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ABSTRACT

This student guide, one of a series of correspondence training courses designed to improve the job performance of members of the Marine Corps, deals with the skills needed by air conditioning mechanics. Addressed in the four chapters, or lessons, of the manual are the following topics: principles of air conditioning, refrigeration components as applied to air conditioning equipment, procedures for servicing air conditioning equipment, and commercial and tactical air conditioning units. In a seperate section following chapter 4 are 4 review units corresponding to the 4 lessons in the guide. Each unit contains a reading assignment, a lesson objective statement, and a written assignment consisting of a series of study questions for that unit. (MN)

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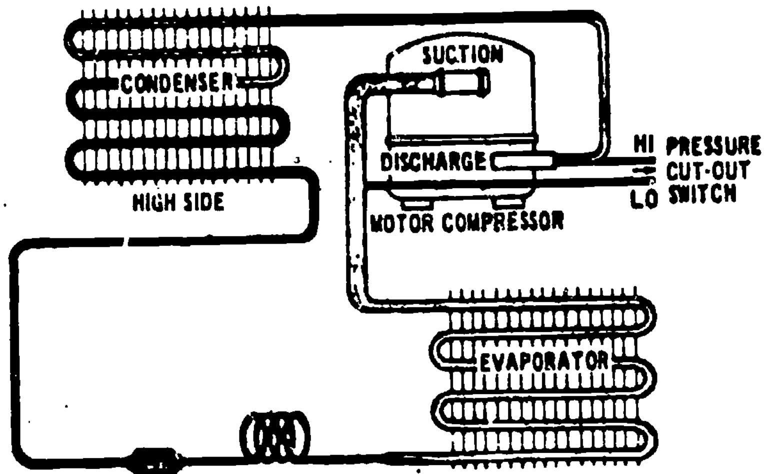
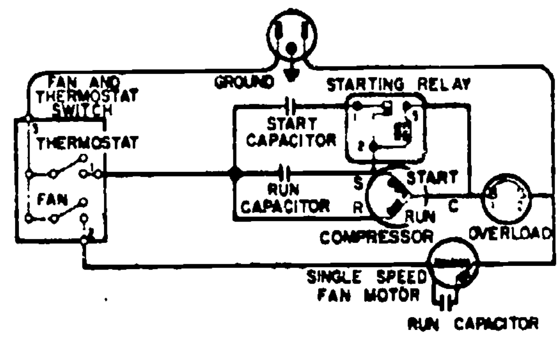
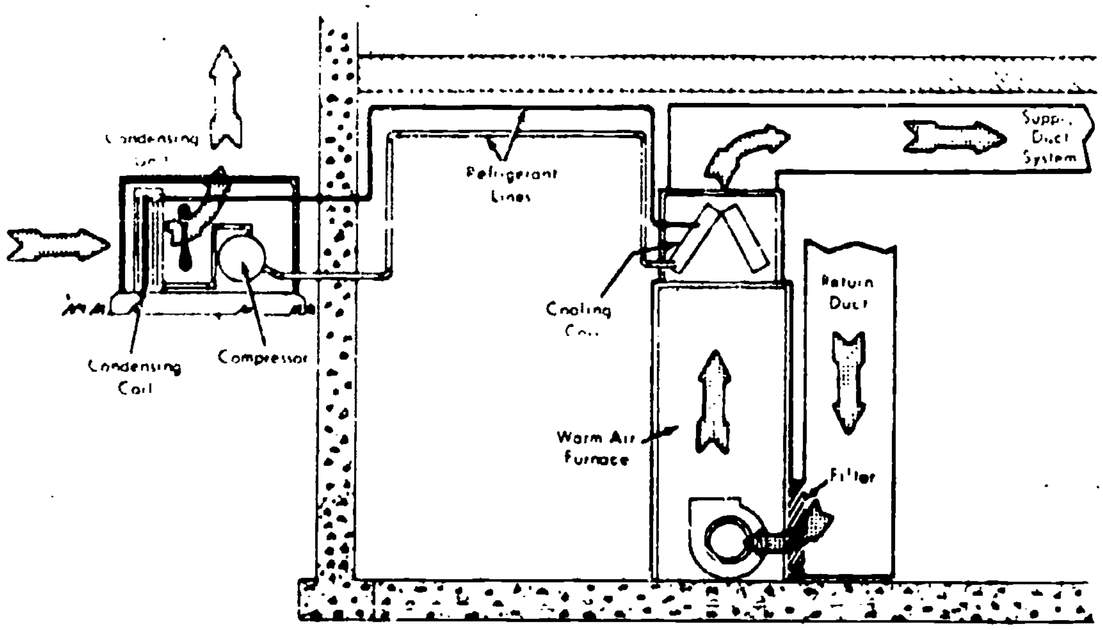




AIR-CONDITIONING MECHANIC



MARINE CORPS INSTITUTE
MARINE BARRACKS
WASHINGTON, D.C.

PREFACE

Air-Conditioning Mechanic has been designed to provide Marines, Corporal and below, in MOS 1161, with a comprehensive coverage of air conditioners and air-conditioning systems. Combining the principles presented in this course with on-the-job training will prepare Marines to install, operate, test, maintain, and perform limited repairs to air-conditioning units and systems.

SOURCE MATERIALS

TM 5-670	Refrigeration, Air Conditioning, Mechanical Ventilation, and Evaporative Cooling, Feb 1962
TM 5-4120-222-15	Air Conditioner: Compact Vertical Models CE 20 VAL6 and CE 20 VAL4, May 1969
TM 5-4120-239-14	Operator, Organizational, Direct Support, and General Support Maintenance Manual, Air Conditioner, Horizontal Compact, 9,000 Btu, Sep 1971 Ch 1
TM 5-4120-243-14	Operator, Organizational, Direct Support, and General Support Maintenance Manual, Air Conditioner, Horizontal Compact, 18,000 Btu, Oct 1971 Ch 1 and 2
TM 4120-15/1A	Principal Technical Characteristics of U.S. Marine Corps Military Standard Air Conditioners with Supplemental Logistics Data, Aug 1975
TM-06505A-15	Air Conditioner, Self/Contained, Trane Model MAC6V40, Sep 1968
MCO 10230.2	U.S. Marine Corps Military Standard Air Conditioners, 9 Mar 1973

CONTENTS

Chapter 1

PRINCIPLES OF AIR CONDITIONING

1-1. INTRODUCTION

a. General. Some 30 to 35 years ago places such as schools, office buildings, factories, and homes were not air conditioned. About the only place to get cool on a hot, humid day was the local movie theater, and even there the humidity was not controlled; just the temperature was lowered. Most people in those days relied upon a system of fans or a nice shady spot on the back porch to get cool. World War II, as it did to so many technical fields, brought about a big change in air conditioning. A large demand for improved technical methods and higher industrial production resulted in a need for improved equipment and techniques with regard to controlling atmospheric conditions. Today, the armed forces, as well as industry, have reached a point where highly trained personnel are needed to operate the equipment that controls our environment. The day of the pedestal floor fan and the small oscillating fan are gone. We now depend on machines to control and condition the air that surrounds us. We have advanced to the point that proper control of atmospheric conditions has become almost a necessity. For example, electronic equipment will corrode and become useless because of high humidity. Training aids, data processing machines, photographic laboratories, storage vaults, hospital laboratories, and operating rooms must all be air conditioned to insure that the air is kept dust free, and that temperature and humidity are maintained at a prescribed level. Air conditioning is also necessary to maintain the health, morale, and efficiency of troops. People, along with the equipment they work with, require satisfactory working conditions and climate. To keep pace with the ever-increasing technical nature of the mission of the Marine Corps, the development and installation of air-conditioning equipment has become a necessity. Air conditioning is the process of conditioning the atmosphere in a given space in order to maintain a predetermined temperature-humidity relationship to meet optimum comfort and technical requirements. This process includes both cooling in the summer and warming in the winter.

b. Purpose of air conditioning. Today air conditioning is used by the military to control the environment in which troops and equipment operate. This environmental control extends not only to the temperature of the space, but to controlling the humidity (moisture content), removal of foreign and undesirable particles from the air, and distribution of the conditioned air throughout the space. Moisture, heat, and foreign particles enter the air in many ways. The human body gives off heat and moisture. The average adult engaged in light work will give off approximately 500 Btu's (British thermal units) of heat per hour and will consume and give off about three pounds of water daily. Equipment will give up heat to the surrounding atmosphere either through friction caused by mechanical motion or by heat created by electricity flowing through wires, contacts, motors, etc. Moisture and foreign particles can enter a conditioned space through windows, doors, minute cracks, ventilation systems, and by people carrying them on their person and clothes. In order to maintain an environment at a specific level of control, air-conditioning equipment is used to raise or lower temperatures, remove moisture and foreign particles, and to distribute air evenly throughout the space to be controlled.

1-2. REFRIGERATION THEORY

a. General. In order to become a successful mechanic in any field, you must first understand the principles and theories that make the equipment work. Since air-conditioning equipment works on the theory of refrigeration, let us first study the basic principles and theories behind refrigeration theory.

b. Heat. Every substance contains heat but some will have more than others. Heat is produced by the movement of molecules within a substance; the more the molecules move, the higher the temperature of the substance becomes. It therefore follows that the opposite is true; the more slowly the molecules move, the lower the temperature. Put another way, the more molecular action, the more heat produced and the less molecular action, the less heat produced. It would also follow that a complete lack of molecular action would produce a complete lack of heat or absolute zero. The terms hot and cold are often heard, hot meaning a high temperature and cold meaning a low temperature. Cold cannot be produced but is simply the result of removing heat. This is done by slowing the molecular action within a substance. Once the molecular action of a substance is slowed, the result is not the production of cold but the production of a lower degree of heat. Heat cannot be lost or destroyed, but it can be transferred to another substance. Heat will travel in one direction only; from an object or substance of a higher temperature to one of a lower temperature. This transfer of heat will often cause many substances to change their state; from a solid to a liquid, liquid to a gas, or vice versa. There are different types of heat and different methods of heat transfer. Let's first look at some different types of heat.

(1) Sensible heat. Sensible heat is heat that raises or lowers the temperature of a substance without changing its state; that is, without changing it from a solid to a liquid, from a liquid to a gas, or vice versa.

(2) Specific heat. This is the amount of heat, in Btu's, that is required to change the temperature of one pound of a substance one degree Fahrenheit. Some substances require more heat than others to produce this change in temperature. Since water is used as the basis of comparison for specific heat values, the specific heat of water is 1.0. All other substances have specific heat values either above or below this figure. Figure 1-1 shows the specific heat value of a few common substances. The amount of heat necessary to cause a desired temperature change in a substance can be calculated quite easily. Simply multiply the weight of the substance by its specific heat by the desired temperature change in degrees Fahrenheit. Expressed as an equation it would be: amount of heat to be added or removed in Btu = weight x specific heat x temperature change in degrees Fahrenheit.

Example: How many Btu's must be added to 20 pounds of copper to raise its temperature from 40° to 65°F? Specific heat of copper is .095 (fig 1-1).

Solution: Btu = 20 x .095 x 25

Btu = 47.5

This formula will work unless the temperature change desired would cause a change of state.

MATERIAL	Specific Heat (Btu #)
Wood	.327
Water	1.
Ice	.504
Iron	.129
Mercury	.0333
Alcohol	.615
Copper	.095
Sulfur	.177
Glass	.187
Graphite	.200
Brick	.200
Glycerine	.576
Liquid Ammonia at 40° F.	1.1
Carbon Dioxide at 40° F.	.6
Methyl Chloride at 40° F.	.38
Sulfur Dioxide at 40° F.	.35

Fig 1-1. Specific heat values.

(3) Latent heat. Latent heat is heat that is added to or removed from a substance causing that substance to change state (i.e., melt, freeze, boil, or condense) while remaining at the same temperature. As you know, water can exist at 32° F in liquid form and also in solid form (ice). In order for water to change from liquid to solid it is necessary to remove an amount of latent heat. In order for it to change its state from ice back to water, the same amount of latent heat must be added. This is known as the latent heat of fusion or melting. There is another

latent heat, the latent heat of vaporization or condensation. As it is possible to have both water and steam at 212° F, it would then follow that a certain amount of heat is necessary to cause the change of state. The amount of heat required to cause vaporization or condensation of water is 970 Btu's per pound; to cause fusion or melting, 144 Btu's per pound would be necessary.

(4) British thermal unit (Btu). A Btu is defined as the amount of heat required to raise the temperature of one pound of water one degree Fahrenheit. Conversely, if water is cooled, Btu's would be removed. There are no instruments for measuring Btu's but they can be calculated by the temperature change.

Example: How much heat would be required to raise the temperature of 73 pounds of water from 33° to 73°F?

Solution: Btu = wt. x degree change

Btu = 73 x 40

Btu = 2920

Example: If you had 50 pounds of water and wished to lower its temperature from 80° to 32°F, how much heat would be removed?

Solution: Btu = wt. x degree change

Btu = 50 x 48

Btu = 2400

(5) Heat transfer. Heat can be transferred from an object of higher temperature to one of a lower temperature. The transfer of heat will take place until both objects reach the same temperature. There are three methods of transferring heat: conduction, convection, and radiation.

(a) Conduction (fig 1-2). Conduction of heat is accomplished by transmitting heat from one part of an object to another part of the same object or from one substance to another when the substances are in direct contact. This can be seen in figure 1-2. By placing one end of the metal rod in the flame, it will become warmer than the other end. The heat will flow along the rod raising the temperature of the cold end. Metals, such as iron, copper, or silver, are good conductors of heat; other materials, such as glass and cork, are not. Materials that offer a low resistance to the flow of heat are called conductors; those that offer a high resistance to heat flow are referred to as insulators. Conduction is aided by providing large surfaces of good heat-conductors.

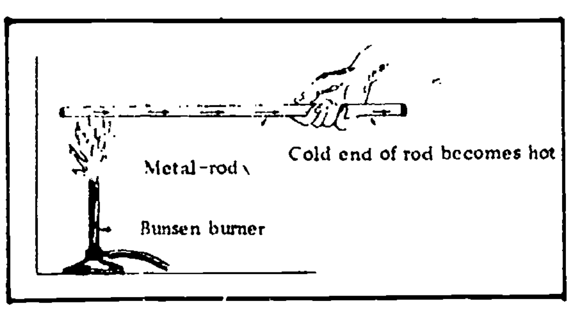


Fig 1-2. Heat transfer by conduction.

(b) Convection (fig 1-3). Convection can be explained by following the principle behind a simple heating system such as the one shown in figure 1-3. First, air is heated and allowed to escape into an area where the air is cooler. Since air expands when it is heated, it becomes lighter than cold air. The cold air will flow under the hot air, forcing the hot air to flow above the cold. As the temperature becomes equalized, the air will begin to fall back towards the heating source and the cycle begins over. Convection is aided through the use of fans, such as in a forced-convection heating system.

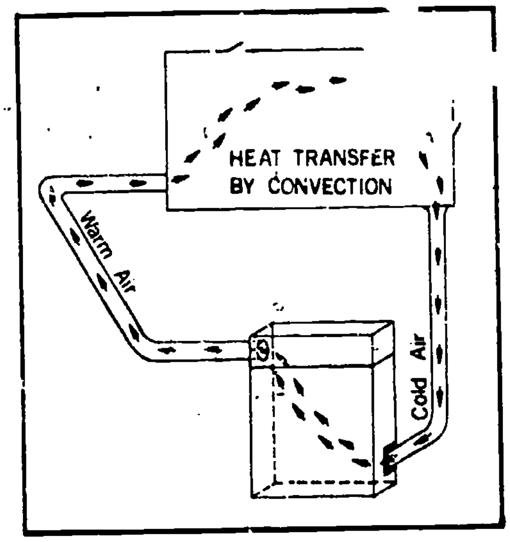


Fig 1-3. Heat transfer by convection.

(c) Radiation (fig 1-4). This is usually accomplished through use of heating coils and a reflecting surface. The heating coils will produce the heat and the reflecting surface will direct the heat toward a given area. Since dark colors usually absorb heat and light ones reflect it, heat transferred by radiation is usually provided with a background of white or silver.

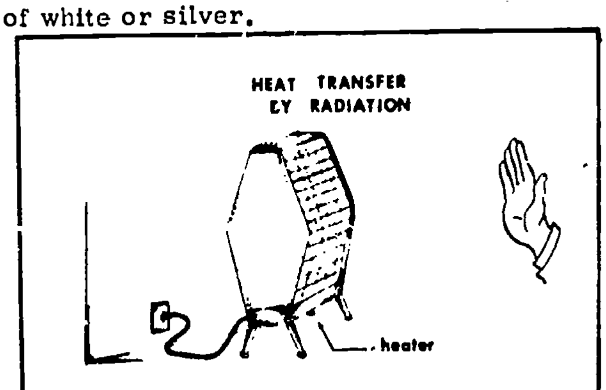


Fig 1-4. Heat transfer by radiation.

c. Temperature and its measurement.

(1) General. The relative degree of a substance's warmth is called temperature. This is not to be confused with the quantity or amount of heat in a substance, but is merely the sensible or measureable warmth of the substance. An ordinary thermometer is used to measure temperature. There are two types of scales in common use today to measure temperature, Fahrenheit and centigrade. Both of these scales were arbitrarily chosen by scientists and both employ a glass tube of uniform bore, a bulb at the bottom of the tube, and contain a liquid, usually mercury or alcohol. The Fahrenheit scale is divided into 180 equal divisions between the freezing (also melting) and boiling point of water, whereas the centigrade scale is divided into 100 divisions. Water will freeze (melt) at 32° on the Fahrenheit scale and boil at 212°. On the centigrade scale, water freezes at 0° and boils at 100°C. A comparison of the two scales can be seen in figure 1-5. Water was chosen as a standard for these thermometers because it has a very constant freezing and boiling point, and is an extremely common substance.

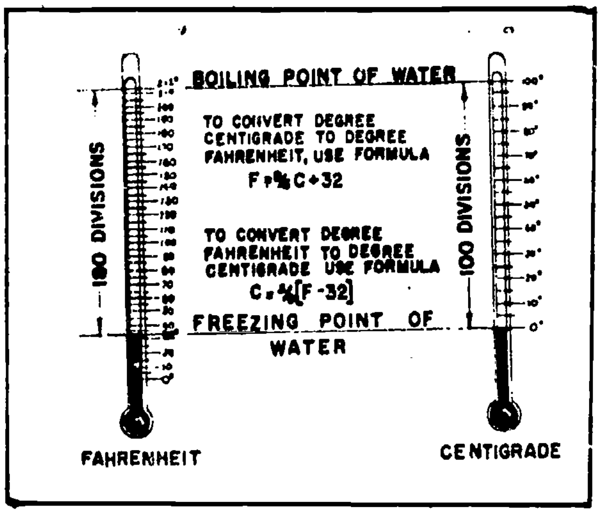


Fig 1-5. Comparison of Fahrenheit and centigrade scales.

(2) Conversion. Although the Fahrenheit scale is most commonly used in air-conditioning work, it sometimes becomes necessary to convert Fahrenheit to centigrade and vice versa. To convert Fahrenheit to centigrade, subtract 32 from the Fahrenheit temperature and multiply the remainder by 5/9, i.e., C=5/9 (F-32). To convert centigrade to Fahrenheit, multiply the centigrade temperature by 9/5 and add 32^{o}. Expressed as a formula, F= 9/5 C+32.

Example: Convert $41^{o}F$ into centigrade.

Solution: C= 5/9 (F - 32)

C= 5/9 (41 - 32)

C= 5/9 (9)

C= 5/9 x 9/1

C= 5^{o}

Example: Convert $20^{o}C$ into Fahrenheit.

Solution: F= 9/5 C + 32

F= 9/5 (20) + 32

F= 9/5 x 20/1 + 32

F= 36 + 32

F= 68^{o}

d. Pressure.

(1) General. Before an air conditioner can operate properly, a pressure difference must exist across the system. Pressure is expressed as the force per unit of area exerted on supporting surfaces, usually expressed in pounds per square inch (psi) or pounds per square foot. The atmospheric or air pressure that is exerted on the human body at sea level is 14.7 psi. Every substance will exert a pressure on the surface that supports it. For example, a table will exert pressure on the floor through its legs. A liquid, such as water in a pail, will exert pressure on the bottom and sides of its container. A gas, such as helium in a balloon will exert a pressure on all sides of its container to an extent that depends on the temperature and the volume of the gas. Gases and liquids have a definite pressure-temperature-volume relationship which is

of great importance to the proper operation of an air-conditioning unit or system. This relationship will be discussed in paragraph 1-2e.

(2) Measuring pressure. Pressure is commonly measured with a gage. However, it can also be indicated in inches of mercury or inches or feet of water. A standard atmospheric pressure of 14.7 psi (atmospheric pressure at sea level) will support a column of mercury of 29.92 inches and a column of water of about 34 feet. Pressure measured with a gage will be measured above atmospheric and is stated as pounds per square inch gage (psig). Pressures below atmospheric are usually indicated in inches of mercury. When working with air-conditioning equipment it will often be necessary to use absolute pressure (psia) for proper computation of pressure and volume. Absolute pressure is gage pressure plus atmospheric pressure. In order to convert gage pressure to absolute, you simply add 14.7 to the gage reading.

Example: What is the absolute pressure when the pressure gage reads 30 psi?

Solution: 30 + 14.7 = 44.7 psia.

e. Pressure-temperature-volume relationship. Understanding the relationship of pressure, temperature, and volume and their effect on refrigerants is vital in understanding the refrigeration cycle of an air-conditioning system or unit. The pressure-temperature-volume relationship of gases is expressed by three laws; Boyle's law, Charles' law, and the general gas law.

Boyle's law states that the volume of a gas varies inversely with its absolute pressure, provided the temperature remains constant. Stated as an equation; $V_1P_1 = V_2P_2$. Boyle's law can be stated in simpler terms by saying; when the temperature is held constant, increasing the pressure on a gas will cause a proportionate decrease in the volume; decreasing the pressure will cause a proportionate increase in the volume. For example; a volume of gas, say five cubic feet (cu ft), is placed in a cylinder and a piston exerting a pressure of 50 psig is inserted in the end of the cylinder to hold the gas in. Now, if the pressure on the piston is increased to 250 psig, the piston would move into the cylinder until the volume is decreased to one cu ft. If the pressure was decreased to 25 psig, the piston would move out of the cylinder until the volume was 10 cu ft.

Charles' law states that the volume of confined gas varies proportionately to its absolute temperature, provided the pressure is kept constant. Likewise, the pressure varies proportionately, to the absolute temperature, provided the volume remains constant. Stated more simply: when the pressure is constant, increasing the temperature of a gas will cause an equal increase in its volume. When the volume is kept constant, an increase in temperature will cause an equal increase in pressure. Expressed as formulas:

Constant pressure $V_1T_2 = V_2T_1$

Constant volume $P_1T_2 = P_2T_1$

The general gas law is a combination of Charles' and Boyle's laws and expresses the relationship between the volume, the absolute pressure, and the absolute temperature of gases. The general gas law is expressed by the equation: $\frac{P_1V_1}{T_1} = \frac{P_2V_2}{T_2}$

It should be noted here that whenever any of these formulas are used only absolute pressures and temperatures are to be used. It should also be noted that we have said that volume and temperature of gas are different after the pressure changes. It is important to note however, that the temperature change will take place while the pressure changes. Compressing the gas raises its temperature; expanding the gas lowers its temperature. As you will see this is an important factor in the refrigeration cycle.

1-3. THE REFRIGERATION CYCLE

a. General. The refrigeration cycle is common to all machines made for lowering and controlling the temperature in our everyday living. This cycle produces a lower temperature through utilization of pressure differences and phase changes. The changes necessary to produce and control the pressure differences are made through the use of two systems: the compression system and the absorption system. These two systems differ in that the compression system uses mechanical energy to produce the necessary change in conditions and the absorption system uses heat energy.

b. Compression system (fig 1-6). The compression system produces a lower temperature by employing the theory of latent heat, pressure differences, and heat transfer. The transfer of heat is accomplished by using a liquid (refrigerant) which vaporizes at a low temperature and pressure. Once the vapor has absorbed the heat, it is compressed and raised to high temperature and pressure. It is then condensed back to a liquid - thereby dissipating the heat. Thus this cycle consists of a high-pressure side and a low-pressure side. As the piston moves down, low-pressure gas enters the compressor through the inlet valve. As the piston starts up, the vapor is compressed increasing the temperature and pressure. (This temperature increase is greater than the temperature of the cooling medium which surrounds the condenser.) When the piston approaches the top of the cylinder, the discharge valve opens and the high-pressure, high-temperature vapor moves to the condenser. The condenser, a series of tubes, is surrounded by a cooling medium (usually air or water). The latent heat of condensation is surrendered to the cooling medium and the vapor becomes a high-pressure, high-temperature liquid. From here the liquid flows on to the receiver, which is merely a storage place for the liquid until it is needed by the refrigerant control (usually an expansion valve). The expansion valve reduces the pressure of the liquid and meters it into the evaporator, where it absorbs heat from the area to be cooled and vaporizes to a low-pressure, low-temperature gas. Then the gas enters the suction line leading to the compressor completing the cycle. A study of figure 1-6 will show that the refrigeration cycle is divided in half with respect to pressure. From the compressor, through the condenser and receiver to the expansion valve is the high side of the system. From the expansion valve through the evaporator and back to the compressor is the low side. Regardless of size and manufacturer's design of air-conditioning equipment, the refrigeration cycle of all compression systems will be the same.

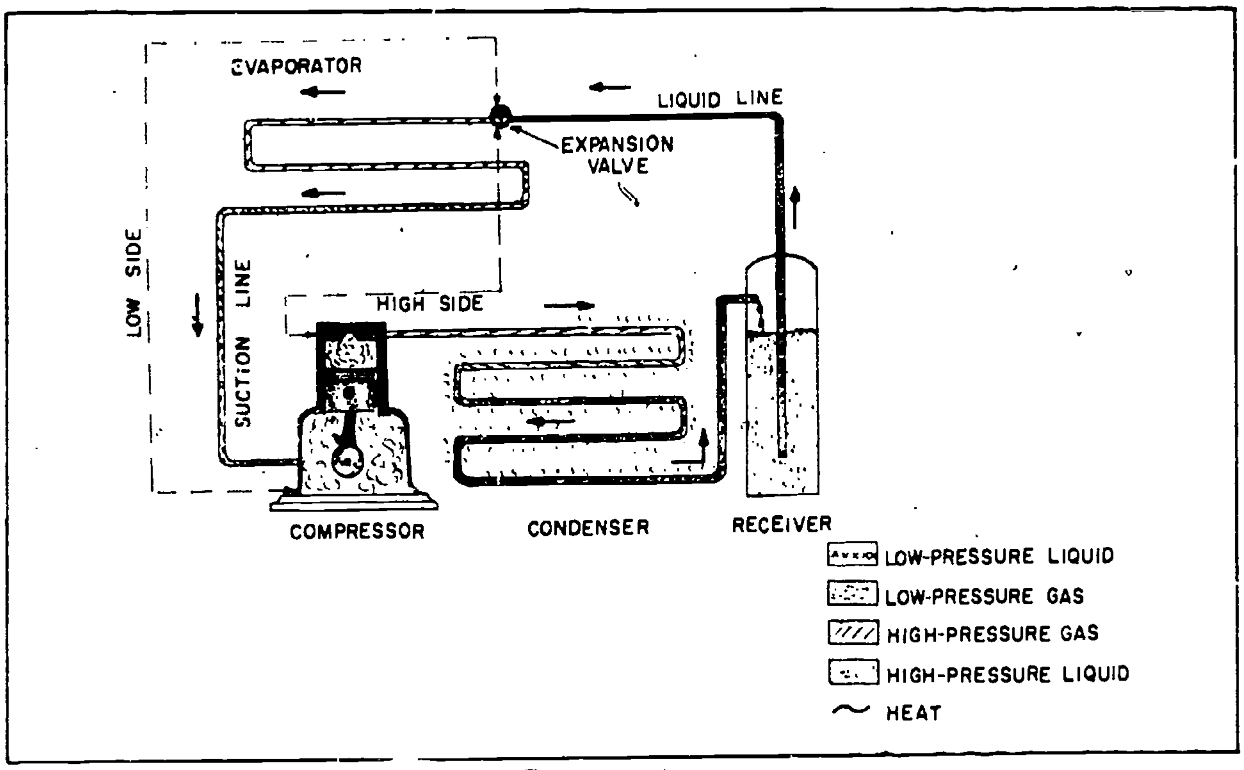


Fig 1-6. Compression system.

1-4. COMPONENTS AND CHARACTERISTICS OF AIR

a. Characteristics of air. Air is not a single substance, but is a mixture of various gases. Approximately 20% of the air is oxygen; a little less than 80% is the inert gas nitrogen; about 0.03% is carbon dioxide; and the rest (less than 1%) is a mixture of argon, helium, krypton, neon, xenon, and hydrogen. These are the components of dry air. Air will also contain foreign matter and water vapor. It is affected by weather conditions and is subject to gain and loss of heat. Since air-conditioning equipment must be able to remove water vapor and foreign matter from the air and counteract the effects of weather and heat gain or loss, it is necessary for you to know how each of these things will affect the design, construction, and installation of air-conditioning equipment.

b. Foreign materials. The air that is used for air conditioning or ventilation contains many impurities ranging from carbon (from incomplete combustion), dust (from the ground), to rubber particles from tires, plant pollen, and lint from clothing. The size, quantity, and type of dust particles picked up by a system vary over a wide range. The atmosphere may include many particles of dust smaller than 5 microns (1 micron is approximately 0.001 millimeter or about 0.00004 in.). However, many of the dust particles are larger than 800 microns, or about 1/32 in. Figure 1-7 shows a comparison scale of dust particles in microns.

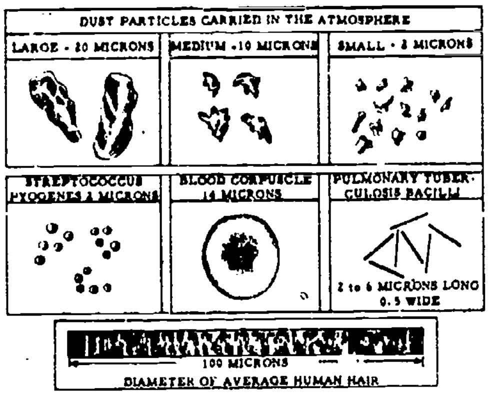


Fig 1-7. Atmospheric dust particles.

c. Removing foreign materials. Since air-conditioning intakes are usually placed near horizontal surfaces from which all this foreign matter can be picked up and distributed, the system must contain a filtering device of some kind. Removing dust particles from air that is to be used by an air-conditioning system can be accomplished by any of the following methods of filtration.

(1) Air washing. This is done by forcing the air through a spray chamber or a screen of water.

(2) Dry filtering. These filters are made of porous material such as steel wool, wire screen, animal hair, hemp fibers, fiberglass, or glass wool. The air passes through the filter and changes direction several times. The dust particles will collect on the fibers, thus cleaning the air.

(3) Wet filters. Wet filters are made up of the same materials as a dry filter; however, they are coated with a viscous material, usually oil. The air passes through them and dust particles are collected in the same manner as with the dry type. As dust particles collect in both the dry- and wet-type filters, resistance to the flow of air through them is increased. These filters will have to be cleaned or replaced depending on whether they are the cleanable or throw-away type.

(4) Electrostatic filters. These filters remove dust particles by passing the air between two electrodes and imparting an electrical charge to each dust particle. Then the air is passed between parallel plates. The electrostatic field that is created between the charged plates and the grounded plates drives the charged particles to the grounded plates where they accumulate. The grounded plates are usually coated with a thin layer of oil to insure that the dust particles stay on the plates.

(5) Centrifugal separation. To filter dust particles from the air in this method, the air is circulated at high speed. The centrifugal force that is created will force the dust out of the air.

d. Air and water vapor. Because air-conditioning equipment must be able to maintain a certain humidity level (depending on the equipment's design) and the humidity level of the air depends on the amount of water vapor that it contains, you should be familiar with how water vapor affects the air. Water is usually present in air, however, it will vary in quantity from day-to-day depending on the weather. Water vapor is present in air as an invisible gas and is in the form of super-heated steam. However, when air is cooled to the dew point, steam in the air starts to condense and may appear as a mist or condensation on cold surfaces. Water vapor is not absorbed or dissolved by air; it is simply mixed with air as you might mix sand and water. The temperature of the water vapor and the air is always the same.

(1) Saturated air. Saturated air is air that contains all the water vapor it can possibly hold. This can be compared with a can filled with sand. Although the can is completely filled with sand, there will still be airspaces in it. If you were to pour water over the sand until all the spaces were completely filled, as soon as no more water could be added, you could say that the sand is saturated with water. The same is true with air. Air will hold different amounts of water vapor. When it is holding all the water vapor possible, it is saturated. The amount of moisture in the air at its saturation point varies with the temperature of the air. The higher the temperature of the air, the more moisture it can hold.

(2) Dew point. The saturation point of air is usually referred to as the dew point. If the temperature of air falls below its dew point, some of the water vapor in the air must condense to water, generally into drops. The dew that appears on foliage early in the morning is condensation. Dew will normally form when the air is moist and there is a drop in temperature. The sweating of cold pipes is also the condensation of dew from the moist air coming in contact with the cold surface of the pipes. Similarly, water vapor condensing on surfaces with temperatures lower than 32° F will form as frost or ice.

(3) Condensation of saturated air. Condensation of water vapor from the air can take place at any temperature below the dew point. In nature, moisture is condensed on foliage and other surfaces as dew if the dew point is above 32° F. If the temperature is below freezing, the moisture condenses as frost. Above the earth's surface, it condenses as mist; when the mist is very thick, the mixture is called fog. If such condensation on dust particles is high in the air, the fog is often called a cloud. Under certain conditions of sudden cooling with a great amount of condensation, the droplets grow so large that they can no longer float in the air and they fall as rain. Sometimes a layer of air at a temperature below 32°F exists in a high storm area. Through this cold layer, raindrops may be carried up and down several times by air currents until they freeze and fall as hail. In cold weather, when the temperature is below 32°F, condensation on the dust particles in the air forms snowflakes.

1-5. AIR TEMPERATURES AND THEIR MEASUREMENTS

a. Air temperature.

(1) Sensible heat of air. Sensible heat is measured by dry-bulb temperature, i.e., the temperature of the air itself without regard to the humidity that it may contain. Sensible heat is the heat of dry air.

(2) Latent heat of air. A complete absence of moisture in air rarely occurs. Probably the only places on earth that this condition could be found would be in the desert regions. Any water vapor that is present in the air contains the latent heat that made it a vapor. This latent heat of the moisture in the air is the latent heat of air.

(3) Total heat of air. Air as it exists around us is a mixture of sensible heat and latent heat. The total heat of air would be the sum of the sensible and latent heats.

b. Air temperature measurements. Since air conditioning deals with the various heats of air and the condensation of the moisture in it, three different temperatures must be considered before you can understand and control the operations of air conditioning. These are dry-bulb, wet-bulb, and dew-point temperatures.

(1) Dry-bulb temperature. This is a measure of sensible heat in the air and is measured with an ordinary thermometer. The dry bulb does not take into account the latent heat of the moisture in the air.

(2) Wet-bulb temperature. This is an ordinary thermometer that has had its temperature-sensitive tip covered with a piece of fabric, usually cotton or wool, which has been dipped in clean, fresh water (preferably distilled). The fabric must be clean, completely free from oil, and it must also be thoroughly saturated with water. The wet-bulb thermometer will measure the ability of the air to absorb moisture. Therefore, the wet-bulb reading will be lower than the dry-bulb, unless the air is already 100% saturated with moisture. The wet-bulb thermometer will indicate the total heat of the air that is measured. The difference between the wet-bulb reading and the dry-bulb reading is known as the wet-bulb depression. What happens is that air moving over the saturated fabric will cause the moisture in the fabric to evaporate. Since evaporation requires a transfer of heat, the heat will be drawn from the thermometer's bulb. Therefore, the wet-bulb reading will be lower by a certain number of degrees. The drier the air that is measured, the greater the wet-bulb depression.

(3) Dew-point temperature. The dew point depends on the amount of water vapor in the air. If air at a certain temperature is not saturated and the temperature of this air drops, a point will be reached at which the air is saturated. At this temperature, condensation begins. This is the dew-point temperature of the air for the quantity of water vapor that is present.

(4) Relationship between the temperatures.

(a) When the air contains some moisture, but is not saturated, the dew-point temperature will be lower than the dry-bulb temperature and the wet-bulb temperature will be somewhere between the two.

(b) As the amount of moisture in the air increases, the differences in the three temperatures will become less.

(c) Once the air becomes saturated, all three temperatures will be the same.

c. Psychrometry. The word psychrometry means the measurement of cold. It is the name that has been given to the science that deals with air and water vapor mixtures. The amount of water vapor in the air has a great influence on human comfort. This atmospheric moisture is called humidity. The expression, "It isn't the heat, it's the humidity," is an indication of the popular recognition of the discomfort produced by moisture-laden air in hot weather.

(1) Relative humidity. Water vapor mixed with dry air in the atmosphere is known as humidity. The weight of the water vapor, which is expressed in pounds or grains occurring in each pound of dry air, is called specific humidity. The amount of moisture that 1 cubic foot of air holds at any given time is its absolute humidity. For example, if a gallon bucket is 1/2 full of water, it is 50% full. If a cubic foot of air that could hold 4 grains of moisture, actually contains only 2 grains, it is 50% full. The ratio of the amount of moisture which the air does contain to what it could contain is called the relative humidity. Generally it is the actual absolute humidity divided by the absolute humidity of the saturated air at a given temperature. The equation would be:

$$\text{percent relative humidity} = \left(\frac{\text{actual grains of water vapor per pound of dry air}}{\text{maximum grains of water vapor per pound of dry air that could be contained at the given temperature}} \right) \times 100$$

(An instrument used to measure relative humidity is called a hygrometer).

(2) Psychrometers. Instruments for measuring both wet- and dry-bulb temperatures at the same time are known as psychrometers. There are several different types of psychrometers. The one which you will use the most is a sling psychrometer (fig 1-8) which is made up of a wet- and dry-bulb thermometer mounted side by side on a common base with a handle that enables the whole apparatus to be whirled around in the air. The fabric covering on the wet bulb is saturated with distilled or clean, fresh water and then the entire apparatus is whirled around in the air (four or five times) as fast as possible until the wet bulb reaches its equilibrium. Then, a reading of both thermometers is quickly taken. The difference between the two thermometers will depend on the relative humidity of the air. Another

type of psychrometer is the aspiration type (fig 1-9). This is a permanent setup. A small fan is used to blow air past the two mounted thermometers until the wet-bulb equilibrium is reached. The wet bulb is saturated with water by the fabric extending into a wetting well into which water is placed.

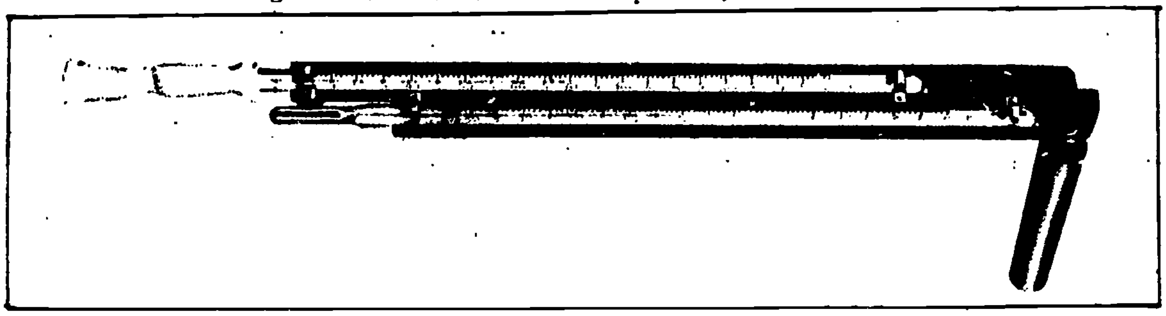


Fig 1-8. Sling psychrometer.

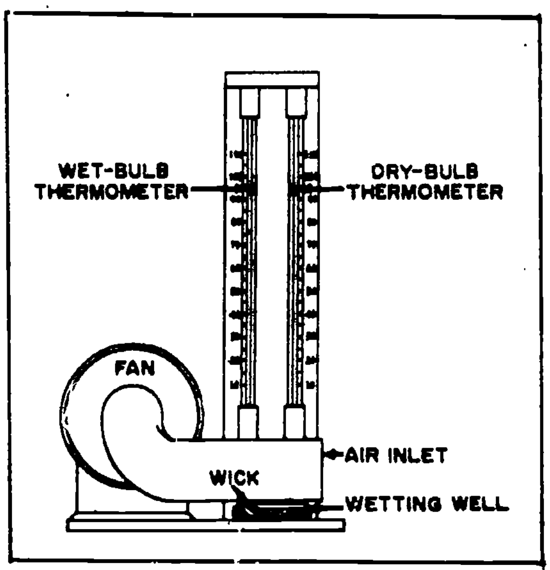


Fig 1-9. Aspiration-type psychrometer.

Some air-conditioning systems use recording-type psychrometers. These psychrometers are placed at various points in the duct system and provide a continuous record of both the temperature and the relative humidity, thereby eliminating the necessity for frequent sling psychrometer readings. Whenever possible, distilled water should be used to wet the fabric on the wet-bulb thermometer since mineral deposits in tap water will build up on the fabric and destroy its capillary action. If a psychrometer is being used in an area where the air is heavily dust-laden and the mineral content of the water being used is high, the fabric should be changed after every use.

(3) Psychrometric charts. These charts are used in conjunction with psychrometer readings to find the properties of a given quantity of air. There is no practical way of isolating water vapor from the air and actually counting the grains of moisture in it. However, a wet-bulb depression is easily obtained and it is a direct index of the amount of moisture present in the air. The relationship between the wet-bulb depression and the grains of water per pound of dry air can be plotted on the psychrometric chart. With no more than the wet and dry psychrometer readings, it is possible to determine relative humidity, dew point, moisture content in grains, and the total heat and volume per pound of dry air. Figure 1-10 shows a psychrometric chart which is constructed for standard atmospheric pressure at sea level, (29.92 inches of mercury). Other charts are constructed for high altitudes and situations where abnormally low surface pressures exist.

(a) Use. To use the psychrometric chart, assume that the readings taken with a sling psychrometer were 85°F dry bulb and 70.8°F wet bulb. Locate the dry-bulb temperature (85°F) at the bottom of the chart. Plot the 85° line straight up, then find the 70.8°F wet-bulb temperature line located along the top curved line on the chart. Plot a line slanting downward from left to right, a fraction below and parallel to the 71° line, until it intersects the 85° line already plotted. You will notice that the point of intersection is near the 50% relative humidity line (the heavy curved line). Now plot a line horizontally to the left until it intersects the wet-bulb scale; this will give you a dew point of 64.5° F. The steep diagonal line running through the wet- and dry-bulb intersection point tells you that 1 pound of air under these conditions will occupy approximately 14 cubic feet. Projecting a point horizontally to the right will show that there are 91 grains of water per pound of dry air. Total heat, found by following the wet-bulb line upward to the left, is 34.70 Btu per pound of air. This is the heat represented by dry air plus the latent heat that is present at this degree of partial saturation (50% relative humidity). Now try a sample problem.

Sample problem. Assume that your sling psychrometer readings were 95°F dry bulb and 86°F wet bulb. Find the relative humidity, dew-point, cubic feet per pound of dry air, grains of water per pound of dry air, and total heat.

Answers:

Relative humidity	= 73%
Dew point	= 84°F
Cu ft per lb of dry air	= 14.52
Grains of water per lb of dry air . . .	= 178 grains
Total heat	= 50.3 Btu per lb of dry air

(b) Application. Most air-conditioning systems are designed to produce 74° to 80°F dry-bulb temperature and maintain a relative humidity between 45% and 50% in the air-conditioned space. By using the psychrometric chart and the sling psychrometer, you are able to determine whether the equipment is operating efficiently and meeting design conditions. Air that is too "wet" prevents moisture from evaporating from the skin and causes more discomfort than air that is too warm. Therefore, obtaining the relative humidity of the air-conditioned spaces should be the first step in estimating the performances of air-conditioning equipment. If a system has been properly designed and installed, high humidities can be traced to improper operation of refrigeration system components or to an increase in the volume of air (cubic feet per minute) that is delivered to the air-conditioned spaces by the system's blower or fan. Common sense tells us that the air leaving the evaporator coils must be lower than room temperature in order to produce a cooling effect. This temperature difference is usually between 15° and 20°. However, the exact difference is determined by the volume, in cubic feet per minute, of air that is delivered to the space. The larger the volume of air, the less temperature difference is necessary between the room and the air leaving the evaporator coil. Conversely, the less the volume of air, the greater the temperature difference required. Size and placement of cool air outlet grilles determine the velocity of the delivered air as well as its volume per minute. Initially, this is a design problem in which the objectives are to supply sufficient cool air to take care of the heat load and to keep air velocities down to a point where objectionable drafts and noises are prevented.

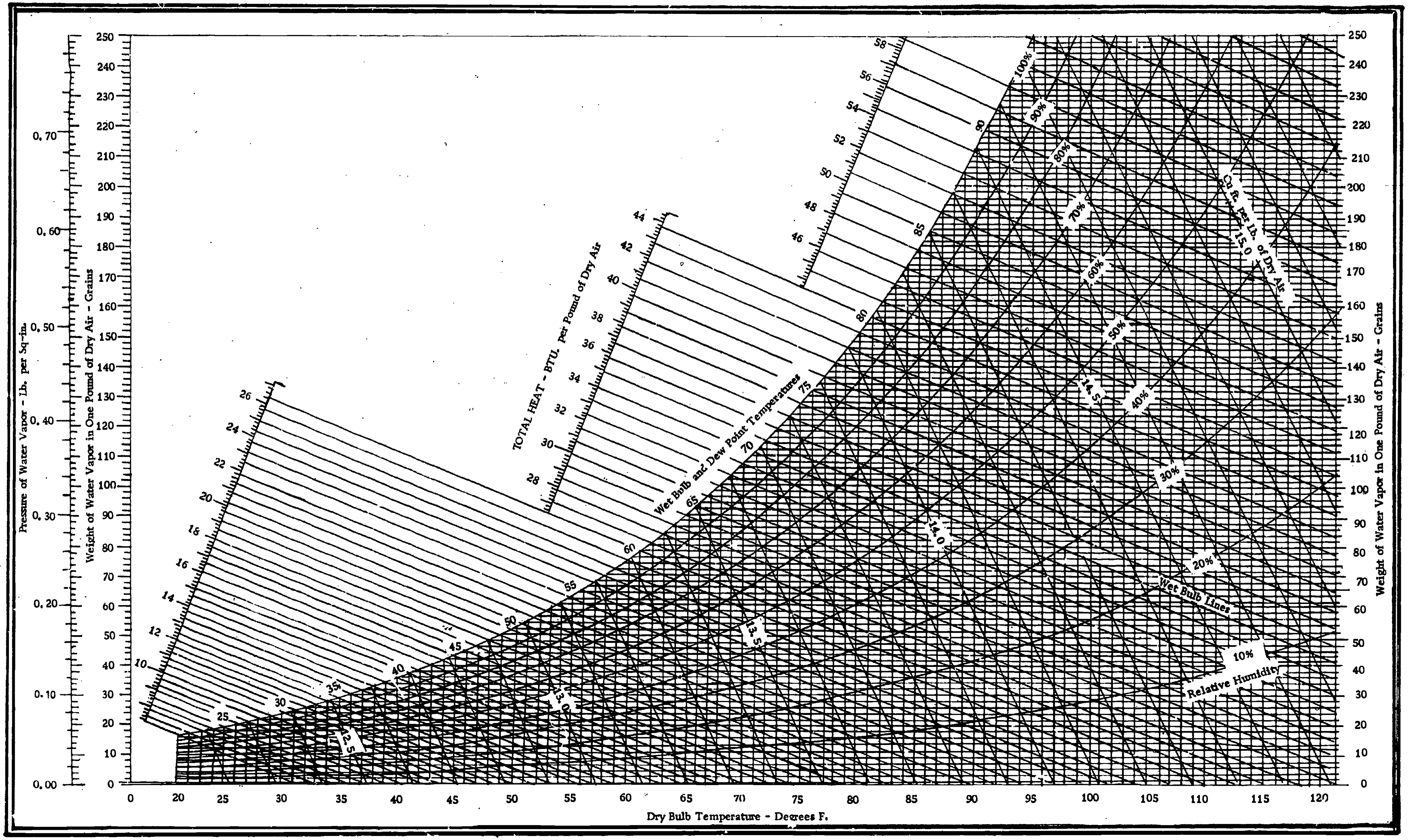


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Fig 1-10 Psychrometric chart.

1-6. MEASURING AIR VELOCITIES

a. Airflow. Proper distribution of the cooled air is vital to the satisfactory operation of an air-conditioning unit. To calculate the volume of air in cubic feet per minute needed per ton of refrigerant capacity, the following factors must be known: (1) The predetermined difference between inside air (inside dry-bulb design temperature) and the temperature of the air leaving the cooling coils, and (2) the sensible heat load of the conditioned space. After the volume of air delivery has been determined, the system can be checked for proper operation by measuring the air velocity at coil faces, grilles, and in the interior of ducts (there are various instruments used to measure the air velocity). Any reduction in the amount of air that is being delivered will indicate that either the flow of air is being blocked by the accumulation of frost, scale, or dust on the evaporator coils; or that improper maintenance of the blower and associated duct work is causing a loss of efficiency. The most common instruments used to measure air velocity are the manometer, pitot tube, anemometer, and the direct-reading velocity meter.

b. Manometers. There are two types of manometers used to measure air velocity: the U-type (fig 1-11) and the slant type (fig 1-12).

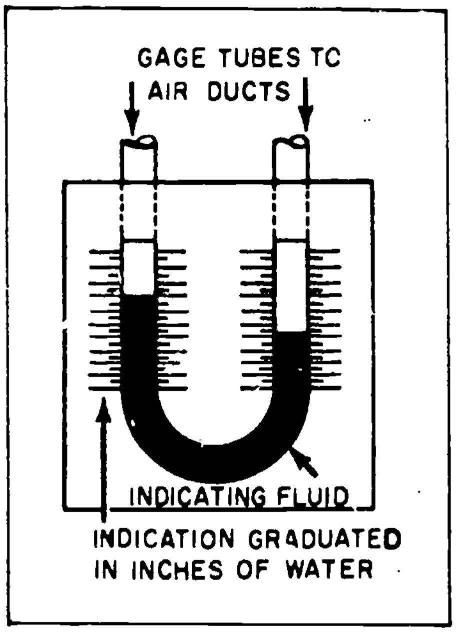


Fig 1-11. U-type manometer.

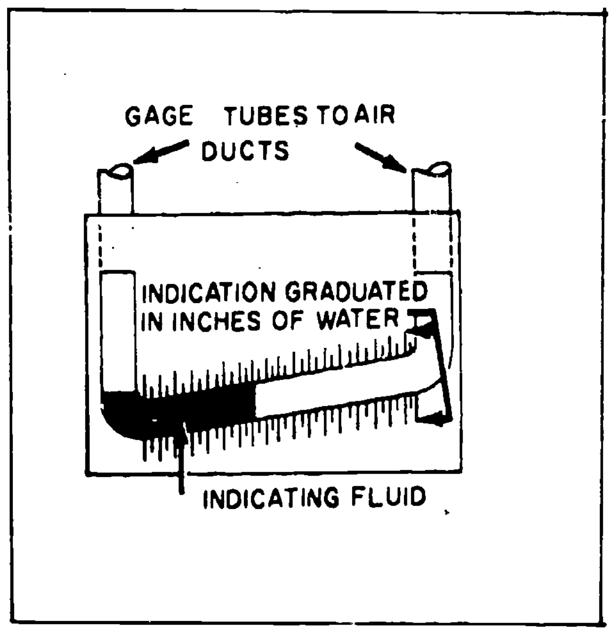


Fig 1-12. Slant-type manometer.

The U-type manometer measures the pressure in two places; its scale is calibrated in inches of water. It is used to measure the pressure difference between an air passage and the atmosphere, or between two separate passages. To do either one, use flexible tubing to connect the openings of the manometer to the spaces to be measured. The gage reading will be the pressure which is exerted on the free flowing liquid and will be in inches of water. The slant-type manometer is usually used to measure the pressure drop across a filter in a duct system. The slant-type manometer operates much the same as the U-type, but must be perfectly level whenever it is used. It is also used with the pitot tube to determine air velocity within a duct system.

c. Pitot tube (fig 1-13). The pitot tube, used in conjunction with a slant manometer, will determine the total velocity pressure in a duct system in inches of water. The pitot tube is constructed of two tubes, one enclosed in the other. The end of the tube is placed in the air passage so that the opening in the end of one tube will pick up the airflow and measure the total pressure. The other opening consists of small holes along the side of the tube (arranged so the air will flow past them) and measures the static pressure. When these two pressures are connected to the slant manometer, the difference between them will be the velocity in inches of water. To insure correct velocity readings in a duct, several readings should be taken in different places in the duct and the readings averaged.

d. Direct flow velocity meters (fig 1-14). This type velocity meter is calibrated to read the air velocity in feet per minute. It may be placed directly in the air stream or may be connected through a flexible tube to special jets which permit the taking of velocity readings.

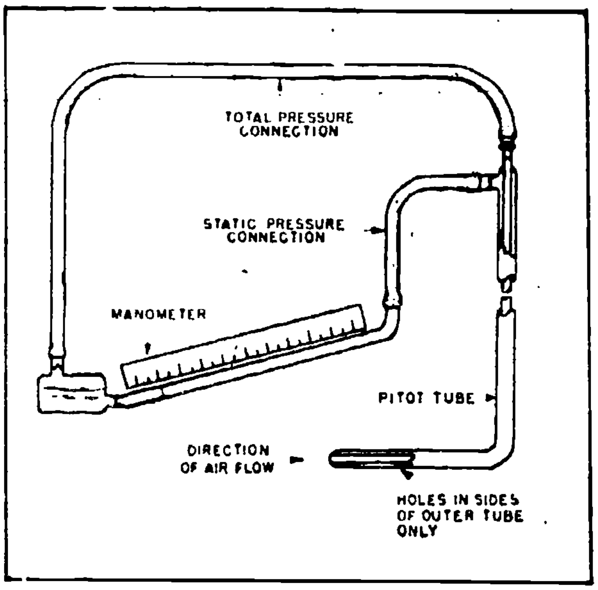


Fig 1-13. Pitot tube.

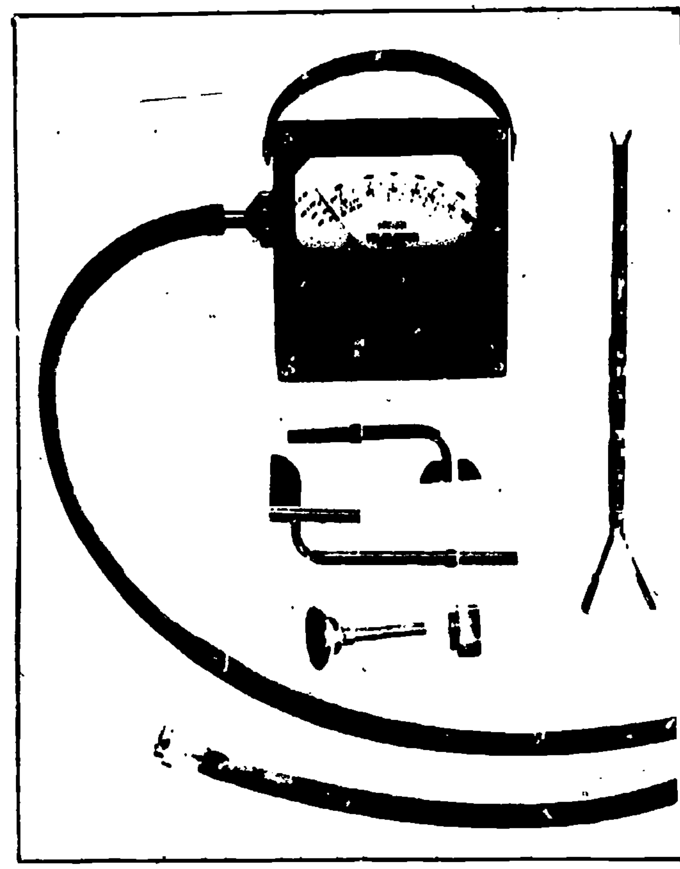


Fig 1-14. Direct-reading velocity meter.

e. Anemometer (fig 1-15). The anemometer is used to measure air velocities at duct openings. It is moved across the entire area of the duct opening for a given period of time and the average velocity in feet per minute is calculated.

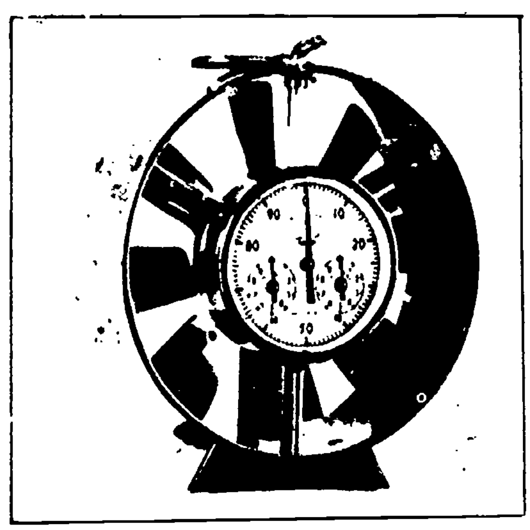


Fig 1-15. Anemometer.

1-7. COOLING REQUIREMENTS

Maintenance personnel need not be thoroughly versed in the intricate design computations of an air-conditioning system. However, they should be familiar with the many factors that affect the design computations and the capacity of a particular unit. Before air-conditioning equipment is installed in a particular space, an estimate of the hourly heat load in Btu's is made. This estimate includes heat that is created by solar radiation, moisture infiltration, lights, power equipment, sunlight coming through windows, latent and sensible heat given off by people, and the amount of activity within the air-conditioned space. This estimate will not apply throughout a 24-hour period during the cooling season. However, the equipment is designed to operate efficiently under all of the combined effects of the heat-producing factors. As a result of the estimate, it is decided to install equipment that has so many "tons" of cooling capacity. One ton of refrigeration is equal to the removal of 12,000 Btu's per hour. This would be equivalent to the cooling effects of melting 1 ton of ice in 24 hours. Such design data can be obtained from charts and original design specifications, and should be used to analyze the performance of any individual air-conditioning system.

Chapter 2

REFRIGERATION COMPONENTS AS APPLIED TO AIR-CONDITIONING EQUIPMENT

2-1. GENERAL PURPOSE AND APPLICATION OF REFRIGERATION COMPONENTS

a. Purpose. Refrigeration equipment cools, dehumidifies, and distributes air to a given area. Air-conditioning equipment must also be able to remove impurities such as smoke, dust, and other particles from the air used to condition a given space. The requirement of removing heat and moisture remains the same; however, the methods of distributing the air and the additional requirement of filtration become quite complex. Methods of distributing the conditioned air range from delivery into the space through louvers and grilles in the front of the unit (such as with a window unit) to delivery through intricate duct systems. Filtration of impurities from the air is accomplished by simple fiber filters to the more complicated electrostatic filtering method. Although air conditioning is usually associated with providing comfort, the military uses only a small percentage of air-conditioning equipment for this purpose. Personnel efficiency, safety, and protection of materials are the primary concerns of the military. Areas such as operating rooms, clinics, recovery rooms, and similar medical facilities must have controlled temperatures and humidities at all times. The same applies to storing of instruments, electronic gear, armament, specialized machinery, training devices, and certain explosives. Other operational facilities that require air conditioning would be photographic laboratories, telephone switchboard rooms, communication centers, control towers, and certain indoor training areas. Obvious reasons for the need to control temperature and humidity in areas housing these facilities and materials are to control corrosion and deterioration and to prevent equipment failure. In some of these areas it is necessary to control the humidity at a specific level. For instance, operating rooms are kept at a relative humidity of 55% to prevent static electricity, whereas spaces housing certain machinery and electronic equipment must be kept at or below 45% relative humidity. The wide variety of uses for air-conditioning equipment on a military base make it necessary for maintenance personnel to be forever studying to keep up with the advances that are being made in the field of air conditioning.

b. Application. Refrigeration components similar to those used in refrigerators, iceplants, freezers, etc. constitute the most important portion of air-conditioning systems. Component parts such as compressors, condensers, evaporators, metering devices, receivers, etc. are very similar and the theory that underlies the use of these components is essentially the same for each unit. The factors, however, that govern the design and arrangement of the equipment for the specific purpose of conditioning a given air space are different. In this chapter we will discuss the use of these components and their use within an air-conditioning system.

