________.

28 A. current at that instant.
26 B. average current.
26 C. resistance.

2

28

In an AC circuit that contains only resistance, the current and voltage are in phase. The power curve then looks like the one in Plate I. Notice that power in Plate I is always above the zero line. This means that all the power delivered to the circuit is positive or is being used.

When both instantaneous current and voltage are negative, instantaneous power is________.

29 A. positive.
27 B. negative.
27 C. zero.

2

29

Thus, in a resistive circuit, all the power delivered to the circuit is used. The power factor is one or unity (1.0).

In a resistive circuit, the voltage is________ with the current.

28 A. out of phase by 90 degrees
30 B. in phase
28 C. out of phase

2

30

When the current lags OR leads the voltage, the power factor is less than one. We can also say it is less than unity.

In a resistive circuit, the power factor is________.

29 A. zero
31 B. one
29 C. one-half

2

31

Current lag is shown in Plate II. Notice that a part of the power curve is negative or lies below the zero line. This means that power flows from the circuit to the source during part of each cycle. This is called a reactive circuit.

When current lags or leads the voltage, the power factor is_______________.

30 A. zero
30 B. one
32 C. less than one

2

32

Power in the shaded areas of Plate II being negative has to be subtracted from the power above the zero line. By doing this, we are finding the net power used.

A reactive circuit supplies power to the source during ___________ of each cycle.

31 A. all
33 B. part
31 C. none

2

33

Most AC circuits have some reactance. Because of this reactance, keeping the power factor under control is a big job in AC distribution.

There will now be a short review of this section.

Press A 34

2

34

REVIEW

Under any phase condition, how is instantaneous power found? By multiplying voltage times ___________.

35 A. resistance.
36 B. current at that instant.
35 C. current times power factor.

2

35

Your answer is incorrect.

Under any phase condition, instantaneous power is found by multiplying voltage times the current at that instant.

This is true whether AC or DC circuits are considered. However. in DC circuits, instantaneous values are also average and effective values. This is not true in AC circuits.

Press A 36

2

36

The product of two negative quantities is___________.

37 A. negative.
38 B. positive.
37 C. determined by other factors.

2

37

Your answer is incorrect.

The product of two negative quantites is a positive quantity.

Thus, (-2) times (-2) equals (+4).

We can also say it equals 4, and leave off the (+) sign.

For negative values, however, the minus sign (-) must always be used.

Press A 38

2

38

In a resistive circuit, all the power delivered to the load is used. What is the power factor?

40 A. One (or unity)
39 B. Zero
39 C. One-half

2

37

Your answer is incorrect.

In a resistive circuit, because all the power delivered to the load is used, the power factor is one or unity (1.0).

In a reactive circuit, the power factor is less than one because some of the power delivered is NOT used, but is returned to the source.

Press A 40

2

40

OK.

When current lags or leads the voltage, what is the value of the power factor?

41 A. More than one.
42 B. Less than one.
41 C. One.

2

41

Your answer is incorrect.

When current lags or leads the voltage, the power factor is less than one.

In a resistive circuit, the voltage and current are in phase. Therefore, here the power factor is one or unity.

Press A 42

2

42

OK. The review shows that you are doing well.

If you would like to go over this section again before going on with power factor, Press A. 36

Press B to go on to new material. 44

X-C 43

2

43

OK.

The review shows that you should cover this section once more to be sure you know it.

If should be easier to understand this time.

Press A 36

2

44

POWER FACTOR ZERO

We know that if the voltage and current are in phase, the power factor equals one or unity.

Also, when the voltage and current are out of phase by exactly 90 degrees, power factor equals zero.

Remember, to find the power used to do work, we multiply the apparent power by the power factor.

Press A 45

3

45

If the power factor is zero, then the power used to do work will be zero. (Zero times any number is still zero). This type of power is called "wattless" or "reactive."

There still is electrical energy in the circuit, but it is not available for work. Power, due to reactive current, pulsates in and out of a circuit without doing any useful work.

Power factor equals zero when voltage and current are out of phase by exactly ____________.

44 A. 45 degrees
46 B. 90 degrees
44 C. zero degrees

3

46

Look at Plate III. Notice that the power curve lies as much above the zero line as below it. This means that the circuit returns as much power to the source as it receives.

Wattless power is also called ____________________.

