REFRIGERATION AND AIR CONDITIONING II (COMMERCIAL REFRIGERATION)
INTRODUCTION

This subcourse is the second of four subcourses devoted to basic instruction in refrigeration and air conditioning.

This subcourse explains the components, operation, and repair of commercial refrigeration systems and provides a detailed explanation of the various uses of compressors. In addition, there is detailed instruction on the use and defrosting of storage cabinets, plant design, special systems, and vehicular refrigeration units.

There are three lessons.


3. Cold Storage, Ice Plants, Special Applications, and Vehicle Units.

Unless otherwise stated, whenever the masculine gender is used, both men and women are included.
PREFACE

THE REFRIGERATION field includes a wide variety of refrigerators, and you must be able to implement the maintenance program that keeps these refrigerators operational. The first chapter is devoted to small commercial refrigeration units, mainly portable types, such as are used in homes, messhalls, and commissaries. We will discuss the absorption type refrigerator as well as the more common compressor type used in most domestic refrigerators and freezers. The components, their operation, and the troubleshooting procedures for both types are discussed. Brazing, welding, and cutting methods are explained, and the last section gives repairs and services.

The subject is expanded in the second chapter to other commercial units, such as water coolers, ice cube machines, and larger equipment like walk-in cabinets and display cases. Large cold storage plants and ice plants merit treatment in a separate chapter. In Chapter 4 we will discuss systems designed for special application, such as those using multiple evaporators and multiple compressors. This chapter also includes a section on ultralow-temperature systems. As you will learn in the last chapter, there have been few changes in automotive air conditioning, but there are some brand new methods for refrigerating food transport trucks.

By becoming familiar with the symptoms that lead to refrigerator breakdowns, you will be able, in many instances, to prevent such breakdowns. Regardless of the type and size of any refrigerator, a specific cycle is followed before the refrigerating effect takes place. Therefore, a thorough knowledge of this cycle and a clear understanding of applicable troubleshooting procedures should make your job less difficult.
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THERE WAS A TIME when Grandma used a block of ice to keep her food from spoiling. Later, a mechanical unit replaced the block of ice. In those days, a service call often meant airing out the kitchen before work could be started because the place was full of ammonia or sulfur dioxide fumes. You do not have that problem today, for the modern domestic refrigerator uses a refrigerant which is practically odorless and harmless.

2. The domestic units explained in this chapter use one of two basic systems: the absorption refrigeration system and the compression refrigeration system. We will take up the construction of domestic refrigerator boxes first, since much of this information is common to the absorption refrigerator and the freezer boxes which follow. The discussion of components such as latches, ice cube makers, and other features will also include specific information relating to their operation, service, or maintenance.

3. A section on compression system components starts with a brief review of operating principles followed by the components which put these principles into action. The section concludes with refrigerator performance which is based on normal operation of the system.

4. Freezers are dealt with by supplying only that information which is necessary. For example, the construction and insulation of a freezer box is essentially like a domestic refrigerator box, so there would be no profit in repeating it.

5. Troubleshooting hermetic systems is divided into electrical troubles and mechanical troubles. The discussion is centered around those components which are essential to the main system. Other components which have been discussed previously are accessories or special features and, as such, they are treated separately because they will vary from one unit to another.

6. A comprehensive discussion of safety introduces the section on brazing, welding, and cutting. Emphasis is placed on those fluxes and alloys commonly used by a refrigeration repairman. This is followed by the repairs which you are normally expected to make on domestic refrigerators and freezers. The necessary services for charging a small hermetic system make the final discussion in this chapter. Since most of us are familiar with the domestic refrigerator, it is the logical starting point for your study.

1. Domestic Refrigerators

1-1. The recent trend has been to make larger domestic refrigerators. Consequently, many homes now use units as large as those found in small cafes or restaurants. Such larger units are quite expensive, but they have been accepted by the buying public because of their proven reliability and greater efficiency; 10 years of continuous service is not uncommon.

1-2. Construction and Components. A refrigerator is made of two steel shells. The outer shell consists of steel plates welded to a steel frame, which gives strength and rigidity. The inner shell is formed from a single sheet of steel, which must provide the mounting arrangement for the shelves and support the evaporator. The space between the two shells is filled with insulation, and the gap at the edge is closed by the breaker strips. The door is formed from a single sheet of steel and is given rigidity by the liner. The door gasket is installed so that it fits into the gap between the liner and the shell. The body of the door is filled with insulation.

1-3. Insulation. When temperature differences exist close to each other, they always try to equalize each other. Insulating materials can retard the transfer so that a cooled area will stay cold longer. From your studies, you may remember that heat is transferred by convection, conduction, and radiation. Convection is the transfer of heat by air currents. Cells of dead air space reduce convection by restricting the movement of air. Conduction is the transfer of heat by a medium acting as a bridge from one temperature zone to another. Material such as paper is a poor conductor. Radiation is the transfer of heat in the same way that light is propagated. Radiant heat can pass through a block of clear ice so that the heat can be sensed on the other side.
from a surface is determined by the color and texture of the material.

1-4. The greatest heat load in a refrigerator is the heat transferred through the door and walls of the box. Better insulation means less heat gain, greater efficiency, lower operating costs, and an extended life for the compressor. Among the basic insulating materials used, you will find spun glass, rock wool, cork, plastics, and metals. These materials are produced as sheets, fibers, cells, or a combination of these. For example, if you will look at the edge of a corrugated cardboard box you will see a combination of sheet and cell constructions. Cells are tubular in cardboard construction, but a honeycomb type of cell will insulate better.

1-5. The manufacture of insulation has been so improved in recent years that present-day boxes are built with a relatively thinner wall. Some new types of insulation will sufficiently reduce heat transfer with only one-fourth to one-half inch of insulation. Among the newer insulation materials are steel and aluminum. Thin sheets of metal are made to form a multilayer sandwich with dead air space between the sheets. However, with such metal insulation, in order to prevent the accumulation of moisture, as with other types of material, it is important that adequate sealing be provided. Among other new insulating materials are synthetic fibers or plastics which can be molded into a form that will fit between the outer and inner shells of a box. Such molded insulation has the advantage of eliminating corner and edge joints.

1-6. Any insulation must have an effective moisture barrier provided to insure its long life. Obviously, because some materials will lose their insulating value if they get wet, they must be waterproofed. To these materials, odorless tars are often applied to seal the surface and keep the moisture out. Why are such tars used? Because the taste of food would be ruined if aromatic tars were used for sealing. Among the methods of sealing are painting or dipping the insulation in a waterproof compound to close the pores in the surface against moisture. As a further protection against moisture, special rubber gaskets are used to close all spaces where wire or tubing passes through the insulation. In fact, every precaution is taken at the time of manufacture to keep moisture from getting into insulation. Also when foam insulations are used, they are nonburning if they are made to Federal Specification HH1-1-00530 (ASTM 1692). Note, too, that some synthetics are not only resistant to rot but also have no nutritional value which might support rodents, insects, or fungi. Finally, while all synthetics are not equally elective, a few have such a low K-factor that when used for the same purpose, they are equivalent to twice the thickness of many natural materials.

1-7. By now, as a refrigeration specialist, it should be obvious that moisture can cause many troubles. In fact, in an area where air circulation is restricted and temperature is near 70°, conditions are right to both promote the growth of bacteria and result in corrosion of the metal. The effectiveness of modern sealing methods is shown by the rare occurrence of this trouble with insulation. Still, the complete replacement of insulation is necessary if flooding has resulted in the seal breaking down. Such seal breakdown occurs if a box is submerged under water too long. You can ordinarily make minor repairs to torn insulation with tape. When you do this, however, paint the patch with a waterproof sealer such as hydrolene, an odorless tar.

1-8. Breaker strips. The gap between the inner and outer shells is closed by means of the breaker strips. These are not required to make an airtight seal, because they are found inside the area of the door gasket. Yet, because the temperature in the box is colder than the insulation space, any moisture will tend to be drawn from the insulation. If you have ever removed or replaced a breaker strip, you will know from experience that those made from plastic are easily broken. Still, whether they are made of metal or plastic, these strips require careful handling, as kinking will permanently deform the strip and result in a gap.

1-9. Stile or mullion heaters. These heaters are found in back of the breaker strip on some boxes. They are low-watt linear elements which operate continuously to prevent frost creepage around the door. This is another reason for using care when removing a breaker strip, since it is possible to damage the wiring or the heater strip.

1-10. Door gaskets. These gaskets are made of rubber or plastic and follow the general shape shown in figure 1. Note the air pocket, which acts as an air cushion and helps to insure an airtight seal between the door and the cabinet. Most manufacturers today place the door-closing magnets in the air pocket of the gasket. In this position, the magnets not only hold the door closed but also insure the gasket making a seal throughout its life without ever needing adjustment. The strip magnet is installed in the top, bottom, and latch side of the door but not at the hinge side, because if placed here, it would tend to close the door. Older models had one or two large magnets with steel plates which took the place of a door latch.

1-11. Door latches. In spite of widespread publicity, 44 children were reported as having lost their lives in unused refrigerators between 1 January and 17 November 1964. Therefore, whenever a refrigerator of the old style is to be stored, the
latch should be removed and taped to the inside of the box. In shipment, the door can be secured by tape or a length of rope. If you remember these precautions, you will never have to worry about having contributed to the death of a child. In fact, in many states it is against the law to abandon a refrigerator without removing the door or the latch.

1-12. Adjustable door latches were used on refrigerators for many years before the introduction of permanent magnets as door closers. A door latch can be adjusted to compensate for a worn or compressed door gasket. To do so, release the locking screw and move the lip closer to the cabinet. Use a thin piece of paper between the gasket and the cabinet to check the seal. With the door closed on the paper, the amount of drag on the paper as you pull it indicates the amount of seal that the gasket furnishes.

1-13. **Location and Power Supply.** A domestic type refrigerator is often located without consideration of the operation of the equipment. As you know, these units are self-contained, with the condenser mounted under or in back of the box. Thus, the unit cannot operate efficiently if it is placed too close to an oven or to a space heater. Note, too, that although the original location of a refrigerator may have been quite satisfactory, subsequent installation of heating unit may inadvertently find the refrigerator in the hottest part of a room. Furthermore, consideration as to the suitability of a location should also take into account the distance from the power source. A domestic box is provided with a cord and plug which can be used in a convenience outlet. As there are usually several outlets on one branch circuit, it is possible that a branch circuit is being operated at close to capacity. A refrigerator will be operating on marginal current under these conditions. If it is connected to an outlet which is last on the circuit, the voltage drop may be so great that the unit will not give satisfactory performance.

1-14. At most overseas bases, where there are government furnished quarters, refrigeration equipment is designed for the voltage and frequency of the electricity in the local area. However, you may find that some refrigerators made for 60-cycle operation have been transported over seas and are being used on 50-cycle current. If the voltage is correct, the unit may give satisfactory operation on the lower frequency. Voltage and frequency are just two of the many new things you should be aware of when you are on an overseas assignment. Refrigerator made for overseas use with unusual electric requirements have a notice posted inside the box stating the specifications.

1-15. **Combination Refrigerators.** Since the freezer section has increased in size, practically all boxes made in the larger sizes today are combination refrigerators. Continued improvement has led to such things as automatic ice cube makers, forced-air circulation, frost-free operation automatic defrosting, and even ultraviolet lamps, which retard bacteria growth and reduce odor. New developments have resulted in more usable cubic feet in the box by reducing the size of the compressor and the insulation space. Most new units use Freon 22, because it is more efficient, requiring less horsepower for equivalent output. As the demand for refrigerators has increased, it has brought about the development of special-purpose storage compartments for different foods.

1-16. **Special compartments.** Meat storage compartments are kept at slightly above freezing, with high humidity—as high as 90 percent. These conditions are favorable for extended storage of unwrapped foods. High humidity prevents desiccation, and the near freezing temperature retards bacterial action.

1-17. High-humidity storage for leaf vegetables, such as lettuce and celery, is provided by drawers located in the bottom of the refrigerator section. Another special-purpose compartment is the butter conditioner, which is located in the door. Butter is maintained at a warmer temperature here than elsewhere in the box so that it will not be too hard for serving. Two methods are used to get the proper temperature for this compartment. For one, when an electrical heater is used, a rheostat is varied to get the desired heat. The heater element is connected to the electric supply whenever the compressor is running. A flexible cord is used at the door hinge to bring the circuit into the door. For the other, when a heater element is not used, the butter conditioner depends on the heat passing through the door at that place to keep the butter from getting too hard. The insulation thickness at that place in the door determines the rate of transfer of heat.

1-18. **Automatic ice cube maker.** An automatic ice cube maker is a specialized item found
in the freezer compartment of some boxes. One popular make uses a solenoid valve, an electric motor, an electric heater, a feeler bulb, and two thermostats. A mechanical valve (globe valve) in the water line is adjusted to reduce the line pressure so that the correct amount of water will be metered into the ice cube tray. This valve will need adjustment if there is a change in supply water pressure. One thermostat senses when the ice is made, and the other thermostat has a feeler bulb in the storage tray which senses when the tray is full. Let us consider the automatic operation, starting with the completion of a batch of ice cubes. Sensing that the water is frozen and that the cubes are ready to be used, the "cold" thermostat energizes the electric heater in the tray. The "hot" thermostat senses when the tray is warm enough to release the cubes, at which time this thermostat starts the electric motor. The motor accomplishes the following operations as it goes through one cycle: It resets the "cold" thermostat and turns off the heater. Mechanical fingers sweep the cubes out and into the storage tray, and the solenoid valve opens the water line to refill the freezer tray. The solenoid valve remains open for an interval determined by the motor operation which closes the solenoid valve at the end of the interval. The motor establishes its own holding circuit when it starts, and it opens this circuit when the cycle is completed. (NOTE: We are dealing here with a time sequence in which some things happen together, while in others there is an overlap of action involved.) Ice cubes will not be ejected if the storage tray is full, because the feeler bulb in the tray will interrupt the circuit of the "cold" thermostat. As soon as enough cubes have been removed, the heater will be turned on to release the cubes in the tray and start another cycle.

1-19. Automatic defrosting. One of the earliest schemes to defrost an evaporator was the manual pushbutton which started the cycle. When defrosting was completed, the compressor was automatically restored to normal operation. By contrast, today there are defrost systems which are completely automatic. We will discuss the more common such systems. One such, a mechanical system, uses a counter which registers each time the door is opened. After a certain number of openings, the device starts the defrost cycle. This system follows the idea that each time the door is opened the coils will accumulate some moisture, and after approximately 60 openings, defrosting will be necessary.

1-20. An electric clock is used in three basic systems. In one system, the clock may be wired in parallel with the compressor so that it measures the total running time of the compressor. The theory here is that after 6 hours of compressor operation, the coils should need defrosting. In another such system, a clock is wired in parallel with the cabinet light so that the clock measures the length of time that the door remains open. The advantage of these two systems is that they indirectly reflect the heat load on the unit. In still another system, one utilizing hot wire defrosting, a 24-hour clock, which is set to defrost at 0300 hours, simultaneously opens the circuit to the compressor and turns on two heaters. Instant heat is supplied by one of the heaters, which is similar to that used on an electric range. The insulated heater wire is installed either alongside the evaporator coil or in the center of the tubing which makes the coil. The other heater is a low-wattage heater used to keep the drain free of ice accumulation. A 70° thermostat, when satisfied, resets the clock mechanism. The heaters are turned off, and the compressor circuit is made ready for operation.

1-21. Defrosting must be scheduled whenever the frost accumulation has reached 1/8 inch thick. Otherwise, the layer of frost will act like an insulating blanket which slows down the transfer of heat.

1-22. Hot gas defrosting, still another method, utilizes an electrically operated solenoid valve controlled by a clock or some other timing device. Figure 2 shows the solenoid valve open. This position allows the hot gas from the compressor to pass through the evaporator. When the defrosting period ends, the valve closes and the compressor will return to normal operation. Accumulated melt
1-23. **Special Features.** Two special features which are found in some boxes are ultraviolet lamps and circulation fans. Ultraviolet lamps are wired into the circuit for continuous operation. Their radiation kills bacteria and counteracts some disagreeable odors. Circulating fans are used to give positive ventilation and to insure frost-free operation with proper control of humidity. The ventilation channels, between the freezer and the refrigerator, must not be blocked by storage containers. The motor-driven fan is wired in parallel with the compressor so that the fan circulates air during the cooling period. A switch in the line to the fan opens the fan circuit when the refrigerator door is open. The fan switch may be incorporated with the door switch that controls the cabinet light. Do not confuse this fan with the one used for cooling a compressor and a condenser. Food stored in a box with forced circulation must be covered to prevent desiccation. Also, if much uncovered, moist food is stored in such a box, it will cause excessive moisture to accumulate in the freezer. This excessive moisture will, in turn, cause frequent defrost cycling and compressor operation, which may lead to complaints about "defective equipment."

2. **Absorption System Refrigerators**

2-1. For many years, the absorption system has proved satisfactory for domestic refrigerators. Large capacity absorption systems are covered in Volume 4. Boxes made for use in the United States are designed to use either natural, liquid petroleum, or artificial gas heat. (In Europe, boxes have been made which use electricity for heating.) Absorption system refrigerators are made with automatic defrosting and ice cube makers. The defrost system is the electric hot wire type, with a timer such as is found in conventional boxes. The automatic ice cube maker is of the type which we have explained in Section 1 under the same title. Identification plates are located in the frozen food or the control compartment.

2-2. Each burner must be provided with the correct size orifice for the gas supply to which the refrigerator is connected. Gases are rated in B.t.u. per cu. ft., with LP gas the highest at 1600 B.t.u. per cu. ft. If you will compare two nozzles for size. You will see that the one for use with LP will have the smaller orifice. The nozzle with the larger orifice is used with natural gas, which has less heat value.

2-3. The most popular domestic refrigerator of the absorption type uses an ammonia-water cycle in an atmosphere of hydrogen. The system is pressure tested at 800 p.s.i.g., but normal pressure in the system is 200 p.s.i.g. A fuse plug will release the pressure in the system if temperature rises to above 175\(^\circ\) F. This release of pressure prevents any accidental explosion of the system.

2-4. **Construction and Components.** The absorption refrigerator box is constructed and insulated in much the same way as we have explained previously in this chapter. The essential parts of an absorption system are a generator, a vapor separator, a condenser, an evaporator, and an absorber. Among the components are some items which may sound unfamiliar. The generator is that art of the system where a water-ammonia solution is heated. The vapor separator is a special chamber where the water is separated from the ammonia. The absorber is so named because water at this place absorbs ammonia vapors. A brief review of the principles involved is given next.

2-5. **Operation.** The principle of operation of an absorption system depends upon the strong affinity which water has for ammonia. When the water-ammonia solution is heated in the generator, a mixture of water and ammonia vapors is given off. This vapor mixture rises to the vapor separator, where much of the moisture is extracted and returned to the generator by way of the absorber. Ammonia vapors rise in an atmosphere of hydrogen to the condenser, which is cooled by air temperature, and the ammonia liquefies. Liquid ammonia falls into the evaporator. The area in the evaporator has a concentration of hydrogen, which encourages the ammonia to vaporize and absorb heat. The evaporator is located in the freezer compartment of the box. From the evaporator, the ammonia vapor falls to the absorber, where it joins the water (from the vapor separator) returning to the generator, thereby completing the cycle. The system is completely closed, and there are no adjustments possible, except to the flame which supplies heat to the generator. The flame operates continuously, and any changes in heat load are met by changing the size of the flame. This adjustment is made automatically by a thermostatic control which regulates the gas supply to the flame. The sensing element is located in the freezer compartment. You will find several items between the unit and the gas line in an installation of this type. Starting from the gas line, these are a shutoff valve, a filter, a pressure regulator, and a gas burner with an automatic control. The gas burner valve is provided with a safety feature which will...
shut the gas off if the flame should be extinguished. In the order in which the device is implemented, the safety consists of a heater, a snap button, and a poppet valve. The snap button is linked to the poppet valve. The snap button is a curved piece of metal which reverses its curve when it is heated. The heater is located in the flame and conveys heat to the snap button. As long as the snap button is hot enough, it will hold the poppet valve open. If the flame fails, the snap button will reverse itself and close the valve, shutting off the gas. To light the flame again, you will have to heat the heater with a match and press a pushbutton to rest the poppet. If the heater should be accidentally dislodged from the flame during cleaning, the flame would be extinguished. The simple remedy for this condition is to move the heater back into the flame path and relight the unit.

2-6. **Maintenance.** To maintain an absorption refrigerator, you need only to keep it clean. Especially, remove all soot from the flue and burner chamber, since it acts as an insulator when it accumulates and thus prevents the generator from getting enough heat to do its job efficiently. Also, keep the flue clear of obstructions, since the flue draft is designed to work with the burner for best operation. In addition, keep dust accumulations off the condenser so that it will be able to transfer heat. This is important, since the condenser in an absorption system is more sensitive than that in a conventional type refrigerator. The only adjustment that you can make is to the flame to insure that it is clean and that it gives a minimum of carbon. A flame which is too yellow gives low heat and will not give satisfactory service because the flue will gather excessive soot and need cleaning too often.

2-7. An important aspect of correct installation of an absorption refrigerator is to be sure that it is placed level. When checking with a level, be sure that you check the unit rather than the box. Why? Because unless the unit is level, the system cannot operate properly. On the other hand when a unit is level, it will work correctly even if the box is slightly out of plumb.

2-8. When a box is placed in service after having been left idle for an extended period of time, it may not function at a cool enough temperature to make ice cubes. One suggested remedy for this condition is to remove the unit from the box and turn it upside down for an hour. Then install the unit and reconnect it to the gas line. Thereafter, it should function properly when fired up. Of course, you might find it simpler to disconnect the gas line and turn the whole box upside down for an hour. Otherwise, the main reasons for poor unit operation are an incorrect flame and/or too much dirt clogging the heat exchanger surfaces.

### 3. Compression System Refrigerator Components

3-1. The main parts of a domestic type refrigerator are discussed in this section. These are compressors, condensers, evaporators, and refrigerant controls. We will cover the common types of each and their various applications. The hermetic system is used with all domestic boxes. We will also discuss refrigerator performance as it relates to the components of compression system refrigeration.

3-2. **Reciprocating Compressors.** The operating principle of a compressor is closely related to the refrigeration cycle. A brief review of the principles of refrigeration is appropriate at this time. When a gas is compressed, it gets hotter. When pressure on a gas is lowered, it gets cooler. When a liquid becomes a gas, it picks up heat. The gas passing through a compressor gets hotter. It gives up this heat in the condenser, where it becomes a liquid. It changes from liquid to gas in the evaporator, where it picks up heat (cools the evaporator) and carries this heat through the compressor back to the condenser, where it is again cooled. The function of the compressor is to make the required pressure changes on the refrigerant so that it can do its work. High pressure is on the condenser side (high side) and low pressure on the suction side (low side).

3-3. The reciprocating compressor consists of a cylinder and head, a piston and connecting rod, intake and exhaust valves, servicing valves, fly-wheel, crankshaft and crankshaft seal, and suction strainer. Clearances as small as 0.0001 inch are possible between the moving parts, because the compressor is operating in a closed environment where the temperature range is relatively narrow.

3-4. The piston may be driven in a number of ways. In one, the crankshaft may be like the kind used in automotive engines. Another type uses an eccentric crankshaft which operates like a cam. Still another is the scotch yoke mechanism which uses a pin mounted off center to the crankshaft. A sliding member inside the piston permits the rotation of the pin to be translated into up-and-down motion. Variations such as these are possible because gases are being pumped which do not produce heavy bearing loads. The piston is made to come as close as possible to the head without touching. Clearance may be as little as 0.01 inch at top dead center.

3-5. Exhaust and intake valves are usually made of thin disks of steel which seat against shoulders in the valve plate. These valves are sometimes called flutter or reed valves. Pressure in the cylinder closes the intake valve and raises the exhaust valve on compression. On the intake stroke, pressure in the suction line opens the intake
valve, while back pressure from the high side closes the exhaust valve. Valves are designed to operate at a maximum lift of 0.10 inch. Beyond this point, the valve gets noisy.

3-6. **Rotary Compressors.** Fewer moving parts and less vibration are advantages of the rotary, which is made in two styles. One style uses an eccentric shaft with blade which is forced against the shaft by a spring. The blade slides back and forth in a slot in the case between the intake and exhaust. As the shaft turns, it traps a gas charge at the intake and sweeps it around to the exhaust. Oil makes the seal for the blade so that the gas will be compressed.

3-7. In another style of rotary, vanes are mounted in slots on the shaft. The shape of the case around the vanes is eccentric. Centrifugal force holds the vanes in continuous contact with the eccentric wall. The inlet port is located in the wall furthest from the shaft, at the spot where a gas charge is picked up between two vanes. As the shaft turns, the space between the shaft and the wall becomes smaller, compressing the charge of gas. The exhaust port is set in the case where the shaft almost rubs against the case. The compressed charge of gas is forced out the exhaust at this point.

3-8. The exhaust valve is a flapper type made of spring steel. A muffler is placed in the high-pressure line to suppress the popping noise which accompanies the release of a gas charge. The suction line is provided with a check valve to prevent gas from leaking back when the compressor is stopped. The suction strainer prevents dirt particles from entering the compressor.

3-9. **Condensers.** Among the kinds of condensers which you should know are (1) the finned coil with forced convection, (2) the finned coil with natural convection, and (3) the plate condenser with natural convection. Coils may be mounted in an upright, an inclined, or a horizontal position. The first few turns of coil may be placed under the pan which collects water from defrosting. Evaporation of this water aids the condenser in dissipation of heat. Between the condenser and the evaporator is a capillary tube firmly soldered to the suction line in order to operate as a heat exchanger.

3-10. **Evaporator Arrangements.** While one condenser may serve a combination refrigerator, there are three general arrangements for the evaporator to cool the two areas. In one arrangement, the evaporator coil in the freezer is extended into the refrigerator compartment. A restrictor separates the two sections of the evaporator coil, as shown in figure 3. The capillary tube is omitted for simplicity. The refrigerant goes first to the cooling coil, which is forced by the restrictor to operate at a higher pressure and temperature. After passing the restrictor, the refrigerant is at a lower pressure and absorbs sufficient heat to drop the temperature in the freezer to the desired low range. The restrictor used in some refrigerators is a weighted valve, and the method employed is called a weighted valve system.

3-11. A box which uses a weighted valve must be installed level to insure proper operation. If the position of the valve is disturbed from the correct position, the box will not perform properly. For example, certain boxes use a weighted valve which is designed to operate properly at an angle of 60° from the horizontal. If the valve is tilted too much toward the vertical, the food compartment will get warmer. On the other hand, too much tilt toward the horizontal will make the fresh food compartment colder. The indication of this trouble is continuous operation of the compressor and partial frosting of the food compartment evaporator coil. Either or both symptoms may be present.

3-12. The second arrangement uses an evaporator coil in the freezer compartment in combination with a secondary closed loop coil. This secondary coil acts as both a condenser and an evaporator. You can see in figure 4 that part of the closed loop is in the freezer. This part of the coil acts as a condenser, while the rest of the loop in the refrigerator acts as an evaporator. One major

![Figure 3. Dual temperature system.](image-url)
advantage of this is that the closed loop can be designed to operate frost free.

3-13. A third arrangement uses one of several combinations of the first two methods. These various combinations are designed with the object of either automatic defrosting or frost-free operation. Some of these combinations rely on air circulation to get better results. Slots between the two areas will allow convection currents to circulate, or a fan may be used for forced air to insure a more uniform temperature.

3-14. When only one coil forms the evaporator in the freezer compartment, it is called "air spill over." The method is called "refrigerant spill over" when two coils are used in series. When a separate evaporator is used to form a closed loop the method is known as a secondary refrigerant system.

3-15. Regardless of which arrangement is used for the evaporator, the system depends on a capillary tube with its heat exchanger function for proper operation.

3-16. **Capillary Tubes.** A capillary tube is used to control the refrigerant by placing a restriction in the liquid line. It is sometimes called a choke tube, a more descriptive name. The inside diameter and the length of the tube are critical factors. The diameter of the tube determines the restriction which it will have to control the flow of refrigerant. The length of the capillary must be long enough so that the liquid will have started to change to a gas as it nears the end of the tube. A selected portion of the tube is soldered to the suction line forming a heat exchanger. The length of the heat exchanger is calculated in the design so that the capillary will deliver liquid at the proper temperature. If the solder connection is broken, the heat exchanger will be lost, and the unit will not perform properly.

3-17. **Starting Relays.** At one time, the thermostat was used directly to control starting and stopping the compressor motor. The feeler bulb in older units was located in the freezer compartment. In some refrigerators, the feeler bulb is above a small access panel in the top of the freezer. Now, you will find that most refrigerators are provided with a starting relay, which provides two advantages: First, the relay can be located close to the motor. Second, the relay can handle the motor current more easily.

3-18. Changes in temperature in a refrigerator cause operation of the thermostat, which controls operation of the relay. The starting and stopping of the compressor motor is under the control of the relay. The characteristics of the motor (current and internal resistance) will determine the size of the relay used with it. Since these relays are sensitive to temperature changes, they are located where they will be least subject to changes. The three most common types are (1) the current relay; (2) the voltage, or potential, relay; and (3) the hot wire relay. We will discuss the operation of each so that you will understand the troubles you might find.

3-19. **Hot wire relays.** One type of hot wire relay uses two bimetal strips and two heater resistors. In figure 5, there is a schematic diagram which shows the connections for the relay and motor. The motor terminals are identified by C for common, R for run, and S for the start winding. When the motor control closes, electricity is applied to both the running and the starting wind-
Figure 6. Current relay.

The capacitor in the circuit of the starting winding gives the motor more starting torque. The resistor, in series with the bottom bimetal strip is designed to heat enough of the starting current so that it will cause the bimetal strip to bend up. This opens the circuit to the capacitor and the starting winding. The bleeder resistor across the capacitor keeps the relay contacts from being burned. The upper bimetal strip is heated by the upper resistor by the current going to the running winding. As long as the current to the running winding is normal, there will not be sufficient heat to make the upper bimetal strip open. Thus, you can see that the strip in the "run" circuit acts as an overload device. The current in the "run" resistor also serves to keep the bimetal strip in the start circuit from cooling so that its contacts remain open until the motor stops. If, for any reason, the motor current becomes excessive, the overload contacts will open and stop the motor. However, a disadvantage of this overload protection is that as soon as the device cools, the contacts will close and the motor will start again. It will then short-cycle until the circuit is opened. Failures such as this are rare, however. A variation of the hot wire relay uses a wire under tension to operate the contacts. In any case, the hot wire relay has been proved reliable in thousands of commercially made refrigerators.

3-20. Current relays. You will find that figure 6 is a schematic diagram of a current relay. Many refrigerators are equipped with this type of relay. For the sake of variety, this schematic shows a diagram which is typical of the control circuit for a water cooler. The only essential difference between this and the circuit for a refrigerator is the freezestat. Its purpose is to prevent the chilled drinking water from being frozen. The freezestat will stop the compressor motor (if the thermostat does not) to prevent the formation of ice which could damage the tank. The thermal overload protects the motor from burning out by opening the circuit if the motor draws太多 current. Excessive heat from the resistors makes the bimetal strip bend, which breaks the circuit.

3-21. Operation of the current relay occurs as soon as the thermostat closes the circuit to the motor. The inrush of current to the running winding is strong enough so that the coil pulls the armature up and completes the starting winding circuit. This happens in a fraction of a second, putting the starting winding and its capacitor in the circuit. As the motor approaches its operating speed, the motor current drops because of counter electromotive force (cemf). The coil in the relay is designed so that it will release when the motor r.p.m. passes three-fourths of its normal speed. The current in the relay coil is not sufficient to hold the weight of the armature when the motor is operating at its normal speed; therefore, the relay contacts open. A bleeder resistor is connected in parallel with the capacitor. Its purpose is to prevent a high-voltage discharge from the capacitor, which would burn the contacts in the relay as they open. An advantage of using a current relay is that the contacts in the thermostat are
only required to close on the inrush current to the running winding. Furthermore, the contacts in the relay are only required to carry the inrush current to the starting winding.

3-22. Servicing (i.e. troubleshooting) a current relay consists of checking the circuits for proper operation. As there are no adjustments, a relay which does not operate properly must be replaced. If the relay contacts are badly burned, the bleeder resistor should be checked for correct resistance. Some capacitors have the bleeder resistor made as an integral part of the capacitor. If the resistor is found defective, a new resistor of the correct wattage and resistance can be connected across the capacitor to make a repair.

3-23. Testing a current relay can be confusing. At least one maker uses a metal washer as the armature. When the coil is not energized, the washer lies (on the bottom of the case. You can hear it rattle when the case is tapped. If you did not know better, you might assume that something had broken loose and that therefore it was defective. Also, a relay of this make might be defective even though you could hear no rattle as the armature could be welded to the contacts. In addition, current relays are sensitive to position; consequently, they must be mounted horizontal or level to insure proper operation and normal life.

3-24. Potential relays. A voltage sensitive, or potential, relay will have its coil connected in parallel with the starting winding of the compressor motor. The schematic diagram in figure 7 is typical of the wiring of a motor provided with this type of relay. The defrost switch and circuits associated with it have been discussed already in the first section of this chapter. The contacts of the thermostat must be heavy enough to carry the inrush starting current to the compressor motor. An advantage of the potential relay is that the relay contacts are normally closed. Even so, the capacitor discharge across the relay contacts when they open may cause them to burn and be welded together. Thus, a bleeder resistor is required across the capacitor to prevent any welding of the contacts. The value of resistance for a bleeder is usually 15,000 ohms, and it is rated at 2 watts.

3-25. Operation of the potential relay does not occur until the motor passes three-fourths of its speed. The relay coil is voltage sensitive and requires considerably more than the line voltage to make it operate. When the thermostat contacts close, the motor starts, because both motor windings are energized. The contacts in the relay are

![Figure 7. Potential relay.](image-url)
speed, the current decreases. Induced voltage in the normally closed. As the motor approaches its operating starting winding now becomes greater than the applied voltage. The reason for this lies in a transformer action between the two windings in the motor. The voltage sensitive coil in the relay is sufficiently energized to open the contacts in the starting winding. The relay remains energized by the voltage induced in the starting winding. When the thermostat opens, the motor stops, and the relay contacts return to the closed position.

3-26. Servicing a potential relay consists of checking the coil and the contacts for continuity if troubles are suspected. Like other relays, the potential relay is sensitive to position and must be mounted level to insure proper operation and normal life. Since there are no adjustments, a defective relay must be replaced. A badly burned set of relay contacts would indicate that the bleeder resistor should be tested and replaced if it is open.

3-27. Resistors. A bleeder resistor should have a resistance between 15,000 and 30,000 ohms, depending on the size of the motor and the capacitor. A 2-watt rating is satisfactory for a refrigerator. The wattage rating is stamped on the body as "2 W." A resistor which is color coded will have bands of color painted on the body. Here are four examples:

<table>
<thead>
<tr>
<th>Ohms</th>
<th>First band</th>
<th>Second band</th>
<th>Third band</th>
</tr>
</thead>
<tbody>
<tr>
<td>15,000</td>
<td>Brown (1)</td>
<td>Green (5)</td>
<td>Orange (000)</td>
</tr>
<tr>
<td>20,000</td>
<td>Red (2)</td>
<td>Black (0)</td>
<td>Orange (000)</td>
</tr>
<tr>
<td>25,000</td>
<td>Red (2)</td>
<td>Green (5)</td>
<td>Orange (000)</td>
</tr>
<tr>
<td>29,000</td>
<td>Red (2)</td>
<td>White (9)</td>
<td>Orange (000)</td>
</tr>
</tbody>
</table>

3-28. Refrigerator Performance. So that you can evaluate the operation of a refrigerator, analyze troubles, and take the most economical means of repair, you must know its performance characteristics. Some of the factors which you should consider are these: electrical consumption, percentage of compressor running time, relative temperatures and types of use, vibration or noise, and continuous operation. Relative temperatures, of course, include room temperature and room humidity (mentioned below) and the temperature, respectively, of the freezer section and the refrigerator section (not discussed below). Continuous operation, although discussed below, is caused by troubles not normally considered in refrigerator performance.