2-2. COMPRESSORS

a. General. The purpose of a compressor within an air-conditioning system is to remove the heat-laden refrigerant gas from the evaporator, compress it to condensing pressure, and move it along to the condenser. Compressors are divided into three types: reciprocating, rotary, and centrifugal. These three types can be manufactured in three different ways: open, semi-sealed, and hermetic (sealed). The open-type compressors are manufactured so that all parts are accessible for repair or replacement and the drive motor is usually connected to the compressor by drive belts. The semi-sealed compressors eliminate the drive belts and the necessity for a crankshaft seal, thus avoiding two major maintenance problems. The hermetic type is a completely sealed unit and eliminates other maintenance problems. The hermetic compressor will be discussed in paragraph 2-2e.

b. Reciprocating compressors (fig 2-1). A reciprocating compressor is very similar to a 2-cycle gasoline engine. Many of its components are similar not only in appearance but in their use. Pistons, connecting rods, bearings, crankshafts, and valves are employed in the construction of a reciprocating compressor. The cycle of operation is also similar in that the intake is on the downstroke and the exhaust is on the upstroke. The refrigerant gas is pulled into the compressor through the intake or suction valve on the downstroke of the compressor. When the piston reaches the termination point of its downstroke and begins its upstroke, the intake valve closes. As the piston ascends, the refrigerant vapor is compressed to condensing pressure, the exhaust or discharge valve opens, and the compressed refrigerant vapor is allowed to escape to the condenser. Figure 2-1 shows the operating cycle of a reciprocating compressor.

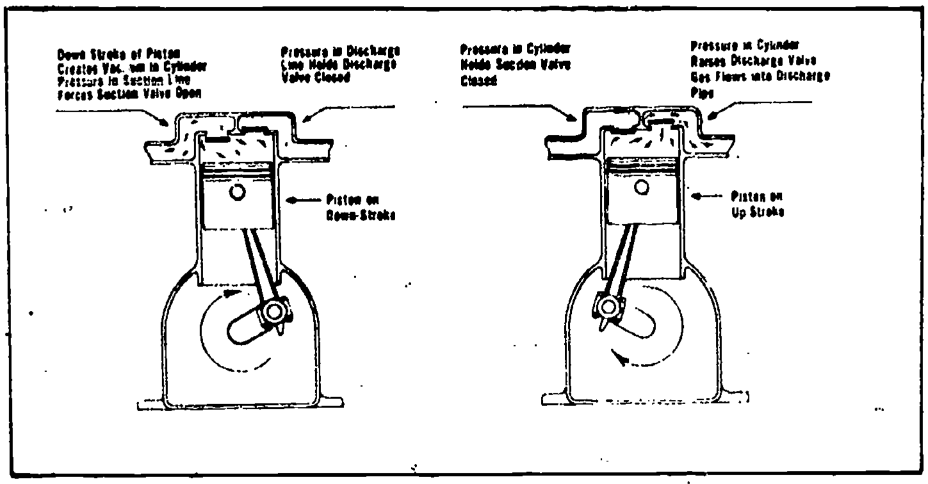


Fig 2-1. Operating cycle of a reciprocating compressor.

c. Rotary compressor. This type compressor is used in many small-tonnage units to convert low-pressure, low-temperature refrigerant vapor to high-pressure, high-temperature vapor. These compressors are simplicity itself in that they have very few moving parts. There are two types of rotary compressors--stationary-blade and rotating-blade. In the stationary-blade type (fig 2-2), an eccentric is mounted on the shaft or the shaft itself is cammed (enlarged on one side) so that it rides constantly around the outer wall of the cylinder or chamber. A spring-loaded blade is mounted in the wall of the cylinder or chamber so that it separates the intake and outlet ports or valves, and maintains a constant pressure on the eccentric or shaft. As the eccentric, or the cammed surface revolves within the cylinder, the low-pressure vapor enters the cylinder, is carried around the cylinder while being compressed, and is finally forced out the outlet port. The blade keeps the compressed vapor from escaping to the intake side of the compressor. In the rotating-blade compressor (fig 2-3), the blades are mounted on the shaft (which is mounted eccentrically in the cylinder) and rotate with it. The low-pressure gas enters the cylinder through the inlet valve, and is trapped between the blades, and is compressed while it travels around the cylinder. The gas escapes through the outlet valve as the blades pass by it. It is kept from escaping back to the inlet side by the extremely close clearance between the blades and the cylinder walls, and the presence of lubricating oil which causes a pressure-tight seal.

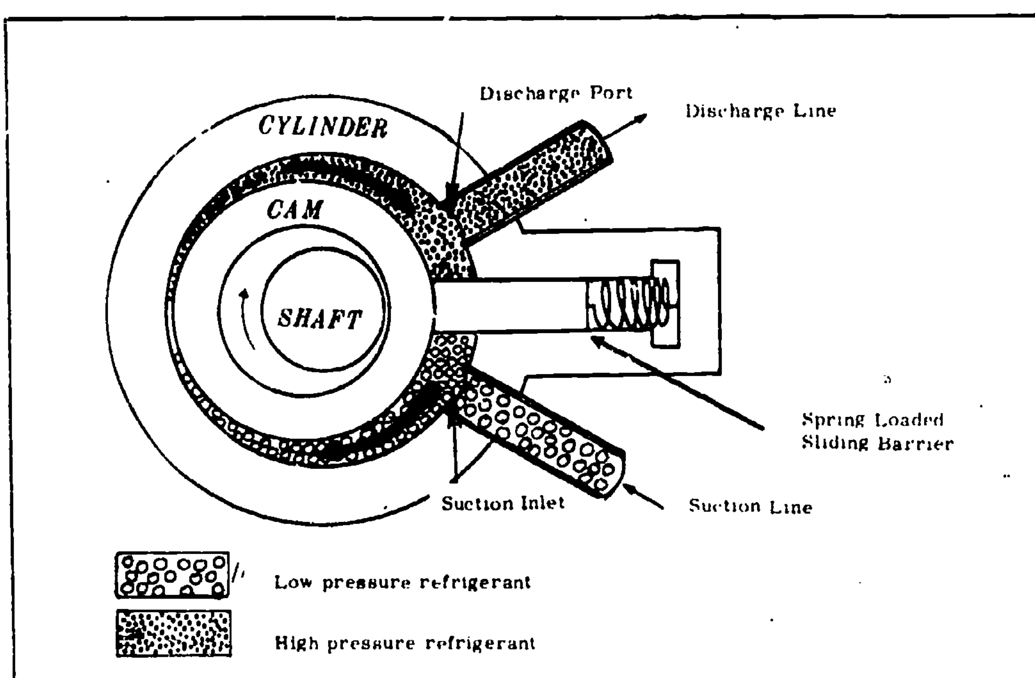


Fig 2-2. Schematic of rotary compressor, stationary-blade.

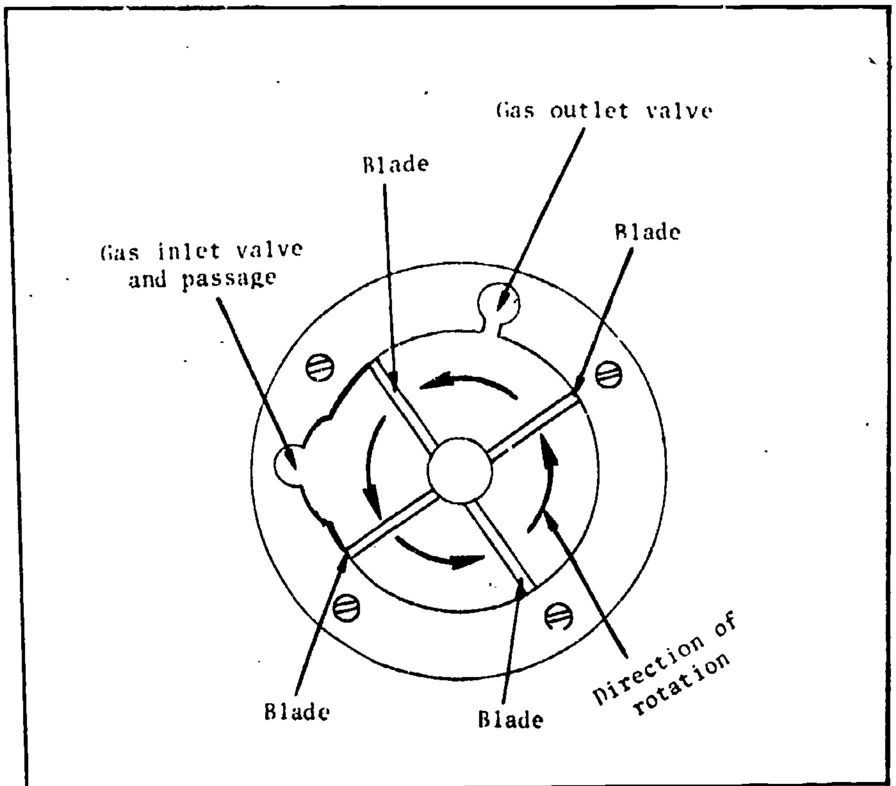


Fig 2-3. Schematic of rotating-blade compressor.

d. Centrifugal compressor (fig 2-4). Centrifugal compressors are used in large air-conditioning systems. These systems handle large volumes of refrigerant gas at low pressure. Centrifugal compressors operate on the principle of centrifugal force to compress the gas and discharge it to the system. The refrigerant is fed into a housing where there is a rotating disk complete with impeller blades (fig 2-5). The impeller rotates at a high speed forcing the gas out against and around the housing to the discharge port. Because the efficiency of these compressors will vary with their speed, they are usually run at speeds much higher than the speed of their drive motors. Therefore, centrifugal compressors are usually equipped with a step-up gear train.

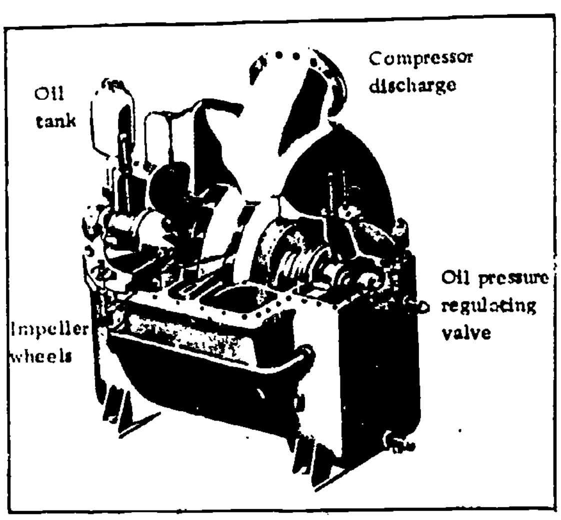


Fig 2-4. Cutaway view of an enclosed centrifugal compressor.

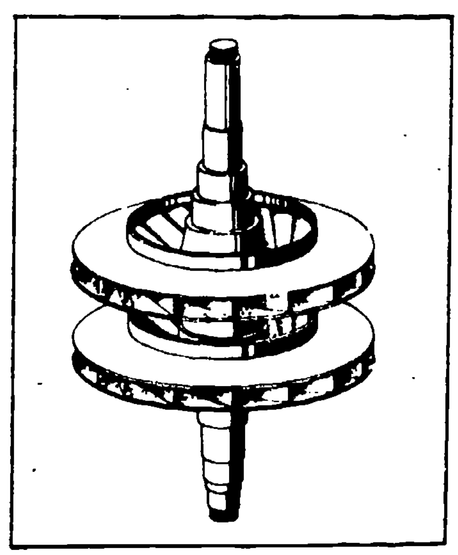


Fig 2-5. Impeller from a centrifugal compressor.

e. Hermetic compressor (fig 2-6). The most commonly used compressor in self-contained military air conditioners today is the hermetic compressor which has the motor rotor and the compressor crankshaft built as one complete unit. Then the entire motor/compressor is sealed into a gas-tight housing. The hermetic compressor is relatively maintenance free as it eliminates compressor shaft seals, flywheels, motor pulleys, and belts which cause many maintenance problems. However, because it is a sealed unit, the valve plates become inaccessible and cooling of the unit becomes a major problem. Manufacturers have attempted to solve the cooling problem by several methods. One is to press the starter into a dome located on one end of the sealed housing. This provides easy heat transfer from the windings to the casing and then to the surrounding atmosphere. Another method is to pass the returning gas around the windings before it is compressed. This does, however, present a problem because the gas may become warm enough to cut down on the volumetric efficiency of the compressor. The hermetic compressor is by far the easiest to maintain, but if internal problems do arise, the entire unit must be replaced since none of its parts are accessible for repair or replacement. Hermetic compressors vary in size from 1/16 hp up to 20 hp. The internal design will depend on the compressor's size and the manufacturer. Some are spring mounted internally, while others are spring mounted externally. Small hermetics have a single cylinder, while 1/2 hp and up will have two or more cylinders. Small hermetics use drive motors that are single phase, 2- or 4-pole motors, but the larger hermetics generally use 3-phase motors.

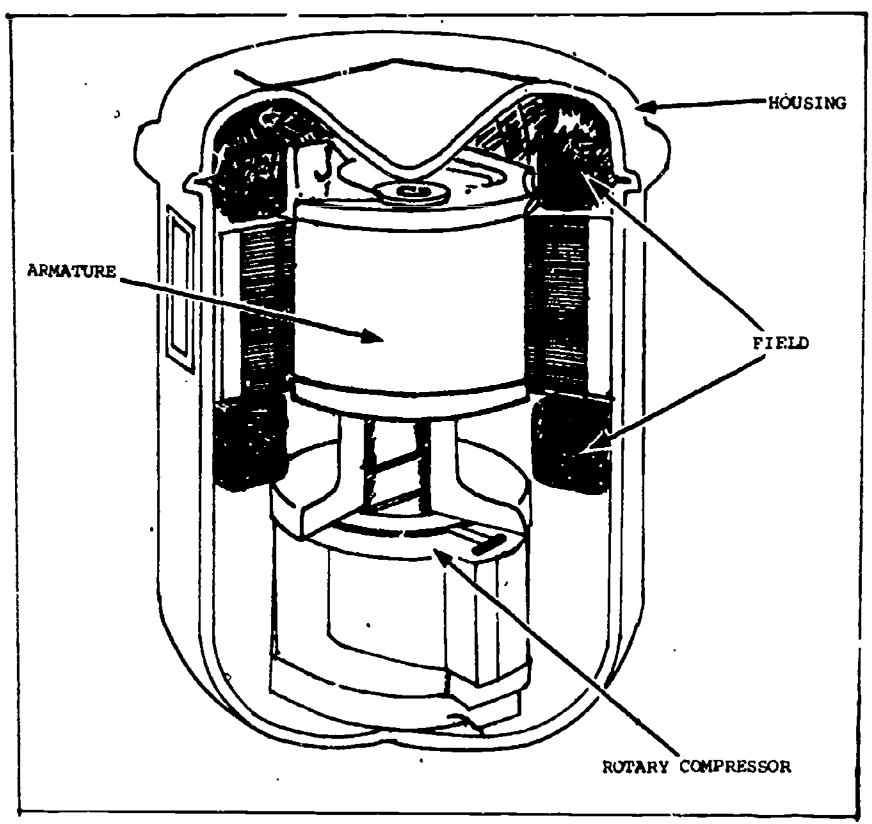


Fig 2-6. Cutaway of a hermetically sealed rotary compressor.

2-3. CONDENSERS

a. General. The function of a condenser in the refrigeration cycle of air-conditioning equipment is to convert the high-pressure hot gas into a high-pressure liquid. This is accomplished by the condenser removing the latent heat of condensation from the refrigerant vapor. Condensation continues until enough of the refrigerant becomes a liquid at the pressure-temperature balance which exists in the high side of the system. Condensers can be generally classified as either air-cooled or evaporative.

b. Air-cooled condensers. Air-cooled condensers consist of either bare tubing coils or finned tubing coils over which air is circulated. In small units, static airflow is used over bare tubes, while in larger units, fans are used to draw or blow air over the surface. The air surface of a condenser is increased through the use of equally and closely spaced fins.

(1) In forced-convection-type units, fans are driven by the compressor motor or by a separate motor in the case of hermetic compressors. To increase the efficiency of a condenser that uses forced convection for cooling, a metal casing or shroud is used. This causes a funneling of the air and directs all air movement over the condenser's surface. These condensers are frequently built with 2 or 3 layers of tubes and are finned.

(2) Some large commercial types of air-conditioning units will have the condenser mounted outdoors away from the rest of the system. The refrigerant vapor is pumped from the compressors through the compressor discharge line to the condenser and the liquid is piped back to the building. These condensers are usually quite large, dissipate a large amount of heat, and are forced-convection type. Figure 2-7 shows a schematic of a simple static-type condenser while figure 2-8 shows a forced-convection type using a finned surface and a fan.

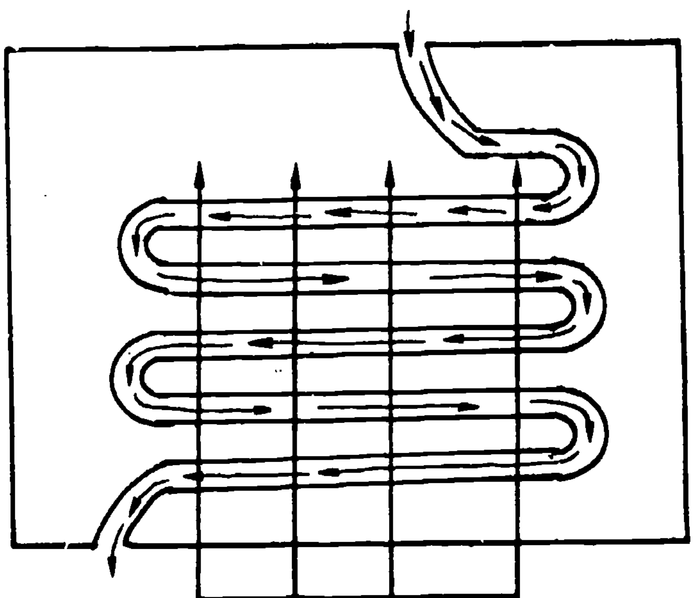


Fig 2-7. Simple static-type air-cooled condenser.

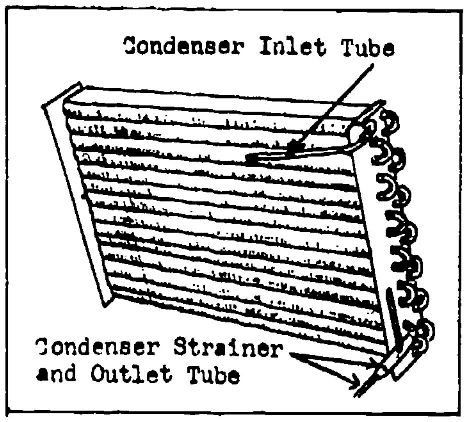


Fig 2-8. Forced-convection-type air-cooled condenser.

c. Water-cooled condensers. Water-cooled condensers are usually employed in large commercial-type air-conditioning units similar to those used in messhalls, clubs, post exchanges, hospitals, and storage areas. Condensers used in these type units are of two types, shell and tube type and tube-within-a-tube type.

(1) Shell-and-tube type (fig 2-9). This type of condenser consists of a sealed tank or shell containing a copper coil or tubes. The hot refrigerant gas is admitted into the shell of the condenser and allowed to circulate around the tubes through which pre-cooled water is flowing. The latent heat of condensation is removed from the vapor and transferred to the circulating water. As the vapor cools and liquifies, it collects in the bottom of the shell. This type of condenser construction is advantageous as it is compact and eliminates the need for a receiver and fans. The shell-and-tube-type condensers are designed in two types. One has a water coil inside the shell while the other has a

number of straight tubes inside the shell which are attached to water manifolds mounted at either end of the shell. With the later design, the water tubes are easily serviced by removing the manifolds and running a pipe cleaner through the tubes.

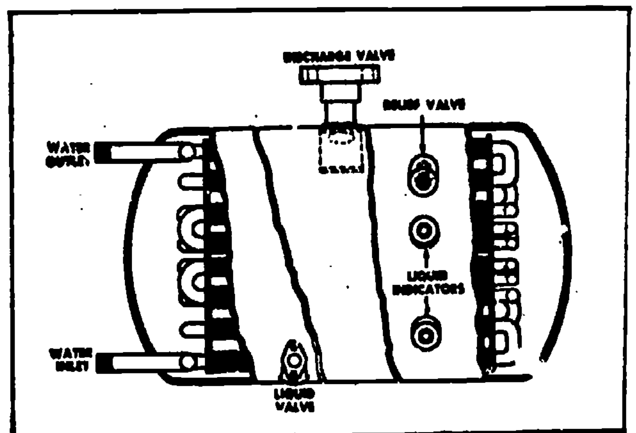


Fig 2-9. Shell and tube-type condenser (cutaway view).

(2) Tube-within-a-tube condensers (fig 2-10). With this type of water-cooled condensers, one tube is inserted into another. Cooled water circulates in the inner tube and the refrigerant vapor in the outer tube. This type condenser can be constructed in cylindrical, spiral, or in a rectangular style using soft copper tubes. They can also be constructed by using straight copper pipes employing an end plate water manifold. These condensers employ a counter-flow method of condensing the refrigerant vapor. That is, the water enters the condenser where the refrigerant leaves and the refrigerant enters where the water leaves.

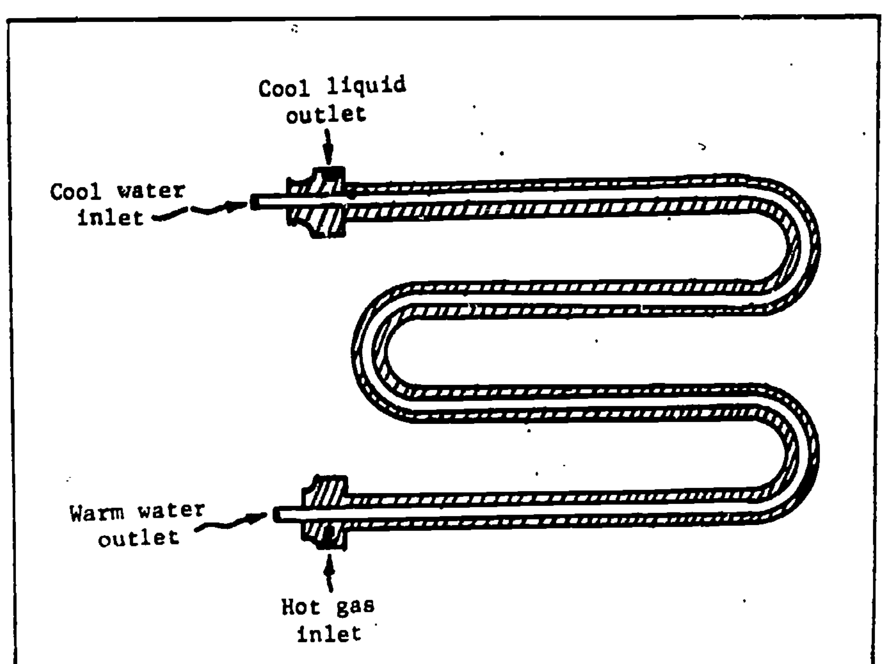


Fig 2-10. Cutaway of a tube-within-a-tube condenser.

d. Evaporative condensers (fig 2-11). These condensers operate on the cooling effect produced by the evaporation of a small amount of water. Standard evaporative condensers are much like cooling towers in that they use a spray or drip chamber, a water-collecting pan, a motor-driven pump, a motor-driven fan, and are usually located outside. Additionally, it is necessary in an evaporative condenser to have a refrigerant condensing coil. Refrigerant vapor is circulated through the condensing coil, water is sprayed over it and air is circulated around the coil. The latent heat of condensation is transferred to the water, evaporating it, and the air carries off the heat. The refrigerant in the coil then liquifies. Evaporative condensers can be mounted indoors; however, air ducts must be installed to provide the proper air circulation.

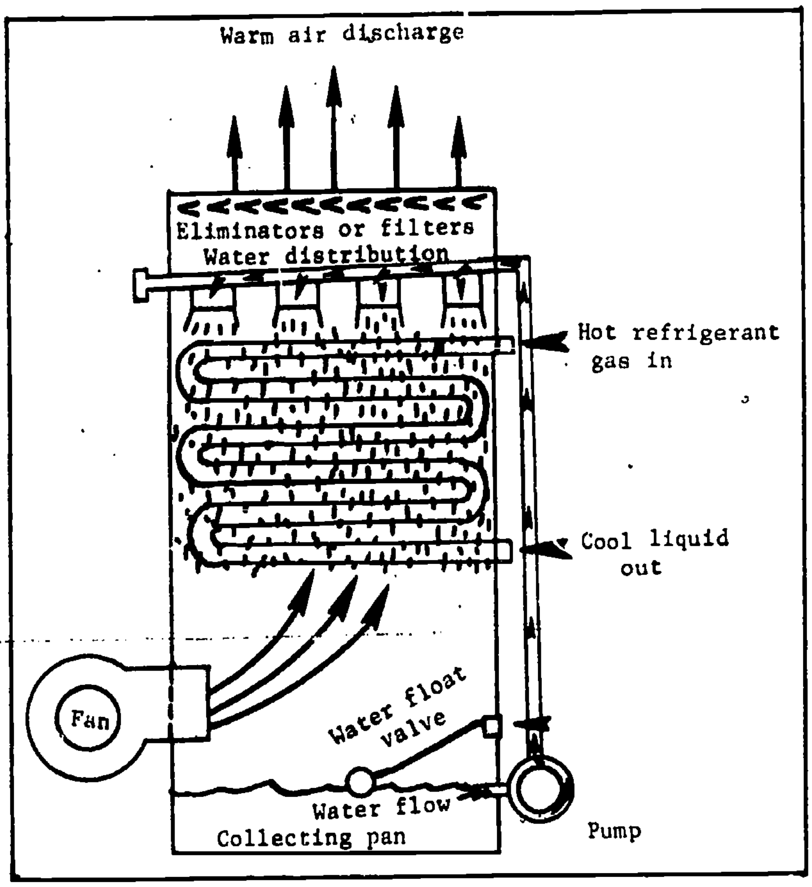


Fig 2-11. Schematic drawing of an evaporative condenser.

2-4. RECEIVERS

a. Use. A receiver is used to temporarily store the high-pressure liquid refrigerant. Once the refrigerant is condensed, it passes to the receiver where the liquid is collected and kept until it is needed by the metering device.

b. Construction. On units of 15 hp or less the receiver is usually a cylindrical steel tank mounted on the base of the unit or underneath it. The receiver is normally equipped with an inlet valve (condenser service valve), outlet valve (receiver or king valve), and a pressure-relief safety device. The safety device is sometimes a simple fusible safety plug of low-melting point metal (about 160° F), or it can be a relief valve that opens at a preset pressure. This pressure can be from 210 to 260 psi, depending on the unit's design and type of refrigerant being used in the system. This type relief valve will close again when the pressure drops below its pressure settings. Some receivers are equipped with a purging valve which is used to purge air and noncondensibles from the system. Many receivers are also equipped with two or more test valves located at different levels in the receiver. These valves are also used to determine the height of the liquid level in the receiver. For the same purpose, other receivers are equipped with "bull's-eye" sight glasses, tubular glass gages, or magnetic or float-operated refrigerant-level gages. Figure 2-12 shows a liquid receiver.

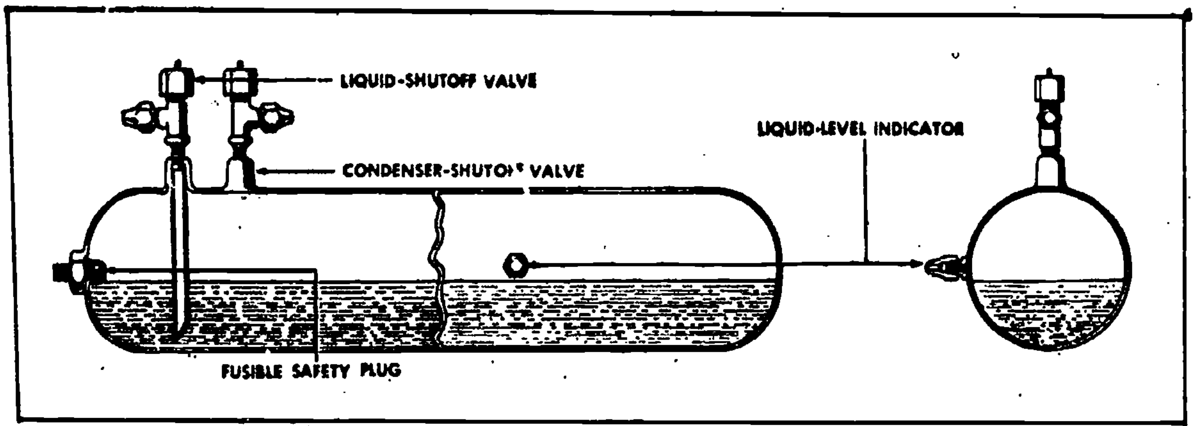


Fig 2-12. Horizontal liquid receiver.

2-5. EVAPORATORS

a. Function. The evaporator is the device within a refrigeration system in which the refrigerant is released and allowed to boil (or evaporate), thus removing (by absorption) heat from the environment.

b. Types. As far as air-conditioning systems are concerned, only two general types are considered. The direct expansion or dry type and the shell-and-tube water chiller.

(1) Direct-expansion-coil evaporators. In this type of evaporator, the air to t cooled flows across the tubes and fins giving up heat to the boiling refrigerant in the tubes. This heat transfer causes the cooling of the air that is delivered to the environment. Direct-expansion coils can be either dry- or flooded-type valves.

(a) In the flooded-type valve (fig 2-13), the refrigerant is metered into the evaporator coils by a float-type valve. This type of valve keeps the refrigerant in the evaporator at a constant level. In other words, as fast as the refrigerant boils away (evaporates), the float admits more liquid refrigerant to replace that which has been lost. This action of the valve keeps the evaporator almost full of refrigerant. The flooded-type evaporator is very efficient because vaporization of the refrigerant can only take place wherever it is in contact with the warm walls of the tubing. However, flooded-type coils are of little use, and are rarely used in air conditioning because of the relatively large refrigerant charge that is necessary to keep the system satisfied.

(b) The dry-type valve (fig 2-14) uses an expansion valve to meter the refrigerant into the evaporator. In this type, the refrigerant enters the evaporator primarily as a liquid and by the time it has traveled through the evaporator, it has completely vaporized. Therefore, the refrigerant in the greatest portion of the evaporator is a mixture of liquid and vapor. These types of evaporators are constructed with from two to twenty-two parallel circuits and are fed by one expansion valve. Some models use an additional distributing device or devices, usually depending on capillary tubes, to evenly distribute the refrigerant to the separate circuits of the evaporator. The dry-expansion-coil evaporator is most commonly used in air-conditioning systems.

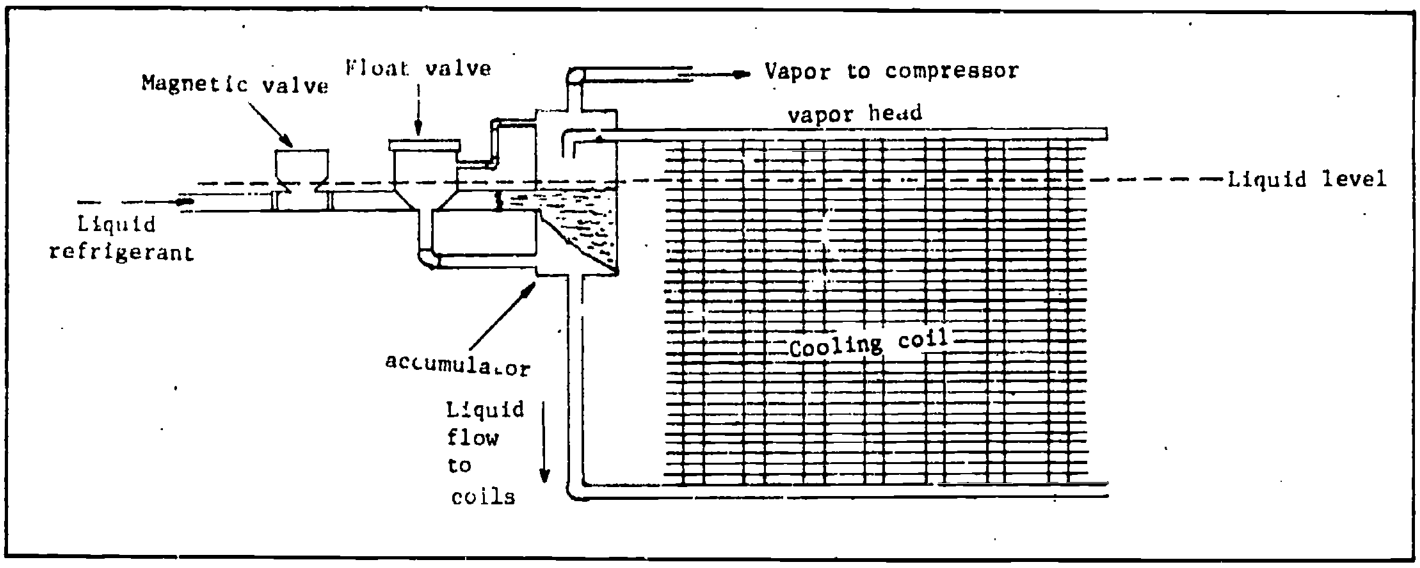


Fig 2-13. Diagram of flooded-coil evaporator.

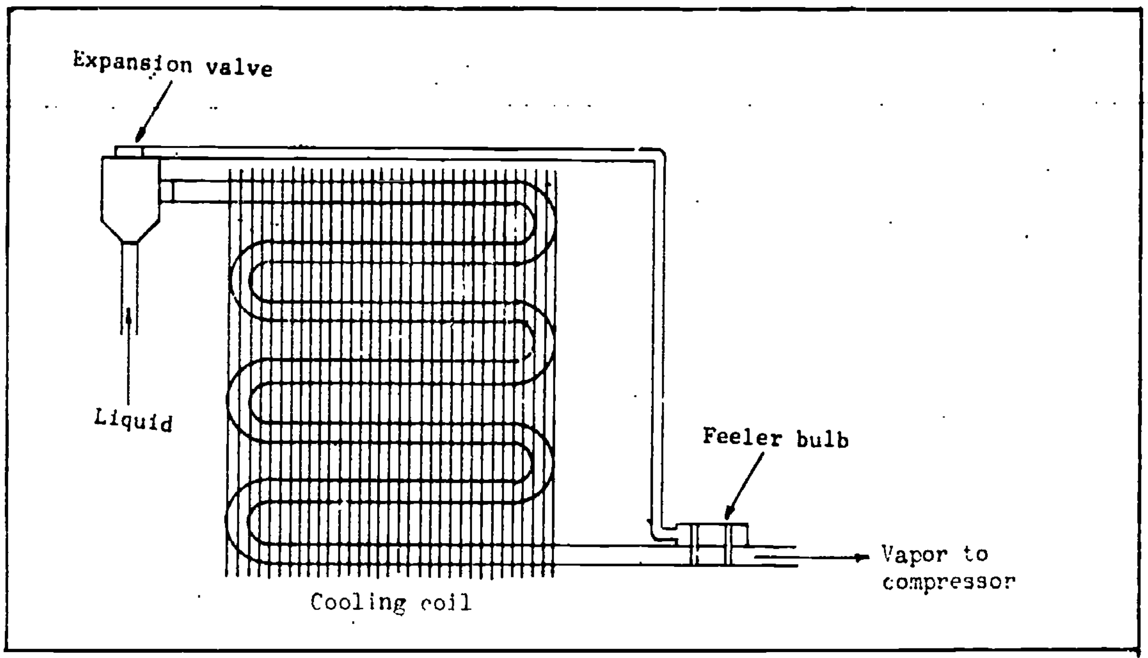


Fig 2-14. Diagram of dry-expansion evaporator.

(2) Shell-and-tube evaporators. With t e shell-and-tube evaporators there are again the two types, flooded and dry. In the flooded type, water is circulated through a tube bundle which is located within a shell. The liquid refrigerant enters the shell and keeps the tube bundle about one-half to three-quarters covered. The refrigerant boils and becomes a vapor by rem... heat from the water within the tube bundle; thereby cooling the water so it can b... culated throughout the cooling system.

In the shell and tube (dry) type, the refrigerant is in the tubes and the water is circulated through the shell. In this type, baffles are employed so the water will pass the tube bundle many times. Shell-and-tube evaporators are rarely found in military air-conditioning systems. However, on some older posts a few may be found in use on old commercial systems.

2-6. LINES AND FITTINGS

a. Lines. The lines that are used to connect the components of an air-conditioning system together are usually made of copper tubing. However, some aluminum tubing is used and, in a system that uses ammonia as a refrigerant, thin-wall steel tubing must be used since ammonia deteriorates copper. All tubing that is used for air-conditioning systems should be kept clean and dry inside. The ends should be kept sealed to insure that the tubes are kept clean and free of moisture in handling. Tubing can be sealed by using a cap or by crimping (pinching together) the ends. Copper tubing is available in hard drawn and soft drawn types and comes in two wall thicknesses, K and L. K thickness has a heavy wall and L a medium wall. Most air-conditioning systems use the L thickness. Both hard- and soft-drawn copper tubing are available in many sizes, the most common of which are 3/16, 1/4, 3/8, 7/16, 1/2, 9/16, 5/8, 3/4, and 1 1/4 in. OD (outside diameter).

Soft-drawn copper tubing is available in 25, 50, and 100 ft. lengths, with the smaller sizes coming in the longer lengths. Soft-drawn tubing is quite flexible and is easily flared and bent. Because it is easily bent it must be supported with brackets or clamps when used in a system. Soft copper tubing may become hardened through repeated bending, twisting, and hammering. When this occurs, the tubing should be replaced.

Hard-drawn copper tubing comes in 20 ft lengths. Because of its relative stiffness it will require a minimum of clamps or brackets, especially in the larger sizes. Also, because of its hardness, hard-drawn tubing should not be bent. Solder type fittings should be used to make the tubing conform to system requirements. Whenever any type of tubing is installed in a system, it should be installed in such a way that no undue stress, strain, or vibration will be exerted on it. A good way to eliminate vibration is to use horizontal loops in the tubing when you are installing it.

b. Fittings. In order to make proper connections between air-conditioning components and connecting lines, fittings are used. When the lines are of soft-drawn copper tubing, flare-type fittings are usually used. Hard-drawn tubing employs the use of solder type fittings.

Flare fittings used in the military are usually made of drop-forged brass and use either pipe thread, or Society of Automotive Engineers (SAE) National Fine Thread. These fittings are carefully machined to form both the threads and surfaces. The fittings are sized according to the tubing size with which they will be used. For instance, a 1/2 in fitting will be used with a 1/2 in copper tubing.

Solder fittings are primarily used with hard-drawn copper tubing. This type of fitting is joined to the tubing with solder rather than threads. Solder fittings are also sized according to the size tube they will be used with. Either hard or soft solder can be used with these fittings depending upon the internal pressures of the system with which they are used (soft solder low pressure, hard solder/ high pressure). The proper methods of making a joint will be covered in chapter 3.

2-7. ACCESSORIES

Along with the major components and the lines and fittings that are necessary to make up an air-conditioning system, certain additional components known as accessories are used to further improve system efficiency. You may not find all of these accessory components in every system, but you will find one or more of these items. Components known as accessories are strainers, scale traps, dehydrators, sight glasses, fusible plugs, and heat exchangers.

a. Strainers and scale traps. Dirt and foreign matter have a way of entering a system no matter how hard you try to keep them out. These particles will clog small openings and deposit themselves on valve seats and mechanisms, causing improper operation of the system. In order to separate this foreign matter from the refrigerant flow, strainers or scale traps are used. They can be inserted in either the liquid or the suction line. Strainers can be constructed of fine wire mesh, asbestos, steel wool, and sometimes glass wool enclosed in a metal container. Scale traps are usually constructed with wire mesh which is removable for cleaning. There are basically two types, cleanable and noncleanable. When a strainer or trap becomes clogged, there will be a temperature difference between its inlet and outlet. When this happens, either clean it or replace it. A strainer placed in the liquid line just before the metering device helps prevent valve trouble and lengthens compressor life. Figure 2-15 shows a sectional view of a liquid line strainer and figure 2-16 shows a cleanable scale trap.

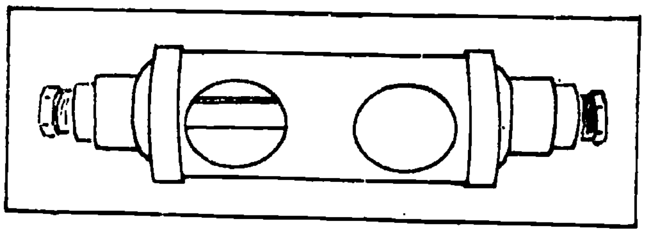


Fig 2-15. Liquid line strainer.

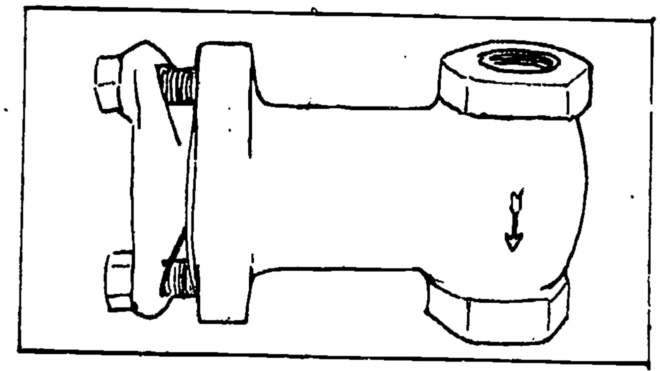


Fig 2-16. Cleanable scale trap.

b. Dehydrators. Moisture in an air-conditioning system will cause a great many maintenance headaches. It will cause corrosion-produced restrictions at metering devices, oil breakdown, and the formation of acids. A dehydrator, or drier as it is more commonly called, is used to remove any moisture that may be present in a system.

(1) Construction. Driers are made of a tubular metal shell with fittings so that they can be installed in the liquid line. The shell is filled with an approved desiccant (drying agent). Strainers are placed in each end to prevent the drying agent from entering the system.

(2) Desiccants. There are three approved desiccants for use in driers: silica-gel, activated-alumina, and drierite (calcium sulfate). Silica-gel and activated-alumina are chemicals composed of millions of tiny pores which absorb moisture as a sponge would water. Drierite absorbs moisture by chemical reaction. Silica-gel is the best of the three agents and is the desiccant usually used. It retains its form completely while the other two yield a powderlike material as a result of their action. Driers using activated-alumina or drierite must have pads in the outlet to prevent this powder from entering the system.

(3) Direction of flow. The direction of flow through a drier is indicated by an arrow located on a side of the shell. The drier must be installed with the arrow pointing in the direction of the refrigerant flow. This prevents any of the drier filler or other foreign material from entering the system.

(4) Recharging. There are basically two types of dehydrators, reusable and not reusable. The ones that are not reusable are charged with a desiccant, soldered, and sealed by the manufacturer and are considered not chargeable. Others have a removable, gasket-sealed end from which the desiccant can be taken out and replaced. Silica-gel and activated-alumina can be reactivated by heating them to a temperature of 250° to 300°F for several hours. This can be done by placing the drier in an oven or by passing hot air through the drier. Figure 2-17 shows a cutaway view of a typical drier used in small systems. Figure 2-18 shows a reusable-type drier.

(5) Drier replacement. Most systems are equipped with an indicator that will show if moisture is present in it. These indicators are usually color coded and will be located either at the drier or the sight glass. Manuals for each individual system should be consulted to determine which color indicates a dry or wet system. If moisture is indicated to be in a system, the drier should be replaced. Also replace driers any time a system is opened for repair. Always be sure that the replacement drier is the same size or larger than the one already present in the system. Never replace a drier with a smaller one.

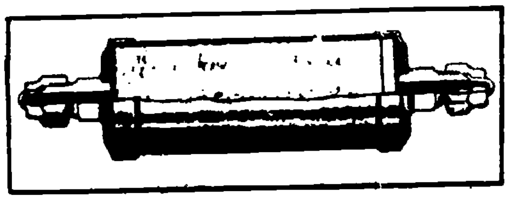


Fig 2-17. Cutaway view of a typical drier.

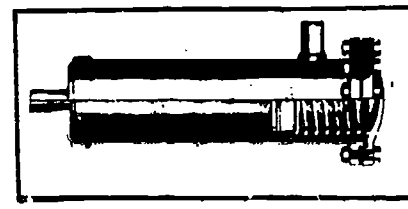


Fig 2-18. Reusable drier.

c. Sight glass (fig 2-19). There are two types of sight glasses. One is an oil sight glass which is installed in the compressor crankcase to provide a visual means of checking the oil level. The other is a liquid sight glass, so named because it is installed in the liquid line between the receiver and the metering device, after the drier. It is used to indicate the amount of refrigerant in a system and to determine the condition of the charge. If the unit is fully charged, the sight glass will appear perfectly clear. If it is undercharged, bubbles will appear.

Note: Although bubbles indicate an undercharge, bubbles could also be an indication of some other problems such as a restriction in the line ahead of the sight glass.

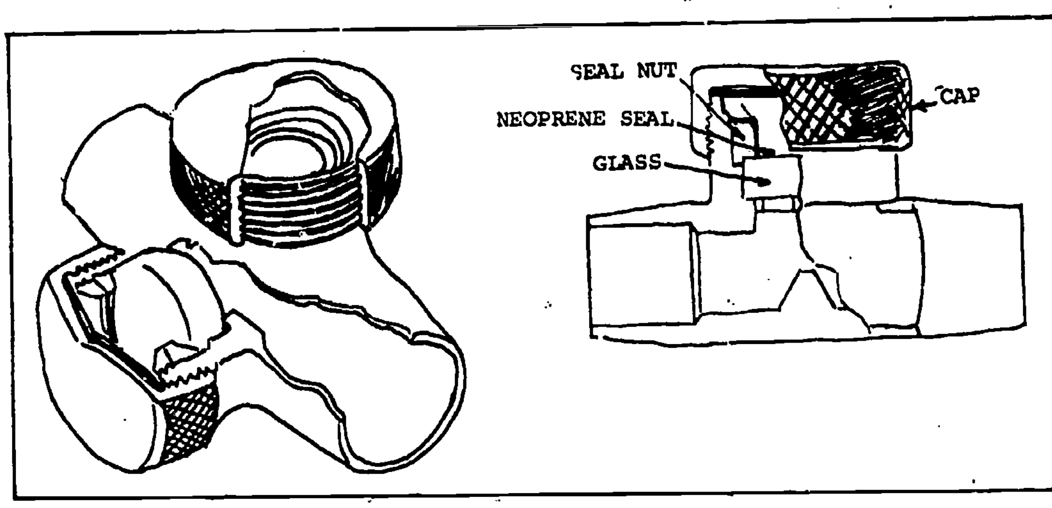


Fig 2-19. Liquid sight glass.

d. Fusible plugs. These plugs are safety devices located on the high side of the system. The core of the plug is made of soft metal. If an excessive rise in pressure or temperature were to occur, the soft core would melt, allowing the high pressure or temperature to escape. The plug is designed so that it will release well below the bursting point of the system's lines and component parts. Thus, all the vital parts of the system are protected as well as personnel who might be in the area.

e. Heat exchangers. A heat exchanger is used to equalize temperatures between the liquid and suction lines. It is a simple enough device, consisting of either the liquid line being soldered to the suction line or employment of a shell and tube type arrangement with the liquid line passing through an enlarged portion of the suction line. Heat exchangers are used in systems employing capillary tubes as metering devices to prevent premature "gassing off" of the liquid and to prevent condensation of the suction gases by warming the suction line. In the case of systems employing expansion valves as metering devices, heat exchangers are used to prevent suction gases from condensing.

2-8. VALVE AND CONTROLS

a. Service valves. For installation, maintenance and service, valves are located throughout an air-conditioning system. Service valves enable a mechanic to isolate one part of a system from the rest, perform maintenance services, install gages or special controls, accomplish repairs, purge or charge a system, and to test a system for proper operation.

(1) Two-way valve (fig 2-20). A two-way valve is a simple open-close valve with a packing gland around the stem to prevent leakage. This valve has many uses in an air-conditioning system. It can be used as a receiver or condenser service valve, a charging or purging valve, a throttling valve, or it can be fitted with a tube and used to draw off liquid from the receiver.

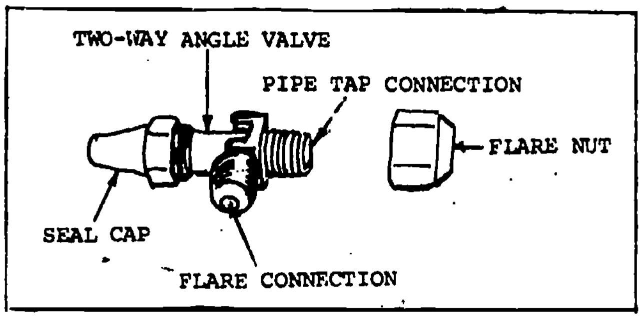


Fig 2-20. Two-way valve.

(2) Three-way valve (fig 2-21). This valve is usually installed for use as a compressor service valve. It has a service port with plug, a suction or discharge port, and a flanged port with gasket. The flanged port with gasket is bolted to the compressor. Then a suction or discharge line is connected to the suction or discharge port and the plug is installed in the service port. To install gages, vacuum pump or charging station, simply backseat the valve (stem screwed all the way out (fig 2-21 (A)), remove the plug, and attach the instrument. To remove or open the compressor, the valve stem is turned until it is closed, sealing off the rest of the system (fig 2-21 (B)). To read pressures, charge, or purge the system, the stem is turned to its middle position (fig 2-21 (C)).

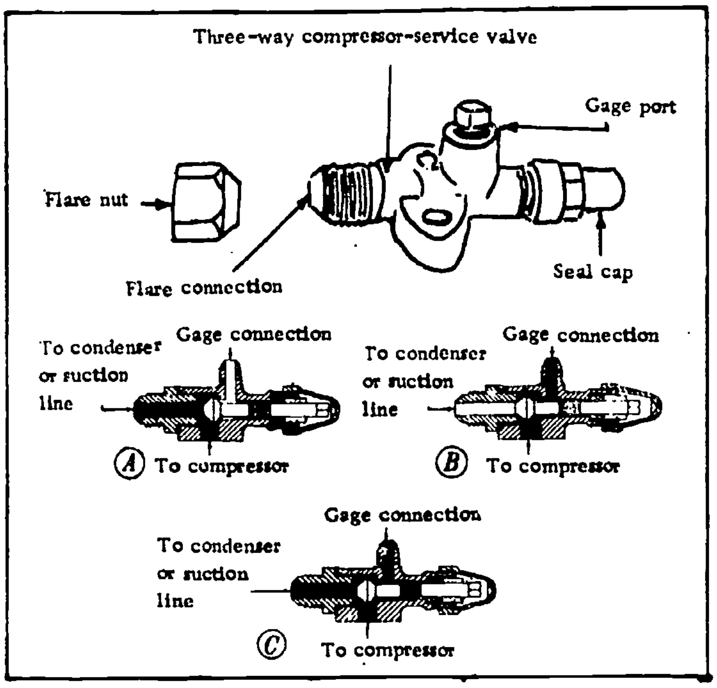


Fig 2-21. Three-way valve and its positions.

(3) Relief valve. This type of valve is usually installed on receivers or water-cooled condensers as a safety device. It is set at a predetermined pressure and will open to relieve high pressure from the system and thus prevent damage.

(4) Line-check valve (fig 2-22). A line-check valve is installed in an air-conditioning system in order to maintain liquid refrigerant flow in one direction only. Any flow in the opposite direction promptly closes this valve. Line checks use either a flapper or ball as flow checks. In the type employing a flapper, the liquid flows much like a person passing through a swinging door. Any attempt of the liquid to reverse its flow will push the flapper back against the seat, stopping the flow. The ball-type valves works much the same way. The liquid flowing in the proper direction will push the ball out of the way. If the liquid attempts to flow in the opposite direction, the ball is pushed back on its seat and the flow is stopped.

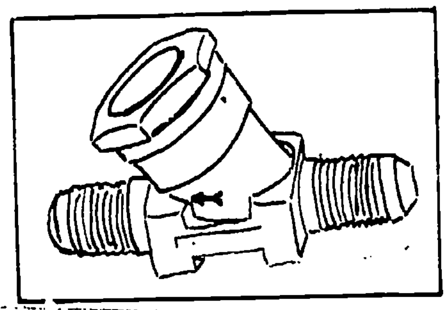


Fig 2-22. Typical refrigerant line-check valve.

(5) Water-regulating valve (fig 2-23). In an air-conditioning system that employs a water-cooled condenser using water from local water supply systems, water flow through the condenser is controlled by a water-regulating valve. This valve operates by a predetermined condensing pressure. The valve is installed by connecting a capillary tube device to the discharge side of the condenser. This transmits condensing pressure to a bellows within the valve body. When the pressure rises to its predetermined point, the valve opens and water is allowed to flow. Conversely when the pressure drops below this point, the valve closes. The range spring can be adjusted to the desired condensing pressure.

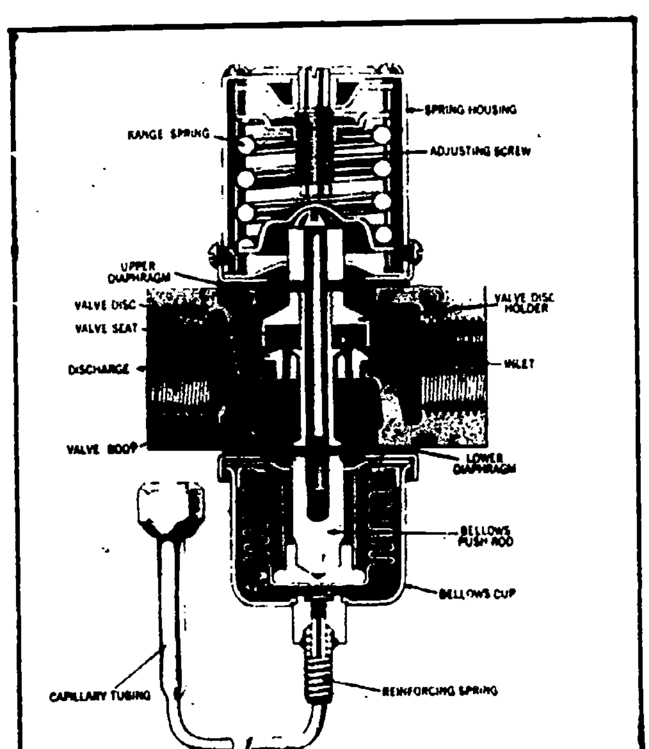


Fig 2-23. Water-regulating valve (sectional view).

b. Refrigerant control. An air-conditioning unit which operates automatically must have some type of control to reduce the high-pressure liquid refrigerant to a low-pressure liquid refrigerant. This control must also be able to meter the low-pressure refrigerant into the evaporator in proper quantities so that the evaporator will function at its highest efficiency. To accomplish this, a mechanical system will use either an expansion valve, float valve, or a capillary tube. Almost every air-conditioning unit or system that you will encounter in the military will use an expansion valve as its refrigerant control. However, you may, on occasion, find a unit or system that is still equipped with a capillary tube or a float valve to control the refrigerant flow to the evaporator.

(1) Automatic-expansion valve (fig 2-24). An automatic-expansion valve consists of a needle valve actuated by spring tension and a bellows sensitive to refrigerant pressure. The refrigerant pressure and the spring tension are on opposite sides of the bellows and oppose each other. When the pressure is low, the spring forces the valve open. When the pressure rises, it overcomes the spring tension and the valve closes. Expansion valves are equipped with adjusting screws so that they can be set for the desired pressure. Because these valves are affected by atmospheric pressure, adjustment must be made at different altitudes and these valves must have the same capacity as the compressor. A valve that is too small would starve (not enough refrigerant) the evaporator and cause the compressor to overwork. A valve that is too large would allow too much refrigerant to enter the evaporator and cause the suction line to sweat or frost. It could even allow liquid refrigerant to enter the compressor and damage it.

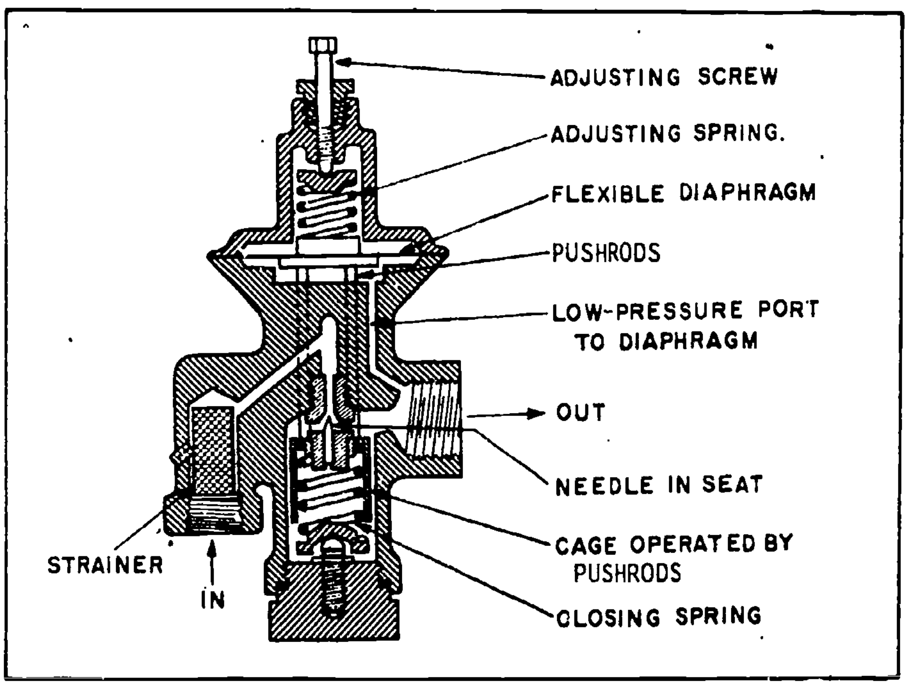


Fig 2-24. Cutaway view of an automatic-expansion valve.

(2) Thermostatic expansion valve (fig 2-25). A thermostatic expansion valve (TEV) consists of a power element (complete with thermal bulb and power charge), capillary tube, and a bellows or diaphragm. The power element is mounted in the valve body which contains another bellows or diaphragm, a needle valve and seat, an adjusting spring and screw, and a filter screen in the valve's inlet port. Refrigerant flow is controlled by the difference between the pressure within the evaporator and the temperature of the thermal bulb. This pressure temperature difference is called the valve's superheat. The valve's power element controls the valve in such a way that the evaporator is kept almost full of refrigerant at all times and works as follows. When pressure in the evaporator builds up, a motor controlling sensing device (either a thermostat or pressure control) will start the compressor motor. At the same time,

the thermal bulb (which is attached to the suction line at the outlet of the evaporator) will warm, causing the power charge to vaporize and increase the pressure on the power element's bellows or diaphragm. This pressure increase within the power element will cause the diaphragm within the valve body to force the needle valve away from its seat. The refrigerant can now enter the evaporator and will continue to do so until the evaporator becomes almost full. Now the evaporator pressure will decrease and the suction line will cool. As the suction line cools, the power charge in the thermal bulb will condense, relieving the pressure on the power element's diaphragm. This decrease in pressure within the power element lets the diaphragm within the valve body free the needle valve to close, thus stopping the refrigerant flow. At the same time the motor controlling device will sense the change and stop the compressor. It should be noted that the refrigerant used as the power charge in the thermal valve and the refrigerant in the system are usually the same. It should also be noted that only a valve of correct capacity and of the same temperature ranges of the unit should be used. Figure 2-26 shows a cutaway view of a thermostatic expansion valve.

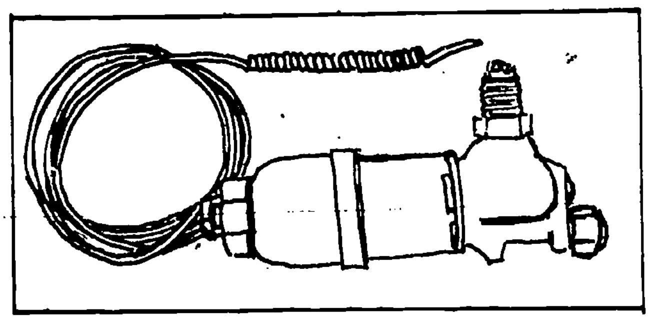


Fig 2-25. Thermostatic expansion valve.