45 A. internal power
45 B. total power
47 C. reactive power

3

47

Thus, except for small losses - usually negligible - the purely reactive circuit returns to the source the same amount of power it receives. The net power used each cycle is zero. Although current flows, it does no work, thus no net power is used.

The purely reactive circuit returns as much power to the ____________ as it receives.

46 A. resistance

46 B. reactance

48 C. source

3

48

The voltage and current are never out of phase by exactly 90 degrees. If they were, the circuit would have all reactance and no resistance. All circuits have some resistance.

If a circuit had all reactance, no external work could be done.

If a circuit had all reactance, how much net power would be used?

47 A. All available

49 B. None

47 C. Volts x amperes

3

49

REVIEW

In a circuit having pure resistance, the voltage and the current are in phase. What is the power factor?

51 A. One or unity

50 B. Zero

50 C. One-half

3

50

Your answer is incorrect.

In a circuit having pure resistance, the voltage and the current are in phase. The power factor is then one or unity.

We said that a purely reactive circuit had voltage and current out of phase by 90 degrees. Because they're out of phase, the circuit power factor is zero.

Press A 51

3

51

OK.

Now, if the power factor were zero, how much power would be used to do work in the circuit?

52 A. All

52 B. One-half

53 C. None

3

52

Your answer is incorrect.

If the power factor were zero, no power would be used to do work in the circuit. On the other hand, if the power factor were one or unity, all the power would be used for work. Thus, if the power factor is one-half, only half the "apparent" power used to supply the circuit is actually doing work.

A circuit of pure resistance has a power factor of one or unity. A circuit of pure reactance has a power factor of zero.

Press A 53

3

53

Remember - if we have a circuit of pure reactance, the power factor is zero and none of the power is used for work.

On the other hand, if we have a circuit of pure resistance, the power factor will be one or unity and all the power will be used for work.

Press A 55

3

X-C 54

54

OK.

The review shows that you should cover this section once more to set everything straight. Remember - if we have a circuit of pure reactance, the power factor will be zero. None of the power will be used for work.

Exactly the opposite is true for a circuit containing pure resistance in which all of the power produces useful work.

Press A 44

3

55

DETERMINING AVERAGE POWER

It is easy to find the average power for an AC circuit with the voltage and current in-phase.

For an in-phase AC circuit, simply multiply the effective voltage times the effective current as you have done before. This gives average power in watts for an in-phase AC circuit.

Press A 56

4

56

Usually, though, the voltage and current will be out of phase. In this case, the total current is made up of two components or parts. These two components are at right angles to each other or 90 degrees apart.

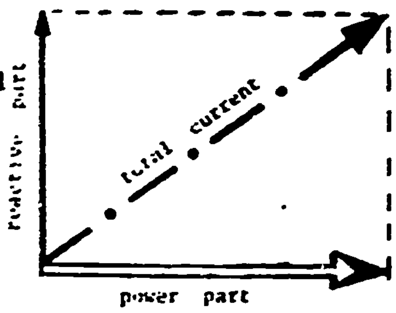
Average power for an in-phase AC circuit equals ______________________.

57 A. effective volts times effective current.
55 B. effective volts divided by effective current.
55 C. effective volts minus effective current.

4

57

We said that in an out-of-phase AC circuit, the total current was made up of two parts. This vector diagram shows how total current is related to its components. The total current is the vector sum of the reactive current and the power current.




The power current component and the reactive current component are______________.

56 A. in phase.
58 B. 90 degrees apart

4

58

We said for an in-phase AC circuit, effective voltage times effective current equals actual power used.

For an out-of-phase AC circuit, the voltmeter reading times the ammeter reading does NOT give us actual power used. This product is called the "apparent" power.

Total current in an out-of-phase AC circuit is the ___________ of the power current and the reactive current.

57 A. sum
59 B. vector sum
57 C. product

4

59

Thus, in order to find the actual power used in an out-of-phase AC circuit, the power current component must be multiplied by the voltage.

If we multiply the voltmeter reading by the ammeter reading in an out-of-phase AC circuit, what is the result called?

58 A. Power
60 B. "Apparent" power
58 C. Reactive power

4

60

So, in an out-of-phase AC circuit:

Total current x voltage = "apparent" power used. (VA)

Total current is made up of power current and reactive current.

If you take a reading with an ammeter, you will read TOTAL current.

Power current x voltage = actual power used. (W)

STUDY THIS SUMMARY. WRITE IT OUT.