3-29. Electrical consumption is figured in kilowatt-hours per 24-hour period. You may obtain a recording type meter from the electric shop on the base or from the local utility company when an actual test is necessary. You may compare the results with standard test curves furnished by the maker of the box. A modern refrigerator may use from 2 kilowatt-hours to 8 kilowatt-hours in a 24-hour period, depending on the size of the cabinet and the difference between cabinet and room temperature.

3-30. The percentage of compressor running time is affected by various variable conditions, but normal use in a 75° F. room will require the compressor to operate one-third of the time. Any large increase in running time indicates there are abnormal conditions. For example, setting the thermostat for a refrigerator temperature of 20° F., when a temperature close to 38° is considered normal will increase the compressor running time.

3-31. Relative temperatures and type of use are just two of the variables which affect performance. Increased room temperature and room humidity put a heavier load on the compressor. A difference of 20° room temperature may double the running time and electric power used. Higher humidity will produce frost at a greater rate causing a reduction in evaporator efficiency. Type of use includes frequency and duration of door openings as well as the foods stored in the refrigerator. Uncovered liquids will cause an automatic defrost to cycle more frequently. Unusual load would also result if the freezer is required to make a great many ice cubes.

3-32. Vibration or noise is rare in the modern refrigerator as the capillary tube system used by most manufacturers requires no moving parts except for the compressor and the motor. Vibration may result from a defective mounting. For instance, one of the more common causes is failure to release the holddown bolts for the compressor, which were installed before shipment of the cabinet. On the other hand, a unit will be noisy if it is low on oil. Thus, if a leak has developed, requiring that refrigerant must be replaced, then it is likely that oil has also been lost and must be replaced. One clue to watch for is this: A noisy capillary tube will usually indicate low refrigerant, and this results in gas noises such as bubbling or hissing. Of course, low refrigerant is also indicated by a partially frosted cooling coil and continuous compressor operation. In the latter event, low- and high-side pressures will be lower than normal. You should also not that a capillary tube which is clogged or pinched will show a high vacuum on the low side and an abnormally high head pressure.

3-33. Continuous operation can be caused by a defective thermostat, one which does not cut the compressor off. Any abnormal condition which causes continuous operation may be obscured at the time you are called because overheating may cause the motor overload protection to operate. Thus, when you get to look at the unit, you may find it short-cycling; that is, the overload device will be shutting the unit off. When it cools enough, the unit will start again. A fast check of
this can be made by feeling the temperature of the motor and compressor with your hand. Many compressors now have the overload protector inside the shell, where the heat from the motor will prevent the unit from short-cycling. One last item which is often overlooked is low line voltage, which will make a motor run slow and overheat. Where a television set is used in the same building as the refrigerator, low line voltage is indicated if the picture fails to fill the tube. This is one way of verifying low voltage when a voltmeter is not available. You must remember to consider all of the factors when you evaluate the performance of a unit.

4. Freezers

4-1. Many homes today have domestic freezers for the storage of large amounts of frozen foods. These freezer cabinets are either of the upright style or of the chest style and range in size from 15 to over 25 cubic feet. In such freezers the capillary type system with a hermetic unit is widely used. Also, in many cases, the compressor employed in this system is similar to those used for refrigerators. Upright freezers are supplied with forced-air circulation when they are made for frost-free operation. Automatic defrosting is done by the hot gas or the hot wire method used in combination refrigerators. Because of the similarity of the two systems, troubleshooting a freezer can be done by the same rules as for a refrigerator. Troubleshooting a hermetic system follows this section. The construction features of a freezer are often the same as a refrigerator. Therefore, the information here is concerned with those features which apply to freezers.

4-2. Operation and Care. The operating temperature for domestic freezers is in the range of 0°F to 10°F. Each such freezer is equipped with a thermostat so that it can be adjusted to satisfy the user's desires. Most foods are already frozen when placed in storage, but when nonfrozen foods are placed in the freezer, it would be desirable for the user to move the control to a colder position in order both (1) to insure faster freezing and (2) to prevent the thawing of other foods. Food must be stacked so as not to interfere with air circulation, as this would cause warm spots to develop in the cabinet. Food must also be wrapped in moisture proof and vaporproof material to prevent desiccation.

4-3. A freezer cabinet in normal usage will require defrosting about twice a year. Frost may be removed by means of a scraper, such as a wooden paddle, or with a stiff fiber brush. Use care not to damage the finish. When you desire a complete defrosting, however, remove all frozen foods and store them in dry ice to prevent thawing. Then shut off the power and use warm water to hasten melting of the ice. Of course, you should never try to chip ice from coils, as such action might damage them beyond repair. Also, wash the box with a solution of baking soda or ammonia, and always dry the inside of the box before putting it back in service.

4-4. Construction Features. To prevent frosting around the door, a mullion heater of low wattage is installed in back of the breaker strip. By this means, too, sweating around the door is virtually eliminated, because the heater is operating continuously. Fiberglas, rock wool, and certain synthetics are used for insulation of present day freezers. Consequently, where formerly a 3- to 4-inch thickness of insulation was used in cabinets, you may now find them built with walls less than 2 inches thick. Yet, because of the colder chest temperature, freezer insulation must be better protected against moisture than that in a refrigerator. The most effective method for accomplishing this has been found to be a combination of venting and sealing. Venting is provided to prevent a partial vacuum which would occur in a sealed box as the temperature of the air is lowered. If the insulation scaling is to be effective, however, it must have greater resistance than the venting. Thus, the vent will allow box pressure to equalize while the seal remains intact.

4-5. Freezer Failure and Alarms. Within 24 hours after a freezer fails, the foods it contains will start to thaw. If this is discovered in time, dry ice can be used to prevent the thawing while repairs are made to the unit. Otherwise, meats and fresh frozen fruits must be used quickly, as it is new satisfactory-or safe-to freeze them a second time. To avoid this situation, alarm devices are made which will signal a rise in temperature to 15°F in the cabinet. The alarm is given by both visual and auditory means. Two kinds of alarms are available. One is made for operation on a 6-volt battery. The other is made for operation on a 110-volt circuit. The latter should be plugged into a branch circuit different from that used for the freezer. The thermal element should be located in the upper part of the cabinet, where it will reflect a rise in temperature quickly. While such alarm devices are not generally supplied for domestic units, they can be installed in any freezer cabinet.

4-6. In the next section, we will deal with troubleshooting hermetic systems. You will not find any distinction between refrigerators and freezers, because they both use the same kind of hermetic systems. The main difference between refrigerators in general and freezers is that only part of a refrigerator is held at near zero temperature.
5. Troubleshooting Hermetic Systems

5-1. The sealed system preferred for freezers and refrigerators is called a closed or hermetic system. The shell which contains the motor and compressors is welded shut, thus the name “sealed unit?” The motor leads pass through a glass insulator, which is bonded to the metal to insure a joint that will never leak. The one big advantage of a hermetic compressor is that there are no seals where leaks can develop. This eliminates at least one trouble spot from the system used in domestic refrigerators and freezers. But, as you know, there are still enough other trouble spots to keep a serviceman busy.

5-2. The best troubleshooter puts his brain to work before reaching for the toolbox. The first action on the job should be to question the user. Ask him, for example, these things:

- When did you first notice this trouble?
- How often does it happen?
- Does it happen at night as well as during the day?
- Has the unit been making a strange noise?
- Is this condition intermittent or is it continuous?
- Does this happen on just certain days of the week?

The answers to such leading questions should enable you to determine whether the trouble is being caused by misuse. By eliminating outside factors at the beginning, you will know that you are dealing with a fault in the equipment itself. After this, consider the possible electrical troubles first, as they can usually be checked easily and quickly.

5-3. Electrical Troubles. There is a logical sequence which should be followed in making tests on the electrical system. The first check seems so simple that it is often overlooked. Remember, the unit cannot operate without electrical power. A quick reference for common faults is given in table 1, together with the possible causes and their remedies. Such a trouble chart is most useful, since it presents a great many facts in a small space. In addition, you will sometimes find the solution to a problem while studying a troubleshooting table, even though the specific fault does not appear in the table. Often, in fact, a common fault is passed by because it seems too obvious. The serviceman may think that a common fault is too easy and could not possibly be the trouble he was hunting. Do not prejudge; instead, make reasonable "guesses" from what you see and the trouble chart, then test to find out the practical results. In the following paragraphs, we have given you a detailed explanation of the most likely troubles to be found in the electrical system.

5-4. Power supply. Check the source of power for voltage to the unit. How? With a voltmeter or a multimeter! In the case of a refrigerator, open the door. If the light does not come on, there are several possibilities: (1) the power circuit is incomplete to the unit; (2) the lamp is burned out; (3) the door switch is defective; (4) the circuit to the unit may be good, but the wires to the lamp and the door switch are broken somewhere in the box. If the lamp lights, you will know that there is power to the unit. However, check the voltage with an accurate voltmeter when you suspect low voltage. Remember: The line voltage may vary 10 to 15 volts with changes in the load during the day. Most units will not show difficulty unless the voltage drops below 105 volts.

5-5. Overload protection and controls. Make sure that the extension cord is disconnected before making a continuity test on the protector. With an ohmmeter or a test lamp, check for a continuous circuit through the overload protector. If it tests open, you have found at least one trouble which will prevent the compressor motor from operating. Replace a defective overload protector and check the unit for normal operation. Many compressors have the overload protectors located inside the shell. A distinctive label on the compressor is used to indicate an internal mounting. Placing a protector inside the shell has the effect of extending the cooling period after an overload trips. Remember, when checking an overload protector mounted inside, allow the compressor sufficient time to cool so that the protector has a chance to automatically reset itself. How long is "sufficient time"? When you can rest your hand comfortably on the shell, the compressor should have cooled enough for you to make a valid test of the overload contacts.

5-6. Check, too, all control switches for proper operation, since one open switch will prevent the unit from operating. Such items as thermostats, defrost controls, and freezestats are all designed to open and close the primary circuit. Remember the function of the item which you are checking, because an open circuit may not mean that the device is defective. A thermostat should show an open circuit if the feeler bulb is colder than its operating point. A defrost control will be open if the timer is in the defrost cycle. Some defrost systems have a reset which is actuated by an increase or decrease in temperature above a set point. A freezestat will show an open circuit when it senses a temperature lower than its operating point. You can check the operation of a device by raising or lowering its temperature. A thermostat is checked by placing the feeler bulb in a glass of ice and water. An ohmmeter or test light is connected across the contacts so that the time of opening and closing can be observed. A thermometer is placed in a glass of water and its temperature is...
read at the time the contacts open. Remove the ice and add warm water slowly till the contacts close. Again read the temperature of the water. Replace the thermostat if it does not conform with manufacturer's specifications.

5-7. *Motor circuit.* A hermetic system can be checked quickly with a motor-start analyzer. It will check for continuity in motor windings, for shorted windings, and for grounded windings. It can also be used to start a motor and can reverse the direction of rotation. The analyzer contains capacitors which can be used in the motor circuit to increase its starting torque. Higher starting torque or momentary reversing are two ways of unlocking a compressor which for some internal reason cannot be started normally. When an analyzer is not available, plug the refrigerator cord into an outlet and test for voltage at the terminal block where the cord terminates. There should be voltage at the terminals if the cord is good. If the motor runs, you should use a clamp type ammeter to check for correct motor current. Next, you must unplug the cord and make some continuity checks with a test light or an ohmmeter.

### Table 1

**Electrical Troubles (Hermetic Units)**

<table>
<thead>
<tr>
<th>Fault</th>
<th>Cause</th>
<th>Remedy</th>
</tr>
</thead>
<tbody>
<tr>
<td>Will not run.</td>
<td>No power.</td>
<td>Close circuit or repair open.</td>
</tr>
<tr>
<td></td>
<td>Defective thermostat.</td>
<td>Replace.</td>
</tr>
<tr>
<td></td>
<td>Defective defrost switch.</td>
<td>Replace.</td>
</tr>
<tr>
<td></td>
<td>Defective defrost timer.</td>
<td>Replace.</td>
</tr>
<tr>
<td></td>
<td>Open overload protector.</td>
<td>Reset or replace.</td>
</tr>
<tr>
<td></td>
<td>Open relay coil.</td>
<td>Replace relay.</td>
</tr>
<tr>
<td></td>
<td>Open motor winding.</td>
<td>Replace compressor.</td>
</tr>
<tr>
<td>Runs noisy.</td>
<td>See mechanical troubles.</td>
<td></td>
</tr>
<tr>
<td>Short-cycles and runs noisy.</td>
<td>Relay contacts not operating.</td>
<td>Replace relay and check capacitor and bleeder resistor.</td>
</tr>
<tr>
<td></td>
<td>Short circuit or grounded motor winding.</td>
<td>Check and replace compressor.</td>
</tr>
<tr>
<td>Units trips circuit breaker or blows fuse.</td>
<td>Short circuit or ground.*</td>
<td>Check out electrical system.*</td>
</tr>
</tbody>
</table>

**Note:** If a fault causes a ground in the box, you can be fatally shocked by touching the refrigerator or the freezer chest!
Unless you are familiar with the electrical system, you will need a wiring diagram for the unit which you are testing.

5-8. Some compressors have an electric heater in the crankcase to prevent condensing of the refrigerant during off time. Liquid refrigerant can cause slugging and damage the compressor. One manufacturer used a capacitor with one of the motor windings to act as a heater during compressor off time. Such a motor would always be "live" even when not running. Be sure of the type of motor used before you attempt to trace the motor circuit. Determine the type of relay (hot wire, current, or potential relay) which is installed in the unit. After you have checked the diagram and understand the circuit, you will be ready to check out that specific motor.

5-9. For purposes of our explanation, refer to figure 7, which illustrates the circuit for a potential relay. We will use the compressor motor circuit shown in figure 7 to identify the motor's terminals in the following discussion. Make a continuity check from C to S and between C and R. A test lamp should light almost normal in each case if the windings are good. An open circuit is indicated when the lamp fails to light. Note that this test is valid only if direct current is used to energize the circuit. If alternating current is the only power available for the test lamp, the common connection at C must be opened. Otherwise, the closed contacts of the relay and the capacitor will make a complete circuit. Opening C is not necessary when checking with an ohmmeter, because it uses direct current from self-contained batteries. The reason is that a capacitor blocks direct current while it allows alternating current to flow. See the paragraph for testing capacitors, where the capacitor is explained more fully.

5-10. To test for a grounded motor winding, check from terminal C to an unpainted part of the compressor motor shell. An ohmmeter must be used to measure the resistance of the motor windings to test for a shorted coil. Readings should compare closely to the specifications of the manufacturer. A severely shorted coil would be indicated by tripping of the branch circuit breaker or by blowing of the fuse when the unit is plugged into the voltage outlet. If tests indicate that the motor windings are at fault, the hermetic unit must be replaced.

5-11. If the motor runs but overheats during operation, a current draw test with a clamp type ammeter will give an indication of conditions. Motor current should be within 10 percent of nameplate rating on the unit. The nameplate may give two amperage figures, such as FLA 3.5 and LRA 18.0. The FLA stands for "full load amperage," while LRA stands for "locked rotor amperage." If the current exceeds the nameplate rating by more than 10 percent, it is considered unsatisfactory, and the hermetic unit must be replaced. A motor drawing its LRA rating indicates that the rotor is not turning. Conditions inside the sealed unit will also be indicated by unusual vibration and noises. For tests of the refrigeration system, see Mechanical Troubles, paragraph 5-17.

5-12. Testing capacitors. We will discuss two methods for testing a capacitor. When the capacitor can be disconnected from the circuit and the bleeder resistor, a reasonable test is to charge and then discharge it with its normal voltage (of over 120 v). Charge it by momentarily applying voltage to its terminals. Then use a piece of insulated wire to short circuit the terminals. A hot spark indicates that the capacitor is able to hold a charge. Some capacitors have a bleeder resistor of between 15,000 and 30,000 ohms which is in the form of an integral part that cannot be disconnected. This type of capacitor may be checked by connecting an ammeter and a 10-, 15-, or 20-amp fuse in series with the capacitor. Apply 120 volts to the capacitor just long enough to read the ammeter. If the fuse blows, the capacitor is shorted and must be replaced. Use a fuse large enough to carry the current and make sure that the current will not be so great as to drive the ammeter needle off the scale. For example, a 20-mfd capacitor at 120 volts should draw less than 1 ampere, while a 400-mfd capacitor at 120 volts will draw 18 amperes. When making a test, apply voltage to a capacitor just long enough to read the ammeter. The current measured should be within 20 percent of that determined by the formula given where mfd is the rating in microfarads and v is the normal applied voltage. The number 2650 is a constant for 60-cycle current, while 3180 is the constant used when calculating a circuit using 50-cycle current.

\[
\text{Capacitor test} \quad \text{amps} = \frac{\text{mfd} \times v}{2650} \quad \text{for 60-cycle} \\
\text{amps} = \frac{\text{mfd} \times v}{3180} \quad \text{for 50-cycle}
\]

A defective capacitor must be replaced by one of the voltage and mfd rating or the equivalent as specified by the manufacturer.

5-13. Testing relays. Before testing a relay, you must know the type. "You may have a schematic diagram which shows the hookup of the relay but does not identify it by name. You should be so familiar with the common types that you know their characteristics well enough to identify them. A fan motor is used in some units for forced-air circulation. The diagram in figure 6 shows an example of a relay and a fan motor in
You will avoid accidents this way: so that you will set a good example for others to follow.

6-2. Safety Rules. Study the following rules so that you should know will be presented. Then we will discuss the equipment and explain procedures for brazing with alloys, silver brazing, welding copper, and cutting metal. Safety for yourself is stressed so that you can do this work without danger to your self. First, the safety rules which must know how to use welding equipment properly. A quick review of mechanical troubles is furnished in table 2, where possible causes are listed with their related faults. As the repair or replacement of components involves the use of soldering and welding equipment, a review of this subject is presented before we discus the procedures to follow with specific items.

5-14. Referring to figure 5, you will see a type of hot wire relay that has two bimetal strips, two resistors or heaters, and two set of contacts. Both sets of contacts should be closed when the relay is not energized. The start contact should open soon as the motor reaches operating speed. You can verify opening of the start contacts with a voltmeter which should read line voltage across the start contacts. A zero reading will indicate that the contacts are not opening.

5-15. The current relay shown in figure 6 can be checked for continuity through the coil and for an open circuit across the contacts when it is not energized. The contacts close on starting but should remain open while the motor is running. Use direct current, such as with an ohmmeter, to test across the relay contacts, as a.c. can feed around through the motor winding and the capacitor, giving a false reading of continuity.

5-16. The potential relay, which is shown in figure 7, must be isolated from the compressor motor before testing. Open the R and S leads at the terminals on the relay. Check the relay connects between R ad S for continuity. The contacts are normally closed; thus, the test should show a complete circuit. A test between S and terminal L should also show a complete circuit through the coil of the relay. If either test shows an open circuit, the relay is defective and must be replaced.

5-17. Mechanical Troubles. The mechanical troubles found in a refrigerator can be divided into two categories: (1) those which are caused by defect in manufacture, and (2) those which are the result of mishandling or accident. A quick review of mechanical troubles is furnished in table 2, where possible causes are listed with their related faults. As the repair or replacement of components involves the use of soldering and welding equipment, a review of this subject is presented before we discus the procedures to follow with specific items.

6. Brazing, Cutting, and Welding

6-1. Before you can join metals or make repairs you must know how to use welding equipment properly. Safety for yourself is stressed so that you can do this work without danger to your self. First, the safety rules which you should know will be presented. Then we will discuss the equipment and explain procedures for brazing with alloys, silver brazing, welding copper, and cutting metal.

6-2. Safety Rules. Study the following rules so that you will understand them. Apply the rules in your work so that you will set a good example for others to follow. You will avoid accidents this way:

- Never drop a cylinder or allow it to fall.
- Never bump a cylinder or otherwise handle it roughly.
- Never lay an acetylene cylinder on its side. In addition to acetylene, the tank also contains infusorial earth, which will get into the regulator and valves if the tank is placed on its side. Also, safety plugs in the bottom of the tank will pass harmlessly into the floor if the cylinder is standing up when they blow out.
- Never allow oil or grease to come into contact with oxygen; specifically, never direct a jet of oxygen at an oil-soaked surface. Spontaneous combustion may result.
- Never lay an oxygen cylinder on its side. The top of the cylinder carries the safety plug. If it blows while the cylinder is on its side, the exhaust pressure released will propel the cylinder like a rocket.
- Never use oil, grease, or any lubricant on a torch.
- Never hang a torch or hoses on regulators or cylinder valves.
- Never use matches for lighting a torch, as your hand may be seriously burned as a result. Use a friction igniter or a suitable pilot light.
- Never light the torch from hot metal when working in a confined space. Accumulated fumes can flare or explode.
- Never weld where hot sparks can set fire to material or where sparks can fall on your legs or on the hoses.
- Always wear goggles designed for the welding work or brazing which you are doing.
- Never block yourself from the cylinders when you are working; make sure that you can get to them easily and quickly from your working position.
- Never store cylinders in direct sunlight or near heaters.
- A valve clogged with ice may be thawed with warm water; however, never use a flame or boiling water for this purpose.
- Never close acetylene on and off near the valve so that it can be turned off quickly in an emergency.
- Always keep the special wrench used to turn acetylene on and off near the valve so that it can be turned off quickly in an emergency.
- Never hammer or beat on a valve; furthermore, do not attempt to adjust a valve or a gauge which does not work.
- Replace protective caps on the cylinders whenever gauges have been removed.

Oxygen and Acetylene Apparatus. In figure 8 you will find an illustration of oxygen and acetylene cylinders and the accessories used with
The rules for properly setting up this apparatus are as follows:

- Place the oxygen and acetylene cylinders on a level floor and secure them so that they cannot be accidentally knocked over. Then remove the protecting caps.
- Crack each cylinder valve just enough to blow out dirt or foreign matter. Close the valve as soon as the throat is clear, then wipe off the seats. (NOTE: Do not stand in front of a valve when cracking it.)
- First, connect the acetylene regulator to the acetylene cylinder; then, second, connect the oxygen regulator to the oxygen cylinder. Use a close-fitting wrench to tighten the connections sufficiently to prevent leakage.
- Connect the red hose to the acetylene regulator. As you do this, note the left-hand threads on the acetylene hose connections. Next, connect the green hose to the oxygen regulator. Screw the connections tight enough to prevent leaking.
- Release the regulator screws to avoid damage to the regulators and gauges and open the cylinder valves slowly. Read the high-pressure gauge to check the pressure of the contents in each cylinder.

### TABLE 2
**Mechanical Troubles (Hermetic Units)**

<table>
<thead>
<tr>
<th>Fault</th>
<th>Cause</th>
<th>Remedy</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fails to run.</td>
<td>Locked rotor.</td>
<td>Replace compressor.</td>
</tr>
<tr>
<td>Fails to cool or runs continuously</td>
<td>Broken valves.</td>
<td>Replace compressor.</td>
</tr>
<tr>
<td>Restrictions:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>- kink or pinch.</td>
<td>Cut out and replace.</td>
<td></td>
</tr>
<tr>
<td>- moisture.</td>
<td>Dry and recharge.</td>
<td></td>
</tr>
<tr>
<td>Low on charge.</td>
<td>Find leak, repair and recharge.</td>
<td></td>
</tr>
<tr>
<td>Vibration.</td>
<td>Loose motor mounts.</td>
<td>Tighten.</td>
</tr>
<tr>
<td></td>
<td>Loose tubing mounts.</td>
<td>Tighten.</td>
</tr>
<tr>
<td></td>
<td>Shipping bolts</td>
<td>Remove.</td>
</tr>
<tr>
<td></td>
<td>installed.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Uneven floor.</td>
<td>Adjust feet.</td>
</tr>
<tr>
<td>Noisy compressor.</td>
<td>Defective part</td>
<td>Replace compressor.</td>
</tr>
<tr>
<td>(internal).</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lost charge.</td>
<td>Punctured coil or leak.</td>
<td>Repair and recharge.</td>
</tr>
</tbody>
</table>
• Blow out the oxygen hose. By turning in the regulator screw; open each regulator (two gauges) so as to blow out the hose; then release the regulator screw. If it is necessary to blow out the acetylene hose, you must do the work in a place which is both well ventilated and free from sparks or flame.

• Connect the red acetylene hose to the torch needle valve stamped "AC" and the green oxygen hose to the torch needle valve stamped "OX." Test all hose connections for leaks at the torch and at the regulator by turning in both regulator screws with the torch needle valves closed. Release the regulator screws after testing and drain both lines by opening the torch needle valves.

• Slip the tip nut over the mixing head, screw the tip into the mixing head, and assemble it in the torch body. Then tighten the assembly by hand and adjust the tip to the proper angle. Secure the adjustment by tightening it with the tip-nut wrench.

• Adjust acetylene working pressure by open-
ing the acetylene torch needle valve and turning the regulator screw to the right for the required pressure according to the size of the tip. Adjust oxygen working pressure in the same manner, according to tables 3 and 4. For tip sizes in the low-pressure or injector type of torch use table 3. For tip sizes in the medium-pressure or balanced-pressure type of torch, use table 4. (NOTE: In table 4, each of the first three sizes requires 1 pound of pressure, while the others take the same number of pounds of pressure as the tip size. The size of the tip that you choose is determined by both the thickness of the metal or tubing and the area which must be heated.)

6-4. Shutting down the torch safely involves the following 6-step procedure:

- First close the acetylene valve on the torch.
- Second, close the oxygen valve on the torch.
- Third, close the acetylene and oxygen cylinder valves.
- Fourth, drain both the regulators and hoses. Open the torch acetylene valve until gas flow stops; then close the valve. Drain the oxygen regulator and hose in the same manner. Both the high- and low-pressure gauges on the oxygen and acetylene regulators should now read "zero."
- Fifth, release the tension on both regulator screws by turning them to the left until they rotate freely.
- Sixth, coil the hose and suspend it in a suitable holder, being careful to avoid kinking the hose.

6-5. Use of Alloys for Brazing. The alloys used for silver brazing all have a melting point above 1000° F. This is, however, still below the melting point of the base metals to be joined. When properly made, the joint will be at least strong as the metals joined. You must swage one end of tubing which is to be joined. The swaging tools must be clean and free of oil. This will produce a swaged end which does not require added cleaning. The most important factor in

### TABLE 3

**Tip Sizes for Injector Type of Torch**

<table>
<thead>
<tr>
<th>Tip Size No.</th>
<th>Acetylene Pressure</th>
<th>Oxygen Pressure</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>1</td>
<td>9</td>
</tr>
<tr>
<td>1</td>
<td>1</td>
<td>9</td>
</tr>
<tr>
<td>2</td>
<td>1</td>
<td>10</td>
</tr>
<tr>
<td>3</td>
<td>1</td>
<td>10</td>
</tr>
<tr>
<td>4</td>
<td>1</td>
<td>11</td>
</tr>
<tr>
<td>5</td>
<td>1</td>
<td>12</td>
</tr>
<tr>
<td>6</td>
<td>1</td>
<td>14</td>
</tr>
<tr>
<td>7</td>
<td>1</td>
<td>16</td>
</tr>
<tr>
<td>8</td>
<td>1</td>
<td>19</td>
</tr>
<tr>
<td>10</td>
<td>1</td>
<td>21</td>
</tr>
<tr>
<td>12</td>
<td>1</td>
<td>25</td>
</tr>
<tr>
<td>15</td>
<td>1</td>
<td>30</td>
</tr>
</tbody>
</table>

### TABLE 4

**Tip Sizes for Balanced-Pressure Type of Torch**

<table>
<thead>
<tr>
<th>Tip Size No.</th>
<th>Acetylene Pressure</th>
<th>Oxygen Pressure</th>
</tr>
</thead>
<tbody>
<tr>
<td>00</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>0</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>2</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>3</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>4</td>
<td>4</td>
<td>4</td>
</tr>
<tr>
<td>5</td>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td>6</td>
<td>6</td>
<td>6</td>
</tr>
</tbody>
</table>
joining tubing is to have proper clearance between the parts. An easy slip fit with tubing should approximate the range .0015 to .005 inch, which is recommended. To insure proper centering of the male pat, insert it so as to evenly contact the shoulder of the swaged member. This procedure will insure a uniform distribution of the alloy with no voids and prevent the alloy from dripping into the inside of the tubing, where it would cause an obstruction. Position the angle of the joint in tubing so that solder or flux will not drop inside. Rely on capillary action to pull the solder throughout the joint.

6-6. The ends of tubing to be joined must be square and uniformly round. The surfaces must be free of oil, scale, grease, and dirt. If you find any oil or grease, you can remove it with hot caustic soda. You can remove scale with an acid pickle bath; however, you must then remove all traces of acid after such treatment, since any trace of acid left in the tubing will cause trouble in the future. Avoid handling surfaces after they have been cleaned.

6-7. The alloys listed in table 5 are all suitable for working with copper, but Easy Flo3, Sil-Fos, and Phos-Copper are considered best. Many manufacturers make alloys for soldering. Sil-Fos is for use with nonferrous metals only. Pros-Copper will make good joints in copper without flux. Easy-Flo3 is 50 percent silver alloy, with the addition of 3 percent nickel. The other Easy-Flo numbers give the percentage of silver in the alloy. These alloys are available from many manufacturers. In using silver solder on fittings, you should be careful to observe installation instructions to insure good joints. One manufacturer specifies that alloys containing phosphorous, such as Sil-Foe or Silvaloy 15, not be used on fittings which are copper-plated steel. They recommend instead, Silvaloy 45 or Easy-Flo.

6-8. It is important that you heat the work to the flow point of the alloy before applying the alloy. Alloys with a large spread between melting and low point are easier to work with, since the alloy with a large spread has a better chance of making a joint before it sets.

6-9. Use asbestos paper or wet cloth to keep heat from pans which might be affected by it. Some valves are provided with neoprene seats, and these must be removed if they are too close to where heat will be applied. Otherwise, the heat will destroy the value of the seat, and the valve will leak.

6-10. When you use flux in making a joint, you should observe the following: Apply the flux evenly to the metal surfaces which are to be protected from oxidation. If the flux wets the surface easily, this indicates that it is clean. If it balls up and spreads unevenly, the surface is oily and requires cleaning. In addition, the behavior of the flux can be used as a temperature gauge. One popular brand used with brazing becomes white and puffy about 600° F. A 800° F. it smoothes out with a milky color, while at 1100° F. it turns clear, and the bright metal surface should show through the flux.

6-11. **Silver Brazing.** This method of joining metals is properly called low-temperature brazing, but it is often incorrectly referred to as silver soldering. It is necessary to heat the metals only to the melting point of the silver solder, 1175° F. A low-melting-point alloy, such as Easy-Flo, is used with a suitable flux, such as that made by Handy and Harmon. The melting point of the flux, 1125° F., gives a good indication of when the metals to be joined are near the correct heat. A carburizing or reducing flame should be used to insure a good point where brazing copper with silver solder. (See fig. 9.) Phos-Copper may be used to join copper to copper without using a flux. No flux is an advantage when tubing or parts are joined in a system which should be kept clean. Remember that a clean, dry refrigeration system is one that keeps working year after year without giving trouble. A slightly carburizing or reducing flame is required when working with Phos-Copper.

6-12. **Welding Copper.** A welding rod should have approximately the same composition as the

### TABLE 5

<table>
<thead>
<tr>
<th>Alloy</th>
<th>Melting Point</th>
<th>Flow Point</th>
</tr>
</thead>
<tbody>
<tr>
<td>Easy-Flo50</td>
<td>1160° F.</td>
<td>1175° F.</td>
</tr>
<tr>
<td>Easy-Flo45</td>
<td>1125° F.</td>
<td>1145° F.</td>
</tr>
<tr>
<td>Easy-Flo35</td>
<td>1125° F.</td>
<td>1295° F.</td>
</tr>
<tr>
<td>Easy-Flo3</td>
<td>1195° F.</td>
<td>1270° F.</td>
</tr>
<tr>
<td>Sil-Fos+</td>
<td>1185° F.</td>
<td>1300° F.</td>
</tr>
<tr>
<td>Phos-Copper</td>
<td>1304° F.</td>
<td>1382° F.</td>
</tr>
</tbody>
</table>

20
Employing such a rod, you must use a slightly oxidizing flame when you are welding copper. Remember, too, that copper will absorb carbon monoxide gases from a carburizing flame and in a porous weld (since silver solder is worked at a lower temperature, a carburizing flame is used).

Welding rods, such as Airco 23 Deoxidized Copper or Oxweld 19 Cupro-Rods, should be suitable for welding copper. The choice of tip for the torch should be about two sizes larger than that which you would choose for steel of the same gauge. A large flame is required because copper conducts heat away much faster than steel. No flux is required to make the weld; therefore the weld must be made fast before oxidation occurs.

Metal is heated for about 3 inches along the seam to a full red heat. The weld should be started inside and worked to the nearest edge. The torch should be held at about a 60° angle to the base. Speed should be uniform and the end of the filler rod should be kept in the molten puddle. During the welding operation, the molten metal is protected by the outer flame envelope. If the metal ceases to flow freely, the filler rod must be raised and the work must again be heated to a full red.

Cutting Torch. Metal is properly cut with a cutting torch which is quite different from the welding torch just discussed. However, it is joined to the hoses in the same manner as the latter, and the same safety rules apply. The main differences are found in the body of the torch and in the tips. Thus, the cutting torch has a compound head which directs a hollow flame of oxyacetylene. Also, a trigger valve in the body controls an added jet of oxygen. When the valve is pressed, this jet of oxygen in the center of the flame makes the cut by superheating the metal at the point of contact. A part of the cut metal is burned in this operation. Stainless steel is difficult to cut with a torch because it is resistant to oxidation. However stainless steel may be cut by laying a steel welding rod on the cut to be made. The heat developed by oxidation of the rod is sufficient to melt a slot in stainless steel plate. Table 6 gives the pressures and tip size to use with steel plates of various thickness. The oxygen pressure is set higher to supply the added oxygen necessary for cutting. Steel is heated to incandescence before the cut is started. As soon as the oxygen jet is applied, the cut will appear at the edge of the plate. The cut should be made at a uniform pace as fast as the metal is removed. If the torch is moved too slow, there will be a waste

<table>
<thead>
<tr>
<th>Plate Thickness</th>
<th>Tip</th>
<th>Acetylene</th>
<th>Oxygen</th>
</tr>
</thead>
<tbody>
<tr>
<td>1/4-inch</td>
<td>0</td>
<td>3</td>
<td>25 to 30</td>
</tr>
<tr>
<td>3/8- to 1/2-inch</td>
<td>1</td>
<td>3</td>
<td>30 to 40</td>
</tr>
<tr>
<td>3/4- to 1-inch</td>
<td>2</td>
<td>3</td>
<td>40 to 50</td>
</tr>
<tr>
<td>1 1/2-inch</td>
<td>3</td>
<td>3</td>
<td>45 to 50</td>
</tr>
<tr>
<td>2-inch</td>
<td>4</td>
<td>3</td>
<td>50 to 55</td>
</tr>
</tbody>
</table>
of both fuel and metal. If the torch is moved too fast, the cut will fail, because the metal is not hot enough.