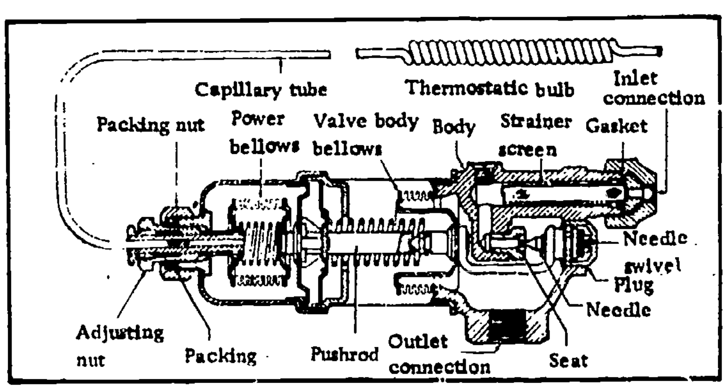


Fig 2-26. Cutaway of a thermostatic expansion valve.

(3) Capillary tube. A capillary tube, or cap tube as it is usually called, is used with thermostatic expansion valves, thermostats, some thermometers, and multicircuit evaporators, as a distributing device and sometimes as a refrigerant control. A cap tube is a length of seamless copper tubing of small inside diameter. Most of its length is usually coiled. The design of a cap tube depends on four variables: length of tube, inside diameter, tightness of tube coils, and tube temperature. The cap tube acts as a throttle by restricting the refrigerant flow, by reducing the temperature and the pressure of the refrigerant. In the last few feet of the cap tube, the refrigerant has already started to vaporize and has reached evaporator pressure and temperature. With this type of refrigerant control, the refrigerant must be carefully measured as all refrigerant will pass to the low side when the compressor is in the off cycle and pressures will be equalized. The most important thing for you to remember about cap tubes is their function in restricting refrigerant flow.

c. Solenoid valves.

(1) Principles. In order to tightly close or completely open a portion of, or a complete refrigeration circuit, solenoid valves are used. A solenoid valve consists of an electromagnet with a movable core, valve needle, seat, electrical leads, and valve housing. Control of a solenoid is accomplished with a simple electrical circuit. A solenoid is constructed by attaching a valve needle to a movable armature. A coil is wound around the valve housing and contains the armature. When the coil is energized the armature is pulled up into the coil, pulling the valve needle away from its seat and opening the valve. When the coil is de-energized the weight of the armature will push the valve needle down onto its seat, closing the valve.

(2) Types. There are three types of solenoid valves in common use; 2-way, 3-way, and 4-way or reversing valve.

(a) A 2-way solenoid is a simple open/close valve that controls flow in one line only.

(b) A 3-way solenoid has an inlet that is always open and two outlets which are either open or closed depending on the position of the armature in the coil. Three-way solenoids have two valve needles or balls attached to the armature.

(c) A 4-way solenoid, often called a reversing valve, is used extensively in heat pumps. Small-tonnage air-conditioning units such as window units use a 4-way solenoid valve which is operated by a single armature that opens or closes several ports at once. These valves can be either electrically or manually controlled. Another type of 4-way solenoid valve is actuated by a pilot solenoid. When the pilot valve (which is a simple open/close-type solenoid) is actuated, the system's low-side pressure takes over and opens the internal three valves, producing a heating cycle. When the pilot is de-energized, the internal valves close and the refrigerant flow is reversed, causing a cooling cycle.

2-9. ELECTRIC MOTOR CONTROLS AND MOTORS

a. Controls. Due to the changing-type load placed on component parts of an air-conditioning unit or system, and the possibility of failure of individual components or units, a variety of electrically operated controls are used. These controls respond to temperature, pressure, and humidity changes. By regulating these variables you can control the system. For instance, as the temperature of a saturated refrigerant increases, the pressure also increases. If you were to control the temperature, you would also control the pressure. The opposite is also true. Each control will have a range and a differential. The range of a control is the width of the pressure or temperature band over which the control can be operated. For example, if you had a temperature control with a range of 0^{o} to 50^{o} F, you could adjust it to operate anywhere within the limits of this band or range. The differential of a control is the difference in pressure or temperature at which a control cuts in and out, depending on the system and refrigerant used. If a temperature control were set to cut in at 40^{o} and cut out at 32^{o}F, the differential would be 8^{o}F.

(1) Low-pressure cutout. A low-pressure cutout provides a way to stop the compressor whenever pressure in the low or suction side of the system is reduced to a predetermined point. This type control consists of a bellows or diaphragm that actuates the switch through a linkage-type mechanism. When the pressure in the low side reaches its low predetermined point, the bellows or diaphragm will open a switch, which in turn opens the motor contacts and stops the compressor. Whenever the pressure in the low side rises above another predetermined point the bellows or diaphragm will allow the switch and the motor contacts to close--restarting the compressor. Low-pressure controls are usually used as one-half of a combination low-pressure control and high-pressure safety cutout. The range and differential of a low-pressure cutout can be adjusted through screws seated on top of the control.

Low-pressure cutouts should not be confused with evaporator pressure regulators or low-side pressure controls which are simply throttling valves which maintains a constant pressure in the evaporator. These valves are used to prevent the coils from frosting, water from freezing, or to maintain a certain minimum air temperature of air flowing across the coils. Low-pressure cutout valves will be wide open at any pressure above their settings and will only throttle back on the suction pressure as the compressor pulls the system down to valve setting. For instance, if the valve setting is 35 psi, the valve will be open if suction pressure is above this setting. As the suction pressure begins to fall to 35 psi, the valve will begin to throttle back. When the suction pressure on the compressor side of the valve falls below 35 psi the valve will throttle enough of the vapor to maintain the pressure on the evaporator side at exactly 35 psi.

(2) High-pressure cutout. The high-pressure cutout is a safety control which is used to protect personnel and equipment from abnormally high pressures which could cause injury or damage. This control is connected into the high side of the system through a small diameter tube or it can be connected directly to the cylinder head. A bellows is attached to a plunger in such a way that any excessive head pressure will expand the bellows, pushing the plunger against the switch and shutting down the motor. A high-pressure cutout usually will have to be reset manually. This is accomplished by pushing a reset button located on the control once the high pressure has been relieved.

(3) Dual-pressure control (fig 2-27). A dual-pressure control is a low-pressure cutout and a high-pressure cutout mounted in the same enclosure. Both controls act as they would if they were mounted separately but they operate only one set of contacts. If the compressor motor was shut down because of an excessively high pressure, the control would have to be reset manually. If the low-pressure control was controlling the compressor operation, it would cut out the compressor at the predetermined low pressure and cut-in would automatically occur at its predetermined higher pressure.

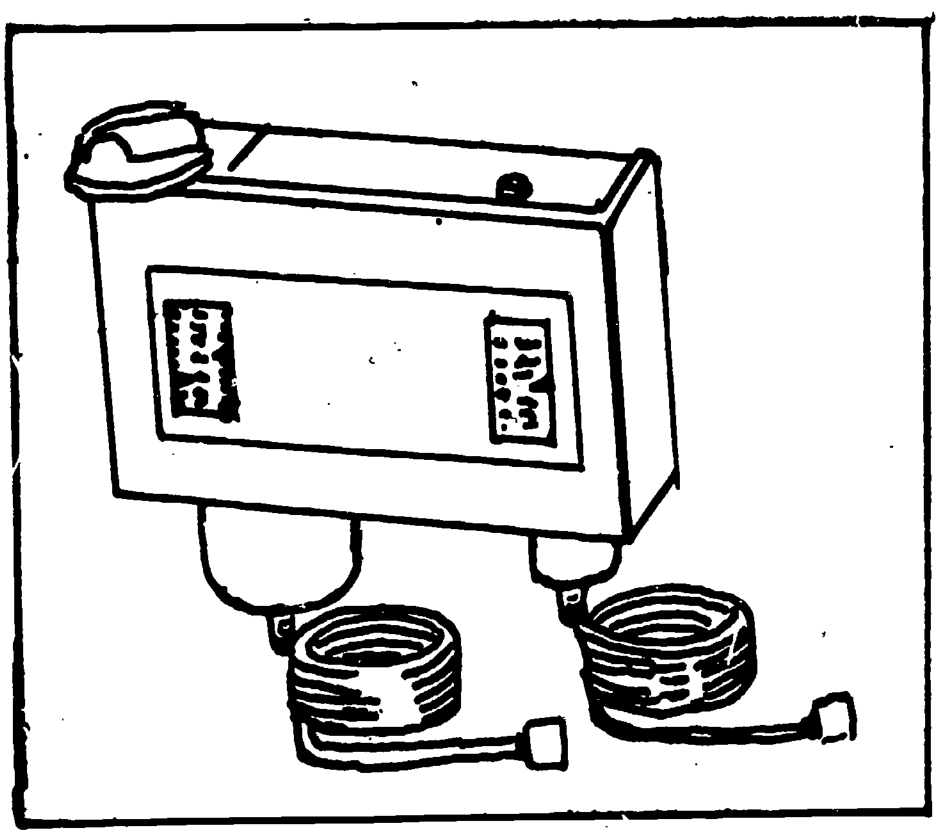


Fig 2-27. Dual pressure control.

(4) Oil-failure cutout switch (fig 2-28). An oil-failure cutout is a time delay differential type control that is used to stop operation of a pressure-lubricated compressor whenever the oil pressure drops below a safe limit. An oil-failure cutout operates on the difference between the pressure of the refrigerant in the suction or low side of the system and the oil pump discharge. The difference between these pressures is known as the usable oil pressure. To measure this usable oil pressure and guard against oil failure, an oil-failure cutout uses two bellows which oppose each other. The suction pressure on one bellows and the oil discharge on the other.

The time delay portion of the control allows the compressor to run for approximately two minutes before cutting off operation. This allows oil pressure to build up to normal operating pressure on initial compressor starting. If the oil pressure were to drop below a safe limit during operation, the time delay would stop the compressor within a given time period. The time delay stops the compressor by opening the circuit to the motor contacts.

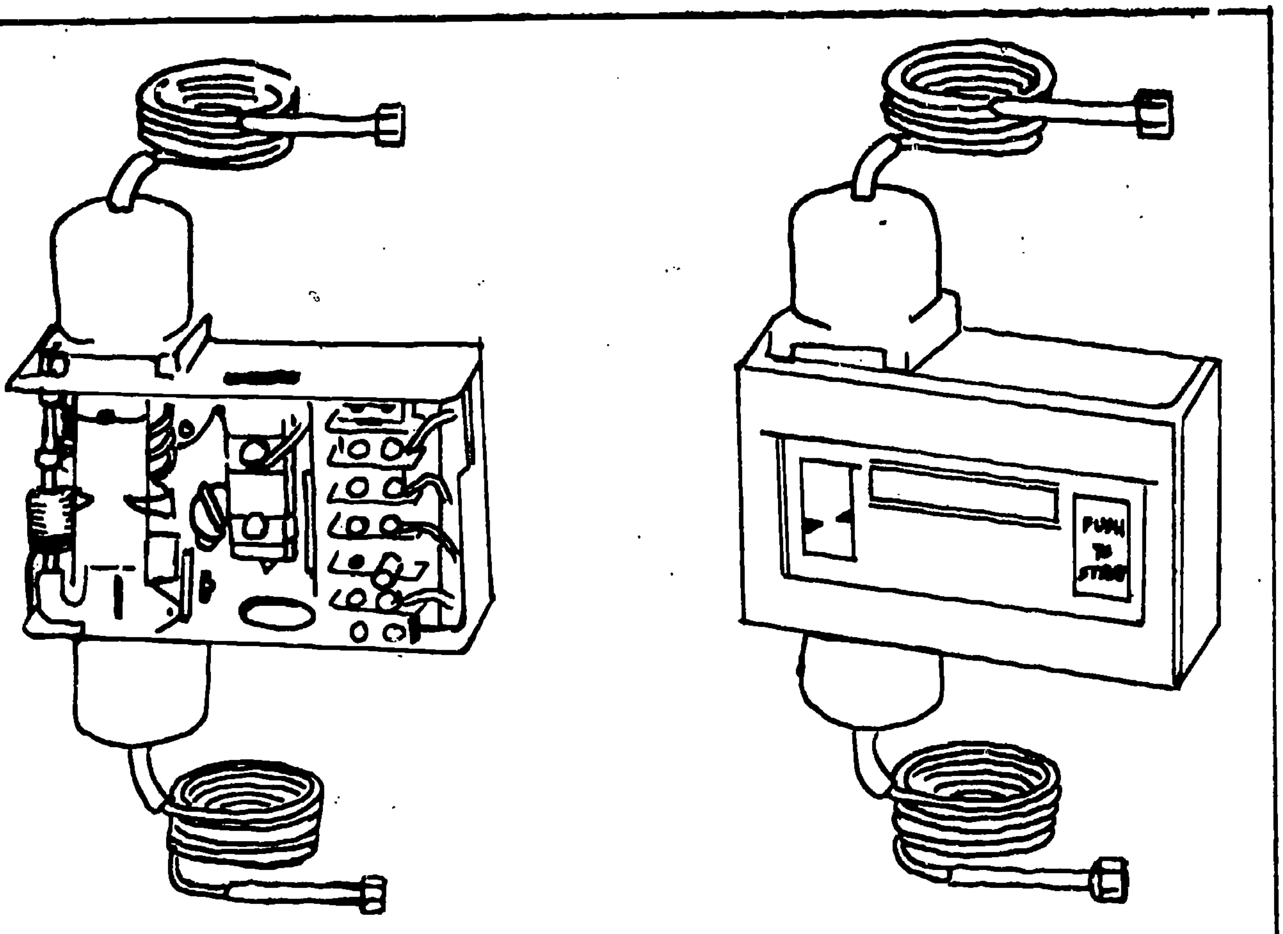


Fig 2-28. Oil-failure cutout switch.

(5) Temperature controls. Temperature controls are much like pressure controls in design, except for the addition of a thermal bulb and capillary tube. These contacts are used to stop and start a unit's compressor motor whenever the temperature on the suction or low side of the evaporator falls below or rises above the differential of the control. The thermal bulb is located in an area specified by the unit's manufacturer. When the temperature of that area rises above a predetermined level, it will cause a corresponding pressure rise in the thermal bulb. This pressure rise is transported

to the diaphragm through the capillary tube and overcomes any atmospheric pressure or spring pressure present. This movement of the diaphragm, which is connected to a switch through a linkage mechanism, will close the switch and the motor will start. As soon as the temperature falls below the control's lower point, the pressure in the thermal element will fall, allowing the spring or atmospheric pressure to take over again on the diaphragm. Then the switch will open, stopping the motor.

(6) Motor starters. A motor starter is the control which connects or disconnects the line current so that the compressor motor can be stopped or started.

(a) Simple starter. A simple starter includes any switch or device normally used to stop or start a motor. For a small motor rated at 1/3 hp or less, the starter may be the attachment plug connector and receptacle. For motors rated at 2 hp or less and 300 volts or less, the controller may be a general-use switch having an ampere rating of at least twice the full-load current rating of the motor. The simplest method of control is an externally operable disconnect switch, generally a circuit breaker or fused type. When fuses are used they should be the time-lag type which is specifically designed for motor circuits.

(b) Magnetic starter. Most motors above 1 hp are started by a magnetic-activated switch called an across-the-line starter. These starters are made in various sizes and types. However, their principle of operation is basically the same. Magnetic across-the-line starters are constructed with two electrical circuits, the power circuit and the control circuit.

1. The power circuit consists of the contact points, line and motor terminals, and the heaters. The heaters are made of a metallic material that will dissipate heat in proportion to the current flowing through them. They are placed in series with the lower contact point and the motor terminal connection. Heaters do not usually come with the starter because they are rated in amperes and must correspond to the ampere rating of the motor the starter is being used with. Whenever the heater detects an overload, it will break the circuit, stopping the motor.

2. The control circuit consists of the overload contact points, retaining points, and the holding coil. The holding coil is the electromagnetic portion of the starter and is free to move. When the circuit is energized, the main contacts and the retaining points close. The holding coil keeps these points closed unless the circuit is interrupted either by an automatic control (such as a temperature or pressure control), manually (stop/start station), or a current overload.

(7) Defrost control. Most air-conditioning units and systems will have a defrost control which will stop the compressor motor before the evaporator can get cold enough to freeze. These controls are much like temperature controls in that they have a temperature sensing device (thermal bulb), capillary tube, and a diaphragm. The diaphragm is connected to a single-pole, single-throw (SPST) switch. When the evaporator temperature becomes too low, the thermal bulb will sense the change and open the switch stopping the motor. As soon as the evaporator has warmed again the control will close and the motor can start. These controls are usually factory set and should not be tampered with.

b. Motors. Most air-conditioning units in use in the Marine Corps today are of the package type and are relatively small and compact. These units use single- and 3-phase motors to drive compressors and fan motors. Evaporator and condenser fan motors are usually driven by single-phase motors, while compressors will usually use 3-phase power. However, some of smaller units (4,000-6,000 Btuh) use single-phase motors for compressor drive. Most of the following information can be found in TM 5-670. It is included here to explain the many types of motors and for future reference.

(1) Split-phase. This type of motor usually operates a fan, blower, or small pump. It is a single-phase motor and is usually of fractional horsepower. The motor has four main parts: rotor, stator, mounting frame, and centrifugal switch. The stator has

two windings, a running winding and a starting winding. These windings are connected in series by the centrifugal switch and are approximately 90° out of phase. Once the rotor reaches approximately 75% of its running speed, the centrifugal switch opens, removing the starting winding from the circuit and causing the motor to run as a simple induction motor. Although this type of motor does not have a very high starting torque (about 175% of full-load torque), once it reaches normal operating speed, it is fairly constant.

(2) Capacitor motors. These motors are easily identified because of a hump that is located on top of the motor housing in which the capacitor is located. They are manufactured in two types: capacitor-start and capacitor-start-run.

(a) Capacitor-start. This type of motor is constructed much the same as the split-phase motor except that a capacitor is connected in series with the starting winding and the motor runs as an induction motor. The advantage of the capacitor is that it increases the starting torque as much as 350% of the motor's full-load torque. Capacitor-start motors are usually found in fractional horsepower sizes.

(b) Capacitor-start-run. These motors vary from the split-phase in that they are 2-phase induction-type motors. They are constructed in two ways: one eliminates the centrifugal switch and allows the starting winding to remain in the circuit while the other uses two capacitors and a centrifugal switch. In the type which eliminates the centrifugal switch, some of the starting torque is lost. This is undesirable in some situations. In the other type the two capacitors are connected in parallel, with one (the starting capacitor) connected in series with the centrifugal switch and the other (the running capacitor) connected in series with the starting windings. With this method you still have the high starting torque and a 2-phase induction motor once the centrifugal switch opens (occurring at 75% of normal speed). The capacitor-start-run motors are usually found in 1-hp sizes and larger. They have high starting torque and dependable constant speed under a changing load.

(3) Shaded-pole. Shaded-pole motors are always single phase and fractional horsepower motors. These motors have very low starting torque and are used to run small fans, clocks, and relays. This type of motor is unique in that it requires no brushes, commutator, or sliprings. It is constructed by placing a rotor in a field that has its pole pieces split at the leading tip. In this split is placed a copper strip which causes a short circuit and a weak opposing magnetic field. This magnetic field keeps the rotor turning in the same direction at all times. The motion of the field produces enough (though weak) torque to allow the motor to start. This is why this type of motor is used for the almost no-load jobs such as relays, clocks, or fans. These motors are very inexpensive to build and maintain.

(4) Polyphase motors. There are many types of polyphase motors. However, they are always 2- or 3-phase motors and are usually 1 hp or larger. Although most polyphase motors are similar in construction, they do differ in several ways. There are two types commonly associated with air-conditioning systems: the squirrel-cage motor and the slipring polyphase motor.

(a) Squirrel-cage motor. This motor has a rotor inserted into a stator or field. Unlike ordinary rotors the squirrel-cage has no windings on the rotor. The rotor is made up of a laminated iron core with bars of copper, aluminum, or an alloy that is a good conductor inserted into slots of the core. These bars are welded to end rings which are of the same material as the bars. This type of rotor has no insulation, brushes, sliprings, or commutator. The stator or field is wound with sets of coils and all connections are made to the field windings. These are constant-speed motors which develop a starting torque of about 300% of full-load torque. They are used to drive compressors, pumps, and large fans. In some of the larger commercial type systems (5 hp and above), a double squirrel-cage motor is used. These motors differ from the single type in that they use two sets of bars in the rotor. The reason for the double set of bars in the rotor is to increase the starting torque to between 400% and 450% of full-load torque.

(b) Slipring polyphase motors. These motors have a rotor similar to the squirrel-cage motor, but that is the only similarity. A polyphase motor does include windings on the rotor, insulated rings (sliprings) on the shaft, and brushes. External resistances are connected to the windings through the orushes which ride on the sliprings. By varying the resistance, you can change the speed and torque of these motors. These motors have high starting torque and are excellent for use with equipment that varies in speed.

2-10. REFRIGERANTS

a. General. In the process of controlling the environment of a given space, we must have something that will effect a heat transfer. In the past, fans were used to cause air movement from one place to another. However, with our advanced technological procedures, mechanical systems have been devised that not only cause air movement but also remove moisture, foreign particles, and heat from the air. To effect the transfer of heat, these mechanical systems employ fluids that have the ability to boil at low temperatures, thus absorbing heat from the surrounding area. These fluids exert a direct action on an area or substance and easily change their state from a liquid to a gas and from a gas to a liquid. The fluids, called refrigerants, are heat carriers. They absorb heat at a low temperature and release heat to a cooling medium at a higher temperature. Refrigerants in common use today are affected by temperature and pressure in a manner similar to water. Because refrigerants are used in automatic mechanical systems (such as air conditioners), they must be safe. Accordingly certain criteria have been established that must be adhered to as closely as possible while still accomplishing the job that a system is designed to do. Fluid used as a refrigerant should have certain properties:

(1) It should be nonpoisonous.
(2) It should be nonexplosive.
(3) It should be noncorrosive.
(4) It must be nonflammable.
(5) Leaks should be easy to detect.
(6) Leaks should be easy to locate.
(7) It should operate under low pressure (low boiling point).
(8) It should be a stable gas.
(9) Parts moving in the fluid should be easy to lubricate.
(10) It should be nontoxic (not harmful if inhaled or if spilled on skin).
(11) It should have a high liquid volume per pound to provide durable refrigerant controls.
(12) It should have a high latent heat per pound to produce good cooling refrigerant controls.
(13) It should have a low vapor volume per pound. This will reduce compressor displacement needed.
(14) The pressure difference between evaporating pressure and condensing pressure should be as little as possible to increase pumping efficiency.

It is desirable to keep normal pressures in the refrigerator as close to atmospheric pressure as possible, because excessive differences may cause leaks, overwork the compressor and decrease the efficiency of the valves.

The standard comparison of refrigerants, as used in the refrigeration industry, is based on an evaporating temperature of 5F. (-15 C.) and a condensing temperature of 86 F. (30 C.). In this chapter, each refrigerant discussed is compared on this basis.

As previously stated, a refrigerant reacts to temperature and pressure. Each refrigerant has a critical temperature and pressure. The critical temperature of a refrigerant is the highest temperature at which a refrigerant can exist as a liquid, regardless of its pressure. The critical pressure of a refrigerant is the maximum pressure at which the refrigerant can exist as a gas, condensing temperature and pressure that is well below its critical temperature and pressure. The refrigerant used in a system must be able to operate at pressures as close to atmospheric as possible and still accomplish the design purposes of the system.

b. Primary refrigerants. There are many primary refrigerants in use today. They range from the hydrocarbons (F-12, F-22, F-114, F-502, etc.) to ammonia. All these refrigerants operate in sealed, pressure-controllable systems. They all do not meet the previously mentioned criteria to the same extent and some are downright dangerous. However, they all, under certain pressure and temperature conditions, will accomplish the design purposes of a certain system. The most commonly used refrigerants in the Corps are the hydrocarbor (F-12 and F-22), which are used in mechanical systems, and ammonia, which is used in absorption systems.

GROUP ONE REFRIGERANTS

REFRIGERANT NO.	NAME AND CHEMICAL FORMULA
R-11	Trichloromonofluoromethane CCl_3F
R-12	Dichlorodifluoromethane CCl_2F_2
R-22	Monochlorodifluoromethane $CHClF_2$
R-500	Azeotropic mixture of 73.8% of (R-12) and 26.2% of (R-152a)
R-502	Azeotropic mixture of 48.8% of (R-22) and 51.2% of (R-115)
R-503	Azeotropic mixture of 40.1% of (R-23) and 59.9% of (R-13)
R-504	Azeotropic mixture of 48.2% of (R-32) and 51.8% of (R-115)

The Group Two refrigerants are toxic. They are irritating to breathe and may be slightly flammable. Methyl chloride is quite toxic. Refrigerants in this group include:

R-717	Ammonia	NH_3
R-1130	Dichloroethylene	$C_2H_2Cl_2$
R-160	Ethyl Chloride	C_2H_5Cl
R-40	Methyl Chloride	CH_3Cl
R-611	Methyl Formate	$C_2H_4O_2$
R-764	Sulphur Dioxide	SO_2

R-717 Ammonia was one of the first refrigerants used.

(1) Dichlorodifluoromethane (F-12). F-12 is a colorless, gaseous compound which, at atmospheric pressure, condenses at -21.7°F. F-12 will dissolve oils and waxes but will absorb only very little moisture. Therefore, F-12 is relatively moisture free and will also keep the system clean because of its solvent action. F-12 is noncorrosive to the ordinary metals that are used in construction of refrigerating or air-conditioning systems. It will attack natural rubber but has little effect on neoprene or chlorroprene. F-12 is nontoxic, nonflammable, and nonexplosive. However, toxic materials may result if F-12 is exposed to a hot flame (approx. 1000°F or higher) or an extremely hot metal surface. Little, if any, anaesthetic action will result from this. One pound of F-12 will occupy 3 cubic feet at 70°F with a vapor pressure of 70 psig. Cylinders which contain F-12 are usually equipped with fusible metal plugs which melt at approximately 160°F. Therefore, care must be taken not to allow overheating. When handling F-12, be extremely careful to keep it out of the eyes. First aid procedures will be covered in paragraph 2-10f.

(2) Monochlorodifluoromethane (F-22). F-22 is a colorless, gaseous compound which condenses at -40°F. F-22 is more soluble in water than F-12, necessitating the use of a drier in systems using F-22 as refrigerant. F-22 is noncorrosive to the metals commonly used in air-conditioning systems. It is nontoxic and nonirritating and its vapors have no appreciable anaesthetic or secondary toxic action. F-22 is shipped in steel cylinders and, like F-12, it must be protected from excessive heat as too great a rise in temperature could cause the cylinders to burst.

(5) Ammonia. Ammonia is one of the oldest refrigerants still in use today. It is used almost exclusively in absorption systems and in some very large industrial mechanical systems. Ammonia is a colorless, gaseous compound of nitrogen and hydrogen. It condenses to a liquid at -28°F. Because of its extremely pungent odor, leaks are easily detected. Ammonia is extremely soluble in water. One volume of water will absorb up to 1,300 volumes of ammonia gas at 32°F at one atmosphere of pressure. Because ammonia is so soluble in water, hose streams, particularly fine sprays, are quite effective in removing the gas from the atmosphere. Ammonia, in itself, is not combustible. In the presence of fire, however, it becomes a fire hazard. It is explosive when mixed with oxygen. However, ammonia will not form an explosive mixture with air if there is a substantial quantity of water vapor present. Ammonia will readily burn upon heating. If mixed with oxygen and heated, the mixture will give off a high temperature greenish-yellow flame. If ammonia vapors are breathed, even in small quantities, acute distress is caused because the vapors will attack the respiratory system. Any exposure to large concentrations is fatal. Concentrations of 0.6% to 1.0% by volume are lethal within a few minutes. Although ammonia is a relatively dangerous gas, accidents will be rare if precautions are taken.

c. Secondary refrigerants. Secondary refrigerants are agents such as air, water, and brine. They are not, in themselves, refrigerants and cannot be used in the primary system. Secondary refrigerants are cooled and passed over or around an area that needs cooling. They pick up heat from that area and are returned to the primary refrigerating system for cooling or are dissapated to waste. These secondary refrigerants may be brine or water sprays, used in coils, or they may be passed over, around, or through an area by use of a blower or fan. Remember: Secondary refrigerants are not, in themselves, refrigerants and cannot be used in the primary system.

d. Marking, storing, and handling of refrigerants and compressed gases.

(1) Packaging. Refrigerants are classified as compressed gases and are packaged in compressed gas cylinders. All compressed gas cylinders used by the Marine Corps and the other armed forces are manufactured under specifications set forth by the ICC (Interstate Commerce Commission). Cylinders used as containers for compressed gases are made of high quality steel. For high-pressure gases, such as oxygen, nitrogen, or hydrogen, they are usually of seamless construction. However, low-pressure gases, such as acetylene, may use welded or brazed cylinders. All cylinders are carefully tested at pressures that exceed the maximum pressure that is permissible. A typical cylinder is an elongated tube with one end that is closed flat and the other rounded. Every cylinder has one or more safety devices to include: spring release plugs, fused metal plugs, breakable disc safety plugs (pressure release disc or valve), or a combination of the fused metal plug and breakable disc safety plug.

There are three types of refrigerant cylinders:

1. Storage cylinder.
2. Returnable service cylinder.
3. Disposable (throw-away) cylinder.

Cylinders are made of steel aluminum. The larger ones usually have a fusible plug safety device threaded into the concave bottom as a protection against overheating or excessive pressures. A valve at the top provides a connection for charging or discharging service cylinders.

Regulations are prescribed by the Interstate Commerce Commission (ICC) to insure the safety of those working with cylinders containing refrigerants.

The ICC regulation requires that cylinders which have contained a corrosive refrigerant must be cheched every five years. Cylinders con aining noncorrosive refrigerants must be checked every 10 years. All cylinders over $4\frac{1}{2}$ in diameter and 12 in. long must contain some type of pressure release protective device, a fusible plug or a spring-operated relief valve, for example.

Never recharge a disposable service cylinder. It may explode.

(2) Marking. All cylinders have permanent markings which are stamped into the metal at the shoulder, top, or neck and are in sequence extending downward. If a color-coded neck ring is employed, the markings start as close to the ring as possible and are also in sequence extending downward. Markings that are found on all government-owned cylinders are the ICC specification mark, the serial number and prefix letter, the ownership symbol, and a disinterested inspector's mark. The name of the gas is also stenciled on the body of the cylinder along is longitudinal axis. Other markings found on cylinders are: the word SPUN placed near the ICC mark if the bottom of the cylinder is formed by a spinning process; the tare weight of cylinders that are filled by weight (such as acetylene); the date of the cylinder's test, which is stamped diametrically dates can be easily added in sequence downward; and the manufacturer's mark stamped above the test date.

Cylinders are also color coded and will be painted in accordance with a strict uniform color code which is specified in MIL-STD-101B. Cylinders containing F-12 and F-22 are painted orange; some cylinders, however, will be painted with two or more colors. For instance a cylinder containing methyl chloride will have its top painted yellow, then a brown band and the body painted orange.

Also included on a cylinder is a diamond-shaped label tag which indicates the characteristics of the cylinder's contents.

(3) Storage and handling. Refrigerants are compressed gases and, because of this, present special problems of storage and handling. Certain conditions must exist for safe storage of refrigerants and special precautions must be observed when handling them.

(a). Storing.

1. Compressed gas cylinders must be stored in an area that is protected from excessive rise and fall of temperature.

2. Compressed gas cylinders may be stored in the open. However, they must be protected against extreme weather conditions and direct contact with the ground. Cylinders stored outside should be kept away from direct rays of the sun in the summer and free from accumulation of ice and snow in the winter. Ventilation must also be provided in the summer to insure that the temperature around the cylinders is kept below 125°F.

3. Keep compressed gas cylinders away from flammable substances such as oil, gasoline, kerosene, waste, etc. Smoking is prohibited in any cylinder storage area.

4. Insure that compressed gas cylinders are kept away from live electrical wires, electrical equipment ground wires, and third rails.

5. Protect compressed gas cylinders from any objects that could cause cuts or abrasions in the surface of the metal. Insure that cylinders are stored in an area where heavy objects, falling or moving, cannot strike them.

6. Store compressed gas cylinders in areas away from continuous dampness and from salt or corrosive chemical fumes. These things will cause rusting, causing protective caps to stick, valves to become inoperative, and weakening of the cylinder walls.

7. Segregate cylinders as to specific gases. Do not store empty cylinders in the same place as full ones. Insure that a fire-resistant partition is placed between areas containing flammable and nonflammable gases.

8. Mark empty cylinders with chalk or tags. Do not use paint. Insure that the valves on empty cylinders are closed.

9. Insure that valve cap covers, if provided, are kept on all compressed gas cylinders when the cylinders are not in use.

10. Insure that all areas and storage rooms that are used to store compressed gas cylinders are well ventilated. This will prevent an accumulation of explosive or harmful gas.

11. Store refrigerant cylinders either upright or on their sides.

(b) Handling.

1. Do not attempt to alter or repair any compressed gas cylinders. Use only specified tools for opening and closing valves. Do not remove or change any of the permanent markings on compressed gas cylinders. Never tamper with any of a cylinder's safety devices.

2. Never fill a cylinder with any gas other than the type for which the cylinder was intended. Do not mix gases. For example, do not put F-22 in a cylinder that contains F-12.

3. When transferring refrigerants, do not completely fill the cylinder. Room must be allowed for expansion of the gas due to any rise in temperature.

4. Do not use cylinders (empty or full) as rollers or supports, or for any purpose other than to carry gas. Do not use electromagnets to lift cylinders. If a crane is used to lift them, insure that a proper sling is used to prevent dropping or other damage. Handle cylinders carefully.

5. Never use compressed gas cylinders in any area where damage could be caused by passing or falling objects, or in areas of concentrated heat (around stoves, welding operations, furnaces, heated flooring, etc). Never open a cylinder valve near welding operations.

6. Do not use a valve regulator, gage, hose, or other apparatus specified for, and used with, a particular kind of gas for any other type of gas.

7. Never place your hands or any part of the body in a gas stream. Any oil or foreign material in the gas could penetrate the skin causing serious injury.

8. Never use wrenches or hammers to open cylinder valves that are equipped with handwheels. Wrenches or hammers would damage the valve seat causing leakage. For those cylinder valves equipped with handwheels, use the cylinder valve wrenches (special tool for opening cylinder valves).

9. After attaching a regulator to a cylinder, insure that the regulator's adjusting screw has been released before opening the cylinder valve. Do not allow the gas to enter the regulator suddenly. Always open the cylinder valve slowly.

10. Before removing a regulator from a cylinder make sure that the cylinder valve is completely closed and all gas has been released from the regulator.

11. If a leak is discovered around the valve stem when the valve is open, close the valve immediately. If this does not stop the leak, tag the cylinder and move it out-of-doors. Keep all peraonnel and sources of ignition from the cylinder.

12. If a leak develops around any of a cylinder's safety devices, the cylinder should be Moved out-of-doors and the valve opened enough to allow the gas to escape slowly. All personnel and sources of ignition must be kept away from the cylinder.

13. Do not attempt to make any repairs to a cylinder. Do not alter connections to make auxiliary equipment fit. Do not force equipment that doesn't fit or use adaptors.

14. Do not try to stop a leak between the cylinder valve and the regulator until the cylinder valve has been closed and time has been allowed for all gas beyond the cylinder valve to escape. Then make any necessary adjustments to stop the leak.

15. Once a sylinder is empty make sure that the cylinder valve is closed, that the cylinder is disconnected, and that the protective cap is replaced.

16. When you use a cylinder in the upright position, make sure that all precautions are taken to prevent it from being tipped over.

17. Never connect a refrigerant cylinder to a system except for charging or evacuating the system.

18. When evacuating a refrigeration system, do not overfill the cylinder. A completely filled cylinder is dangerous because a temperature rise could cause the cylinder to burst.

e. Transferring refrigerants. Refrigerants are shipped in compressed gas cylinders as a liquid under pressure. Liquids are usually removed from the shipping container and transferred to a service drum (cylinder) or to a refrigeration unit. When small quantities of gaseous refrigerant are desired, they must be removed directly from the upright cylinder. However, since vaporization of the refrigerant requires heat, the cylinder must be heated from some external source, other than room temperature, unless only small quantities are required. Cylinders may be heated by immersing them in hot water or wrapping them in hot towels of less than 125°F. Heating by flame is not recommended because of the fire or explosion hazard.

When a service drum is to be filled, it should be placed on a scale to determine its weight. A platform scale is usually used. After the drum is initially weighed, it should be chilled by placing it in ice water or a refrigerated tank. It is then connected to the supply cylinder vith a charging hose and again placed on the scale. The air should then be purged from the charging hose by opening the supply cylinder valve for an instant with the flare nut loose on the service drum. After purging the charging hose, tighten the flare nut and open the valve on the service drum. Now, open the valve on the supply cylinder to permit the refrigerant to flow into the service drum. When the weight of the cylinder indicates that the proper amount of refrigerant has been transferred, close all valves tightly, disconnect the charging line at the service drum, and cap all openings.

f. First aid and safety. Because working with refrigerants can be dangerous, especially if they are improperly handled, it is important for you to be familiar with first aid procedures. In all cases of exposure to refrigerants, medical attention should be summoned as soon as possible. In the meantime, there are some things that you can do to make the victim comfortable and to prevent any further injury.

(1) Halogen refrigerants (F-12, F-22, etc). When you are working with halogen refrigerants, goggles should be worn to prevent any liquid refrigerant from getting into your eyes. A gas mask should be kept handy because halogen refrigerants become toxic if they become involved in a fire.

If any liquid-type refrigerant should get into the eyes, drops of sterile mineral oil should be put into the eyes to irrigate them and wash away the refrigerant. If this does not stop the irritation, then the eyes should be washed with a weak boric acid solution or a sterile salt solution (sodium chloride), not to exceed 2%. If any liquid should come in contact with the skin, treat the area as if the skin had been frost-bitten or frozen. Should a person be overcome due to a high concentration apply artificial respiration. In all cases, summon medical attention immediately.

(2) Ammonia. Ammonia is extremely irritating to the eyes and skin and is toxic even in small quantities. Because of this, goggles and protective clothing (gloves, rubber apron, etc.) should be worn when there is a potential danger of spillage. In areas where ventilation is not good, a gas mask should be kept handy. For persons exposed to ammonia fumes you should remove the victim to fresh air as quickly as possible: keep the patient quiet and warm and if the victim is not breathing, apply artificial respiration. If liquid ammonia gets into the eyes hold the lids open and wash them out with water or a 2% boric acid solution. Once the eyes are washed thoroughly, insert two drops of liquid petrolatum on the eyeball. If liquid ammonia comes in contact with the skin, strip any saturated clothing away from the affected area, wash the skin thoroughly with plenty of water, and then paint the affected skin surface with a solution of picric acid (if affected area is around the eyes, use a boric acid solution instead of picric). Do not cover ammonia burns with bandages or clothing. If the victim's nose or throat is affected, have him rinse his mough thoroughly with a boric acid solution and then drink as much water as possible. Whenever any accident occurs while working with ammonia gas, medical help must be summoned immediately.

2-11. LUBRICANTS

Refrigeration units require the use of lubricating oils to provide lubrication of moving parts and, in some hermetic compressors, cooling of motor windings. Because of the extreme temperatures which are encountered in refrigerating units, these oils must have special properties that would not be found in ordinary lubricating oils. Refrigerating oils are specially prepared mineral oils having a paraffin or napthene base. Refrigeration oil must be able to mix well with the refrigerant with which it is used, since the oil circulates throughout the system with the refrigerant. It must also be able to withstand the extreme temperature changes within the unit. It must be almost completely free of moisture as moisture will damage a refrigeration system. Properties of a good refrigeration oil are:

Low viscosity - which refers to the thickness of the oil and its ability for a specified amount to flow past a certain size opening at 100°F. An oil with a low viscosity will not break down at high temperatures or become thick and lose its fluidity at low temperatures.

Low wax content - desirable because at high temperatures wax becomes separated from the lubricant. When this happens, valves, fittings, and strainers become chogged, which could cause excessive pressure, evaporator and compressor starvation, and damage to the system.

Low pour point - this refers to the lowest temperature that an oil will remain a liquid and maintain it fluidity.

Chemical stability - because the oil and the refrigerant must mix as they travel throughout the system. The oil must be stable so as not to react against the refrigerant. Also, the oil used cannot affect any of the materials used in the construction of a refrigeration system.

Heat stability - so as not to cause carbon deposit at any hot spots within the system, such as at compressor valves or discharge ports.

Refrigerant oils must be kept in sealed, chemically clean containers. Any lines or containers used to transfer these oils must be chemically clean. Refrigerant oil left exposed to air for any length of time becomes contaminated due to moisture absorbed from the air and cannot be used. Any oil removed from a system should be discarded. Never re-use refrigeration oil in a system, always use new oil. Be sure that any container from which new oil is taken is sealed immediately after drawing off the needed amount. Whenever oil is removed from a system it should be checked for discoloration and odor. If either or both are present, it

Refrigeration oils are rated by viscosity to operate at certain temperatures. You should check the TM for the particular system you are working on before putting oil into it. In this way you will insure that you are using the proper oil for the temperatures at which the system operates.

A refrigeration system will use other type of lubricants such as grease and motor oil. These lubricants will also be listed in the appropriate TM's for the equipment. The TM's will also tell you the proper type and grade of lubricants to use and the proper interval at which lubrication services should be performed.

2-12. SUMMARY

In this chapter we have learned that an air-conditioning system is very similar to a refrigeration system, in that many of the components are the same. We have taken each of these components and learned their function and how they are used to complete an air-conditioning system. Although each system varies in design, the basic refrigeration components (compressor, condenser, evaporator, and metering device) are included plus certain valves and controls, depending on the indivudual system's use and the manufacturer's design. It was not the purpose of this chapter to explain the operation of an entire air-conditioning system, but to show what is needed to construct a system and what can be included to complete the system and improve its efficiency.

Also included in this chapter was another important factor in the proper operation of an air-conditioning system, i.e., refrigerants. Because the refrigerant used governs the design and capabilities of a system, it is necessary for you to understand what a refrigerant is, what its properties are, and just how a refrigerant effects the design and efficiency of a system. Because you, as the mechanic, must work with these refrigerants, procedures for safe handling and storage of refrigerants and related compressed gases were covered. Also covered were the lubricants that are used in conjunction with these refrigerants, why they are different from ordinary lubricants, and how they are used within an air-conditioning system.

In order for you to be a competent air-conditioning mechanic, it is important for you to understand the function and purpose of each of the components of a system. It is also necessary for you to know how these components are assembled into a complete system and used in conjunction with a refrigerant and lubricant to efficiently accomplish the manufacturer's designed purpose. Once you have this knowledge and understanding you are well on your way to becoming a competent air-conditioning mechanic.

When a leak is suspected, make certain that the room is thoroughly ventilated before starting to work on the unit. Always check for recommended operating pressures for each refrigerant and install gauges to find the pressures in the system.

Check refrigerant R-number before charging to avoid mixing refrigerants. It the refrigerant is a fluorocarbon, make certain there are no lighted flames near a system that is suspected of having a bad leak. The refrigerant may break down and produce dangerous gases. Always check the ICC cylinder stamp to make sure it is a safe cylinder.

Wear goggles and gloves at all times, especially when charging or discharging. These will protect the eyes, skin and hands in case of a sudden leak.

Always charge refrigerant vapor into the low side of the system. Liquid refrigerant entering a compressor may injure the compressor and may cause the unit to burst.

Liquid refrigerant on the skin may freeze the skin surface and cause "frost bite." If this should happen, quickly wash away the refrigerant with water. Treat the damaged surface for "frost bite."

Accidents involving refrigerants should be immediately referred to a doctor.

Chapter 3

SERVICING AIR-CONDITIONING SYSTEMS

3-1. INSTALLATION.

In order to insure proper operation of any air-conditioning system, regardless of size and type, proper installation is a must. Equipment should be installed in a neat, clean, workmanlike manner. To insure long, trouble-free operation, the system must be dry and clean. Special consideration should be given to the following when installing any system.

a. Visual inspection. Once the equipment has been uncrated, it should be inspected for any signs of damage during shipment. A check of the equipment should be made to insure that all accessories, such as starters and controls, are tied to the unit or are present. Check for leaks, loose connections, and signs of weak or cracked tubing. Also check to see that all electrical connections made by the manufacturer are tight and correct.

b. Leveling and mounting. Any unit must be installed properly, leveled, and mounted in a secure position. Be sure that the support or mounts provided or recommended by the manufacturer are used. Proper leveling of the unit will eliminate unnecessary noise and vibration and improper lubrication of the unit. Also inadequate refrigerant flow may result if the unit is not leveled according to manufacturer's specifications.

c. Air circulation and cooling. When installing air-cooled units, it is essential that adequate airflow is available to insure proper cooling of the condenser and motors. A means of exhausting the air must also be provided to prevent recirculation of used air which would cause a rise in the ambient temperature resulting in reduced efficiency of the unit. Water-cooled units must be provided with an adequate water supply at sufficient pressure as specified by the manufacturer's design. Where cooling towers are used, the cooling tower connections of the condenser can be used to reduce the pressure drop through the condenser. (This is not true with all units, although it will apply to most.) Care must be taken that nothing interrupts or restricts the flow of air around the condenser or the intake or discharge. This is especially true with units that have the condenser located away from the rest of the unit (split units), or of units with the condenser out-of-doors (such as a window unit). Any unit intended for free flow application on the outdoor portion (window units or split units) must never be installed with duct connection to outdoors unless specific approval is given by the manufacturer. Insure that air-cooled compressors are provided with forced convection air cooling and that the air blows against the motor housing. Make sure that nothing is blocking this flow of air. Water-cooled compressors must have water of the temperature specified by the manufacturer. Make sure that a bleed valve is provided with cooling towers and evaporative condensers to prevent a concentration of impurities. This bleed valve should dissipate 1 1/2 to 2 1/2 gallons per hour (gph), depending on unit size and manufacturer's recommendations.

d. Sound. Noise, even that of a steady hum, is objectionable in many areas. Places such as sickrooms and sleeping quarters demand a low noise level. Therefore, care should be taken to insure that units are installed in areas away from such places or in such a manner as to insulate the objectionable sound from them.

e. Electrical connections. Electrical connections can be very simple, such as plugging in a cord as in the case of a window unit, to extremely complicated, such as providing a separately fused circuit breaker with stop-start stations and magnetic starters with large remote units. In all cases, electrical connections must be made properly and tightly. Poorly made electrical connections can cause arcing, overloading of service wires and internal connections, and burning of contact points. Poorly made electrical connections can also cause motor-compressors to run hot, fuses to blow unnecessarily, excess power to be consumed, and other things too numerous to mention here. Always insure that electrical connections are properly and safely made.

The electrical outlet for the system must provide the correct electrical supply. Be sure to read the electrical ratings on the refrigerator and check these against the electrical supply at the wall outlet. The modern household refrigerator-freezer may need more current than the older, simpler refrigerators and freezers.

It is best to have a separate circuit from the fuse or circuit breaker box to the refrigerator-freezer outlet. Avoid using an extension cord between the refrigerator power cord and the wall outlet. The resulting voltage may be too low.

f. Leak testing. All joints, whether factory- or field-made should be checked for leaks. Any leaks found, regardless how small or of what type (refrigerant or lubricant), should be repaired. Continued operation of equipment without loss of capacity or deterioration requires that ALL leaks be detected and repaired.

Note: See paragraphs 3-3 through 3-5 for leak detection and repair.

g. Safety. Always work safely. Adhere to local safety regulations that pertain to the equipment you are working with. Use the proper tool for the particular job that you are doing. Always check manufacturer's manuals and pertinent TM's for any special safety precautions that must be observed when working with a particular system or unit. Make sure that protective gear such as goggles, gas mask, and protective clothing are being used when working with refrigerants that require their use. Work safely to insure that your job will be done properly and that you will be around to complete it.

3-2. PREVENTIVE MAINTENANCE

Preventive maintenance to air-conditioning equipment is usually limited. However, making periodic checks of the critical points will insure a longer maintenance-free life for your unit. Probably the most important areas of preventive maintenance will be keeping the filters clean and the condenser fins free from dirt and dust. These items must be checked reqularly because any restriction of the normal airflow will reduce the efficiency of the unit or system. Poor maintenance and a malfunctioning defrost control can cause evaporator freezeup. Repeated occurrences of evaporator freezeup will cause the compressor to short cycle and eventual damage could result. Check electrical connections and contacts and keep them free from dirt, grease, and moisture. Also make sure that the contact points are not burned. Make sure that traps, special filters, and dehydrators within the system are kept clean and/or dry. Make the necessary replacement or cleaning. Keep a check on the unit or system for any unusual noises or vibrations. If any occur, determine the reason and make any necessary adjustments include leveling the condensing unit, carefully bending cooper tubing away from whatever it may be hitting, adjusting belts, and making any small adjustmen that may be necessary. Lubrication should be performed at the proper intervals as prescribed by the manufacturer. If you keep track of the small things, the unit will have a long life and be free of major maintenance problems.

3-3. TESTING

To properly maintain, troubleshoot, and repair air-conditioning equipment, you should be familiar with a number of tests. You must be able to detect leaks, find the causes of electrical problems, and determine refrigerant and oil levels.

a. Leak detection. To operate efficiently, an air-conditioning unit or system must remain perfectly sealed. The refrigerant must be kept in the system, and air, foreign matter, and moisture must be kept out. The most common cause of leaks is poor workmanship, indicated by improper flaring, poor soldering or sweating, and failure to tighten connections. Other causes can be traced to normal operation, such as wear due to friction, heat, pressure, and vibration. Some units can come from the manufacturer in defective condition or are damaged when moved from one place to another. You should thoroughly check all units upon receipt or when it is necessary to move them to another location. There are three methods used to detect leaks: positive, nonpositive, and special. A positive method is one that no only determines if a leak is present, but also gives its exact location. A nonpositive method indicates the presence of a leak, but does not indicate its exact location. A special method is also a positive method, but it is one that can be used only on units using certain types of refrigerants.

52

(1) Halide torch (fig 3-1). This is a special method used on units or sy...ms which use the halogen refrigerants (i.e., F-12 or F-22) and methyl chloride. The halide torch may be heated with alcohol, natural gas, propane, or acetylene. A copper reactor plate is located at the discharge end of a flexible exploring tube. With the torch lit, the exploring tube is passed over and around joints or areas of suspected leaks. If the slightest bit of refrigerant is leaking, it will be drawn up the tube and the normally blue flame will turn green. If a large amount of refrigerant is encountered the flame will turn purple or it may go out. To use the halide torch, proceed as follows.

(a) Light the torch and adjust it so that it produces a small blue flame.

(b) Insure that the exploring tube is clean.

(c) Hold the open end of the exploring tube as close to the area being tested as possible so that sample air will not diluted by stray a r currents. The exploring tube should be moved slowly over the area being tested, because there is a time lag between the instant the sample air enters the tube and the time it reaches the reactor plate. Leak testing cannot be hurried.

(d) Do not use the torch in an area that has a high concentration of refrigerant gas because it will foul the torch.

(e) Make sure that the area in which you are to conduct a test is well ventilated. Halogen refrigerants will form phosgene gas when exposed to temperatures of 1,022°F and inhalation of this gas must be avoided.

(f) If possible, accomplish testing when the system is on a running cycle. This is to insure that there is sufficient pressure throughout the system to insure detection. If the system is in an off cycle it is quite possible to miss a leak in the low side because of insufficient pressure.

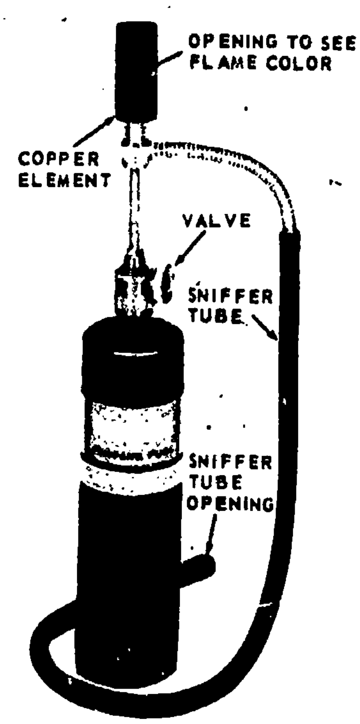


Fig 3-1. Halide Torch Leak Detector

(2) Soap or oil bubble test. (Fig 3-2). The use of soap or oil to detect a leak is a positive method. In this method you mix soap and water to make a thick solution. Let it sit until the bubbles from mixing have disappeared. Then apply the solution to the suspected leak with a soft brush. If a leak is present, bubbles will appear in the solution (fig 3-2). This is the best method of leak detection when testing under hazardous conditions. Oil can also be used in the same manner. Spread a film of oil around the joint or suspected leak and bubbles will appear.

Fig 3-2. Soap bubble test

(3) Pressure and vacuum tests. These tests are nonpositive methods of detecting leaks. All that they will determine is that there is a leak somewhere in the system. In the pressure test, a positive pressure is built up inside the system and a reading is taken. After 24 hours another reading is taken. Any drop in pressure from the first reading indicates a leak. In the vacuum test, you would draw a vacuum on the system· any rise in pressure over a 24-hour period indicates a leak.

(4) Electronic tester. (Fig 3-3). Another tester that could be used by the air-conditioning mechanic is the electronic tester. This is the most sensitive of the testers. On sensing the refrigerant leak, there will be a change in current flow that will show on the meter.

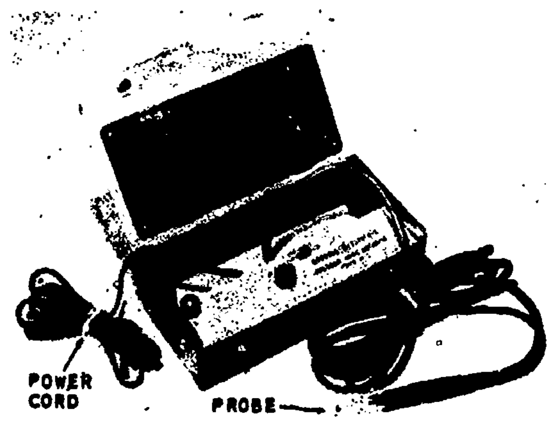


Fig 3-3. Electronic tester

b. Electrical testing. Since most of the air-conditioning units in use within the Corps today have electric motors and controls, it is necessary to be able to use the various items of electrical test equipment available to determine the condition of a motor/compressor unit. Through proper use of this equipment (wattmeter, ammeter, voltmeter, and multimeter) you will be able to determine proper load, open circuits, defective relays, and numerous other malfunctions.

(1) Wattmeter (fig 3-4). Through use of a wattmeter you will be able to determine the power consumption of a unit. You will also be able to determine whether or not the starting winding is open, if relays are operating correctly, and if the load on the motor is excessive or not. Wattmeters are available in many makes and models. Some read wattage only, while others are combination types. Some combination types will read voltage or amperage in addition to wattage, while others will read all three. These meters will have from two to six leads. Spec ·c instructions on the operation of an individual meter will be included with each meter as it comes from the manufacturer. When properly connected into the circuit, your meter will give you three successive readings. As the power is turned on, the needle or pointer will swing up to a point and pause momentarily; this will be the "overswing" or "start" reading. Then, almost immediately, the needle will move back to the left (most wattmeters read from left to right) and will give you the combined start and running running reading. The needle should pause for approximately 1 to 1 1/2 seconds and then drop farther back to the left and give you the running reading. If the starting winding or relay is bad, the needle will swing to the right and move all the way back to the running reading only, not pausing at the starting and running reading. If the compressor has a shortage of refrigerant,

causing the motor to work harder to provide enough refrigerant to the evaporator, the running reading will be higher than stated on the data plate. However, in order to determine an overloaded condition, observation is necessary for a period of time. (Time period can be found in the appropriate TM or manufacturer's manual.) If the motor is shorted internally, causing the safety devices to kick out, then the only reading will be the initial pull and the needle will drop back to zero.

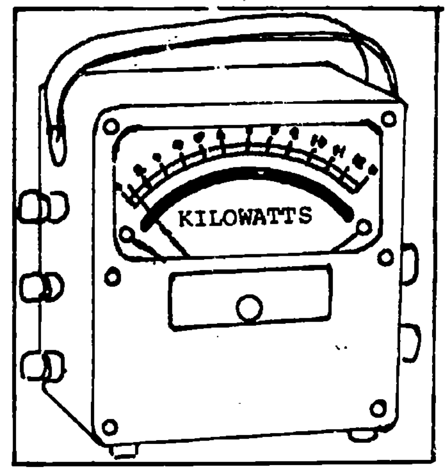


Fig 3-4. Wattmeter.

(2) Multimeter. The multimeter is a multipurpose instrument that can measure resistance, voltage, or current. Figure 3-5 shows a multimeter that is widely used in the Marine Corps. The following is an explanation of its use.

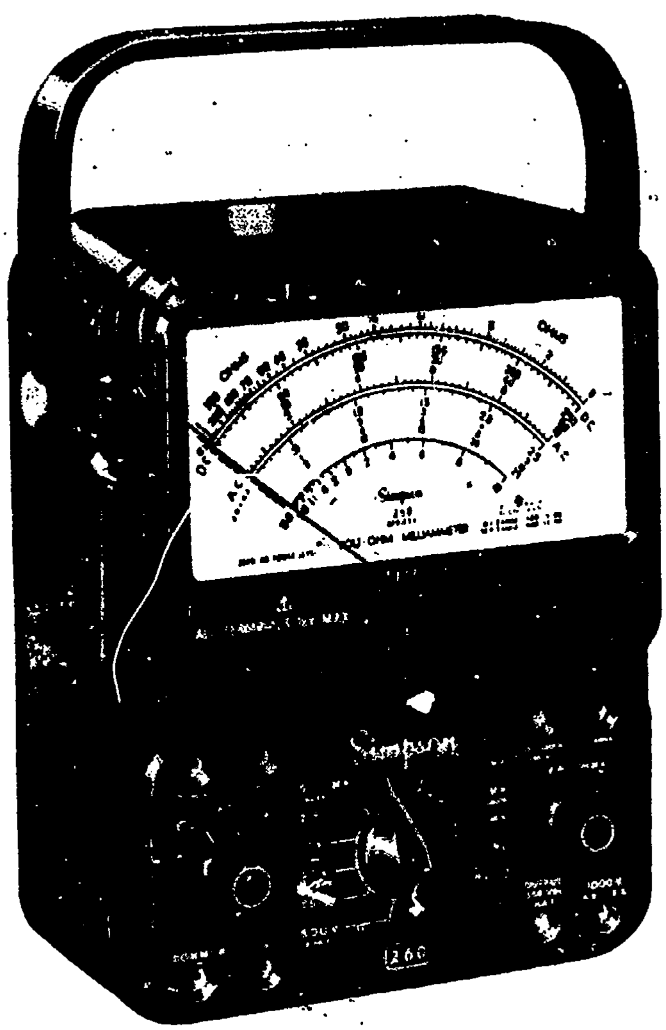


Fig 3-5. Simpson 260-6 Volt-Ohm-Milliammeter

a. Power Source. There are two batteries in the ohmeter circuits; one is a D size cell that furnishes 1.5 volts for the Rx1 and the Rx100 ranges (resistance), and a 9 volt battery for the Rx10,000 range (resistance).

b. Fuse Protection. A 1 ampere, 250 volt and a 2 ampere, 600 volt high capacity fuse are provided to protect the Simpson 260's low impedance circuits from misuse on the ohm and current ranges. The 1 ampere fuse is used for normal overload conditions, and the 2 ampere fuse is connected in series with the 1 ampere fuse as a protection against excessive high energy overloads applied to current or ohm's ranges.

Note: If the multimeter fails to indicate, the 1 amp or the 2 amp fuse may be burned out.