Then, press A 61

4

61

Thus, one way to find the actual power used is:

power current x voltage = actual power

There is another way, using the power factor:

We know that total current x voltage = "apparent" power.

Well - "apparent" power x power factor = actual power.

Total current is made up of two components. They are the power current and the__________current.

60 A. resistive
62 B. reactive
60 C. "apparent"

4

62

The letter "K" is sometimes used before electrical quantities and symbols, such as 1 KW. K stands for KILO, and means 1000. Thus, 1 W = one watt.

1 KW = 1000 watts or 1 kilowatt.

1000 VA = one thousand volt amperes. We abbreviate this to: 1 KVA.

1 KVA = one thousand volt amperes or one kilovolt ampere.

Actual power used or watts (W) = ___________current x voltage.

61 A. reactive
63 B. power
61 C. total

4

63

REVIEW

Average power for an in-phase AC circuit equals effective voltage times __________________.

65 A. effective current
64 B. power current
64 C. reactive current

4

64

Your answer is incorrect.

In an IN-PHASE AC circuit, average power = effective voltage x effective current.

In an OUT-OF-PHASE AC circuit, there is a total current made up of the power current and the reactive current. This does not apply to in-phase circuits since the reactive current in these circuits is zero.

Press A 65

4

65

OK.

In an out-of-phase AC circuit, what does a voltmeter reading times an ammeter reading give us?

66 A. Actual power (W)
67 B. "Apparent" power (VA)
66 C. Reactive power (RVA)

4

66

Your answer is incorrect.

For an out-of-phase AC circuit, a voltmeter reading times an ammeter reading gives us "apparent" power.

We said that total current was made up of two components: reactive current and power current.

The reactive current does no work. But when we take an ammeter reading in a circuit, the reactive current is included.

Because of this, when we multiply total current by the voltage, our answer is "apparent" power (VA), not actual power used. (W)

Press A 67

4

67

One way to find the actual power used in an out-of-phase AC circuit is to multiply the power current by the voltage.

What is another way to find the actual power used? Multiply the _______________.

68 A. total current by the voltage.
69 B. "apparent" power by the power factor.
68 C. reactive current by the voltage.

4

68

Your answer is incorrect.

Another way of finding actual power used in an out-of-phase AC circuit is to multiply the apparent power by the power factor. W = (VA) x (PF)

You chose the formula for "apparent" power, which is

"apparent" power = total current x voltage

Remember - "apparent" power includes the part of the current that is not doing work as well as the power current.

Press A 69

4

69

OK.

The letter (K) stands for kilo- What does it mean?

70 A. 100
71 B. 1,000
70 C. 10,000

4

70

Your answer is incorrect.

The letter (K) stands for kilo-.

It means 1,000.

Thus, 1 W means one watt.

1 KW means one kilowatt, or, one thousand watts.

Thus, a (K) in front of a quantity such as watts (W), or resistance ($\Omega$) means to multiply the quantity by 1,000.

Press A 71

4

71

OK. The review shows that you are doing well. If you would like to review the section just covered on average power, Press A. 55

Press B to move on to new material. 73

X-C 72

4

72

OK.

The review shows that you should go over this section once more to get everything straight.

Write down the ways of finding "apparent" power, actual power, and total power as they are given. This may make it easier to understand the differences between them.

Press A 55

4

73

EFFECTS OF POWER FACTOR LESS THAN ONE

It is usually best to keep the power factor close to 1.0. Then most of the power paid for is actually used to do work.

A low power factor, generally meaning one below about 0.7. causes many wastes which could be avoided.

Remember, the lower the power factor, the greater will be the losses associated with using any given amount of power.

Press A 74

5

74

The effects of low power factor are felt in all industries. Waste results in reduced efficiency for all of the electrical supply system, because the power losses for a given load are increased as the power factor decreases.

It is usually best to keep the plant power factor close to__________.

73 A. 0.7
73 B. 0.5
75 C. 1.0

5

75

Low power factor, causes poor voltage regulation. The effects of poor voltage regulation may become noticeable in the manufactured product of any plant. Poor voltage regulation may result in fluctuating motor and line speeds.

Low power factor causes____________in power losses. ($W = I^2R$)

74 A. a decrease
76 B. an increase
74 C. no change

5

76

Low power factor can also increase operating costs, which affects everyone in the long run. Because of low power factor, manufacturers operating their own generating plants may require larger alternators. All plants may require larger transformers, switchgear, and feeders to carry the reactive current which does no useful work.