6-16. **Hydrocarbon Torch.** Smaller torches which use LP gas can be used for silver solder work, but they are limited to smaller work. They do not produce as large a flame, and the temperature of the flame is not as hot as that of the oxyacetylene torch. Otherwise, the same rules and techniques apply to both kinds of torches.

### 7. Repairs and Service

7-1. Very few refrigerators have service valves or fittings. You can remedy this by installing an accessory service valve or line tap, clamping it to a line where it becomes a permanent part. A gasket makes a seal between the valve and the line, while the valve stem is provided with a piercing tool which breaks into the line. However because these gaskets leak in time and the valves are expensive, most shops will maintain a valve kit and a set of adapters. Having such a kit, you can use the adapters to install valves and gauges in a system when it becomes necessary for you to make pressure tests. These adapters, valves, and gauges do not become a permanent part of the system, and you can remove them after completing the tests. You may also install a gauge manifold in the system to make tests. The use of a gauge manifold is illustrated in Chapter 2, figure 23, where we have described cleaning of the system with a circulator.

7-2. The repair of refrigerators and freezer cabinets is generally limited to service and minor repair work. However, because you may be required to make more extensive repairs, the explanations are made as complete as time and space allows. The material covers leak detecting and repairing, pressure testing, replacing of a capillary tube, a condenser, a compressor and an evaporator, the cleaning of a system, the removal of moisture from a system and the charging of a small hermetic system.

7-3. **Detecting Leaks.** When a hermetic system has lost some of its charge, you can be sure that there is a leak which must be found and repaired. We will discuss here only the two detectors which are most commonly employed: the halide and the electronic leak detectors. But first, several fundamentals should be clarified. Some detectors are so sensitive that they can prove unreliable in air contaminated with a low concentration of halogens. In such a situation, the system should be charged with nitrogen or carbon dioxide at 60 to 80 p.s.i.g. and checked with a soap solution. If a pressure test of the system is also required, follow the recommendations of the American Society of Refrigeration Engineers as given in the American Code and explained in paragraph 7-12.

7-4. **Halide leak detector.** The halide leak detector (see volume 1) uses bottled gas to heat the reactor plate. A sampling tube is used to pull air and the refrigerant vapor (in case of a leak) into the flame. To test for leaks, light the torch and let the reactor plate turn cherry red, then hold the open end of the rubber tube near the joint to be tested. A leak is indicated when the flame color changes from blue to blue-green or bright green.

7-5. **Electronic leak detector.** Several companies produce electronic detectors which will detect a Freon leak as small as 1/2-ounce per year. The general rules of operation for this equipment are as follows:

- Be sure to use the detector with the correct voltage or the correct batteries. Follow instructions for the detector you are using.
- Allow the unit sufficient time to warm up before testing.
- Do not exceed the normal duty cycle if the tester is limited to intermittent duty.
- Keep a record of the hours of operation. The element has a limited number of hours of life in some instruments.
- Make correct adjustments for background contamination. Even after proper adjustment, contaminated air may cause erratic operation of the instrument.
- Do not place the detector probe in heavy concentrations of refrigerant, as it overloads the instrument.

**WARNING:** Be sure to observe the warning that some instruments carry stating that their use is prohibited in a combustible or explosive atmosphere.

- Always turn the detector off as soon as you have finished testing.

7-6. **Repairing Leaks.** Unless someone has punched an ice pick through a line, the only place a leak should occur is at a joint. Before a joint can be soldered, the pressure must be released from the system. Prepare the system as for charging by connecting a "T" and stub into the suction line. Purge the system to atmospheric pressure. Sweat the joint just as if you were making a new joint, but do not overheat it. Use asbestos paper to protect adjacent surfaces from the flame. Wrap the tubing with wet cloth where you wish to keep the heat from spreading. After you sweat the joint, partially charge the system and again test for a leak. If the joint holds, charge the system.
to its normal capacity and triple pinch the stub to seal it.

7-7. Small pinhole leaks in tubing on the low side of a refrigerator may be repaired in several ways. For example, either cold solder plastics or special resin glues made for refrigeration work may be used to make a patch. At least one resin glue on the market has the same thermal characteristics as aluminum. A glue like this will expand and contract with the metal and will not crack. However, when making a patch with glue, be careful not to force the material through the hole in such a way as to cause an obstruction in the tubing. Also, the surface must be kept free of any traces of oil so that the glue will bond properly and completely seal the hole.

7-8. Larger holes in aluminum tubing can be repaired by soldering with 95-5 solder, which can be worked at a lower temperature than that which is required for brazing. Here, the right flux to use is just as important as the right solder, because flux also has a critical temperature. Some men may be able to use higher temperature alloys to solder aluminum tubing; but as the work gets hotter, the danger of melting out a chunk of material becomes greater.

7-9. Repairs to tubing on the high-pressure side are made with appropriate solder and flux. The higher pressure in the high side-30 pounds or more-makes it advisable to repair with hot solder rather than attempt a cold glue patch. Remember that the methods we have discussed here apply to systems using R-12, which include domestic refrigerators and freezers. If, for example, you should try to cold patch a leak in a system using R-22, your results would probably be unsatisfactory. Furthermore, the higher operating pressure of R-22-about 250 p.s.i.g. requires more strength than can be obtained by cold patch methods available at the present time.

7-10. Flare connections and fittings. Flare connections may be provided with seal. These cannot be removed without tearing them. When opening such a flare connection, cut away the seal with a knife, being careful not to nick or scratch the flare. A new seal is installed when the flare is reconnected. Always slip the flare nut over the tubing before making a flare. If the nut is too loose, look closely at it size; you may have picked a nut which is a size too large.

7-11. Flaring. In making a flare, by placing a drop of refrigerant oil on the flaring cone, you can produce a smoother flare. Also, apply refrigerant oil to the nut and the flare surfaces before assembling them. The oil will allow the flare connection to be drawn up tight without overstraining the nut. It will also lubricate the threads so that there will be no doubt in your mind as to when the nut is snug.

7-12. Pressure Testing and Leak Testing with Nitrogen or Carbon Dioxide. There may be times when refrigerants are not readily available or in short supply. To save refrigerant, you can make pressure checks of a system using dry nitrogen or CO₂. If the pressure test is satisfactory, you can conduct a leak test in two ways. One method calls for charging the system with a small amount of refrigerant and raising the pressure in the system by means of nitrogen. A halide leak detector is then used to check for leaks. The other method calls for charging the system to the desired pressure, then testing it for leaks, using a solution of soap and water. With both methods the system must be evacuated to bleed off all nitrogen or CO₂ after tests are satisfactory and before charging with refrigerant.

7-13. Replacing Capillary Tubes. A broken or plugged capillary tube requires a replacement which is exactly the same as the original in its length and inside diameter. Approximately the same length of the replacement should be soldered to the suction line to make a heat exchanger. The variations in diameters of some capillary tubes are shown in table 7.

7-14. Many refrigerators have a capillary size of .114-inch OD and .049-inch ID when used with R-12. Of course, the outside diameter of each can readily be checked with a micrometer, while the inside diameter can be checked with a wire. Notice that both the gauge and diameter of wire is compared with capillary tube diameters in table 7. Do not try to force a wire into a capillary to check the inside diameter. Also, make certain that the wire has not been burred on the end as a result of being crushed by cutters. You can check the diameter of a wire with a wire gauge or a micrometer. In any case, the correct size wire should slip easily into the capillary.

7-15. When exact replacements are not available, you may install an adjustable capillary tube in the system. In such an event, the capillary tube should be cut to equal the length of the one which it replaces. A heat exchanger of the same length is made by soldering the capillary to the suction line. Note that the ends of the capillary should be cut with a tube cutter to get a uniform end. Also,
swage appropriate ends of the tubing so that the capillary can be soldered into the system. (NOTE: Keep ends taped or plugged with rubber caps to keep moisture out while the system is open.) If fittings are available, the tubing may be quickly joined. However, because such fittings are expensive, most shops will use a torch and solder the connections.

7-16. After installation, test the unit for leaks, evacuate it, dry it, charge it with refrigerant, and test it. Set the capillary adjustment so that the evaporator frosts evenly. Then make a final check for proper adjustment by seeing that the lines to and from the evaporator are not frosted.

7-17. Replacing the Condenser, Compressor, and Evaporator. Normal service for the condenser, compressor, and evaporator is to clean them with a stiff bristle fiber brush or with compressed air. The replacement of these would involve the detailed procedures just described. Open the system and cap the ends with tape or rubber plugs to keep air and moisture out. Then prepare the ends to be soldered and assemble the system. After that, charge the system and test it for leaks. Next, dry and evacuate the system. Then charge the system with refrigerant and make an operational check.

7-18. System Cleaning. After a hermetic motor has burned out, the system will be contaminated with burned pieces of metal and insulation. The dark color and pungent odor of an oil sample will give mute evidence of such a motor burnout. When it happens, remove the compressor and thoroughly clean the system before putting it back into service. As most smaller units in this condition should have the entire system replaced, the discussion of cleaning is related in Chapter 2, where it is most appropriately related to larger systems.

7-19. Removing Moisture. Since a comprehensive explanation of procedures for removing moisture from both large and small systems is more appropriate to the equipment discussed in Chapter 2 of this volume, it is given there instead of here. The procedures described there for systems under 5-ton capacity apply equally well to domestic refrigerators and freezer cabinets.

7-20. Charging a Small Hermetic. Charging a small hermetic system with refrigerant is a simple procedure which generally requires three steps: (1) dry the system, (2) install a suction line stub and a high-pressure line stub, and (3) add the refrigerant. As you know, a few other jobs related to charging must also be done at the same time. Thus, if the system has a leak, the system must be repaired and then tested. The amount of oil lost can be estimated by the size of the oil spot, which will not evaporate. Since most of the oil will remain in the compressor, the presence of a large amount of oil will indicate a leak in that area. Similarly, if the system has been opened and you suspect that an appreciable amount of moisture has entered it, evacuate the system. First charge the system with a small amount of refrigerant and then evacuate it to 50 microns (about 29 inches of vacuum) for from 5 to 30 minutes. Remember, too, that when a system has lost a part of its charge, you should assume that some moisture has been drawn into the system. To counteract this problem, your first step is to install a new drier-strainer.

7-21. Replacing the drier-strainer. The drier-strainer is located between the condenser and the capillary tube. To replace it, cut the old drier-strainer out of the system and install a new drier-strainer in its place. The new drier will be able to hold the small amount of moisture which might have entered the system.

7-22. Installing stubs or process tubes. A system which has no provision for charging and purging must have stubs installed. To do this, prepare a “T” with about a 1-foot stub connected to the foot of the “T.” Provide the stub with an appropriate fitting and cap the fitting until you are ready to use it. The stub and “T” can be heated to insure that they are dry. Cut the suction line at a convenient location and install the “T” and stub permanently in the line. Also, cut the high-pressure line at a convenient place and install a “T” and stub there too. Note that some servicemen claim that this is not necessary if the system is still under pressure. In any event, if the stub is connected at the highest part of the condenser, it will work best for purging air from the system.

7-23. Adding refrigerant. When adding refrigerant, first install a valve and a gauge in the high-side stub. Then connect a charging line to the low-side stub. Do not tighten the stub connection until you have purged the charging line by cracking the refrigerant cylinder valve long enough to blow out trapped air. Do this by cracking the valve in the high-side stub and slowly opening the valve in the charging line. Next, start the compressor and shut the purging valve when refrigerant appears there. Be sure to observe any frosting of the evaporator and shut the charging valve when the coil has become frosted completely.

7-24. Continue to observe operation of the unit. High head pressure in excess of 160 p.s.i.g. indicates that there is still air in the system which requires purging. Remember that the pressure will vary with the ambient temperature. Air in the system will also be indicated by a lack of uniform warmth of the condenser coil. A check with your hand will reveal spots which are cooler near the top of the coil, where air pockets are displacing warm liquid. From 15 minutes to half an hour may be required to properly charge the system.
the end of this period of observation, check the low side of the evaporator coil. If the frost line extends too far beyond the evaporator coil on the suction side, the system has been overcharged and some refrigerant should be bled from the system by cracking the valve on the high side. If frost shows on the tubing at the inlet (high side), too far from the evaporator coil, increase the size of the heat exchanger. Solder another 2 inches of the capillary to the suction line. This correction would apply when a new capillary tube has been installed.

7-25. When the performance is satisfactory, close all of the valves and triple pinch the stubs to seal them. Gauge lines and fittings can then be removed. Remember the necessary steps to prepare a system for service when moisture is present in it. First, partially charge and purge the system of air. Second, pump down to 29 inches of mercury to remove the moisture. Third, install a new drier-strainer. Fourth and fifth, charge the system with refrigerant and start the compressor. In the charging step, no purging of air will be necessary if the system has been evacuated. Obviously, pulling a vacuum on the system removes air as well as moisture.

**Review Exercises**

The following exercises are study aids. Write your answer in pencil in the space provided after each exercise. Use the blank pages to record other notes on the chapter content. Immediately check your answers with the key at the end of the test. Do not submit your answers for grading.

1. What are the main construction features of a modern domestic box? (1-2)

2. Insulation must be able to reduce what three forms of heat transfer? (1-3)

3. What puts the greatest heat load in a refrigerator? (1-4)

4. What has been the result of using improved insulating materials in a refrigerator? (1-5)

5. What must be used with insulation make it effective in a refrigerator? (1-6)

6. What are some of the big advantages of new synthetic insulation? (1-6)

7. Why do breaker strips require careful handling? (1-8,9)

8. A stored or abandoned refrigerator should be treated in what way? (1-11)

9. How is the door gasket checked for a seal? (1-12)

10. What factors should you consider in the location of a refrigerator? (1-13)

11. How can you distinguish a refrigerator made for use overseas? (1-14)

12. An automatic ice maker in a refrigerator may be provided with two thermostats. What is the function of each? (1-18)

13. Why is a second electric heater used in the drain with an automatic defrost system? (1-20)
14. Explain a simple automatic defrost system which uses only one valve for defrosting with hot gas. (1-22)

15. What are the methods of heating used in an absorption system refrigerator? (2-1)

16. With regard to exercise 15, what is the main distinction with on fuel? (2-2)

17. Give the principle of operation of the absorption system refrigerator. (2-5)

18. Since the flame burns continuously, how does the absorption refrigerator meet changes in heat load? (2-5)

19. After cleaning, what might prevent the burner from operating, and how can this problem be solved successfully? (2-5)

20. Describe the maintenance for a refrigerator with an absorption system. (2-6)

21. How can installation result in poor or faulty operation of an absorption refrigerator? (2-7)

22. When a refrigerator with an absorption system is placed in service after an idle period of 6 months, it may refuse to cool. How might this be corrected? (2-8)

23. Why can a compressor operate so well with such fine clearances? (3-3)

24. How close may a compressor's piston approach the head? (3-4)

25. At what point may compressor valves get noisy? (3-5)

26. What advantages do rotary compressors have over the piston type? (3-6)

27. What is one way of helping to cool the condenser without having to use a fan? (3-9)

28. A restrictor placed between two sections of an evaporator serves what purpose? (3-10)

29. A weighted valve requires what special consideration? (3-11)

30. What are the critical factors in the makeup of a capillary tube? (3-16)

31. Where is a bleeder resistor used and how does it protect a relay? (3-19)

32. What functions are performed by a hot wire relay? (3-19)
33. How does a current relay operate? (3-21)

34. Where would you first check for the cause of badly burned relay contacts? (3-24)

35. What does a noisy capillary tube indicate? (3-32)

36. How could low voltage cause excessive electrical consumption? (3-33)

37. What are the proper methods of manually defrosting a freezer? (4-3)

38. What would you suspect if you found heavy frost had frozen a freezer door shut? (4-4)

39. When troubleshooting, what common fault is often made by a serviceman? (5-3)

40. State the advantage of locating an overload protector inside the compressor's shell. (5-5)

41. What is the difference in operation between a thermostat and a freezestat? (5-6)

42. Why is it better to use direct current for checking a motor circuit? (5-9)

43. What is indicated when a test shows a motor drawing its LRA rating? (5-11)

44. Give two methods for checking a capacitor. (5-12)

45. Describe the main characteristics of a current relay. (5-15, also 3-21)

46. Describe the main characteristics of a potential relay. (5-16, also 3-24)

47. What are some of the causes of vibration in a refrigerator? (5-17, Table 2)

48. Why must an acetylene cylinder be secured in an upright position? (6-2)

49. Why must an oxygen cylinder be used in an upright position? (6-2)

50. Which is the correct test for an acetylene leak? (6-2)

51. Why must oil and grease be kept away from oxygen? (6-2)

52. How can you always identify the acetylene valve in a torch? (6-3)
53. Why must regulator screws be released before the cylinder valves are opened? (6-3)

54. In soldering tubing, what is considered the most important factor in making a leakproof connection? (6-5)

55. How hot should the work be heated before you apply the alloy when you are brazing cooper tubing? (6-8)

56. What precautions must be observed when you are brazing certain valves to tubing? (6-9)

57. When you are brazing using a flux, what clue tells you how hot the joint is? (6-10)

58. In view of the last question, how is it that when you are brazing copper with silver solder, you should use a carburizing flame? (6-11)

59. Why must you use a slightly oxidizing flame when you are welding copper? (6-12)

60. Why does the welding of copper require a larger flame than that required for welding steel? (6-13)

61. How is a cutting torch used to cut stainless steel? (6-15)

62. What are the disadvantages of using a line tap? (7-1)

63. How could a leak detector be too sensitive? (7-3, 5)

64. Why should a heavy concentration of halogen be avoided when you are using an electronic leak detector? (7-5)

65. Where may cold solder or glues be used successfully for repairs? (7-7)

66. What precautions must be observed when you are patching a hole in tubing? (7-7)

67. Why is it important to use the right flux with the right solder? (7-8)

68. Cold solder or special glues are limited to which systems? (7-9)

69. In what two ways can a system be leak tested with dry nitrogen? (7-12)

70. What are the most important factors in a replacement capillary tube? (7-13)

71. How can you measure the inside diameter of a capillary tube? (7-14)
72. What is the purpose of using tape or caps, and when are they needed? (7-15, 17)

73. After installation of a major part, what are the proper steps toward placing a system back in service? (7-16)

74. If you find a very large oil spot, where would you expect to find a leak? (7-20)

75. What would happen if you forgot to purge the charging line? (7-23)

76. When frost extends out on the suction line beyond the evaporator coil, what condition is indicated? (7-24)

77. After replacing a capillary tube, you find that the frost line extends too far on the inlet line or high side of the evaporator. What action will correct this condition? (7-24)

78. Why must a refrigerator serviceman be able to make joints like an expert—quickly and correctly? (7-1-24)
CHAPTER 2

Commercial Refrigeration Systems (Continued)

GRANDPA MAY HAVE had problems with his old ice box, but the problems of his neighborhood grocer trying to keep meats and vegetables fresh were much greater. His corner druggist also had trouble keeping the ice cream hard and had to keep a cold drink chilled with ice. By way of contrast, today's grocer has large storage cabinets which are automatically cooled, and the present-day druggist has refrigerated cases which keep ice cream hard and cold drinks really cold. In addition, many stores now have water coolers for the comfort of their customers.

2. Continuing the discussion which we began in Chapter 1, we will now explain different applications of compressors for water and beverage coolers, for ice making machines (such as ice cube makers and flake ice machines), and for soda fountains. Other applications which we will discuss are those involving storage cabinets (such as reach-in, walk-in, and display cabinets) and the defrosting for such cabinets. (Of course, these larger systems may use a hermetic unit, such as we have discussed in Chapter 1 in reference to refrigerators and freezers.) You will find the open type compressor discussed in Section 13, under the heading "System Components." Similarly, you will find system cleaning explained (under the same name) in Section 17. The troubleshooting and repair sections are a continuation from the preceding chapter.

8. Water Coolers

8-1. Package units for cool drinking water are used in offices, shops, and messhalls. They are rated in gallons of water cooled per hour, with capacities ranging from 3 to 20 gallons per hour. The control of each is adjusted to supply water at a temperature of 50° F. These range from the bottle type through the bubbler type to the remote unit multiple type. All, of course, develop troubles which require servicing or repairing.

8-2. Bottle Type. The bottle type water cooler is installed where drinking water connections are not readily available. A freezestat is employed in the control circuit with the thermostat to insure against ice damage to the tank. The thermostat is set so that a thin coat of ice will form on the coils before the compressor is stopped. The freezestat opens the control circuit before ice formation damages the tank if the thermostat should fail to stop the compressor. The schematic diagram shown in figure 6, Chapter 1, is typical of the control circuit using a current relay for a unit type water cooler. The major components in such a water cooler are the same as in a simple refrigerator.

8-3. Bubbler Type. The bubbler type water cooler has a tap water inlet connecting to the water service line and a drain outlet connecting to the waste system. The unit may be designed to take advantage of cold waste water in a bubbler fountain by using a precooler. Typically, the warm water coming into the unit first passes through a coil which wraps around the drain sump. Then the water passes into an accumulator tank, where the evaporator coil is located. The design is calculated to cool the unit enough to produce a small amount of ice in the tank. This procedure thereby assures a reserve carryover during compressor off time.

8-4. Remote Unit Multiple Type. You will find the remote unit multiple type water cooler in a large modern hospital or office building. A compressor unit of the required size will be located at some remote place in the building. It may be a hermetic unit, but if the heat load is great enough, an open type compressor may be installed. From the heat exchanger at the remote location, insulated pipes carry the cold water to bubbler fountains and other outlets throughout the building. A large installation may require a 10-ton unit to insure an adequate supply of cold water in hot weather.

8-5. Troubleshooting. Troubleshooting procedures are the same as those described for the hermetic unit in a refrigerator, with these additions. You may be called to service a unit which has a faulty valve or a plugged drain. One of the troubles with a valve is a slip in the linkage of the foot pedal which requires readjustment and lock-
ing. Another trouble is salt formation in the valve. Disassembly and cleaning of the seat and washer will solve the latter problem in most cases. However, you must replace the washer if it is grooved or warped. Also, a plugged drain requires disassembly and cleaning, whereas a leaking water tank or line may be repaired with a plastic or synthetic glue, provided it is not toxic and not poisonous.

9. Beverage Coolers

9-1. There are some persons who would have you believe that beverage coolers are a "big deal." However, there is nothing mysterious about them. Their purpose is to cool bottled beverages in the range of 27° to 40° F., depending on the freezing point of the liquid. The cooling system is designed to meet the following factors:

- Anticipated heat load.
- Freezing point of beverage.
- Desired temperature of beverage.

9-2. If a box is loaded with a different beverage from that for which it was designed, it may be necessary to change the "cold setting" to prevent freezing the product. The position of the feeler bulb and the thermostat setting determine what range of temperature a box will hold.

9-3. A self-contained unit of the horizontal type will use a hermetic system layout similar to that of a freezer chest, whereas a vertical unit will have a layout like that of a refrigerator. A heavy duty hermetic unit will be provided with an oil pump and an oil cooler. The condenser shown in figure 10 illustrates a heavy duty type which includes a coil for the oil cooler. The oil cooler coil will normally be hotter than the condenser. The larger display type beverage cooler has a remote compressor and condenser located in a compressor room or in an outside shed. The one major difference between a horizontal and an upright case lies in the style and layout of the evaporator. The horizontal case will have a wall type evaporator, while the upright case will use a plate type with forced air. Repairs and service for a hermetic system are the same as those which you studied for a refrigerator. Remote compressors of the open type are explained in Section 13.

10. Ice Making Machines

10-1. Several types of machines are manufactured for making ice cubes or flakes. For example, one type of automatic ice cube maker has already been explained in our discussion of domestic refrigerators. Ice cube makers are classed according to the evaporator as of the tray type, the tube type, the cell type, or the plate type. In comparison, machines for making ice flakes are classed as of the plate type, the rotating cylinder type, and the flexible membrane type. These latter machines all have the same purpose, but they employ different types of evaporators.

10-2. Components. Whatever the type, the parts ordinarily found in most icemaking machines are a hermetic compressor; a condenser cooled by air, water, or a combination of both; and a receiver-drier-strainer. The refrigerant control can be a capillary tube, a constant-pressure expansion valve, or a thermostatic expansion valve. Of these, a system using a thermostatic expansion valve will require a receiver. Where evaporator heat is used to loosen the ice, you will find a hot gas solenoid valve. The water-handling system will be continuous flow or intermittent. Also, the control of the ice forming and harvest cycle will be on a continuous basis in the rotating cylinder type, with the starting and stopping of the unit being the main control function. An automatic tray type will follow a cycle which is timed in the manner which we have already described for an automatic ice cube maker in a refrigerator.

10-3. Ice Cube Evaporators. The biggest difference found among ice making machines lies in the evaporator used. Because the tray type evaporator has already been described, it should give you no difficulty. Since the main difference among
such machines lies in the method of ejecting the cubes from the tray, we will not discuss it here; tube type evaporators will be taken up first instead.

10-4. Tube types evaporators. This arrangement has the evaporator form a bank of tubes. Water flows down the inside of the tube and is frozen. As more ice is formed, the hole in the center becomes smaller and restricts the flow of water until finally the excess water triggers the harvest cycle. A hot gas solenoid valve operates to allow the evaporator to release the ice. In one machine the long rods are cut into suitable lengths. In another machine, the evaporator tubes are chilled in sections so that rods of the desired length are formed between the warm spots. Still another method uses accumulated water pressure to eject the ice rod with enough force to break it.

10-5. Cell type evaporator. There are two major variations of the cell type evaporator. In one the cell operates under water, and when the ice is released it floats to the surface where it is forced from the tank by a current of water. In the other type, inverted cells are used which have water sprayed against them. The ice forming period is set by a timer, which then frees the ice by hot gas.

10-6. Plate type evaporators. Among the variations of the flat plate type, there is one main distinction: the plate may be either horizontal or vertical. For instance, in one type of machine, the horizontal plate produces a slab of ice, which is then moved on to a hot wire grid which is heated electrically. Here the slab melts into individual cubes, which then fall through into a storage bin.

10-7. Another type of such a machine uses a grid which is moved into position against a vertical plate. After the cube is formed, the grid is moved against a knockout plate which ejects the cubes. In one design, two vertical plates have matching cold spots which face each other. A unique feature of this model is a variable control over the length of the period for forming ice. Within a short period, the ice produced will be like a lens. If the period is long enough, the two opposite lenses will build a bridge to each other and produce a piece of ice which looks like a Yo-Yo.

10-8. Blowdown. Units are provided with a siphon the water pan to blow down the water system each time the unit stops. A complete flush removes the accumulated salts. The water left behind from each freezing cycle concentrates the salts in the water. Where the water is very hard, a manual blowdown may be necessary to move the salt and insure proper formation of ice.

10-9. Flake Ice Machines. These units use some evaporators which are similar to those of the cube makers, but the harvesting method employed is different.

10-10. Plate type evaporator. In this type of evaporator a thin sheet of ice is formed on the plate. When the desired thickness is reached, hot gas is directed to the plate to loosen the ice, which then passes through a crusher or grinder. Another arrangement freezes the slab in a spring-metal grid. After it is free of the plate, the flexible grid is drawn over a sharp bend, causing the ice to fracture into small pieces. A variation of this last method uses a flexible belt or membrane which passes over a plate or a refrigerated roller. The belt breaks up its cargo by passing around a sharp bend.

10-11. Cylinder type evaporator. Again, in this type, there are many variations, but the essential items are the refrigerated cylinder and a cutter-scraper for harvesting. Water may be flowed or sprayed on the cylinder continuously. Harvesting occurs when the ice becomes thick enough to contact the cutters. The machine will continue to make ice until a level is reached in the storage bin, where the ice contacts a feeler which, in turn, will stop the machine. The operation of the feeler is the same as that in the storage bin of an automatic cube maker. The position of the feeler determines the amount of ice which will be stored in the bin before the machine is stopped.

10-12. Troubles in Ice Makers. With so many different types of icemaking machines being used, you will find that it is necessary to have the right service manual for the equipment on hand when you are dealing with mechanical trouble or needed adjustments. You will find, too, that after mechanical problems, the water supply is probably the next greatest source of trouble. Sediment, scale, and salt formation are problems which vary widely from one locality to another. In fact, under severe conditions, water treatment may be the only means of keeping an automatic ice maker in satisfactory operation. On the other hand, in some localities, the domestic water supply contains so much salt that crystals lodge in the seat of a faucet, causing it to drip. Thus, such faucets in everyday use require that incrustation be removed from the stem and gasket every 2 or 3 months.

11. Soda Fountains

11-1. A recent addition to your responsibilities is the maintenance of soda fountains. A complete fountain has an ice cream compartment, cold bottle storage, syrup cooler, and a beverage cooler. Among other things, we will discuss a dry type eat exchanger coil aid a carbonator system. A typical soda fountain is shown in figure 11, with one compressor attached to a multiple evaporator. The syrups and the drinking water are kept at 45° to 50° F, while the ice cream compartment is held between 0° and 10° F. The heat exchanger, at the left in figure 11, serves to cool the liquid
Figure 11. A typical soda fountain.

refrigerant so it can absorb more latent heat as it changes to a gas. As you know, a lower refrigerant temperature also reduces the tendency of the liquid to ash to a gas as it passes the control valve. Flashing at the valve reduces the valve’s capacity and also reduces the efficiency of the system.

11-2. **Dry Type Coil**. The beverage cooler, shown at the right in figure 11, is a dry type heat exchanger. It consists of an aluminum casting which contains at least two sets of coils. Additional coils are provided when more than one beverage is to be cooled. One coil is an evaporator, and the other coil (or coils) carries the liquid to be cooled. A heat exchanger of this type must be large enough to meet the cooling demands of the system. At the same time, it must provide sufficient transfer of heat so that it does not increase the pressure drop in the low side too much. To prevent this condition, a suction pressure regulating valve may be placed in the suction line from the heat exchanger. A component which is often part of a soda fountain is the carbonator which makes soda water.

11-3. **Carbonator System**. The carbonator which is included in some soda fountains is not as complicated as some people suppose. With the information which follows, you should be able to maintain a carbonator in satisfactory operation. It has four essential parts: a CO₂ tank, a mixing tank, a water pump, and an electrical control to operate the water pump. The CO₂ tank is used to charge the mixing tank with gas at 80 p.s.i.g. The correct pressure is adjusted by means of a pressure regulating valve. The water pump is used to deliver a high-velocity jet into the mixing tank. The turbulence is so great that the water readily absorbs several times its own volume of CO₂. The water from the pump should be chilled before it enters the mixing tank, since cold water absorbs CO₂ much more readily than warm tap water. The mixing tank is also refrigerated to ensure delivery of cold soda at the valve, because warm soda water loses its charge very quickly. Carbonated water is drawn from the bottom of the tank below a baffle, which keeps turbulence from this area.

11-4. The pump motor is started and stopped by a magnetic contactor which is controlled by a float or by an electrode circuit in the tank. Operation of an electrode circuit is illustrated in figure 12. However, the CO₂ tank and charging connections are not shown. The transformer serves to isolate the control circuit from the house electrical service. Of course, the tank ground and the trans-
The former secondary ground need not be connected to each other if both connections are made to a cold water pipe. The figure shows the position of the switch contacts with the pump running and the tank being filled with water. When the water level reaches the upper electrode, a circuit is completed for the holding coil by way of the water and the ground path. This energizes the holding coil, which pulls the armature down and opens the circuit to the pump motor. At the same time, another pair of contacts close a circuit to keep the holding coil energized by way of the bottom electrode. The pump motor will start again when water drops below the lower electrode, because then the holding coil will no longer be energized and the spring will pull the armature up, closing the circuit to the pump motor.

12. Storage Cabinets

12-1 The types of cabinets which you will find used at military installations are reach-in, walk-in, and display cabinets. The temperature range for storage of different foods is shown in table 8. From the information in this table, you can see that a display cabinet designed for fresh meats would not have the cooling capacity for frozen foods. Thus, while two cabinets may appear to be similar, they may be quite different in design and performance. Defrosting problems related to these cabinets are also discussed later in this section.

12-2. Reach-In Cabinets. This type of cabinet is familiar to many of us as the self-service refrigerator used for dairy products at the neighborhood grocery store. In appearance it looks like an oversize refrigerator with glass doors. If it uses wooden shelves, they must be made of spruce or maple, as these woods have no appreciable odor. The larger sizes of such cabinets may have as much as 100 cubic feet capacity. Either self-contained or remote condensing units are available. Evaporators are forced air or natural convection, depending on the purpose of the cabinet. A modern reach-in cabinet for a messhall has forced-air circulation and automatic defrosting. The defrost cycle is designed so that the unit will give frost-free operation. However, manual defrosting is necessary when the equipment is subjected to such adverse conditions as operation in a highly humid atmosphere. Remember, too, that reach-in cabinets used for low-temperature service will accumulate frost at a much higher rate than those operated at temperatures above freeing.

12-3. Walk-In Cabinets. These are used to provide temporary cold storage of food in messhalls and commissaries. A large consolidated
messhall has three walk-ins operated at temperatures appropriate to the food held in them. Older models use hot water defrost in which the unit is turned off and water is flushed over the evaporator coils until the frost is washed off. Since evaporators are of the forced-air type, the unit must be shut off before defrosting to prevent water being blown all over the cabinet. Late model cabinets have automatic defrosting controlled by an electric clock; they use the hot gas method. The compressors for these cabinets are mounted in a shed outside in mild climates. However, a compressor room is preferred in cold climates to insure operation of all compressors.

12-4. For many years wooden cabinets with cork-fill insulation were standard for walk-ins. In contrast, new construction methods now use metal panels with porcelain or enamel finish for the cabinet. This change has led to more sanitary conditions and easier maintenance. This is especially true since some synthetic insulating materials are as good as cork. In fact, if production costs drop low enough, these synthetics may replace cork. Unlike organic materials, synthetics are vermin-proof and are not readily susceptible to fungus when moisture gets past the seal. The application of modern insulation is explained in detail in Chapter 3, Cold Storage and Ice Plants.

12-5. Display Cabinets. These are known as open or closed and single- or double-duty cabinets. In the double-duty case, both the display section and the base section are refrigerated. The type of food to be stored will determine operating temperature of the case and the design of the evaporator. The evaporator may be of either the plate type or a finned tube with forced-air circulation. Sections may be joined together to make a cabinet of any desired length. A cabinet made of several sections will usually have a multiple evaporator system, such as we will discuss in Chapter 4.

12-6. Display cabinets are constructed of steel panels with baked enamel and porcelain finishes. Corkboard, glass wool, or synthetics may be used for insulation. In some type of construction, certain parts may rely on formed insulation for some of the strength and rigidity of the cabinet. The insulation may be blanket type, batts, panel, or formed member. Electric heater strips are provided around doors or access openings to prevent frost which could freeze a door shut.

12-7. Open type display cabinets are successful because of the development of the air curtain which keeps heat gain at a minimum. Careful design of the forced-air system has led to an ideal combination of fans and ducts to produce a curtain of cold air. Anything which interferes or disrupts the flow of air would result in excessive operation of the compressor. Thus, the open type display case must be in an air-conditioned space for satisfactory operation. Otherwise, the unit will accumulate frost at an abnormal rate so that manual defrosting is required. This latter is necessary because the frost layer disrupts the air current when the frost gets too thick and must be removed by manual means, such as flooding with hot water. However, the defrosting methods which we discuss next will function properly if the cabinet is used in an area which is air conditioned.

12-8. Defrosting Methods. The methods for defrosting storage cabinets are (1) compressor off time, (2) hot gas, (3) hot wire, (4) hot water, and (5) secondary solution. If you are stationed at an older base where equipment has been purchased over a long period of years, you may find all of these defrost methods being used.