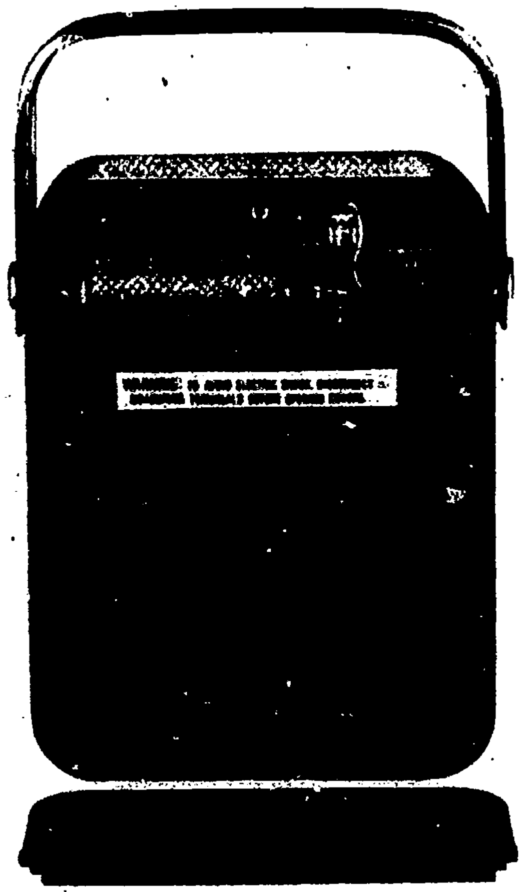


Fig 3-6. Battery and Fuse Compartment

(c) Meter Face. Although the meter face has five graduated scales, we will concern ourselves with only four of the five. The top graduated scale is for the resistance readings (ohms) only. You'll notice that the ohm's scale numbers run backwards as compared to the other three scales. The DC scale is to be used for D.C. voltage and current readings only. There are 3 sets of numbers that are read left to right. The appropriate row of numbers are determined by the range switch setting. The AC scale is to be used for A.C. voltage readings only. This meter does not measure A.C. current. The first A.C. scale (in red on the actual meter) is to be used in conjunction with the three sets of black numbers above it, for any range between 0-250VAC (Volts-Alternating- Current). The second A.C. scale (in red on the actual meter) is to be used for A.C. voltage ranges between 0-2.5 volts. The last Decibel (DB) scale is not used by the Air Conditioning Mechanic.

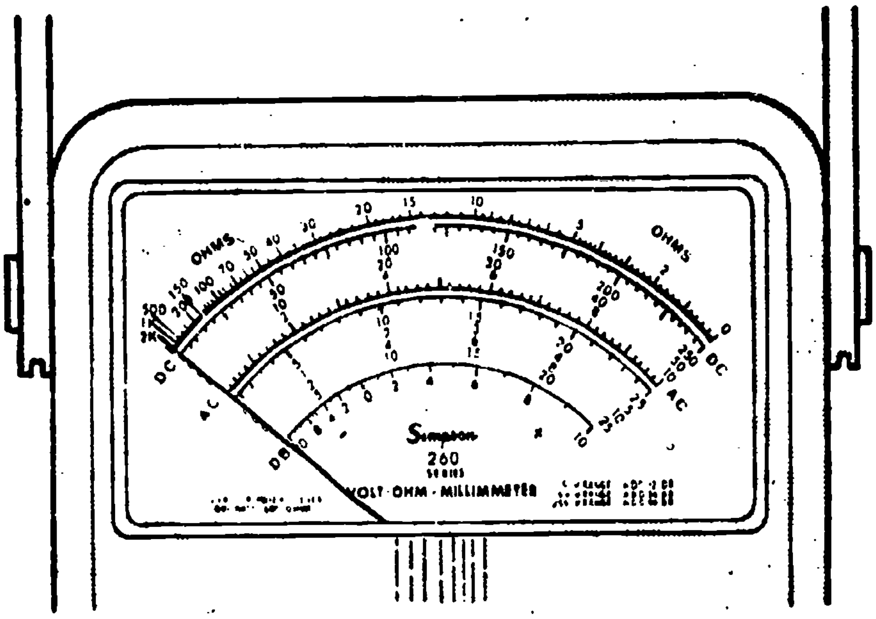


Fig 3-7. Meter scales

(d) Front Panel: The 260-6 Volt-Ohm-Milliammeter is a large, easy-to-read $4\frac{1}{4}$ inch indicating instrument. Below the Instrument are four controls and eight circuit jacks. Switch positions and circuit jacks are marked in white characters for easy reading.

(e) Range Switch: Has 12 positions: May be turned in either direction. There are 5 voltage positions, 4 direct current positions, and 3 resistance positions used to select desired ranges.

(f) Function Switch: The function switch has three positions: -DC, +DC and AC. To measure DC current or voltage, set the function switch at the -DC or +DC position, depending on the polarity of the signal applied across the test leads. To measure AC voltage set the function switch to the AC position. For resistance measurement, the switch may be set in either the +DC or -DC position. The polarity of the internal ohmmeter battery voltage at the (+) pos jack is identical to the function switch polarity setting and opposite at the (-) common jack.

(g) Zero Ohms: This control is used to compensate for variation in the voltage of the internal batteries.

(h) Circuit Jacks: There are eight jacks on the front panel marked with the functions they represent (Figure 3-1). These jacks provide the electrical connections to the test leads. The COMMON (-) jack is used (in conjunction with the black test lead) as the reference point for the measurement of all the functions with the exception of the 10A range. (Refer to the Operation Section for details.)

(i) Pointer Adjust For Zero: With the Volt-Ohm-Milliammeter in an operating position, check that the pointer indicates zero at the left end of the scale when there is no input. If pointer is off zero, adjust the screw located in the case below the center of the dial. Use a small screwdriver to turn the screw slowly clockwise or counterclockwise until the pointer is exactly over the zero mark at the left end of the scale.

With the indicating pointer set on the zero mark, reverse the direction of rotation of the zero adjuster. Rotate the zero adjuster a sufficient amount to introduce mechanical freedom or "play" but insufficient to disturb the pos tion of the indicating pointer. This procedure will avoid disturbances to the zero setting by subsequent changes in temperature, humidity, vibration, and other environmental conditions.

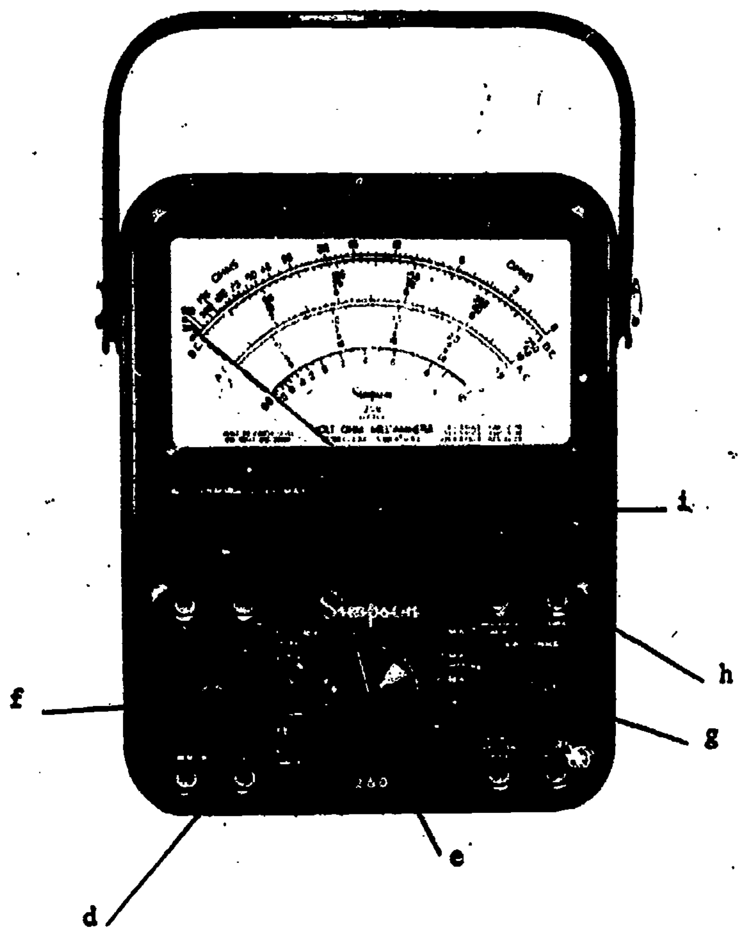


Fig 3-8. Front Panel Controls, Jacks and Indicators

Safety. Before we cover the procedures when making electrical tests, we must first go over some general safety precautions.

a. Inspect the test leads for cracks or breaks in the insulation, prods and connectors before each use. If any defects are noted, replace the test leads immediately.

b. Voltages may appear unexpectably in defective equipment. Turn off power and discharge all capacitors before connecting or disconnecting test leads to and from the circuit being measured.

c. Hands, shoes, floor and workbench must be dry to avoid shock.

d. For maximum safety, do not touch leads or instruments while power is applied to the circuit under test.

e. Do not make measurements using tests leads of lesser safety than those originally furnished with the instrument.

f. Do not touch any object which could provide a current path to the common side of the circuit under test or power line ground. Always stand on a dry surface capable of withstanding the voltage being measured, or that could be encountered.

g. When making voltage and current measurements, ALWAYS start with the highest range. to avoid "pegging" the meter's needle and or blowing the meter.

Note: Pegging" the needle or meter is when the Range Switch setting (Voltage and Current) is set too low for the value being measured. This causes the needle to swing off scale hitting the "stops" located beneath the meter face. Many times it is done hard enough and often enough that it will bend the needle, causing all readings that follow to become inaccurate.

Operation. The following precautions and procedures are to be observed when making a voltage, current and resistance measurement using the Simpson 260 multimeter.

Note: Most of the following procedures and precautions apply to most other makes of multimeters as well.

1. Voltage Measurement.

a. Ensure that the "bananna" plugs of the test probes are in the appropriate jacks; Black probe in the "common (-)" jack and the Red probe in the "+" jack. (Most of your measurements will be made using these jacks).

b. Set the "Function Knob" on "+DC" (set on AC when making AC voltage measurements). Most of your measurements will be made using this setting.

c. Set the Range Switch on the highest voltage setting (bold face numbers-500V), if the maximum voltage value is unknown for the circuit being measured.

d. De-energize (turn off) the circuit to be tested.

e. Place the test probes across or in parallel position with the component to be measured, observing polarity (Black to the negative (-) side and Red to the positive (+) side).

f. Energize (turn on) the circuit and try to obtain the most accurate reading, a "full scale deflection" (getting the meter's needle as far right as possible without "pegging it"). This is accomplished by lowering the Range Switch setting.

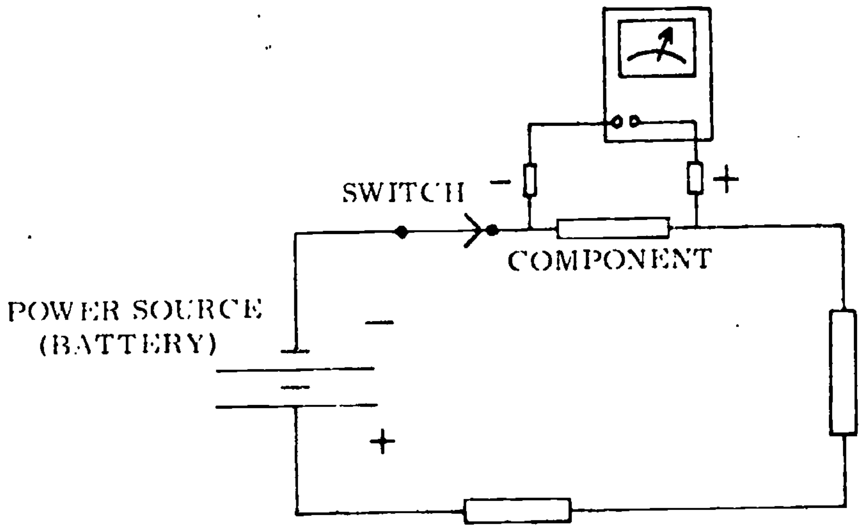


Fig 3-9. Voltage Check

2. Current Measurement.

a. Ensure that the bananna plugs of the test probes are in the appropriate jacks; Black probe in the "common (-)" jack and the Red probe in the "+" jack.

b. Ensure that the function knob is set on "+DC" (This meter DOES NOT read AC current).

c. Set the Range Switch setting on the highest current range (bold face number-500MA), if the current value of the circuit under test is unknown.

d. De-energize the circuit.

e. Physically "break" into the circuit and place the test probes in series with the component to be measured, OBSERVING POLARITY. This is done by placing the Black probe on the negative (-) side and the Red probe on the positive (+) side of the component to be measured.

f. Energize the circuit.

g. Try to obtain the most accurate reading by trying to obtain a "full scale deflection" (the needle as far to the right of the scale as possible, without "pegging" it). This is done by lowering the range switch setting.

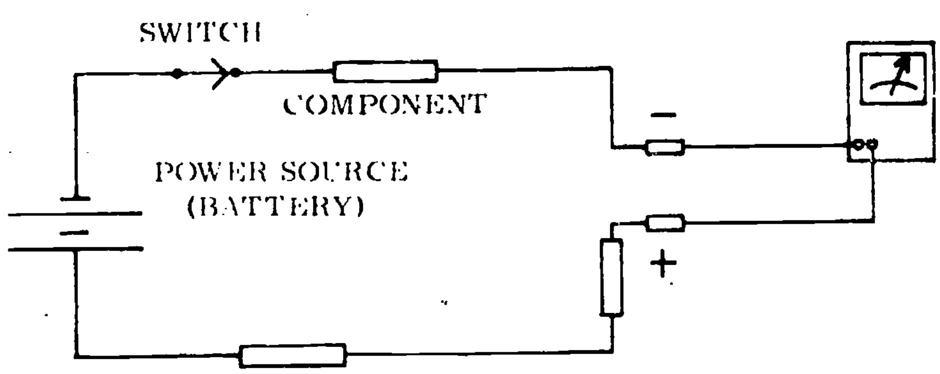


Fig 3-10. Current Measurement.

3. Resistance Measurement.

a. Ensure that the bananna plugs of the test probes are in the appropriate jacks; Black probe in the "common (-)" jack and the Red probe in the "+" jack.

b. Ensure that the function knob is set on the "+DC" setting.

c. Set the Range Switch on the approximate resistance range of the component to be measured (if known). If unknown, set the Range Switch on Rx1 or Rx100 (especially for "continuity" checks, which will be explained).

d. De-energize the circuit and keep it de-energized (off).

e. Isolate (disconnect the component to be measured, so there is no electrical return path) the component to be measured.

f. "Zero" the multimeter (always prior to measurement and each and every time you change resistance range settings). This is done by touching the ends of the test probes together, which should cause the needle to deflect (move) to the right. If the needle does not go all the way to zero (ohms scale), adjust it by using the "zero ohms adjust knob".

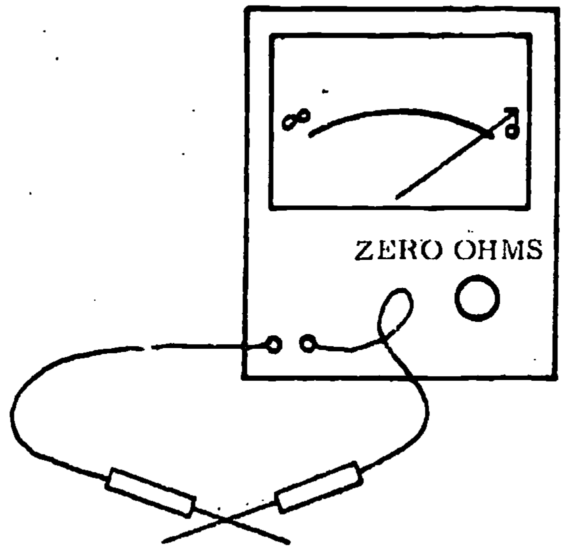


Fig 3-11. "Zero the Meter."

g. Place the test probes across or in parallel with the component to be measured. You do not have to observe polarity (remember, the power is off).

h. Try to obtain the most accurate or "mid scale" reading. This is done by changing the resistance range settings. Remember to "zero" the meter each and every time you change range switch settings.

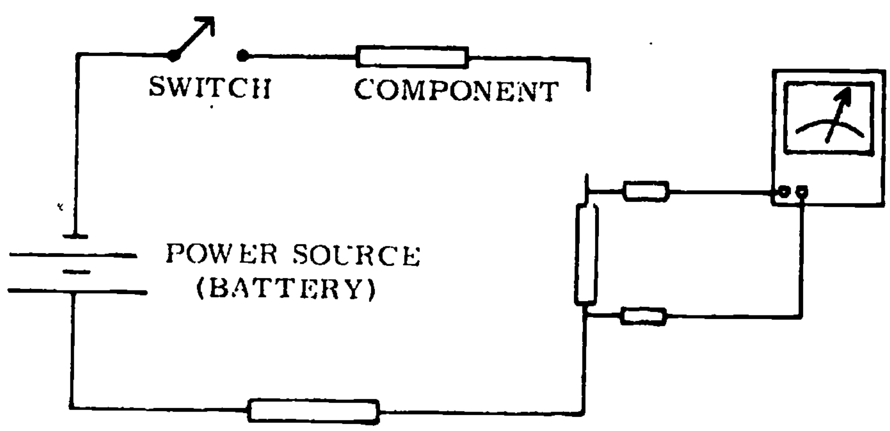


Fig 3-12. Resistance Check.

Continuity Checks. It means the same as resistance checks, so the procedure is the same. Continuity checks are normally associated with checks made in connections or wires for breaks (Opens) and shorts (grounded).

(4) Ammeter. Your shop should be equipped with an ammeter capable of reading at least 100 amps. It should be of the internal shunt type. Ammeters are connected in the circuit in series and indicate the amount of amperage being used or "pulled" by the circuit. Ammeters will have a positive (+) lead and a negative (-) lead and are hooked into the circuit so that the electron flow will be from negative to positive. When inserting your ammeter into the circuit, make sure the power is off. Once you are satisfied that your meter is hooked up correctly, turn on the power and obtain a reading. To remove the meter from the circuit, turn off the power, unhook the meter, reconnect the circuit, and turn the power back on. If you are not sure of the direction of the electron flow in the circuit, once you have the meter hooked up, turn on the power momentarily and observe the pointer or needle movement (most ammeter pointers move from left to right). If the needle moves in the wrong direction, reverse the leads and you will be able to get a proper reading. A commonly used ammeter in the Marine Corps is the hook-on-type voltammeter (fig 3-13). This meter simply hooks around the conductor and the current can be measured safely without too much inconvenience. Voltage can usually be read with this meter; however, the switch would have to be set to volts and the leads attached to voltage terminals across which voltage could be measured.

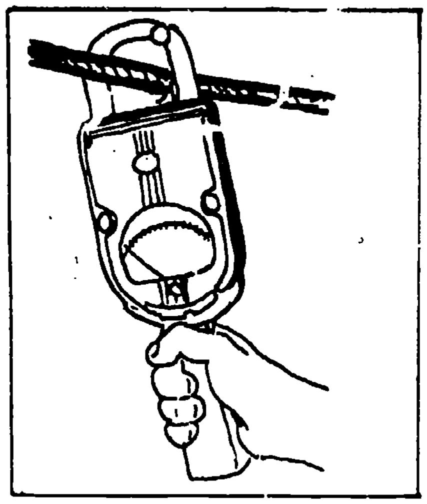


Fig 3-13. Hook-on voltammeter.

(5) Hourmeter. An hourmeter can also be used as a means of testing a unit. It can be used to check the cycling or running time of a unit that is kept in continuous operation. By keeping a periodic check on a unit's hourmeter you can determine whether or not a unit is short- or long-cycling or if it is running continuously. An hourmeter is also very helpful in the performance of preventive maintenance. Since maintenance is scheduled and based on unit running time, the hourmeter will give an accurate accounting of running time, thus allowing for the performance of maintenance at the proper intervals.

3-4. USE OF THE BAR GAGE MANIFOLD

a. Installing the bar gage manifold. The purpose of the bar gage manifold is to allow you to observe both low- and high-side operating pressures at the same time. It also permits charging, evacuating, adding oil, and purging of noncondensible gas with comparative ease. It is most important that the bar gage manifold be installed carefully and correctly. If it isn't, air may enter the system and leaks may occur. The following is the proper procedure for installing the bar gage manifold. (Refer to figure 3-14 for picture of the bar gage manifold.)

(1) Backseat the suction and the discharge service valves.

(2) Remove the caps from the gage ports.

(3) Connect the pressure gage line from the bar gage manifold to the discharge service valve gage port. Tighten the hose connections.

(4) Connect the compound gage line from the bar gage manifold to the suction service valve gage port. Leave the hose connection loose.

(5) Make sure that the center charge port on the bar gage manifold is capped tightly.

(6) Open the compound and pressure gage valves on the bar gage manifold 2 complete turns off their seats. (Turn the handles counterclockwise.)

(7) Crack the discharge service valve off its backseat, allowing the refrigerant to push air out through the loose hose connection on the suction service valve; then, tighten the hose connection on the suction service valve.

(8) Close the compound and pressure gage valves on the bar gage manifold.

(9) Crack the suction service valve off its backseat.

(10) Observe the pressures.

b. Removing bar gage manifold. It is also important to be equally careful when you remove your bar gage manifold. The following is the proper procedure.

(1) Backseat the discharge service valve.

(2) Open the compound gage valve off its seat 2 complete turns.

(3) Make sure that the unit is running (if possible).

(4) Crack the pressure gage valve off its seat very slowly, allowing the discharge pressure in the gage lines to bleed into the low side of the compressor.

(5) Backseat the suction service valve.

(6) Remove the bar gage manifold and install the gage ports, caps, and valve covers.

c. Evacuating. Before dismantling any air-conditioning unit, it is first necessary to remove the refrigerant. The only exception to this is when a pump-down operation (explained in para 3-4d) is applicable. It is considered a good practice to discard the refrigerant from small units (if fresh refrigerant is available). On large units, the refrigerant can be reused if it is free of contamination. There are two ways or methods of evacuating a refrigeration system: using the unit's compressor (if it is operative) and using a vacuum pump. If the unit's compressor is hermetic, it should not be used for evacuation.

(1) Evacuating by using the unit's compressor (fig 3-14). To evacuate by using the unit's compressor, you should:

(a) Stop the unit.

(b) Backseat the discharge and suction service valve.

(c) Install the bar gage manifold.

(d) Place an evacuated (empty) refrigerant cylinder, of the right size to hold the system's refrigerant charge, in a container of ice water.

(e) Connect a flexible charging line between the center port of the bar gage manifold and the service cylinder. Leave connection at the service cylinder loose.

(f) Crack the discharge service valve.

(g) Open the pressure gage valve on the bar gage manifold.

(h) After the air bleeds out of the lines (3-5 seconds), tighten connection at the service cylinder.

(i) Open the service cylinder valve.

(j) Start the unit.

(k) Crack the suction service valve to obtain suction pressure readings.

(l) Slowly frontseat the discharge service valve, observing the head pressure. If the head pressure reaches 150 psig, stop the unit until head pressure drops to 100 psig. Continue the operation when the head pressure has dropped.

(m) Complete the evacuation. When the compound gage reads 0 psig, evacuation is complete.

(n) Close the service cylinder valve.

(o) Close the pressure gage valve and stop the unit. Warning: If any part is to be removed or opened for repair, make sure that the unit is not in a vacuum (below 0 psig). Figure 3-14 illustrates evacuation by using the compressor.

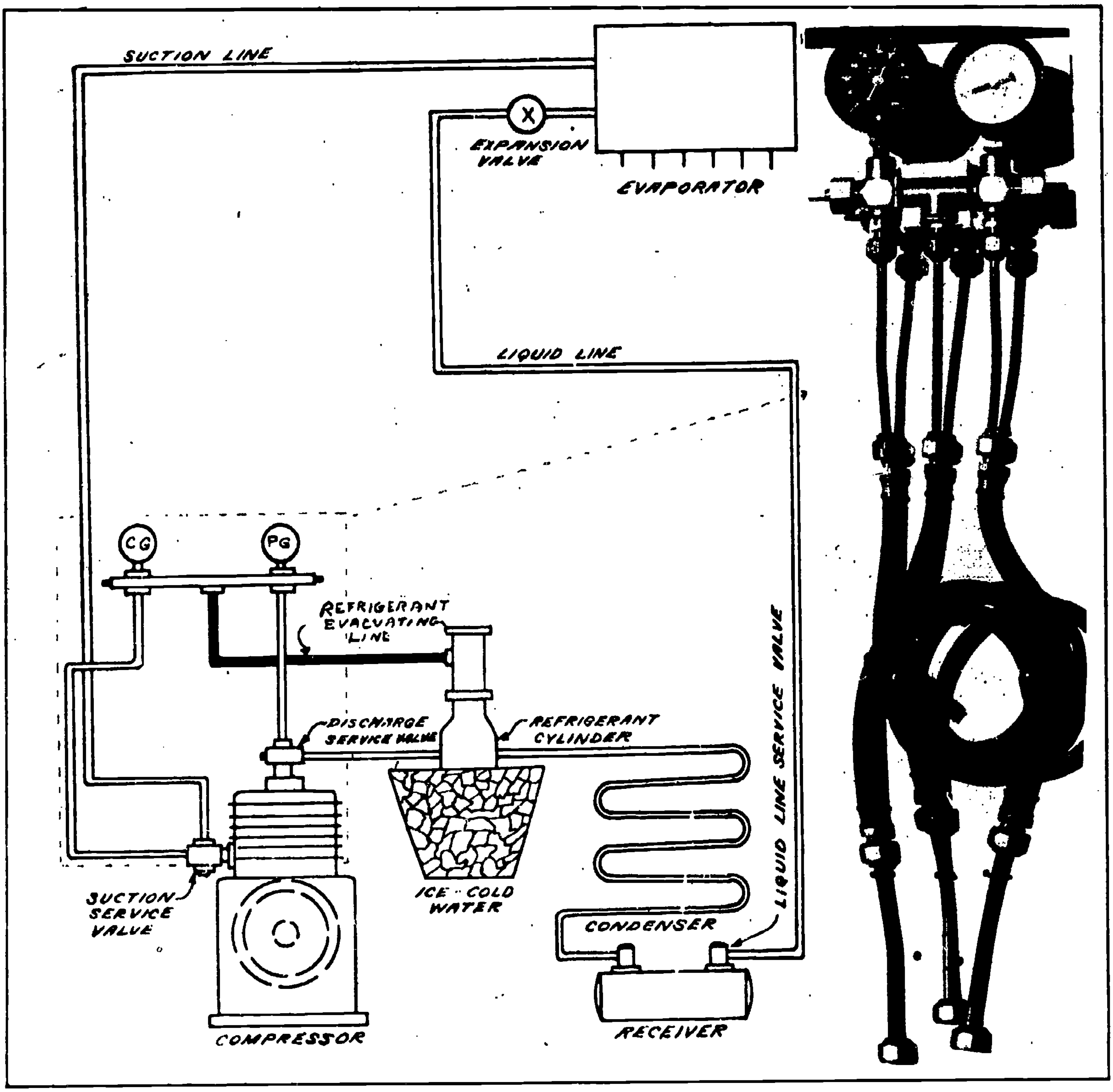


Fig 3-14. Evacuation by using the unit's compressor.

(2) Evacuating by using a vacuum pump. You should:

(a) Stop the unit.

(b) Backseat the discharge service valve and the suction service valve.

(c) Install the bar gage manifold.

(d) Connect a flexible charging line between the center port of the bar gage manifold and the suction port of a vacuum pump.

(e) Connect a flexible charging line from the discharge port of the vacuum pump to a servic cylinder, leaving service cylinder connection loose.

(f) Crack the compressor discharge service valve.

(g) Open the pressure gage valve and turn the pump over, purging the lines between the bar gage manifold and the service cylinder.

(h) Tighten the service cylinder connections.

(i) Close the pressure gage valve and open the compound gage valve.

(j) Open the service cylinder valve.

(k) Crack the suction service valve of the compressor to obtain a suction pressure reading.

(l) Start the pump. Evacuation is completed when the compound gage reads 0 psig.

(m) Close the service cylinder valve, then stop the pump.

(n) Close the compound gage valve.

(o) Backseat the suction service valve. Warning: If the system is to be opened for repair, make sure that the unit is not in vacuum.

d. Pump-down (fig 3-15). The purpose of pumping down a unit is to trap the refrigerant in the receiver in order to repair or replace components without evacuating the system. The sequence for pump-down is: Install the bar gage manifold, close the king valve, set the low-pressure control at 2 psig, and then operate the unit until it stops. Turn off the power and check the compound gage. If the pressure builds up above 2 psig, start the unit again and run it until the gage remains at 2 psig. Once the compound gage remains at 2 psig, frontseat the discharge service valve. Now you can repair or replace any lines or parts from the king valve up through the evaporator, metering device, drier, and back to the discharge service valve; this includes the compressor itself.

Note: To make sure that the discharge reeds in the valve plate are not leaking back to the low side, you should frontseat the suction service valve and run the unit until 0 psig is reached. Then stop the unit. If the compound gage remains at 0 psig, the discharge valves are not leaking.

Once pump-down has been completed and the parts have been repaired or replaced, you can restore the unit to operation. To do this, you would tighten all connections and then loosen the flare nut on the suction service valve with the valve frontseated. Next, open the king valve and allow the refrigerant to push whatever air has entered the system out through the loose flare nut at the suction service valve. Tighten the flare nut on the suction service valve and then open all other valves to resume normal operation.

e. Charging. Refrigerant is added to the unit by supplying it through the suction service valve (low-side charging) or through the discharge service valve (high-side charging). In low-side charging, the refrigerant is always added in gaseous form. Low-side charging offers good control of the charging process and should be used whenever possible. Although it takes longer, it is much safer and you are in complete control of the entire process. In high-side charging, the refrigerant is always added in liquid form. High-side charging is very rapid. The amount of refrigerant to be added must be weighed or measured. While the charging process is going on the service cylinder must be inverted (turned upside down).

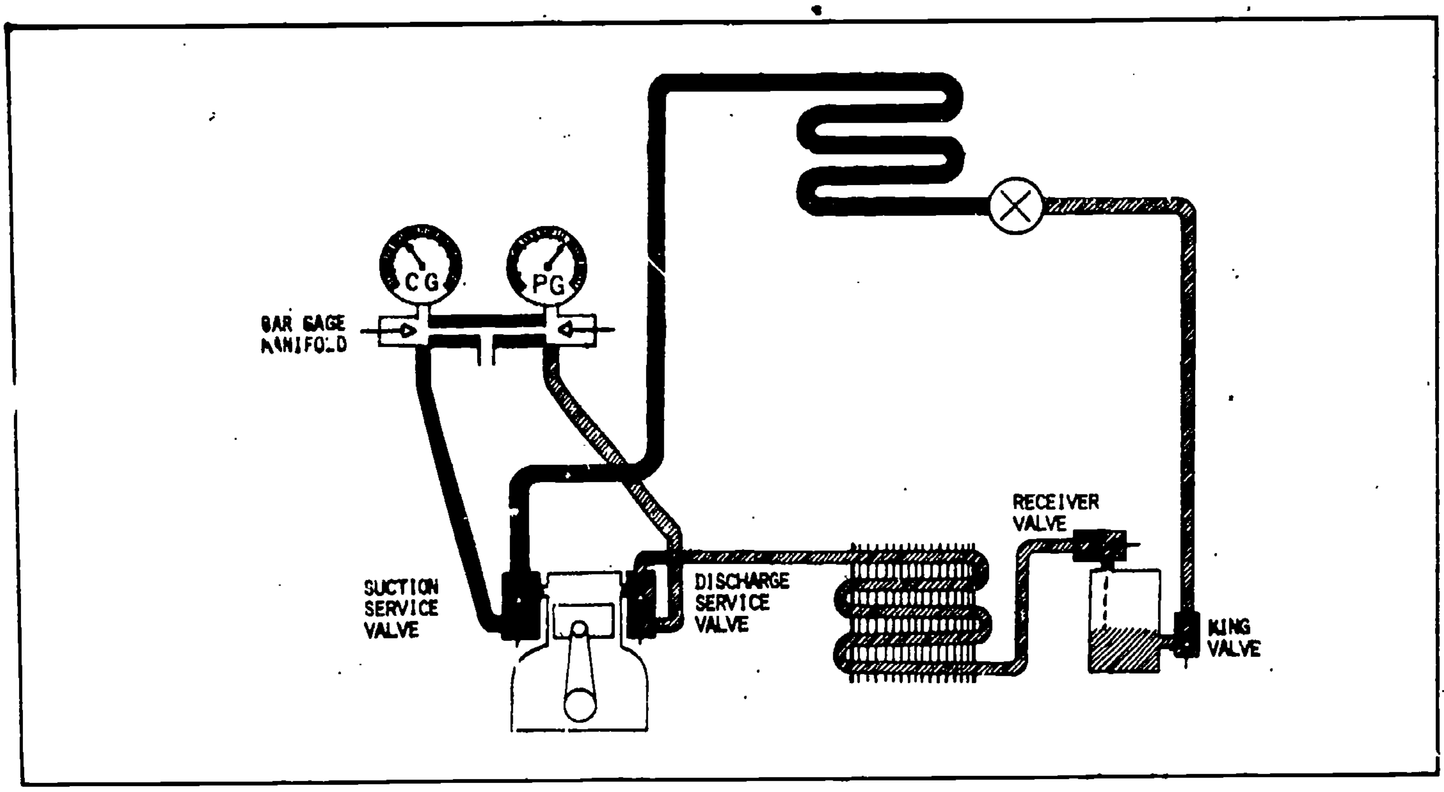


Fig 3-15. Pump-down

(1) Low-side charging (fig 3-16). For low-side charging, proceed as follows:

(a) Backseat service valves.

(b) Install the bar gage manifold, leaving the connections loose at the service valves.

(c) Open both of the valves on the bar gage manifold.

(d) Attach a flexible line from the service cylinder to the center port on the bar gage manifold.

Note: Service cylinder will be in an upright position.

(e) Momentarily open the service cylinder valve to purge the service lines.

(f) Tighten all the connections at the service valves.

(g) Close the compound and pressure gage valves.

(h) Crack the suction service valve.

(i) Crack the discharge service valve and get the head pressure reading.

(j) Crack the compound gage valve.

(k) Start the unit.

(l) Keep suction pressure at approximately 30 psig by adjusting the compound gage valve.

(m) Charge the required amount of refrigerant into the system.

Note: If the exact charge is unknown, charge a small quantity at a time and continually check the operating pressures, sight glass, and frostline. To speed up the charging process you can place the service cylinder in a container of warm water.

(n) When enough refrigerant has been added to the system, close the service cylinder valve.

(o) Backseat the discharge service valve.

(p) Allow the compressor to draw the remaining refrigerant out of the lines.

(q) Close the compound pressure valve.

(r) Backseat the suction service valve.

(s) Check the unit for proper operation.

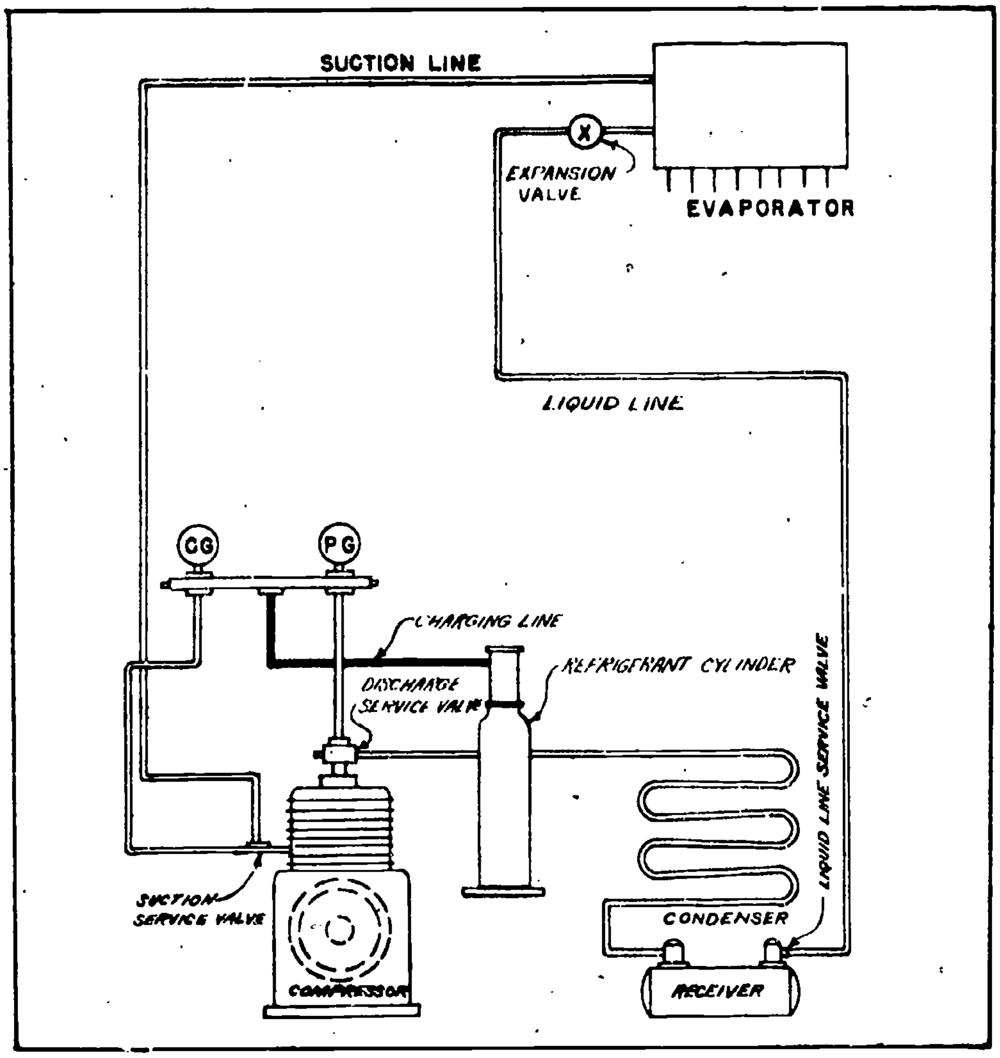


Fig 3-16. Low-side charging.

(2) High-side charging. In high-side charging, you must remember several things: first that the refrigerant is always added in liquid form and that the exact charge must be in the service cylinder--no more and no less. Remember that the unit is not running, that that the service cylinder must be inverted, and that this is a rapid method of charging a unit. You should also be aware that high-side charging is dangerous and unless it is done correctly, lines may be ruptured and the compressor can be damaged beyond repair. In order to charge liquid refrigerant into the high side of a system, the pressure in the service cylinder must be higher than that in the system. If the system you are charging is water-cooled, the pressure in the liquid receiver, with the water running, will be low enough to force the refrigerant from the cylinder into the system. If the unit to be charged is an air-cooled system, the pressure in the refrigerant drum will have to be increased. The high-side charging procedure is as follows:

(a) Backseat both of the service valves.

(b) Install the bar gage manifold and leave the connections loose at the service valves.

(c) Open both of the valves on the bar gage manifold.

(d) Attach a flexible charging hose from the center port of the bar gage manifold to the service cylinder.

(e) Open the service cylinder valve and purge the lines to the service valves.

(f) Tighten the connections at the service valves.

(g) Close both valves on the bar gage manifold.

(h) Invert the service cylinder with the exact charge and support it securely.

(i) Open the pressure gage valve.

(j) Crack both service valves.

(k) Liquid refrigerant will be forced into the condenser and receiver.

(l) Apply heat to the service cylinder by using rags soaked in hot water; when the cylinder is empty, remove the rags.

(m) When the cylinder is empty, close the cylinder valve.

Note: When charging through the high side with liquid refrigerant, the refrigerant will make a gurgling sound. When this stops you will know that the cylinder is empty.

(n) Close the pressure gage valve.

(o) Remove the service cylinder.

(p) Start the unit and check its operation.

(3) Determining the charge. There are three methods of determining whether you have the correct refrigerant charge in a system: sight glass, pressure determination, and weighing the charge.

(a) Sight glass. In a system that is fully charged, the sight glass will show a clear flow of refrigerant; in fact, it will appear empty. If the glass appears cloudy or bubbly, it usually means that the system is undercharged and that more refrigerant is necessary.

(b) Pressure determination. After charging a unit with an estimated charge, it may be necessary to determine if the charge is correct by using the pressure determination method. This can be done in two ways, either by using the head or discharge pressure, or by using the suction pressure. After the charge has been added to the system, the unit must be run until the pressure stabilizes. Once the pressure stabilizes, the ambient temperature must be determined. The ambient temperature will vary depending on the type of condensing unit that the system uses. The actual temperature of the condenser is taken and then a certain number of degrees Fahrenheit is added (see fig 3-17 for the correct number of degrees). Then by checking the pressure/temperature chart you can determine whether the pressure is correct.

Example 1. To determine the head pressure of a natural convection unit, first take the temperature of the condenser. If the temperature is 75° F, you add 35°F to it (fig 3-17). Thus: 75° + 35°F = 110° F. Now check the pressure/temperature chart. If the refrigerant is F-12, you find that the pressure gage should read 136.4 psig. If it reads less, more refrigerant is needed. If it reads more, some refrigerant will have to be evacuated.

Type of Condenser	Temperature
Natural convection	Ambient temp +35° F
Forced convection	Ambient temp +30° F
Water-cooled	Ambient temp +20° F

Fig 3-17. Temperature chart for determining ambient temperature.

68

Example 2. The normal suction pressure of a unit would be equal to the evaporator temperature minus 10° F regardless of the type of condensing unit. Assume you find that the evaporator temperature is 30° F. You subtract 10° to give you an ambient temperature of 20° F. The pressure/temperature chart shows that the gage should read 21.04 psig.

(e) Weighing the charge. This is a simple method; however, the charge must be known in advance. First an evacuated cylinder is weighed and then the necessary refrigerant is put into the cylinder.

Example: If an evacuated cylinder weighs 15 lb and the TM specifies that the unit needs 5 lb of F-12, the filled cylinder should weigh 20 lb. The cylinder is placed on a scale and the system is charged (filled) until the scale again reads 15 lb.

f. Removing and adding refrigeration oils.

(1) Removing refrigeration oils. In case there is an overcharge of oil in a system, the excess must be removed. If the oil has become contaminated, it must be changed. To remove oil from a system, follow this procedure:

(a) Attach a compound gage to the low side of the system.

(b) Start the compressor and gradually frontseat the suction service valve until the pressure in the crankcase drops to 1 psig.

(c) Stop the compressor and frontseat both the service valves.

(d) Drain the oil through any valve or plug below the service valves.

(e) Replace the plug and tighten or close the valve.

(f) Place the system back in operation.

Note: Always purge air from a system, whenever it has been opened.

(2) Adding refrigeration oil. There are two methods of adding oil to a compressor: the low-side vacuum method and the oil plug method.

(a) Oil plug method. To use this method, proceed as follows:

1. Attach a compound gage to the low side.

2. Start the compressor and slowly frontseat the suction service valve until a pressure of approximately 2 psig is reached.

3. Stop the compressor and frontseat both of the service valves.

4. Slowly remove the oil gage or the oil filler plug.

5. Slowly add the required amount of oil through a clean, dry funnel. Do not add more than 1/4 pint at a time

6. Replace and tighten oil plug or gage.

7. Return the service valves to their normal positions.

(b) Vacuum method (fig 3-18). To add oil to the compressor using the vacuum method, proceed as follows:

1. Install the bar gage manifold.

2. Frontseat the suction service valve.

3. Run the unit until the compound gage registers a 15-inch vacuum.

4. Stop the unit.

5. Install a flexible charging line from the center port of the bar gage manifold to the oil container.

Note: Always place the end of the charging line well below the surface of the oil in the oil container. This will insure that only moisture-free oil is drawn into the compressor.

6. Crack the compound gage valve; atmospheric pressure will force the oil into the compressor crankcase.

7. Add only about 1/4 pint of oil at a time.

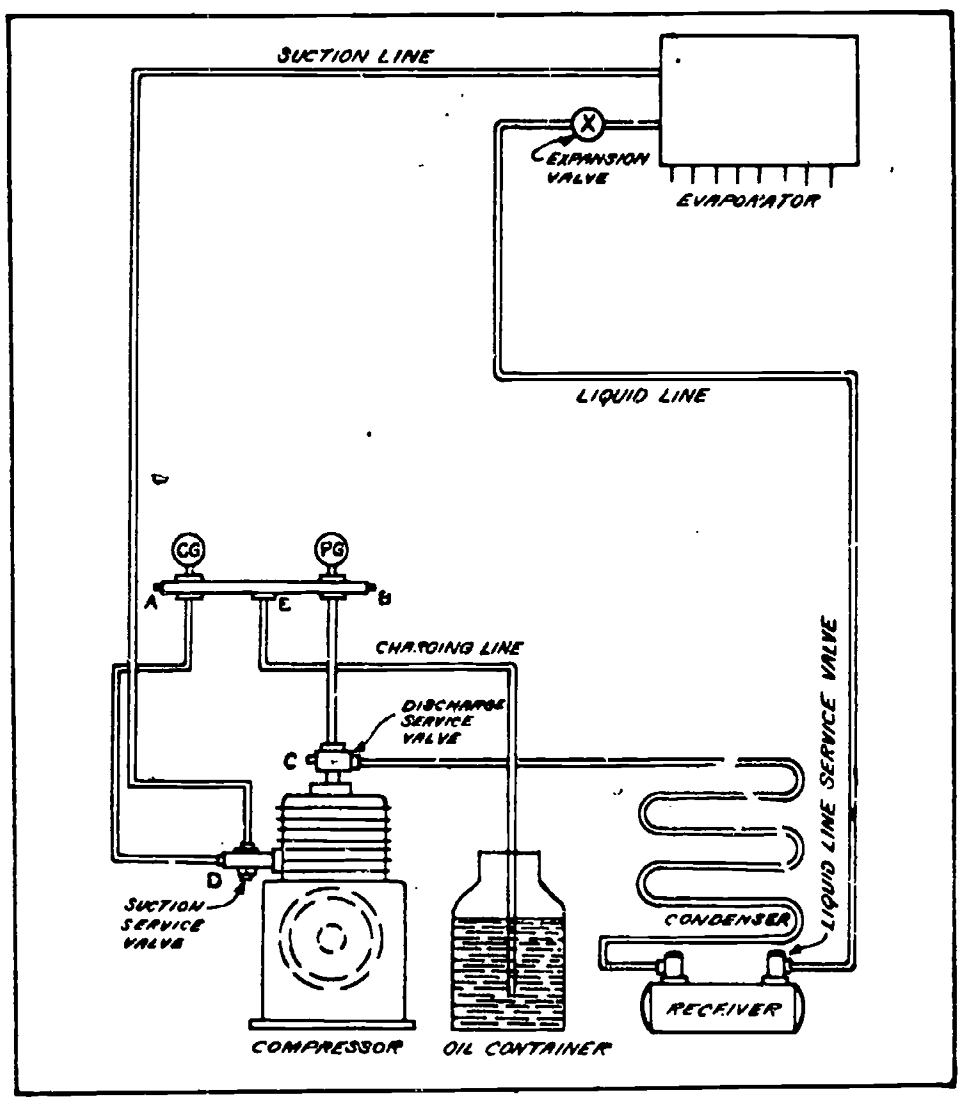


Fig 3-18. Adding oil to the compressor, vacuum method.

3-5. METHODS OF MAKING A JOINT

a. General. As an air-conditioning mechanic, you will have to be able to solder and braze joints. These joints must be gastight to prevent leakage of refrigerant or loss of pressure. To make these joints, you will be using the solder and brazing kit and associated materials found in the expendable supplies kit (solder, solder and brazing flux, and acetylene). There are two types of solder joints: soft solder joints and hard solder or brazed joints. The difference in the joints is determined by the degree of temperature and the stress that the individual joint must withstand. Joints that are under little or no stress and are required to withstand temperatures not exceeding 250° F can be soft-soldered. Other joints will be hard-soldered or brazed. When making joints of any type, you must remember that they have to be strong and leakproof. This is especially important when working with solder because you can't take a wrench and tighten a solder joint. There are six things to remember when making a solder connection:

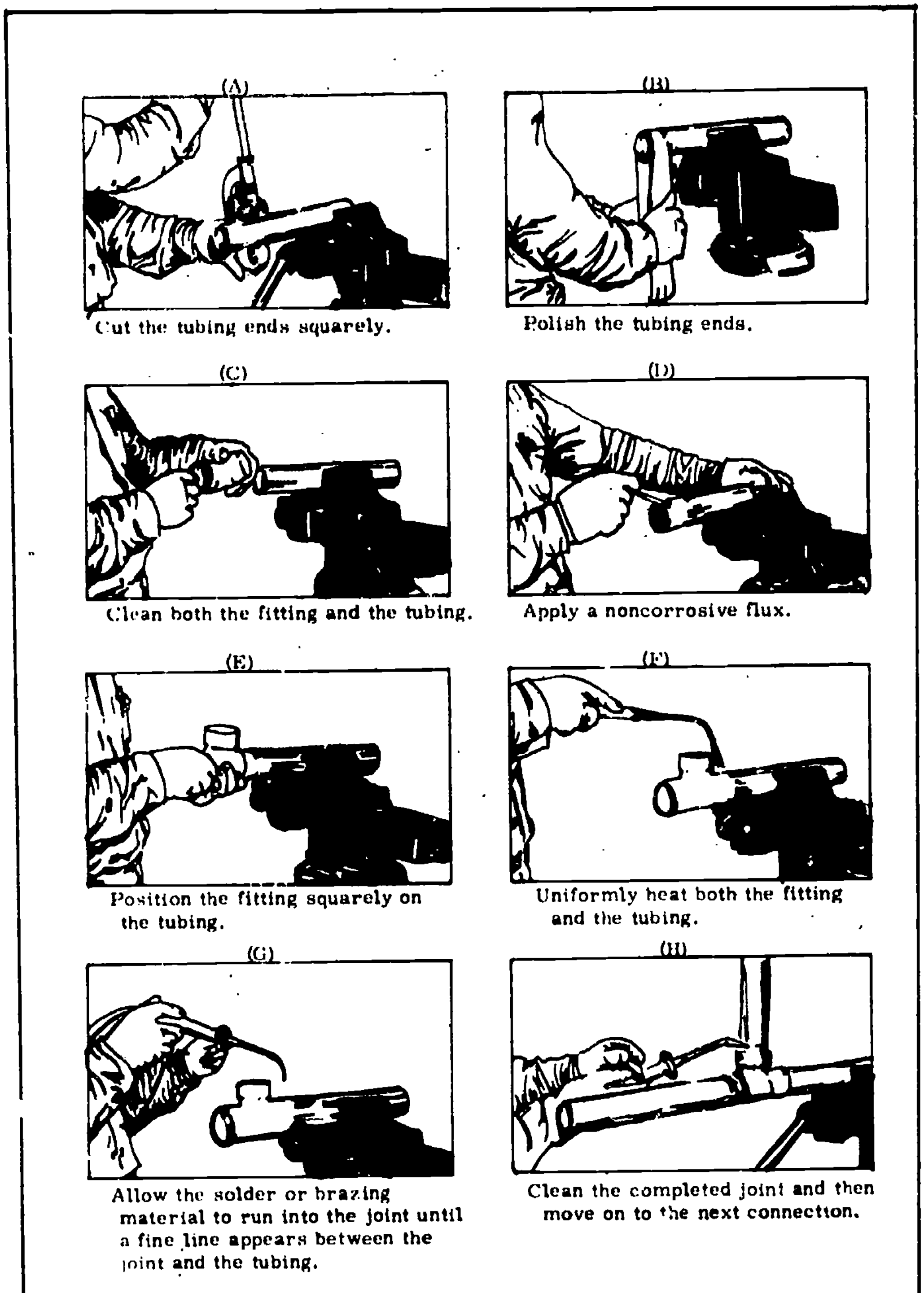
- The joint must fit properly and have the right clearance.
- The surfaces that are to be connected must be thoroughly cleaned.
- Flux must be applied evenly over the connecting surfaces.
- The joints must be properly assembled and supported.
- The joint and connection must be uniformly heated and the bonding material properly applied.
- Once the connection is completed, it must be cleaned.

b. Soldering. In most cases you will be dealing with joints that must withstand temperatures of less than 250° F and that will be under little or no stress; therefore, you will be making soft solder joints. Also, you will be dealing with tubing of less than 1 inch in diameter. First, the tubing must be squarely cut. To do this, you should use a tubing cutter. However, if a cutter is not available, you can use a hacksaw if a miter box is available to insure a square cut. Next, thoroughly clean the ends of tubing, both inside and out. You can use 00 sand paper, 00 steel wool, crocus cloth, or emery paper for cleaning the tubing ends. Make sure that you wipe the cleaned surfaces off with a lint-free cloth. Now apply a noncorrosive flux or soldering paste, insuring that the surfaces are thoroughly covered. The flux or paste prevents oxidation which would cause the joint to be weak or to leak. Then, assemble the joint. Now select one of the small tips from your brazing and soldering kit and prepare to heat the joint. Heat must be applied evenly over the entire joint area. When the joint is hot enough, touch the solder to the metal surface and allow it to run into the joint. Do not melt the solder with the flame from the torch. Allow the joint to become hot enough to melt the solder and run into the joint. Once the joint is completely soldered (the joint is completed when a thin line of solder appears at the top of the joint), allow it to cool and harden. Do not cool a soldered connection by any means other than natural cooling. Then, clean the joint to remove excess solder and flux. It is not necessary to use a lot of solder; only use what is necessary to seal the joint and make it gastight.

c. Hard soldering and brazing. The terms hard soldering and brazing are often used interchangeably; however, there is a difference. Brazing requires heating of the metal surfaces to a temperature above their melting point and allowing the metal to fuse together with the use of a brazing rod. Brazing flux is used to prevent oxidation and weakening of the joint.

> Note: Critical point and composition of the metal must be known, and an experienced supervisor should be on hand whenever brazing is attempted.

Hard soldering requires the use of silver alloy solder which has a high melting point. Hard soldering techniques are much the same as those used for soft soldering, however, hard soldering requires more heat. To get more heat to the joint areas, you would use a medium tip or maybe even the large tip, depending on the size of the joint and the amount of heat required. When making a hard solder joint, you still must cut it squarely, properly clean it, properly put it together, and apply flux. The joint is then evenly heated to the metal's melting point and the silver solder applied as you would when using soft solder. Once the joint is completed, it must also be cleaned. Figure 3-19 shows the proper sequence for soldering and brazing.



(A) Cut the tubing ends squarely.

(B) Polish the tubing ends.

(C) Clean both the fitting and the tubing.

(D) Apply a noncorrosive flux.

(E) Position the fitting squarely on the tubing.

(F) Uniformly heat both the fitting and the tubing.

(G) Allow the solder or brazing material to run into the joint until a fine line appears between the joint and the tubing.

(H) Clean the completed joint and then move on to the next connection.

Fig 3-19. Sequence for making a soldered or brazed joint.

3-6. TROUBLESHOOTING

Troubleshooting is being able to discover what is wrong with a unit or system and to determine what to do to fix it. Tables 3-1 and 3-2 are troubleshooting charts which are generally applicable to all types of air conditioners. These charts will list a complaint followed by one or more causes and the possible remedy. Although these charts apply to most air conditioners, manufacturers include more detailed and specific information in publications (TMs, operating manuals, etc.) pertaining to their units.

Table 3-1. Troubleshooting Chart for Air Conditioners with Open-type Compressor

Complaint	Cause	Possible remedy
a. Electric motor will not start.	1. Power failure.	1. Check circuit for power source.
	2. Compressor stuck.	2. Locate cause and repair.
	3. Belt is too tight.	3. Adjust the belt tension.
	4. Manual reset in starter is open.	4. Find cause of the overload and repair it. Reset overload cutout.
	5. Thermostat is set too high.	5. Lower the setting.
	6. Low voltage.	6. Check out with voltmeter then call base maintenance or an electrician.
	7. Burned-out motor.	7. Repair or replace motor.
	8. Frozen compressor caused by a locked or damaged mechanism.	8. Remove and repair the compressor.
b. Unit cycles on and off.	1. Intermittent power interruption.	1. Tighten connections or replace defective power supplv parts.
	2. High-pressure cutout is defective.	2. Replace high-pressure cutout.
	3. High-pressure cutout is set too low. Overload opens once it has been reset.	3. Raise the cutout pressure. Check the voltage and current being drawn.
	4. Leaky liquid line solenoid valve.	4. Repair or replace.
	5. Dirty or iced evaporator.	5. Clean or defrost the evaporator. Check the filters and fan drive.
	6. Overcharge of refrigerant or noncondensible gas.	6. Remove any excess refrigerant or purge system of noncondensible gas.
	7. Leak of refrigerant.	7. Locate and repair leak then recharge the system.
	8. Restricted liquid line strainer.	8. Clean or replace the strainer.

Table 3-1. Troubleshooting Chart for Air Conditioners with Open-type Compressor--contd

Complaint	Cause	Possible remedy
b. Unit cycles on and off.--contd	9. Faulty motor.	9. Repair or replace the motor.
c. Coil frosts.	1. Dirty filters.	1. Clean or replace filters.
	2. Not enough air circulating over the coil.	2. Clean out or remove any restrictions from the supply or return air ducts or grilles.
	3. Defective expansion valve.	3. Replace the valve.
d. The unit runs but will not cool.	1. The unit is not fully charged.	1. Recharge slightly, then locate and repair any leaks. Then recharge the unit.
	2. Leaky suction or discharge valve.	2. Remove the compressor cylinder head and clean or replace the valve plate.
	3. Expansion valve is improperly set.	3. Adjust the expansion valve.
	4. Strainer is clogged.	4. Remove, clean, and replace the strainer.
	5. Air in the refrigerant.	5. Purge air from the unit.
	6. Moisture in the expansion valve orifice.	6. Clean the valve orifice and install silica-gel dryer.
	7. Flash gas in liquid line.	7. Add refrigerant.
e. No air blowing from the supply grille.	1. Ice or dirt on the evaporator.	1. Clean the coil or defrost.
	2. The blower belt is broken or loose.	2. Adjust tension or replace the belt.
	3. Blower bearing is frozen.	3. Free or replace bearing.
f. Discharge pressure is too high.	1. Condenser is not operating properly.	1. Correct the airflow.
	2. Air in the system.	2. Purge.

Table 3-1. Troubleshooting Chart for Air Conditioners with Open-type Compressor--contd

Complaint	Cause	Possible remedy
f. Discharge pressure is too high.--cont'd	3. Overcharge of refrigerant.	3. Remove excess or purge the system.
g. Discharge pressure is too low.	1. Lack of refrigerant.	1. Locate and repair leak. Charge.
	2. Broken or leaky compressor discharge valves.	2. Remove the head, locate and replace any valves that are operating improperly.
h. Suction pressure is too high.	1. Overfeeding of the expansion valve.	1. Regulate the expansion valve's superheat setting. Check to see that the remote bulb is properly attached to the suction line.
	2. Expansion valve is stuck open.	2. Repair or replace the valve.
	3. Broken suction valve in the compressor.	3. Remove the head, locate and replace any valves that are operating improperly.
i. System pressure is too low.	1. Lack of refrigerant.	1. Locate and repair leak. Charge.
	2. Clogged liquid line strainer.	2. Clean or replace.
	3. Expansion valve power element has lost its charge.	3. Replace the valve's power element.
	4. Obstructed expansion valve.	4. Clean valve. Replace if necessary.
	5. Control thermostat contacts are stuck in closed position.	5. Repair thermostat. Replace if necessary.

Table 3-2. Troubleshooting Chart for Air Conditioners with Hermetic Compressor

Complaint	Cause	Possible remedy
a. Compressor runs continuously; good refrigeration effect.	1. Air over the condenser is restricted.	1. Remove the restriction or increase the air circulation.
b. Compressor runs continuously; unit is too cold.	1. Thermostatic switch contacts are badly burned.	1. Replace the thermostatic switch.
	2. Thermostatic switch bulb has become loose.	2. Secure the bulb in place.
	3. Thermostatic switch is improperly adjusted.	3. Readjust correctly.
c. Compressor runs continuously; little refrigeration effect.	1. Extremely dirty condenser.	1. Clean the condenser.
	2. No air circulating over the condenser.	2. Provide proper air circulation.
	3. Ambient temperature is too high.	3. Provide ventilation or move unit to a cooler location.
	4. Load is too great.	4. Analyze the load and make appropriate changes.
d. Compressor runs continuously; no refrigeration effect.	1. A restriction preventing the refrigerant from entering the evaporator. (A restriction is usually indicated by a slight refrigerant effect at the point of restriction.)	1. Locate the possible points of restriction, and try jarring with a plastic hammer, or heating to a temperature of about 110° F. If the restriction does not open, replace the unit.
	2. Compressor not pumping. This would be indicated by a cool discharge line and a hot compressor housing. The wattage is generally low.	2. Replace the unit.
	3. Short of refrigerant.	3. Check manufacturer's instructions and add refrigerant.