Poor voltage regulation caused by low power factor can affect______________.

77 A. motor and line speeds
75 B. watts
75 C. current

5

77

The operating power factor of most electrical equipment is essentially fixed in the design. However, devices can be added to the circuit to correct low power factor.

Low power factor requires_____________transmission and distribution equipment.

78 A. larger
76 B. less
76 C. smaller

5

78

THE CONTROLLING EFFECT OF SYNCHRONOUS MOTORS ON POWER FACTOR

Synchronous motors are AC motors which run at a constant speed. This speed is determined by the line frequency and the number of poles in the motor.

The field of a synchronous motor is magnetized with DC from a separate variable source.

Press A 71

5

79

By varying the strength of the synchronous motor field, we can create over excitation or under excitation.

Under excited fields are magnetized weakly.

Over excited fields are strongly magnetized.

The field of a synchronous motor is magnetized with ______.

80 A. DC

78 B. permanent magnets

78 C. AC

5

80

When a synchronous motor is run with an over excited field, it draws a leading current from its AC source. This means that in this case, the reactive component of total current leads the line voltage.

Over excited fields are ______ magnetized.

79 A. weakly

81 B. strongly

79 C. un-

5

81

When a synchronous motor is run with an under excited field, it draws a lagging current from its AC source.

This means that in the case of under excitation, the reactive component of total current lags the supply voltage. In either case the power component of total current is determined by the load.

In the case of over excitation, line current ______ the line voltage.

82 A. leads

80 B. lags

80 C. is in phase with

5

82

The power factor of a circuit containing a synchronous motor can be varied. Power factor is varied by changing the field excitation of the motor. Thus, low power factor can be corrected with a synchronous motor.

A synchronous motor with an under excited field draws a ______ current from the source.

81 A. leading

83 B. lagging

81 C. reactive

5

83

We can use a synchronous motor to correct power factor. At the same time, we can use it to deliver mechanical power, or let it operate at no load.

Power factor in a circuit with a synchronous motor can be varied by changing the motor's ______.

82 A. speed

82 B. voltage

84 C. field magnetization or excitation

5

84

When operated at no load to correct a lagging power factor, the over excited synchronous motor is called a synchronous condenser.

We can use ______ to correct the power factor.

83 A. induction motor excitation

85 B. a synchronous motor

83 C. any AC motor

5

85

USING A SYNCHRONOUS MOTOR TO CORRECT A LAGGING POWER FACTOR. Here a lagging current is drawn by the circuit. If an over excited synchronous motor is connected in parallel, it draws a leading current. In effect, the leading current and the lagging current cancel each other. Another way to put it, is that the synchronous motor supplies the reactive current to the inductive circuit.

Press A 86

5

86

Because the leading and lagging currents seem to cancel each other, the net reactive current in the circuit will be the difference between the two. Because the reactive current is reduced, the power current becomes a larger part of the total current.

Thus, if the net reactive current is reduced, the power factor increases.

Press A 87

5

87

Now we see how important synchronous motors and capacitors are in improving the power factor of AC transmission and distribution systems.

Now for a final review.......

Press A 88

5

88

FINAL REVIEW

A plant's electrical system operates most efficiently and economically when the plant power factor is closest to________.

A. 0.7 89
B. 0.5 89
C. 1.0 90

5

89

Your answer is incorrect.

It is usually best to keep the power factor close to 1.0. Then the electrical distribution system operates at maximum efficiency and economy.

A low power factor, generally meaning one below 0.7, causes many wastes which could be avoided. The idea, then, is to keep the plant power factor as close to 1.0 -- as practical. Generally, average power factors from about 0.9 to 0.95 will be found most economical.

Press A 90

5

90

OK.

The operating power factor of most electrical equipment is essentially fixed in the design. However, devices can be added to the__________to correct low power factor.

91 A. equipment
92 B. power factor
93 C. circuit

5

91

Your answer is incorrect.

Devices such as synchronous motors and capacitors can be added in parallel with the circuit to correct low power factor.

We said that the power factor of most equipment is fixed in the design. This usually makes it impossible to change power factor by adding to the equipment itself.

Press A 93

5

92

Your answer is incorrect.

We cannot add devices to the power factor.

Power factor is only a ratio - not a thing.

We can add devices to the circuit, though, to change the power factor.

Press A 93

5

93

OK.

If the net reactive current is reduced, what is the result?