12-9. Compressor off time. The compressor off-time method is limited to cabinets operating at temperatures above 28°. Ambient temperature is relied on to bring the evaporator coil temperature up to where the frost will melt.

12-10. Off-time defrost may be controlled (1) by suction pressure, (2) by time clock, or (3) by a combination, with a time clock used to start the cycle. The first, suction pressure control, has two disadvantages which affect operation of the unit. For one thing, under an increased heat load, ice forming on the evaporator will cause the unit to stop for a defrost period. Another drawback is found in cold weather, when low outdoor temperature can make the compressor cooler than the evaporator. Under this condition the suction pressure can remain below the cut-in point and the unit will remain idle. This last condition would occur in a normally mild climate when a cold wave has sent temperatures to below freezing level. The second control method, time clock control defrost, is independent of temperature variations when it has both the start and terminate function. However, when timer start is combined with suction pressure termination, you can expect to find the difficulty we have just described.

12-11. Hot gas defrosting. When this method is used for large display cabinets, it requires some modification from the simple system that we have explained for a domestic refrigerator. One disadvantage (among many) of this system is that in cold weather the compressor may not deliver enough heat for the rapid defrosting which is expected from a modern unit. Consequently, a number of variations of the simple system are used to overcome the disadvantages as follows: (1) Meter the hot gas to the evaporator so as to prevent formation of liquid which could get back to the compressor. (Just a small amount of liquid entering the compressor will cause pistons to hammer.) (2) Use a liquid receiver and meter the liquid into the suction line. (3) Add sufficient heat to insure that the refrigerant will be a gas
when it returns to the compressor. (4) Use a four-way valve in the system to completely reverse it so that the evaporator functions as a condenser and the condenser serves as an evaporator during the defrost cycle. The obvious disadvantage to avoid here is that hot gas can defrost the coils so rapidly that the drain lines may require heating to prevent melted water from freezing in the drains and plugging them.

12-12. Hot wire defrosting. This method has the big advantage of being unaffected by changes in ambient temperature. The heater wire may be laid in contact with the evaporator, or it may be hung in the form of a grid between the evaporator and the fan when forced-air circulation is used. A fan switch is a necessary part of the automatic defrost system where the forced-air may drive melted water out of the drains. The hot wire defrost cycle is so short that the drains require heating to prevent freezeup. Improved electrical heating elements account for the speed, because heating is almost instantaneous through the whole evaporator.

12-13. Hot water spray. Defrosting with hot water uses a water bath or spray aimed directly on to the evaporator. This system requires that the compressor and air circulation fan be shut off before the water is turned on. The cycle must be long enough to insure drainage of water from the evaporator before the unit is restarted.

12-14. Secondary solution. This method of defrosting uses a refrigerant which is heated and passed through a secondary coil in the evaporator. You should recognize that this system is similar to hot wire defrosting in that it will not be affected by changes in ambient temperature. It appears that at the present time the secondary solution method has generally been replaced by the hot wire system.

12-15. High-temperature control. Safety controls are an important part of automatic defrosting systems applied to large commercial cabinets. You will find that a high-temperature control is used to terminate the defrost cycle, thereby preventing the cabinet temperature from going too high and thus endangering the food in storage. This is an added safety feature which will take over if the defrost cycle should be interrupted and fail to complete itself.

12-16. High-pressure control. A system which uses hot gas defrosting may have a pressure cutout switch to keep the unit from operating at too high a pressure. The defrost valve will have an auxiliary outlet connected by capillary tubing to the pressure control. When the defrost valve is open, it supplies pressure to a bellows in the pressure control. The pressure control is set to open at 180 pounds and close at 155 when it is used on a system charged with R-12. The contacts in the pressure control will open the compressor motor circuit if pressure exceeds its setting.

13. System Components

13-1. In the last section we discussed cabinets which are often made in large sizes. A walk-in cabinet for milk products handled at a big commissary store may require enough capacity to cool a room 20 by 40 feet. The refrigerant flow in such a system is shown in figure 13. The valves and accessories of the system are discussed in this section.

13-2. Open Type Compressors. So far, we have discussed the hermetic compressor, which, normally, you will not be able to repair. The welded case of a hermetic unit is beyond the capability of the repair shop. However, a semi-hermetic unit has a bolted case which can be disassembled to make repairs to the compressor. The one big difference is that a semi-hermetic does not require the shaft seal which an open type compressor must have. If you have not had the opportunity of working with a larger system, you will probably benefit greatly from a review of the major components. The following discussion is related to the items illustrated in figure 13, which shows a low diagram of a refrigeration system.

13-3. Separator. The oil separator is a simple trap designed to remove the oil from the hot refrigerant gas and return the oil to the compressor. A float is used to open a valve which allows the accumulated oil to return to the sump.

13-4. Service Valves. The suction service and the discharge service valves are provided with fittings so that they may be connected to gauges and to charging lines. The valves also serve to isolate the compressor from the system if it is necessary to replace the compressor unit.

13-5. Condensers. Several types of condensers may be found with large installations. The choice is dictated by the cooling load of the unit and the weather factors of the locality.

13-6. Air-cooled condensers. This condenser is the most simple type and gives the least amount of trouble. For heavy duty, the condenser is enclosed in a shroud, and a fan forces air across the coils to cool them.

13-7. Water-cooled condenser. Water-cooled condensers are of the shell-and-tube type or the tube-within-a-tube type. In the first type, water circulates through the tubing while the shell serves as both condenser and receiver. In contrast, the double-tube type circulates the refrigerant through the outer tube to take advantage of the air cooling the refrigerant. When a compressor is also water cooled, the exhaust water from the condenser is circulated on through the cylinder heads. Where water is at a premium, a spray pond or cooling
tower is used to cool the water so that it can be used over again.

13-8. Receivers. The receiver in a system must be large enough so that it can hold all of the refrigerant in the system. The receiver is the tank where the refrigerant is stored after a system is pumped down. The receiver outlet valve is a quill type, with its inlet tube (quill) reaching to the bottom of the receiver. It is referred to as a king valve, because this is the valve which is closed while a system is being pumped down. The receiver inlet valve is closed after pumping down is completed.

13-9. Drier-Strainer. The drier-strainer is a cartridge type with direction flow indication on the case. Direction flow must be observed as it is arranged so that the strainer will hold particles of drier which might be dislodged. Also, the unit is properly baffled for liquid flow in the direction indicated.

13-10. Sight Glass. The sight glass enables you to see the flow of refrigerant in the system. Bubbles will appear when the charge gets low; they indicate that the system is losing refrigerant.

13-11. Refrigerant Controls. The principles of refrigerant control are the same for valves as for capillary tubes. However, valves provide a variable control over a wider range of load. Modern valves are designed so as to modulate refrigerant flow to meet variations in load. The valve must not starve the evaporator; this is not good economy. Likewise, the valve must not cause flooding, since this can damage the compressor. As you study these valves, see if you can find examples of the types mentioned here which are present in the equipment used at your installation. NOTE: Although figure 13 illustrates an automatic expansion
valve, such as is covered first below, other types of valves are also discussed including thermostatic expansion valves, high-side float valves, and low-side float valves.

13-12. Automatic expansion valves. The first valves to be developed as automatic were known as the constant-pressure type. The automatic expansion valve has a spring on each side of a diaphragm. Evaporator pressure under the diaphragm acts with the closing spring to close the valve when the pressure rises. This kind of valve has been used in systems with ammonia. It does not modulate, so it is not used as a refrigerant control where the load change is great. One quite common application of the automatic expansion valve is in drinking water coolers, because their heat load is fairly constant in a narrow temperature range. The automatic constant-pressure expansion valve has also been used successfully as a pilot valve for larger valves. One such application is for the control of a suction pressure regulator. As a pilot, the automatic expansion valve may even be used to operate a suction service stop valve to prevent freezing. An equalizer line is used to compensate for the pressure drop across the valve.

13-13. Thermostatic expansion valves. Valves of this type use a bulb and capillary tube to transmit pressure to a spring-loaded bellows or diaphragm. Such valves are identified by (1) the size of connections, (2) the length of the capillary, (3) the internal or external equalizer connection, (4) the capacity, and (5) the type of refrigerant charge. The type of charge is indicated by the color used on a valve according to the following list:

<table>
<thead>
<tr>
<th>Refrigerant</th>
<th>Color</th>
</tr>
</thead>
<tbody>
<tr>
<td>12</td>
<td>yellow</td>
</tr>
<tr>
<td>22</td>
<td>green</td>
</tr>
<tr>
<td>500</td>
<td>orange</td>
</tr>
<tr>
<td>502</td>
<td>orchid</td>
</tr>
<tr>
<td>40</td>
<td>red</td>
</tr>
<tr>
<td>717</td>
<td>white</td>
</tr>
</tbody>
</table>

The capacity is the nominal capacity of the valve in tons of refrigeration. There are three kinds of refrigerant charge used in thermostatic expansion valves: liquid charge, gas charge, and cross charge.

a. Liquid charge. This valve has the remote bulb and capillary charged with the same refrigerant (R-12 for example) as that which is used in the system with which the valve is to be used. The liquid charge is sufficient so that some liquid will be left in the bulb under all conditions. The advantage of such a charge is that it will control the refrigerant even when the valve or diaphragm is colder than the bulb. Among the disadvantages of such a charge are possible flooding and hunting. Its main application is found in low-temperature systems of large capacity.

b. Gas charge. This valve has the bulb and capillary charged with the same refrigerant as that present in the system with which it is to be used. However, the amount of the charge employed is smaller than that found in the liquid charge; thus at a predetermined point, all of the liquid will become vapor. This point is the maximum operating pressure of the valve. The disadvantage of such a charge is that the control will be lost if the diaphragm and case are colder than the bulb, since refrigerant will then condense in the valve. For this reason the application is only suitable to a system which operates at temperatures above freezing and where the evaporator pressure drop insures that bulb temperatures will be colder.

c. Cross charge. The cross charge expansion valve uses a liquid charge in the bulb and capillary which is different from the refrigerant found in the system with which it is used. The pressure-temperature curve of the charge is such that it will cross the pressure-temperature curve of the refrigerant used in the system. By careful selection of the refrigerant used for the cross charge, the manufacturer can make a valve which will perform best in any desired range or for any set of conditions. Some of the advantages of such a charge are these: (1) the valve closes quickly when the compressor stops; (2) the valve exercises control at high suction temperature, preventing floodback; and (3) the valve is more sensitive to pressure changes rather than bulb temperature changes, which reduce hunting.

13-14. High-side float valves. This control is normally used with a single evaporator, but it can control several evaporators if they are connected in series and if each is provided with an individual bypass. The high-pressure float valve, used with a flooded evaporator, has two advantages: First, all of the refrigerant is liquid when it enters the evaporator, so there is no cooling lost from expansion taking place in the delivery line. Second, all of the refrigerant passing through the valve is liquid, so the capacity of the valve is not subjected to changes from flashing. The evaporator may be a bunker type with forced-air circulation or a shell-and-tube type for brine water chilling. A surge drum is installed at the evaporator to prevent flooding of the compressor during changes in load. The amount of refrigerant charge is critical, for if the system is charged beyond its capacity, flooding will damage the compressor. The evaporator is provided with an oil drain and return line to the compressor.

13-15. Low-side float valves. Such valves are each connected into the low-pressure side of the system, but the function of this valve is almost the same as that of the high-side float valve. The difference is that a part of the evaporator space is taken up by the tank and float control. Adjust-
ment of the low-side float is critical. If the refrigerant level is too low, oil may accumulate in the float chamber, leaving the compressor with insufficient oil to lubricate it. Another effect of the layer of oil on top of the refrigerant is that it may cause the refrigerant to refuse to boil until a much lower temperature-pressure point is reached. Ebullators are used as catalysts to insure boiling of the refrigerant at its normal point.

13-16. **Compressor Pressure Switch.** In figure 13 you will find that item 12 is a switch with capillary lines to the high side and low side of the compressor. In such a situation, a combination switch can be used in many ways. One application would be as a high-pressure and low-pressure safety switch. Another application would be as a high-pressure safety switch and low-pressure motor control. Specific functions are, of course, determined by the system involved and the purpose intended.

14. **Troubleshooting and Repairs**

14-1. When a service call is received, it usually means trouble. If you were the boss and had a choice, who would you send? Would you choose the most experienced man, the one best able to do the job quickly? But what about the man with little experience? He needs the opportunity to learn. The solution is to, perhaps, send the inexperienced man along as a helper. As you do this, you can make sure that the challenging jobs will go to the better qualified, while the simpler jobs will go to the less qualified. After all, whether you are in military or civilian life, it is usually the best qualified man who gets the most pay and the most interesting assignments, isn't it? In this section we will discuss many problems you would encounter in troubleshooting the larger systems which use an open type compressor. Then, in Sections 15, 16, 17, and 18, we will take up several aspects of servicing, each an open type compressor. Then, in Sections 15, 16, 17, and 18, we will take up several aspects of servicing, each a high-pressure safety switch and low-pressure motor control. Specific functions are, of course, determined by the system involved and the purpose intended.

14-2. **Electrical Safety.** In spite of repeated warnings many servicemen forget the safety rules and become involved with a live circuit. Then they learn the hard way—perhaps even fatally—that memorizing the safety rules is not enough; these rules must be practiced—consistently, automatically! Briefly they are:

- Do not wear shoes with metal clips or hobnails.
- Treat all circuits as live circuits unless you know they are dead.
- Be sure switches are of and tagged before working on a circuit.
- Do not wear rings or metal watchbands at work.
- Do not wear shoes with metal clips or hobnails.
- No horseplay. Distractions cause accidents.
- When testing or working on a live circuit, use the buddy system. A loner may lose his life.

Remember, the man who practices safety will develop habit patterns which will protect him. Then—having such habits—such a man can devote more of his attention to the particular problem he is trying to solve.

14-3. **Electrical Troubles.** Let us discuss normal operation first. For a brief review of electricity, consider what a circuit does: Something happens when a circuit is completed. Something happens when a circuit is opened. Keep these two things in mind when you are looking for a trouble, and the solution will be easier to find. Actually, you are looking for the answers to a series of unspoken questions. Yet, their answers will become more obvious if you will state the questions to yourself. For example, "Why doesn't the compressor motor start?" Answer! "An open circuit!" "Where?" This is what you are really seeking. "Where is the open circuit?" Here are your six possible answers:

- At the circuit breaker or fuse box.
- At the motor starter.
- At the control switch.
- At one of the safety or lockout switches.
- At an open connection or a loose terminal (which may be one and the same thing).
- At a broken wire.

14-4. **Electrical Repairs.** Several specific remedies are available, depending on where a fault is located. To name a few: (1) At a circuit breaker, pressing the "Reset" button will restore the circuit if it has opened because of overload. (2) A blown fuse calls for a replacement of the same size. (3) A loose terminal can be tightened. (4) A broken wire can be spliced, soldered, and then insulated with electricians' tape.

14-5. When several safety controls are used in one circuit, they are connected in series with each other. The operation of any one of the safety control devices opens the circuit. When more than one control switch is used to complete the circuit to a motor from different locations the control switches must be connected in parallel. Thus, you must know the purpose and function of a control before you start to troubleshoot it.

14-6. Three-phase motors are preferred in units larger than 5 horsepower. Tests on a three-phase motor are quite different from a single-phase. When a three-phase motor will not start, one or more phases are open. (See mechanical troubles for a locked rotor.) To test, you must first check all three phases for voltage on the source.
side (top) of the switch. Using a voltage tester, check with the test prods from A to B, B to C and C to A. To check a three-phase switch or starter, you must have it closed to a live circuit. Then cross-check by going from A phase (input or top connection) to B phase (output or bottom connection). If this test shows no voltage, B phase is open at the switch. Cross-check the other two phases in the same manner.

CAUTION: Do not attempt the above test if the motor hums but does not start. It is possible to damage the motor while making the test. The trouble is not in the motor if it starts when belt tension is released.

14-7. If the switch and the control circuit tests show that they are operating correctly, the fault may be either in the terminal block of the motor or in one of the motor windings. Serious trouble in the motor will be indicated by evidence of overheating, such as charred insulation or the smell of burned insulation. Such damage would call for the services of the electric shop, which may be able to supply you with a replacement motor of the right horsepower and direction of rotation.

14-8. **Mechanical Troubles.** Mechanical troubles also concern you. For example, when there is evidence that a trouble is in the compressor, here are two mechanical causes which are most common: (1) A locked rotor may be caused by a frozen bearing or it can be the result of high head pressure. (2) A frozen bearing occurs in the compressor from lack of oil more often than from a faulty oil pump. Of course, a mechanical failure in the compressor is possible, but this will seldom cause a locked rotor. The usual symptoms are an inability to cool sufficiently and noisy operation of the compressor.

14-9. **Abnormal pressures.** When the cause of a trouble is not obvious and the compressor will operate, gauge readings are necessary to help spot the cause. Abnormally high head pressure indicates a restriction in the high side. The cause may be (1) air in the system, (2) moisture in the system, (3) dirt or sludge. (4) a kink or a pinched line, and last but often unsuspected—(5) a partly closed valve.

14-10. An abnormally low head pressure on the high side would not be a positive indication of compressor failure because it would also depend partly on the state of charge in the system and what the suction pressure gauge measures. Low charge is checked by looking for bubbles in the sight glass, which should show a solid flow of liquid under normal conditions.

14-11. **Refrigerant controls.** The refrigerant control is the source of many troubles. Indications of a restriction at the control are low suction pressure and an inability of the evaporator to pull the temperature down. The compressor may run continuously or it may cycle on safety controls. Whenever the refrigerated area is too warm, the thermostat will be calling for compressor operation all the time. The thermostat may be checked by turning its setting toward warmer to see that it will operate properly. The cause of trouble at a thermostat can be loss of charge, a pinched capillary tube, or improper adjustment. The first two troubles would require a replacement. An ice bath and thermometer are necessary to make the correct adjustment of a thermostat.

14-12. Troubles at a refrigerant control valve are restrictions or improper adjustment. Ice at the valve seat or needle reduces the capacity of the valve and causes abnormal readings of pressure gauges. Dirt or metal particles in the strainer can clog it to produce the same effect. A flare fitting which is not frostproof or one in which the seal has failed can cause hidden trouble. Ice will accumulate under the nut slowly, crushing the tubing. Thus, a careful inspection is necessary to reveal the defective fitting. It is for this reason that solder joints are preferred in below-freezing areas. Check for ice by warming the suspected trouble spot.

14-13. **Adjustment of controls.** Before attempting the readjustment of an expansion valve, you should make sure that one of the following is not a cause of your trouble:

- A worn needle and seat.
- A leaking bellows.
- Ice forming on the bellows.

When a valve will not close completely, the condition indicated might be a worn needle and seat, which can be replaced with new parts. A leaking bellows generally requires that the valve be replaced. Ice forming on the bellows may be prevented by coating them with vaseline, but this will not work in zero cold areas. A better solution is to keep moisture out of the housing by sealing it. After a valve has been repaired, it can be tested with an expansion valve test assembly. This consists of a refrigerant tank and service valve, two gauges for high- and low-pressure readings, and a cooling chamber with crushed ice. A source of dry air at 100-pound pressure can be used in place of refrigerant. For low-temperature work, dry ice may be used for the cooling chamber and a low-reading thermometer to check the temperature. A test assembly setup is shown in figure 14. The connection for the gauge on the outlet side of the valve is left loose enough for escape of pressure to simulate refrigerant low. As the valve adjustment is changed, the opening pressures are noted on the gauges. A valve that will not adjust to its required specifications must be replaced.

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Figure 14. Expansion valve test assembly.
14-14. If replacements are made to a float valve, there is one consideration which must be observed. Operating levels of the float must be the same as they were originally to insure proper operation. Any change in the operating levels will change the operation of the system.

14-15. Condenser and Evaporator Service and Repair. Dry type condensers and evaporators are cleaned with a stiff fiber brush or compressed air. The direction of air should be opposite to the normal flow. The frequency of cleaning recommended is based on a time interval for average conditions. The interval will be shorter when conditions require more frequent cleaning. Bent fins must be straightened to maintain adequate airflow. An outdoor mounted condenser can have a large part of its air passages closed by hail driven against the fins by the wind. Pinhole leaks in tubing can be repaired by brazing. Use flux sparingly as excess flux may pass through the hole into the tubing.

14-15. Pressure Testing. After extensive repairs or replacement of major components in a system, you may be called on to check the system with high pressure. Pressure testing of a system may be done with nitrogen or carbon dioxide to determine the strength of tubing and joints. Specified test pressures as recommended by ASRE in the American Code should be followed. Be careful to apply the test pressure by building up pressure slowly. Avoid sudden shock loads to the system. Take reasonable precautions to protect yourself and other personnel with suitable barricades so that no one will be injured if a line should rupture.

15. Preparing To Open the System

15-1. Before you can open a system, you must take the necessary steps to save the refrigerant in the system and prevent air from entering. The usual procedure is to pump down. First, close the receiver outlet valve and operate the compressor until the suction pressure gauge reads 3-5 PSIG and levels off at this pressure. This indicates that pumping down is complete. At this point, the receiver inlet valve is closed and the compressor is stopped. Of course, it may be necessary to allow some refrigerant back into the system, because the system should not be opened without a positive pressure. Such a procedure will keep air out and leave you less work to do when the time comes for you to put the system back into operation.

15-2. When equipment, such as a strainer, is provided with valves and a bypass line, it is not necessary for you to pump down the system. One precaution is necessary as it may be possible to trap liquid refrigerant in the equipment when it is isolated from the system. To avoid this, you must be careful that you do not unload a dangerously high pressure accidentally, when you open the system in these circumstances. The moral? Always purge equipment of refrigerant in the manner specified and you will be on the safe side.

16. Open Type Compressor Overhaul

16-1. Among the causes of compressor failures, valve trouble and a lack of oil are probably the most common. We will not discuss valve trouble at this time. As for a lack of oil, it can result in trouble with all of the moving parts in a compressor which require lubrication. This section deals first with the use of a micrometer to check dimensions and then with the special knowledge you should have to enable you to overhaul a compressor. Of course, the manufacturer's service book is indispensable, since it contains the overhaul instructions for the compressor. In it you will find those rules with which you should have to enable you to overhaul a compressor. Of course, the manufacturer's service book is indispensable, since it contains the overhaul instructions for the compressor. In it you will find those rules with which you should approach every job. Any exceptions to the rules will be found in the specific instructions for each piece of equipment. Now, let us begin by explaining special measuring tools.

16-2. Measuring Tools. Among the measuring tools which you must use are several types of micrometers and calipers. Let us consider first those tools which are least accurate, then move on to a discussion of the more accurate measuring tools.

16-3. Spring type caliper. Look at figure 15, which is an illustration of spring type calipers. The accuracy of this type is limited to how close you can read the measurements on a scale; it is also
dependent on the amount of feel (or pressure) which you place on the ends of the caliper when you are checking a piece of work.

16-4. **Caliper rule.** As shown in figure 16, the caliper rule has one fixed jaw and one movable jaw which slides on the rule. The sliding arm is marked with two lines labeled “OUT” and “IN”. For measuring an outside diameter, the scale is read where the OUT line matches it at $\frac{51}{64}$ inch, as shown in the bottom half of the illustration. To measure an inside diameter, the width of the jaw must be taken into account. To measure the ID of a cylinder as shown in figure 16, read the scale where the IN line matches it at $\frac{42}{64}$ inch. The smallest ID that a caliper rule can measure is the width of the jaws.

16-5. **Micrometers.** Four types of micrometers are used in making precision measurements of machine parts. These are the outside micrometer, the inside micrometer, the depth micrometer, and the dial micrometer. The accuracy of these tools is no better than the skill of the user. They must be used correctly to give precise measurements.

a. **Outside micrometer.** An outside micrometer is used to measure the diameter of a shaft or the thickness of a sheet. The outside micrometer, shown in figure 17, is used to measure diameters of less than 1 inch, which is the limit of movement of the barrel. Common sizes of the micrometer are 1 inch, 2 inches, and 3 inches. The ratchet stop in the base of the handle is used to drive the spindle when you are taking a measurement. The first step is to have the micrometer set wider than the shaft to be measured. Next, the shaft should be held firmly against the anvil (fixed face) so that the shaft is parallel with the anvil face. Use the ratchet stop to drive the spindle in against the shaft. But note that the ratchet stop is a drive which will slip. However, it always applies the same driving force to the spindle so that results will be uniform. Figure 18 shows three examples of making a correct reading on a 1-inch micrometer. Each number on the barrel marks one-tenth of an inch (0.1 inch). Between adjacent lines on the barrel, there are twenty-five hundredths of an inch, 0.025, marked off by 25 divisions around the thimble. Each complete revolution of the thimble moves the spindle twenty-five thousandths of an inch, 0.025. This is the distance marked off between two adjacent lines on the barrel. Four of these divisions, from the zero mark on the barrel will bring up the number “1” on the barrel. This indicates 0.1 inch, or one-tenth of an inch. The bottom example in figure 18 shows a micrometer set to measure 0.224 inch. The 0.2 is read from the barrel, and the 0.024 is read from the thimble. In the middle example, the correct reading is 0.226 inch, even though the next line on the barrel does not show under the thimble. The position of the zero on the thimble indicates that it has more than completed one additional revolution. The top example shows the barrel exposed beyond the 0.30
line, indicated by the position of the thimble. The zero has already passed the revolution line on the barrel. A micrometer with a vernier scale can measure to ten thousandths of an inch. Figure 19 gives an enlarged picture of the scale of a micrometer set to measure 0.2862 inch. The vernier scale is etched in the barrel, the lines being parallel with its length. The vernier reading is made by locating the line on the thimble which matches the vernier line on the barrel. In this case it is the 16th thimble line which matches the vernier line 2, which gives the reading of 0.0002, or two ten-thousandths.

b. Inside micrometer. To make accurate measurements with an inside micrometer, you must give careful attention to several details. Figure 20 shows the extension rods and their use with an inside micrometer. An extension rod must be absolutely clean before it is mated to the micrometer. Any particles of dirt which prevent the extension from bottoming would cause inaccurate readings. Its length can be checked with an outside micrometer of sufficient size. The micrometer must be held parallel with the diameter line of the cylinder being gauged. The "feel" or drag of the tool should be only slight and is checked by holding one end firm against the cylinder wall while the other end is moved straight up and down. Out-of-round and runout is checked by taking sample readings at several points of a cylinder for comparison. The barrel and the thimble are marked and read in the same manner as an outside micrometer.

c. Depth micrometer. The use of a depth micrometer and its extension rods are shown in figure 21. The same rules apply to the assembly of this tool as those given for the inside micrometer. The extension rod must be clean, and it
must mate exactly to give accurate measurements. You must hold both shoulders of the gauge flush against the edge of the opening while making a measurement. The spindle is driven by the ratchet stop so that its travel will be arrested as soon as the rod touches bottom.

d. Dial micrometer. A dial micrometer is a precision tool in which measurements are read directly on a dial. The dial micrometer, shown in figure 22, is provided with a handle so that it can be easily handled to check a cylinder wall. The steel spring at one end of the micrometer provides a two-point contact with the wall to insure better accuracy. Runout is easily checked, as the tool gives a continuous reading while it travels down the cylinder. The dial micrometer is mounted in a fixed holder when it is used to check a shaft to see whether or not it is true.

16-6. Compressor Disassembly. After you pump down a system you must front seat the compressor suction and discharge valves. You can then remove the compressor from the system. However, there is one note of caution which you should observe. Before a compressor is removed from the system, the crankcase should be vented and the oil drained. The drain plug should be loosened slowly, and pressure should be bled from the crankcase before the plug is taken completely out. The oil should be inspected and a note made as to its color and condition. You will find signs of wear indicated by the presence of fine particles of metal or a substance like grit in the oil or in the bottom of the crankcase. If the oil appears good and if there are no signs of grit in the crankcase, you could safely assume that the bearings were in good condition. A compressor teardown is not necessary if trouble is caused by a defective oil pump. With the oil pump system, however, there are two items which might also cause a trouble. These are the oil pressure regulating valve and the oil pressure safety switch. Failure of the regulator or switch can cause much needless work if tests are not made properly. Parts which cannot be adjusted to factory specifications should be replaced.

16-7. What is it that we are trying to emphasize in our last paragraph? Just this! The condition of the oil is a reliable and accurate gage of internal conditions in the compressor. Even if a mistake were made in the interpretation of conditions, that is no reason to make a major overhaul out of a simple replacement. An exception to this would be where a compressor was approaching the end of the time interval when a major inspection would be required. As a supervisor, you will be expected to make wise decisions in matters of this kind. One important item which may be overlooked is the cause of a failure. Repairing or replacing a part is not enough unless you know the cause of a failure and take measures to correct it.

16-8. Oil Seals. A seal is used where the crankshaft passes through the crankcase. This seal must be able to hold the pressure in the system whether the shaft is moving or at rest. One type of seal uses a bellows made from a thin metal tube. One end of the tube has a flange which is secured to the crankcase, while the other end has a metal and graphite ring which is forced against a shoulder on the crankshaft by a spring. In this mounting, the tube is stationary. A variation on this type has the tube and bellows mounted on the shaft, and the seal is pressed against a shoulder on the crankcase. The main disadvantages of this type of seal are that it requires that the shoulder which the seal presses against must be hardened and that a scratch across the shoulder can cause the seal to leak. New developments in synthetics have led to the use of materials which provide a seal without needing a specially hardened surface.

16-9. One new type of seal is the rotating seal head, which is precision built and assembled at the factory. It has a neoprene bellows, a lapped carbon seal washer, a retainer shell, a driving band, and a flange retainer. The seal washer mates with a stationary seat on the cover plate. The seat is also precision lapped. The driving band presses the bellows against the shaft to insure its turning with the shaft. The bellows is made so that it will ride along the shaft, permitting end play of the shaft while maintaining contact of the seal with the seat.
16-10. On some compressors, a seal nut must be removed from the shaft first before the cover plate or seal guard is removed. Check the threads carefully before attempting to remove the nut. A nut with a left-hand thread must be turned clockwise to loosen it. When the seal has been removed, check all of the seal faces for scratches and signs of wear which could prevent a new seal from doing its job. Remove all packing compound and rust preventive from the new seal with approved cleaning solvent. Failure to clean the seal thoroughly will introduce foreign grease into the system, which can cause trouble. After cleaning and drying the new parts, mating surfaces must be coated with refrigerant oil before assembly.

16-11. After installing a new seal, proper operation may be checked as follows: Frontseat the suction service valve and run the compressor until the vacuum levels off. Then frontseat the compressor discharge valve and watch for an increase in discharge pressure. A rise in discharge pressure indicates that air is being drawn into the system.

16-12. **Valves and Plates.** You will find that suction and discharge valves in a large compressor are mounted in a valve plate. You can replace these as a complete assembly for each cylinder when necessary. Replacement is necessary whenever the limits specified by the manufacturer are exceeded. Check the depth of the seat for both suction and discharge valves to see that the amount of wear is within limits. Check the valve disks to see that they are not worn too thin. A depth micrometer will serve to check the depth of a seat from the face. An outside micrometer is used to measure the thickness of disks for evidence of wear beyond recommended limits.

16-13. If a spring steel valve is replaced, the new valve must seat properly. Some replacement valves will be found with a slight burr on one side. This burr side must be placed up or away from the seat. Otherwise, the valve will not seal properly, and the seat will be scored. The burr should be removed if it is heavy enough to break up and cause metal chips in the system. A slight feather edge should not produce chips but does indicate the side which should be up when it is installed. Valve seats that are of the raised type may be lapped with fine compound if the seat is worn. Care must be used that the lapping tool is flat. The tool must not be allowed to rock during the lapping as the seal surface would be lost. All compound must be removed after the lapping operation is completed, as a small amount of the compound will quickly ruin every bearing in a compressor. Unless well-qualified personnel are available to perform precision lapping, it would be advisable for you to make valve and valve plate replacements and save work, such as lapping, for experts. Always use new gaskets with valve plates and cylinder heads. Remember that new cylinder head gaskets must have the same thickness when installed as the old gaskets, or the compression ratio will be changed. A gasket that is too thin will cause the compressor to be noisy, while one that is too thick will reduce compressor efficiency.

16-14. **Connecting Rods, Pistons, and Cylinders.** These parts should be checked for wear against the table of specifications for the compressor. Wear limits vary from as little as 0.001 inch for wrist pins and bushings to as much as 0.003 inch for cylinder sleeves. Label the caps and rods so that they can be reinstalled in the same positions from which they were removed. Some compressors are provided with removable cylinder sleeves. If the connecting rod will not pass through the sleeve, then the rod, piston, and sleeve must be removed together. You must be careful that the piston does not come through the top of the sleeve during removal, as the rings will give you trouble. Check bearing surfaces for correct measurements and for scratches or other signs of damage. Lubricate pans with refrigerator oil before reassembling them. Bearing caps should not be filed unless this action is specifically directed by the manufacturer.

16-15. Ring gap is checked by inserting the ring about 3/8 inch from the top of the cylinder. Compression rings have a taper toward the top of the ring. If installed upside down, the compressor will be noisy in operation, indicating that oil is being pumped. The top of the ring (marked "TOP") must face up so that it will be toward the cylinder head when it is installed. Oil rings which have no taper may be installed with either side up. Check the ring gap with a feeler gauge after the ring is inserted into the cylinder about 3/8 inch below the top. Ring gaps must be staggered around the piston. Side clearance between the piston and ring should be about 0.001 inch, and the ring must be free to move. When the new rings are installed, be sure to break the glaze on the old cylinder wall so that the rings will wear in properly.

16-16. **Crankshaft.** A crankshaft whose bearing surfaces are worn but otherwise are in good condition may be used if undersize bearing inserts are available. Remember that worn bearings for the connecting rods may mean worn parts at other places also. So be sure that you take all factors into account before attempting a repair that may not prove satisfactory all around.

16-17. **Oil Pump and Accessories.** Oil pumps are gear type positive displacement to insure delivery of oil at the pressures required for refrigeration compressors. For example, a system designed for oil pressure of 45 to 55 p.s.i. above suction pressure should have an oil pressure gauge reading between 85 and 95 if the suction pressure is
40 p.s.i. An oil regulating valve of the spring-loaded type insures correct oil pressure automatically. Some of these valves are adjustable, while others are factory set. When pressure cannot be adjusted high enough, it may be an indication of badly worn bearings.

16-18. An oil safety switch operates on differential pressure, which is the difference between pump discharge and crankcase pressure. If oil pressure drops too low, the compressor motor is shut off. Low oil pressure can result from low oil, pump failure, worn bearings, and crankcase dilution by refrigerant. Diluted oil may be caused by worn rings.

16-19. After repairs are made to a compressor, the system may require cleaning before it can be put back in operation. While the following section is written for a hermetic motor burnout, the cleaning procedures can be applied to any system, large or small, which requires cleaning. The process also applies to a new system which has just been assembled or installed and which requires cleaning before it can be considered ready for operation.

17. System Cleaning

17-1. This section is in part reprinted from April 1961, and June 1962, Refrigeration Service and Contracting. A new system requires cleaning before operation to insure removal of any foreign material left in the system. Also a system requires cleaning after burnout of a hermetic motor. In either case the method you use for cleaning a system will be determined by prevailing conditions and by the equipment you have available. With a new system the first step is to install a filter-drier in the suction line to prevent damage to the compressor. The filter-drier is changed as often as necessary. Such a change is called for whenever suction pressure drops, as the drop indicates a clogged filter. The following methods are generally considered to do a satisfactory job of cleaning.

17-2. Cleanup Procedure for Small Capacity. After you have established that a burnout has occurred, follow the cleanup methods recommended by the equipment manufacturer. If the manufacturer's service manuals are not available, you may follow the procedures outlined in this section. The procedures that we will discuss in the following paragraphs apply to most hermetic compressors. On larger systems a single filter-drier, connected in the suction line, may cause pressure drops. If this occurs, you must use parallel driers.