Table 3-2. Troubleshooting Chart for Air Conditioners with Hermetic Compressor --contd

Complaint	Cause	Possible remedy
e. Compressor short cycles; poor refrigerating effect	1. Loose electrical connections.	1. Locate and tighten loose connections.
	2. Defective thermostatic switch.	2. Replace the thermostatic switch.
	3. Defective motor starter.	3. Replace the motor starter or relay.
	4. Air restricted at the evaporator.	4. Remove the restriction.
f. Compressor short cycles; no refrigerating effect.	1. Dirty condenser.	1. Clean the condenser.
	2. Ambient temperature is too high.	2. Provide ventilation or move the unit to a cooler location.
	3. Defective wiring.	3. Repair or replace the wiring.
	4. Thermostatic switch is operating erratically.	4. Replace thermostatic switch.
	5. Relay erratic.	5. Replace the relay.
g. Compressor runs too frequently.	1. Poor air circulation around the condenser.	1. Increase the air circulation.
	2. Ambient temperature too high.	2. If possible, increase ventilation or move unit to a cooler location.
	3. Load too great. Worn compressor. Generally accompanied by rattles and knocks.	3. Analyze load. Replace unit.
h. Compressor does not run.	1. Motor is not operating.	1. If trouble is outside sealed unit, it should be corrected; i.e., wires, switches, and relays repaired or replaced. If the trouble is inside the sealed unit, replace the unit.

Table 3-2. Troubleshooting Chart for Air Conditioners with Hermetic Compressor--contd

Complaint	Cause	Possible remedy
i. Compressor will not run (assume here that the thermostatic switch and relay, electric wiring, and current supply are in good condition and operating properly).	1. If the cabinet has been moved, some oil may be on top of the piston.	1. Wait about an hour and then attempt to start the motor by turning the current on and off several times. With some compressors, it may be necessary to wait 6 to 8 hours.
	2. Compressor may be stuck, or some internal parts broken.	2. Replace the unit.
	3. Connections broken internally, or motor windings may be open.	3. Replace unit.
	4. Piston stuck in cylinder due to long period of standing idle.	4. May be possible to start the compressor by turning on current and tapping the outer housing with a rubber mallet.
j. Compressor is unusually hot.	1. Dirty condenser.	1. Clean the condenser.
	2. Lack of air circulation.	2. Increase air circulation.
	3. Unusually heavy service or load.	3. If possible decrease the load. Perhaps another unit is required.
	4. Low voltage.	4. Check unit's wiring. Wires may be too small. Hot wires indicate they are too small for the load and should be replaced with larger ones. If wires are okay, call an electrician and have power source checked.
	5. A shortage of oil.	5. Add oil if possible; if not possible, replace the unit.
k. No refrigerating effect when starting after a long shutdown or upon delivery.	1. Generally, during a long shutdown, an amount of liquid refrigerant will get into the crankcase of the compressor. When this occurs, the compressor operation will cause no refrigerating effect until after all the liquid refrigerant has evaporated from the crankcase.	1. Allow compressor to operate until its internal heat drives all the liquid from the crankcase. Under some conditions this may take as long as 24 hours.

Complaint	Cause	Possible remedy
l. Noisy compressor.	1. Mountings have become worn or deteriorated.	1. Replace the rubber mountings.
	2. Unit is placed near a wall of an extremely hard surface which greatly amplifies any slightest noise.	2. Place sound-absorbing material on wall, or move the unit to a different location.
	3. Shortage of oil and/or refrigerant.	3. If possible, add oil and refrigerant. If not possible, replace the unit.
	4. The sealed unit mechanism has become worn.	4. Replace the unit.
m. After each defrosting there is a long on cycle before the refrigerating effect is again normal.	1. Slight shortage of refrigerant.	1. Replace refrigerant if possible; if not, replace the unit.
	2. Dirty condenser.	2. Clean the condenser.
	3. Thermostatic switch bulb is loose.	3. Secure the bulb in place.
	4. Restriction between the receiver or condenser and/or the evaporator.	4. Attempt to remove the restriction by jarring with a plastic hammer, or by heating to about 110° F. If this does not correct the problem, unit will have to be replaced or brought to the shop for repairs.

3-7. REPAIR AND REPLACEMENT OF MAJOR COMPONENTS

a. General. To insure long and satisfactory operation of air-conditioning units and systems, there are additional tests and maintenance procedures necessary to determine whether to repair or replace a major component of a unit or system. These components are compressors, condensers, motors, metering devices, evaporators, and controls. We will discuss general procedures that are necessary to determine proper operation of these components.

b. Motor service. Motors are usually quite rugged and reliable. Therefore, motor maintenance is usually simple. Major motor repairs, such as rewinding, are not attempted at your level of maintenance. As far as you are concerned, motor care will consist mainly of lubrication, cleaning, and seeing that the motor is not abused. You may experience problems with bearings, dirt and grease, and, in the case of open motor/compressors, belts.

(1) Bearings. The most common causes of bearing trouble are improper alinement during installation and inadequate lubrication. If a bearing gives you trouble, it must be replaced. Bearings should not be removed unnecessarily because they are easily damaged. Normally, to remove a ball bearing, the end bells of the motor are removed and the rotor, shaft, and bearing assembly are removed from the motor. If the bearing housing has a removable outer cap, it is sometimes possible to remove the bearings without removing the end bells. When removing a ball bearing from the shaft, you should exert pressure only on the inner race (fig 3-20). If this is not possible, pressure on the outer race must be evenly distributed over the entire race. Pressure should be applied steadily and parallel to the shaft. Before removing a sleeve bearing, an air gap measurement is normally made to determine the amount of wear and to see if the bearing is out-of-round. Small sleeve bearings may be carefully tapped out, but bearing pullers are usually required to remove the larger size sleeve-type bearings. Bearings are replaced by applying steady, even pressure or by tapping lightly. Ball bearings must not be forced onto a shaft that is too large or badly worn. Grease retainers and oil slingers must be in place. Dirt and foreign matter must be kept out of bearing recesses as they will scar the surfaces and cause the races of ball bearings to become distorted. If a race is distorted, the balls will get out-of-round and cause an excessive friction load on the motor. After installation, bearings should be rotated by hand to see that they roll freely and without noise. Protective covers must be in place and be tight to prevent dirt and moisture from entering the bearing housing.

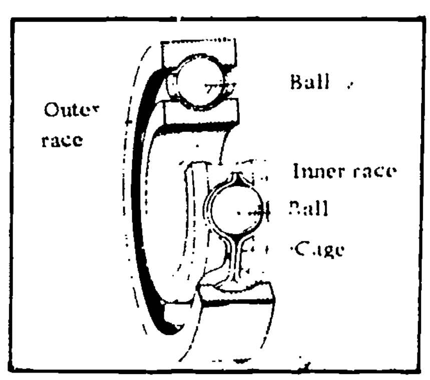


Fig 3-20. Single-row radial ball bearings.

(2) Cleaning. Except for totally enclosed motors such as those in hermetic units, dirt, dust, and grease will accumulate inside a motor during long periods of use. Whenever a motor is dismantled, you should clean it thoroughly. Only fluids of good dielectric quality should be used. There are several fluids approved for motor cleaning.

(3) Belts. Belts will be found on units that employ an open-type motor/compressor. In order to obtain long and satisfactory use from V-belts, the motor pulley and flywheel must be in exact alinement and the belts under proper tension. Both the motor and the compressor must be securely mounted on the base. An improperly adjusted belt will cause slippage, excessive wear, and deterioration--often to the point of burning. A correctly adjusted belt can be depressed 1/2 to 3/4 inch by the pressure of one finger at a point midway between the motor pulley and the flywheel. You can adjust the belts

by moving the adjustable motor rails or by adjusting the belt-tightening device. When replacement of one belt of a multiple V-belt drive is necessary, a complete new set of matched belts should be installed. Belts stretch considerably during the first few hours of operation. If you were to replace a single belt, the load balance would become upset between the old and new belts causing the load to be unbalanced. Belts, motor pulleys, and flywheels should be kept free of oil and grease and kept dry at all times.

c. Compressor testing and servicing. Common troubles with compressors are: leaks at the suction or discharge valves, leaks at the gaskets, and leaks past the piston and piston rings. These leaks may cause such malfunctions as: (1) A sudden decrease of refrigerating ability, (2) a gradual decrease of refrigerating ability, or (3) an inability to produce or maintain the necessary low-side pressures or vacuums which would cause the compressor to either run continuously or too long during each cycle.

(1) Compressor tests. Before you tear into a compressor you must be sure that the trouble is in the compressor and not in another part of the system. Below are the procedures for testing for compressor leaks at valves, pistons, or gaskets.

Step 1. Connect a compound gage to the suction service valve and a pressure gage to the discharge service valve.

Step 2. (preliminary pump-down). Start the compressor and partly close the suction service valve. This must be done carefully so that the vacuum is reduced to 20 to 25 inches of mercury in not less than 10 minutes. (You will have to constantly adjust the suction service valve and keep your eye on the compound gage and the clock.) By slowly reducing the low-side pressure, you prevent rapid separation of the refrigerant from the crankcase oil and excess oil from getting on the compressor valves which may make them temporarily free of leaks. If you cannot obtain a vacuum of more than 10 or 15 inches of mercury, or if it takes a long time (15 min or longer) to get the vacuum down to 20 or more inches of mercury, indications are that the suction service valve or compressor valves are leaky.

Step 3. Stop the compressor, open the suction service valve all the way, and wait for 0 psig low-side pressure to build up. To speed up the pressure buildup, you can open the cabinet doors or warm the evaporators with warm rags or water.

Step 4. Start the compressor again. Close the suction service valve and wait for a maximum vacuum to build up. As soon as maximum vacuum is obtained, stop the compressor. Maximum vacuum should be reached in 30 seconds or less. This vacuum should remain almost without change for as long as 5 minutes. If the vacuum does not hold, it indicates either leaky valves or leaks past the piston or piston rings. This could also indicate a leaky head gasket.

Note: You should not attempt the test for maintaining a vacuum until after preliminary pump-down (step 2) because so much refrigerant may be released from the crankcase oil that the gage pressure could be raised even with the suction service valve closed.

Step 5. Open the suction service valve. Wait for the vacuum to decrease. Then close the discharge service valve.

Step 6. Using the flywheel, turn the compressor over slowly by hand until the pressure gage reaches 125 to 150 psig. If the pressure rises slowly, or rises and falls, or does not rise high enough, it would indicate that: the discharge valve is leaking, there are leaks past the piston or piston rings, or the head gasket is leaking.

If the pressure drops rapidly after the compressor has been stopped, the same faults listed above are indicated. If there are no leaks, the head pressure will increase to a certain point (between 125 to 150 psig) and remain constant. After observations have been made and you are satisfied as to what is or is not wrong, the high pressure should be relieved.

(2) Servicing. When servicing the compressor, you should remove only the parts necessary to make repairs. Before reassembling the compressor, inspect any other parts which have become accessible. All parts should be carefully cleaned with an approved cleaning fluid and allowed to dry in air. When you disassemble a compressor, be very careful not to scratch or mar gasket sealing surfaces. New gaskets of the correct material and thickness must be installed when you reassemble a compressor. When you are disassembling a compressor, all parts should be clearly marked so that they may be replaced in their original positions. Clean lubricant should be applied to all bearing and rubbing surfaces of parts that are being installed. The compressor crankcase should be drained, cleaned, and filled with fresh oil.

(3) Servicing compressor valves. Once tests have shown a decided possibility of valve trouble, the valve plate will become accessible by removing the cylinder head. Check the sealing surfaces to insure that there are no dirt particles or foreign matter on them that would cause the valves to leak. Also check to see that the sealing surfaces are not scarred or marred as this will also cause leaking. If the valves are defective in any way, it is advisable to replace the entire assembly. Usually, if valve operation is faulty, the valve seats as well as the valves are damaged. Broken valves will usually cause scratches in the valve plate seat. If a broken valve is discovered, every piece must be accounted for. If any piece is left in the compressor, damage to the piston, piston rings, cylinders, or bearings may result. New valves should not be used in old or damaged seats unless seats are put in perfect condition. This is done by lapping which should not be used unless you have the proper tools and are qualified to do the job. A machinist or an experienced automotive mechanic will usually do the job for you. However, in case of emergency you may do it if you have the proper tools and lapping compound of the right grit (lapping compound is found in your expendable supplies toolkit). After lapping, the parts should be washed in an approved cleaning solvent and dried. They then should be coated with oil to protect them against fingerprints and moisture until they are to be put back into the compressor. Once you have the valve plate reassembled and put back into the compressor, all sealing surfaces cleaned, and new gaskets installed, put the head back on. All head bolts should be turned down snugly, but not tightly. Then tighten all head bolts to the proper torque, starting with the center bolt and working outward. Clean the seating surfaces for service valves and install new gaskets. Then bolt both service valves in place.

(4) Servicing the crankshaft seal. As a rule, you will encounter only a couple of troubles with the crankshaft seals: a squeaky noise caused by a dry seal, and a leaky seal caused by a scored seal surface. A noisy seal left uncorrected will soon become leaky. Air that enters a system because of a leaky seal is indicated by high condensing pressures. Testing with a halide torch for shaft seal leaks can often be misleading because the normally small amount of oil that leaks through the seal will have traces of refrigerant in it and the halide torch will pick them up. The best method for testing for shaft seal leaks is to use a soap solution. To use this method, you first must raise the low-side pressure, then apply the soap solution as you would when testing for refrigerant leaks. These seals should be capable of holding the highest vacuum possible (approximately 30 inches of mercury) for many hours. If a shaft seal is found to be defective it should be replaced. The tolerances and surface finish of these seals are very critical. To remove the seal, the compressor is pumped down and the low-side pressure balanced. The drive belts are removed and then the flywheel is removed. If the seal cover does not extend below the oil level in the crankcase, you can remove the seal without draining the oil; if it does, you must drain the crankcase. The seal parts are taken out next (you must mark seal parts so that they can be correctly replaced). Frequently, seal parts are attached to a flange that must be carefully pried out.

Note: If you have a bad leak and suspect the seal is broken, do not pump down the compressor because air and moisture will be drawn into the system. In this case, close the service valves, relieve the internal pressure, drain the oil, and leave the drain open. Then proceed as before. All parts are cleaned and the sealing surfaces lapped to each other. Some seals use a molded synthetic rubber gasket instead of metal-to-metal contact. When a new seal is installed, all parts are coated with clean oil and special care is exercised in alining and replacing the unit. If the seal is to function efficiently, a critical spring tension must be maintained on the sealing surfaces. Always consult your TM's and manufacturer's instructions before you start to repair a compressor.

(5) Servicing other compressor components. Pistons, pins, rods, bearings, crankshafts, cylinders, block, etc. in compressors will seldom become damaged or give you trouble unless they are abused. A refrigerating compressor is seldom subject to a wide variation of loads and pressures. It is used to pump clean, cool refrigerant gas at a constant head pressure. Therefore, the component parts of a refrigerating compressor will usually give long and trouble-free service. Any work that must be done on component parts (other than valves and shaft seals) is done by methods similar to those used in working on an automotive engine. If you have to work on a compressor, remember to keep all parts perfectly clean and free from moisture. Also, carefully mark all parts so that they can be properly reassembled. After repairs are complete, the compressor should be tested. Air must be purged from the compressor and oil replaced in the crankcase. Run the compressor for about an hour to make sure that pistons and bearings are free. You ca test the compressor for leaks by using a couple of spare service valves. Admit compressed air (about 40 psi) through the valve ports with the valves closed. Air admitted through the discharge valve will l ak past defective discharge valves. Air admitted through the suction valve will leak through a bad shaft seal. A soap solution should be used when you perform these tests.

d. Hermetic compressor test and replacement. Although a hermetic compressor is relatively trouble free, there will be (on when testing and possible replacement will be ecessary. Pistons will hang up or become frozen, valves will crack or break, and internal motor circuits will develop sho' or opens. Because these internal problems will necessitate the replacement of the unit, it is i perative that you are sure that the problems are internal and are not caused by external failur s such as problems with the control circuits, switches, and external wiring.

(1) Compr ssor-motor test. A rather simple test hookup that can be put together in your shop and used to check a compressor motor (capacitor start/induction run or capacitor start/capacitor run) is shown in figure 3-21. It consists of a starting capacitc a running capacitor and a simple switch. To use this test hookup, you must first remove all wires from the compressor terminals. (Be sure that you tag each wire to insure that they can be correctly reconnected.) Then connect the hookup to the starting, running, and common terminals as shown in the figure. Now pl the test circuit into the power supply and immediately close the switch for 1 to 2 seconds (holding the switch closed for a long period of time may result in the starting winding being burned out) then open the switch. The compressor motor should continue to run if it is not defective. If the compressor motor does not run then the compressor unit must be replaced.

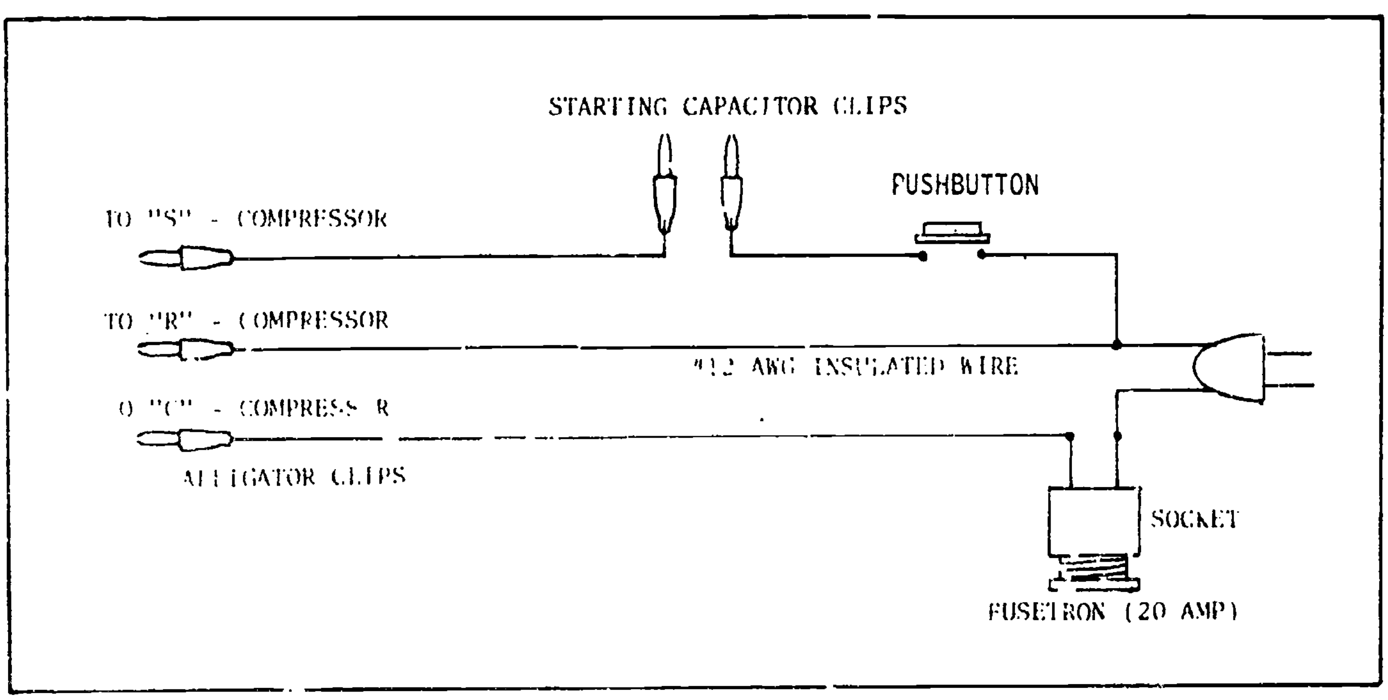


Fig 3-21. Hermetic motor running test.

(2) Symptoms of defective valves. If the compressor valves of a hermetic compressor are broken or cracked, little or no cooling will occur in the evaporator and little or no heating of the condenser. Once the unit is started the wattage will drop to an abnormally low reading. The pump will need no balance time after it is stopped. Little or no capillary feed noise will be heard.

(3) Symptoms of an overcharge of oil. Noticeable signs of an oil overcharge are: excessive compressor noise and vibration, low capacity, and continuous nigh wattage. To remedy this situation, the compressor will have to be changed.

(4) Replacing hermetic compressor. Defective hermetic units should be replaced with new or factory rebuilt ones. When replacing hermetic units, it should be remembered that electric wiring, thermostatic switches, relays, and motor starter are not considered parts of the sealed unit and therefore must be removed from the old unit and remounted on the new one. Because a sealed compressor operates at higher speeds than an open type, the valves, pistons, and valve orifices are much smaller than in an open type. Consequently, great care must be exercised when installing a sealed unit to insure that any foreign matter is kept from entering the sealed unit when it is open during installation. The following procedure is used tc remove and replace a sealed unit.

(a) Using a pair of side-cutting pliers, cut the discharge line in two, allowing the unit charge to escape into the air. A cloth should be placed over this cut section to prevent the possibility of oil being blown around.

Note: If the escaping refrigerant has a burned odor, it indicates a shorted stator and the condenser and evaporator should also be replaced.

(b) While the gas is escaping, remove the compressor terminal cover and the relay bracket mounting screws.

(c) Remove the electrical leads from the compressor terminals (if not previously removed during diagnosis). Lift away this electrical assembly. Tag the electrical leads for reference when reconnecting them.

(d) Remove the compressor holddown bolts.

(e) Cut the suction line near the compressor with your side-cutting pliers. Again, place a rag over the cut to catch any oil that may escape.

(f) Lift the old unit off the base. Pinch the discharge and suction tube several times with your side-cutters and then bend the tube ends over. This will prevent any oil loss and keep foreign matter out of the compressor.

(g) Check the tubing on the new compressor and on the unit to determine where it should be cut. Then with a tubing cutter, cut all tube ends. Leave about two inches of straight tubing so that fittings can be installed.

(h) Transfer the rubber mount grommets or vibration isolators from the old compressor to the new one and lift the new compressor into place on the unit's base.

Note: If rubber grommets or vibration isolators are defective in any way they must be replaced.

(i) Assemble the proper fittings on the tube ends.

(j) Install a tee assembly in the suction line. Insure that the leg of the tee is pointing in such a direction that a flare nut can be connected later for recharging.

(k) Install a tee assembly in the discharge line. Insure that the cap seal and bonnet are tight

(l) Reassemble the electrical connections and the compressor mounting washers and nuts.

(m) After insuring that all connections are properly made and are tight, check the unit for leaks.

e. Condenser repair and service. In an air-conditioning system, the job of a condenser is to remove the heat that is absorbed by the refrigerant. The refrigerant absorbs heat from the evaporator and absorbs more heat that is caused by friction in the suction line and the compressor. The condenser must be able to efficiently and continually remove all this heat. In order for the condenser to perform properly, it must be kept clean both inside and out, and repairs made when necessary. There are two general types of condensers: air-cooled and water-cooled.

(1) Cleaning and repairing air-cooled condensers. Dirt and dust either in or passing through an air-cooled condenser will stick to the outside surfaces. The accumulation of this dirt and dust cuts down the condenser's efficiency by reducing the rate of heat transfer. This, in turn, allows temperatures within the condenser to become too high, causing the oil to carbonize. This carbonized oil sticks to the internal surface of the condenser and causes a further reduction in efficiency. If a condenser is very dirty on the outside, it will be almost as bad on the inside. To return a condenser to its proper efficiency, it must be cleaned both inside and out. Dirty outside surfaces may be cleaned with ordinary brushes and mild soap solutions. However, in such places as bakery shops and meat processing rooms, particles of grease, sugar, and flour along with dirt and dust will build up on the condenser. An alkaline solution will have to be used to dissolve and remove these deposits. (A good remover may be made by mixing 1/2 lb of trisodium phosphate in 1 gallon of water.) If the condenser has carbon deposits on the inside, you should replace the condenser and possibly the metering device.

(a) Leaks. When a condenser develops a leak it is usually better to replace it rather than to repair it. Soldering a leak in a condenser will usually cause another leak because of the expanding and contracting of the metals due to heating and cooling. However, if you do decide to attempt repair, you must remove the condenser from the system. You will have to pump down the unit and drain the refrigerant.

(b) Brackets, holders, hangers, and frames. These items should be permanently soldered, friction-fitted, or bolted in place. Loose frames or brackets could rub holes in a condenser. If the condenser is allowed to vibrate, the vibration could cause discharge lines to break. Always check these items and insure that they are properly and securely in place.

(c) Discharge lines. Discharge lines must be large enough to carry the heat-laden gases from the head of the compressor to the condenser. They must be arranged so that any liquid that might condense in them cannot flow back into the compressor head. To do this, form the tubing into a U-shape right after it leaves the compressor with the bottom of the U extending below the level of the compressor head. Because the hottest gas in a refrigeration system is carried in the discharge line, these lines are subject to greater carbonization than the condenser. Also the gas is at its highest velocity in the discharge line. This high velocity tends to wear out the tubing. It is good practice to replace the discharge line whenever you overhaul the condenser.

(d) Condenser-to-receiver line. This line carries liquid refrigerant under high pressure from the condenser to the receiver. Since this line carries the same amount of liquid as the liquid line, it should be the same size. Only in extreme cases will the receiver line become coated with carbon deposits. This line still should be cleaned out whenever you clean the condenser. If you have any doubt as to its capacity or structural strength, you can replace it easily when the condenser is being overhauled.

(2) Servicing and repairing water-cooled condensers. Water-cooled condensers consist of the shell-tube, the double-pipe, and the spiral types. These condensers can be made of iron pipe, steel pipe, or copper tubing. There are two methods of cleaning shell-and-tube-type and double-pipe-type condensers. The best way is with special brushes and rods (similar to ones you use for cleaning your rifle, only larger) provided by the manufacturer. These brushes are graduated in size. You should start with the smaller sizes and work up until you reach the size of the inside diameter of the pipe or tube that you are cleaning. You should not use excessive force to push the brush through the pipe or tube. The easiest way is to put the brush and rod into a large, low speed drill and let it go slowly through the pipe or tubing. If you force the brushes you may scar or seriously weaken the walls of the pipe or tube. The other method of cleaning is with a strong

caustic soda or a mild muriatic solution. However, when you use this method, you must run tests of the solution to be used on another tube of the same material to insure that the solution is not too strong. If the solution is too strong, it will attack and weaken the material used in the construction of the condenser. Just about the only way to clean the spiral-type condensers is with caustic soda or muriatic acid solutions. If the tubes of these condensers become weak or develop leaks, it is best to replace them or, in the case of a double-pipe type, the entire condenser. Sometimes it is possible to blow out condenser tubes that have scale deposit built up around connections and fittings. Compressed air or carbon dioxide of less than 100 psi can be used to do this. Probably the biggest problem you will have with water-cooled condensers is with the water system controls. The most common trouble is incorrect water flow. This can be caused by faulty water valves, clogged screens, improper adjustment, broken components, leakage, or stoppages. If you have problems with the water valve you can either replace it, fix it, or adjust it. Water system controls can usually be removed from the system without pumping down the system. However, to clean or replace condensers and condenser tubes, the condenser will have to be pumped down and opened.

f. Evaporator servicing and repair. The evaporator itself very seldom causes any trouble. Problems with the evaporator can usually be corrected by adjusting, repairing, or replacing system components and controls that directly affect the refrigerant's action in the evaporator or those that keep the evaporator free from excessive frost buildup. Those components and controls are the metering device, defrost controls, and fans or blowers (if it is a forced convection-type evaporator). Problems with the evaporator itself are usually caused by leaks due to corrosion or a puncture because of abuse. If an evaporator becomes corroded, it is best to replace it. If a leak develops through abuse, it can be soldered in all cases except when the evaporator is made of aluminum. If an evaporator is made of aluminum it can be repaired by using epoxy cement (follow directions for individual brand used). If problems with evaporators do not result from leaks or corrosion and do not result from inoperative system components and controls, then it is stopped up from oil carbonization and should be replaced.

g. Service and adjustment of automatic controls. Exact procedures in adjusting the various automatic controls used in different systems will va: , with each switch design. All we can do here is give you some general rules for adjusting and servicing typical controls. (Always consult TM's for the particular system before attempting service or adjustment.) Cycling or motor control switches start the compressor when temperature and low-side pressure rise to a predetermined level and stop the compressor when temperature and pressure fall to another level that is determined by a range setting. It is a general rule that operating pressures or temperatures are lowered by decreasing the spring tension of a control unit and raised by increasing the spring tension. Some cycling control devices are provided with a differential adjustment that is used to set the difference between the cut-in and cutout points.

(1) Typical pressure-type control adjustment. The range and differential of a low-side pressure control may be adjusted as follows:

(a) Attach a compound gage to the suction service valve.

(b) Set the range adjustment for the lowest pressure and the differential adjustment for the largest difference.

(c) Start the compressor and operate it until the compound gage shows the desired pressure or vacuum for cut-in or starting the compressor in normal operation.

(d) Change the range adjustment until the control cuts out the compressor.

(e) Move the range adjustment slowly in the opposite direction until the control cuts in the compressor. This sets the cut-in point.

(f) Let the compressor run until the gage shows the pressure at which cutout is desired.

(g) Adjust the differential slowly until the control cuts out. This sets the cutout point.

(h) Let the system operate normally through at least one complete cycle, and on the next cycle note the gage readings at which cutout and cut-in occur. It is possible that slight adjustments will have to be made.

(2) Temperature control adjustment. The procedure used to adjust a temperature or thermostatic type of cycling control is very similar to that used to adjust a pressure control. However, instead of using a compound gage, you would use a thermometer at the place where the temperature control sensing bulb is located. Remember that a temperature control should always start the compressor when the sensing bulb is warmed by hand. If it doesn't, the bulb and bellows have lost their charge. Before attempting any repairs or adjustments of a temperature-type cycling control, make sure that the sensing bulb is properly mounted. Normally, with this type of control, the range is adjusted before the differential is changed. Only in unusual cases will the differential have to be changed on domestic units; however, on larger commercial units, the differential will sometimes have to be changed to accommodate different types of service. You should also remember that when you adjust this type of control, range adjustment will affect the differential and vice versa. Once you have completed adjustments, and have observed temperatures and pressures and found them to be right, check that all locking nuts or screws are tight.

(3) Control switches. Since the exact methods, pressures, and temperatures used in setting automatic control devices differ depending on the characteristics and type of service of an individual system, only some general examples can be given here. Consult TM's and manufacturer's directions for detailed operation and repair of individual system controls.

(a) High-pressure cutout switches. This type of switch is usually installed as a safety device. The cutout is determined by the manufacturer and is stated in the operating instructions. These switches will cut out at a certain pressure (when the normal operating pressure is exceeded); when the pressure drops, they cut in automatically, but are equipped with a reset button that must be pushed manually. Sometimes this type of switch is mounted in the same housing as the suction-pressure control switch.

(b) Suction-pressure control switches. These switches stop and start the compressor according to the demand for refrigerant in the evaporator coil. The suction-pressure control should be set at a suction pressure that corresponds to a temperature that is a few degrees lower than the temperature to be maintained in the evaporator.

Example: If the evaporator was to maintain a temperature of 34° F and the refrigerant is F-12, the suction-pressure control should be set between 31.7 and 26.8 psig. (The pressure is found by consulting your refrigerant charts.)

(c) Thermostatic switches. Thermostatic switches control solenoid valves that feed the liquid refrigerant to the evaporator. These controls open the solenoids at a predetermined temperature and close them at a lower predetermined temperature. It is a good practice to set the cut-in point 2 Fahrenheit degrees higher than what is required.

SUMMARY

In this chapter you have learned the proper procedures for installing an air-conditioning system. You learned that before doing anything you must first visually inspect the unit for any apparent damage or malfunction. Then you must insure that the unit is properly leveled, that the unit has sufficient air circulation to enable it to function at its proper capacity, that all electrical connections are properly made, and that the refrigerant is released before the unit is ever started. Then, once the unit is installed and operating, you have seen what should be done in the way of preventive maintenance to keep the unit operating efficiently. Filters and condenser fins must be kept clean, periodic lubrication must be accomplished on schedule, and the evaporator must be kept free of dirt and any excessive frost buildup.

We have also covered the various methods of testing an air-conditioning system. When testing for leaks it is possible to use one of several methods or a combination of methods. In review, the methods are: pressure and vacuum test, soap or oil bubble test, and the halide torch. You must remember that the pressure and vacuum tests are nonpositive tests and will indicate a leak but not where the leak is; whereas the halide torch, soap, and oil bubble test will positively identify the exact location of a leak. We also covered the various electrical instruments used to test units and the proper methods of connecting the instruments to the circuits and what would be indicated by readings obtained from these instruments.

Also covered in this chapter were the installation and use of the bar gage manifold. We have shown how they are used when performing tests, evacuation, pump-down, charging, and removing or adding refrigeration oils.

We also covered the methods of making a joint and stressed the importance of making it properly. An improperly made joint in an air-conditioning system will seriously affect the proper operation of that system.

Troubleshooting was covered to enable you to properly identify problems that commonly occur in most air-conditioning systems, and to identify the proper remedies for these problems. Troubleshooting is most important, for without proper diagnosis it is unlikely that the proper repairs can be made.

Repair and replacement of the major components of an air-conditioning system were also covered. We have discussed the proper methods of repairing or replacing all the components of a system, from the compressor, condenser, and evaporator right through the service, adjustment, or replacement of any of a system's automatic controls.

It is important to remember that whenever you, as a mechanic, are working on any system or unit, you should consult the proper TM or manufacturer's repair manual for that particular unit or system. Also when servicing a unit or system, take into consideration the job that must be accomplished by that system or unit. Insure that it is capable of the designated job before attempting repairs that may not help the unit or system to accomplish that job.

Chapter 4

COMMERCIAL AND TACTICAL AIR-CONDITIONING UNITS

Section I. COMMERCIAL UNITS

4-1. WINDOW OR THROUGH-THE-WALL UNITS

a. Description. These units mount in a window and are relatively easy to install. They will fit into either double-hung or casement windows or they can be installed in a hole cut in the wall of the building. They usually operate with two separate airflows and the refrigerant is controlled by either a capillary tube or a bypass-type, automatic-expansion valve. The control switches are usually an integral part of the unit and are mounted on either the top, face, or sides of the unit. Window units are air-cooled and operate on 120-v or 220-v single-phase circuits. They will vary in capacity from 4,000 to 40,000 Btu's per hour.

b. Installation. When a unit is installed in a window, metal plates, gaskets, sealing compound, weather stripping, brackets, and braces will be necessary for proper installation. The first step is to remove the unit from its housing or cabinet. It will slide out easily. Be careful when handling the unit and do not lift or carry it by any of its components other than the base. Do not use tubing or coils as a handhold. Next, place the housing in the window opening and secure it in place. Be sure that all braces and brackets are securely fastened. Next, the filler board or metal plates must be put in position. Make sure the filler boards do not extend above the top of the cabinet, but are level with it so that the window will close flush on the cabinet and filler boards. Check and make sure that the cabinet tilts approximately 1/4" to the rear so that the unit will drain properly. Make any adjustments before the unit is placed in the cabinet. Once the cabinet is securely in place, close the window flush with the top of the cabinet and make any further necessary adjustment. Slide the unit into the cabinet and install control knobs and front cover. The unit should slide into the cabinet freely. If it doesn't, do not force it, because the cabinet has not been installed properly and it is not placed squarely in the window. Use a level to square up the cabinet installation. Once the entire unit is in the window, check for any air gaps around the installation. They must be sealed with caulking or sealing compound. If the unit is installed in a double-hung window, there will be an air gap between the upper and lower sash. This space should be filled with a sponge-rubber strip. When installing a unit in a casement window, you use basically the same procedure. However, the glass will have to be removed from the window and the braces and fillers will have to be installed a little differently. Window units should be hooked up electrically on a separate circuit, if possible. Once the unit is in the window and plugged in, it is ready for operation. Figure 4-1 shows a unit installed in a double-hung window; figure 4-2 shows a unit installed in a casement window. Each manufacturer includes instructions for installing his particular units. Follow these instructions carefully as each manufacturer has different procedures for installation, although the basic principles are the same.

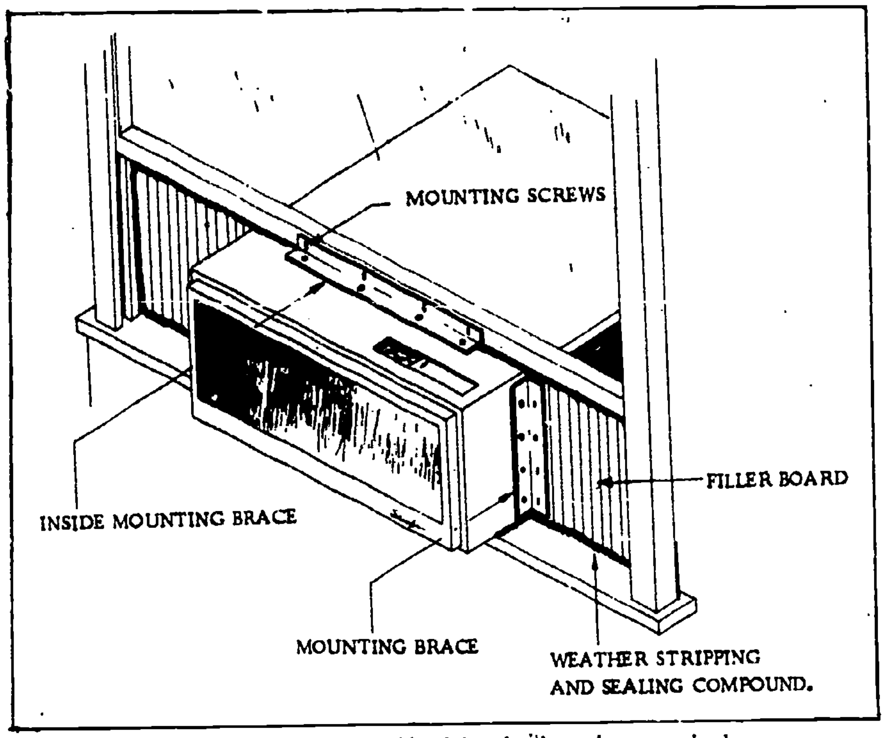


Fig 4-1. Unit installed in double-hung window.

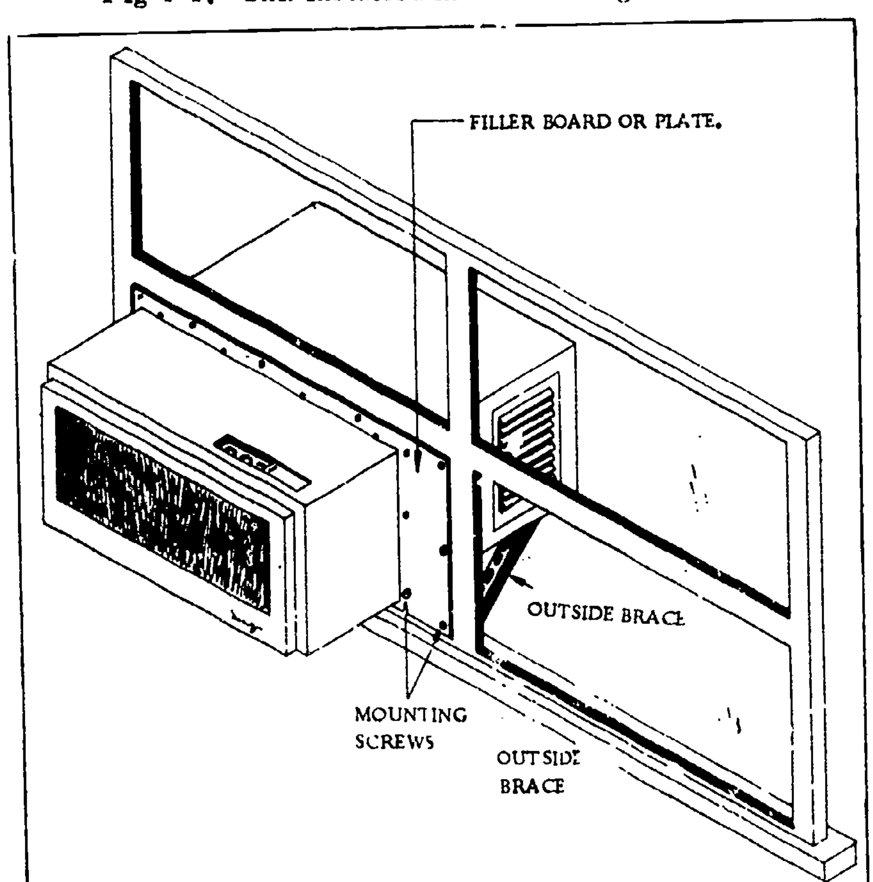


Fig 4-2. Air conditioner installed in a casement window.

c. Operation. A window unit contains the basic refrigeration components, such as condenser, evaporator, compressor, refrigerant metering device, liquid receiver, and fan. The condenser is air-cooled, and the air is forced over it by a fan. The air is circulated within the room by another fan that blows the air over the evaporator coils and into the room. Moisture that will condense on the evaporator coils from the humid air that is circulated over the evaporator coils, will be collected at the base of the unit and drain toward the back. The condenser fan will pick up some of this moisture and use it in light spray or mist to help cool the condenser coils. The remaining moisture will drain out the rear of the unit. Window units use two separate airflows. The air to cool the condenser is pulled in through the sides of the unit and is blown over the condenser to dissipate the heat. Room r is pulled in over the evaporator coils, cooled, and blown back into the room. Figure 4-3 is a schematic of these two separate airflows.

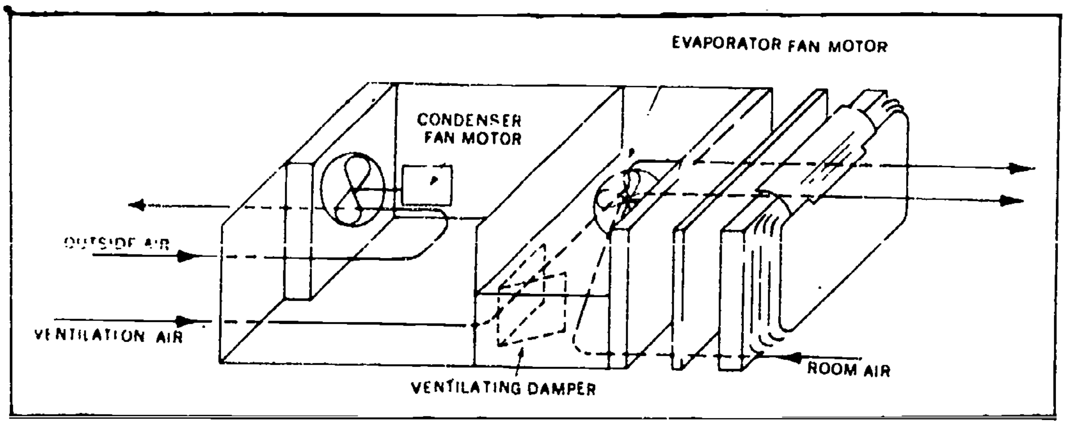


Fig 4-3. Schematic of condenser and conditioned airf'ow.

d. Maintenance. Refrigerating components of a window unit are serviced and maintained as previously discussed in chapter 3. Filters should be checked on a monthly basis and should be cleaned or replaced, depending on the type of filter, as necessary. Evaporator coil, condenser coil, fan blades and motors, and the cabinet should be cleaned and serviced just prior to putting a unit into service for the season and just after removing it for the winter months. All motor bearings should be lubricated at these times unless they are the permanently sealed type. Electrical wiring should be checked over and repaired if necessary prior to placing a unit into operation. Any troubles with the wiring system can be checked out as discussed in chapter 3. Fan motors are usually 2- or 3-speed and wiring diagrams should be consulted whenever you are checking the circuits. Whenever you are servicing a window unit, have the manufacturer's operating and servicing instructions handy.

4-2. CONSOLE UNITS

a. Description. A console-type air-conditioning unit is a complete system mounted in a single cabinet. These systems are usually water-cooled and vary in size from 2 to 10 hp. Console units can be found in small clubs, PX's, messl..lls, restaurants, etc. If a console unit is air-cooled, it will need ducts to the outside, both for bringing in air for condenser cooling and discharging the heat-laden air back outside again. Console units are usually constructed with the condensing unit in the lower section, the blower in the middle section, and the evaporator in the top section. Air enters a console through the lower grille : id cool a'r is discharged through the upper grilles. Ducts can be attached to sections of the air di..charge grilles to distribute air to areas that are partitioned off from the rest of the air-conditioned space. Console units are equipped with filters at the air intake. Some of these units also contain filters at the air discharge.

b. Installation. Because console units are assembled at the factory, installation is limited to physically moving the unit into place and making any necessary external connections, such as plumbing, electrical, and duct work. Once the unit is in place it should be leveled. Any necessary duct work should be installed according to the volume of air needed and the manufacturer's instructions. All refrigerant components and controls should be checked prior to putting the unit into operation. A console unit must be hooked up on a circuit of its own and should have a quick-disconnect switch mounted close by.

c. Maintenance. Filters in a console unit must be checked monthly and cleaned or replaced as required. The evaporator coil, fins, and the fan motor should be cleaned periodically. If the fan motor is not constructed with permanently sealed bearings, it should be lubricated in accordance with manufacturer's instructions. If the unit is water-cooled, the drain pan and drain tube should be cleaned at least every 2 months. Sometimes lint and dust will build up on the inner lining of a console unit. The lint should be removed either with a vacuum cleaner or by brushing it away. Maintenance of the refrigerant components and the water system is accomplished in accordance with the methods outlined in chapter 3.

4-3. REMOTE UNITS

Remote air-conditioning units have the refrigerating equipment located away from the space that is to be air conditioned. These units range in capacity from 2 tons to thousands of tons. Some of these units condition the air then distribute it to the conditioned spaces through a duct system. Other systems use chilled water to condition the spaces. In chilled water systems the water is chilled and then circulated to wall or baseboard coolers within the areas to be cooled. Most remote units are complete comfort units and provide cooling in the summer and heating in the winter. The chilled water systems usually use an absorption system to provide refrigeration, whereas most of the chilled air systems use a mechanical refrigeration system. The newer chilled water systems use water as the refrigerant and lithium bromide (salt solution) as the absorber. The older units use the ammonia and water systems. Systems using water and lithium bromide are large industrial units running into hundreds of tons' capacity and presenting special installation and maintenance problems. These systems are built to fit a particular set of cooling circumstances and will often completely baffle experienced personnel when it comes to servicing or repairing one of them unless they are familiar with the particular installation. Because of this and the fact that you, as a refrigeration mechanic in the Corps, will probably never be called upon to service or repair a remote unit of this type, the installation and maintenance will not be covered.

4-4. TROUBLESHOOTING

Troubleshooting commercial units is accomplished in the same manner as discussed in chapter 3. The charts in chapter 3 cover most problems that you might encounter with any commercial type air conditioner that you may encounter in the Corps. Always remember to consult the manufacturer's instructions when troubleshooting. If they are not available, check with someone who has worked on that particular unit. Remember that each unit is used for a specific purpose and a specific set of cooling circumstances.

Section II. TACTICAL UNITS, MARINE CORPS MILITARY STANDARD AIR CONDITIONERS

4-5. GENERAL DESCRIPTION

The Marine Corps military standard air conditioners consist of self-contained vertical and horizontal units. They are normally rated from 7, 000 to 54, 000 Btu. Various models are designed to operate on 115-, 208-, or 230-volt, 60-Hertz or 400-Hertz power sources. When installed within an area to be conditioned, one of these units will provide for cooling or heating the air to maintain temperatures within a desired, predetermined range for both equipment and personnel. These units are factory tested and shipped completely assembled and charged with refrigerant. They are manufactured by either Trane Co., American Air Filter Co., or Keco Co. and are used as a principal means to control the environment of an area. Each of these units contains three systems: a refrigeration system, an air-handling system, and an electrical system. We will discuss the vertical units first. Horizontal type units will be discussed starting in paragraph 4-10.

a. Refrigeration system. The refrigeration system includes a hermetically sealed motor compressor, condenser, evaporator, thermal expansion valves, solenoid valve, filter-drier, charging valves, regulating valve, pressure relief valve, and a high-pressure cutout control. Fig 4-4 shows the refrigeration schematic for the A/E 32C-17 air conditioner. This refrigeration schematic is the same in each Trane military air conditioner.

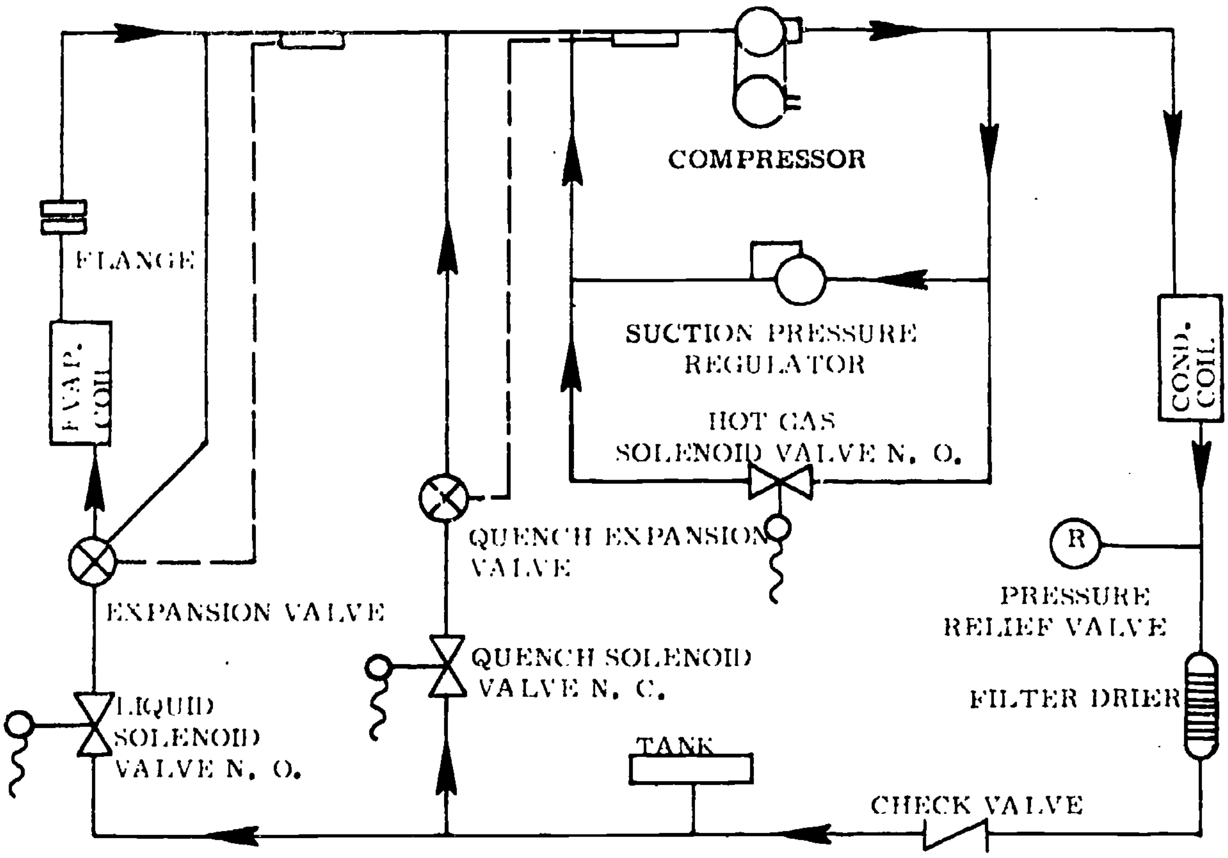


Fig 4-4. Refrigeration schematic A/E 32C-17.

b. Air-handling system. The air-handling system includes a return-air register; supply-air register; evaporator fan; condenser fan; evaporator and condenser fan motors; mist eliminator; fresh air duct; nuclear, biological, chemical(NBC) duct; and a fresh air damper.

c. Electrical system. The electrical system consists of main powerline voltage to the fan motors, compressor, and strip heaters through relays or contactors. Control voltage is routed through a 187-v d.c. rectifier to fuses, solenoids, outside thermostat, conditioned space thermostat, circuit breakers, and heater thermostat. All internal wiring is completed at the factory. Refer to foldout figure 4-32 at end of chapter for wiring diagram of A/E 32C-17&18.

d. Model differences. The following figures and tables explain the design differences in the models. The units may have been made by o⁻ of three companies: Trane, Air Filter, or Keco. The major assemblies may have some minor differences but the description will remain the same. The performance characteristics and specifications will be the same no matter what company makes the unit. Table 4-1 gives you the operation and technical characteristics of the units. Tables 4-2, 4-3, 4-4, and 4-5 describe the major assemblies of the units. Figures 4-5, 4-6, and 4-7 show the various units. The major difference in the units is as follows: A/E-32C-117, A/E32C-24, A/E32C-26, A/E32C-29, and A/E32C-39 ~ perate on 60 Hz current and the A/E32C-18, A/E32C-25, and A/E32C-27 operate on 400 Hz current. Figure 4-8 shows a line drawing of the A/E32C-29 air-conditioning unit with its dimensions. Figure 4-9 shows a line drawing, with dimensions, of the A/E32C-39. The major difference with this model is that it was designed so that the components are protected in a ruggedized frame and cabinet to allow shipping without crating.

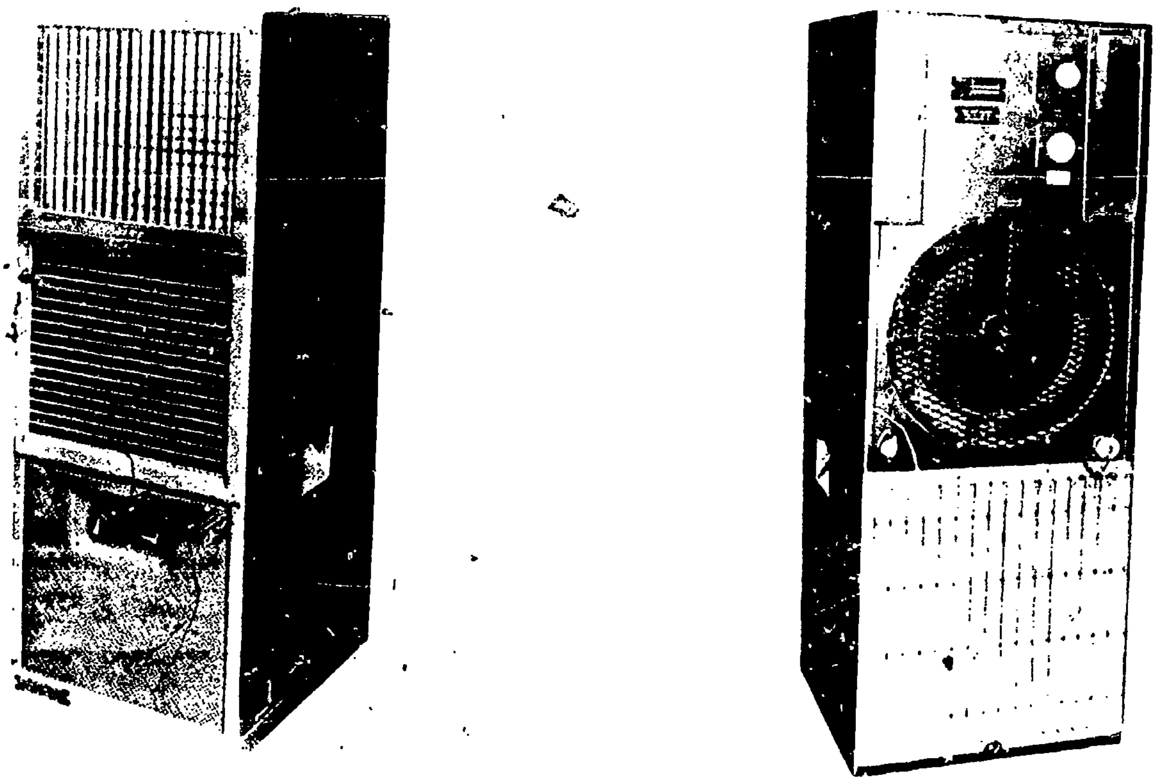


Fig 4-5. A/E 32C-17 and A/E 32C-18 air-conditioning unit.

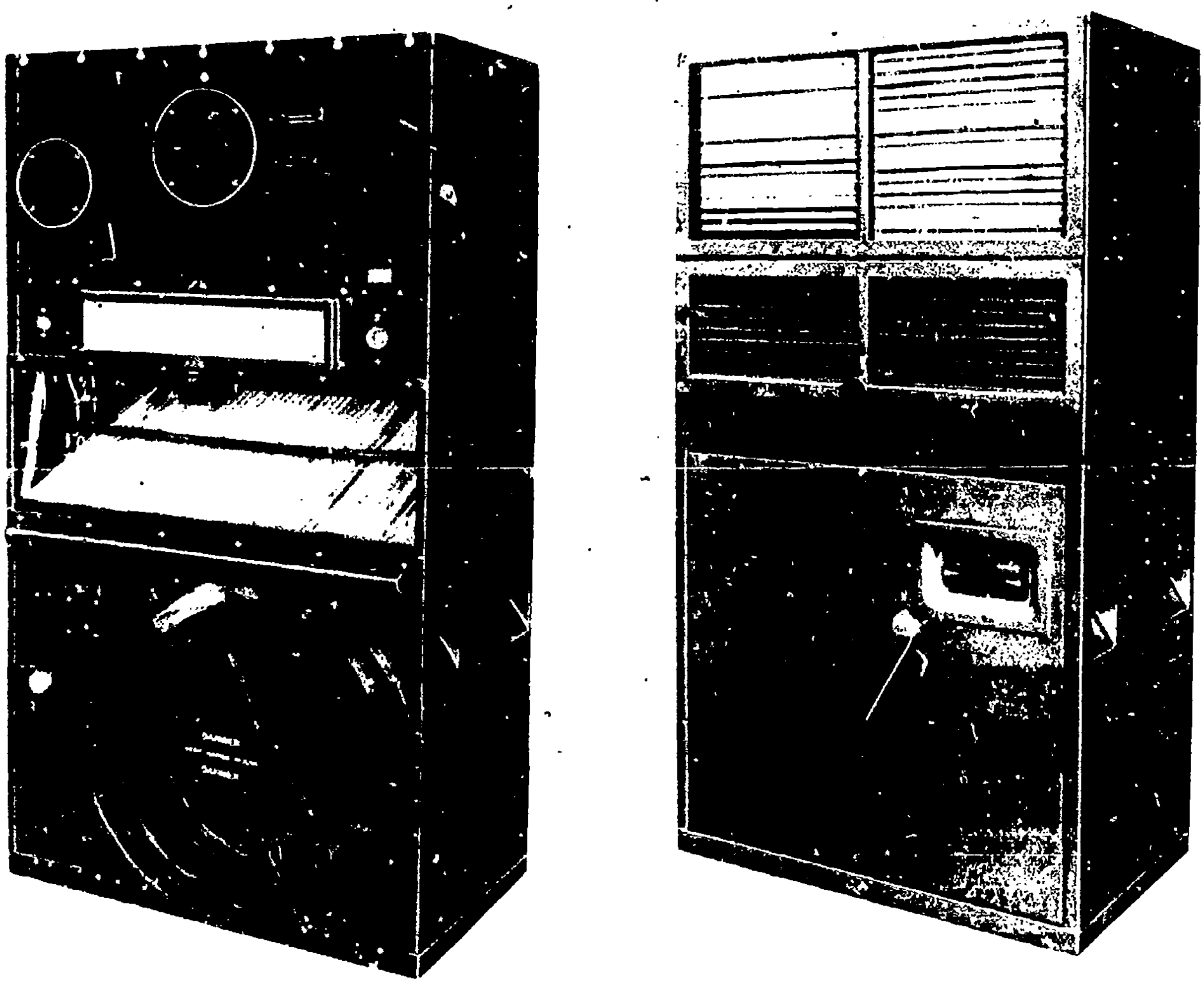


Fig 4-6. A/E 32C-24 and A/E 32C-25 air-conditioning unit.