95 A. The power factor increases.
94 B. The power factor decreases.
94 C. The power factor remains the same.

5

94

Your answer is incorrect.

If the net reactive current in a circuit is reduced, the power factor increases. Because the net reactive current is reduced, we know that the power current becomes a greater part of the total current.

Because we can decrease the reactive current without changing the power current, the power factor increases.

Press A 95

5

75

The final review shows that you have done well.

You have successfully completed this film on power factor. If you would like to read over this last section once more, Press A. 73

Otherwise, press REWIND.

X-C 96

5

76

OK.

The review shows that you should cover this section once more to be sure you know it.

It will be easier to understand this time through.

Read for new ideas you may have missed.

Press A 15

5

# DIDACTOR

FILM NO. EM 1-4D/E

Evaluation of effectiveness of instruction films by
Human Engineering Institute

Name____________________ Date____________

Pre-Survey____________ Post Survey____________

Directions: Circle the letter of the answer you think is correct for each item.

You know that E = IR. ( I times R )
Now, you know what the letters stand for. You should be able to figure out the voltage in a circuit having 10 amps of current and 24 ohms of resistance. The voltage for this circuit is: ( choose one )

A. $2\frac{2}{5}$ volts

B. 34 volts

C. 240 volts

1

What is the resistance of 5 amp, 120 volt electric flat iron?

A. 24 ohms

B. 115 ohms

C. 550 ohms

1

Now, a 240 volt lamp has a resistance of 10 ohms. How many amps flow in the circuit?

A. 24 amps

B. 210 amps

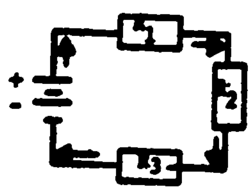
C. 2200 amps

1

This is a circuit wired in:
(pick one)

A. series

B. parallel



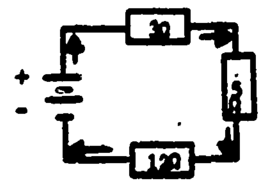

2

So, a series circuit having resistances of 3 ohms, 5 ohms, and 12 ohms in series would have a total resistance of:
(pick one)

A. 10 ohms

B. 20 ohms

C. 180 ohms




2

the total resistance is 20 ohms, what is the current needed in the circuit carrying 240 volts ?

A. 12 amps

B. 24 amps

C. 240 amps

2

OK. You remember our formula of $I = \frac{E}{R}$. Good.

Now, lets say that a string of Christmas tree lights is connected in series. (This means that when one burns out, the others will go out as well, because the bulb becomes a part of the circuit in series. So, when one burns out, the entire circuit goes open.) Lets say that there are 8 lights on a 120 volt line. If the current in each lamp is 0.2 amps, what is the resistance of each lamp?

A. $9\frac{3}{8}$

B. 75 ohms

C. 600 ohms

2

# DIDACTOR

FILM NO. EM 1-4D/E

We have an electric motor with a resistance of 25 ohms. It's on a 120 volt line. The current has to be kept down to 2 amps when starting. What size resistor would we use in the series circuit with the motor?

A. $4\frac{4}{5}$ ohms

B. $9\frac{3}{5}$ ohms

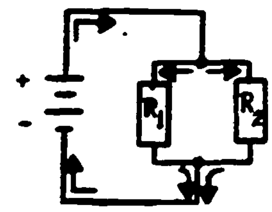
C. 35 ohms.

2

Now - This circuit is wired in:

A. Parallel

B. Series



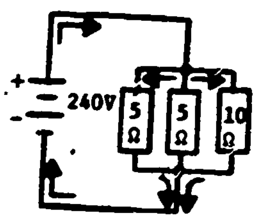

3

Now, what is the total current of a circuit wired in parallel with resistors of 5 ohms, 5 ohms, and 10 ohms on a line of 240 volts?

A. 12 amps

B. 120 amps

C. 250 amps




3

Three resistors of 4, 6, and 12 ohms are connected in parallel.
A 6 volt battery is connected to the circuit.
What is the current delivered by the battery?

A. $\frac{3}{11}$ amps

B. 2 amps

C. 3 amps

3

how many watts are used in a circuit in which a 240 volt lamp has a current of 10 amps?

A. 22 watts

B. 240 watts

C. 2400 watts

4

what is the voltage in a circuit using 3 KW of power and having 150 amps current? (use the power formula).