CAUTION: Acid burns can result from touching the sludge in a burned out compressor. You must wear rubber gloves when handling any contaminated pan.

17-3. To clean a system with a liquid line filter-drier and less than 10 pounds of refrigerant charge, you must follow these procedures:

- Evacuate the system from the high side (discharge shutoff valve).
- Flush the system completely with new refrigerant.
- Install the new hermetic compressor-motor.
- Install a filter-drier in the liquid line, using a size larger than specified.
- Charge the system with new refrigerant.
- Start the system according to the manufacturer's instructions or local SOP's.
- Check the oil and filter-drier on followup calls to establish the need for replacement.
- On the first followup call, install a moisture and liquid indicator (liquid eye) in the liquid line, after the filter-drier and before the expansion valve. This will indicate when moisture content is within acceptable limits.

17-4. Cleanup Procedure for Large Capacity. The procedure to follow if the system contains more than 10 pounds of refrigerant is:

- Bleed some refrigerant from the high side. If the refrigerant has a burned or acid odor, it must be evacuated to the atmosphere. If there is not a strong odor, you can evacuate the refrigerant into a clean, dry drum.
- If the system did not have a drier in the liquid line, you must clean the expansion valve strainer and the internal expansion valve parts.
- If the system has a drier in the liquid line, remove and discard it.
- Install the new compressor.
- Install a filter-drier in the suction line.
- Install an oversized filter-drier in the liquid line.
- Evacuate the entire system with a vacuum pump capable of pulling 0.2 inches of Hg.
- Break the vacuum with refrigerant.
- Re-evacuate and charge the system with the original type of refrigerant. Charging should be accomplished through the low side of the system.
- Change the liquid line filter-drier and remove the filter-drier from the suction line after 48 hours.
- The filter-drier in the suction line can be changed sooner if the pressure drop affects system capacity, but it is considered good practice to leave it in the system for at least 6 hours.
- Install a moisture and liquid indicator in the liquid line and check the oil color and odor. It must be changed if it appears dirty or smells burned.
- In 2 weeks, recheck the oil and change it if necessary. The moisture indicator will show whether or not the drier needs replacement.

17-5. Flushing the System. One of the accepted methods of cleaning the system after a hermetic motor burnout is flushing. Dry air, nitrogen, or
carbon dioxide gases are often used for this purpose if there is no sludge in the system. However, most manufacturers recommend the use of refrigerant (the same as that used for system charge) as the flushing agent. Purging with gases (air, nitrogen, carbon dioxide, etc.) does little good, because the sludge adheres tightly to the internal surfaces of the system. The solvent action of the refrigerant is essential for adequate system cleanup. Refrigerant 11 has been found to be the best solvent. It remains in liquid form at normal room temperature, because its boiling point is 74°F at atmospheric pressure. Its cost is low, and it is readily available from local wholesalers.

17-6. Circulation of the solvent (R-11) can be accomplished with the setup shown in figure 23. To flush the system, you would open valves B and C and close valve A and D. Backwashing is accomplished by opening valves A and D and closing B and C. The flow of solvent through the strainer and filter-drier is always in the same direction, as shown in figure 23. The pump is of the diaphragm type. All of these components are usually available so that you could build your own circulator and mount it on a dolly or two-wheeled cart for mobility.

17-7. **Procedure for Cleaning a System with a Circulator.** We have discussed procedures for system cleanup. The procedure that we will discuss now is considered much more efficient, but to use it, a circulator is needed. The setup for such a circulator has been illustrated in figure 23. The procedure for cleaning a system with a circulator follows:

- Make sure that the compressor motor is burned out; then remove the electrical leads from the motor terminals.
- Remove the refrigerant and oil as a liquid, but do not purge off in the gaseous state. Since, at this time, the acid content may be high, be careful to avoid contact of it with your skin or eyes.
- Remove the filter-drier and expansion device.
- Install bypass where components were removed, except at the suction and discharge lines to the compressor.
- Attach the circulator to the system.
- Circulate the solvent for at least 4 hours.
- Change filter-drier in the circulator as frequently as it is necessary to insure removal of moisture.
- Shut off the circulator and blow the system out with R-12 or R-22. Get the system as dry as possible.
- Install the new compressor, filter-drier, and expansion device.
- Partially charge the system and make a leak test with a halide torch.
- Evacuate the system three times. Break vacuum with refrigerant each time.
- Charge the system with new oil and refrigerant after the third evacuation is complete.
- Check the system after 48 hours of operation. Change the oil if dirty, and replace the filter-drier.
- Check the system again in 40 to 60 days. Again, change the oil if necessary and replace the filter-drier.

18. **Removing Moisture from the System**

18-1. The amount of moisture in a refrigeration system must be kept at a minimum to provide satisfactory operation. The main sources of moisture are low-side leaks, contaminated oil or refrigerant, and leakage in a water-cooled condensing unit. Moisture may enter the system whenever it is open, such as during installation or when you are making repairs.

18-2. **Moisture Troubles.** You will find that moisture in the system will cause one or more of the following undesirable effects:

- Freezing at the expansion device.
- Corrosion of metals (this forms sludge).
- Copper plating.
- Chemical damage to the motor insulation or to other system components.
- A restricted or plugged filter.

We will discuss two methods of dehydration, one
18-3. **Driers**. The drier unit contains desiccant, screens, and filters. Figure 24 shows the internal construction of a nonrefillable drier. The distribution baffle prevents a solid stream of refrigerant from passing through the desiccant block. It also eliminates turbulence and insures a smooth flow of refrigerant through the drier. The spun glass filter is held in place by the anti-bypass ring. The ring forces a portion of the refrigerant to flow through the desiccant block and then through the porous bronze filter. The filter casing carries model identification and positive directional flow arrows or inlet and outlet markings. The model number indicates the size of the filter. The total charge in a system is the basis for the size drier selected. If the total charge is unknown, you can assume that it is 8 pounds per ton for R-12 and 6 pounds per ton for R-22 and R-502. **NOTE**: The following general rule may be used to estimate the system charge in relation to the horse-power rating of the condensing unit:

- R-12 = 8 lbs/hp
- R-502 = 6 lbs/hp
- R-22 = 6 lbs/hp

The directional indication must be observed during installation. If it has been connected in backwards, it will cause a restriction. Why? Because particles of desiccant will get into the system, since the screen will be on the wrong side.

18-4. **Desiccants**. A desiccant is a compound capable of absorbing the moisture in the refrigerant-oil mixture. We will discuss three commonly used desiccants: activated alumina, silica gel, and calcium sulfate. You must be familiar with the correct use of these desiccants. All three are rated as highly acceptable, but the use of the wrong desiccant in a system can cause trouble and breakdowns.

18-5. **Activated alumina**. Alumina removes moisture by absorption. It is used on systems containing sulfur dioxide (SO₂), methylene chloride, methyl chloride, R-11, and R-12. It can be used in the suction or liquid line for all these refrigerants except sulfur dioxide. However, on an SO₂ system, you can install it in the suction line only. Activated alumina is available in granular, ball, tablet, and solid core form.

18-6. **Silica gel**. Silica gel is a glasslike silicon dioxide gel which removes moisture by absorption. It also removes acids and does not dust. It is available in granular, bead, and solid core form and is used on most refrigerating systems, since it is compatible with most refrigerants.

18-7. **Calcium sulfate**. The anhydrous form of calcium sulfate is also used to remove moisture from a system. Although it forms dust somewhat more than activated alumina, it can still be left in the system permanently. It is available in granular,
stick, and special block form. Calcium sulfate cannot be used with SO₂ refrigerant.

18-8. The reactivation temperature for these desiccants are:
   - Activated alumina 350°-600° F.
   - Silica gel 350°-600° F.
   - Calcium sulfate 450°-480° F.

18-9. **Installation of Driers.** Before installation, a drier should have both ends open and be baked in an oven at 300° F. for 24 hours. The drier should be capped after baking to prevent accumulation of moisture. Caps are removed just before the drier is placed in the system. Even a drier which has been sealed by the manufacturer should be dried before installation if there is any reason to suspect that moisture may have passed the seals.

18-10. **Dehydrating with a Vacuum Pump.** This material is in part reprinted from April 1964 Refrigeration Service and Contracting. To start our discussion, let us think of pressure as the column of mercury it will support. Think of atmospheric pressure as equal to 29.92 inches of mercury instead of 14.7 p.s.i.g. at sea level. This will permit us to use the pressure-temperature relationship shown in figure 25 when we determine the vacuum which must be attained to boil water at various ambient temperatures.

18-11. Referring to figure 25, a vacuum pump capable of eliminating all but 1 inch of H₂g is able to remove moisture at an ambient temperature of 80° F. or more. While a pump pulling within 1 inch of H₂g can eliminate moisture, it must also be capable of holding this vacuum throughout the dehydration process. Before we consider the variables that affect a vacuum pump's performance, we should first review some general classifications of pumps relative to their ability to remove moisture by the boiling process.

18-12. The piston type compressor might pull a vacuum of 28.2 inches of H₂, which is actually 1.7 inches of H₂ on a manometer. Quite a number of these pumps have been used for vacuum work, but they are impractical in removing water by the boiling method. Under normal ambient temperature, moisture contaminates the crankcase oil.

18-13. A rotary type compressor can pull a vacuum of 29.63 inches of H₂. This pressure will cause the water to boil at an ambient temperature of approximately 45° F. For these reasons, the rotary compressor is practical for use as a vacuum pump.

18-14. The compound two-stage high vacuum pump is capable of pulling down to about 50 microns for prolonged periods of time. Because such pumps are two-stage pumps, they can be equipped with a gas ballast or vented exhaust. The gas ballast or vented exhaust feature is a valving arrangement which permits relatively dry air from the atmosphere to enter the second stage of the pump. This air mixes with the air being passed from the first to second stage and helps to prevent the moisture from condensing into a liquid and mixing with the vacuum-pump oil.

18-15. Frequent vacuum-pump oil changes should be anticipated and recognized as the single most important factor in preventive maintenance. Even a pump equipped with a vented exhaust cannot handle large amounts of moisture without having some of it condense into the oil. If the water is allowed to remain in the pump, the moisture will attack the metal pans and result in a loss of efficiency or capacity. The oil should be changed after each major evacuation or dehydration process.

18-16. When, you are determining the size of the pump (c.f.m. capacity) to meet your needs, you must remember that the length and diameter of the line being dehydrated dictates the size pump to be used. The 75-c.f.m. capacity pump will handle most applications, since the system is normally dehydrated through a 1/4-inch line.
Review Exercises

The following exercises are study aids. Write your answers in pencil in the space provided after each exercise. Use the blank pages to record other notes on the chapter content. Immediately check your answers with the key at the end of the test. Do not submit your answers for grading.

1. Why would a bottle type water cooler have a freezestat in the control circuit when the thermostat is so that ice will form? (8-2)

2. What is the purpose of a precooler in a bubbler fountain? (8-3)

3. Of several methods you may use when patching a leak in a water tank or line, in which method must precautions be observed for good health? (8-5)

4. Describe the adjustment you would make to a beverage cabinet used to cool four different kinds of bottled beverages. (9-2)

5. When checking a condenser for warm spots, how might a warm coil be misleading to you? (9-3)

6. What is the big difference that distinguishes types of ice making machines? Give some examples. (10-1)

7. What are three types of evaporators you may find in an ice cube machine? (10-4-6)

8. Why is frequent blowdown necessary in ice making machine? (10-8)

9. In addition to mechanical troubles, what is the biggest source of trouble with ice making machines? (10-12)

10. Why is a heat exchanger necessary in the liquid line of the soda fountain shown figure 11? (11-1)

11. A dry type coil like the beverage cooler in figure 11 must be correctly sized for what reason? (11-2)

12. What is the function of the water pump in a soda fountain carbonator? (11-3)

13. If you find the water pump for a carbonator is running continuously, where would you check first to try to locate the trouble? (11-4)

14. What simple test can be made to prove that a break in the ground circuit has caused the carbonator pump motor to run continuously? (11-4)

15. What might cause constant complaints of having bad taste or flavor from a storage cabinet which has been properly refrigerated? (12-2)
16. On older models not provided with automatic defrosting, what must be done before water is used for evaporator defrosting? (12-3)

17. What is meant by a “double duty” display cabinet? (12-5)

18. In addition to special illumination, what other feature may be found around the door of a display cabinet? (12-6)

19. Why must there be a continuous flow of cold air in the display section of a refrigerated open display case? (12-7)

20. Give the five methods you have studied for storage cabinet defrosting. (12-8)

21. What is the limitation on compressor off-time defrosting? (12-9)

22. Describe the reverse cycle used for cabinet defrosting. (12-11)

23. What is one purpose of using a high-temperature control in a low-temperature cabinet? (12-15)

24. What is the purpose of the capillary tube connected to a defrost valve? (12-16)

25. The service valves in a system serve what purpose? (13-4)

26. Give the advantage or characteristic of two types of water-cooled condensers. (13-7)

27. Why must a receiver be sized to the system? (13-8)

28. What is peculiar about a receiver outlet valve? (13-8)

29. How might reversed flow affect a drier-strainer? (13-9)

30. What are the three features considered essential in an expansion valve? (13-11)

31. Give the reasons why a water cooler can use an automatic constant pressure expansion valve. (13-12)

32. What is the purpose of an equalizer line with an expansion valve? (13-12)

33. Give the descriptive items you would use to identify a thermostatic expansion valve. (13-13)

34. What are the three kinds of charge used in the bulb and capillary of a thermostatic expansion valve? (13-13)
35. Explain the meaning of a cross charge. (13-13)

36. Give the arguments for and against the liquid charged bulb. (13-13)

37. Give the pros and cons for a gas-charged bulb. (13-13)

38. What are the advantages of a high-side float valve? (13-14)

39. What effect is produced by a layer of oil on top of the refrigerant? (13-15)

40. Before making tests on a "live" circuit, why should you remove rings and not wear a metal watchband? (14-2)

41. When you find a circuit breaker tripped, what else should you do besides resetting the breaker? (14-4)

42. A compressor motor will not start and an ammeter test reads full LRA. For what purpose would you release belt tension? (14-5, 6; also 5-11)

43. Why is it poor practice to try repeatedly to start a motor which does not turn over? (14-6, 8)

44. List the causes of abnormally high head pressure. (14-9)

45. You find a compressor unit continuously running yet unable to cool sufficiently. What checks would you make to locate the cause of the trouble? (14-10, 11)

46. How would a compressor act if the thermostat controlling it had lost the charge from its capillary? (14-11)

47. How would you make a quick check for ice blocking a refrigerant control? (14-12)

48. What is the indication of a worn needle and seat in an expansion valve? (14-13)

49. When adjustments or repairs are being made to a float valve, what consideration must you observe? (14-14)

50. Where a drier-strainer is provided with valves and a refrigerant bypass, what precautions must you observe before you remove the item from the system? (15-2)

51. What is the purpose of a rachet stop in an outside micrometer? (16-5)

52. In figure 18, the top illustration shows an arrow at the right on the thimble. If the thimble is turned 12 divisions in the direction of the arrow, what will be the reading of the micrometer? (16-15)

53. How can you check to see that an extension rod with an inside micrometer is properly seated to give correct readings? (16-5)
54. What is the best tool to use to check a crankshaft to see whether or not it is true? (16-5)

55. Give five causes for loss of oil pressure in a compressor. (16-6, 18)

56. When installing a new oil seal, what precautions should you observe? (16-8-10)

57. How is a compressor operated to check a new seal for a leak? (16-11)

58. What are two important checks which you should make when you are inspecting compressor valves? (16-12)

59. Replacement valves made of spring steel should be inspected before installation. How should you perform this inspection? (16-13)

60. What is the difference between most oil rings and compression rings used in a refrigeration compressor? (16-15)

61. How would you obtain indications that a set of compression rings has been installed upside down? (16-15)

62. How would you check the ring gap of the rings used in a refrigeration compressor? (16-15)

63. Unless cylinder sleeves are replaced, what must also be done when a new set of rings is installed? (16-15)

64. What other factors must be taken into account when bearing inserts are replaced? (16-16)

65. When is system cleaning required? (16-19)

66. After a hermetic motor burnout, why must you use precautions when cleaning the system? (17-2, 7)

67. In system cleaning, where is evacuation equipment connected and why? (17-3)

68. Why is a new filter-drier installed after a system is cleaned? (17-3)

69. What is the purpose of using refrigerant to break the vacuum when cleaning a system? (17-4, 7)

70. What is the limitation on the use of activated alumina drier? (18-5)

71. Which system is not compatible with anhydrous calcium sulfate as a drier? (18-7)

72. What are the general procedures recommended before a drier is installed? (18-9)
73. What vacuum is necessary to boil water at a room temperature of 80° F.? (18-11)

74. Why are frequent oil changes recommended for the oil in a vacuum pump? (18-15)
DO YOU SUPPOSE that this chapter should be introduced with the importance of preserving food? Perhaps. But for a change, let us consider your job if you are assigned to work at a cold storage warehouse or an ice plant. You can make the job dull and boring or very interesting. In the operation of a plant there will usually be some time each day when you will have nothing to do but observe the equipment. The wise man will use this time to study the equipment. He will learn how it is laid out and where the various parts are located. While you are taking readings, you should make a mental note of changes which you observe and try to determine the causes of the changes. In this way you will both pass the time quickly and become more familiar with your equipment's proper operation. Remember, too, the man who is alert to operating conditions will recognize the symptoms of impending trouble and can thus often prevent a major breakdown. The larger plants are attended by operators on shift duty 24 hours a day.

2. This chapter is divided into two major headings. The first covers the design, insulation, layout, and operation and maintenance of large cold storage plants. The second covers the layout, operating principles, components, and the ammonia system operation and maintenance. We will undertake the discussion of a large cold storage plant first.

19. Large Cold Storage Plants

19-1. Have you ever observed the different types of cold storage in a commissary store? You will find similar areas in a large cold storage plant. Let us consider the effect of these areas on the design of a plant.

19-2. Plant Design. In the layout of a refrigerated warehouse, consideration is given to the operating temperatures by using the center of the building for the coldest operations. Warmer rooms are located around the center and act as a buffer for the colder areas. The temperatures of the rooms which follow are presented as examples of one warehouse.

19-3. Rail rooms. A refrigerated warehouse is usually laid out in the shape of a rectangle. The two longest sides of the building are occupied by rail rooms. Meat hooks suspended from an overhead rail provide the means for moving heavy loads. The rail room is normally maintained at about 35° F. Inside doors provide access to the processing room and meat cooler room, which are also part of the overhead rail system.

19-4. Processing room. This room is held at 45° F., and because of its warmer temperature, it is located at one end of the building. This is where the butcher cuts a carcass into smaller parts before storage or distribution. Such processing rooms are dangerous areas. During normal operations the floors become extremely slippery; therefore, you must be careful in order not to fall whenever your work requires that you pass through these rooms.

19-5. Meat cooler. A temperature of 30° F. should be maintained in the meat cooler for holding fresh meat prior to distribution. A meat holding and issue room at 30° F. provides additional storage area for the same purpose.

19-6. Milk, butter, and egg room. This area is normally held at 35° F. and is one of the colder areas.

19-7. Fruit and vegetable room. An average temperature of 40° F. is recommended for general storage, so this room is also eligible for location by an outside wall.

19-8. Potato room. You may already know that potatoes in storage give off heat and carbon dioxide. Consequently, the potato room should have a high ceiling and must have positive ventilation to insure the safety of personnel. Otherwise, the carbon dioxide will form a dense layer at the floor if the fans are turned off. An unsuspecting person would not realize his danger in an atmosphere so heavy with carbon dioxide until he felt himself fainting. Then it would be too late for him, as asphyxiation follows quickly. Furthermore, potatoes should not be piled more than 6 feet high to insure removal of heat. If the pile is too high, the heat will not be removed fast enough, and they
will spoil rapidly. Outside air ducts are used to bring fresh air into the room by means of fans. The fresh air is directed across the evaporator coils for cooling. To insure the safety of personnel, operating instructions for this room must be strictly observed. Operating temperatures from 35° to 45° F. may be used, depending on the type of potatoes in storage. Early crop potatoes keep best 50° F. but must be considered for short-term storage of less than 3 months. Late-crop potatoes will age best and keep from 5 to 8 months if the storage room is kept between 35° and 40°. In very cold weather, heaters are turned on to keep the products from being frozen.

19-9. Freezer room. Occupying the center of the warehouse are the freezer rooms. A below-zero room is used both for freezing products and for long-term storage. Products already frozen may be kept in a 10° F. room, where storage is for a short period, such as a week. If the insulation is installed properly in the cold rooms, your job will be easier, because the refrigeration equipment will not be overloaded. The total heat load of the warehouse will be lighter than if the rooms were poorly insulated.

19-10. Vapor Barriers and Insulation. Information on insulation is in part reprinted from January 1964 Refrigeration Service and Contracting. There was a time when a cold storage warehouse was insulated with sawdust. But now, new materials and methods of installation produce improved construction. You must be familiar with these improvements so that you can properly maintain equipment in rooms with modern insulation. There are four basic fundamentals to be considered in construction of a modern cold storage room. These are:

- Design the structure so the room and the building can move independently of each other.
- Apply a continuous vapor barrier on the warm side of the insulation, using a plastic film or laminate with the lowest permeability.
- Select insulation which has a permeability rating considerably higher than the vapor barrier but has a low permeability to air.
- Select a finish with a permeability rating considerably higher than the insulation.

19-11. The vapor barrier should consist of a plastic film or laminate with the lowest "permeability value" available. The value in permeability equals the number of grains of moisture that will pass through 1 square foot of the material in 1 hour under a vapor pressure differential of 1 inch of mercury. It has been found that a building using plastic film as a vapor barrier is more efficient thermally and less costly as compared with a building using the common adhesive or hot asphalt treated insulation. A structure constructed according to the four fundamentals will allow the insulated room to move independently of the building structure. This means that when proper techniques are followed for the installation of the vapor barrier, the vapor seal at the wall-ceiling juncture remains intact, and no leakage occurs at the joint. Modern construction allows the outer shell of the building to breathe with changes in ambient temperature while the cold storage room is held stationary in a narrow temperature range. If the original vapor barrier adhesive was inadequate or ruptured, a moisture vapor and air leak would occur and cause deterioration of the insulation.

19-12. With a new construction which follows the four basic fundamentals, the vapor barrier is installed prior to the insulation. This vapor barrier is not cemented to the walls of the building structure or the insulation but is supported independently of them. This is very important, since it allows building and cold room movement to have no effect upon the integrity of the vapor barrier. In effect, the insulation is enveloped in a vapor barrier on the warm side. This vapor barrier can be inspected after installation prior to the application of the insulation. Do not overlook the importance of being able to inspect the vapor barrier to insure adequate protection from vapor and airflow. Any damage can be repaired a this time, and overlaps can be carefully inspected to see whether specifications have been followed.

19-13. Insulating materials. Materials which have been used successfully include 6 to 8 mil polyethylene film in wide sheets, laminates of aluminum foil with polyester film, and creped paper. The width is sufficient to greatly reduce the number of laps and joints. Laps and joints require sealing with vapor barrier pressure sensitive tape. Some contractors use rolls of foil laminates because of its case of application. The insulation is installed dry without adhesives. A vapor permeable finish is applied to hold it in place. The finish protects it from damage and provides a sanitary washable surface. In some cases the finish is fire resistant. With proper materials, any small amount of vapor which does pass through the vapor barrier can flow through the insulation without changing its state. It remains as a vapor to be condensed on the cooling coil. The moisture does no condense within the insulation to impair its thermal efficiency, and the cooling load due to heat gain through the insulation remains relatively constant at or near its original U-factor.

19-14. Sealing fasteners. The fastener locations on the framing should be premarked and a strip of caulking ribbon placed behind each location. This will seal the hole in the vapor barrier caused by the fastener. After the framing for the ceiling is installed, the vapor barrier sheet is spot
stapled to the inside of the framing. Seal the ceiling vapor barrier to the wall barriers with vapor barrier pressure-sensitive tape. The ceiling framing is securely fastened to the top of all wall framing members so that movement of the building will not affect the wall-ceiling juncture. The framing for the self-supporting walls should also rest on a plate securely fastened through the floor vapor barrier into the subslab.

19-15. After the necessary bracing is in place, the vapor barrier is installed on the self-supporting walls. It is installed on the outer side of the framing and sealed to the overlap of the ceiling vapor barrier. The first layer of insulation is force-fitted between the wall studs and nailed to the underside of the ceiling. The second layer is installed horizontally on the walls and perpendicular to the ceiling framing under the suspended ceiling. This layer is held in place with plastic skewers or nails.

19-16. Lay polyethylene vapor barrier over the subslab and tape all joints and seal with tape to the ends of the wall vapor barrier. You will then be ready to lay in the insulation. The joints must be tight. Then lay a vapor permeable sheet, such as 15-pound roofing felt, over the floor insulation and up over the wall insulation, above the height of the concrete curb that will be poured later. Also pour the concrete wearing slab and install a curb of the proper height. After this, cut off the 15-pound felt even with the top of the curb. The felts acts as a slip sheet. It allows the floor and curb to move independently of the walls. It also prevents excess water in the concrete from wetting the floor insulation.

19-17. At this point, the job is ready for installation of the permanent fasteners and the stabilizers. Fasten 4-inch-wide galvanized metal lath over each framing member. Apply a portland cement finish in two coats over the walls and ceilings. The finish should be cured with water spraying in accordance with recommendations for wiring. This treatment reduces shrinkage and gives maximum strength to the finish.

19-18. Plant Layout. In order to understand the layout of a cold storage plant, you should be able to read blueprints. Standard drawings are often used with additions and note added so that the diagram may be applied to a specific installation. You should recognize that this is the case with the illustrations used in this section. At the time when a facility is built, an accurate drawing is made of the equipment. These drawings are referred to as "as-built drawings." Changes or modification should be entered in the drawings; thus the drawings should be kept up to date by appropriate entries of modifications or additions to the plant.

19-19. Machine room. If you have ever seen the machine room in a cold storage plant, you were probably impressed by the array of tubing. Some of it you recognized without a doubt, while other parts of the tubing seemed strange to you. Look at figure 26 and you will see a diagram of the layout of tubing and equipment in a machine room. Appropriate labels are provided so that you can identify each item. Notice how a pitch is specified for horizontal lines to prevent pockets of liquid from being trapped in the lines. A few words of explanation may help you to read such a diagram.

19-20. Look at the upper right part of figure 26 and find a line which is labeled "LL to HT System coolers." The abbreviation means liquid line to high-temperature-system coolers. At the upper left you will find a line marked "S.L. 4," which means "4-inch suction line." Beside the legend "Sight glasses" you will see a number "1" in a small triangle. This 1 refers to an item which was added after construction has been completed. When items are added, such as symbols with special meaning, a notation should be made under "added notes" or "revisions" on the blueprint. Appropriate forms, such as status and operational records, component replacement, and historical records, must be maintained for plant equipment as directed by inspection TO's.

19-21. Under the label "Liquid Receiver" is a note telling you to "See detail." Several details may be shown on the same blueprint. A detail of a typical receiver is shown in figure 27. Note the two driers, which makes it possible to replace one without shutting down the system. You can see many things in the detail which could not be included in figure 26 because of lack of space.

19-22. Cold rooms and evaporators. The various cold rooms are provided with evaporators of appropriate size. In figure 28 you will find a detail of typical connections to an evaporator. Each large cold room may have one or more evaporators, and valves must be located so that an evaporator can be isolated while the rest of system remains operating. Let us now consider the operation and maintenance of a cold storage plant.

19-23. Operation and Maintenance. For purposes of this discussion, we will start with the motor controls and compressors and follow the flow of refrigerant. Thus, we can explain the operation of the plant in a logical sequence.

19-24. Compressors, controls, and accessories. From our previous discussion of a machine room, you will remember the four compressors shown in figure 26. Two 15-hp compressors supplied the high-temperature evaporators, while two 20-hp units furnished the low-temperature evaporators. In either side, the loss of one compressor will not halt operations completely. When possible, compressors of the same size are installed so that the
Figure 26. Machine room diagram.
system can be standardized and spare parts will be interchangeable. The inventory of spare parts will thus be smaller because there will not be a need for duplication.

a. Pressure control. Generally, motors larger than 5 hp are three phase and require a starter. The motor starter is controlled with a pressure motor control tapped into the low-side suction line. The cutout pressure is set for 10°F below the coil temperature, while the cut-in pressure should be set for the desired coil temperature. The spread between the two settings determines the frequency of compressor operation. Operation in very cold weather may produce conditions which will prevent some systems from operating automatically because of abnormal pressure. The receiver outlet valve (king valve) may be throttled so as to force the pressure to increase. As pressure builds up to a near normal level, the valve should be opened more. Be sure, however, to restore valves to normal operating positions after the condition is corrected. Remember, a pressure control's function is to close and open a set of contacts in the circuit to the operating coil of the starter for the motor.

b. Magnetic starter. The motor control is essentially a three-phase magnetic switch which is closed when its coil is energized. The coil serves to close the switch and to hold it closed. The switch is closed against spring pressure, which throws the contacts open as soon as the circuit to the coil is interrupted. Two overload protection provide protection against shorts in all three phases. Protectors are located in A and C phases, which should be the two outside wires. Remember, when testing a switch for supply voltage, the upper terminals are connected to the feeders. Check the upper terminals from A to B, B to C, and A to C for voltage on all three phases. If one phase is dead, the trouble is in the feeder or supply. The lower three terminals are connected to the motor. When a small fourth contact is part of a switch,
it provides a holding circuit to the closing coil. The wiring diagram inside the cover of the switch box will give the wiring diagram for that particular switch. Maintenance consists in replacement of overload protectors which have failed or a magnetic coil which has an open circuit. In both cases an exact replacement or a substitute as specified by the manufacturer must be used. If the switch contacts are severely burned, the entire switch may require replacement. Excessive heat may damage other parts, such as the springs, which would cause more trouble in the future if the switch was partly rebuilt.

c. Time-delay relay. You will remember that in the illustration of a machine room, each system was supplied by two compressors. If both these motors were started at the same time, there would be twice the load on the electrical system. For example, a three-phase, 220-volt, 15-hp motor will draw about 100 amperes starting load of 200 amperes would cause a voltage drop, resulting in slower starting. This would extend the starting period, and the motor windings would be subjected to unnecessary overheating. Such a situation is avoided by using a time-delay relay with one motor so that it is not started until the other motor reaches operating speed. A time interval of from 3 to 8 seconds is sufficient. The time-delay relay consist of a solenoid coil and plunger with a set of contacts which close the circuit to one of the motor starters. The plunger operates in a dashpot filled with oil. Maintenance requires that the relay be kept clean. If oil needs replacing, be sure to use oil that is approved for use in a dashpot. Dash-pot oil keeps the same viscosity over a wide range of temperature. The time interval can be changed by turning the adjustment screw. An ordinary light switch maybe wired in parallel with the time-delay relay if the relay fails. The second compressor can then be started manually after the first compressor starts. Operation can thus be continued until the relay can be replaced.

d. Motors and drives. Three-phase motors have the high starting torque required by large compressors. Once a motor is installed properly, all it needs is cleaning and oiling. Motor bearings should be checked daily for normal temperatures. They should not be so hot that you cannot hold your hand comfortably on the bearing shell. Always open the motor switch before checking the belt driver end. Lubrication of motor bearings it done on a regular schedule as directed. Proper installation means that the motor must be lined up so that its pulley drum is parallel with, and in the same plane as, the pulley on the compressor shaft. An initial test of the direction of rotation of the motor should be made before the terminal’s connections are made permanent and insulated with tape. If at the test, the motor rotates incorrectly, its direction is reversed by interchanging two of the motor leads with the supply leads. By transposing two of the phases, a three-phase motor will have its rotation reversed.

You may have to remove a motor at some time for repairs. Before disconnecting the wires, be sure that you attach labels to all of the supply leads and the motor leads. Then, when you are ready to reconnect the motor, wire it the same as before.

A large compressor is driven by multiple V-belts, which should be provided with a safety enclosure. Belt guards are for your protection and must always be in place during normal operation. Loose or damaged guards must be repaired or replaced. Always open the compressor switch so that the motor cannot start while you are working around or in the immediate area of the belts. If the oil is spilled on V-belts, they must be cleaned immediately. Again, open the compressor switch so that the unit cannot start while you are working on it. If the oil soaks into the belts before they can be cleaned, plan on replacing the set soon, because oil causes the material to deteriorate rapidly.

Multiple drives of four or five belts are common. When one belt becomes too loose or worn, it may be removed and operation continued temporarily. You should expect some drop in output from the compressor because of belt slippage. It is impractical to replace one belt at a time, because V-belts are supplied in matched set. However, you will always find some variation in individual length. This variation becomes apparent when you try to adjust the tension on a newly installed set. When you need to replace a set of belts, be sure to follow all relevant safety rules. First, open the electrical supply switch to the motor. Then hang a caution or danger tag on the switch handle if there is any possibility that someone might close the switch while you were working on the motor. Next, release the holding bolts and the locknut on the jackscrew. Also, back off the jackscrew to release tension on the belts, remove the old set and install a matched set of belts on the pulleys. After this, take up the jackscrew until belt deflection indicates correct tension; then, set the locknut on the jackscrew and tighten the holding bolts.

You will find some variation in belt tension recommendations, but these are determined by operating conditions. For instance one beltmaker recommends a belt deflection of from 1/2 to ¾ inch for each foot between the pulley shafts. In contrast, another recommendation calls for a deflection of 1/64 inch per inch of span between pulley shafts. Experience is probably your best gauge as to the correct tension. In operation, too little
tension is indicated when most of the belts show a pronounced flutter. As an example, the right tension on a matched set of belts may be most nearly correct when one belt shows a small flutter while the rest are steady during operation. The object of adjustment is to get a minimum amount of vibration without getting the belts too tight. Belts which are too tight will wear out quickly. On the other hand, belts which are too loose will slip and result in lost efficiency and reduced output. In any case, most V-belts are made of material which will not glaze. Belt dressing should never be used on V-belts unless it is recommended by the manufacturer. When adjustment will not correct belt slippage, it would at best be a temporary measure to apply a dressing, and you should plan to replace the set.

e. Gauges and records. The gauge for high pressure and low pressure are located on a single panel so that the operating conditions can be observed quickly. Alarms and indicator lights are also mounted on the same panel. Oil pressure gauges may be on the panel but are generally mounted on the compressor. Readings are taken at regular intervals to check for normal operation. You, as a supervisor, may require readings made continuously to monitor the system during unusual conditions, such as when the system is first placed in operation after major repairs. The period of close observation may be long or short, depending on what changes have been made ad how long it will take the system to settle down into a normal pattern of operation.

Abnormal pressure changes are indications which must be interpreted correctly. A gradual change in pressure may be from a change in ambient temperature, from loading or unloading work in the cold rooms, or from a trouble developing. A rapid change in pressure is usually an indication of trouble. The possibility of this latter, rapid change points up the advantage of making frequent readings and recording them. If the gauges have not been checked in several hours and a big change has been noted in pressure, the operator may have no way of knowing whether the change is sudden or gradual. For example, when the ambient temperature drops low during a cold winter's night, you an expect below-normal gauge readings.