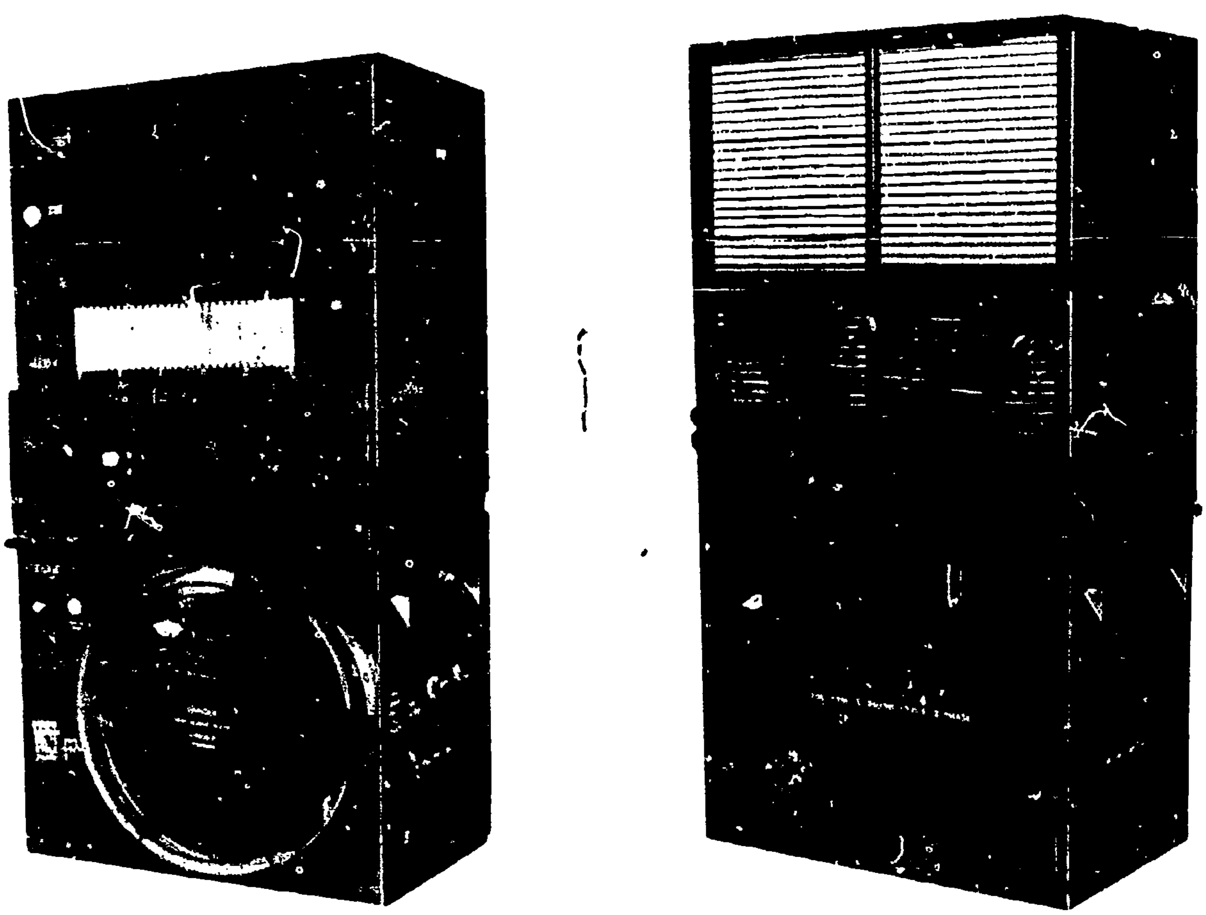


Fig 4-7. A/E 32C-26 and A/E 32C-27 air-conditioning unit.

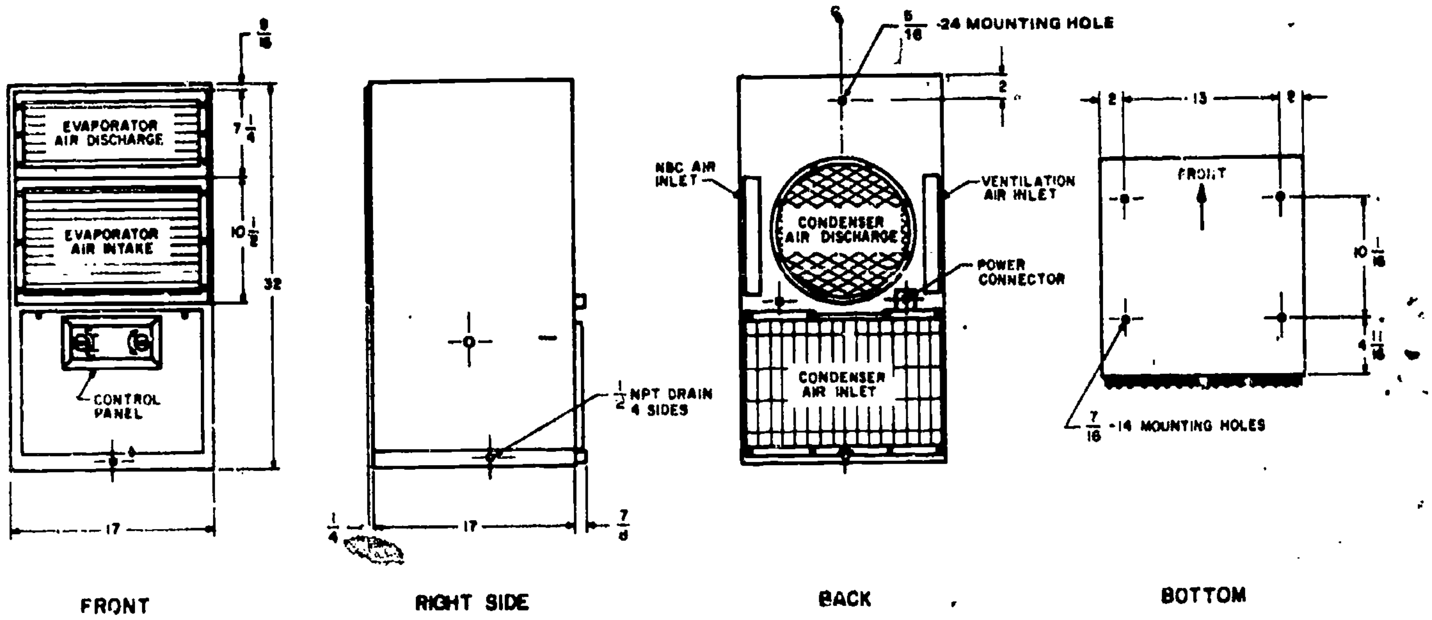


Fig 4-8. A/E 32C-29 air-conditioning unit.

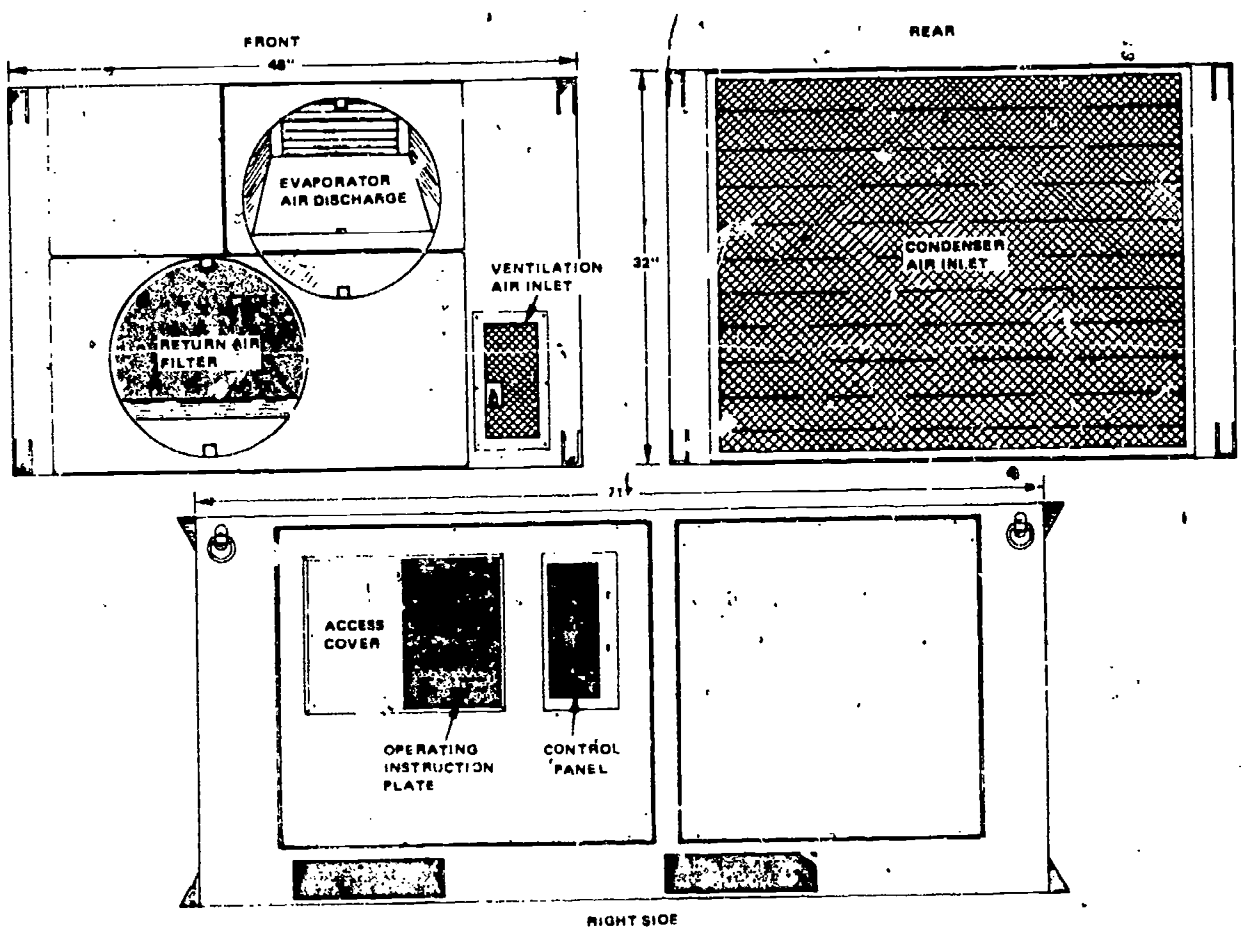


Fig 4-9. A/E 32C-39 air-conditioning unit.

Table 4-1. Operational And Technical Characteristics

Model	Btu/Hr		Electrical Characteristics				Airflow			Physical Data	
	Cool[1]	Heat[1]	v	Hz	ph	kw[2]	Ducts	cfm @ 0"H_2O	Wt (lb)	Dimensions[4] W x D x H	Cube[5]
A/E 32C-17	18,000	12,300	208	60	3	6.0	8"	655	260	17-1/16 x 19-1/16 x 45-1/2	8.56
A/E 32C-18	18,000	12,300	208	400	3	7.1	8"	670	230	17-1/16 x 19-1/16 x 45-1/2	8.56
A/E 32C-24	36,000	28,600	208	60	3	10.3	12"	1290	445	30-1/16 x 18-1/16 x 55-3/32	17.31
A/E 32C-25	36,000	28,600	208	400	3	12.4	12"	1375	435	30-1/16 x 18-1/16 x 55-3/32	17.31
A/E 32C-26	54,000	47,100	208	60	3	16.3	16"	2010	580	34-1/16 x 20-1/16 x 65-1/8	25.76
A/E 32C-27	54,000	47,000	208	400	3	20.0	16"	2100	570	34-1/16 x 20-1/16 x 65-1/8	25.76
A/E 32C-29	9,000	6,100	115	60	1	3.25	8"	315	175	17-1/16 x 17-1/16 x 32-3/32	5.41
A/E 32C-30	54,000	32,500	208	60	3	10.0	16"	2200	885	48 x 71 x 32	63.00
MC9HAL6-208	9,000	7,000	208	60	3	3.0	None	370	200	23-7/8 x 26-1/2 x 16-1/8	5.90
MC18HAL6-208	18,000	14,300	208	60	3	6.5	None	640[3]	265	30 x 28 x 20	9.72

Notes:
1. Nominal capacities per verified test results
2. Maximum capacities
3. CFM @ 0.25" H_2O
4. Width, depth, height dimensions in inches
5. Cubic feet

Table 4-2. Major Assemblies, A/E 32C-17 And A/E 32C-18

Item	Description	Manufacturer	No. Req.
Evaporator Condenser	Direct motor drive (fans mounted on opposite ends of double extended shaft); power input-208 volts, 60 Hertz or 400 Hertz, 3 phase; built-in thermal overload and over-current protector. 1.42 hp for 60-Hertz motor, 1.62 hp for 400-Hertz motor.	Welco	1
Compressor	Hermetically sealed rotary type.	Whirlpool	1
Condenser Fan	Cast aluminum propeller type; counter-clockwise rotation, facing room air inlet.	Trane	1
Evaporator Fan	Centrifugal type with airfoil blade. (BI-single width), counterclockwise rotation, facing room air inlet.	Trane	1
Condenser Coil	Finned tube	Trane	1
Liqui Line Expa ion Valve	Pilot-operated expansion valve	Alco	1
Evaporator Coil	Finned tube	Trane	1
Liquid Line Solenoid Valve	Pilot-operated solenoid valve	Asco	1
Liquid Bypass Solenoid Valve	Direct-acting solenoid valve	Asco	1
Hot Gas Bypass Solenoid Valve	Direct-acting solenoid valve	Asco	1
System Access Valves	Packless charging valves	Hoke	2
Filter-Drier	Desiccant Drier	Sporlan	1
Electric Heaters	Stainless steel sheath; 120 volts, 60 watts each.	Indeeco	6

Table 4-2. Major Assemblies, A/E 32C-17 And A/E 32C-18--contd

Item	Description	Manufacturer	No. Req.
High-Limit Thermostat	Open 194°F (90°C), closed 140°F (60°C)	Klixon	1
Control Switch	Manual, 5-position, rotary selector switch	Cutler-Hammer	1
Conditioned Air Thermostat	Range, +40° to +90°F	Penn Controls	1

Table 4-3. Major Assemblies, A/E 32C-24 And A/E 32C-25

Item	Description	Manufacturer	No. Req.
Evaporator Fan Motor	Direct motor drive (fans mounted on opposite ends of double extended shaft); power input-208 volts, 60 Hertz or 400 Hertz, 3 phase; built-in thermal overload and over-current protector; 0.7 hp for 60-Hertz motor, 0.5 hp for 400-Hertz motor.	Welco	1
Condenser Fan Motor	Direct motor drive; power input-208 volts, 60 or 400 Hertz, 3 phase; built-in thermal overload and over-current protector; 0.7 hp for 60-Hertz motor, 2.2 hp for 400-Hertz motor.	Welco	1
Compressor	Trane Military Model "J", Hermetically sealed reciprocating type; 2 cylinders; 2" bore; 31/32" stroke; force-feed lubrication. 208 volts, 60 Hertz or 400 Hertz, 3 phase.	Trane	1
Condenser Fan	Vane axial type.	Trane	1
Evaporator Fan	Centrifugal (airfoil, single width)	Trane	2
Condenser Coil	Finned tube	Trane	1
Liquid Line Expansion Valve	Multi-outlet thermal expansion valve	Alco	1
Evaporator Coil	Finned tube	Trane	1

Table 4-3. Major Assemblies, A/E 32C-24 And A/E 32C-25--contd

Item	Description	Manufacturer	No. Req.
Liquid Line Solenoid Valve	Pilot-operated solenoid valve	Asco	1
Liquid Bypass Solenoid Valve	Pilot-operated solenoid valve	Asco	1
Hot Gas Bypass Solenoid Valve	Pilot-operated solenoid valve	Asco	1
System Access Valves	Packless charging valves	Hoke	2
Filter-Drier	Desiccant Drier	Sporlan	1

Table 4-4. Major Assemblies, A/E 32C-26 And A/E 32C-27

Item	Description	Manufacturer	No. Req.
Evaporator Fan Motor	Direct motor drive (fans mounted on opposite ends of double extended shaft); power input-208 volts, 60 Hertz or 400 Hertz, 3 phase; built-in thermal overload and over-current protector; 1.25 hp for 60-Hertz motor, 1.60 hp for 400-Hertz motor.	Welco	1
Condenser Fan Motor	Direct motor drive; power input-208 volts, 60 and 400 Hertz, 3 phase; built-in thermal overload and over-current protector; 4.0 hp for 60-Hertz motor, 5.0 for 400-Hertz motor.	Welco	1
Compressor	Trane Military Model "J", Hermetically sealed, reciprocating type; 3 cylinders; 2" bore; 31/32" stroke; forced-feed lub 'cation. 208 volts, 60 Hertz or 400 Hertz, 3 phase.	Trane	1
Condenser Fan	Vane axial type.	Trane	1
Evaporator Fan	Centrifugal (airfoil, single width)	Trane	2
Condenser Coil	Finned tube	Trane	1

Table 4-4. Major Assemblies, A/E 32C-26 And A/E 32C-27--contd

Item	Description	Manufacturer	No. Req.
Liquid Line Expansion Valve	Multi-outlet thermal expansion valve	Alco	1
Evaporator Coil	Finned tube	Trane	1
Liquid Line Solenoid Valve	Pilot-operated solenoid valve	Asco	1
Liquid Bypass Solenoid Valve	Pilot-operated solenoid valve	Asco	1
Hot Gas Bypass Solenoid Valve	Pilot-operated solenoid valve	Asco	1
System Access Valves	Packless charging valves	Hoke	2
Filter-Drier	Desiccant Drier	Sporlan	1

Table 4-5. Major Assemblies A/E 32C-29.

Item	Description	Manufacturer	No. Req.
High-Limit Thermostat	Open 194° F(90° C), Closed 140° F (60° C)	Klixon	1
Control Switch	Manual, 5-position, rotary selection switch	Cutter-Hammer	1
Conditioned Air Thermostat	Range, +40° to 90° F	Penn Controls	1
Evaporator Condenser Motor	Direct motor drive (fans mounted on opposite ends of double extended shaft); power input--115 or 230 volts, 60 Hertz, single phase or 208 volts, 400 Hertz, 3 phase; built-in thermal overload and over-current protector; 1.15 hp for 60-Hertz motor, 1.40 hp for 400-Hertz motor.	Welco	1
Compressor	Hermetically sealed rotary type.	Whirlpool	1
Condenser Fan	Vane axial type; counterclockwise rotation, facing room air inlet. Cast aluminum.	Trane	1

Table 4-5. Major Assemblies, A/E 32C-29--contd

Item	Description	Manufacturer	No. Req.
Evaporator Fan	Centrifugal, airfoil blades, single width, counterclockwise rotation, facing room air inlet.	Trane	1
Condenser Coil	Finned tube	Trane	1
Liquid Line Expansion Valve	Multi-outlet thermostatic expansion valve.	Ajco	1
Liquid Bypass Expansion Valve	Thermostatic expansion valve.	Trane	1
Liquid Line and Liquid Bypass	Direct-acting solenoid valve. A three-way solenoid valve is used for the liquid line solenoid valve and the liquid bypass solenoid valve.	Asco	1
Hot Gas Bypass Solenoid Valve	Direct-acting solenoid valve.	Asco	1
System Access Valves	Packless charging valves.	Hoke	2
Filter-Drier	Desiccant Drier	Sporlan	1
Electric Heaters	Stainless steel sheath; 115 volts, 300 watts each.	Indeeco	6

4-6. OPERATIONAL THEORY

a. General. All of these units are equipped with three operating cycles: cooling, heating, and ventilating. The particular operational cycle is determined by setting the selector switch and thermostat located on the control panel to the desired environmental conditions.

b. Cooling. When the selector switch is set to the COOL position, the compressor and fan motors are energized and the compressor operates on the cooling cycle until the conditioned air thermostat is satisfied. The system then transfers to bypass operation until the air temperature in the conditioned space rises above the setting of the conditioned air thermostat, at which time the system automatically transfers back to the cooling cycle.

(1) Cooling cycle (fig 4-10). During the cooling cycle, the liquid refrigerant, which is under condensing pressure, is metered into the evaporator through a thermostatically controlled expansion valve. As the refrigerant passes through the valve into the relatively low-pressure evaporator, a certain portion of the liquid immediately flashes (vaporizes). This flashing draws heat from the remaining liquid in the evaporator, lowering its temperature. Heat is then transferred from the warm indoor air passing over the evaporation coil to the chilled refrigerant, causing the refrigerant to vaporize. Then the heat-laden refrigerant vapor is drawn from the evaporator, through the suction line, to the compressor. Upon entering the compressor, the refrigerant vapor is compressed to condensing pressure and passed through the hot gas line to the condenser. Since compressing refrigerant vapor substantially raises its condensing temperature, the relatively warm outdoor air passing over the condenser coil surfaces is sufficient to condense the refrigerant vapor to a liquid. The liquid then leaves the condenser and returns to the expansion valve, through the liquid line, to complete the cycle. A back-pressure regulating valve prevents frost from forming on the evaporator.

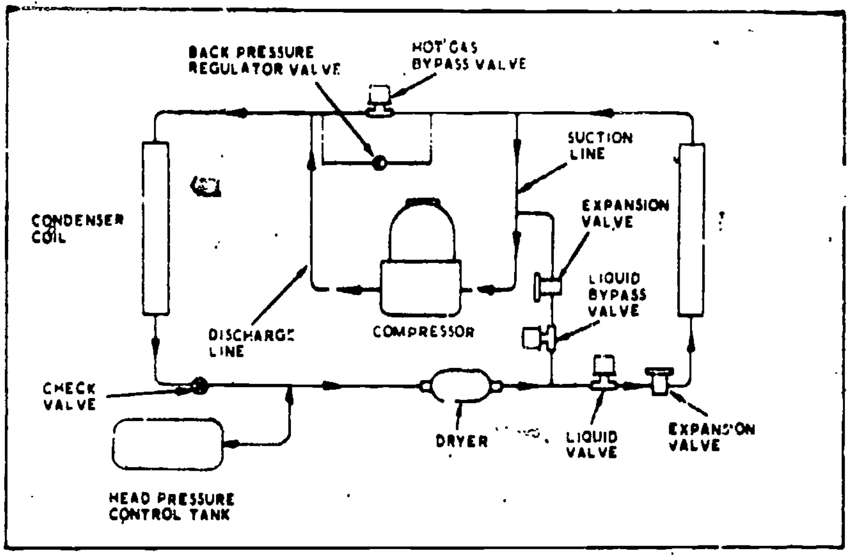


Fig 4-10. Cooling cycle.

(2) Bypass cycle (fig 4-11). When the temperature of the conditioned air falls below the thermostat setting, the circuit which controls the refrigerant valves is energized. This causes:

(a) The liquid line valve to close, stopping the flow of liquid refrigerant to the evaporator. This completely halts the cooling function.

(b) The hot gas bypass valve to open, cycling a major portion of the compressed refrigerant vapor directly back to the suction side of the compressor.

(c) The liquid bypass valve to open, which transfers a small amount of liquid refrigerant through an expansion valve into the suction piping. When the unit is operating in this bypass condition, the flow of refrigerant into the suction line places a small load on the system. This reduces the temperature of the suction gas which prevents the compressor from overheating.

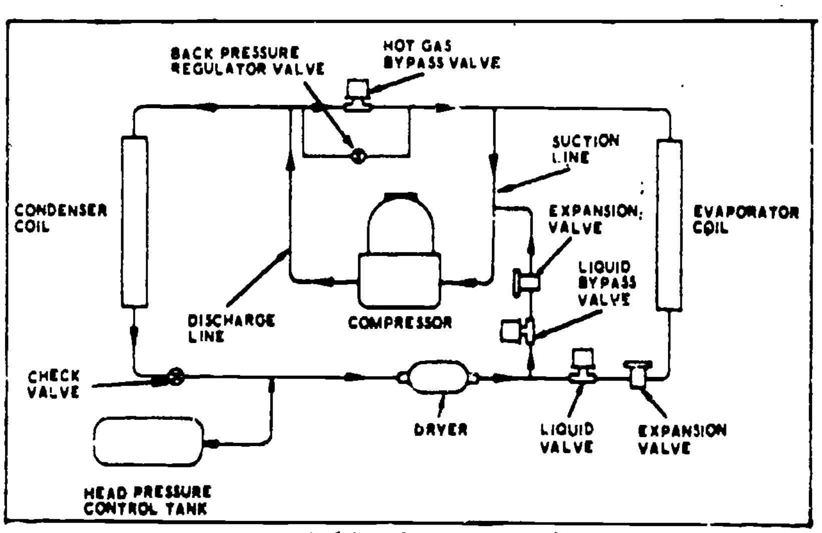


Fig 4-11. Bypass cycle.

c. Heating. Two ranges of heating are provided by a bank of electrical resistance heaters which are mounted in the conditioned air stream directly behind the evaporator coil. Placing the selector switch in the LO-HEAT position energizes half of the heaters. The remaining heaters are energized when the switch is placed in the HI-HEAT position, thus providing maximum heating capacity. When the selector switch is in the HI-HEAT position, the fan motor is in operation and one bank of heaters is on continuously while the second bank is controlled by the conditioned air thermostat. As the air temperature falls below the set point of the conditioned air thermostat, the thermostat contacts will close. This energizes the heater contactor which supplies power to the second bank of heaters through the normally closed contacts of the high temperature control. Moving the selector switch to the LO-HEAT position provides the same control sequence, but reduces the heating capacity by supplying power to the first bank of heaters only as called for by the conditioned air thermostat.

d. Ventilating. With the selector switch at VENT, the fan motor operates, the compressor and heater circuits are off, and air is circulated as determined by the damper control.

Note: When the selector switch is set to OFF, power is supplied only to the compressor crankcase heater. The unit must be disconnected from the power source to disconnect all circuits.

4-7. INSTALLATION

The installation of an air-conditioning system will be determined by the requirements and space limitations.

a. Through-the-wall. When this method is used, the unit rests inside the area to be conditioned while the condensing and fresh air inlet side are vented through an opening in the wall to the outside. An opening, 1/4 in. larger than the outside dimensions of the unit, is cut in the wall. The clearance helps prevent transmission of vibration to the wall structure (fig 4-12). The unit is centered in the opening and bolted to the floor. All units have 15/32-in.-diameter holes with 7/16-14 nuts in the base for mounting. Aluminum or steel angles with rubber gasketing may be installed around the unit to seal the opening. A drain line is connected to one of the 1/2 in. NPT drain connections located at the front, back, and sides of the unit. A trap or loop is required in the drain line to achieve proper drainage. Electrical connection is generally made at the back of the unit with an MS connector. Alternate connections are located on each side of the unit.

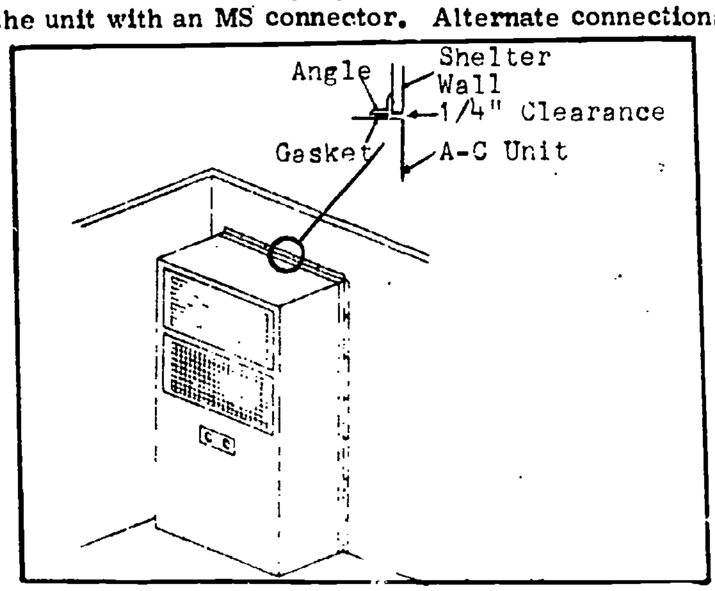


Fig 4-12. Through-the-wall installation.

b. Telescoping rail. The telescoping rail arrangement is particularly applicable when the air-conditioning unit is to be installed in a van or shelter. Mounted on a telescoping rail arrangement, the unit is moved laterally through the wall before use. When not in use, the rails are retracted, placing the unit inside the shelter (fig 4-13). An opening is cut in the side of the shelter. The telescoping rail assembly is centered in the opening and bolted in place. The unit is then bolted to the base. A flexible canvas or rubber boot is installed to close the opening between the shelter and the unit. The electrical and drain connections are made as described in the through-the-wall installation. Either flexible or removable duct connections are used to accommodate the movement of the unit. To complete the installation, the wall opening is covered by a hinged or removable door.

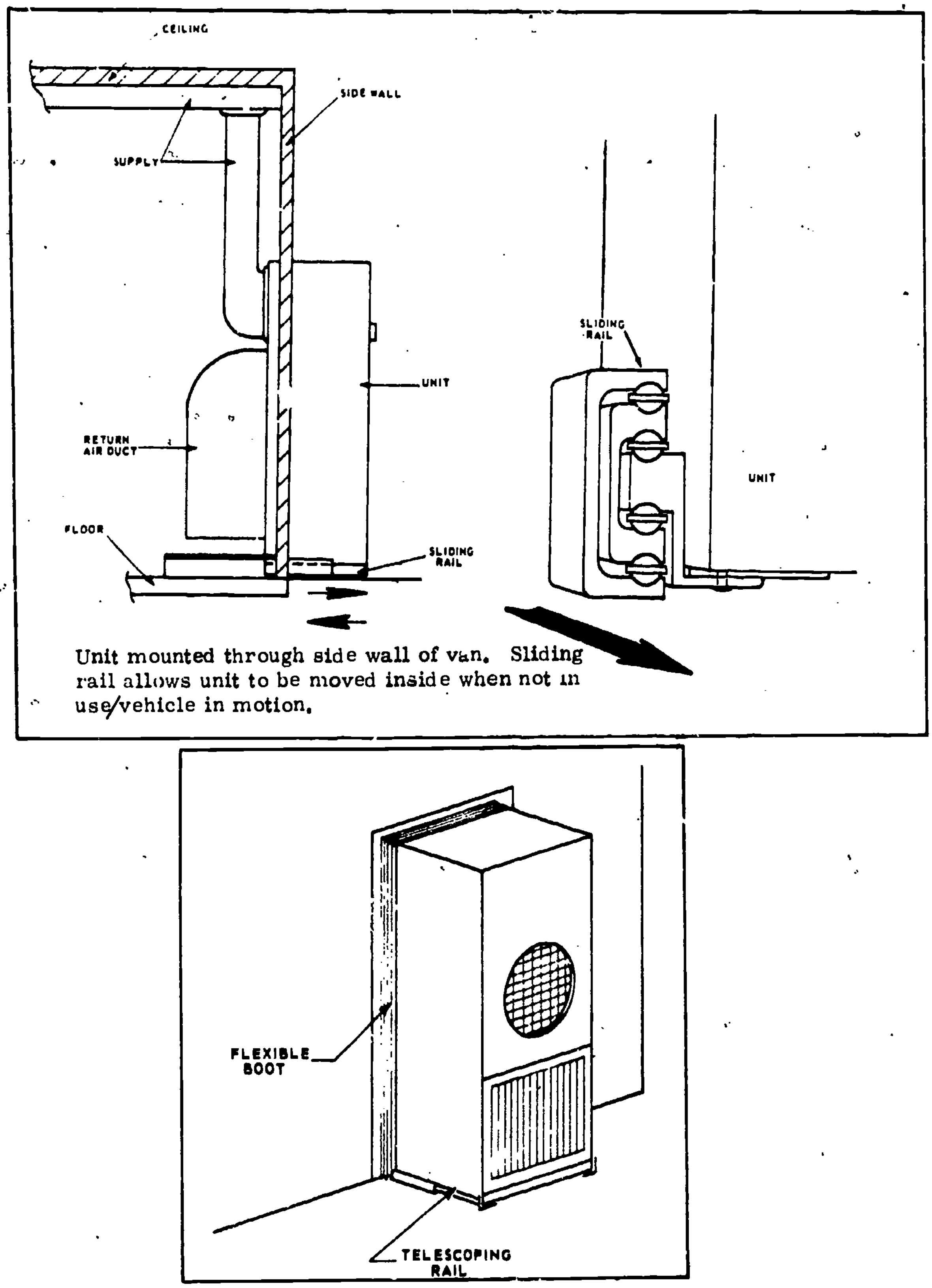


Fig 4-13. Telescoping rail installation.

c. Skid mounted. Skid-mounted units are designed for mobility. They are used to provide air conditioning at a location remote from the area to be conditioned by a system of flexible ducts. Remote location is desirable when exceptionally low sound level is required. Installation consists of a "retrofit" package with connecting flexible ductwork and cables to permanent fixtures on the unit and shelter (area to be conditioned). Figure 4-14 shows the components of the retrofit package. The skid-mounted version (see fig 4-15) permits easy access for maintenance and facilitates rapid replacement of the complete unit. The tubular lifting frame, which is integral with the skid base, provides support for the ducting storage canister.

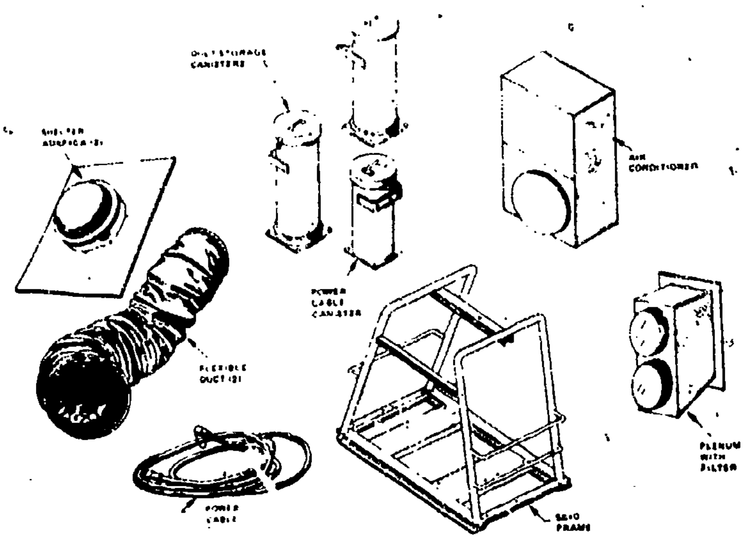


Fig 4-14. Retrofit package components.

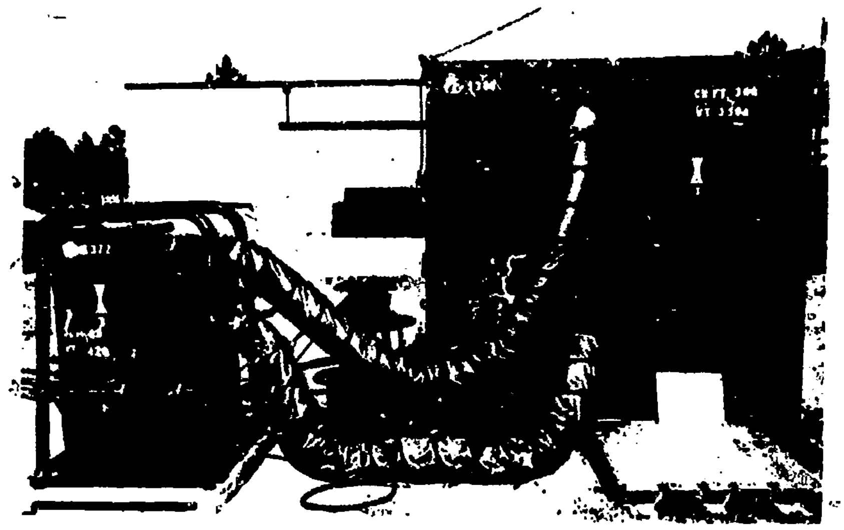


Fig 4-15. Skid-mounted air conditioner using retrofit package.

d. <u>Exterior mounted.</u> This method is a variation of the through-the-wall method described above, and is one that saves valuable working space in small areas such as shelters. A permanent or temporary platform is attached to the outer wall of the shelter. Openings are cut in the shelter wall for supply and return air connections. The unit is then bolted to the platform and the air and other connections made as necessary.

e. <u>General installation instructions.</u>

(1) Move the unit to the installation site before removing the shipping carton. Remove the top, ends, and sides of the carton and the kimpac covering the unit. Retain both the carton and the kimpac covering for use in future moves.

> <u>Note:</u> The unit must be set in the upright position for at least 12 hours prior to running refrigerant system.

(2) The unit is secured to the shipping base by four 7/16"-14 x 2 1/4" hexagon head screws, four 7/16" flat washers, and four 7/16" Kant-Link washers. Remove these fasteners and move unit off the shipping base.

(3) Inspect the entire unit for signs of in-transit damage. Pay particular attention to the evaporator and condenser coils and the coil grilles.

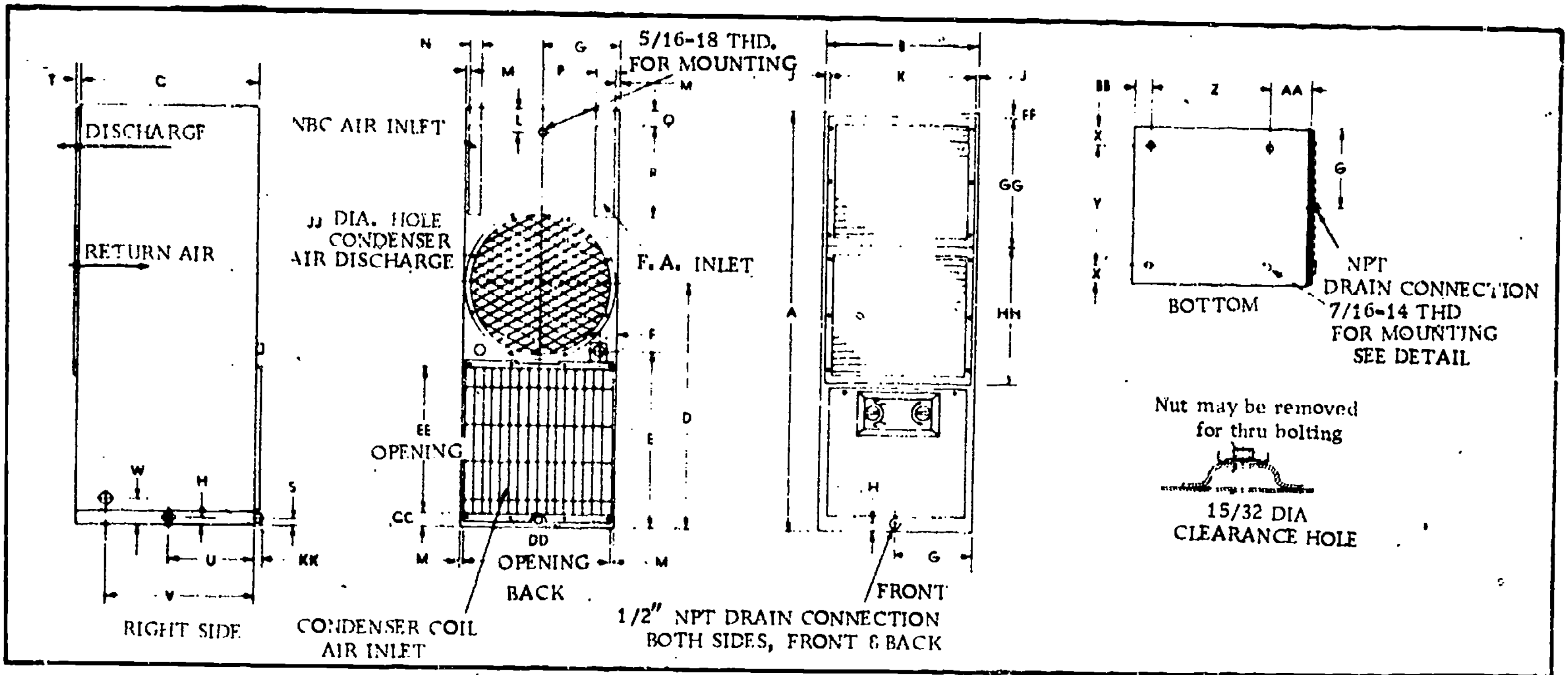
(4) The unit should be set level to allow proper condensate drainage. However, operation will be satisfactory with the unit sitting at no more than an 8.5° angle and using one of the alternate drain connections.

(5) In order for the unit to operate efficiently at rated capacity, you must consider accessibility and unobstructed airflow when locating the unit.

(a) The removable lower front panel and the conditioned air supply and return air grilles must be accessible for normal service and maintenance.

(b) The condenser air intake grille must be unobstructed to allow sufficient air condensing purposes. For maximum unit capacity, the conditioned air supply and return openings at the front of the unit should be free of obstruction.

(6) Mounting hole dimensions for fastening the unit to the floor are given in figures 4-16 and 4-17.

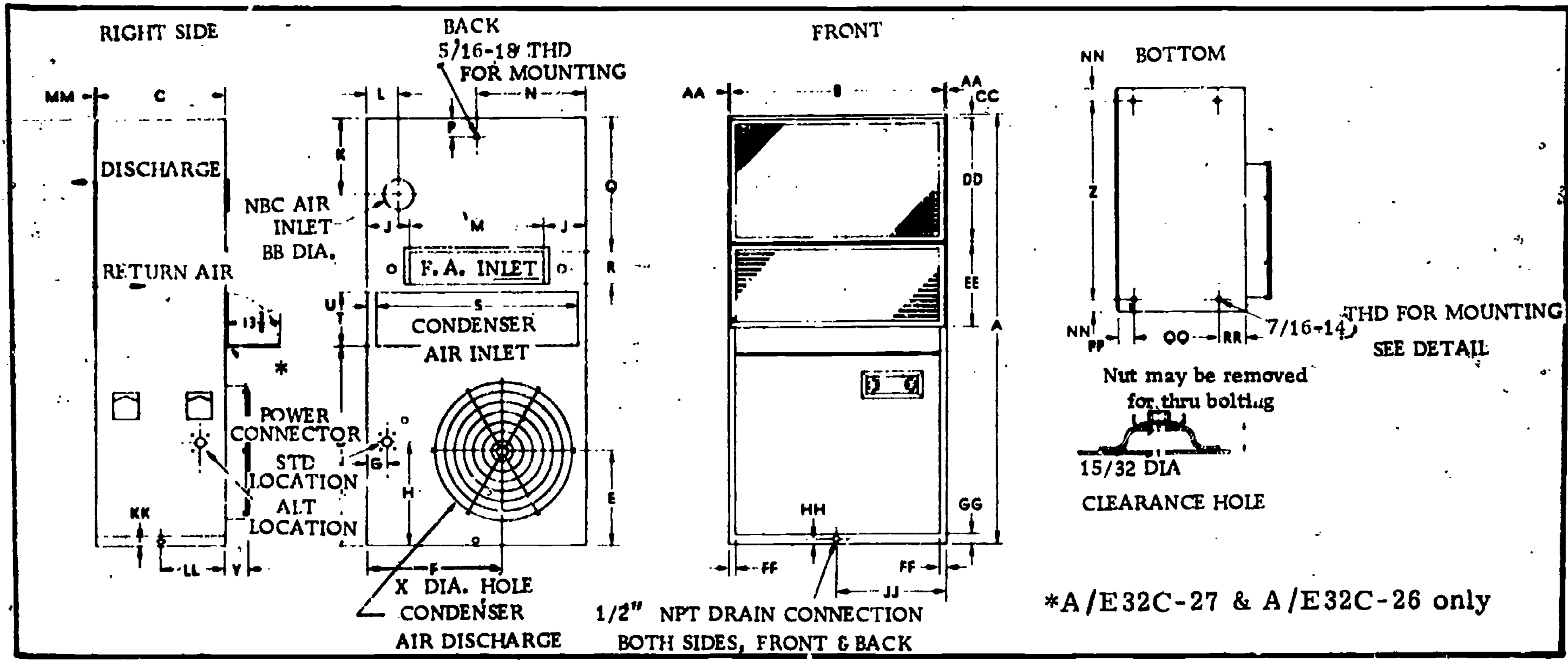


Dimensions

MODEL	A	B	C	D	E	F	G	H	J	K	L	M	N	P	Q	R
A/F32C-17 A/F32C-18	45 9/16	17	19	26 1/4	19 1/4	2	8 1/2	3/4	1/4	16 5/8	2 7/16	5/16	1 1/4	2 1/4	1 5/16	9 5/8

S	T	U	V	W	X	Y	Z	AA	BB	CC	DD	EE	FF	GG	HH	JJ DIA	KK
3/4	1/4	9	16	2 7/8	2	13	13	4 1/4	1 3/4	1 1/2	16 3/8	16	3/8	14	15	13 3/4	7/8

Fig 4-16. Installation diagram, A/E 32C-17, A/E 32C-18.



Dimensions

MODEL	A	B	C	D	E	F	G	H	J	K	L	M	N	P	Q	R	S	T	U
A/E32C-24 A/E32C-25	55 1/16	30	18	25 1/2	12 1/8	28 3/4	3	[illegible] 1/2	6 1/2	8 5/8	3 7/8	17 1/8	15	2	16	3 1/8	28 5/8	9	3/4
A/E32C-26 A/E32C-27	65 1/16	34	20	29 3/8	14	20 5/8	3	[illegible] 1/2	5 3/4	6	29 3/4	22 1/2	17	2 1/8	16 7/8	7 1/4	32 3/4	9 7/8	1

V	W	X	Y	Z	AA	BB	CC	DD	EE	FF	GG	HH	JJ	KK	LL	MM	NN	PP	QQ	RR
2 7/8	13 1/2	21 1/8	3	2 1/2	1/4	4	3/8	14	9 1/8	1	1 1/2	3/4	15	3/4	9	1/4	2 1/4	1 3/8	13	3 5/8
3	15 1/2	24 1/2	3 1/2	29 1/2	1/4	4 3/4	5/8	18 5/8	12 1/4	1	1 1/2	3/4	17	3/4	10	1/4	2 1/4	2	12 3/8	5 5/8

Fig 4-17. Installation diagram A/E 32C-24, A/E 32C-25, A/E 32C-26, and A/E 32C-27.

(7) Connect a drain hose to the 1/2" NPT condensate outlet at the base of the unit. Lead the drain hose away from the unit. As shown in figure 4-18, include a 3" gooseneck trap in the drain connection next to the unit. Alternate 1/2" NPT drain connections are provided at both sides and the front of the unit. If one of the alternate drain connections is used, insert a 1/2" square-head plug in the rear drain connection.

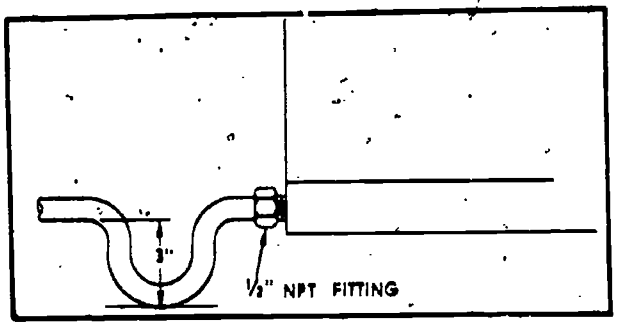


Fig 4-18. Condensate connection.

(8) All unit internal wiring is complete as shipped.

(a) Different units have different electrical characteristics. The correct power source for each unit is stenciled on the side of the unit and a wiring diagram is located on the back of the lower front panel.

(b) An MS3100R receptacle is located on the back panel of the unit. Connect the proper electrical power source to this receptacle using an MS3106R plug or acceptable alternate.

(c) Alternate power connections are located on both sides of the unit. A change to an alternate power location can be easily accomplished in the field.

Caution: When you connect the power, energize the unit briefly in the ventilation mode and check condenser fan rotation. Note rotation arrow on back of unit. If rotation is backward, reverse any two of the power leads to the power connector. Recheck for rotation.

(9) The control panel, shown in figures 4-19 through 4-23 and in figure 4-24, is located at the front of the unit. This panel may be mounted remotely by means of an interconnecting cable assembly. A blank cover panel may be installed in the front panel opening when remote control is used.

Note: If the remote cable is not shielded, the radio frequency interference (RFI) integrity of the unit will be destroyed.

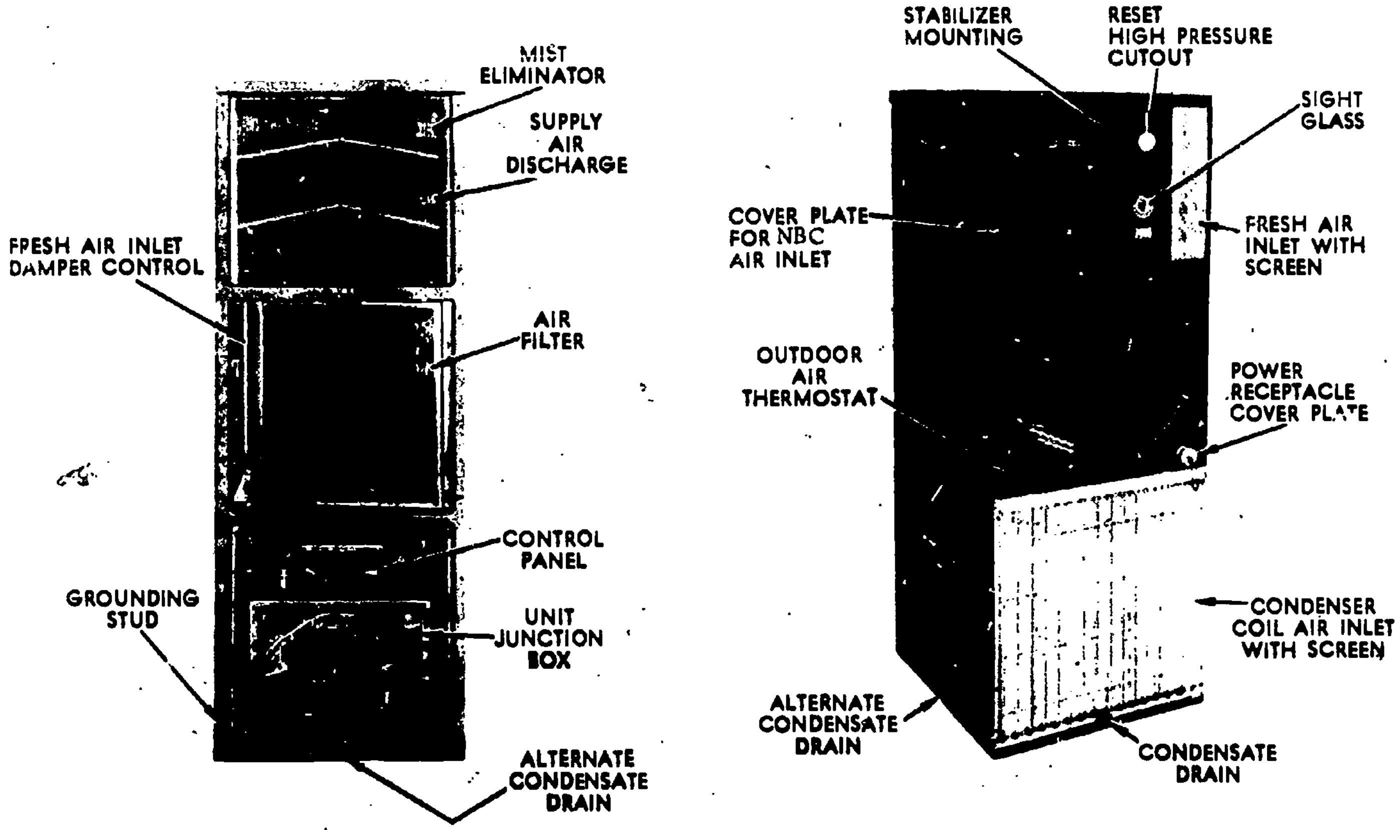


Fig 4-19. Component location, A/E32C-17 and A/E32C-18.

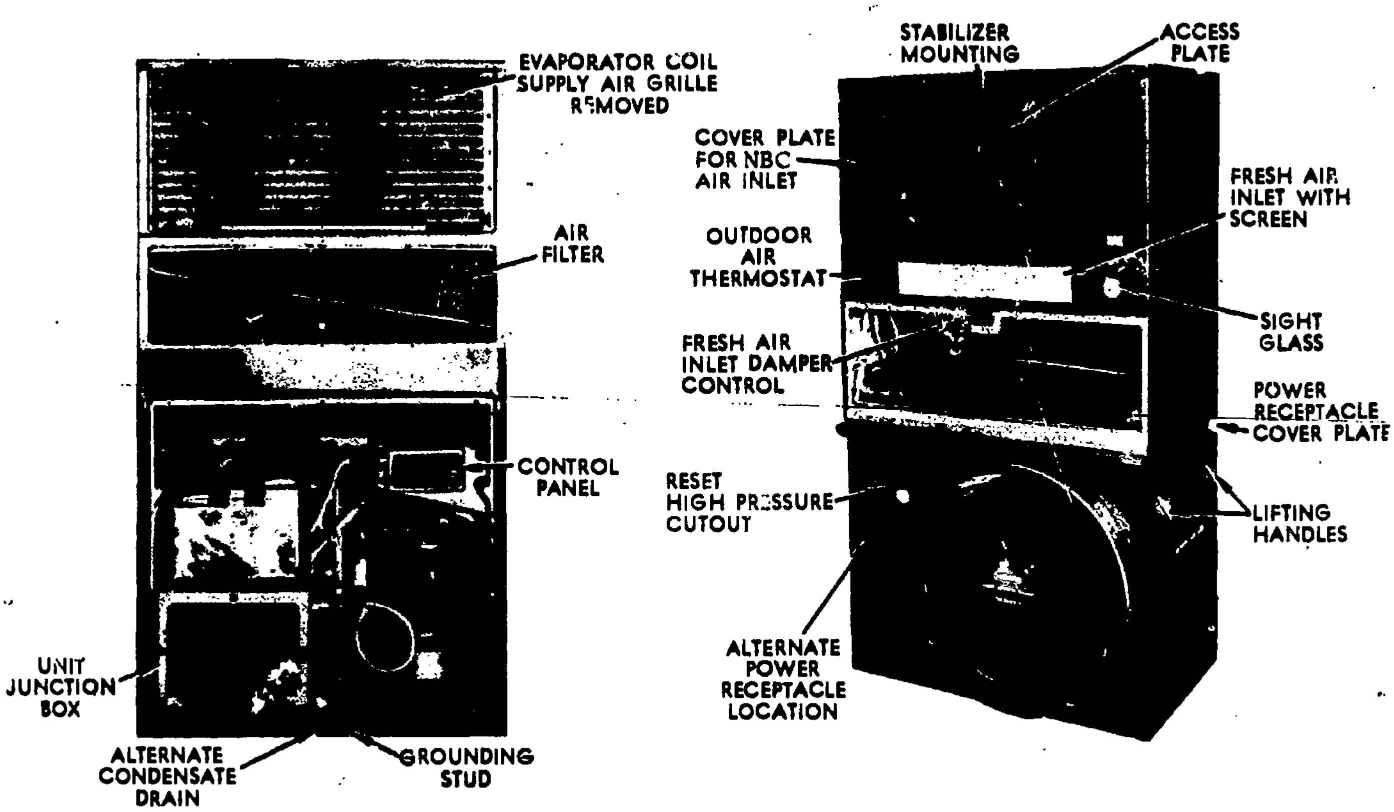


Fig 4-20. Component location, A/E32C-26 and A/E32C-27

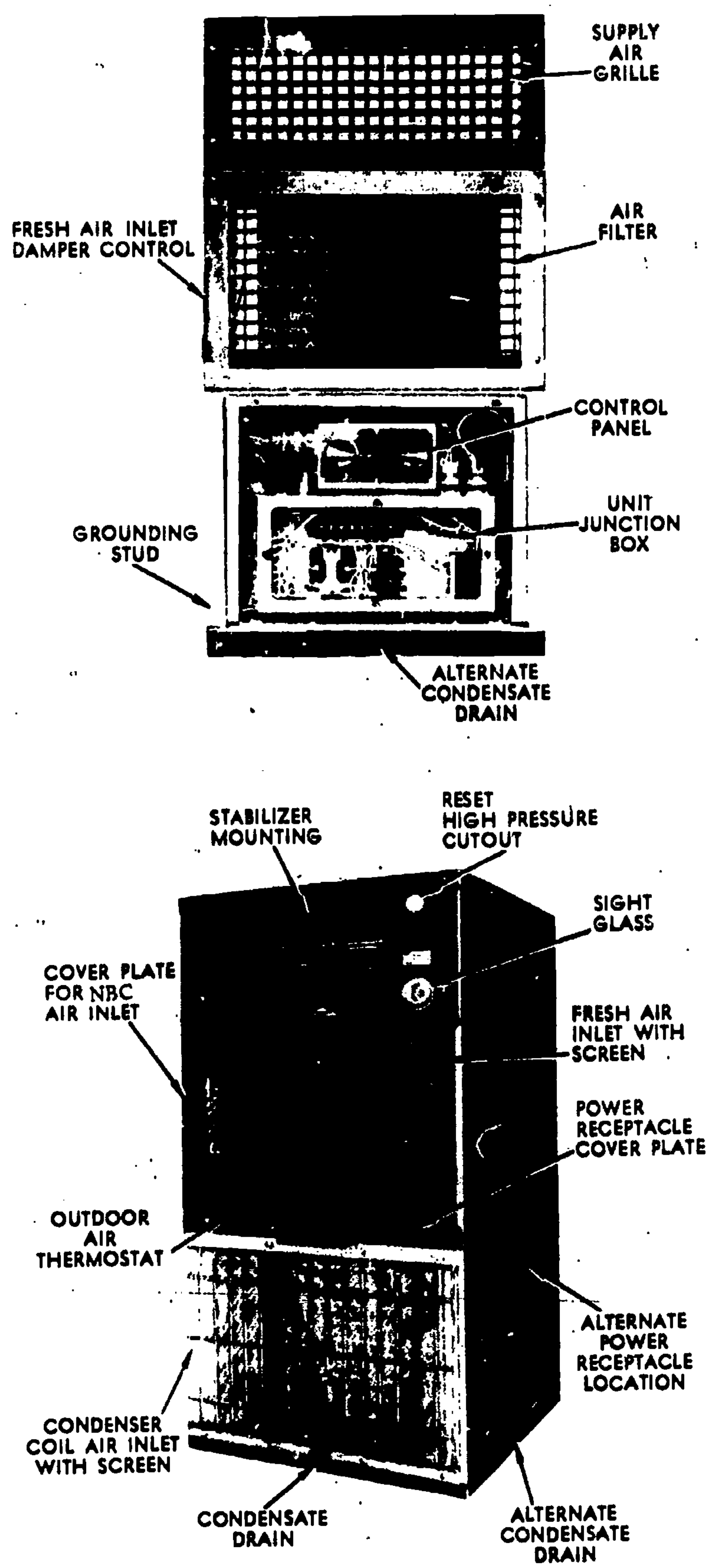


Fig 4-21. Component location, A/E32C-29.

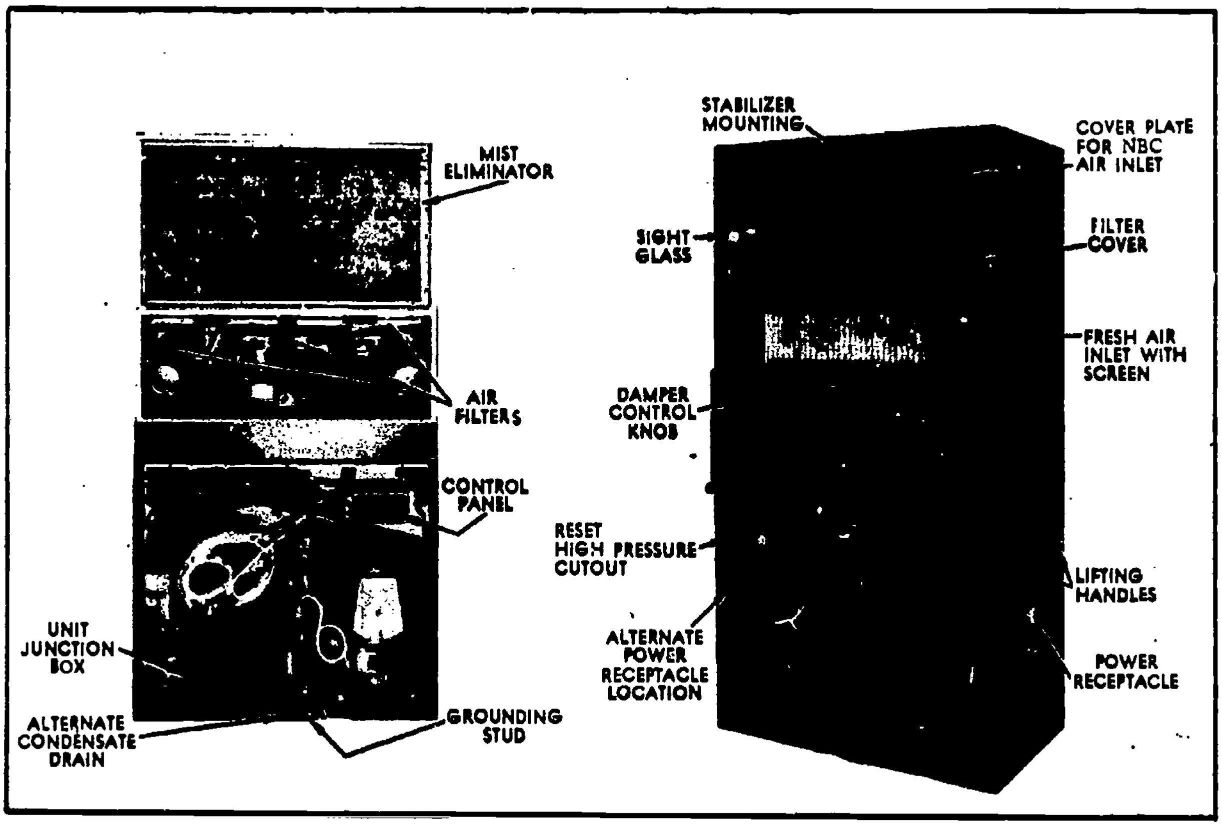


Fig 4-22. Component location, A/E 32C-24 and A/E 32C-25.