A. 50 volts

B. 20 volts

C. $\frac{1}{50}$ volts

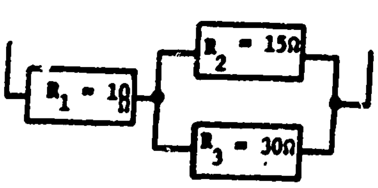
4

Now find the total resistance in this series - parallel circuit:

A. 6Ω

B. 20Ω

C. 55Ω



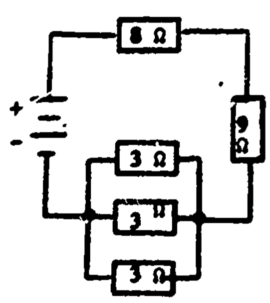

4

What is the total resistance?

A. $13\frac{4}{17}$ Ω

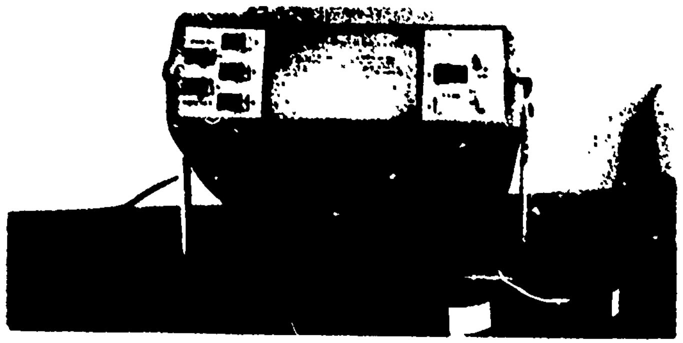
B. 18Ω

C. 26Ω




4

## Accelerating and Improving Learning.



### A PROVED TOOL for TODAY'S and TOMORROW'S more demanding LEARNING REQUIREMENTS.

Mankind's progress is the history of tools developed to improve upon natural manual skill, senses, strength and speed.

Today there are pressing needs for another tool - -**One to help people learn what they must know to function competitively in our kind of society.**

**A TOOL IS NEEDED** to improve upon man's natural learning process so that he can **learn faster and retain more.** Ease and speed of learning usually has been associated with well-written, well-spoken, or visually attractive material. But much more is involved in helping the learning process than just presenting material with simplicity, clarity and attractiveness.

**ACTIVE PARTICIPATION,** for example, is most important. Just absorbing words or watching pictures is not efficient for learning. Learning is greatly improved when the student is called upon to respond, to make some personal expression about what is presented.

**DIRECT ANSWERS** to his responses are vital! If he is to respond often, he needs to know constantly that he is on the right track. He needs to know if he is responding correctly. And if not, why not.

**REPETITION** is essential - - but not just simple repetition. The student needs repetition that is **structured** . . . first permitting a certain amount of trial and error experience, perhaps . . . then familiarization and orientation with a group of related concepts . . . finally, demanding in repetition that he exercise a careful discrimination and precision of response. This is the path through which **overlearning** is achieved, and overlearning is essential for the student to transfer what he learns to new situations.

**TIMED DRILLS** reinforce the student's learning. He really does not learn a fact until he also learns to use it quickly. He may have a "feeling" for a method or a fact, but only when he responds with it positively, directly, and without hesitation has he truly learned the material.

A book, a slide film, a movie, a lecture can all be helpful, but they cannot provide the combination of active participation, direct answers, structured repetition and timed drills. These media leave the student to provide most of the learning process control -- and he is often pretty clumsy at it. He needs a more effective tool to help him learn better and faster.

The **DIDACTOR** utilizes linear, branched and unique programming techniques to help students (adult or child) to learn - - better, faster and more economically - - the knowledge required to succeed in modern industrial, commercial, military or scholastic life.

The **DIDACTOR** presents filmed, coded lesson series, frame by frame. In each frame, the learner is given a choice or a number of choices (up to 5), the response to which will indicate either his level of understanding at that point, or a personal preference.

On the basis of these responses, the **DIDACTOR** will:

a) proceed through straightforward sequences as long as appropriate responses are made.
b) take the learner to a corrective frame or a whole series of frames when an inappropriate response is made.
c) skip over informational material if responses indicate advanced understanding.
d) repeat a series of presentations for review, or use special corrective frames not in the initial sequence.
e) remember the learner's responses over a series of frames and take corrective action if trend of responses shows a weak grasp of material, or guessing, or illogical train of thought.
f) advance and test at predetermined rates-- if so set - - in order to teach subjects where speed of responses is important