If you are fortunate enough to pull an assignment at a plant equipped with automatic temperature and pressure recorders, you will be able to read a continuous record of plant operation. An automatic recorder has one or more pens which trace a line in ink on appropriately marked graph paper. The pens are delicately balanced and driven electrically by a bridge circuit. Be careful, however, when changing charts or putting ink in the pen reservoir, since rough treatment will damage the pen's mounting and cause an error in the recording. You may still be required to make one or more readings of the gauges each shift. Your records serve as a double check on system operation. The best part about a graph chart is that the frequency and duration of each cycle of operation can be seen clearly at a glance. The chart is a useful tool for the supervisor because, by comparing charts, he can detect day-to-day changes.

f. Oil receivers. The oil receivers provide a means of temporary storage of the oil returned from the oil separators. Sight glasses provide a means of checking the oil level in the receiver. Oscillation of the oil level indicates that the oil separators are performing their function of returning oil to the receiver. The oil level will drop each time that the float valve opens to return oil to the compressors. In case of low oil level, do not add oil to the system until you have determined that oil has been lost. Why? Because the low level can be an indication that oil is accumulating in one of evaporators.

19-25. Condensers and water towers. Two types of condensers are favored for large systems. These are the evaporative and the tube-and-shell types of condensers.

a. Evaporative condenser. You will find the first type illustrated in figure 29. The upper section of the unit contains the blowers, which pull air through the coils. The center section contains an array of spray headers, which spray water over the condenser coils. The combination of air and water acts to produce a water temperature considerably lower than the air because of evaporation. Efficiency of the condenser falls off as humidity goes up. The water pump circulates water from the sump up to the spray headers. Makeup water is added to the sump by means of a valve and float control located in the sump near the pump intake. Bleed-off water is tapped from the far side of the sump ad discharged to the sewer. Bleed-off and makeup connections are not shown in figure 29. Bleed-off water must drain at a rate sufficient to insure that salts do not accumulate in the unit. The condenser operation would be seriously lowered by even a small salt deposit. If salts start to appear, it is advisable to increase the amount of makeup water by opening the bleed-off valve wider. When scale appears on the condenser coils, they must be cleaned with a stiff bristle brush. Bristles must be hard enough to remove the scale but not so hard as to damage the tubing. Water which has an acid pH will not cause scale, but too much acid will cause corrosion.

Operation in cold weather may require the pump to be turned off. In extreme cold the fans may have to be stopped and the water drained to prevent freezing.

Capacity control of a condenser is necessary to
insure efficiency of the system. There are four ways to control the capacity of the condenser. One method controls the water pump by a pressure-operated switch. When head pressure drops below a predetermined point, the pump is stopped and the unit acts as an air-cooled condenser. Another method is to use a pressure-operated switch to turn off the blowers when pressure drops to a predetermined point. Still another method is to use a two-coil condenser, with a solenoid valve to cut one coil off when a pressure switch operates at its low-pressure setting. A fourth method uses modulating dampers on the air inlet. The dampers are designed to close when the compressor is idle. This last method has advantages for cold weather operation as the dampers may be operated so that freezing of the water is not a problem.

b. Tube-and-shell condenser. Another type of condenser is the tube-and-shell, which circulates water through the tube. The condenser shell may also serve as a receiver for the system. The condenser water is circulated through a cooling tower, where evaporation drops the temperature of the water. The spray headers in a cooling tower are similar to those shown in figure 29. A water bypass line around the tower is the usual method of capacity control. This also serves for cold weather operation, but in extreme cold the system may have to be drained to prevent freezing and breaking of pipes. Makeup water is added to the system automatically by means of a float control in the sump. Bleed-off water may be used as a method of scale control. Algae control and water treatment are discussed in Volume 4. Capacity control may also be attained by means of a water-regulating valve located in the condenser inlet water pipe. The valve is controlled by compressor discharge pressure so that head pressure remains relatively constant within a predetermined range. The water regulating valve is a modulating type which controls the volume of water through the condenser. Where water is cheap and plentiful, it may be discharged overboard after passing through the condenser instead of recirculating it through a cooling tower. Both evaporative condensers and cooling towers accumulate sludge which must be flushed. The unit must be taken out of service, the sump drained, and the mud removed. Twice a year cleaning should be sufficient, except where dust conditions are very severe.

19-26. Liquid refrigerant receivers. The liquid receiver must be large enough to hold all of the refrigerant in the system. Any time the system is to be opened, it must first be pumped down. This is done by closing the receiver discharge (king) valve and operating the compressor until the suction pressure levels off at 3-5 PSIG indicating that the system has been pumped down. The receiver inlet valve is then closed, and all the refrigerant is stored in the receiver. Repairing of leaks, testing and major repairs has been explained in the preceding chapter.

19-27. Expansion valves. Expansion valves should be checked during each walk-through inspection. Look for unusual signs of frosting or extension of the frost line on the tubing. Frost on the high side of the valve indicates a restriction in the liquid line. Check fans for operation. Note also any unusual noises, such as hissing, which would indicate a low refrigerant change. When a
expansion valve begins to get plugged, a from ice which is formed by moisture in the system, one of the observable signs will be an unaccountable rise in the temperature of the room. When this happens, you must do more than just clean out the valve. In addition, the system drier should be changed and the system carefully checked to find where the moisture is getting in. The leak must be on the suction side at a joint, unless the tubing has been punctured.

19-28. Evaporators. The evaporator used in a cold room is a coil and fin type with a fan or blower for cooling. Hot gas defrosting is the most practical method for zero operation, but some older units may still require manual defrosting with water. These methods are the same as those you studied in the last chapter.

19-29. Evaporators and blowers should be inspected for security of their mountings. Any unusual noises should be investigated and traced to their source. Unusual odors in a cold room may be caused by a hot motor or a bearing which needs lubrication. Conditions which you cannot correct should be reported so that proper action can be taken.

19-30. A large evaporator in a zero cold room may become sluggish in operation over a period of time. These conditions are caused by a gradual accumulation of oil in the coils. A hot gas defrost system will usually prevent the oil from condensing in the evaporator. However, this discussion of oil condensing in the evaporator brings up one of the big advantages of defrosting with hot gas. Should oil accumulate in one of the evaporators, the first indication would be a drop in oil level at the oil receiver with no external signs of the loss. By operating the hot gas system for an additional period of time, the oil can be picked up by the refrigerant gas and moved out of the evaporator. The success of this operation will be reflected by a rise in the level at the oil receiver.

20. Ice Plants

20-1. Both portable and permanent type of ice plants are used by the military. You may find the portable plant in sizes ranging from 1-ton to 15-ton units using standard halocarbon refrigerants. The operation of a system using such a refrigerant has already been explained. While this section will deal with a permanent type plant using an ammonia system, ice making is done by the same procedure regardless of which refrigerant is used for freezing the water. Building design will generally call for insulation similar to that used for cold storage. The discussion which follows is centered around an ice plant using an ammonia system.

20-2. Plant Design and Layout. A permanent ice plant requires special construction of a building, as illustrated in figure 30. You will see that part of the floor has been omitted from the drawing. Below the floor is a large tank which is filled with a brine (salt) solution. The evaporator is a flooded type with the coil weaving back and forth between rows of ice can set in the brine tank. The area above the tank is used to store ice. Above the evaporator coil and the ice cans. To the right of the evaporator coil is the can dump is illustrated. Warm water may be sprayed over the can to loosen the ice.

20-3. In figure 30 you can see an illustration of a compressor with a shell and tube condensing unit. A cooling tower would be necessary unless fresh water is very plentiful. At the opposite corner of the room, you will see the agitator motor. This motor circulates the brine to increase the rate of transfer of heat between the evaporator coil and the ice cans. To the right of the agitator is the accumulator. This is a large vertical tank which extends down into the brine tank. It serves to provide liquid ammonia to the bottom header of the evaporator. The ice storage room is not illustrated here; but in some plants, the overflow from the main evaporator is used to cool the ice storage room.

20-4. Operating Principles and Application. Let us start at the compressor for a brief review of the operating cycle. Coming from the compressor is a hot gas under high pressure. The gas is cooled and becomes a liquid in the condenser. At the float valve, the liquid passes into a reduced pressure area-the evaporator-where it boils and absorbs heat as it changes to a gas. From the accumulator, the suction line returns low-pressure vapor to the compressor. The refrigeration cycle is illustrated in figure 31, where we have also shown the cooling water path through the tubing of the condenser and the compressor heads. The temperature of the brine is maintained at 15° F. This will free a 300-pound block of ice in 45 to 48 hours. At warmer brine temperature, the freezing period becomes too long to be economical. At temperatures colder than 15° F., the ice is too brittle and fractures easily.

20-5. There are three factors to make a good block of ice: (1) A brine at 15° F. has the lowest practical temperature which will make good ice. (2) The ice water should be agitated continuously while the main part of the block is being frozen. This is done by means of a small rubber hose which puts a jet of low-pressure air into the water. The pressure is adjusted so that the hose pulses back and forth. This insures a good grade of clear ice. (3) The core water should be sucked out and re-
20-6. **Components.** The usual accessories, such as strainers, are just as vital in an ammonia system as in any other similar system. Of more specific concern to you here are such new components as ice cans, can fillers, agitators, core suckers, ice can hoists, dip tanks, and can dumps. These are discussed, in the order named, below.

20-7. **Ice cans.** The ice cans used at an ice plant are all of the same size in order to standardize operation and handling. Cans are made in different sizes, with the smallest one capable of making a 50-pound block of ice. The largest cans are made to produce a block weighing 300 pounds. The lifting arrangement at the top of the can must be standardized so that one hoist attachment will fit all of the cans.

20-8. **Can fillers.** A permanent type can filler uses a tank of sufficient capacity and a float valve to shut off the water automatically at the right level. The tank is mounted on a raised platform higher than the top of the ice can. When a can is placed under the tank, a dump valve is tipped and the ice can is filled with the right amount of water. The water supply to the tank is shut off while the dump valve is tripped. When the dump valve is shut off, the tank is automatically refilled. A portable type of can filler is shown in figure 32. You must be sure that the float ball and trip level operate properly to shut off the water when the ice can is full.

20-9. **Agitators.** The brine agitator consists of an electric motor, a shaft, and an impeller. This motor runs continuously to insure transfer of heat from the cans to the evaporator. Another agitator consists of a small air pump and the necessary hose to reach the ice cans. Air is used to agitate the water during the early stages of ice formation to insure a good grade of ice.

20-10. **Core suckers.** A core sucker is a pipe long enough to reach the bottom of the ice can. A hose connects it with an injector or suction pump. The sucker is used to remove the core water, which contains a concentration of salt and other impurities, after most of the ice block has formed. The core water is discharged to the sewer system, and fresh water is added to fill the core so that freezing of the block can be completed. This
operation insures purity of the ice and freedom from objectionable taste and smell.

20-11. *Ice can hoists.* The can hoist is used to load and unload ice cans from the brine tank. A small plant may use a portable band winch of the type you saw in figure 30. A large volume plant usually has a rail-mounted overhead hoist which can be moved to any position over the brine tank.

20-12. *Dip tanks.* A large tank of water may be used to free the finished block from the can. The can is lowered into the tank, where it remains long enough to melt the surface of the block. Tap water temperature may be warm enough so that it is not necessary to add any more heat to the dip tank.

20-13. *Can dumps.* After the block is free, the can is removed from the dip tank and placed on a dump rack. The rack tips the can at an angle to allow the ice to slide out. When a dip tank is not available, the ice can may be positioned on the dump and warm water sprayed over the can to loosen the ice.

20-14. **Ammonia System Operation and Maintenance.** The operation of an ammonia system requires temperatures and pressures different from those for halogens refrigerants. Also new to you is the makeup of the brine solution used in an ice plant.

20-15. *Brine solution.* If you have operated a car in a cold climate, you know that an antifreeze solution insures that a liquid will remain liquid at below freezing temperatures. Although glycol or alcohol can be used as an antifreeze additive, the most common additive is salt, which gives the name "brine" to the solution. A salt solution may be checked for its freezing point with a hydrometer if the temperature of the solution is taken into account. Four brine solutions and their specific gravity are given in table 9. The specific gravity is given for a solution temperature of 60° F. A sodium chloride solution reaches its eutectic point at -6° F. Beyond this point, the addition of more salt will cause the solution to thicken.

20-16. A brine solution made with 2 1/2 pounds of calcium chloride to 1 gallon of water will not freeze at 0° F. Two pounds of ordinary table salt (sodium chloride) per gallon of water will freeze at slightly below 0° E A 40-percent solution of alcohol is good at 0° F., while an ethylene glycol solution requires about 45 percent glycol to insure that it will remain a liquid at 0° F. You will note that any of the above solutions would be adequate, as a brine temperature of 15° F., can usually be maintained with an evaporator temperature of 5° F.
TABLE 9
REFRIGERANT SOLUTIONS

<table>
<thead>
<tr>
<th>Freezing Temp. °F.</th>
<th>10°</th>
<th>0°</th>
<th>-10°</th>
</tr>
</thead>
<tbody>
<tr>
<td>Calcium Chloride</td>
<td>1.140</td>
<td>1.175</td>
<td>1.200</td>
</tr>
<tr>
<td>Sodium Chloride</td>
<td>1.118</td>
<td>1.156</td>
<td>*1.175 at -6°</td>
</tr>
<tr>
<td>Ethylene Glycol</td>
<td>1.080</td>
<td>1.105</td>
<td>1.225</td>
</tr>
<tr>
<td>Alcohol</td>
<td>0.970</td>
<td>0.960</td>
<td>0.950</td>
</tr>
</tbody>
</table>

*Sodium Chloride solution reaches eutectic point at -6° F.

20-17. Ammonia temperatures and pressures. Let us first deal with normal operating conditions which you would expect in warm weather. With a suction gauge pressure of 20 p.s.i.g., you should have an evaporator coil temperature of about 5° F. A normal head pressure of 185 p.s.i.g. should carry a vapor temperature of 238° F. Since temperatures approach 250° F., water jackets are used to cool the compressor head. At this head pressure, ammonia will condense at 96° F. In colder weather, head pressure may drop to 155 p.s.i.g., with the temperature of the vapor dropping to 212° F. At a gauge pressure of 155 p.s.i.g., ammonia condenses at 86° F. It is necessary to raise the operating pressure on the system. You may use a manual valve in the liquid line to throttle the system. As pressure builds up, be sure to open the valve and restore it to its normal operating position.

20-18. Condenser cleaning. Even with proper treatment, the tubes in a shell and tube condenser may accumulate scale. A temperature rise of 5° above normal in condenser output is an indication of scale formation. We will discuss next the most effective method for removing scale. The necessary equipment for cleaning is shown in figure 33. The drum or barrel should have a capacity of 50 gallons. It may be wood, stone, porcelain, or metal. Galvanized metal must not be used, as it will react too fast with the acid used for cleaning. The fine mesh screen (bronze or copper) in the barrel serves to prevent scale from entering the pump. Look at the position of the pump in the suction line and note how scale from the condenser will be held in the drum. The circulator pump must be made of acid-resistant parts. The vent pipe provides a way of voiding hydrogen gas from the system. This gas is evolved as part of the chemical reaction between the acid and the scale. Galvanized pipe or fittings must not be used in the setup.

20-19. Goggles, rubber gloves, and aprons must be worn while you are mixing acid or handling the solution. Furthermore, bicarbonate of soda (baking soda) should be immediately available to counteract any spills or neutralize accidental skin burns. (NOTE. Always add acid to water when mixing, particularly sulfuric acid. It gives off a large amount of heat, which the water can absorb and dissipate. Avoid inhaling acid fumes as they can easily damage mucous tissues.) An inhibited acid solution is prepared by using commercial grade hydrochloric acid (muriatic acid) with a specific gravity of 1.190. The solution may be prepared in the barrel used with the cleaning setup. Each 10 gallons of water requires that 3 2/5 ounces of inhibitor powder be dissolved in it. Add acid to this solution at the rate of 11 quarts of acid for each 10 gallons of water. Commercial grade sulfuric acid may be used if muriatic is not available, but the solution will not do as satisfactory a job of cleaning the tubing.

20-20. The inhibited acid should be circulated through the tubes for about 12 hours to remove scale deposits of average thickness. Cleaning time will be slower if the solution is cold, whereas cleaning will be faster with a hot solution. The strength of the solution may be checked by applying a few drops to some baking soda. The rate of bubbling or gassing indicates how much strength remains in the solution. When the solution becomes very weak, there is little point in continuing to circulate it through the condenser. Be sure to flush out the condenser tubing immediately after cleaning. Flush the condenser tubes with fresh water until the discharge water becomes clear. The effectiveness of the cleaning may be indicated by the amount of scale deposited in the barrel. The final measure, of course, is the return of the condenser to normal temperature range during operation.
Review Exercises

The following exercises are study aids. Write your answers in pencil in the space provided after each exercise. Use the blank pages to record other notes on the chapter content. Immediately check your answers with the key at the end of the test. Do not submit your answers for grading.

1. Where are the coldest rooms located in a refrigerated warehouse? (19-2)

2. Outside of the machine room you will find certain areas which may be dangerous. Explain the dangers in these areas. (19-4, 5, 8)

3. What will probably happen if potatoes are piled too high in storage? (19-8)

4. Modern methods of construction have introduced what two new basic fundamentals to a cold storage building? (19-10)

5. With modern construction of a refrigerated warehouse, to what should the vapor barrier be attached? (19-14, 15)
6. How should you use the blueprint of a cold storage plant? Give several uses and applications. (19-18-21)

7. What are details on a blueprint? (19-21, 22)

8. A cold storage plant has what operating advantages when four or more compressors are installed? (19-24)

9. What factor is used to determine the setting of a suction side pressure control which starts and stops the compressor motors? (19-24)

10. (True)(False) Evaporator coil temperature is a more reliable indicator of system operation than suction pressure. Why? (19-24)

11. What are two ways of building up head pressure during cold weather operation? (19-24, 25)

12. Describe the proper way to check a three-phase magnetic switch for voltage. (19-24)

13. Where is dashput oil used? (19-24)

14. What test should you make of a motor when you install it? (19-24)

15. Your personal safety is at stake when you work on V-belt. What precautions must you observe to keep from injury? (19-24)

16. How should you treat V-belts which get splashed with oil? (19-24)

17. How would you adjust the tension when one V-belt of a set shows a more pronounced flutter than that of the others? (19-24)

18. How would you interpret a gradual drop in head pressure as compared with a sudden drop? (19-24)

19. What is the purpose of a recording chart? (19-24)

20. In an evaporative condenser what is the purpose of bleed-off water? (19-25)

21. How can bleed-off water affect the volume of makeup water? (19-25)

22. What is probably the best method of capacity control of an evaporative condenser during cold weather operation? (19-25)

23. What are the main disadvantages of a cooling tower? (19-25)

24. What are the checks which should be made on a walk-through inspection of the freezer rooms in a cold storage plant? (19-27-29)
<table>
<thead>
<tr>
<th>Question</th>
<th>Answer</th>
</tr>
</thead>
<tbody>
<tr>
<td>25. What is a big advantage of a hot gas defrost system for a large evaporator in a zero cold room? (19-30)</td>
<td>29. Why is it necessary to use a core sucker? (20-5, 10)</td>
</tr>
<tr>
<td>26. Why is an agitator necessary in the brine tank of an ice plant? (20-3)</td>
<td>30. How is it that the brine solution is operated at 15° F, but it is made up so as not to freeze at 0° F.? (20-15, 16)</td>
</tr>
<tr>
<td>27. Why is the head of an ammonia compressor cooled with a water jacket? (20-3, 17)</td>
<td>31. How is inhibited acid prepared for cleaning scale from the tubes of a condenser? (20-19)</td>
</tr>
<tr>
<td>28. What are three important factors in making a good grade of ice? (20-5)</td>
<td>32. Why is baking soda necessary when you are cleaning scale with inhibited acid solution? (20-19, 20)</td>
</tr>
</tbody>
</table>
CHAPTER 4

Special Application Systems

SOMETIMES we try to make things more complicated than they are. You can avoid confining yourself if you keep in mind that a basic system is modified to make it work for a special application. Yet, not one of the system’s basic principles is changed. This chapter deals with multiple evaporators and multiple compressors and concludes with systems for producing ultralow temperatures. Technical information on these systems is reproduced from Commercial and Industrial Refrigeration, by C. Wesley Nelson, copyright 1952, McGraw-Hill Book Company; used by permission. You are already familiar with the name of items which will be discussed, but differences result from the conditions under which this equipment operates. Let us consider first the problems of a system using several evaporators.

21. Multiple Evaporator Systems

21-1. A multiple system is one in which several evaporators are operated from one compressor. A variation is the operation of two or more compressors with one evaporator. Multiple units are installed in restaurants, soda fountains, bars, and in other places where more than one refrigeration fixture is used. Capacity control is obtained by using two or more compressors for one evaporator. An example is an ice plant when the compressors are started or stopped according to the load demand.

21-2. Classification of Multiple Evaporator Systems. Fundamentally there are only two classifications of multiple-unit systems. The first is the one in which all the evaporators operate at the same temperature. This is the simplest, although not the most common. The second is the one in which the temperatures in the different refrigerators are not the same. In order to control the temperature in a multitemperature installation, various combinations of valves and controls must be used. The correct selection and installation of these valves and controls have a decided bearing on the success of the installation.

21-3. Cord Valves for Multiple Units. When two or more evaporators are operated from the same compressor and the temperature of the warmer refrigerator is not more than 5° F. higher than the colder, no special valves are necessary. When the temperature difference is greater than 5° F., some sort of valve or control for the warmer refrigerator is essential. A thorough knowledge of the operation and application of the types of available control valves is necessary before a satisfactory multiple system can be laid out.

21-4. Suction-pressure regulating valve. This valve, also called an evaporator-regulating valve, is placed in the suction line of the warmer evaporator, and controls its pressure (and consequently its saturation temperature) so that it will remain substantially constant and not go below the predetermined setting of the valve. Thus, when two or more evaporators are operated with one compressor, the desired temperature in the warmer evaporators can be maintained by the proper setting of the valve. The locations of the valves in a system are shown in figure 39. (See paragraph 21-19.)

21-5. Bellows type. A bellows type evaporator-regulating valve has the inlet connection from the evaporator and the outlet connection to the compressor. The evaporator pressure acting under the bellows and the force of a small spring under the valve are both opposed by a spring. When the forces are equal, the valve is in equilibrium and maintains a definite opening. A reduction in evaporator pressure will cause an unbalancing of forces, and the valve will throttle. The resulting decrease in the flow of vapor will prevent the pressure from going too low. The condensing unit continues to operate on the other evaporators at reduced suction pressure. This valve has a fitting where the evaporator pressure may be taken. A gauge adapter valve must be used. The cap is removed and the adapter is screwed onto the fitting with the key engaging the needle valve. The gauge is connected to the
Figure 34. Method of bypassing evaporator-regulating valve.

Figure 35. Diaphragm type evaporator-regulating valve.

21-6. **Diaphragm type.** Another type of evaporator-regulating valve is illustrated in figure 35. This valve has a diaphragm instead of a bellows. One of the features of this valve is the collar with pressure graduations under the adjusting knob. By turning the knob until the bottom lines up with the graduations, you can make the correct setting without reading the pressure or without waiting for the refrigerator to arrive at the desired temperature. The operation of this valve is similar to the one previously described in that the valve remains open when the warmer evaporator pressure is high and then throttles as the compressor lowers the pressure. This valve has a gauge port for checking pressure and for bypassing. To get a reading, you attach the gauge to the port, remove the cap, and open the gauge shutoff valve. The valve range is from 40 p.s.i. to 0 in. Hg vacuum, and it can be used on Freon units up to 1/2 ton and up to 3/4 ton on methyl chloride and SO₂ units.

21-7. **Two-temperature type with manual closing.** Still another type of two-temperature valve is the one shown in figure 36. You adjust this valve by the adjusting nut; the handwheel is used only for closing the valve without affecting the setting. You use the auxiliary valve when attaching a gauge. You may also use it to bypass the main valve when you want to pump out the coil. During normal operation, the auxiliary valve is closed, and when the coils being evacuated, the valve is turned into midposition. The valves men-
tioned above should be installed in a location where frosting will not occur and should be reasonably close to the refrigerator which is to be controlled. These valves may be used on flooded or direct-expansion evaporators, providing defrosting is not required.

21-8. **Snap-action type.** A suction-pressure regulating valve of the snap-action type is not a throttling type and can be set to cut in and out at definite predetermined pressures. This valve is either wide open or closed tightly. You use it when you want to operate an evaporator on a defrosting cycle, and when a shorter operating time than that provided by the condensing unit is required. The effect of using a snap-action valve on an evaporator in a multiple system is the same as if it were connected to a separate compressor. This valve should be used only with a low-side float or with a thermostatic expansion valve. Most valves of this type have a gauge port to which a gauge may be attached to aid the proper setting.

21-9. **Thermostatic type.** A thermostatically controlled suction-pressure valve is shown in figure 37. This valve is used where close, nonelectrical control of single evaporators is desired. Such applications are sweetwater baths, water coolers, beverage coolers, and soda fountains. In multiple installations, you place the valves in the suction line from the warmer evaporator, with the thermal bulb in the refrigerated space or liquid. This valve gives closer temperature control than does the pressure type. The valve illustrated in the figure is of the snap-action type, but the thermostatic type is also available in a valve which has throttling action. Before the refrigerator has reached the desired temperature, the valve is wide open and the coil is subject to refrigeration from the condensing unit. When the desired temperature is reached, the valve snaps shut and the coil is isolated from the rest of the system. If the refrigerator temperature is above freezing, the coil will defrost while the valve is closed. You must install this valve in a horizontal part of the suction line, and place a strainer ahead of it. The bulb should be located where it will reflect the average conditions, and in water baths it should be placed in the liquid but not too close to the coils.

21-10. **Check valves.** When evaporators are connected in multiple and the temperatures are different, the pressure in the warmer evaporator is higher than that in the colder. When the control valve opens, the high-pressure vapor in the
warmer evaporator would back up into the colder evaporator if no means were provided to prevent it. This vapor would cause a warming up of the colder evaporator and would impair its efficiency. To prevent this, you install a check valve which will permit the vapor to flow in only one direction. See figure 39 for the proper location of check valves in a multiple system. Next, let us review some important points before discussing the use of solenoid valves in a multiple system.

21-11. Important Points for Multiple Installations. Because of the large number of possible multiple combinations, it is impossible to give a set of rules and expect them to apply to all cases. Although there are exceptions to the rules, the eight rules explained next should be adhered to whenever applicable.

1. The coldest evaporator or evaporators must comprise more than one-half of the total load on the condensing unit. If the warmer evaporator were the major part of the load, the condensing unit would be operating at the higher suction pressure a greater portion of the running time and would not be able to bring the colder refrigerator down to the desired temperature.

2. The capacity of the condensing unit is selected at the suction temperature or pressure of the colder evaporator. Since the colder evaporator constitutes the major part of the load, the compressor will be operating at its pressure most of the time, although the pressure in the warmer refrigerator will be higher. This is another case where we must remember that the capacity of a compressor is less at lower suction pressures.

3. The evaporator for each refrigerator is selected at the suction pressure which will give the correct temperature and humidity for the particular application. The selection is made just as if each evaporator were to be connected to its own compressor.

4. When the temperature difference between the colder and the warmer fixture is greater than 5°F., a control for the warmer evaporator or evaporators is necessary. This control may be either a suction valve of the pressure or temperature type or a solenoid valve. In some cases, although the temperatures are the same, one refrigerator will be used much more than the other. In instances like this, a control valve should be used and placed in the suction line of the refrigerator with the least usage.

5. A snap-action type of suction-pressure control should be used if defrosting on the off cycle is required. This cannot be done, even though a snap-action valve is used, unless the refrigerator temperature is above 35°F.

6. The coldest evaporator should always be directly connected to the compressor, and a check valve should be located in the suction line between the outlet and the first takeoff. In following the rule that half of the total load should be the cold evaporator, there is sufficient load on the compressor to eliminate low back pressure even though the control devices have isolated all the warmer evaporators.

7. In general, thermostatic expansion valves should be used as the liquid control when direct expansion evaporators are installed in multiple. The control of temperature in any refrigerator should not be by the adjustment of any expansion valve. This should be done by the adjustment of the suction-pressure valve in order to obtain the best operating conditions.

8. The liquid and suction lines should be sized according to the amount of refrigerant flowing and according to the load on each branch or main. These important points place a limitation on the applications in which a multiple installation should be made. When the temperature difference between the warmer and the colder refrigerators is greater than 25°F., multiplexing should be considered the exception rather than the rule unless humidity is not a factor. When high humidities are to be maintained, such as in florist's boxes, it is better to use a compressor for each evaporator.

21-12. Evaporators with forced convection. Although multiple installations can be made with all expansion coils, all low-side float coils, or with a combination of both, you must give extra thought when you want to use forced-convection coolers. A forced-convection unit must be caused to defrost during the OFF cycle unless some means for artificial defrosting is provided. In some multiple installations where the forced-convection unit is the colder evaporator, a sufficiently low suction pressure may occur so that the unit cannot defrost, and it thus become inoperative in a short time. If the forced-convection unit is the colder evaporator, successful multiplexing may be done if suction-control valves are used.

21-13. Low-pressure cutout. Multiple installations, where suction-pressure or temperature-control valves are used, have the colder refrigerator controlled by the low-pressure cutout at the condensing unit. The warmer refrigerator, in this type of arrangement, does not require any electrical control. The low-pressure electrical control is set at the proper cut-in and cut-out points just as if it were operating on a single evaporator. Some of the modern suction-control valves that are used on the warmer evaporators are calibrated so that the temperature setting can be made in advance. If this is not so, you must operate the system until the refrigerators come
down to the desired temperature; you then adjust the control to shut off the evaporator from the compressor at this point. In any event, the final adjustment of the controls is governed by the thermometer readings in the various refrigerators.

21-14. **Solenoid Valves in Multiple Systems.** Solenoid valves are used extensively in a multiple system. They may be placed in either the liquid line or the suction line. Figure 38 shows a multiple hookup using solenoid valves in the liquid line. As may be seen from the diagram, there is a thermostat in each refrigerator, and each thermostat is connected to the solenoid valve that is in the liquid line leading to its refrigerator. The operation of the system is as follows: Assume that all the thermostats call for cooling and that the compressor is operating on all of the evaporators. When one thermostat is satisfied, it opens the circuit and the solenoid valve closes the liquid line to the evaporator. The compressor pumps out the refrigerant from that evaporator and continues to operate on the others. As each thermostat is satisfied, its solenoid valve closes; and finally, when all valves are closed, the compressor is stopped by a low-pressure cut-out.

21-15. There are several important factors that must be considered in connection with multiple systems using solenoid valves. As each solenoid valve closes, its evaporator is pumped out and the refrigerant is returned to the receiver. The receiver, therefore, must be large enough to hold the entire charge in the system. When the compressor is operating on all the evaporators, it is at full load and the suction pressure is high. As one evaporator after the other stops refrigerating, the suction pressure drops progressively lower. This drop in suction pressure has the disadvantage of continually upsetting the balance between the refrigerator temperature and the coil temperature. The result affects the humidity in the box and, in some cases, prevents the defrosting of the coil. A suction-pressure regulating valve placed in the suction line near the compressor will hold the pressure at the desired point in the evaporation although the crankcase pressure will be low when only one evaporator is operating from the compressor. The low-pressure control, which shuts off the compressor after the last solenoid valve closes, must be set lower than the suction pressure when the compressor is operating on only one evaporator. The setting of the cut-in point should be made so that the opening of one solenoid valve will start the compressor.

21-16. Solenoid valves that are used in the suction line from the evaporator should be selected so that the pressure drop through the valve will not be over 2 p.s.i. When a solenoid valve is so used, the refrigerant remains in the

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**Figure 38. Multiple system using solenoid valves.**
coil and does not return to the receiver. If the valve is placed in the suction line, there is danger of accumulated liquid flooding over into the compressor in the event of a leaking float or expansion valve.

21-17. **Installation.** A multiple system is installed like a simple one insofar as the coils and condensing units are concerned. In order to simplify service operations, a manifold is usually placed on the wall near the condensing unit. Three-way valves are sometimes used to allow the refrigerant to pass through the valve unobstructed on the run of the valve, while the branch line from the side outlet may be shut off. Prefabricated manifolds may also be obtained.

21-18. **Evaporators at same temperature.** When the temperatures are the same in all of the refrigerators, there is an expansion valve on each coil. When two coils are located in the same case, it is not good policy to connect coils in series, because the second coil will not maintain its rating. Two coils should not be connected to one expansion valve, regardless of whether they are in series or parallel. There are no pressure-control valves needed when all evaporators are operated at the same temperature. The entire low side of the system is controlled by a low-pressure control located on the base of the compressor unit.

21-19. **Evaporators at different temperatures.** The line diagram in figure 39 shows the connections for three coils at different temperatures. Note the presence of a suction-pressure control valve in each of the warmer coils. The suction line from the coldest evaporator is directly connected to the compressor with a check valve in the line. In this diagram, the -10° evaporator should constitute the major portion of the load. A check valve is also found in the suction line from the 35° evaporator, since this evaporator is colder than 45° and there would be the possibility of the warm vapor backing up and condensing.

22. **Multiple Compressors**

22-1. Compressor units are sometimes connected in parallel to obtain greater flexibility or to use small units on one evaporator where a larger one that will balance properly is not obtainable. The practice of operating compressors in multiple is not new; in fact, it is quite common in ammonia plants and cold storage warehouses. The principle difficulty in interconnecting condensing units is in the oil return to the crankcase. Ammonia does not present any problem in this regard, since oil and ammonia are not miscible. Freon, methyl chloride, and other oil-miscible refrigerants, on the other hand, present a real difficulty when condensing units that use them are

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Figure 39. Multiple systems using evaporative-regulating valves.
interconnected. Multiple installations of condensing units should be avoided and made only when it is not possible to split up the units that each evaporator has its own condensing unit.

22-2. Connections Between Compressors. Compressors that are to be interconnected should be of the same manufacture and preferably of the same size. A good installation is one in which each condensing unit will carry its share of the load and the oil return will be such that the proper level will be maintained. To get this balance of the load, the liquid, suction, and discharge lines are interconnected and it is necessary that oil- and gas-equalizer lines are installed between the crankcases. The compressors should be placed close to each other so that the connecting lines will be as short as possible.

22-3. Balanced refrigerant lines. Lines should be connected as shown in figure 40 so that the elbows and length of pipe from the tee to one compressor are the same as to the other compressor. Thus the frictional resistance between each receiver and the manifold should also be approximately the same. Both suction and discharge lines should be balanced in the same manner as we have just described. Suction lines should be connected so that the oil which is returning through the line will divide between the compressors as evenly as possibly. Suction lines from a manifold to the compressor, if used, should be taken off at the side to facilitate oil return.

22-4. Oil-equalizer line. The crankcase oil-equalizer line may be connected in one of two ways, A or B, as shown in figure 41. The A method is preferable although the B method is more often used because of the location of plugs in the crankcases of some compressors where the equalizer lines may be connected. In the method shown in A, the oil-equalizer connection should be made at the lowest safe oil level. Condensing units should be placed on their foundations so that the oil level in each is in the same horizontal plane. The gas-equalizer connection is made above the maximum oil level. All equalizer lines should be level. The size of the manifold to which the various branches are connected should be at least equal in area to the sum of the branches. Crankcase oil- and gas-equalizer lines should be not less than 3/4-inch ID up to 10 tons capacity and 1-inch ID over 10 tons.

22-5. Control of Multiple Compressors. When condensing units are interconnected for purposes of capacity control, usually you have to provide a means for starting and stopping the compressor according to load demands. The compressors are manually operated only when an operator is in attendance and when load changes can be anticipated beforehand. For liquid or air cooling, if close temperature control is not required,
two temperature controls may be used, one being set a degree or two higher than the other. A more common method is to use pressure controls on the common suction line, set in sequence so that the compressors will start and stop according to changes in suction pressure. When this method is used, thermostats and solenoid valves are almost always installed.