(10) Ductwork may be installed from the outside to the fresh air inlet at the back of the unit; from a nuclear, biological, and chemical (NBC) filter system to a second inlet at the back of the unit; or from the front of the unit to the areas to be air conditioned. Ductwork and the NBC filter system are furnished by other manufacturers.

(11) The air-conditioning unit contains a full operating charge of refrigerant and compressor oil. Further service is not required. The evaporator and condenser fan motors are permanently lubricated by the manufacturer and require no additional lubrication.

4-8. OPERATION

a. Operator's service requirements. To make sure that the air conditioner is ready for operation at all times, the operator must inspect it systematically so that defects may be discovered and corrected before they result in serious damage or failure. The necessary preventive maintenance services to be performed are outlined in paragraph 4-9a.

b. Controls and instruments. The various controls and instruments which govern the operation of the air-conditioning unit are described below.

(1) Selector switch. The selector switch, located on the control panel (fig 4-23), is a five-position switch which controls the type operation the unit is to perform.

(a) HI HEAT. Energizes the evaporator fan motor. One bank of electrical heaters is on continuously and the second bank is under control of the temperature control (conditioned air thermostat).

(b) LO HEAT. Energizes the evaporator fan motor. One bank of electrical heaters is under the control of the temperature control (conditioned air thermostat) and the second bank is inoperative.

(c) VENT. Energizes the evaporator fan motor but all other systems are inactive.

(d) COOL. Energizes the fan and compressor motors. Whenever the air temperature falls below the temperature control setting, the compressor, while continuing to operate, transfers to a bypass (no load) condition.

(e) OFF. The power circuit is de-energized except for the crankcase heater.

> Note: When the selector switch is set to OFF, power is supplied to the compressor crankcase heater. The unit must be disconnected from the power source to disconnect all circuits.

(2) Temperature control (conditioned air thermostat). The temperature control is also located on the control panel. It provides both heating and cooling control over a 50°F temperature range (40° to 90°F). Center position is approximately 65°F. To decrease the temperature, turn the knob counterclockwise; to increase temperature, turn the knob clockwise.

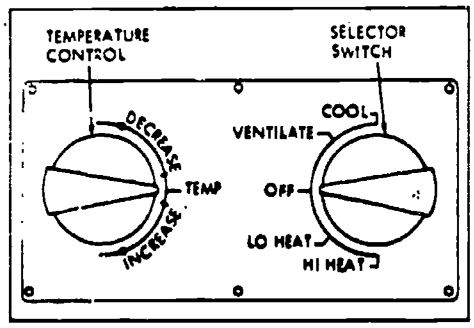


Fig 4-23. Control panel.

(3) Damper control. The fresh air inlet damper, located within the unit, is controlled by a pull chain on the front of the smallest units and by a knob on the two biggest units (this knob may be on the front or on the back of the unit). When the fresh air damper is opened, the louvers on the conditioned air inlet on the front of the unit should be closed if the maximum of fresh air is desired. These louvers are controlled by a lever on the front of the unit. An air inlet is provided on the back of the unit for attaching the NBC filtered air system to the unit. When the NBC system is in use, the fresh air inlet damper must be closed. Figure 4-24 shows how to operate the damper knob.

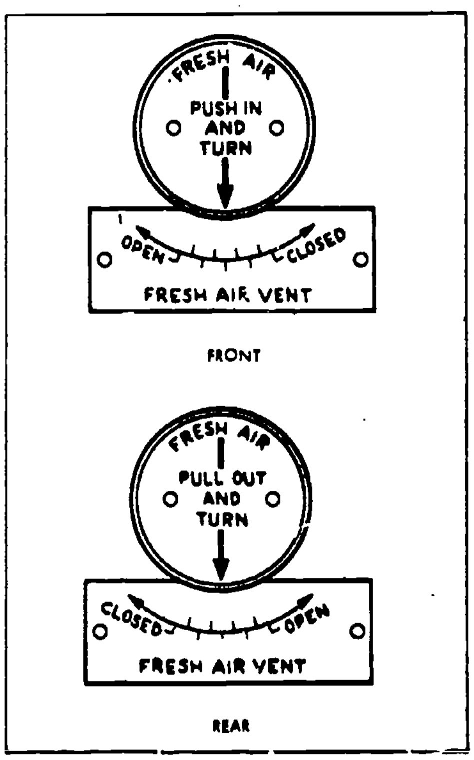


Fig 4-24. Damper control knobs.

(4) Outside air thermostat. The function of the outside air thermostat is to prevent compressor start-up when the outside air temperature (ambient temperature) drops below a specified point. This prevents operation at a time when low condensing and suction pressures will hamper system operation. On the two smallest size units, the outside air thermostat is set to cut out at 50°F ambient, while on all others it is set to cut at 0°F ambient.

(5) Sight glass (fig 4-25). The liquid line sight glass, located on the back panel, indicates if there is moisture in the refrigerant or if there is a shortage of refrigerant. Moisture is shown by the indicator turning from green to yellow. A shortage of refrigerant is indicated by bubbles appearing continuously in the sight glass.

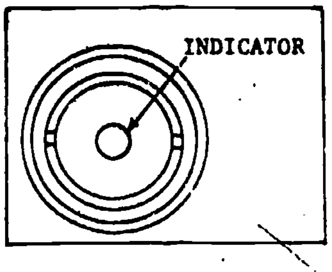


Fig 4-25. Sight glass.

(6) High-temperature control. The high-temperature control switch functions to prevent over-heating when the system is operating on the heating cycle. This device is designed to cut out at 194° F (90°C) and automatically reset at 140°F (60°C).

Note: 194°F will be reached only if the evaporator fan becomes inoperative.

(7) High-pressure cutout switch. The high-pressure cutout switch is a manual reset type. Contacts open at 445 psig $\pm$ 10 psig, and will close after being reset manually at 385 psig or below (see fig 4-19).

(8) Back-pressure regulator. The back-pressure regulator is designed to regulate evaporator pressure to a minimum of 58 psig to prevent evaporator coil freezeup.

c. Operating instructions. There are a few things to check before you start the unit. For instance, you should see if the unit is secure on its mount and make sure there are no obstructions to the free flow of air to both front and rear intake grilles. Turn the selector switch to OFF. Apply power to the unit. (This energizes the compressor crankcase heater to vaporize any refrigerant present in the oil--this may take 5 hours.)

(1) Starting the unit. The first step is to jog the fan motor by turning the selector switch to COOL and then back to OFF. Check the condenser fan for proper rotation (refer to paragraph 4-7e (8) Caution).

(a) Cooling operation. Set the temperature control at the desired temperature setting, then set the selector switch to the COOL position, thus starting the compressor. Allow the system to operate until it is discharging cooled air. Raise or lower the temperature control to maintain the desired temperature.

(b) Bypass. With the selector switch in the COOL position, raise the thermostat setting; as the set point passes above the ambient temperature, the unit should go into bypass operation.

(c) Heating operation. Turn the selector switch LO HEAT. For additional heating capacity, turn the selector switch to HI HEAT. Raise or lower the temperature control to maintain the desired temperature.

(d) Positioning of controls. Adjust the temperature control setting, fresh air inlet damper, and select switch in accordance with the system operating information in figure 4-26.

Type of Air Conditioning Required	Thermostat Setting	Indoor Return Air Damper	Outdoor Air Damper	Selector Switch Position
Cooling—100% Recirculated Air	Desired Temperature	Open	Closed	COOL
Cooling—With Fresh Makeup Air	Desired Temperature	Partially* Closed	Open	COOL
Cooling—With Fresh Makeup Air Drawn Through NBC Filter (Outdoor Air Contaminated)	Desired Temperature	Open	Closed	COOL
Heating—100% Recirculated Air	Desired Temperature	Open	Closed	LO-HEAT or HI-HEAT
Heating—With Fresh Makeup Air	Desired Temperature	Partially* Closed	Open	LO-HEAT or HI-HEAT
Heating—With Fresh Makeup Air Drawn Through NBC Filter (Outdoor Air Contaminated)	Desired Temperature	Open	Closed	LO-HEAT or HI-HEAT
Ventilation—Maximum Outdoor Air	Any	Closed	Open	VENTILATE

*The closing of the indoor return air damper causes a greater portion of the total airflow to be drawn from the outside.

Fig 4-26. Operating information.

Note: The center of the temperature control scale corresponds to approximately 65°F.

(2) Stopping the unit. To shut down the unit, turn the selector switch to OFF. To shut the system down for an extended period of time, proceed as follows:

(a) Turn the selector switch to OFF.

(b) Disconnect the power supply.

(c) Close the fresh air inlet damper.

(d) Cover the condenser air intake and outlet openings.

(3) Operating precautions. The following precautions shall be observed at all times:

(a) Keep hands away from fans when unit is operating.

(b) Do not remove any panels to perform work or tests on the air conditioner while conditioner is connected to power source.

(c) If the motor or the compressor become overheated, stop the unit immediately and check for the cause.

(d) Should liquid refrigerant come in contact with the skin, the injury should be treated as for frostbite or frozen condition.

(e) Do not use water on a motor fire.

d. Operation under unusual conditions. The unit is designed to operate over the range required for air-conditioning units.

(1) Extreme heat. The unit is designed to operate satisfactorily up to a temperature of 125°F ambient.

(2) Extreme cold. The outside air thermostat prevents the compressor from being started when the outside air temperature is below a specified point (see paragraph 4-8b(4)).

(3) Dusty or sandy areas. Remove and clean the air filter as described in paragraph 4-9a(1)(c) and (d). Under extreme conditions or extended operating periods, clean the evaporator condensate drain pan and the unit drain pan to remove accumulated dust or sand.

4-9. MAINTENANCE

In this paragraph we will cover instructions for periodic inspection, servicing, and maintenance of the air-conditioning unit. Periodic inspection and proper maintenance will result in better operation and minimum repair. Deficiencies may also be discovered before they cause major damage.

a. Preventive maintenance. Special tools are not required to perform routine organizational maintenance. As far as lubrication is concerned, the evaporator and condenser fan motors are permanently lubricated and the compressor and compressor motor are fully lubricated by the manufacturer and require no additional lubrication.

(1) Periodic inspection. Periodic inspection intervals are listed in chart form. (Refer to table 4-6 for the periodic inspection intervals.) All deficiencies noted during inspection should be corrected before further operation of the unit is attempted. Adjustment and repair procedures that are beyond the scope of operational maintenance shall be referred to maintenance personnel possessing the proper tools, equipment, and information to perform the needed repairs. The intervals appearing in the periodic inspection chart are for a normal 8-hour day operation. During abnormal conditions it may be necessary to shorten intervals accordingly. In addition to the daily inspections, the operator shall at all times be alert for any unusual noises or other indications of malfunctions during operation of the air conditioner.

Table 4-6. Periodic Inspection Chart

Component	FREQUENCY		
	Daily	Monthly	6 Months
GENERAL			
Check for visual damage.	X		
Check legibility of decals and instruction plates.		X	
Check for obstructions to free movement of air at front and rear of unit.	X		
Check for clogged or damaged grilles.	X		
COMPRESSOR AND PIPING			
Check compressor for any unusual noises during operation.	X		
Check liquid sight indicator for bubbles or indication of moisture.	X		

Table 4-6. Periodic Inspection Chart--contd

COMPONENT	FREQUENCY Daily	Monthly	6 Months
COMPRESSOR AND PIPING--contd			
Check operating pressures.			X
Check piping for damaged tubes and fittings.		X	
Check piping for leaks with halide leak detector.			X
DRAIN PAN			
Inspect drain pan for presence of foreign matter and clogged drains.		X	
Inspect drain pan piping for damage or clogged condition.		X	
Inspect check valve for proper operation.		X	
FILTERS			
Check filters and mist eliminator for dirt or other foreign matter.		X	
COILS			
Inspect coils for dirt or other foreign matter.		X	
Inspect coils for loose mounting hardware.		X	
MOTORS AND FANS			
Inspect motors and fans for loose mounting screws.		X	
Inspect fan blades for damage and accumulation of dirt or other foreign matter.		X	
ELECTRICAL WIRING AND CONNECTIONS			
Inspect wiring for insulation damage and loose connections.		X	

(2) Service.

(a) Grilles. Dust, insects, and other foreign matter on the grilles will restrict the flow of air through the grilles. Cleaning instructions which follow apply to any of the grilles.

1. Remove screws, washers, and lockwashers securing the grille to the casing. Remove the grille.

2. Wash the grille thoroughly by flushing in hot water and allow the grille to dry thoroughly.

3. After cleaning the evaporator intake or discharge grille, inspect gasket for damage or loose cement.

4. Install the grille and secure it with the screws, flat washers, and lockwashers previously removed.

(b) Mist eliminator. Clean the mist eliminator as follows:

1. Remove the screws, flat washers, and lockwashers securing top cover panel assembly to the casing. Lift the panel from the unit.

2. Slide the mist eliminator up and out of the evaporator coil slides.

3. Flush the mist eliminator with hot water. Do not oil.

4. Install the mist eliminator in its slides.

5. Install the top cover panel and secure it with the screws, flat washers, and lockwashers previously removed.

(c) Air intake filter. The air intake filter is permanent and requires only periodic cleaning.

1. Remove the evaporator air intake grille.

2. Remove the five screws, flat washers, and lockwashers, and lockwashers securing filter support to bottom of drain pan. Remove the support from the air conditioner.

3. Slide the filter up and out of the air conditioner.

4. Wash the filter with hot water or steam. When dry, dip the filter in Standard Air Maze Filterkote or its equivalent.

5. Install the filter in the air conditioner and install the support over the end of the filter. Secure the support with screws, flat washers, and lockwashers.

(d) Fresh air filter. The fresh air filter is also a permanent type requiring only periodic cleaning.

1. Remove the screws, flat washers, and lockwashers which secure the filter cover to the casing.

2 Remove the filter cover and filter.

3. Wash the filter with hot water or steam. When dry, dip the filter into Standard Air Maze Filterkote or its equivalent.

4. Install the filter and filter cover over the fresh air inlet and secure the cover with screws, flat washers and lockwashers.

(e) Evaporator coil. The evaporator coil is cleaned without removing the coil from the air conditioner.

1. Remove top cover panel assembly and mist eliminator as instructed in subparagraph (b) above.

2. Clean the surface of the coil and blow any dirt out from between the fins with compressed air. Hold the nozzle of the air hose at least 6 to 8 inches away from coil to avoid damaging the fins.

Warning: Do not use steam to clean coils.

3. Install the mist eliminator and the top cover panel.

(f) Condenser coil. The condenser coil is cleaned without removing it from the air conditioner.

1. Remove the front panel by loosening the panel fastening screws at the top of the panel.

2. Remove the condenser air intake grille by removing the screws flat washers. and lockwashers.

3. Clean the surface of the coil and blow any accumulated dirt out from between the fins with compressed air. Hold the nozzle of air hose at least 6 to 8 inches away from coil to avoid damaging the fins.

Warning: Do not use steam to clean coils.

4. Install the air intake grille and secure it with screws, flat washers, and lock-washers.

5. Install the front panel and tighten the panel fastening screws.

(g) Refrigerant sight indicator. The liquid sight indicator should be checked periodically for indications of moisture or shortage of refrigerant. Indications of moisture or shortage of refrigerant shall be reported to higher authority for correction.

1. Moisture in the refrigerant is shown by the indicator turning from green to yellow.

2. A shortage of refrigerant is indicated by bubbles in the indicator.

(h) Drain piping. The drain pan and drain piping shall be kept clean to provide adequate drainage of condensate.

1. Remove the top cover panel assembly and mist eliminator as instructed in paragraph, 4-9a(2)(b).

2. Remove the front lower panel.

3. Loosen the lower hose clamp and work the drain connection assembly from hose.

4. Remove the cotter pin from the end of check valve housing and remove the check valve ball and spring.

5. Clean both the ball and spring. Clean the inside of the tubing gooseneck and housing. Flush the drain pan and the piping.

6. Install the check valve ball and spring in their housing and secure them with the cotter pin.

7. Install the drain connection assembly into hose and tighten the hose clamp.

8. Install the mist eliminator and top cover panel assembly. Install the front lower panel.

b. Troubleshooting. Troubleshooting procedures and instructions for the isolation of causes of common problems that may arise during operation are listed in table 4-7.

Table 4-7. Troubleshooting Guide

Trouble	Probable Cause	Remedy
a. Compressor will not start.	1. No power to air conditioner.	1. Connect power.
	2. Selector switch improperly set.	2. Set selector switch to "COOL".
	3. Contacts of circuit breaker open.	3. Reset circuit breaker.
	4. Outside air temperature below 0° F.	4. Normal.
	5. Open control circuit.	5. Make continuity check of circuit. Replace defective controls or refer to higher authority.
	6. Loose electrical connections or faulty wiring.	6. Tighten loose connections. Repair wiring if necessary.
	7. Defective circuit breaker.	7. Check circuit breaker.
	8. Defective compressor motor.	8. Check motor for open windings and grounds.
b. Compressor starts but goes out on overload.	1. Fan motor failure.	1. Check fan motor.
	2. High head pressure.	2. Clean condenser coil and condenser air intake grille. Check condenser fan for proper operation. If this does not correct the trouble, refer to higher authority.
c. No heat or low capacity heat.	1. Selector switch improperly set.	1. Set selector switch to "LO HEAT" or "HI HEAT"
	2. Insufficient air movement over heating elements.	2. Check evaporator coil, mist eliminator, filters, and grilles for dirt or other obstructions. Clean if necessary.
	3. Loose connections or defective wiring in heater or fan circuits.	3. Tighten loose connections. Repair damaged wiring.
	4. Defective fan motor.	4. Test motor.
	5. Defective high temperature thermostat.	5. Replace thermostat.
d. System losing cooling capacity or otherwise indicates improper functioning.	1. Malfunction or combination of malfunctions resulting in abnormal operating pressures.	1. Run pressure test. Troubleshoot any abnormal pressure readings.

Table 4-7. Troubleshooting Guide--contd

Trouble	Probable Cause	Remedy
e. Low suction pressure.	1. Insufficient volume of air passing over evaporator coil.	1. Clean any dirt or obstructions from grilles, filters, or mist eliminator.
	2. Excessively low air temperature in the conditioned space.	2. Raise temperature control setting.
	3. Defective expansion valve.	3. Check operation of expansion valve.
	4. Clogged filter drier, restricting the flow of refrigerant in the liquid line.	4. Refer to higher authority.
f. Low discharge pressure.	1. Liquid bypass valve leaking liquid refrigerant into the suction line.	1. Check solenoid valves.
	2. Defective compressor.	2. Refer to higher authority.
g. High suction pressure.	1. High temperature in the conditioned area.	1. Condition will remedy itself as temperature is reduced.
	2. Faulty expansion valve.	2. Check operation of expansion valve.
	3. Hot gas bypass valve leaking discharge gas into suction line.	3. Replace valve.
	4. Defective valves in compressor. Compressor pumping refrigerant vapor into suction line.	4. Refer to higher authority.
h. High head pressure.	1. Insufficient volume of air passing over condenser coil.	1. Clean condenser coil and condenser air intake grille. Check condenser fan for proper operation.
	2. Overcharge of refrigerant.	2. Refer to higher authority.
i. High suction with low discharge pressure.	1. Defective compressor valves.	1. Refer to higher authority.
j. Low suction and discharge pressures.	1. Lack of refrigerant.	1. Check for bubbles in liquid sight indicator. Check for leaks.

c. Testing procedures. The test procedures given herein should be used in conjunction with the troubleshooting chart to isolate malfunctions and verify troubleshooting results. Remedies that are beyond the scope of operational maintenance should be referred to maintenance personnel having the proper tools, equipment, and information needed to perform the repairs.

(1) Circuit breaker. The circuit breaker will trip instantaneously if there is a short in the compressor motor. It cannot be switched on again until the compressor has been replaced. If the circuit breaker is suspected of being defective, it can be checked by attaching two insulated jumper wires, one to each of the two lower terminals on the breaker, and then momentarily touching the other ends of the jumper wires to the two upper terminals on the breaker; touch the jumper attached to the lower left terminal to the upper left terminal and the jumper on the lower right terminal to the upper right terminal. If the compressor motor starts when the jumpers are touched to the upper terminals, the circuit breaker is defective and must be replaced.

(2) Control circuit. The cause for a system's failure to operate can be greatly narrowed if the control which caused the failure can be isolated. It is the function of safety devices to open the circuit under certain conditions; therefore, additional checking may be required to determine whether the safety device is open because it is defective or is performing its designed function. The following steps contain instructions for checking the control circuit and additional information on safety devices.

(a) Disconnect the power from the air conditioner.

(b) Test the continuity across each control in the affected circuit with an ohmmeter.

(c) Replace any defective parts or refer to higher authority, taking into consideration that open safety devices may not be defective.

(d) The outdoor air thermostatic switch will open the circuit when the outdoor air is below 0° F $\pm 3^{\circ}$, if the switch is cutting out above 0° F $\pm 3^{\circ}$, it must be replaced.

(e) The circuit breaker will break the circuit if the compressor is drawing high current caused by high head pressure, defective compressor motor, or low voltage. Refer to (1) above for circuit breaker test.

(f) The compressor winding thermal cutout will open if compressor is not receiving adequate cooling, head pressure is high, or voltage is low. Refer to the compressor wiring diagram (fig 4-27).

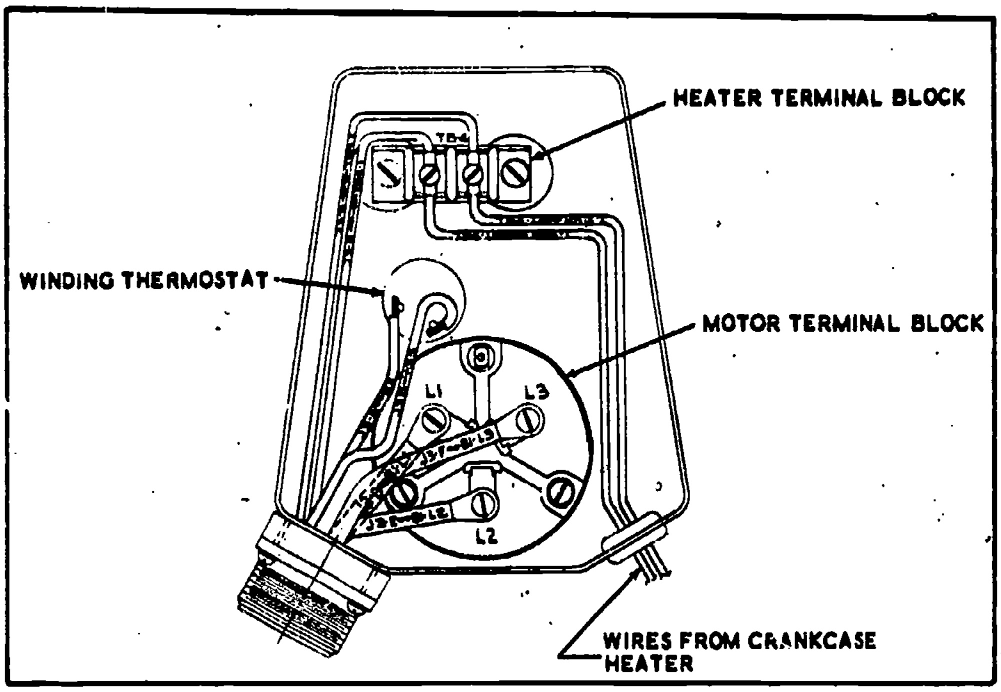


Fig 4-27. Compressor wiring diagram.

(3) Motors. There are three motors in the air conditioner: the compressor motor, the condenser fan motor, and the evaporator fan motor. The following test procedures apply to all motors.

(a) Disconnect the power supply to the unit and test the continuity across each combination of the motor terminals. Lack of continuity indicates an open winding.

(b) Place one contact of insulation tester or megger, if available, against the motor housing and the other against one of the terminals of the motor. If the reading is substantially below 1 megohm, the motor is grounded.

(4) Refrigerant solenoid valves. Test the valves as follows:

(a) Energize the valve and note if the valve clicks. If it fails to click, check the coil connection and the coil wiring. Replace or repair the wiring as required.

(b) Place your hand on the downstream piping from the valve; if the piping warms, the valve is opening properly. If the piping cools, the valve is not opening fully. Attempt to free the valve by tapping the valve body. If this fails, refer to higher authority for replacement of the coil or valve.

(5) Hot gas bypass solenoid valve. Energize the valve and place your hand on the downstream piping. If the piping warms up immediately, the valve is operating properly. If the piping warms up slowly or fails to warm, check the coil connection and coil wiring. If this fails to correct the condition, refer to higher authority.

(6) Evaporator expansion valve. A faulty evaporator expansion valve will result in overfeeding or underfeeding the evaporator.

(a) Overfeeding the evaporator coil results in an abnormally high suction pressure and, extreme cases, the carryover of liquid to the compressor. The condition is usually caused by an improper expansion valve superheat adjustment or the remote bulb of the valve not making good contact with the suction line. Tighten the remote bulb clamp and make certain that the full length of the bulb is contacting the bare suction line. If this fails to correct the symptom, the superheat adjustment of the valve should be checked. Refer to higher authority.

(b) Underfeeding of the evaporator results in an abnormally low suction pressure. The operation of the power element is tested in the following manner.

1. Stop the system and allow the suction line to warm up to room temperature.

2. Remove the remote bulb from the suction line and place it in a container of ice.

3. Start the system.

4. Remove the bulb from the container and warm it in your hand; at the same time feel the suction line. If a temperature drop is noticed, the power element is operating. If there is little change in the suction line temperature, the power element is faulty and must be replaced.

5. Refer to higher authority for power element replacement and for checking the valve superheat adjustment.

Caution: Do not allow liquid to enter the suction line for any longer than is necessary to check the operation of the valve. Excessive floodback will damage the compressor.

(7) System pressure test. Install pressure gages on the gage ports of the suction and discharge diaphragm valves. Turn valves two turns to open, exposing gages to the system pressure. Compare the gage readings with the normal ranges of system pressures shown in table 4-8.

Table 4-8. Normal Operating Pressures-PSIG

OUTDOOR AMBIENT - DEGREES F				
	50	75	100	125
90° F DB RETURN AIR TO UNIT				
Suction Discharge	58 - 65 125 - 160	58 - 70 175 - 210	60 - 75 255 - 295	75 - 90 370 - 410
80° F DB RETURN AIR TO UNIT				
Suction Discharge	58 - 65 120 - 155	58 - 70 170 - 205	60 - 75 250 - 290	65 - 75 370 - 410

(8) Leak test. Check all piping and connections with a halide leak detector. The halide leak detector consists mainly of a small bottle of propane gas (sometimes alcohol) with a burner, valve, and exploring tube. With the flame lit and adjusted slightly above the top of the burner, the exploring tube is placed at the point of inspection. A sampling of air from this point will be drawn to the burner through the exploring tube. If refrigerant is present in the air sample, the color of the flame will change; greenish tinge for small leaks and purple for large leaks. If any leaks are present, the condition shall be reported to higher authority for correction and recharging.

d. Repairs. Repairs and replacements of defective parts are limited to those covered in the following paragraphs of this section. Repair and replacement beyond the scope of operational maintenance should be referred to maintenance personnel having the proper tools, equipment, and information to perform the needed operations.

(1) Heater thermostat. The heater thermostat is designed to cut out at 194° and automatically reset at 140° F. If the switch becomes inoperative proceed as follows:

(a) Disconnect the power from the unit.

(b) Remove all screws, flat washers, and lockwashers securing the top cover panel assembly to the casing. Lift the panel off the air conditioner.

(c) Disconnect the switch from the heaters.

(d) Remove the two mounting screws and switch.

(e) Install the new switch and mounting screws.

(f) Connect the switch leads to the heaters as shown in wiring diagram.

(g) Install the top cover panel assembly and secure the panel with screws, flat washers, and lockwashers.

(2) Outside air thermostatic switch. Replace the outside air thermostatic switch as follows:

(a) Remove the evaporator air intake grille and filter.

(b) Remove the switch mounting screws, nuts, and flat washers. Remove the gasket.

(c) Disconnect the switch leads and remove the switch.

(d) Connect the leads and install the new switch and gasket on the casing. Secure with screws, nuts, and flat washers.

(e) Install the filter and intake grille.

(3) Control panel. Replace the control panel as follows:

(a) Remove the front panel.

(b) Remove the evaporator air intake grille and filter.

(c) Loosen the clamp screw and pull the thermostatic bulb from the clamp and into compressor compartment.

(d) Disconnect the harness connector at the control panel receptacle.

(e) Remove the screws, flat washers, and lockwashers securing the control panel to the mounting bracket. Lift the panel from the bracket.

(f) Install the control panel on the bracket and secure it with screws, flat washers, and lockwashers.

(g) Connect the wiring harness to the control panel.

(h) Install the bulb and tighten the clamp.

(i) Install the air intake filter and grille.

(j) Install the front panel.

(4) Selector switch. (See figure 4-28). Replace the selector switch as follows:

(a) Remove the control panel as instructed in (3)(a) through (e) above.

(b) Remove the control knobs.

(c) Remove the screws and nuts securing the control panel case to the mounting plate. Partially separate the plate from the case.

(d) Disconnect the wiring from the switch and remove the switch.

(e) Install the switch in the case and connect the wiring. Make sure the wiring connections are correct.

(f) Install the mounting plate on the case and secure them with screws and nuts.

(g) Install the control knobs.

(h) Install the control panel as instructed in (3)(f) through (j) above.

(5) <u>Temperature control.</u> (See figure 4-28). Replace the temperature control on the control panel as follows:

(a) Remove the control panel ((3)(a) through (e) above).

(b) Remove the control knobs.

(c) Remove the screws and nuts securing the mounting plate to the case. Partially separate the panel from the case.

(d) Disconnect the wiring from the temperature control.

(e) Remove the switch mounting screws and self-locking nuts, and remove the switch.

(f) Install the switch on the mounting plate and secure it with screws and self-locking nuts.

(g) Connect the wiring to the switch.

(h) Install the panel on the case and secure it with screws and nuts.

(i) Install the control knobs.

(j) Install the control panel as instructed in (3)(f) through (j) above.

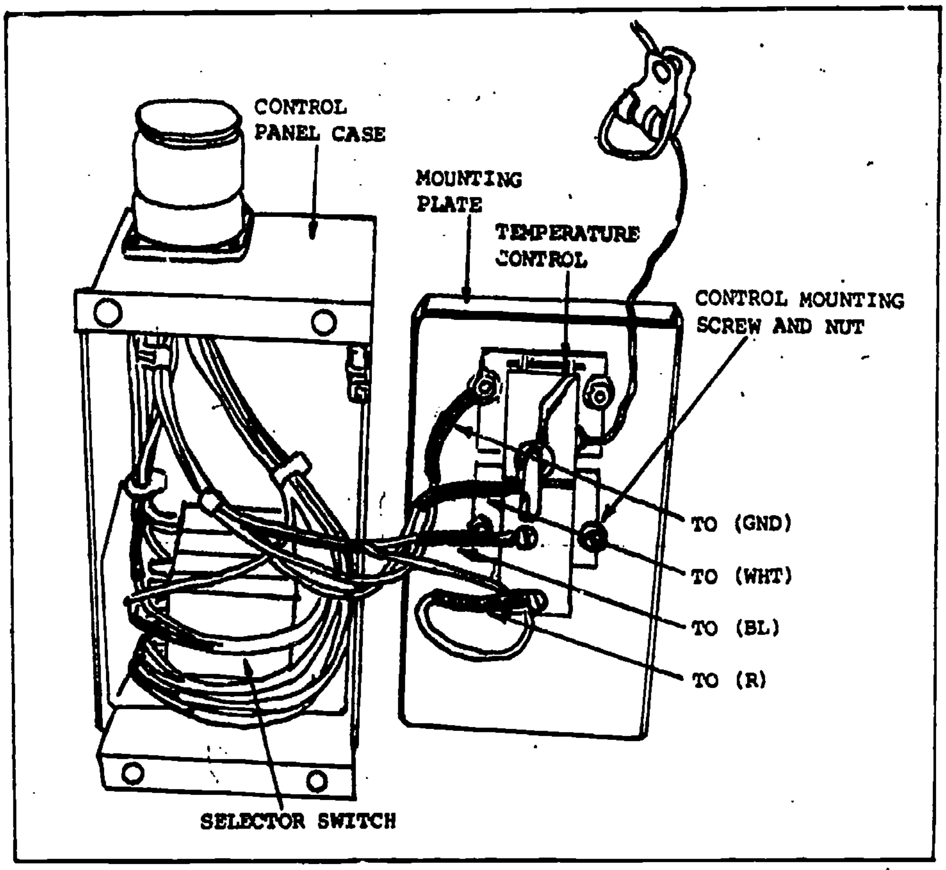


Fig 4-28. Control panel with case removed.

4-10. HORIZONTAL UNITS.

a. General. The air conditioners being procured for FMF application also include two horizontal models as shown below in table 4-9. Maximum use is being made of 60Hz power to the exclusion of 400Hz power. The Marine Corps will make use of the skid-mounted, remote version wherever possible, as it is the easiest to maintain and has the greatest degree of flexibility of application.

Table 4-9. Horizontal Units

NOMENCLATURE	POWER	NOMINAL COOLING
Air Conditioner, Marine Corps Std, Horizontal, MC9HAL6-208	60Hz	9,000 Btu/hr
Air Conditioner, Marine Corps Std, Horizontal, MC9HAL6-208	60Hz	18,000 Btu/hr

Both horizontal units are constructed of durable, lightweight materials and are designed to meet military specifications for use on shelters, vans, compartments, and trailers in mobile, portable, and transportable applications. They provide complete environmental air conditioning (including cooling, heating, ventilation, dehumidification, and filtering).

b. Technical description. Both the horizontal models and the vertical models are designed for economy of space and ease of movement, and for minimum power requirements, without sacrificing maximum efficiency, reliability, or maintainability. All components are manufactured to insure complete interchangeability with air conditioners of the same capacities. The units are self-contained, air-cooled, and motor-driven. The compressors are hermetically sealed and have a force-feed lubrication system. Both the evaporator and the condenser are constructed as compact, fin/tube heat exchangers, with lightweight aluminum fans, directly connected to squirrel-cage, induction-type motors. Condensate drain pans are protected from corrosion by a coat of nonabsorbent latex material. In the vertical models, pipe nipples are flush-mounted on each side of the drain pan to allow condensate drainage when the unit is tilted in any direction. In the horizontal models, condensate is allowed to drain when the air conditioner is tilted up to 8° from horizontal, in any direction. The evaporator sections are insulated with foam rubber for protection against moisture condensation and to reduce external heat gain to the unit. The control panel is designed so that it can be removed from the unit to allow remote mounting of the air conditioner. Thermostatic control provides automatic heating and cooling modes. Two-stage heating is obtained with tubular, resistance-type heating elements. The cooling mode utilizes a hot gas bypass system which permits the compressor to run continuously, thereby avoiding voltage fluctuations due to frequent starting and stopping. Each unit has an opening covered with a removable plate for interfacing (connecting) with an NBC filter unit. Both condenser and fresh-air openings in all units have a fine mesh screen to prevent entry of insects. The condenser fan inlet and discharge openings are protected by heavy-duty guards. Provision for admission of fresh air is provided for all operation modes of all units. The flow of fresh air is controlled by an adjustable damper. The unit is constructed of a heavy gage aluminum external casing with removable panels. This affords easy access to unit components for maintenance and repair. The air conditioners are designed to operate in excess of 4,000 hours without major overhaul.

d. Horizontal models. The MC9HAL6-208 and the MC18HAL6-208 were selected for FMF applications requiring the air conditioner to be mounted either inside, through the wall, or hung on the exterior wall of the application.

(1) Technical characteristics. The following tables give some of the technical characteristics of the horizontal model air conditioners.

Table 4-10. Performance Data

Model	Electrical				Cooling	Heating
	Volts	Hz	Ø	Kw	Btuh	Btuh
MC9HAL6-208	208	50/60	3	3.0	9,000	7,000
MC18HAL6-208	208	50/60	3	6.5	18,000	14,300

Table 4-11. Dimensions and Weights

Model	Length	Width	Height	Weight
MC9HAL6-208	26 in	23.8 in	16 in	200 lb
MC18HAL6-208	27.8 in	30 in	20 in	250 lb

(2) Initial service and installation. When unloading the air conditioner, be sure to use a forklift or handtruck that has at least a 300-lb capacity. Keep the air conditioner right side up during the unloading. If possible, unload the unit near the place it is going to be installed. Remove the crate, being careful not to damage the air conditioner. Inspect the entire air conditioner for signs of damage and loose or missing hardware. Make sure that all wiring, lines, and tubing are secure. Pay particular attention to the evaporator and condenser coils and main power receptacle connectors. Make sure that visible wiring and insulation is not frayed or broken. Check the evaporator and condenser fan motors. Report all damage and defects to organizational maintenance. Perform the services as listed below in table 4-12. Be sure all hardware is securely in place.

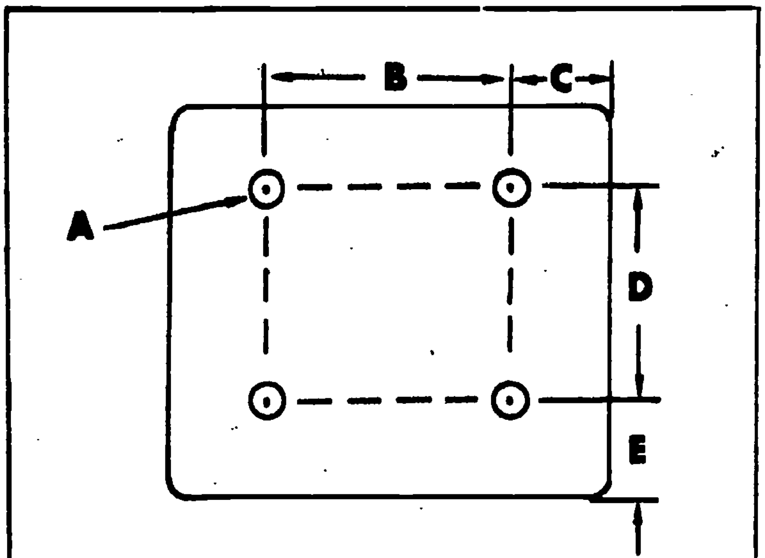
Table 4-12. Initial Checks and Services

Item to be inspected	Procedure
Evaporator outlet louver.	Remove obstructions. Clean louvers. Tighten mounting screws.
Evaporator inlet louver.	Remove obstructions. Clean louvers. Check for ease of operation. Tighten mounting screws.
Condenser cover.	With cover rolled up for operation, check securing ties for damage.
Fresh air inlet screen.	Inspect for obstructions and loose mounting. Remove obstructions, clean and tighten loose mounting screws.
Drains.	Inspect drains for obstructions. Remove obstructions.

Table 4-12. Initial Checks and Services--contd

Item to be inspected	Procedure
Condenser louver.	Check for loose mounting and damaged louvers.
Condenser guard.	Remove obstructions and clean guard.
Controls.	Check for visual damage. Check operation of damper control.
Main power receptacle connector.	Check for secure power connection. Tighten if necessary.

Remember, when the air conditioner is shipped from the factory, it is assembled and ready for operation (to include a full charge of refrigerant and compressor oil). Install the unit on a firm, level surface to allow proper condensate drainage. The unit should be installed in such a way as to permit easy access to it by operator and maintenance personnel. Make sure that obstructions are removed so that the unit will have sufficient air. Base mounting hole dimensions are shown below in figure 4-29.



MODEL	A	B	C	D	E
MC9HAL6-208	3/4-24UNF	11 3/4"	6"	16 3/16"	4 1/4"
MC18HAL6-208	3/8-24 UNF 3B	24 1/2"	2 3/4"	17 9/16"	4 7/32"

Fig 4-29. Base mounting holes.

Caution: For safe operation, connect a No. 10AWG (min) ground wire to ground connection.

Connect the main power cable. If air ducts are required, connect them also, mounting an air filter in the ductwork if an evaporator return air duct is required. Just a little word of caution here---if you operate the unit without filtration, the coils will become clogged.

(3) Operation. The following list of steps is a brief explanation of things to do to put the horizontal model air conditioners into operation and to shut them down. Refer to figures 4-30 and 4-31 for location of controls.

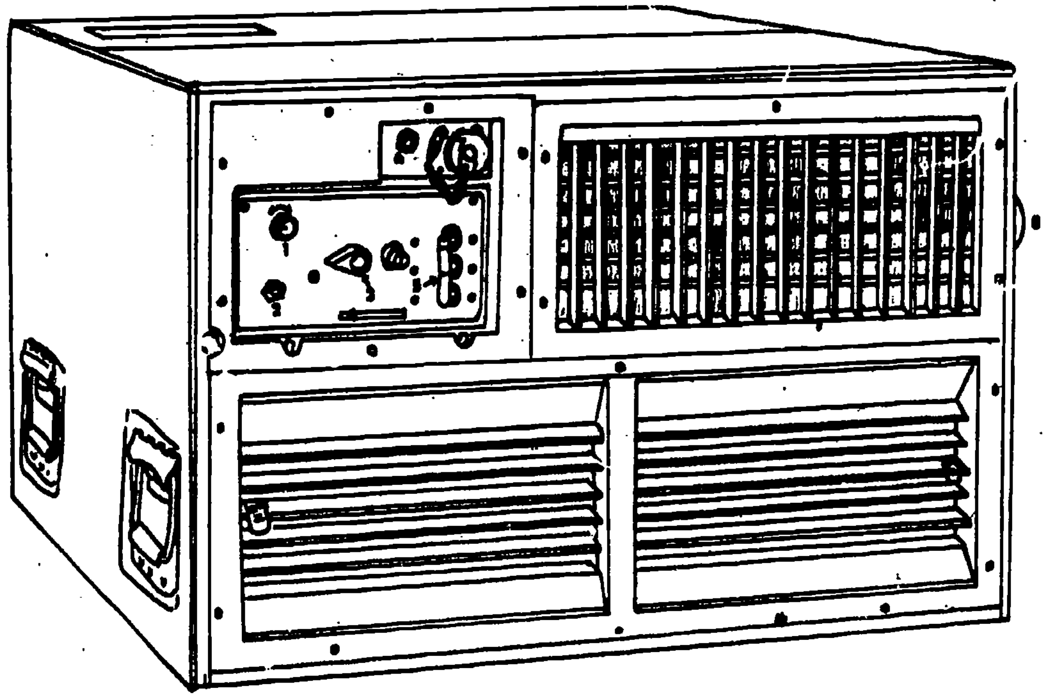


Fig 4-30. Horizontal air conditioner, front view.

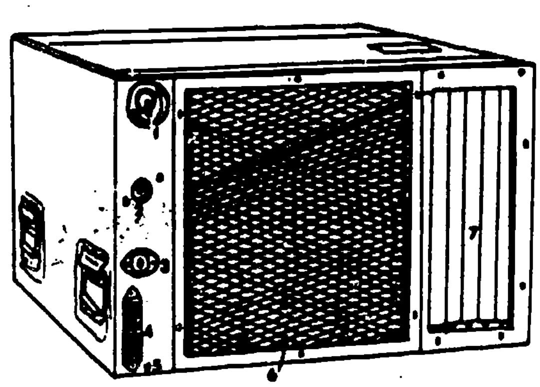


Fig 4-31. Horizontal air conditioner, rear view.

For Cooling

Step 1. Be sure condenser cover is rolled up.

Step 2. Lift tabs and open intake louvers.

Step 3. Turn vent control actuator to close damper door.

Step 4. Turn temperature selector switch to furthest clockwise position (warmer).

Step 5. Turn on control circuit breaker.

Step 6. Turn mode selector switch to VENTILATE and allow fan to reach full speed, then turn to COOL.

Step 7. Adjust temperature selector switch to degree of cooling desired.

Step 8. Set evaporator fan speed switch to desired postion.

Step 9. Adjust air outlet louvers to direct airflow as desired.

For Heating

Steps 1-3. Same as above.

Step 4. Turn temperature selector switch to furthest counterclockwise position (cooler).

Step 5. Same as above.

Step 6. Turn mode selector switch to LOW HEAT. Turn to HIGH if more heat is desired.

Step 7. Turn vent control actuator to open damper door.

Step 8. Partially close intake louver blades.

Step 9. Adjust temperature selector switch to desired enclosure temperature.

Step 10. Adjust air outlet louvers to direct airflow as desired.

For Ventilating

Step 1. Be sure condenser cover is rolled up.

Step 2. Turn vent control actuator to open damper door.

Step 3. Partially close intake louvers.

Step 4. Turn mode selector switch to VENTILATE.

To Stop Unit

Step 1. Turn mode selector switch to OFF.

Step 2. Close intake louvers.

Step 3. Turn actuator to close fresh air vent damper.

Note: If the unit is going to be shut down for an extended period of time, cover the condenser and evaporator grilles and disconnect the power cable.

(4) Maintenance. The principles and procedures covered earlier in the course apply, in most cases, to the horizontal model air conditioners also. So, we will cover here

some charts and precautionary notes and refer you to the pertinent TM (TM 5-4120-239-14 for the 9,000 Btu units and TM 5-4120-243-14 for the 18,000 Btu units) for a more detailed explanation to follow in maintaining or repairing the unit. Also TM-4120-15/1A will provide help with the technical characteristics of our air conditioners.

Note: The evaporator fan and condenser fan motors are permanently lubricated by the manufacturers and require NO additional lubrication. The compressor and compressor motor are fully lubricated by the manufacturers and require NO additional lubrication.

Table 4-13. Operator's Preventive Maintenance

Interval and sequence number			Item to be inspected	Procedure
Before operation	During operation	After operation		
1	--	12	Evaporator outlet louver.	Remove obstructions. Clean louvers. Tighten mounting screws.
2	--	13	Evaporator inlet louver.	Remove obstructions. Clean louvers. Check for ease of operation. Tighten mounting screws.
3	--		Condenser cover.	With cover rolled up for operation, check securing ties for damage.
4	--	14	Fresh air inlet screen.	Inspect for obstructions and insecure mounting. Remove obstructions clean and tighten loose mounting screws.
5	--	15	Drains.	Inspect drains for obstructions. Remove obstructions.
6	--	16	Condenser louver.	Check for insecure mounting and damaged louvers.
7	--	17	Condenser guard.	Remove obstructions and clean guard.
8	--		Controls.	Check for visual damage. Check operation of damper control.
9	--		Main power receptable connector.	Check for secure power connection. Tighten if necessary.
	10		Liquid sight indicator.	Check for moisture and low refrigerant charge. Yellow indicates moisture, bubbles or milky appearance indicates low charge.
	11		Air conditioner operation.	Check for abnormal operation, vibration, unusual noise, failure to respond to controls.
		18	Condenser cover.	Check for damaged fasteners.

Table 4-14. Operator's Troubleshooting Chart

Malfunction	Probable Cause	Corrective Action
1. Air conditioner fails to operate.	a. Main power cable disconnected.	a. Connect power cable to receptacle.
	b. Control or compressor circuit breaker in "OFF" position.	b. Reset circuit breaker.
	c. Mode selector switch in "OFF" position.	c. Turn selector knob to desired operation.
2. Insufficient cooling.	a. Mode selector switch improperly positioned.	a. Set switch to COOL.
	b. Temperature selector switch set incorrectly.	b. Adjust setting to COOLER.
	c. Insufficient air passing over evaporator coil.	c. Open evaporator inlet louvers. Remove any obstructions from evaporator inlet and outlet louvers.
	d. Too much outside air entering unit.	d. Close or adjust damper door.

Table 4-14. Operator's Troubleshooting Chart--contd

Malfunction	Probable Cause	Corrective Action
	e. Insufficient refrigerant in system.	e. Check liquid sight indicator.
	f. Evaporator fan speed switch set at low speed.	f. Reset switch to high speed.
	g. Insufficient air passing through condenser coil.	g. Remove any obstruction from condenser fan inlet and outlet. Make sure louvers are open.
3. No heat or low capacity heat.	a. Mode selector switch improperly.	a. Set switch to LOW HEAT or HIGH HEAT.
	b. Temperature selector switch set incorrectly.	b. Reset switch.
	c. Insufficient air movement over heater.	c. Remove any obstructions from evaporator air intake and discharge louvers. Make sure intake louvers are open.

Table 4-15. Organizational Preventive Maintenance-Monthly Schedule

Sequence number	Item to be inspected	Procedures
1	Evaporator inlet and discharge louvers	Clean, inspect for damage. Replace if necessary.
*2	Air filter	Inspect and service or replace as necessary.
3	Condenser guard	Inspect and clean. Replace if damaged.
*4	Fresh air screen	Inspect and clean or replace as necessary.
5	Evaporator coil	Clean and inspect.
6	Condenser coil	Clean and inspect.
7	Condenser cover	Inspect, clean, and repair or replace if damaged.
8	Housing covers	Repair or replace damaged covers.
9	Fans	Check fans for damage. Check motors for evidence of overheating. Replace damaged fans and motors.
10	Heaters	Check for breaks in wiring and insulation. Tighten loose connections.
11	Controls and instruments	Check for damage to any controls in control module. Replace defective parts or control module.
12	Junction box components	Check for defective relays and circuit breaker.
13	Wiring and electrical components	Check for damaged or frayed wiring. Check for defective electrical components. Repair or replace defective wiring. Replace defective electrical components.
14	Liquid sight indicator	Check for damage.
15	Refrigeration system	Check compressor, valves, and piping for damage. Report damage to 3d echelon maintenance

*Weekly instead of monthly

Table 4-16. Organizational Troubleshooting Chart

Malfunction	Probable Cause	Corrective Action
1. Air conditioner fails to operate.	a. Main power cable disconnected.	a. Connect cable.
	b. Main power receptable connector defective.	b. Replace connector.
	c. Loose electrical connections.	c. Tighten connections.
	d. Rotary selector switch improperly adjusted or defective.	d. Turn selector switch to COOL or VENTILATE. Replace a defective switch.
	e. Control or compressor circuit breaker in OFF position or defective.	e. Reset circuit breaker(s) or replace.
	f. Defective phase sensing relay.	f. Replace defective phase sensing relay.

Table 4-16. Organizational Troubleshooting Chart--contd

Malfunction	Probable Cause	Corrective Action
	g. Defective control circuit transformer.	g. Replace defective transformer.
	h. Defective control circuit rectifier.	h. Replace defective rectifier.
2. Insufficient cooling.	a. Mode selector switch improperly positioned.	a. Set switch to COOL.
	b. Insufficient refrigerant charge.	b. Report condition to 3d echelon maintenance.
	c. Condenser coil dirty.	c. Clean coil.
	d. Evaporator return air filter dirty.	d. Clean filter.
	e. Temperature selector switch set incorrectly or defective.	e. Adjust setting or replace switch.
	f. Fresh air damper control set incorrectly or incorrectly adjusted.	f. Check setting of control. Adjust fresh air damper control.
	g. Defective compressor.	g. Report condition to 4th echelon maintenance.
	h. Evaporator outlet louver bent or stuck in closed position.	h. Repair or replace louver.
	i. Evaporator fan motor worn or defective.	i. Report deficiency to 3d echelon maintenance or replace motor.
	j. Evaporator fan loose or defective.	j. Tighten or replace fan.
	k. Evaporator fan motor thermal protector defective.	k. Replace thermal protector.
3. Evaporator or condenser fan fails to operate.	a. Main power cable disconnected.	a. Connect cable.
	b. Defective fan motor.	b. Replace motor.
	c. Evaporator or condenser fan defective or binding.	c. Relieve binding or replace.
	d. Defective condenser motor thermal protector.	d. Replace thermal protector.
	e. Defective evaporator fan motor thermal protector.	e. Replace thermal protector.
	f. Defective receptacle or plug connectors.	f. Replace connectors or receptacles.
	g. Defective high-low condenser fan thermostatic switch.	g. Replace thermostatic switch.
	h. Defective condenser fan relay.	h. Replace defective relay.
	i. Defective evaporator fan speed control switch.	i. Replace defective switch.
	j. Mode selector switch improperly adjusted or defective.	j. Replace a defective switch.
4. Compressor will not start.	a. Compressor or control circuit breakers or selector switch improperly set.	a. Reset controls properly.
	b. Contacts of high- or low-pressure cutout switch open.	b. Reset pressure switches. Report deficiency to 3d echelon maintenance if condition continues.
	c. Loose electrical connections or faulty wiring.	c. Tighten loose connections. Repair wiring if necessary.
	d. Open control circuit.	d. Make continuity check of circuit.
	e. Defective circuit breaker.	e. Replace defective control or compressor circuit breaker.
	f. Defective control transformer.	f. Replace defective transformer.
	g. Defective rectifier.	g. Replace defective rectifier.
	h. Defective time delay relay.	h. Replace defective relay.
	i. Defective compressor relay.	i. Replace defective relay.

Table 4-16. Organizational Troubleshooting Chart--contd

Malfunction	Probable Cause	Corrective Action
	j. Defective starting relay or capacitor (single-phase compressor).	j. Replace defective capacitor or relay.
	k. Defective phase sequence relay (three phase compressor).	k. Replace defective relay.
	l. Defective or tripped compressor internal temperature overload switch.	l. Allow unit to cool. Report deficiency to 3d echelon maintenance if condition continues.
	m. Defective compressor motor.	m. Check and report deficiency to 4th echelon maintenance if motor is defective.
5. Compressor starts but goes out on overload.	a. Condenser fan motor failure.	a. Replace defective motor.
	b. High head pressure.	b. Clean condenser coil and louvers. Check fan for proper operation.
	c. Defective or "tripped" compressor internal temperature overload switch.	c. Allow unit to cool. Report deficiency to 3d echelon maintenance if condition continues.
	d. Improperly adjusted or defective refrigerant control valves.	d. Report condition to 3d echelon maintenance.
	e. Evaporator fan speed switch set at low speed.	e. Reset switch to high speed.
6. Evaporator air output volume low.	a. Dirty or damaged filter or louvers.	a. Clean or replace filter. Clean or replace louvers as required.
	b. Iced or dirty evaporator coil.	b. De-ice and clean coil.
	c. Defective evaporator fan.	c. Replace fan.
	d. Defective fan motor.	d. Replace motor.
	e. Evaporator fan speed switch set at low speed.	e. Reset switch to HIGH speed.
7. Condenser air output volume low.	a. Dirty condenser coil or guard.	a. Clean coil and guard.
	b. Defective HIGH-LOW condenser fan thermostatic switch.	b. Replace switch.
	c. Defective condenser fan.	c. Replace fan.
	d. Defective fan motor.	d. Replace motor.
	e. Air outlet louvers stuck in closed position.	e. Free louvers and control cable. Adjust control or refer to 3d echelon maintenance if actuating cylinder is not functioning properly.
8. Air conditioner fails to heat.	a. Selector switch improperly adjusted.	a. Reset selector switch to LO HEAT or HI HEAT.
	b. Temperature control switch set incorrectly.	b. Reset switch.
	c. Dirty evaporator return air filter.	c. Clean filter.
	d. Defective evaporator fan motor.	d. Replace motor.
	e. Defective temperature selector switch or mode selector switch.	e. Replace defective switch.
	f. Defective heaters or wiring.	f. Tighten connections and repair damaged wiring. Replace defective heater.
	g. Defective heater relay.	g. Replace defective relay.
	h. Defective heater high temperature cutout thermostatic switch.	h. Replace defective thermostatic switch.
9. Excessive noise.	a. Evaporator or condenser fan.	a. Tighten fans on shafts. Tighten all mounting screws.
	b. Evaporator or condenser fan motor worn or defective.	b. Replace worn or defective motor.
	c. Compressor knocks or chatters.	c. Stop air conditioner and report condition to 3d echelon maintenance.

Table 4-17. Field Maintenance Level Troubleshooting Chart

Malfunction	Probable Cause	Corrective Action
1. Compressor will not start.	a. Open control circuit.	a. Make continuity check of control circuit.
	b. Defective circuit breaker.	b. Replace circuit breaker.
	c. Defective starting relay or capacitor (single-phase compressor).	c. Replace defective capacitor or relay.
	d. Defective phase sequence relay (three-phase compressor).	d. Replace defective relay.
	e. Defective high- or low-pressure cutout switch.	e. Replace defective switch.
	f. Defective compressor motor or thermal protector.	f. Replace compressor.
2. Compressor starts but goes out on overload.	a. Defective compressor run capacitor (single-phase compressor).	a. Replace capacitor.
	b. Defective compressor.	b. Replace compressor.
3. Little or no heating capacity.	a. Loose electrical connections or faulty wiring.	a. Check wiring and repair if necessary.
	b. Defective temperature selector switch or mode selector switch.	b. Replace defective switch.
	c. Defective heaters.	c. Replace defective heaters.
	d. Defective heater high temperature cutout switch.	d. Replace defective thermostatic switch.
	e. Defective heater relay.	e. Replace defective heater relay.
	f. Defective evaporator fan motor.	f. Repair motor.
4. Insufficient cooling.	a. Low refrigerant charge.	a. Charge refrigerant system.
	b. Dehydrator clogged.	b. Replace clogged dehydrator.
	c. Pressure regulator valve defective.	c. Replace defective valve.
	d. Air in refrigerant system.	d. Purge and charge system.
	e. Thermal expansion valve defective.	e. Replace defective valve.
	f. Defective solenoid valve.	f. Replace defective solenoid valve.
	g. Defective quench thermal expansion valve.	g. Replace defective valve.
5. Low suction pressure.	a. Defective thermal expansion valve.	a. Replace defective valve.
	b. Dehydrator clogged or defective.	b. Remove restriction or replace dehydrator.
	c. Pressure regulating valve defective.	c. Replace defective valve.
6. Low discharge.	a. Compressor not pumping due to defective compressor.	a. Replace defective compressor.
	b. Defective high-low condenser fan thermostatic switch.	b. Replace defective switch.
7. Low suction and discharge pressure.	a. Lack of refrigerant.	a. Check sight glass for bubbles or milky appearance and check system for leaks. Repair leaks and add refrigerant as necessary.
	b. Defective thermal expansion valve.	b. Replace valve.
	c. Defective quench thermal expansion valve.	c. Replace valve.
8. High suction pressure.	a. Defective thermal expansion valve.	a. Replace valve.
	b. Defective pressure regulator valve.	b. Replace valve.

Table 4-17. Field Maintenance Level Troubleshooting Chart--contd

Malfunction	Probable Cause	Corrective Action
9. High head pressure.	a. Overcharge of refrigerant.	a. Discharge refrigerant as necessary.
	b. Condenser coil dirty.	b. Clean coil.
	c. Defective condenser fan motor.	c. Repair motor.
	d. Inoperative or improper adjustment of condenser louvers or actuating mechanism.	d. Adjust and clean as necessary. Replace inoperative components.
	e. Compressor defective.	e. Replace defective compressor.
	f. Quench thermal expansion valve defective.	f. Replace defective valve.

Note: The cause for a system's failure to operate can be determined much easier if the control which caused the failure can be isolated. It is the function of safety devices to open the circuit under certain conditions; therefore, additional checking may be required to determine whether the device is open because it is defective or because it is performing its designed function. The following steps contain instructions for checking the control circuit.

Step 1. Disconnect power from air conditioner.

Step 2. Test the continuity across each control in the affected circuit with a ohmmeter, using the schematic as a guide. Check the wiring diagrams for connections.

Step 3. Replace defective parts.

Warning: Avoid bodily contact with liquid refrigerant and avoid inhaling refrigerant gas. Be especially careful that refrigerant does not come in contact with the eyes. In case of refrigerant leaks, ventilate area immediately.

As stated earlier, detailed explanations for maintenance and repair of the horizontal model air conditioners are found in TM 5-4120-239-14 (9,000 Btu) and TM 5-4120-243-14 (18,000 Btu). Be sure and follow the instructions therein carefully.

4-11. GENERAL SAFETY

a. General. In chapter two we discussed safety and first aid when working with refrigerants. But safety is something that an air-conditioning mechanic must never forget.

b. Electrical equipment. The Marine air-conditioning mechanic works with electrical equipment that has high voltage. Disconnect the power source when servicing or maintaining your equipment. Insure that your equipment is grounded. Do not wear metal bracelets, etc. when working around electrical gear.

c. Operating equipment. When you are working around equipment that is operating, you should make sure that all guards have been installed on the machine. Do not wear loose clothing around operating machinery. Do not tolerate any horseplay in the workshop.

d. Cleaning. Use only approved solvents and methods for cleaning condensers, etc. Do not use steam on condenser coils. If any solvent gets on skin, wash immediately with a mild soap and flush with plenty of water. Seek immediate medical attention if solvent gets in your eyes or if you should happen to swallow some.

e. Cleanliness. Remember to keep your tools clean and your work area uncluttered. A greasy tool can slip and cause an injury to yourself or fellow workers. Keep oily rags in a covered metal container that is used for this purpose only. Cigarette smoking is a bad practice anywhere but especially in the workshop. Smoking should not be permitted in the workshop.

f. First Aid. Immediate medical attention is the best first aid that can be administered, but most of the time this is not possible. Prompt first aid by a fellow worker or yourself might be the difference in saving the life of a Marine.

(1) Artificial respiration. If electrical shock should occur, the victim's breathing will sometimes stop. Artificial respiration using the mouth to nose method, or the chest-pressure arm lift method must be given. If the victims heart stops, then closed-chest massage must accompany the artificial respiration. Your Marine Essential Subjects handbook gives detailed instructions on artificial respiration and heart massage, in the first aid section.

(2) Bleeding. Uncontrolled bleeding will cause death or shock. The bleeding may be controlled using a bandage dressing and applying pressure. Use a tourniquet if all other methods of controlling bleeding fail. Again refer to your Marine Essential Subjects handbook for instructions.

(3) Shock. Shock can result from any type of injury. Keep the victim breathing, heart beating, and control bleeding if any. Elevate the feet 6-8 inches if the victim is conscious. Reassuring talk is very beneficial. Refer to Marine Essential Subjects handbook for further details.

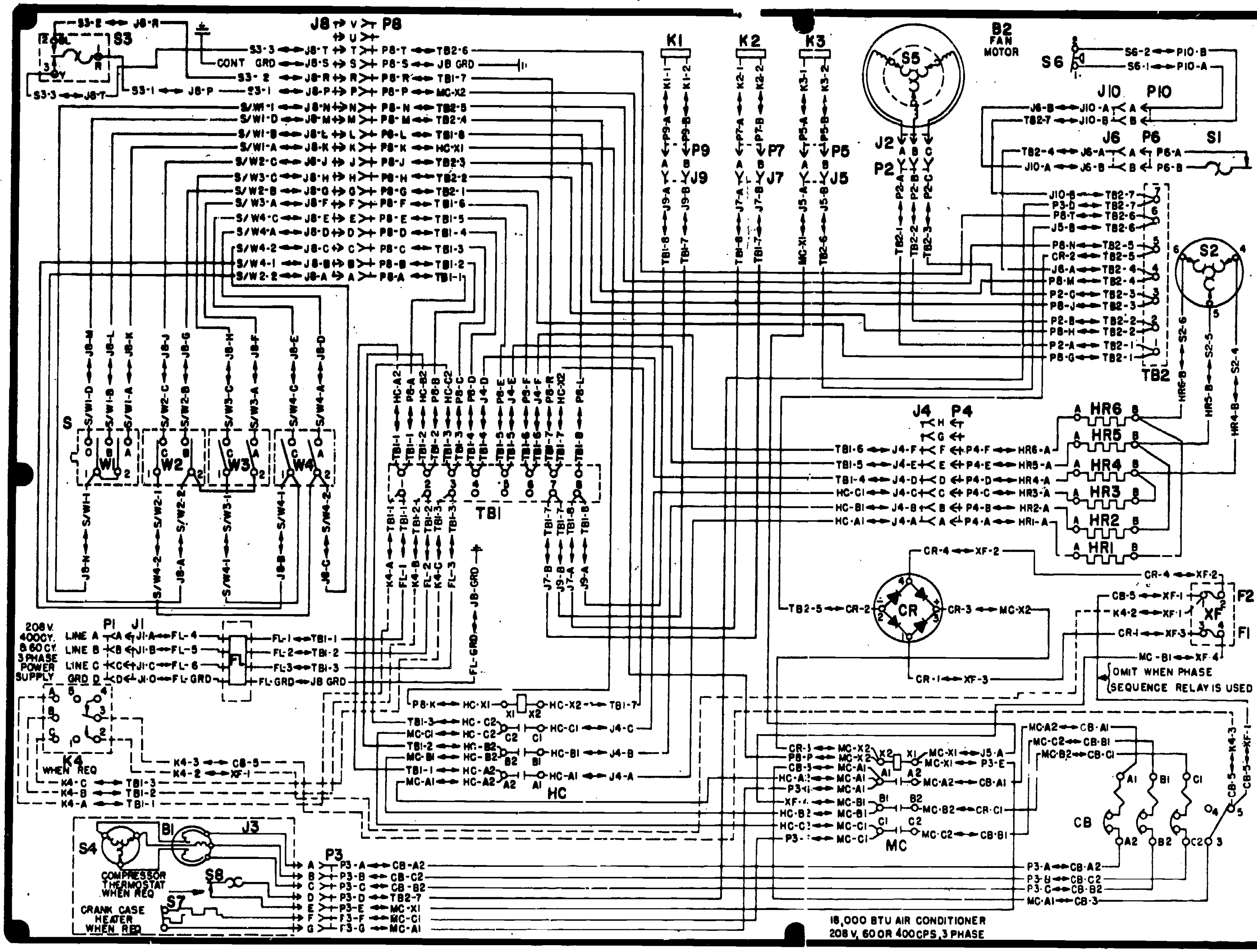
(4) Medical Attention. In any serious accident where the eyes are involved or something is swallowed, get prompt medical attention.

4-12. SUMMARY

In this chapter you have learned the proper procedures for installing window or through-the-wall units. You learned that before doing anything you must first visually inspect the units for any apparent damage or malfunction. Window units vary in capacity from 4,000 to 40,000 Btu's per hour. We also covered console units, a complete system mounted in a single cabinet. These units can be found in small clubs, PX's, messhalls, and restaurants.

This chapter covered remote units, which are located away from the space that is to be air conditioned. Troubleshooting was also covered. Always remember to consult the manufacturer's instructions when troubleshooting. Remember that each unit is used for a specific purpose and a specific set of cooling circumstances. The Marine Corps Military Standard air conditioners has been covered, the differences in models, the operational theory, also the heating and cooling capacities (remember these units have two ranges of heat). Installation of these units was covered. Remember the installation will be determined by the requirements and space limitations. As a air-conditioning mechanic, you should always insure that the unit is capable of the designated job before attempting any repairs that may not help the unit or system to accomplish the job. Remember that the Marine Corps doctrine stresses the use of 60 Hertz power over 400 Hertz and the skid mounted, remote version of the vertical air conditioner wherever possible. Safety and first aid were briefly covered. It should be remembered that a good source of information covering first aid is the Marine Essential Subjects handbook which all Marines should have and read.

*U.S. GOVERNMENT PRINTING OFFICE: 1982-0-381-318/536



SWITCH POSITION						
WAFER NO.	CONTACT NO.	1 HI HEAT	2 LO HEAT	3 OFF	4 VENT	5 COOL
1	2 & A	CLOSED	CLOSED	OPEN	OPEN	OPEN
	2 & B	OPEN	OPEN	OPEN	OPEN	CLOSED
	1 & C					
	1 & D	OPEN	OPEN	OPEN	OPEN	CLOSED
2	2 & A					
	2 & B	CLOSED	CLOSED	OPEN	CLOSED	CLOSED
	1 & C	CLOSED	CLOSED	OPEN	CLOSED	CLOSED
	1 & D					
3	2 & A	CLOSED	OPEN	OPEN	OPEN	OPEN
	2 & B					
	1 & C	CLOSED	CLOSED	OPEN	CLOSED	CLOSED
	1 & D					
4	2 & A	CLOSED	OPEN	OPEN	OPEN	OPEN
	2 & B					
	1 & C	CLOSED	OPEN	OPEN	OPEN	OPEN
	1 & D					

LEGEND		
SYMBOL	PART NO.	DISCRIPTION
J1	MS310[illegible]R22-22P	CONNECTOR-RECEPTACLE
P1	MS3106R22-22S	CONNECTOR-PLUG
J2	MS3102R14S-7P	CONNECTOR-RECEPTACLE
P2	MS3106R14S-7S	CONNECTOR-PLUG
J3	MS3102R20-15P	CONNECTOR-RECEPTACLE
P3	MS3106R20-15S	CONNECTOR-PLUG
J4	MS3102R22-23S	CONNECTOR-RECEPTACLE
P4	MS3106R22-23P	CONNECTOR-PLUG
J5	MS3102R16S-4S-W	CONNECTOR-RECEPTACLE
P5	MS3106R16S-4P-W	CONNECTOR-PLUG
J6	MS3102R16S-4S-X	CONNECTOR-RECEPTACLE
P6	MS3106R16S-4P-X	CONNECTOR-PLUG
J7	MS3102R16S-4S	CONNECTOR-RECEPTACLE
P7	MS3106R16S-4P	CONNECTOR-PLUG
J8	MS3106R22-14P	CONNECTOR-RECEPTACLE
P8	MS3100R22-14S	CONNECTOR-PLUG
J9	MS3102R16S-4S	CONNECTOR-RECEPTACLE
P9	MS3106R16S-4P	CONNECTOR-PLUG
J10	MS3102R16S-4S	CONNECTOR-RECEPTACLE
P10	MS3106R16S-4P	CONNECTOR-PLUG
TB1		TERMINAL BOARD NO.1
TB2		TERMINAL BOARD NO.2
S1		THERMOSTAT-OUTSIDE AIR
S2		HIGH TEMPERATURE CUTOUT
S3		TEMPERATURE-CONTROL
S4	WITH COMPR	THERMAL CUTOUT
S5	WITH FAN MTR.	THERMAL CUTOUT
S6		HIGH PRESSURE CUTOUT
S7		THERMOSTAT-CRANKCASE HTR
S8		COMPRESSOR THERMOSTAT
K1		SOLENOID VALVE-NORM. CLOSED
K2		SOLENOID VALVE-NORM. OPEN
K3		SOLENOID VALVE-GAS BYPASS
HC		CONTACTOR-ELECTRIC HTR
MC		CONTACTOR-COMPRESSOR MTR.
B1		COMPRESSOR MOTOR
B2		FAN MOTOR
HR		HEATER ELEMENT-120 V, 600W
S		SELECTOR SWITCH-ROTARY
CR		RECTIFIER
CB		CIRCUIT BREAKER, COMPRESSOR
K4		PHASE SEQUENCE RELAY
XF		FUSE BOARD
F1 & F2		FUSE
FL		FILTER-RFI WHEN REQ'D

Fig 4-32. Wiring diagram for A/E32C-17 & -18.

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AIR-CONDITIONING MECHANIC

Course Introduction

AIR-CONDITIONING MECHANIC is designed to provide you with a general background of air conditioners and air-conditioning systems including: theory, operational procedures, installation, servicing, and limited repair of these units and systems. This course will assist Corporals and below in MOS 1161 in becoming better qualified air-conditioning mechanics. The course will provide theoretical knowledge to back up practical experience in the field.

ORDER OF STUDIES

Lesson Number	Study Hours	Reserve Retirement Credits	Subject Matter
1	2	0	Principles of Air Conditioning
2	4	2	Refrigeration Components as Applied to Air-Conditioning Equipment
3	4	1	Servicing Air-Conditioning Systems
4	3	1	Commercial and Tactical Air-Conditioning Units
	2	1	FINAL EXAMINATION
	15	5	

EXAMINATION: Supervised final examination without textbook or notes; time limit, 2 hours.

MATERIALS: MCI 11.15a, Air-Conditioning Mechanic

Lesson sheets and answer sheets.

RETURN OF MATERIALS: Students who successfully complete this course are permitted to keep the course materials.

Students disenrolled for inactivity or at the request of their commanding officer will return all course materials.

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AIR-CONDITIONING MECHANIC

Lesson 1

Principles of Air Conditioning

STUDY ASSIGNMENT: Information for MCI Students.
Course Introduction.
MCI 11.15b, Air-Conditioning Mechanic, chap 1.

LESSON OBJECTIVE: Upon successful completion of this lesson you will be able to identify the components of air and their effect on air-conditioning equipment and its design. You will be able to identify basic refrigeration theory and its application to air conditioning. You will be able to identify the correct methods of converting temperature from Fahrenheit to centigrade and vice versa. You will be able to identify sensible, latent, and total heat of air. You will be able to determine the correct procedures for obtaining wet-bulb, dry-bulb, and dew-point temperatures. You will be able to use a psychrometric chart for determining the properties of air from wet- and dry-bulb temperature readings. You will be able to identify the instruments that are used to measure air velocities within an air-conditioning system.

WRITTEN ASSIGNMENT:

A. Multiple Choice: Select the ONE answer which BEST completes the statement or answers the question. After the corresponding number on the answer sheet, blacken the appropriate box.

Value: 1 point each

1. What is the main purpose of the air conditioning equipment used by the military?

   a. To provide comfort for troops
   b. To control humidity in areas where delicate equipment is used and/or stored
   c. To control the environment in areas where troops and/or equipment work and operate
   d. To remove dust and foreign matter from the air

2. Heat is produced in a substance by

   a. slowing the molecular action.
   b. increasing the molecular action.
   c. increasing the substance's size.
   d. lowering the substance's resistance.

3. What is sensible heat?

   a. Heat that causes a change of state
   b. The amount of heat required to change the temperature of 1 pound of a substance 1° F
   c. Heat that does not change the temperature of a substance
   d. Heat that can be added to or subtracted from a substance without changing its state

4. What is specific heat?

a. Heat that is hidden
b. Heat that raises or lowers the temperature of a substance
c. The quantity of heat
d. The amount of heat required to change the temperature of 1 pound of a substance 1° F

5. How many Btu's are required to raise the temperature of 15 pounds of iron from 35° to 81°F?

a. 69.01
b. 72.315
c. 89.010
d. 98.101

6. How is a Btu defined?

a. The amount of heat required to change the temperature of 1 pound of copper 1° F
b. The amount of heat required to change the temperature of 1 pound of water 1° F
c. The amount of heat required to melt one pound of ice
d. The amount of heat required to boil one pound of water

7. How much heat must be added to 75 pounds of water to raise its temperature from 45° to 60° F?

a. 125.5 Btu
b. 750 Btu
c. 1125 Btu
d. 2511.82 Btu

8. Heat transferred from one part of an object to another part of the same object is known as

a. convection.
b. conduction.
c. transition.
d. radiation.

9. To best aid heat transfer by convection you would use

a. large heating surfaces.
b. dark background.
c. light background.
d. fans or blowers.

10. Heat transfer that is accomplished through the use of heating coils and a reflecting surface is called

a. conduction.
b. reflection.
c. radiation.
d. convection.

11. What instrument is used to measure the temperature of a substance?

a. Psychrometer
b. Thermometer
c. Anemometer
d. Barometer

12. On the centigrade scale, water will boil at _______ degrees.

a. 100
b. 180
c. 212
d. 275

13. Convert 41° C into Fahrenheit.

a. 5°
b. 16.5°
c. 22.77°
d. 105.8°

14. Convert 46° F into centigrade.

a. 7.7°
b. 25.2°
c. 57.5°
d. 82.8°

15. What is standard atmospheric pressure?

a. 0 psia
b. 14.7 psia
c. 14.7 psig
d. 34 psig

16. Standard atmospheric pressure will support a column of mercury of _____ inches.

a. 34
b. 29.92
c. 23.99
d. 14.7

17. Normally, if you take a pressure reading with a gage, the pressure you read will be

a. above atmospheric pressure.
b. below atmospheric pressure.
c. absolute pressure.
d. in inches of mercury.

18. What is the absolute pressure when the gage reading is 23 psi?

a. 8.3 psia
b. 23.7 psia
c. 37.7 psia
d. 65.3 psia

19. What is used to counteract the effects of weather and heat gain or loss to equipment and personnel?

a. Refrigeration equipment
b. Air-conditioning equipment
c. Fans
d. Blowers

20. Filtration that is accomplished by forcing air through a spray chamber or a screen of water is called ______ filtration.

a. wet
b. air wash
c. electrostatic
d. centrifugal

21. What is the difference between a wet filter and a dry filter?

a. Water is circulated through a wet filter.
b. The air is forced through a screen of water in a wet filter.
c. A wet filter is coated with a viscous material.
d. A wet filter is kept coated with moisture that is removed from the conditioned air.

22. Porous materials such as hemp fibers or steel wool (without oil coating) are used to construct ____________-type filters.

a. dry
b. wet wash
c. electrostatic
d. centrifugal

23. Which types of filters can be disposable?

a. Electrostatic and wet
b. Centrifugal and dry
c. Air wash and dry
d. Wet and dry

24. Water vapor present in air is ______ the air.

a. dissolved by
b. absorbed by
c. separate from
d. mixed with

25. What is the temperature relationship between any water vapor present in air and the air itself?

a. The water vapor is cooler than the air
b. The air is cooler than the water vapor
c. The air and the water vapor are the same temperature

26. What begins to happen when air reaches its dew-point temperature?

a. The air becomes dry
b. The water vapor condenses
c. The water vapor is absorbed by the air
d. The air dissolves the water vapor

27. Air that contains all the water vapor it can possibly hold is said to be at its

a. condensation point.
b. dew point.
c. lowest humidity point.
d. freezing point.

28. The amount of moisture contained in the air at its dew point varies with the air's

a. temperature.
b. saturation point.
c. total heat only.
d. latent heat only.

29. What is required for water vapor to condense directly to the solid state?

a. An air temperature at or below 32° F
b. A water vapor at or below 32° F
c. A surface at or below 32° F
d. Finely subdivided drops combined into liquid form

30. What is the sensible heat of air?

a. The heat of the moisture in the air
b. The heat that is measured with a wet-bulb thermometer
c. The heat of dry air
d. The dew point of air

31. The three temperatures that are considered in air conditioning are

a. wet-bulb, dry-bulb, and sensible.
b. sensible, dew-point, and dry-bulb.
c. dew-point, sensible, and wet-bulb.
d. wet-bulb, dry-bulb, and dew-point.

32. What will a wet-bulb thermometer measure?

a. The sensible heat of the air
b. The latent heat of the air
c. The ability of the air to absorb moisture
d. The amount of sensible heat minus the latent heat of the air

33. What is the dew-point temperature?

a. The sum of the latent and sensible heat of the air
b. The amount of moisture in the air
c. The temperature where air can absorb more moisture
d. The temperature at which condensation begins

34. If the wet- and dry bulb temperature readings are 75° F, what will the dew-point temperature be?

a. 55°F
b. 65°F
c. 75°F
d. 85°F

35. The science that deals with air and water vapor mixtures is called

a. hygrology.
b. psychrometry.
c. hygrometry.
d. hygrostatics.

Note: Items 36 through 38 are based on the following situation:
Assume that your sling psychrometer readings were 90° F dry-bulb and 75° F wet-bulb
Using the psychrometric chart, find:

36. Relative humidity (percent)

a. 90
b. 76
c. 53
d. 48

37. Dew point

a. 67°F
b. 70° F
c. 72° F
d. 75° F

38. Cubic feet per pound of dry air

a. 12.62
b. 14.17
c. 15.86
d. 16.41

Total Points: 38

* * *

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AIR-CONDITIONING MECHANIC

Lesson 2

Refrigeration Components as Applied to Air-Conditioning Equipment

STUDY ASSIGNMENT: MCI 11.15b, Air-Conditioning Mechanic, chap 2.

LESSON OBJECTIVE: Upon successful completion of this lesson, combined with on-the-job training using the principles presented, you will be able to: identify the procedures involved in installing, operating, and maintaining an air-conditioning system and accessory material; recognize the general nomenclature of the components of an air-conditioning system and determine the functions of the various components, parts, and accessories thereof; determine the characteristics of refrigerants and identify the methods of proper storage and handling of refrigerants; and recognize the symptoms of overexposure to refrigerant gases and the first aid methods to be used to counteract the effects.

WRITTEN ASSIGNMENT:

A. Multiple Choice: Select the ONE answer which BEST completes the statement or answers the question. After the corresponding number on the answer sheet, blacken the appropriate box.

Value: 1 point each

1. What purpose does the compressor in an air-conditioning system serve?

a. Acts as a pump to move the refrigerant throughout the system.
b. Removes the refrigerant gas from the evaporator, compresses it, and moves it on to the condenser.
c. Regulates the running time of the system.
d. Insures a constant and steady pressure throughout the system.

2. The operational cycle of a reciprocating compressor is very similar to the operational cycle of a(an)

a. gasoline engine.
b. electric motor.
c. turbine engine.
d. steam-driven motor.

3. When does the refrigerant vapor enter a reciprocating compressor?

a. On the downstroke of the piston
b. On the upstroke of the piston
c. When the revolving blade moves to allow the inlet to be unobstructed
d. When the enlarged portion of the eccentric is directly opposite the inlet port

4. In a rotary compressor that employs rotating blades, gas is kept from escaping back to the inlet side due to extremely close tolerances between the blades and the cylinder walls and the presence of

a. lubricating oil.
b. spring-loaded valves.
c. a sliding barrier.
d. liquid refrigerant.

5. Which compressor employs a spring-loaded blade to separate the suction and exhaust ports?

a. Stationary-blade rotary compressor
b. Rotating-blade rotary compressor
c. Reciprocating compressor
d. Centrifugal compressor

6. Which type of compressor is equipped with a step-up gear train?

a. Reciprocating
b. Rotary
c. Centrifugal

7. Self-contained military air-conditioning systems usually use ____-type compressors.

a. open
b. semi-sealed
c. hermetic

8. Although hermetic compressors eliminate many maintenance problems, one major problem that exists is

a. lubrication.
b. charging.
c. heating.
d. cooling.

9. What is the function of a condenser in an air-conditioning system?

a. To convert low-pressure gas into a high-pressure gas
b. To convert low-pressure gas into a low-pressure liquid
c. To convert high-pressure gas into a high-pressure liquid
d. To convert high-pressure gas into a low-pressure gas

10. How does the condenser accomplish condensation of the refrigerant vapor?

a. By removing the latent heat of condensation
b. By adding the latent heat of condensation
c. By reducing the ambient temperature
d. By increasing the ambient temperature

11. How is the air surface of a static airflow condenser increased?

a. By increasing the amount of airspace between the parallel tubes
b. By decreasing the distance between the parallel tubes
c. By using equally and closely spaced fins
d. By using widely spaced fins

12. Which type of condenser eliminates the need for a receiver in an air-conditioning system?

a. Tube-within-a-tube
b. Shell-and-tube
c. Static airflow
d. Forced convection

13. The counterflow method of condensing the refrigerant vapor is employed in the ______ condensers.

a. tube-within-a-tube
b. shell and tube
c. static airflow
d. forced convection

14. What is the purpose of a receiver?

a. To temporarily store high-pressure liquid refrigerant until it is needed by the system
b. To temporarily store high-pressure refrigerant vapor until it is needed by the system
c. To store the refrigeration oil
d. To store the lubricating oil

15. The sight glass or tubular glass gage mounted on the receiver is used to determine the

a. amount of moisture in the system.
b. level of lubricating oil in the system.
c. height of the liquid level in the receiver.
d. state of the refrigerant charge.

16. The device within an air-conditioning system in which the refrigerant boils and absorbs heat from the surrounding environment is the

a. condenser.
b. heat exchanger.
c. receiver.
d. evaporator.

17. Which evaporator is most commonly used in air-conditioning systems?

a. Flooded-direct-expansion-type
b. Dry-expansion-type
c. Shell-and-tube
d. Flooded shell-and-tube

18. What type tubing is used for the lines in an air-conditioning system using ammonia as its refrigerant?

a. Soft copper tubing
b. Hard-drawn copper tubing
c. Aluminum tubing
d. Thin-wall steel tubing

19. How should copper tubing be kept during handling and storage to keep it free from dirt and moisture?

a. In a dirt-free storage area
b. The ends should be crimped or capped
c. In a well-ventilated storage room
d. No special precautions are necessary

20. When installing tubing in a system, horizontal loops are used to prevent excessive

a. air surface.
b. vibration.
c. heat loss.
d. liquid flow.

21. Which type copper tubing requires the use of braces and clamps?

a. Short lengths of aluminum tubing
b. Thin-wall steel tubing
c. Hard-drawn copper tubing
d. Soft-drawn copper tubing

22. Flare-type fittings are usually used in conjunction with what type tubing?

a. Hard-drawn copper tubing
b. Soft-drawn copper tubing
c. Aluminum tubing
d. Small diameter thin-wall steel tubing

23. What should be used in conjunction with hard-drawn tubing to make it conform to system requirements?

a. Solderless fittings
b. Solder-type fittings
c. Hand bending set
d. Mechanical benders

24. Why are strainers used in an air-conditioning system?

a. To remove moisture from the system
b. To remove dirt and foreign matter from the system
c. To separate the lubricating oil from the refrigerant
d. To control the liquid flow in the liquid line

25. Dehydrators are used in an air-conditioning system to remove

a. moisture.
b. dirt.
c. foreign matter.
d. scale.

26. Strainers are placed in each end of a dehydrator to prevent

a. moisture from entering the system.
b. moisture from entering the dehydrator.
c. the drying agent from entering the system.
d. liquid refrigerant from entering the dehydrator.

27. A dehydrator should never be replaced with one that is _____ the original.

a. the same size as
b. smaller than
c. larger than

28. Bubbles in the liquid sight glass could indicate that a system is

a. undercharged.
b. overcharged.
c. operating correctly.
d. on the defrost cycle.

29. The liquid sight glass in an air-conditioning system is used to check the refrigerant and to determine the

a. condition of the charge.
b. moisture content of the refrigerant.
c. foreign matter content of the refrigerant.
d. oil level in the refrigerant.

30. Fusible metal plugs are installed in an air-conditioning system to serve as

a. drain plugs for the receiver.
b. cleaning plugs for water-cooled condensers.
c. high-pressure-release safety devices.
d. low-pressure safety devices.

31. Why are heat exchangers employed in an air-conditioning unit using an expansion valve as its metering device?

a. To prevent premature "gassing off" of the liquid in the liquid line
b. To prevent the suction gases from condensing
c. To maintain a specific desired temperature level in the receiver
d. To warm the liquid line and maintain its temperature at a specific level

32. Service valves are used in a system to accomplish repairs, purge or charge a system, install service gages or special controls, and

a. isolate one part of a system from the rest of the system.
b. aid in reducing compressor load.
c. prevent moisture from entering the system.
d. control the refrigerant gas entering the compressor.

33. Which type of valve can be fitted with a tube and used as a draw-off valve for the receiver?

a. Two-way
b. Three-way
c. Relief
d. Regulating

34. Which type valve is usually used as a compressor service valve?

a. Two-way
b. Three-way
c. Automatic
d. Single action

35. In order to remove the compressor from a system, in what position must the valve stem of the suction and discharge service valves be?

a. Turned all the way out
b. Turned to the middle position
c. Turned all the way in

36. Which valve is installed on receivers to prevent damage to the system from high pressure?

a. Check
b. Relief
c. Three-way service
d. Four-way service

37. What type of valve is installed in a system to insure refrigerant flow in one direction only?

a. Regulating
b. Gate
c. Line-check
d. Globe

38. The refrigerant metering device that operates on low pressure and maintains a constant-evaporator pressure is a(an)

a. automatic-expansion valve.
b. thermostatic expansion valve.
c. float valve.
d. capillary tube.

39. What would happen if a system were equipped with a 1-ton compressor and an automatic-expansion valve of 3/4-ton capacity?

a. The refrigerant would become a gas in the liquid line, causing the compressor to stop.
b. Liquid refrigerant would get into the suction line, causing possible damage to the compressor.
c. Not enough refrigerant would be allowed to enter the evaporator, causing the compressor to overwork.
d. The suction line would frost or sweat and liquid refrigerant would be allowed to enter the compressor.

40. How does a thermostatic expansion valve control the refrigerant flow into the evaporator?

a. By a pressure/temperature difference between the evaporator and the condenser
b. By a pressure difference between the evaporator and the valve
c. By a temperature difference between the high and low side of the evaporator
d. By a pressure temperature difference between the thermal bulb and the evaporator

41. Where should the thermal bulb of the thermostatic expansion valve be located in an air-conditioning system?

a. At the inlet side of the evaporator
b. Attached to the suction line at the outlet of the evaporator
c. Attached to the center of the evaporator on the air discharge side
d. Attached to the liquid line before the expansion valve

42. What is the most important thing to remember about a capillary tube?

a. Its spray action
b. Its throttling or reducing action
c. The fact that most of its length will be coiled
d. The length and diameter of the tube

43. What type solenoid valve is used extensively in heat pumps to open or close several ports?

a. Two-way
b. Three-way
c. Four-way
d. Single action

44. A 2-way solenoid would be used to control refrigerant flow in

a. two separate lines.
b. two separate directions.
c. one line only.
d. several lines, but flow in one direction.

45. The differential of a control is defined as:

a. The axis around which the control knob rotates.
b. The difference in temperature or pressure, between the cut-in and cut-out points of a control.
c. The difference between the operational range of a control and the boiling point of the refrigerant.
d. The operational range of the control.

46. The total amount of pressure or temperature over which a control can operate is the control's

a. range.
b. differential.
c. cut-in.
d. cutout.

47. A low-pressure cut-out will allow the compressor to start whenever the pressure

a. rises above a predetermined point.
b. falls below a predetermined point.
c. remains within the pressure range of the control.
d. remains within the differential of the control.

48. A low-side pressure control is a throttling valve that is used to

a. reduce the condensing pressure.
b. maintain a constant pressure in the receiver.
c. maintain a constant pressure in the evaporator.
d. increase the suction pressure.

49. A high-pressure cutout is a safety device which will stop the compressor whenever the _____ pressure becomes excessive.

a. condensing
b. evaporator
c. high side
d. head

50. Which control operates on the difference between the pressures in the low side of the system and the oil pump discharge?

a. Low-pressure cutout
b. High-pressure cutout
c. Dual-pressure control
d. Oil-failure cutout

51. Temperature controls differ from pressure controls in that along with a bellows or diaphragm, they also employ a

a. thermal bulb.
b. mercury switch.
c. high-pressure cutout.
d. float valve.

52. Magnetic across-the-line starters consist of two electrical circuits. They are the _____ circuit and the _____ circuit.

a. power--heater
b. control--holding
c. power--control
d. control--overload

53. When first obtaining a magnetic across-the-line starter, which part (s) is (are) not usually included?

a. Lower contact points
b. Holding coil
c. Overload contact points
d. Heaters

54. Which type control is used on air-conditioning units and systems to prevent the evaporator coil from freezing?

a. Temperature
b. Defrost
c. Low-pressure
d. Dual

55. Which type motor is easily identifiable by a hump located on top of the motor?

a. Split-phase
b. Shaded-pole
c. Polyphase
d. Capacitor

56. Which type motor would be found operating a small fan, blower, or pump?

a. Split-phase
b. Shaded-pole
c. Polyphase
d. Capacitor

57. Which type motor rotor has no insulation, brushes, sliprings, or commutator?

a. Slip-ring polyphase
b. Squirrel-cage
c. Capacitor-start
d. Split-phase

58. Refrigerants in common use today are affected by pressure and temperature in a manner similar to

a. gasoline.
b. water.
c. mercury.
d. bottled gas.

59. What relationship must exist between a refrigerant's normal condensing temperature and pressure and its critical temperature and pressure?

a. The critical temperature and pressure should be exactly the same as the normal condensing pressure and temperature.
b. The critical temperature and pressure should be well below the normal condensing temperature and pressure.
c. The critical temperature and pressure should be well above the normal temperature and pressure.
d. The normal condensing temperature and pressure should be well above the critical temperature and pressure.

60. Which refrigerants are most commonly used in the Marine Corps today?

a. Ammonia, F-114, and F-12
b. F-12, F-22, and ammonia
c. F-12, F-22, and methyl chloride
d. Ammonia, methyl chloride, and F-502

61. Which refrigerant boils at -21.7° F?

a. F-12
b. F-22
c. F-114
d. Ammonia

62. F-22 boils at _____ degrees Fahrenheit.

a. -21.7
b. -28
c. -32.7
d. -40

63. Which material would NOT be used in a system that uses F-12 as its refrigerant?

a. Copper
b. Stainless steel
c. Neoprene
d. Natural rubber

64. The most dangerous of the commonly used refrigerants used in the Corps today is

a. ammonia.
b. F-12.
c. F-22.
d. F-114.

65. Agents such as air, water, and brine are examples of ____ refrigerants.

a. primary
b. secondary
c. perfect
d. natural

66. Which statement about secondary refrigerants is NOT true?

a. They are not, in themselves, refrigerants.
b. They must be cooled and then circulated around or over an area to be cooled.
c. They can be used in the primary system.
d. They must be used only in the secondary system.

67. All compressed gas cylinders used by the Corps to package refrigerants are manufactured under specifications as set forth by

a. HQMC.
b. DOD.
c. ICC.
d. SEC.

68. All compressed gas cylinders are essentially the same except those that are used for

a. refrigerants.
b. propane gas.
c. oxygen.
d. acetylene.

69. Cylinders containing F-12 and F-22 are painted what color?

a. Brown
b. Yellow
c. Green
d. Orange

70. Where would you find the name of the gas stenciled on a cylinder?

a. On the cylinder body, along the longitudinal axis
b. On the base of the cylinder
c. Around the upper band on the cylinder
d. Around the neck of the cylinder just above the ICC mark

71. Ventilation must be provided in any area in which compressed gas cylinders are stored in order to keep temperature below ______ °F.

a. 100
b. 112
c. 125
b. 136

B. True-false: Items 72-76 complete the sentence below. Blacken a or b on your answer sheet after the corresponding number to indicate your choice of true or false.

Value: 1 point each

Proper storage of compressed gas cylinders is accomplished by

		a	b
72.	protecting them from any extreme weather condition.	T	F
73.	storing them in a cool, damp area.	T	F
74.	segregating the cylinders as to specific gases.	T	F
75.	storing them in a well-ventilated area.	T	F
76.	marking the empty cylinders with paint.	T	F

C. Multiple Choice: Select the ONE answer which BEST completes the statement or answers the question. After the corresponding number on the answer sheet, blacken the appropriate box.

Value: 1 point each

77. Which statement is true concerning handling of compressed gas cylinders?

a. Repair immediately any damaged cylinder.
b. Cylinders may be filled with any gas of the same family.
c. Never alter or change any of a cylinder's permanent markings.
d. When transferring refrigerants, insure that the cylinder is completely filled.

78. Which statement is true concerning handling of compressed gas cylinders?

a. Empty cylinders may be used as supports or rollers if proper circumstances arise.
b. Electromagnets may be used to lift cylinders.
c. Never use wrenches, other than a cylinder valve wrench, to open cylinder valves.
d. Valve regulators, gages, hoses, and other attachments can be interchanged between different compressed gases.

79. When filling a service cylinder with refrigerant, what should be done after the cylinder is initially weighed?

a. Connect it to the supply cylinder.
b. Connect and purge the charging hose.
c. Chill the service cylinder.
d. Weigh the supply cylinder.

80. When transferring refrigerants, how should you heat the supply cylinder?

a. With a blow torch
b. Immerse it in boiling water
c. Use the flame from the halide torch
d. Immerse it in hot water of less than 125° F

81. When transferring refrigerants, how do you determine that the proper amount has been transferred?

a. By the weight of the service cylinder
b. By the weight of the supply cylinder
c. By an indicating gage on the service cylinder
d. When the hissing sound stops at the supply cylinder

82. If any liquid halogen-type refrigerants come in contact with the skin, how should the area be treated?

a. Treat as if the victim has 3d degree burns.
b. Treat the victim for frostbite.
c. Treat the victim for skin poisoning.
d. Treat the victim as if he has sunstroke.

83. What is the first thing that should be done if a person is overcome by refrigerant fumes?

a. Remove him from the area
b. Apply artificial respiration
c. Loosen his clothing
d. Summon medical help

84. What should be used to remove liquid ammonia from the eyes or skin?

a. Water
b. Sterile mineral oil
c. Sterile salt solution
d. Gauze pads

85. Refrigeration lubricating oils have what type of base?

a. Water
b. Carbon
c. Paraffin
d. Viscous

86. What does it mean if you say an oil has a low viscosity?

a. That it won't break down at high temperatures or lose its fluidity at low temperatures
b. That an oil and the refrigerant will mix together without causing a chemic· reaction
c. That the oil will not burn at high temperatures causing carbon deposits at hot spots
d. That the oil will not deposit wax throughout the system

87. What is meant by an oil having a low pour point?

a. That it won't break down at low temperatures
b. The lowest temperature at which an oil remains a fluid
c. The ability of the oil and refrigerant to mix
d. The amount of wax contained in the oil

88. What should be done with any oil that is removed from a system?

a. Throw it away.
b. Save it if it is not contaminated.
c. Save it so it can be reclaimed.
d. Reuse it in the system.

89. If discoloration or odor is present in oil just removed from a system, it indicates that

a. the compressor is operating at extremely high temperatures.
b. the condenser is operating inefficiently.
c. there is moisture in the system.
d. the low-side pressure is too high.

Total Points: 89

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AIR-CONDITIONING MECHANIC

Lesson 3

Servicing Air-Conditioning Systems

STUDY ASSIGNMENT: MCI 11.15b, Air-Conditioning Mechanic, chap 3.

LESSON OBJECTIVE: Upon successful completion of this lesson combined with on-the-job training using the principles presented, you will be able to identify the proper steps and methods of installing an air-conditioning unit or system. You will be able to recognize the proper preventive maintenance procedures. You will be able to identify the proper procedures necessary to locate leaks and to diagnose electrical problems. Further, you will be able to recognize and identify the proper procedures for evacuating, pumping down, charging, and adding or removing refrigeration oils. You will also be able to recognize faults in a unit and to identify possible causes and remedies for these faults. You will also be able to identify the proper methods of repairing or replacing major components within a unit or system.

WRITTEN ASSIGNMENT:

A. Multiple Choice: Select the ONE answer that BEST completes the statement or answers the question. After the corresponding number on the answer sheet, blacken the appropriate box.

Value: 1 point each

1. When installing an air-conditioning system, when should you first check for loose connections, leaks and signs of weak or cracked tubing?

   a. During the initial charging
   b. After the system has been run for 48 hours
   c. Right after the system has been uncrated
   d. After the system has been installed but prior to the initial starting

2. Why should a bleed be provided when installing an evaporative condenser or a cooling tower?

   a. To equalize the pressure across the condenser
   b. To reduce the pressure drop across the condenser
   c. To allow the drainage of the used water
   d. To prevent a buildup of impurities

3. When installing an air-cooled air-conditioning system, how would you prevent an excessive rise in the ambient temperature?

   a. Provide a means of exhausting the used condenser cooling air
   b. Install the condensing unit in a cool, dark area
   c. Increase the amount of water circulating through the cooling coils
   d. Increase the unit's motor speed

4. When, if ever, can a unit designed for free airflow application on the outdoor portion be installed with duct connections to the outdoors?

   a. Never
   b. Whenever the need for ducts arises
   c. Only if specific approval is given by the manufacturer

5. Other than keeping the condenser free from dirt and dust, what is the most important area of preventive maintenance to air-conditioning systems?

a. Evaporator
b. Filters
c. Automatic controls
d. Belts

6. What should be done to keep copper tubing from hitting on something and causing unnecessary noise?

a. Install shorter tubing
b. Carefully bend it away from whatever it is hitting
c. Install vibration absorbers on the unit's base
d. Braze tubing to whatever it is hitting

7. What is the most common cause of leaks in an air-conditioning unit?

a. Poor workmanship
b. Excessive temperature
c. Excessive wear
d. Excessive vibration

8. A method of leak testing that not only determines if a leak is present but gives the exact location is a ________ method

a. positive
b. nonpositive
c. special

9. A special method of leak detection is a method that

a. indicates a leak is present but does not give its exact location.
b. can only be used with certain types of refrigerants.
c. cannot be used in a primary refrigerant circuit.

10. A halide torch would be used to test for leaks on systems using which type refrigerant?

a. F-22
b. Ammonia
c. F-290
d. Lithium Bromide

11. When testing with the halide torch, what color will the flame become when a leak is detected?

a. Blue
b. Green
c. Yellow
d. Red

12. When preparing to use the halide torch, how should the flame be adjusted?

a. Small blue flame
b. Small green fame
c. Large blue-green flame
d. Large reddish-orange flame

13. When testing with the halide torch, how should the exploring tube be moved over the test area?

a. Quickly, so as not to allow any stray air currents to enter the tube
b. Quickly, and as close to the area being tested as possible
c. Slowly, and as close to the area being tested as possible
d. Slowly, so as not to foul the torch

14. What is the best positive method of leak detection when testing under hazardous conditions?

a. Halide torch
b. Soap or oil bubble test
c. Pressure or vacuum test
d. Liquid

15. Which test instrument should be used to determine if the compressor motor has an open starting winding?

a. Ammeter
b. Galvanometer
c. Multimeter
d. Wattmeter

16. If the starting winding of a compressor motor is open, what readings, if any, would you get on a wattmeter?

a. None
b. Running reading only
c. Overswing reading only
d. Overswing and running reading only

17. When preparing to test an air-conditioning unit for continuity or resistance, what should you do first?

a. Discharge any capacitors in the circuit.
b. Disconnect all power from the circuit to be tested.
c. Disconnect the wiring from one side of the part to be tested.
d. Set the selector switch to ohms.

18. When using the Simpson 260 multimeter to test for voltage, which position should the selector point to if the maximum voltage value is unknown?

a. R X 100 b. 50V C. 100MA D. 500V

19. Which electrical measuring device must always be hooked into the circuit in series?

a. Multimeter
b. Odometer
c. Ammeter
d. Wattmeter

20. The electrical measuring device that must always be hooked into a circuit in parallel, when checking for voltage, is the

a. ammeter. b. hourmeter. c. multimeter.

21. The multimeter is used to measure resistance, current, and

a. wattage. b. capacitance. c. voltage.

22. When installing the bar gage manifold, the compound gage line is connected to the

a. suction service valve.
b. discharge service valve.
c. vacuum pump.
d. refrigerant cylinder.

23. When connecting the bar gage manifold to a unit for the purpose of obtaining pressure readings, the center charge port is

a. connected to a vacuum pump.
b. capped tightly.
c. connected to the suction service valve.
d. connected to the discharge service valve.

24. When installing the bar gage manifold, the pressure gage line is connected to the

a. suction service valve.
b. discharge service valve.
c. refrigerant cylinder.
d. vacuum pump.

25. When evacuating using the unit's compressor, you must insure that the head pressure does not exceed _______ psig.

a. 150
b. 100
c. 50
d. 0

26. When is evacuation of a unit considered to be complete?

a. When the head pressure drops to 100 psig
b. When the pressure gage reads 0 psig
c. When the compound gage reads 0 psig
d. When the compound gage indicates a complete vacuum

27. Before a unit can be opened for repair you must insure that

a. the unit is not in a vacuum.
b. the head pressure is below 100 psig.
c. all air has been bled from the service hoses.
d. the king valve is closed.

28. What is the purpose of pumping down a unit?

a. To remove the refrigerant from the system without having to discard it
b. To check pressure tolerances of the evaporator and condenser
c. To trap the refrigerant in the receiver in order to repair or replace components without evacuating the system.
d. To remove air and noncondensibles from the system

29. When pumping down a unit, you should continue the process until the compound gage indicates

a. 30 hg.
b. 0 psig.
c. 2 psig.
d. 30 psig.

30. Once pump-down is completed, which component CANNOT be removed from the unit for repair?

a. Compressor
b. Evaporator
c. Metering device
d. Condenser

31. When charging a unit through the high side, how is the refrigerant added to the system?

a. In gaseous form through the suction service valve
b. In gaseous form through the discharge service valve
c. In liquid form through the suction service valve
d. In liquid form through the discharge service valve

32. When charging a unit through the low side, how is the refrigerant added to the system?

a. In gaseous form through the suction service valve
b. In gaseous form through the discharge service valve
c. In liquid form through the suction service valve
d. In liquid form through the discharge service valve

33. When charging through the low side, what should be done right after the service lines are purged?

a. Tighten all connections at the service valves.
b. Adjust compound gage valve so as to maintain pressure at approximately 30 psig.
c. Open the service cylinder valve.
d. Backseat the suction service valve.

34. When charging through the high side, the refrigerant charge in the service cylinder must be

a. in gaseous form.
b. under a lower pressure than in the system.
c. exact and in liquid form.
d. cooled to lower the pressure.

35. When using the sight glass to determine the refrigerant charge, if the system is fully charged, how will the sight glass appear?

a. Cloudy
b. Bubbly
c. Misty
d. Clear

36. Before removing refrigeration oil, the crankcase pressure must be reduced to _____ psi.

a. 2
b. 1
c. 1/2
d. 1/4

37. Once the crankcase pressure has been reduced, how is the oil drained from it?

a. By using a siphon hose
b. By using a vacuum pump
c. Through the discharge service valve
d. Through any valve or plug below the oil level

38. When replacing refrigeration oil in a unit, how much oil should be added at one time?

a. 1 pint
b. 3/4 pint
c. 1/2 pint
d. 1/4 pint

39. Soft-solder joints can be made if the joints are under little or no strain and if they do not have to withstand temperatures that exceed _____°F.

a. 175
b. 200
c. 250
d. 300

40. When making a solder joint, how is the heat applied?

a. Directly to the solder
b. To the solder and the joint at the same time
c. Evenly over the entire joint area
d. Just below or above the joint area

41. When making a solder joint, why is flux or soldering paste applied to the joint?

a. To prevent oxidation
b. To keep the solder from running
c. It helps the joint harden quickly.
d. To clean the joint before soldering

42. How should a completed solder joint be cooled?

a. With cold water
b. With warm water
c. Let it cool naturally
d. Wrap with water soaked rags

43. You receive a maintenance call on a self-contained unit with an open-type compressor. When you arrive you find that the motor will not run. What could be a possible cause?

a. Thermostat set too low
b. Belts loose
c. Lack of refrigerant
d. Compressor stuck

44. You receive a maintenance call on an open-type self-contained unit and discover that the evaporator is iced and that the unit is cycling on and off. What would be the remedy?

a. Locate and repair refrigerant leak.
b. Raise the high-pressure cutout valve setting.
c. Defrost evaporator and check filters and fan drive.
d. Replace or clean the liquid line strainer.

45. What would cause a hermetic compressor to run continuously, yet produce no refrigerating effect?

a. No air circulating over the condenser
b. Ambient temperature is too high
c. Thermostatic switch is improperly adjusted
d. A restriction preventing the refrigerant from entering the evaporator

46. What would cause a hermetic compressor to be noisy during operation?

a. Loose drive belts
b. Worn compressor mountings
c. Piston stuck in cylinder
d. Oil on top of the piston

47. What are the most common causes of bearing trouble?

a. Dirt or dust between the bearings and the motor shaft
b. Improper alinement at installation and inadequate lubrication
c. The motor shaft becomes worn or warped
d. Extreme friction and wear caused by long periods of motor overload

48. When removing ball bearings from the shaft, where should you exert pressure?

a. Only on the inner race
b. Only on the outer race
c. Evenly over the entire bearing surface
d. Parallel to the bearing and at right angles to the shaft

49. If one belt in a set of matched V-belts breaks, you should replace

a. the broken belt only.
b. the broken belt and any others that may show excessive wear.
c. the entire set.

50. With the pressure of one finger exerted at a point midway between the motor pulley and the flywheel, a properly adjusted belt can be depressed ____ to _____ inches.

a. 1/4 -- 1/2
b. 1/2 -- 3/4
c. 3/4 -- 1
d. 1 -- 1 1/4

51. When testing a compressor for leaks, what would be an indication that the suction service valves are leaking?

a. Maximum vacuum of 20-25 inches of mercury is reached in 10 min during preliminary pump-down.
b. Maximum vacuum of 20-25 inches of mercury can be held for 5 min.
c. Maximum vacuum of 20 inches of mercury or more is reached after 15 min of preliminary pump-down.

52. After turning the compressor over by hand, at what point should the head pressure remain constant to indicate no leaks?

a. Between 20 and 25 inches of mercury
b. Between 10 and 15 inches of mercury
c. Between 50 and 100 psig
d. Between 125 and 150 psig

53. When opening a compressor for repair, what parts should be removed from the unit?

a. The entire compressor should be disassembled and all parts cleaned and checked.
b. Only the parts necessary to make the repairs
c. All gaskets plus the parts necessary to make repairs

54. If valve operation is faulty, what should be replaced?

a. The faulty valve
b. The entire valve assembly
c. The valve assembly and the head
d. Replace the entire compressor

55. What is the best method of testing for a shaft seal leak?

a. Pressure test
b. Liquid leak detector
c. Halide torch
d. Soap solution

56. In checking a unit with a hermetic compressor, you discover that there is little or no cooling in the evaporator, little or no heating of the condenser, and that once the unit starts the wattage is abnormally low. What should this indicate?

a. An overcharge of oil
b. An open running winding
c. Defective valves
d. Defective control circuit

57. When checking a hermetic unit, what would excessive compressor noise and vibration, low capacity, and continuous high wattage indicate?

a. Defective wiring
b. Defective mounts
c. Broken valves
d. Overcharge of oil

58. When removing a hermetic compressor from a unit you discover that the escaping refrigerant has a decidedly burned odor, what does this indicate?

a. Broken compressor valves
b. Dehydrator stopped up
c. Shorted stator
d. Oil on top of the piston

59. When removing a hermetic compressor from a unit, with which tool should the tubing be cut?

a. Tube-cutter
b. Side-cutter
c. Hacksaw
d. Pinchoff tool

60. After removing a hermetic compressor from a unit, how should moisture and foreign matter be kept out of it and loss of oil prevented?

a. Stuff oil-soaked rags in tube end openings.
b. Pinch off tubing ends and bend them over.
c. Tape tube ends closed with friction tape.
d. Place the compressor in a moisture-free, dirt-proof container.

61. Whenever a condenser is removed from a unit for cleaning or repair, what other component should be replaced?

a. Condenser-to-receiver line
b. Discharge line
c. Receiver
d. Dehydrator

62. What is the best way to clean the internal surfaces of a double pipe, water-cooled condenser?

a. Superheated steam
b. Caustic soda solution
c. Muriatic solution
d. Special rods and brushes

63. How is a leak repaired in an evaporator which is constructed of aluminum?

a. Soldering
b. Brazing
c. Epoxy cement
d. Evaporator sealing compound

64. What should be done with an evaporator that has become stopped up due to oil carbonization?

a. Replace it.
b. Clean it with superheated steam.
c. Clean it with a mild muriatic solution.
d. Clean it with a strong caustic soda solution.

11.15
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Total Points: 64

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AIR-CONDITIONING MECHANIC

Lesson 4

Commercial and Tactical Air-Conditioning Units

STUDY ASSIGNMENT: MCI 11.15b, Air-Conditioning Mechanic, chap 4.

LESSON OBJECTIVE: Upon successful completion of this lesson combined with on-the-job training, you will be able to: identify the steps of installing, performing preventive maintenance on, and repair procedures for air-conditioning systems; identify the sequence of steps for testing air-conditioning systems; identify the nomenclature of air-conditioning equipment peculiar to the Marine Corps and how it functions; identify safety precautions pertaining to air-conditioning systems and related equipment.

WRITTEN ASSIGNMENT:

A. Multiple Choice: Select the ONE answer which BEST completes the statement or answers the question. After the corresponding number on the answer sheet, blacken the appropriate box.

Value: 1 point each

1. The refrigerant in a window or through-the-wall air conditioner is controlled by which valve?

   a. Thermostatic
   b. Solenoid
   c. Throttle
   d. Automatic-expansion capillary

2. Commercial window units operate on ________________ circuits.

   a. 120-v or 220-v single-phase
   b. 120-v or 220-v three-phase
   c. 208-v three-phase
   d. 115-v single-phase

3. You are given the job of installing an air conditioner in a barracks window. After getting the unit and materials ready, what is your first step?

   a. Fit the entire unit into the window opening.
   b. Secure the housing in the window opening.
   c. Remove the unit from its housing (cabinet).
   d. Securely fasten the braces and brackets.

4. Window units use __________ separate airflows.

   a. 5
   b. 4
   c. 3
   d. 2

5. How often should the filter be checked on a window unit?

   a. Every 6 months
   b. Every 4 months
   c. Every 3 months
   d. Every month

6. Console air conditioners are usually constructed with the condensing unit in the ____ section.

   a. middle
   b. side
   c. lower
   d. top

7. What are the three systems in the military standard air-conditioners?

a. Refrigeration, evaporator, and automatic
b. Thermostatic, condensing, and refrigeration
c. Refrigeration, electrical, and air-h dling
d. Electrical, air-handling, and motor

8. The voltage in the control system of the military standard air-conditioners, is routed through a ______________ rectifier.

a. 160-v a.c.
b. 220-v a.c.
c. 180-v d.c.
d. 187-v d.c.

9. The heating capacity in Btuh of the A/E 32C-26 is

a. 4,400.
b. 12,300.
c. 28,600.
d. 47,100.

10. The A/E 32C-17 air-conditioner operates on 60 Hz power; the A/E 32C-18 operates on ______________ Hz.

a. 60
b. 115
c. 208
d. 400

11. What is the maximum weight in pounds of the A/E 32C-24?

a. 150
b. 225
c. 445
d. 585

12. A feature of the A/E 32C-39 air-conditioning unit is that it is constructed with a

a. lightweight frame.
b. "horizontal" type frame.
c. ruggedized frame.
d. wooden frame.

13. The evaporator fan motor on the A/E 32C-27 air-conditioning unit operates on either ______________ Hz.

a. 60 or 115
b. 60 or 400
c. 115 or 208
d. 115 or 400

14. The cooling capacity of the A/E 32C-18 is ______________ Btuh.

a. 18,000
b. 20,000
c. 36,000
d. 40,000

15. The control switch on the A/E 32C-29 air-conditioning unit has ______________ position(s).

a. 1
b. 3
c. 5
d. 7

16. When does the system transfer to the bypass operation?

a. When the compressor and fan motors are energized
b. When the air temperature rises above the thermostat setting
c. During the cooling cycle
d. When the conditioned air thermostat is satisfied

17. When the air temperature rises above the thermostat setting, the system will

a. transfer to the heating cycle.
b. transfer to the cooling cycle.
c. de-energize the compressor.
d. transfer to the bypass operation.

18. During the cooling cycle the liquid refrigerant is metered into the evaporator through a _____ valve.

a. hand expansion
b. capillary
c. automatic-expansion
d. thermostatic expansion

19. If the liquid bypass valve fails to open it would cause the compressor to

a. freeze up.
b. stop.
c. overheat.
d. short cycle.

20. When the selector switch is set to OFF, power is supplied only to the

a. compressor motor.
b. fan motor.
c. crankcase heater.
d. control panel.

21. When installing an air conditioner in the through-the-wall method, a hole, 1/4" larger than the outside dimensions of the unit, is cut in the wall. What is the purpose of making this hole larger?

a. Reduce noise
b. Prevent vibration
c. Facilitate drainage
d. Facilitate electrical connections

22. The purpose of the NPT drain is to

a. drain off excess refrigerant.
b. drain off excess oil.
c. drain off condensation.

23. How long must the unit be in the upright position prior to running refrigerant system?

a. 6 hr
b. 8 hr
c. 10 hr
d. 12 hr

24. The unit should be sitting at level position, but will operate satisfactorily sitting at a __________ angle.

a. 8.5°
b. 5°
c. 3°
d. 1.5°

25. When the selector switch is on LO HEAT, one bank of the electrical heaters is inoperative and the other is under the control of the

a. conditioned air thermostat.
b. compressor.
c. evaporator fan motor.
d. expansion valve.

26. The temperature control ranges from

a. -20° to 80°F.
b. 40° to 90° F.
c. 40° to 95°F.
d. 50° to 100°F.

27. When the NBC system is in use, the fresh air inlet damper must be

a. closed.
b. open.
c. up.
d. down.

28. Except for the two smallest units, the outside air thermostat is set to cut out at ________ ambient temperature.

a. 50°F
b. 30°F
c. 20°F
d. 0°F

29. The high temperature control cuts out at __________°F and automatically resets at ______ °F.

a. 156 -- 200
b. 180 -- 134
c. 194 -- 140
d. 225 -- 240

30. How often should the piping be checked for leaks using the halide leak detector?

a. Daily
b. Weekly
c. Monthly
d. Every 6 months

31. What would cause the compressor not to start?

a. Fan motor failure
b. Defective high temperature thermostat
c. High head pressure
d. Outside air temperature below 0°F

32. To determine if the circuit breaker is defective, you would attach two insulated jumper wires, one to each of the ________ terminals.

a. two side
b. two upper
c. middle
d. two lower

33. Excessive floodback of refrigerant will damage the

a. compressor.
b. evaporator.
c. condenser.
d. motor.

34. While energizing the refrigerant solenoid valve, if it fails to click, what should you check?

a. Compressor motor and condenser fan motor
b. Evaporator motor and control panel
c. Coil connection and the coil wiring

35. If the outdoor ambient temperature is 50°F, the suction pressure should read

a. 58-65 psi.
b. 58-70 psi.
c. 125-160 psi.
d. 175-210 psi.

36. What would be the second step in removing the control panel?

a. Remove front panel
b. Disconnect harness connector
c. Loosen clamp screw
d. Remove evaporator air intake grille and filter

37. When using air conditioners in FMF applications, what method of installation does the Marine Corps recommend?

a. Through-the-wall
b. Interior mount
c. Window mount
d. Skid mount

38. Which method of installing an air conditioner would allow the greatest ease of accessibility for maintenance?

a. Window mount
b. Skid mount
c. Through-the-wall
d. Interior mount

B True - False: In the cluster true-false group of items below, use answer sheet column a for true and column b for false.

Value: 1 point each

The Marine Corps military standard air conditioners share certain characteristics. Some of these include:

39. All components are completely interchangeable in conditioners of the same capacities.
40. The control panel is designed so that it can be removed for remote operation.
41. The flow of fresh air is automatically controlled by the damper.
42. The conditioners are designed to operate in excess of 4,000 hours without a major overhaul.
43. The evaporator sections are insulated with foam rubber to minimize internal heat loss.

C. Multiple Choice: Select the ONE answer which BEST completes the statement or answers the question. After the corresponding number on the answer sheet, blacken the appropriate box.

Value: 1 point each

44. What is the cooling capacity in Btu's of the MC9HAL6-208?

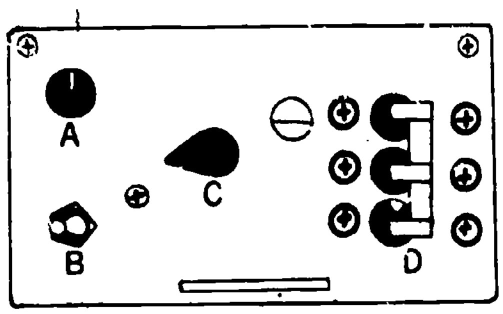
a. 7,000
b. 9,000
c. 12,000
d. 18,000

45. You have just uncrated an MC9HAL6-208 air conditioner and are checking it out. Which of the following components is NOT part of the initial check?

a. Evaporator
b. Condenser
c. Fan motors
d. Compressor

46. What is the function of the control at C on the accompanying illustration?

a. It opens and closes the damper.
b. It selects the mode of operation.
c. It controls the temperature setting.
d. It selects the fan speed.



47. The air-conditioner operates, but does not cool down as it should. Which of the following would be a probable cause?

a. Loose electrical connection
b. Defective evaporator
c. Too much outside air entering unit
d. Defective circuit breaker

48. How often should the fresh air screen on the MC9HAL6-208 be serviced?

a. Daily
b. Weekly
c. Monthly
d. Quarterly

49. The compressor starts but goes out on overload. You check it and determine that the refrigerant control valve is defective. What is the lowest echelon of maintenance that is authorized to repair or replace the valve?

a. 2d
b. 3d
c. 4th
d. 5th

50. What must the air-conditioning mechanic do before servicing electrical equipment?

a. Fill out the safety form.
b. Make sure unit is grounded.
c. Build a working platform.
d. Disconnect the units power source.

51. If a Marine air-conditioning mechanic accidently swallows some solvent, what should he do?

a. Seek immediate medical attention
b. Use his finger to make himself vomit
c. Drink warm milk
d. Drink large amounts of water

52. What first aid measure should be administered to a victim of electrical shock whose breathing has stopped?

a. Apply closed heart massage
b. Apply artificial respiration
c. Keep victim warm
d. Elevate the lower limbs

53. Where should the Marine air-conditioning mechanic refer to for further details and instructions on first aid measures?

a. Engineer records manual
b. Marine's Handbook on essential subjects
c. Marine's Handbook on squad tactics

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