22-6. When a number of compressors are connected together or when an installation consists of a number of single evaporator and condensing-unit installations in one refrigerated space, situations occur in which all compressors will start at the same time. This puts a very heavy load on the electric lines and power system. A timer, which will delay the starting of compressors until after the first one, should be installed. The action of the timer is such that when the contactor for the first compressor has closed, there is a delay of 10 or 15 seconds before the timer closes the control circuit of the second compressor and allows it to start. If there are more than two compressors, a timer may be used on each except the first one.

23. Ultralow Temperature Systems

23-1. The use of ultralow-temperature refrigeration in industrial work has increased tremendously in the past few years. Commercial units are now manufactured to produce temperatures below -100°F for various applications. An example is the production testing of various instruments and appliances, such as radios, cameras, clocks, and meters which may be subject to low temperatures in arctic climates or in outer space. Ultralow temperatures find application in various kinds of metal treatment. The hardness of certain kinds of steels has been materially increased after a conventional hardening process by lowering the temperature to about -110°F, allowing them to warm to room temperature, and then tempering. Another development is the shrink-fitting of parts by using cold instead of heat. The male part is reduced in temperature to -100°F, after which it is fitted to the female part and the unit allowed to warm to room temperature. The extensive use of aluminum riveting in aircraft and other metal work has led to the use of special alloy rivets which may be prevented from age hardening and kept soft by holding them at -40°F to -45°F until ready for use.

23-2. Test chambers which are designed for simulating conditions encountered by military and other aircraft are being used increasingly. They are used for testing instruments, clothing, military weapons, and equipment that is normally carried in an airplane. Weather bureau information shows a temperature of -50°F to -60°F at elevations around 50,000 feet, and cabinets for testing are usually kept between -60°F and -70°F. Some cabinets are equipped so that any temperature from +100°F to -100°F may be obtained.

23-3. Insulation Requirements. Ultralow-temperature cabinets require more consideration in regard to insulation and construction than do zero cabinets. Insulation thicknesses of 10 and 12 inches are needed, and extra care must be taken with vaporproofing to prevent the entrance of moisture. When a refrigerator is intended to maintain a low temperature at all times, it is usually desirable to use an insulating material which has a high thermal capacity such as cork. Any interruption in refrigeration will not be so serious because of the slow warming up of the box. On the other hand, when rapid fluctuations in temperatures are desired, such as in simulated flight, an insulation of low heat capacity should be used. Ferrotherm (a number of thin steel sheets with air spaces) and Santocel (silica aero-gel) are two such insulating materials. Tests at Wentworth Institute using dry ice in a box insulated with nine sheets of Ferrotherm with 36-inch air space between the sheets gave a temperature reduction from +70°F to -70°F in 45 minutes.

23-4. Refrigerant and Compressor Problems. A simple refrigeration cycle is neither suitable nor economical for ultralow-temperature application. In order to obtain heat extraction from a box at a temperature of, say, -70°F, it is quite evident that a coil temperature less than -70°F is necessary. If a 10°F temperature difference were assumed, a design temperature of -80°F for the coil would be used. If Freon 12 were the refrigerant selected, the corresponding absolute pressure and volume would be 2.885 p.s.i.a. and 11.57 cubic feet respectively. This would give a compression ratio of over 30 to 1 with normal condensing temperatures. This is much higher than is possible with a conventional compressor. As a matter of fact, a compressor operating with any such ratio would not discharge vapor but would simply compress and expand the vapor in the cylinder without doing any useful work. The compression ratio for units working under average commercial conditions is approximately 4 to 1. Ratios up to 8 to 1 are considered as being satisfactory for a single compressor. When ratios are above these values, because of extremely low temperatures, you must employ staging in order that there will be less work required per ton of refrigeration.

23-5. Staging. In a simple compression system, the heat that is absorbed at the low level of temperature is rejected at a higher level in one.
step. In a low-temperature application where this is either impossible or impractical, the heat may be "pumped" in two or more steps. This is called staging. Staging may be done by two methods in refrigeration work: (1) by using compound compression in which the vapor is removed from the evaporator by the low-pressure compressor and discharged by it to the high-pressure compressor, which discharges to the condenser in the usual manner; (2) by using an arrangement called cascading which is, in effect, two cycles operating at different heat levels. The low-pressure compressor discharges into a condenser which is the evaporator for the high-pressure cycle. The final heat is rejected to the cooling water as in the simple system. In direct staging the same refrigerant is used throughout, while in the cascade system different refrigerants may be used in the high- and low-pressure stages.

23-6. **Compound Systems.** Although a compound compression system consists essentially of two or more compressors in series, the addition of intercoolers and subcoolers will increase the efficiency and reduce the cost of operation. Of the several arrangements, two of the most common, the direct compound and the cascade systems, are included here.

23-7. **Direct compounding.** Direct compounding with an intercooler is illustrated in figure 42. This is a two-stage compression in which the refrigerant vapor is drawn from the evaporator through the heat exchanger by the first-stage compressor. The discharge from this compressor passes through a water-cooled intercooler, which is located between stages, and from there to the suction of the high-pressure compressor (second stage). The vapor is then liquefied in the condenser and flows through the other side of the heat exchanger to the expansion valve. The use of an intercooler reduces the superheat and the work of compression. The piston displacement of the low-pressure compressor is greater than that of the high-pressure compressor because of the greater volume of the vapor at low pressure. The proper sizing of the high- and low-pressure cylinders is such that the desired capacity will be obtained, and the compression ratios for each compressor will be approximately the same and within reasonable limits. When two individual compressors are used, they should be at the same level, and oil-equalizer lines between them must be provided as shown in the illustration. The intermediate pressure which exists between stages is not controlled and will fluctuate within small limits as the load varies.

23-8. A compound compression system with a liquid subcooler is shown in figure 43. The colder the refrigerant when it enters the expansion valve, the less flash gas will be formed when the refrigerant cools down to the evaporator.

![Figure 42. Direct compounding with an intercooler.](image-url)
Figure 43. Direct compounding with a subcooler.

Figure 43. Direct compounding with a subcooler.

temperature. The purpose of the subcooler is to subcool the refrigerant and thus increase the refrigeration effect. Referring to the diagram, you see that the liquid leaves the condenser, and a portion of it expands in the subcooler coil at the suction pressure of the high-pressure compressor. The remainder, at a much lower temperature, leaves the subcooler and goes to the expansion valve. What actually happens here is that the flash gas generated in the coil of the subcooler need only be compressed in the high-pressure compressor. The vapor has a smaller volume at this intermediate pressure, and for these reasons, a considerable amount of work may be saved. Without the subcooler, the flash vapor would have to be compressed from the evaporator pressure, where the volume is high, through both the first- and second-stage compressors. This arrangement, or one which will attain similar results, is a necessity in ultralow-temperature refrigeration. In place of single compressors, a V-design of a compound compressor is used in smaller size units. This type of compressor requires only one motor and eliminates the problem of oil level equalizing.

23-9. Cascade systems. A cascade system consists of two or three separate simple cycles operating in conjunction with each other at different temperature levels. The connecting point is a heat exchanger between the stages. This interstage heat exchanger is the condenser for the first stage and the evaporator for the second stage. An elementary diagram of a cascade system is shown in figure 44. Beginning with the low-pressure cycle, the vapor from the evaporator is compressed in the first-stage compressor and goes to the interstage heat exchanger, where it gives up its heat to the second-stage evaporator coil. The condensed liquid then flows to the first-stage expansion valve and the evaporator, completing the low-pressure cycle. The vapor which is generated in the coil in the heat exchanger because of the heat it has absorbed is compressed in the second-stage compressor, and the high-pressure vapor is condensed, its heat going to the cooling water. Each stage is an independent simple cycle, and for this reason has some advantages over the compound compressors. There is no problem of oil equalizing, and a different refrigerant may be used in each stage. There is some loss in the cascade system because a temperature difference must exist in the heat exchanger in order that the heat from the first stage will flow into the second stage. At the present time, the use of Freon 22 in the low stage and Freon 12 in the high stage will produce temperatures down to -90°F. 23-10. A two-stage cascade system with a second heat exchanger for subcooling the liquid and with an oil separator in the discharge of the first
stage compressor is shown in figure 45. There are a number of variations of this arrangement as far as the location of the second heat exchanger is concerned. The interstage heat exchanger, however, is always located in the same place—between the two stages.

23-11. Refrigerants for Compound Systems. At the present time, the number of refrigerants that are suitable for ultralow-temperature applications are few. Of the common refrigerants, ammonia, SO2, methyl chloride, and CO2 are not used. Ammonia and methyl chloride have higher specific volumes than either Freon 12 or Freon 22, and SO2 has a freezing point of -98° F., in addition to a high boiling point. Carbon dioxide becomes a solid when it expands to a temperature below -70° F. Freon 12 and especially Freon 22 possess the best characteristics for low-temperature applications. The condensing pressure of Freon 12 at 80° F. is 98.76 p.s.i.a., whereas for Freon 22 it is 159.7 p.s.i.a. Compressors designed for Freon 12 may ordinarily be used with Freon 22, but in the large sizes particularly, compressors designed for Freon 22 should be used. The displacement of the compressor is less for Freon 22 than it is for Freon 12. Therefore a Freon 12 compressor would have a greater capacity when using Freon 22 than when using Freon 12. Under some conditions, then, a larger motor would be required when using Freon 22. In systems under 10 h.p., other parts such as liquid and suction lines would be the same as for Freon 12. Ethane, ethylene, and methane are hydrocarbon refrigerants which are occasionally used in applications where the temperatures are below -100° F. These refrigerants are explosive and are, therefore, unacceptable where there would be a hazard. Freon 13 is a refrigerant which is replacing the hydrocarbons for ultralow temperatures. All of the low-boiling-point refrigerant have high head pressures, and pressure-relief valves must be provide wherever they are used.

23-12. Controls. In an ultralow-temperature system, the flow of refrigerant to the evaporator may be controlled either by an expansion valve or by a float control. Ordinary expansion valves are not suitable because excessive superheating at the bulb location is necessary to operate the valve. A differential-temperature expansion valve designed for ultralow application has two power element operated by thermal bulbs. When an expansion valve is used, a solenoid valve is always placed ahead of it, and the coil is pumped down at the end of the running cycle.

23-13. The high-side float is used quite extensively and is simple and inexpensive. When used with an accumulator, the charge is not too critical, and since the float valve is in the high side of the system, any moisture is less subject to freezing.

![Figure 44. Elementary cascade system.](Copyright 1932. McGraw-Hill Book Company. Used by permission.)
23-14. There are various ways to wire the controls in a compound compression system, depending on the particular application. In a system which consists of one condensing unit and one evaporator, the simplest arrangement is to use a solenoid valve and a low-pressure cutout with a temperature control in the refrigerated space. The temperature control actuates the solenoid valve, and the pressure control operates the compressor. A special cutout must be used since the conventional tools are not satisfactory for vacuums over 20 inches Hg. Design of these control circuits should consider overload protection because of heavy loads and excessive pressures which occur during pulldown. The electrical controls for cascade systems consist fundamentally of a set of controls for each cycle.

23-15. **Lubricating Oil for Low Temperature.** It is very important that the lubricating oil which is to be used for low-temperature applications be an oil from which no wax will separate at or below the lowest expected operating temperature. The Freons as well as other chlorinated refrigerants possess solvent-extraction properties which remove wax from oil. With a refrigerant-oil mixture, there are two conditions which bring about wax separation. These are low temperatures and a high percentage of oil in the mixture. The use of a high-grade oil which has been processed especially for low-temperature refrigeration and the use of oil separators will minimize if not eliminate wax formation.

23-16. An expansion valve or other refrigerant control in which there has been wax formation acts somewhat like one in which moisture has frozen. With wax formation, the valve will "let go" at a temperature lower than 32°F if heated. Also, if the valve is taken apart, the wax may be seen in the orifice or at the outlet. Such conditions would indicate that a poor grade of oil had been used in the system.

**REVIEW EXERCISES**

The following exercises are study aids. Write your answers in pencil in the space provided after each exercise. Use the blank pages to record other notes on the chapter content. Immediately check your answers with the key at the end of the test. Do not submit your answers for grading.

1. How is capacity control obtained in a large system with a variable heat load? (21-1)
2. Give two applications of multiple evaporator systems. (21-2)

3. Name five type of evaporator-regulating valves. (21-4-9)

4. Where are check valves installed in multiple evaporators at different temperatures? (21-10)

5. Why must the coldest evaporator make up more than half of the heat load? (21-11)

6. With multiple evaporators at different temperatures, which evaporator will be controlled by a low-pressure cutout at the compressor? (21-13)

7. How is the size of the receiver affected in a multiple evaporator system with solenoid valves in the liquid line? (21-15)

8. What is the possible danger to the compressor when solenoid valves are used in the suction line? (21-16)

9. What is the main difficulty with compressors connected in parallel? (22-1)

10. What are the installation requirements for satisfactory operation of compressors in parallel? (22-2)

11. What two equalizer lines are necessary for proper lubrication of multiple compressors? (22-4)

12. In the case of multiple compressors, what is done to reduce heavy electrical loads on starting? (22-6)

13. List two applications of an ultralow-temperature system to Air Force problems or testing. (23-2)

14. What is the main requirement of an insulation for an ultralow-temperature chamber which must respond to rapid changes in temperature. (23-3)

15. What are two methods of “staging” to produce ultralow temperatures. (23-5)

16. Describe a direct compound system which has good efficiency. (23-6, 7)

17. Why may two different refrigerants be used in a cascade system? (23-9)

18. Name three refrigerants used for ultralow temperatures. (23-11)
19. Why is an ordinary expansion valve unsatisfactory at ultralow temperatures? (23-12)

20. Why is a special cutout necessary for ultra-low temperatures? (23-14)

21. How is wax prevented from causing trouble in an ultralow-temperature system? (23-15)

22. How can you tell the difference between wax and moisture as the cause for a frozen expansion valve? (23-16)
FROM MARKET TO warehouse and from warehouse to dining hall, refrigerated Air Force trucks transport many tons of perishable foods safely without risk of spoiling. The safe delivery of these foods is dependent on the operation of refrigeration units. Part of your job is proper maintenance of truck-mounted units to insure the delivery of good food to all the troops. This chapter discusses the units for truck refrigeration and car cooling.

24. Refrigeration Unit for Trucks

24-1. Since trucks and semitrailers transport perishable or frozen foods long distance, they require some type of refrigeration. Refrigeration units for trucks and semitrailers are of the same type, design, and size as units used in reach-in and walk-in refrigerators. Specifications will depend on the demand.

24-2. Refrigerator trucks and semitrailers have specially designed bodies adapted for the transportation of material under refrigeration. These bodies are designed with a double wall or shell, with Fiberglas insulation between them. The refrigerator unit is installed where it will give the best circulation of refrigerated air for the demand. The source of power and control operation of the condensing unit and engine will be explained in the following section.

24-3. Types of Units. The refrigeration units used today are called package units. In such a package unit, the refrigeration unit, gasoline engine, starter-generator, and battery are all mounted on one frame as a single self-contained unit. Older type units may, however, have the gasoline engine and the starter-generator mounted on a separate frame with a belt to the compressor.

24-4. There are two types of compressor drives which get their power from the truck's engine: (1) the engine-driven electric generator and motor and (2) the transmission shaft-driven compressor. If either of these types is used, the refrigeration unit stops when the truck engine stops, thus requiring an outside source of refrigeration during layovers.

24-5. On the other hand, the package type gasoline-engine-driven units are automatically controlled to start and stop as the system may require. The space, or opening for the refrigeration unit, is designed for the demand, as are the special bodies. Both the size of the bodies and the type of material to be under refrigeration determine the type, size, and number of refrigeration units to be installed.

24-6. Installation. Refrigeration units for trucks and semitrailers are usually mounted on the front of the bodies, either at the top or bottom. When the unit is mounted other than on the front, the trailer may have a rack or platform designed for the purpose, as well as mounting bolts to secure the unit to the trailer body.

24-7. Power Connections. Power is furnished by a gasoline engine, which is usually of the 2-cylinder, 4-cycle, L-head, air-cooled type. This engine is equipped with a 12-volt, d.c., combination starter-generator, with the armature mounted on the engine crankshaft. The engine is started electrically by the power from two 6-volt storage batteries, connected in series, that are mounted on the front of the truck or trailer body near the refrigerator unit. Most of these engines are governor controlled so that the engine runs at a speed of 2400 r.p.m. This speed will give a maximum horsepower of 9.4. The power is transmitted from the engine to the evaporator blower, the condenser fan, and the compressor by the use of V type belts and pulleys. The compressor is set to run at 1800 r.p.m. when engine speed is 2400 r.p.m.

24-8. Starting Procedures. The starting procedures are the same for most truck refrigeration units. After checking for leaks, valve settings, compressor oil level, engine oil, and fuel level, etc., turn the refrigeration unit thermostat until the pointer indicates the temperature to be maintained within the truck or semitrailer. Then set the heat-cool switch to the cool position. (NOTE: Some units have an electric heating coil mounted
in the evaporator blower which is used in the refrigeration system to cool the trailer. The blower forces air across the heating coil surfaces to raise the temperature in subzero weather. On other units the cooling element of the thermostat is bypassed when the heat-cool switch is on HEAT. The heating element of the thermostat completes the circuit to start the engine and to energize the defrost solenoid valve. When the defrost valve opens, hot refrigerant gas is permitted to flow to the evaporator to provide heat, which will raise the temperature a few degrees above freezing inside the trailer.

24-9. Electrical Circuit Operation. The starter switch is turned to the ON position in order to close the circuit and energize the thermostat, which operates the starter-relay coil. This action setups a magnetic field that attracts the relay contractor bar to complete the circuit to the starter-genera tor. When the relay circuit is opened or broken, the relay coil is deenergized, and the contact bar springs away from the coil and opens the circuit to the starter-generator circuit. This stops the engine. The thermostat bellows expands or contracts with the temperature change at the feeler bulb to automatically open or close the contacts of the switch within the thermostat. In turn, the opening or closing of this switch opens or closes the circuit to the starter-relay coil.

24-10. When the starter-relay closes, it also completes a circuit to the choke-solenoid relay. This relay armature closes the contacts that operate the automatic choke and the defrost solenoid valve. When the engine starts, the current flowing through the choke-solenoid relay reverses direction and decreases in magnitude so that the relay is deenergized. This releases the relay armature and opens the contacts to the automatic choke and the defrost solenoid valve.

24-11. When the automatic choke coil is energized, it attracts an armature lever attached to the carburetor choke valve by a linking rod. When the lever is drawn to the magnetized coil, the carburetor choke valve closes. As the engine starts, a reverse flow of current is set up in the choke-solenoid relay circuit, and the relay contact point break the circuit to the automatic choke.

24-12. The starter-generator has a charging rate resistor placed in the generator field circuit to regulate the generator charging rate, which is controlled by the voltage regulator. As the batteries near a fully charged state, voltage in the field circuit of the voltage regulator rises. At 17 volts, magnetism created by the regulator winding insufficient to pull the armature down. This opens the contacts of the normal control circuit, causing the current to flow through the resistor in the field circuit and forcing the generator to operate at a minimum output.

24-13. The defrost thermostat is energized when the defrost switch is pressed and completes the circuit to the defrost holding relay. This permits an increase in the evaporator coil temperature to 50° F. This temperature increase causes a bimetallic disk in the thermostat to snap to a reverse position. The thermostat switch contacts open and deenergize the defrost holding relay. This last action returns the refrigeration unit to its normal cooling cycle.

24-14. Operational Check. All of the controls which we have been discussing operate automatically, except the starter switch, the heat-cool switch, and the defrost switch. Also, the gasoline gauge registers continually when the starter switch is on.

24-15. Blast Chilling. The technique known as blast chilling saves time, investment, and fuel. In blast chilling, liquid carbon dioxide or nitrogen is injected into mechanically refrigerated trucks, resulting in quick cooling. Paragraphs in this section identified by an asterisk (*) are in part reprinted from January 1964 Refrigeration Service and Contracting by permission of Nickerson and Collins Company.

24-16. Do not confuse this type of cooling with total truck refrigeration by liquid CO₂ throughout the run. We will discuss total liquid CO₂ cooling later in this chapter. Blast chilling is used at maximum cooling demands. Such a demand occurs, for example, after loading has been completed.

24-17. Blast chilling is also an excellent means of auxiliary refrigeration in transit, especially after partial unloading or extended periods of parking (meal times, vehicle servicing, etc.). In addition, it can supplement mechanical cooling if the mechanical refrigerating system should fail.

*24-18. Let us compare blast chilling with mechanical cooling in regard to initial temperature pulldown. Thus, while some tests made by some users and reported in trade publications have shown that blast chilling with liquid CO₂, started at +40° F., drops trailer temperature to -40° F. in 3 minutes, mechanical cooling required 12 hours to cool the same trailer from +40° F. to -10° F.

*24-19. There are two supplemental benefits when blast chilling is used. First, the refrigerants (carbon dioxide and nitrogen) are inert gases, which will not harm most cargoes but will in many cases benefit the cargo by blanketing it against contact with the oxygen and moisture of the air. Secondly, the quick temperature reduction minimizes initial thawing and cuts down or eliminates refreezing. Blast chilling cools the entire
The equipment for blast chilling is very simple. It consists of CO₂ tanks, a liquid control valve, flexible hose, and a nozzle arrangement. A manifold is necessary if a bank of tanks is used.

Safety measures. Adequate vents or openings must be provided to relieve any buildup in pressure and facilitate the complete displacement of warm air with cold CO₂ vapor. During the first half minute or so of blast chilling, we recommend that you leave a door partially open. Special clothing should be worn during blast chilling. This may include gloves, coveralls, face shield, etc. You must be conscious at all times that you are working with liquids at very low temperatures and substantially high pressures. Blast chilling fills the entire cargo space with refrigerant gas, CO₂ or gaseous nitrogen, and, at the same time, decreases the oxygen concentration to a point where the atmosphere is no longer safe for breathing. During this operation, no one may be present in the space. Furthermore, the compartment must be vented before anyone enters it after the operation is completed.

Dry ice versus liquid. The use of liquid CO₂ (dry liquid nitrogen) for blast chilling must be compared to the more conventional use of solid CO₂ (dry ice). One pound of liquid CO₂ does produce less refrigerating effect (B.t.u./lb.) than a pound of dry ice, but several factors make the liquid a more suitable refrigerant for blast chilling. These are: (1) the immediate vaporization of liquid CO₂ can pull the temperature down much faster than dry ice can; (2) the injection of liquid CO₂ can be controlled automatically and at much higher rates than are feasible with dry ice; and (3) liquid CO₂ is easily stored and is ready for use at any time. Also, (4) dry ice requires delivery shortly before it is to be used and cannot be stored for practical purposes for long periods of time. Finally, (5) and (6) liquid CO₂ can be handled more easily and at a lower cost than dry ice can.

Complete Liquid CO₂ Truck Refrigeration. The use of liquid CO₂ for truck refrigeration has been developed recently. Carriers have long desired a refrigeration system that would require less maintenance and fewer breakdowns than is usual with mechanical systems. Tests have shown that a liquid CO₂ system is practical. It has only one moving part, which is the control valve used to turn the system on or off. A pressure reduction valve is also necessary for safe operation of the system. Besides the ducts and nozzles, there are the storage tanks, which present the main drawback of the system. These tanks are very heavy, have a charge which is limited by the size of the tank, and need special equipment for recharging.

For continuous cooling, the control valve would be operated by a thermostat. For blast chilling, the same system would serve by operating the control valve manually to attain the desired cooling. The same precautions and safety rules for blast chilling must also be observed with continuous cooling. Remember, when either liquid carbon dioxide or dry ice is used, the refrigerated area becomes dangerous to life because of the displacement of oxygen.

25. Automotive Air Conditioning

25-1. There are various types of automotive air-conditioning installations. Among these are the dash, trunk, dash-and-roof, and dash- and trunk-mounted units. The basic components in each of these installations remains the same as those for the reach-in and walk-in refrigerator. Paragraphs in this section which are marked by an asterisk (*) are reprinted in whole or in part from the Mark IV Service Manual by courtesy of John E. Mitchell Company, Dallas, Texas. This source is used so that specific information can be given on the latest components and procedures. Let us first consider the refrigerant and oils recommended for Mark IV units.

25-2. Refrigerant. R-12--clean, dry and free from contamination—is the only fluid to be used in Mark IV units. It is nontoxic, noncorrosive, nonflammable, nonexplosive and odorless under ordinary usage. CAUTION: There is one exception to the above: R-12 released in the presence of an open flame will form phosgene gas, a lung irritant. Although it is a safe refrigerant, certain precautions must be observed when handling it or when servicing any unit in which it is used. At normal atmospheric pressure it will, in a liquid state, evaporate so quickly that anything it contacts will freeze.

25-3. Refrigerant Oil. The Yolk or Tecumseh compressor may be used in a Mark IV unit. Either of two types and grades of compressor oil may be used with York compressors: Suniso No. 5 or Texaco "Capella E." The Tecumseh model HA compressor uses a special dual inhibited oil: Suniso 3 G Dual inhibited or Texaco Capella B inhibited. These oils have been highly refined and sealed against moisture contamination.

- DO NOT transfer to any other container for use or storage.
- DO NOT at any time, other than when pouring, allow the oil container to remain uncapped or loosely capped because moisture from the surrounding atmosphere will be absorbed.
It is especially important to use only recommended oils in a compressor during the warranty period. Use of other oils will void the warranty in the event of failure.

*25-4. Safety precautions. The following list of safety precautions is intended for you, the automobile air-conditioner serviceman. Observance of these points may avoid personal injury to you, damage to your equipment and to your customer's car—as well as possible lost manhours.

a. Never remove the automobile radiator pressure cap when the engine is hot.

b. Never close the compressor discharge valve with tie unit in operation.

c. Keep your hands clear of the automobile engine fan and belts when the engine is running. This should also be considered when opening and closing the compressor service valves.

d. Be sure gauge manifold hoses are in good condition. Never let them come in contact with the engine fan or exhaust manifold.

e. Make sure refrigerant hoses are clamped so that they cannot come in contact with any sharp metal or with the exhaust pipe or manifold.

f. Always wear goggles when opening the refrigeration system. Refrigerant liquid or gas can permanently damage the eyes. (See paragraph 25-5 for first aid treatment.)

g. Never apply heat from a torch to a sealed refrigeration system. Refrigerant will expand rapidly with heat and could cause an explosion.

h. Refrigerant 12 in the presence of an open flame produces phosgene gas. This is toxic. Never breathe it.

i. Do not use refrigerants other than R-12.

j. Extreme care should be taken never to use methyl chloride refrigerants, because a chemical reaction between methyl chloride and the aluminum pans of the system will result in the formation of product which burn spontaneously on exposure to air or decompose with violence in the presence of moisture.

k. Be sure all engine capscrews are tight and are of the correct length for their particular application. Pulleys coming off at high speed can cause costly damage to the automobile and possible injury to the occupants.

l. Wear goggles when using a hole saw or portable jig saw. This is cheap insurance for eye protection.

m. Use extreme caution when drilling holes in the automobile. Holes drilled into the electrical wiring or into the gasoline tank can cause fire or explosion.

n. Do not run the automobile engine in an area not well ventilated. Carbon monoxide displaces oxygen.

o. Keep hands away from moving evaporator fans and blower wheels. High-speed motors have enough power to cause painful injury.

p. Use caution when working around exposed evaporator coil fins. Painful lacerations can be inflicted by the fins.

q. Do not run the automobile engine with automatic transmission fluid lines disconnected or costly damage to the transmission may result.

25-5. First Aid. The skin and eyes should also be protected from contact with R-12 liquid or vapor. Since R-12 is readily absorbed by most oils, a small bottle of sterile mineral oil and a small quantity of boric acid should be located near the service stall. Should R-12 contact the eyes, wash them immediately with a few drops of mineral oil, followed by a thorough cleansing with a weak solution of boric acid. See a physician if irritation continues. FOR YOUR OWN PROTECTION, WEAR GOGGLES when opening the refrigeration system.

25-6. Components. As you know, the parts of an auto air conditioner do the same things as the parts in a refrigerator. However, because of location and environment, the installation and operation of some parts are quite different in an auto.

25-7. Condenser. The condenser is mounted ahead of the radiator for the car's engine. For this reason the engine tends to run hot, particularly at low speeds. This may be compensated for by using a larger fan or one with more blades. When air conditioning is added to a car, it may also be necessary to change the standard radiator and install a larger size to keep the engine from overheating.

The addition of an air conditioner imposes these three new factors on the car's operation: (1) the condenser reduces the volume of air to the radiator and the engine compartment, (2) the compressor requires the engine to produce more horsepower while it is engaged, and (3) the heat output from the engine is more for any given speed. The use of ethylene glycol in the car's radiator will help to get rid of heat from the engine faster. Also, the engine cooling system is pressurized to increase cooling. The radiator cap is spring-loaded to retain a certain operating pressure, usually from 4 to 16 pounds, in the system. Failure of the cap to maintain cooling system pressure will result in the engine's overheating.

25-8. Evaporator. Most units are made for mounting under the dash or on the firewall. However, some units have been mounted in the trunk or in back of the rear seat. The disadvantage of the rear mounting is the long runs of tubing required to connect the unit. On the other hand, a
mounting under the dash makes the lines much shorter but fills the center space between the dash and the floor. In any case, copper lines are not satisfactory for automotive work, because vibration over a long period of time will cause copper to harden and become brittle. Consequently, refrigerant lines for an automobile air-conditioning installation are made from high-pressure neoprene hose.

25-9. Receiver, drier, and strainer. On most automobile air-conditioning systems, the receiver, drier, and strainer are combined into one compact unit which is installed in the liquid line. The function of these components is similar to those previously mentioned. A sight glass is the means of observing refrigerant leaving the condenser. Under normal operating conditions, a fully charged system will deliver a solid stream of liquid refrigerant to the liquid line leading to the expansion device. A clear sight glass usually indicates a fully charged system, unless the system is completely discharged. Bubbles in the sight glass are an indication of a partially charged system. Some units also have a moisture indicator in back of the sight glass. The moisture indicator should be blue if moisture is not present in the system. Moisture in the system would cause the blue indicator to turn pink. Do not confuse this type of indicator with those which you may find in large refrigerator systems. (For example, one indicator is green but turns bright yellow with moisture, while others show different color combinations.)

*25-10. Expansion valve. Control of the liquid refrigerant entering the evaporator coil is done by a thermostatic expansion valve. The power element or thermobulb and connecting tube will be charged with either a liquid or gaseous refrigerant, usually of the type used in the air-conditioning system. The power element is connected to the open area above the diaphragm by means of a small capillary tube. The lower side of the diaphragm actuates a ball check valve by means of push rods. Thus movement of the diaphragm provides control of the valve inlet opening. The power element clamped to the evaporator coil outlet responds to the suction as temperature. An increase of this temperature increases the pressure and temperature of the refrigerant in the power element. Conversely, a decrease of suction gas temperature decreases the pressure and temperature of the power element refrigerant. It can be seen from this that increased suction gas temperature causes the expansion valve to open, admitting more refrigerant, while a decrease in suction gas temperature causes the expansion valve to move toward the closed position.

*25-11. RoboTrol valve. The RoboTrol valve replaces the SelecTrol valve which was used in older models of Mark IV units. The RoboTrol valve is, like the SelecTrol, a suction line flow control valve; but, unlike the SelecTrol, its operation is entirely automatic with no provision for manual temperature control. The function of the RoboTrol is to control evaporator pressure and volume flow to the compressor to provide the coldest possible consistent air temperature without allowing condensate to freeze on the evaporator coil fins.

*25-12. Refer to figure 46, which is a cross-sectional view of the RoboTrol revealing its internal construction. Actually the valve is quite simple, operating through a balance between a coil spring (6) and a sealed metal bellows (7) which is subjected to suction line pressure and flow pressure drop at the valve. Increased pressure collapses the bellows against the spring, thus moving the conical valve head away from its seat. Reduced suction line pressure allows the spring to overcome the bellows action, thus pushing the valve head back toward its seat.

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Figure 46. RoboTrol valve.
*25-13. Spring tension is regulated at the factory to close the valve when suction line pressure indicates a temperature in the evaporator coil that would cause freezing of condensate on the fins. An adjusting screw (1) is provided for changing spring tension in the field if specific humidity conditions require a different setting from that made at the factory. Turning the adjusting screw clockwise increases spring tension to provide a higher pressure setting. This may be necessary in areas of extreme humidity where ice can form on the coil rapidly.

*25-14. It should be understood that adjustment of the RoboTrol must not be made unnecessarily. Many miles of highway driving may be required to prove an inadequate valve setting. A low setting will be satisfactory at city driving speeds where ice has little chance of forming but will be very unsatisfactory at road speeds when refrigeration capacity is in surplus. A high setting may rob the unit of efficiency at all speeds.

*25-15. Correct setting of the RoboTrol will maintain about 26 p.s.i.g. in the evaporator coil. Because the valve is connected directly to the compressor and suction-pressure readings are normally taken at the compressor, pressure drop in the suction line must be considered. For normal operation in all areas the valve should be set to close at 17 p.s.i.g. and to open at 19 p.s.i.g. pressure with readings taken upstream from the valve.

*25-16. Other than adjustments described above, no service to the valve can be carried out. A leaking valve must be replaced. When installing a RoboTrol, use the backup flats provided on the inlet side fitting to avoid strain and possible distortion of the outlet connection at the compressor. This distortion will cause icing of the evaporator regardless of the adjusting spring setting.

*25-17. Thermostat controls. Three types of thermostats have been used in Mark IV units, beginning with the Commuter and Sportsman Evaporators in 1961. These units used a bimetal type thermostat responsive to discharge air temperature. The thermostat as applied in the 1962-63 Monitor has a control lever and pin. When replacing this lever-actuated thermostat, move the control lever to the extreme right end of the slot. Position the thermostat so that the lever and pin lightly touch one another. Tighten the mounting screws in this position.

Low temperature cut off is 28° F.

*25-18. Electrical system. All wiring is stranded copper with plastic covering. Most 12-volt units will have No. 16 wire, while No. 12 wire is furnished for 6-volt units. The Sportsman unit uses No. 14 wire for either voltage.

*25-19. Fuses. Prior to the 1962 Monitor, all units provided for a fuse or fuses between the automobile ignition switch accessory terminal and the evaporator switch. Fuse requirements are a 20-amp fuse for 14-volt circuits and a 30-amp fuse for 6-volt circuits. Instead of a conventional fuse, the 1962-65 Monitor has a 15-amp circuit breaker, mounted at the rear of the evaporator. The circuit breaker has a current rating of 15 amps at 20 percent overload for 30 minutes.

*25-20. Motors. Three motor types have been used since 1958 with Mark IV units. While differing in size and number as well as length of shaft extension, all are series wound D.C. Both 6- and 12-volt applications are used. No service to the motors should be required. Bearings are porous bronze with oil saturated wicks and are designed to last the lifetime of the automobile without additional lubrication. Occasionally a motor may chatter audibly, especially on rough roads or when the automobile is driven rapidly around a corner. This can usually be attributed to excessive armature end play. Correct end play, when the motor shaft is moved by hand, should be about 1/64 inch. Additional spacing washers placed on the armature shaft inside the motor will reduce end play. The motor housings must be separated for installation of these washers.

25-21. Magnetic clutch. A magnetic clutch has a field coil which is stationary in one type. Another type has a field coil which rotates, and this type requires brushes and two collector rings to supply electricity to the coil. The rotating field has the possibility of trouble from poor contact between the brushes and rings. The stationary coil is not subject to such trouble and is therefore considered to be more reliable.

*25-22. Operation of the magnetic clutch is very simple. When the current to the clutch is off, the rotor pulley idles free on the clutch bearing. The compressor shaft does not rotate. When current flows to the field of the clutch, the rotor-pulley and armature (attached to the compressor shaft) are "locked" together magnetically. The compressor shaft rotates and refrigeration is provided. Note the following instructions for refrigerant lines which will conclude our discussion of components.

*25-23. Refrigerant lines. Always use grommets wherever rubber refrigerant lines pass through the radiator yoke, firewall, or trunk compartment floor. All holes for refrigerant lines should be cut with a hole saw of the proper size, as indicated by the instruction sheet. Be sure that rubber lines are not against the exhaust manifold or any sharp metal edges and that they are clamped properly in enough places to keep them from sagging under the car. Clamps should be
attached to the car with No. 10 sheet metal screws. Use a 1/8-inch drill for these screws.

25-24. Control of Refrigeration. There are three methods to control the cooling. Some units may be more sophisticated than others, combining two of these methods. Here is a brief discussion of three types of control.

25-25. Thermostat. A thermostat which operates a switch is used on some units. The feeler bulb is located in the airstream next to the evaporator. The switch closes the circuit to the magnetic clutch when cooling is called for. With this type of control the compressor will only operate when cooling is demanded.

25-26. Pressure-operated bypass. This method of control uses a bypass valve which is operated by pressure on the low side of the system. A diaphragm in the valve controls the bypass by responding to changes in pressure on the low side. As the temperature in the car becomes lower, the pressure in the low side reduces, and this reduced pressure on the diaphragm causes it to open the bypass so that refrigerant no longer flows to the evaporator. Operation of the valve is adjusted by a linkage which changes spring pressure on the diaphragm.

25-27. Solenoid-operated bypass. The solenoid valve is controlled by a thermostat set in the airstream from the evaporator. The valve opens the bypass line when the thermostat senses that the temperature in the car is cold enough. When the air becomes warm enough, the thermostat will cause the solenoid valve to close the bypass line, and the unit will again operate to cool the car.

25-28. Servicing and Adjusting. In this area we will present service information which can be applied to most installations. The owner's service manual is required when it is necessary to make exact adjustments. It is not practical to adjust valves without the specification, because you can do more harm than good. Let us begin with the drive pulley.

25-29. Crankshaft drive pulley. The seating and centering surfaces, both on the air-conditioner crankshaft pulley and the original pulley hub, or balancer to which it is to be attached, must be wiped free of all dirt and grit before installation. Any foreign material on these surfaces can prevent the pulley from seating properly, resulting in a wobble which may permanently damage the pulley and balancer or cause the V-belt to fail prematurely. This is especially true with respect to pulleys of the type secured to the crankshaft with only one retaining bolt. Where a key is employed with this type of pulley, make sure the key length is correct to just fill the key-way without causing any pulley wobble. File or mind the key to length if necessary. To check pulleys which appear to be out of line, hold a straightedge against the faces.

25-30. Magnetic clutch removal. In most units you can remove the clutch as follows: Remove the center bolt and washer from the crankshaft. Screw a 5/8-inch NC (National Coarse) capscrew into the threads in the end of the clutch hub and tighten it against the crankshaft until the clutch comes free. Use a centering disc when you reinstall a clutch. If no centering disc is available, check the edge of the clutch against a fixed point on the compressor while the clutch is slowly turned. No runout will be observed when the clutch is properly centered.

25-31. Belts. While exact specifications are given for some belts, you will seldom have the equipment to make exact adjustments. The general rule calls for 1/2-inch belt deflection between pulleys. If a belt shows rapid wear, check the pulleys for dents or scratches in the grooves. A damaged groove will tear up a new belt. If the belt shows signs of the cord separating from the rubber, it indicates the belt has been stretched in attempting to force it over the pulleys. This is the main cause of ruined belts and pulleys. The fan pulley is designed to have at least 3/8-inch clearance between the fan and the radiator. Make a check for the cause if there is much departure from the correct clearance.

25-32. Oil. Occasionally, after having been in service some length of time, some units may show a grayish discoloration of the refrigerant and oil. This can be observed through the sight glass which may become coated on the inside until it is opaque. This condition is caused by moisture contamination and should be rectified immediately. Usually, replacement of the drier is sufficient, but in cases of extreme coating the expansion valve should be removed and cleaned out manually. Then replace the valve along with a new drier. Check the compressor oil for severe discoloration. Drain and refill with clean, dry refrigeration grade of oil if required.

25-33. Expansion valve. Perhaps the most important thing to remember here is to make sure the thermobulb is good tight metal-to-metal contact with the copper suction line. When replacing the expansion valve, sand the bulb and suction tube mating surfaces. Then tighten the bulb clamp securely, To avoid twisting the copper tubing, always use a backup wrench on the valve when loosening or tightening connections.

25-34. Inadequate compressor oil, aside from causing possible damage to the compressor, will result in improper lubrication of the valve needle. Lack of oil at the needle and seat materially affects the liquid seal, resulting in excessive wear.

25-35. Refrigerant lines. All hose assemblies
are manufactured to rigid specifications. Each length of hose is thoroughly cleaned and dried before being cut to length for installation of couplings. When servicing, use clean refrigeration oil on all fittings—nothing else. The use of refrigeration oil on all fittings will aid in making leakproof connections. DO NOT USE SEALANT COMPOUNDS. If these compounds (blue or red in color) are introduced into the system they will clog strainers. The result will be complete failure or lowered efficiency and a voided warranty.

*25-36. Lines must be clamped to prevent their contact with exhaust manifolds, carburetors, linkage, etc. Be sure grommets are installed to protect hoses where they pass through metal partitions.

*25-37. Switches and rheostats. Defective switches should be replaced. Attempted repairs are seldom satisfactory. Intermittent unit operation may be caused by a defective rheostat. Rheostat switches with built-in clutch circuits have, on rare occasions, been known to cause intermittent cooling. This could result from an uneven bedding of the resistor coil in the ceramic switch base. The sliding contact shoe, being moved along the resistor coil as the switch knob is turned, may ride up on a section of the coil that is sufficiently high to lift the shoe almost clear of the clutch circuit ring. The resulting poor contact may cause the clutch to slip or cut out. If a condition of this sort is suspected, check the clutch circuit with a voltmeter while turning the rheostat knob slowly back and forth. If the voltage varies sharply, replace the rheostat switch.

*25-38. Evacuation with a vacuum pump. The following procedure is given for Mark IV units. However, they may be generally applied to most auto air conditioners when it is necessary to remove air or moisture from a system.

a. Remove protective caps from gauge ports of compressor service valves. Connect gauge manifold hoses to appropriate compressor service valves.

b. Schrader gauge line adapters are required for all 1964 compressors.

c. Connect gauge manifold center hose to refrigerant container. OPEN refrigerant container valve. (Use only refrigerant grade R-12.)

d. Crack open high-pressure gauge manifold valve and allow refrigerant vapor to enter system until a pressure of 50 p.s.i.g. is observed on low-pressure gauge. CLOSE high-pressure gauge manifold valve. CLOSE refrigerant container valve and disconnect hose from container.

e. Using a leak detector, thoroughly check all connections, the compressor, evaporator, condenser, and service valve operating stems or Schrader fittings with protective caps in place. Repair any leaks at this time.

f. Connect gauge manifold center hose to vacuum pump. OPEN both gauge manifold valves and start vacuum pump.

g. After vacuum pump has run at least 15 minutes, CLOSE both gauge manifold valves and stop vacuum pump. Low-pressure gauge should indicate at least 28-inch vacuum. High-pressure gauge should read zero (0) p.s.i.g. or below.

h. Disconnect gauge manifold center hose at vacuum pump and connect to refrigerant container. OPEN refrigerant container valve. Loosen gauge manifold center hose at gauge manifold. Refrigerant released will purge air from hose. Tighten center hose connection at gauge manifold.

i. Crack open high-pressure gauge manifold valve and allow refrigerant vapor to enter system until a pressure of 0 to 5 p.s.i.g. is observed on low-pressure gauge. CLOSE high-pressure gauge manifold valve. CLOSE refrigerant container valve and disconnect hose from container.

j. Repeat steps f. and g. This will complete double evacuation procedure necessary for thorough moisture and air removal.

k. Disconnect gauge manifold center hose at vacuum pump.

l. Connect portable charging cylinder filled with R-12 to the center gauge manifold hose. Open charging cylinder valve and purge center hose. Open both gauge manifold hoses and admit 34 ounces of R-12 for the monitor. OR

An alternate method of charging the system involves the use of cans or factory filled drums of refrigerant. Connect the container(s) to the center gauge manifold hose. Purge hose and admit refrigerant until the system is at container pressure. Do not invert the container.

m. CLOSE charging container valve and both manifold valves.

n. Start engine and set idle to approximately 1500 rpm. If shop temperature is 90° or above, place a fan in front of radiator to simulate ram airflow.

o. With temperature control knob or lever turned to maximum cold position, allow unit to operate for 2 minutes with blower(s) on. (Monitor evaporator only must have a jumper wire connector from a 12-volt source to the clutch.) Observe the sight glass located in top of receiver-drier or in expansion valve body. If bubbles appear, OPEN low-pressure gauge manifold valve and container valve. Add charge until bubbles disappear.

p. CLOSE low-pressure gauge manifold valve

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and turn blower(s) off. Bubbles should not appear in sight glass until low-pressure gauge reading reaches 12 p.s.i.g. At low-pressure gauge reading of 8 p.s.i.g., it is normal for bubbles to appear in sight glass. If bubbles do not appear between 12 and 8 p.s.i.g., disconnect gauge manifold center hose from container and purge a small amount of refrigerant from system. After purging refrigerant from system repeat this step until bubbles appear within a low-pressure range of 12 to 8 p.s.i.g.

q. Turn blower(s) on. When low-pressure gauge reading indicates 25 to 30 p.s.i.g., sight glass should not show bubbles. Turn blower(s) off. Observe sight glass; bubbles should not appear at low-pressure gauge reading of 12 p.s.i.g. or above. Make at least two complete cycles of this step. If bubbles appear above 12 p.s.i.g., add refrigerant as described in steps o. and p.

r. Close container valve and disconnect gauge manifold hose from container. Remove clutch jumper wire.

s. Place a thermometer inside of discharge or cold air outlet. Turn blowers on full. Run unit 10 to 15 minutes. Thermometer should read 50° dry bulb or below, with a return air temperature of 80° dry bulb or below.

t. If equipped with conventional service valves, BACKSEAT both valve operating systems and open gauge manifold valve to purge charging hoses. If equipped with Schrader type service valve, slowly loosen charging hoses at valve to purge. Replace all protective caps on compressor service valves.

*25-39. If a unit has lost its charge, follow the above procedure to recharge and BE SURE TO LEAK TEST THOROUGHLY.

**REVIEW EXERCISES**

_The following exercises are study aids. Write your answers in pencil in the space provided after each exercise. Use the blank pages to record other notes on the chapter content. Immediately check your answers with the key at the end of the test. Do not submit your answers for grading._

1. Why do some trucks and semitrailers require refrigeration? (24-1)

2. What are the two prime sources of power which may be used to drive a compressor for a refrigerated truck unit? (24-3, 4)

3. Which source of power (see question 2) has a disadvantage and why? (24-3, 4)

4. What is the relationship between the governed speed of the engine and the speed at which it drives the compressor? (24-7)

5. Explain the two methods of supplying heat to the storage area in very cold weather. (24-8)

6. Is the gasoline-engine-operated refrigeration unit on trucks automatic? Explain. (24-9-13)

7. Explain the use of liquid for blast chilling a trailer. (24-15-20)

8. Are there dangers as well as advantages to blast chilling? Explain. (24-15-21)

9. How does the use of dry ice compare to liquid CO₂ for cooling a trailer? (24-22)

10. What would be the advantages of liquid CO₂ refrigeration of a trailer as compared with those of mechanical refrigeration? (24-23)

11. Why should you use only the manufacturer's specified grade of refrigerant oil in a compressor for an automotive air conditioner? (25-13)
12. Give two conditions which require you to wear goggles when working on an auto air conditioner. (25-4)

13. How can a pressure radiator cap cause an engine to overheat? (25-7)

14. Why are copper lines unsatisfactory in an automobile? (25-8)

15. Where would you look for a sight glass in an auto air conditioner? (25-9)

16. Compare the operation of an expansion valve with the RoboTrol valve. (25-10-12)

17. What are the two means of protecting the electrical system of an automobile air conditioner? (25-19)

18. What two types of fields may be used in a magnetic clutch? (25-21)

19. What should always be installed where refrigerant lines pass through a metal wall? (25-23)

20. How could failure to clean the crankshaft or pulley hub result in wobble of the pulley? (25-29)

21. Describe how a magnetic clutch with a threaded hub can be removed without resorting to a puller. (25-30)

22. What are two causes of belt failure? (25-31)

23. The thermobulb should be checked for what condition if you suspect improper operation of an expansion valve? (25-32)

24. Why must sealant compounds never be used on fittings? (25-35)

25. To insure a clean system, what is the most important operation to perform when you connect lines for charging? (25-38)
CHAPTER 1

1. A modern refrigerator is constructed of two metal shells separated by a layer of insulation. (1-2)

2. The insulation in a refrigerator must reduce heat transfer by convention, conduction, and radiation. (1-3)

3. The greatest heat load is usually from the heat outside the box. (1-4)

4. Improved insulating material has resulted in molded insulation which is very effective and yet takes much less space than older types. (1-5)

5. A moisture or vapor barrier must be used to seal the insulation. (1-6)

6. (1) New synthetic materials can be molded to fit. (2) They have such a low K-factor that only half the space is needed as for some natural products. (3) The synthetics are more resistant to rot. (4) They have no food value to attract rodents. (1-6)

7. Breaker strips are often brittle and may be broken or kinked. Consequently, you should know the proper way to remove each type to prevent damage to it from forcing. Also, carelessness may break the wiring or heaters in the stile or mullion. (1-8,9)

8. The latch of such a refrigerator should be removed so that the door cannot be locked. (1-11)

9. The seal of a door gasket is checked with a sheet of thin paper for uniform drag. (1-12)

10. The refrigerator should not be placed near an oven or heater and should have its own branch circuit, where possible. (1-13)

11. Refrigerators for use overseas will have a special notice (usually posted in a conspicuous place inside the box) stating the voltage and frequency of the current for which each is designed. (1-14)

12. One thermostat senses when ice is made and starts the harvest cycle. The other thermostat senses when the storage tray is full and holds off the harvest cycle. (1-18)

13. Automatic defrosting with an electric heater can be completed so quickly that the melted water would freeze in the drain pipe if a second heater were not used to warm the drain. (1-20)

14. Automatic defrosting with hot gas can be done with a solenoid valve, which allows hot gas from the compressor to pass directly through the evaporator. (1-22)

15. Electricity supplies the heat for some units made in Europe but absorption systems in America are made for LP or natural gas. (2-1)

16. The main distinction regarding fuels is that the burner orifice used with LP gas is smaller, because LP gas has much more heat value. (2-2)

17. The absorption cycle is based on the principle that water has a strong affinity for ammonia. (2-5)

18. Changes in heat load are reflected by a thermostat in the freezer compartment which regulates a valve to vary the size of the flame. (2-5)

19. If the heater should be dislodged from the flame during cleaning, the pushbutton would not reset the poppet. To correct this, move the heater back into the flame, and the reset will hold. (2-5)

20. An absorption system must be kept clean. Dust and soot must be removed periodically from all heat exchangers, and the flame must be properly adjusted for maximum heat and minimum carbon. (2-6)

21. If installation is made so that the unit is not level, the system will not perform properly. (2-7)

22. If the fault is in the ammonia-water cycle, it may be corrected by turning the unit upside down for about an hour. (2-8)

23. Clearances in a compressor may be as little as 0.0001 inch, because it runs in a closed environment (no moisture, no acids) with a relatively narrow temperature variation. (3-3)

24. A piston may approach the head as close as possible without touching. Clearance may be only 0.01 inch at top dead center. (3-4)

25. Compressor valves may get noisy when their maximum lift is greater than 0.10 inch. (3-5)

26. Rotary compressors have fewer moving parts and produce less vibration than piston types. (3-6)

27. To do this, part of a condenser coil may be placed so as to evaporate the water collected from defrosting. (3-9)

28. A restrictor placed between two evaporator sections forces the first coil to operate at a higher pressure and temperature than the second. (3-10)

29. Because a weighted valve is sensitive to its position, any departure from the correct mounting angle will cause improper operation. (3-11)

30. The critical factors in the makeup of a capillary tube are its internal diameter, its length, and the length of the heat exchanger portion. (3-16)

31. A bleeder resistor is connected in parallel with a capacitor to help absorb the discharge of the capacitor when the relay contact open. This arrangement prevents burning of the relay contact. (3-19)

32. A hot wire relay opens the circuit to the starting winding after the motor is started and provides overload protection if the motor draws too much current. (3-19)

33. A current relay is sensitive to current and is designed to release when the current in the relay falls below a certain point. (3-21)

34. You would first check for an open circuit at the bleeder resistor when you have found relay contacts badly burned.
35. Bubbling noise or hissing from a capillary tube is usually an indication of low refrigerant. (3-32)

36. Low voltage will cause a motor to run slow so that a compressor might have to run continuously to cool a refrigerator, resulting in high electric bills. (3-33)

37. A freezer may have frost accumulations scraped off with a wooden paddle or with a stiff fiber brush. However, ice should never be chipped off; it should be melted with warm water. (4-3)

38. For a freezer door to become frosted shut, the electric heater strip would have to be out of operation. (4-4)

39. A mistake made by many servicemen when troubleshooting is to pass over one of the more common faults because it seems too obvious or too easy. (5-3)

40. The advantage of placing the overload protector inside the shell is to extend the off time in case of an overload operation which keeps the unit from short-cycling. (5-5)

41. A thermostat closes its contacts when temperature rises, while a freezeostat opens its contacts when temperature drops below its operating point. (5-6)

42. Checking a motor circuit with direct current is better where there is a capacitor, because alternating current passes through a capacitor easily and may lead to a false conclusion. (5-9)

43. When a test shows that a motor is drawing current equal to its LRA rating, it indicates that the rotor is locked. (5-11)

44. A capacitor may be checked either (1) by charging and discharging it or (2) by measuring the current through it. (5-12)

45. The current relay is current sensitive, and its contact first close and then open in normal operation. (5-15, also 3-21)

46. The potential relay is voltage sensitive, and its contacts are normally closed. The contacts should be open when the motor is running normal. (5-16, also 3-24)

47. Some of the causes of vibration in a refrigerator are loose motor or tubing mounts, failure to remove shipping bolts, and uneven floor or refrigerator feet. (5-17, Table 2)

48. An acetylene cylinder must be secured upright because: (1) It must not be allowed to fall. (2) If the safety plugs blow, they will pass harmlessly into the floor. (3) In any but an upright position, the material in the cylinder may become dislodged and foul the gauges and valves. (6-2)

49. For two reasons: (1) The safety plug is at the top of the cylinder, and if it blows in an upright position the plug will be blown through the roof. (2) The tank will vent itself harmlessly if upright, but if lying flat, it will be jet propelled. (6-2)

50. Soapy water is the correct test for an acetylene leak, since a flame could cause a flareback resulting in a cylinder fire. (6-2)

51. The reason is that even a small amount of oil or grease in contact with pure oxygen can result in spontaneous combustion or an explosion. (6-2)

52. The red hose identifies it. The acetylene valve can only be attached to the red hose because of the left-hand threads of the connection. (6-3)

53. Regulator screws must be released before valves are opened, to avoid damaging the regulators and the gauges. (6-3)

54. The most important factor in making a leakproof solder joint in tubing is to have correct clearance between the parts. (6-5)

55. You should heat the work to flow point of the alloy before applying it to the joint. (6-8)

56. Valves with neoprene seats must have them removed before you begin any soldering; otherwise, the heat will destroy the valve seat, and it will leak. (6-9)

57. Flux changes its appearance with temperature. At 600° F. it may appear puffy, and it will smooth out with a milky color at 800° F., while at 1100° F. it will turn clear. (6-10)

58. In silver brazing, the copper is not heated to as high a temperature as it is in copper welding; thus the copper would not tend to absorb carbon monoxide from a carburizing flame. (6-11)

59. The reason is that the oxidizing flame is used to prevent formation of carbon monoxide which copper would absorb, forming a porous weld. (6-12)

60. Copper conducts heat away faster than steel; thus the welding of copper requires a larger tip for the torch, which will give a larger flame. (6-13)

61. In stainless steel, the cut is covered with a length of welding rod. When heated the welding rod will burn, supplying the added heat necessary to melt out the cut. (6-15)

62. A line tap is expensive and can only be used once. Also, as the gasket hardens, it will start to leak; then the leak will have to be repaired. (7-1)

63. In a contaminated atmosphere a leak detector may be so sensitive that results continue to be erratic even after adjustments have been made for the background. (7-3, 5)

64. If the probe is exposed to a concentration of halogens, the electronic leak detector will be overloaded and may be damaged. (7-5)

65. Small holes in the low side of a refrigerator or freezer can be patched with a cold solder or glue made for refrigeration work. (7-7)

66. Before cold patching a hole, the surface must be absolutely free of oil so that the patch will bond to the metal and make a complete seal. Do not pack the material or force it into the tubing, where it would form an obstruction. (7-7)

67. Flux has a critical temperature. If a high-temperature flux is used with a lower temperature solder, the solder will flow easily long before the flux. In contrast, the right flux will flow at about the same temperature as the solder. (7-8)

68. Cold solders or special glues are limited to systems charged with R-12 and should be used for patching only in the low side. (7-9)

69. A system can be pressurized with dry nitrogen and leak tested with soapy water. If the system is partially charged and then pressurized with nitrogen, a halide leak detector can be used. (7-12)

70. These are that a capillary tube should have the same length and diameter as the one which it re-
places. Also, the length soldered to the suction line should be the same as that of the original heat exchanger. (7-13)

71. Gauge a wire to be sure that it is slightly smaller than the ID of the capillary tube. If it is the correct size, it should slip inside the capillary easily without forcing. (7-14)

72. At any time that a system is opened, the ends should be taped or capped to keep moisture and air out. (7-15, 17)

73. After major replacement, the system should be leak tested, evacuated, dried, charged, and checked for proper operation. (7-16)

74. The leak must be in the low part of the system at or near the compressor, because most of the oil is stored in the compressor. (7-20)

75. If the charging line is not purged, air will be forced into the system when the charging valve is opened. (7-23)

76. When the suction line shows frost extending too far from the evaporator, the system is overcharged, and some refrigerant should be bled from it. (7-24)

77. When frost extends too far on the inlet line to the evaporator (after the capillary has been replace), increase the size of the heat exchanger by soldering more capillary tube to the suction line. (7-24)

78. The refrigeration serviceman must be able to make a leakproof joint quickly and correctly so that moisture and air may be kept at a minimum. The shorter the time that a system is open, the better are your changes of purging air quickly. (7-1–24)

CHAPTER 2

1. The thermostat is set so that a thin coat of ice will form before the compressor is stopped. This ice provides a cushion so that the unit will not operate for each drink which is drawn. The freezeastat insures that the unit will stop before ice gets thick enough to damage the tank if the thermostat fails. (8-2)

2. The waste water from a bubbler fountain is already cold, so it is made to pre-cool the warm water before it enters the cold tank. (8-3)

3. Patching a water tank or line used for drinking purposes requires approved materials only. Certain plastics or synthetics are very poisonous. (8-5)

4. When different bottled beverages are cooled in the same cabinet, the thermostat would have to be set high enough for the one kind most liable to freeze. (9-2)

5. A warm coil could lead you to a wrong conclusion if you mistake an oil cooler for a condenser coil. (9-3)

6. The big difference between ice making machines lies in the evaporator. Examples are the tray, plate, tube, channel, and cell types. (10-1)

7. In an ice cube machine, you may find a tube type evaporator, a cell type evaporator, or a plate type evaporator. (10-4–6)

8. Dissolved salts concentrate in the water that is left from ice making. These salts would make unpalatable ice or could lower the freezing temperature so that the machine would not make ice properly. (10-8)

9. Aside from mechanical troubles, the water supply is the biggest source of trouble, because it produces sediments, scale, and salt crystals, which affect both metals and nonmetals adversely. (10-12)

10. Where multiple evaporators are used, a heat exchanger is necessary to insure that the line will deliver liquid refrigerant to all of the expansion valves. (11-1)

11. A dry type heat exchanger must be correctly sized so that it can cool the liquids sufficiently without producing too much pressure drop in the low side. (11-2)

12. The water pump supplies a high-velocity jet of cold water so that it will absorb CO₂. Water pressure must exceed the CO₂ pressure which charges the tank to 80 pounds. (11-3)

13. If the ground connection is broken at the isolating transformer, the water pump motor would run continuously until stopped by operation of an overload device. (11-4)

14. A simple test is to connect a jumper wire from the tank to the ground side of the isolating transformer. When the ground circuit is completed, the motor should stop if the tank is full. (11-4)

15. The use of aromatic woods, which will spoil the flavor of foods, could do this. This spruce and maple are used inside a cabinet, since they are hard and do not have an obnoxious odor. (12-2)

16. On such models, not only must the system be shut down but also, where forced air is used, the fan must be turned off to prevent the blowing of water all over the cabinet. (12-3)

17. A "double duty" display cabinet is one in which the lower compartments under the display section are also refrigerated. (12-5)

18. The area around the door of a display case may be warmed with a heater strip to prevent the formation of frost. (12-6)

19. The flow of cold air must be continuous across the display section of an open case because it must have a curtain of cold air in order to operate properly. (12-7)

20. Storage cabinet defrosting methods are (1) compressor off-time, (2) hot gas, (3) hot wire, (4) hot water, and (5) secondary solution. (12-8)

21. Compressor off-time defrosting is limited to cabinets operating above 28° F. (12-9)

22. Reverse cycle defrosting is a hot gas method, using a four-way valve so that the evaporator becomes the condenser and the condenser becomes the evaporator. (12-11)

23. A high-temperature control is a safety device to terminate the defrost cycle before the cabinet temperature rises too high. (12-15)

24. The capillary tube from a defrost valve supplies pressure to operate a high-pressure safety control to limit pressure in the system. (12-16)

25. The service valves provide connection points for gauges and charging and permit isolating the compressor from the system. (13-4)

26. The shell-and-tube condenser uses the shell to serve
27. This is done because the receiver must be able to hold all of the refrigerant when the system is pumped down. (13-8)

28. The receiver outlet valve, sometimes called a king valve, is provided with a quill, or inlet tube, which reaches to the bottom of the receiver to insure the picking up of liquid rather than gas. (13-8)

29. Reversing the flow of a drier-strainer might allow particles of the drier to get into the system. (13-9)

30. A good expansion valve should have modulating action, it should not starve the evaporator, and it should not cause flooding. (13-11)

31. The automatic expansion valve works well with a water cooler because the load is uniform in a narrow temperature range and because the valve is not required to modulate. (13-12)

32. The equalizer line is used to compensate for pressure drop across the valve. (13-12)

33. You can identify a thermostatic expansion valve by: (1) the size of the connections, (2) the length of the capillary, (3) the type of charge, (4) the internal or external equalizer, and (5) the capacity in tons. (13-13)

34. Three types of charge used in a thermostatic expansion valve are the liquid, the gas, and the cross charge. (13-13)

35. The cross charge is a refrigerant different from that used in the system so that the cross charge temperature-pressure curve will cross the curve of the refrigerant used in the system. (13-13)

36. The liquid-charged bulb will always have some liquid left in the bulb; thus it will continue to hold control even when the valve is colder than the bulb. Its drawbacks are the possibility of flooding and/or of hunting. (13-13)

37. The gas charge is smaller than the liquid charge; therefore the maximum operating pressure of the valve can be determined by fixing the amount of the charge. Its disadvantage is that control is lost if the diaphragm is colder than the bulb, since gas will condense away from the bulb. (13-13)

38. The advantages of a high-side float valve are that the capacity of the valve is not subject to change from flashing and all of the refrigerant enters the evaporator as a liquid, so there is no lost cooling. (13-14)

39. A layer of oil on top of the refrigerant may cause the refrigerant to refuse to boil unless it is agitated or unless an ebullient is used. (13-15)

40. Before making tests on a "line" circuit, you should remove rings and metal watchbands, because safety records show many severe burns from metal jewelry which has caused a short circuit. (14-2)

41. When a circuit breaker is reset, you should determine what caused the trip to operate, as you can often find and correct a minor defect before it becomes a major problem. (14-4)

42. A compressor motor which draws full LRA may be good if it starts normally with belt tension released. The indication is that there is a locked compressor. (14-5, 6 also 5-11)

43. Trying repeatedly to start a motor with a locked rotor can cause more damage because of excessive current in the circuit. (14-6, 8)

44. Causes of abnormally high head pressures are restrictions caused by pinch, air, a clogged screen, a frozen expansion valve, a partly closed valve, or a thin head gasket. (14-9)

45. When a compressor continuously runs but does not cool, check for high suction pressure, which would indicate a low-side restriction; or check for bubbles in the sightglass, which would indicate a low charge. (14-10, 11)

46. If the capillary in a thermostat had lost its charge, the bellows could not expand. Since warming of the charge expands the bellows to make the compressor run, the unit would remain idle. (14-11)

47. A quick check for ice blocking a refrigerant control is to warm the control and watch to see whether or not the pressure gauges return to normal readings. (14-12)

48. When a valve is supposed to be shut and it continues to leak refrigerant, it indicates that the needle and seat are worn. (14-13)

49. When you make adjustments or repairs on a float valve, be sure to restore its operating point to the original level of the fluid. (14-14)

50. Equipment which can be isolated from the system by valves must have been purged by bleeding off pressure before it is removed from the system. (15-2)

51. The ratchet stop in a micrometer makes it possible to exert the correct driving force on the spindle when a measurement is made. (15-5)

52. In figure 18, the top illustration will read 0.012 inch less if the thimble is moved 12 divisions in the direction of the arrow. Thus, the reading would be 0.292 inch. (16-5)

53. You can check the proper mating of an extension rod with an inside micrometer by measuring it with an outside micrometer. (16-5)

54. The best tool for checking a crankshaft to see whether or not it is true is a dial micrometer. (16-5)

55. Loss of oil pressure may be from (1) a low oil supply, (2) worn bearings, (3) a defective oil pump, (4) a defective oil pressure regulator, or (5) oil diluted with refrigerant. (16-6, 18)

56. When installing a new oil seal, be sure to clean all grease and preservative from the seal, apply refrigerant oil to the seal, and carefully inspect all seal surfaces for scratches which would cause a leak. (16-8–10)

57. To check a new seal for a leak, operate the compressor with the suction line closed till the vacuum gauge levels off. Then close the compressor discharge line and watch the high-pressure gauge for a rapid rise, which would indicated that air is being drawn into the compressor. (16-11)

58. Check the depth of the valve seat for too much wear, and check the valve to see that it is not worn too thin. (16-12)

59. Check for a slight burr or feather edge on one side of a spring steel valve. The burr could damage the sea; therefore the valve is installed with the
burr side up. A heavy burr should be removed, as it could produce metal particles in the system. (16-13)

60. In a refrigeration compressor, the compressor ring usually has a taper which slopes to the top of the ring (marked “TOP”). The top side must be installed facing the head. Oil rings which do not have a taper may be installed with either side up. (16-15)

61. Two indications of upside-down compression rings would be low oil in the sight glass and noisy compressor operation – knocking because of pumping oil. (16-15)

62. Ring gap can be checked with a feeler gauge after the ring has been inserted into the cylinder about 3/8 inch below the top. (16-15)

63. When a new set of rings is installed in an old cylinder, the glaze must be broken from the cylinder wall so that the rings will wear in quickly. (16-15)

64. When a compressor has worn to the point of requiring new bearing inserts, other moving parts must also be inspected for signs of wear beyond specified limits. (16-16)

65. System cleaning is required on a new installation before it is placed in service as well as on a system which has suffered a hermetic motor burnout. (16-19)

66. While cleaning a system after a hermetic motor burnout, avoid contact with the sludge, as it may contain acid. Also avoid bleeding contaminated refrigerant into the air, as the acid may be strong enough to burn your eyes. (17-2,7)

67. System cleaning is done by evacuating from the high side. The reason for doing this is to reverse-flush the system. (17-3)

68. After a system is cleaned, the drier will have absorbed considerable moisture, and the installation of a new drier will insure a dry system. (17-3)

69. When cleaning a system use refrigerant to break the vacuum in order to keep air and moisture from enter the system. (17-3)

70. Activated alumina may be used as a drier only on the suction side of a system charged with SO2 (18-5)

71. Anhydrous calcium sulfate must not be used as a drier in a system charged with SO2. (18-7)

72. Before installing a drier, it should be opened and baked at 300º F. for 24 hours to insure dryness. (18-9)

73. A vacuum of about 1-inch mercury is required to boil water at 80º F. (18-11)

74. A vacuum pump requires that the oil be changed to get rid of the moisture which accumulates in the oil during service. (18-15)

Chapter 3

1. The coldest rooms are located in the center of a refrigerated warehouse surrounded by warmer areas which act as a buffer and make it easier to maintain zero temperatures in freezer rooms. (19-2)

2. During normal work, the floors in meat processing and storage rooms become very slipper. Also, where large quantities of potatoes are stored, you must have positive ventilation, as accumulations of CO2 can cause asphyxiation. (19-4, 5, 8)

3. If potatoes in storage are piled too high – more than 6 feet – heat will accumulate in the center of the pile, and they will spoil rapidly. (19-8)

4. Using modern methods of construction provides a cold storage room with a continuous vapor barrier to keep out moisture; also, a room which can move independent of the building. (19-10)

5. In the construction of a modern refrigerated warehouse, the vapor barrier must be attached only to the cold room walls, because they can move. (19-14, 15)

6. A blueprint can be studied to learn the meaning of symbols and give one a mental picture of the layout of equipment. For example, a blueprint will show changes and additions to the plant. Also, a blueprint will often help you find the location of equipment. Finally, you should use a blueprint to record modifications to the plant as they are made. (19-21, 22)

7. Blueprint details are enlargements of small parts of a drawing to show fine points which would be lost in a small-scale diagram. (19-21, 22)

8. When four or more compressors are installed, the plant can be split into two systems, with two compressors for high temperature and two for low temperature. Either system can continue operation at reduced capacity, even if one compressor fails. (19-24)

9. The determining factor for setting the operating points of a pressure control in the suction side is temperature. Adjustment is made so that the control cuts in when the evaporator coil is at its desired operating temperature and cuts out when coil temperature has dropped 10º F. While it is essentially a pressure control, its adjustment is most satisfactory when made according to temperature. (19-24)

10. True. Evaporator coil temperature is more reliable because our concern is to keep a room within temperature limits. Suction pressure is more susceptible to variations which occur during the operation of the system. (19-24)

11. In cold weather when compressor discharge pressure drops, you can build up pressure in the system by (1) throttling the king valve and (2) reducing the capacity of the condenser. (19-24, 25)

12. In checking for voltage at a three-phase magnetic switch, check the upper terminals from A to B, B to C, and A to C. (19-24)

13. Dashpot oil is used in time-delay relays. Use of other oils in a dashpot would result in erratic operation with changes in temperature. (19-24)

14. On the installation or replacement of a motor, you should test it for correct rotation and line up the pulleys. (19-24)

15. When working on or around V-belts, you should plan on replacing them soon, as oil causes the belt material to rot. (19-24)

16. If oil cannot be cleaned off a set of V-belts, you should plan on replacing them soon, as oil causes the belt material to rot. (19-24)
17. When one belt shows a flutter more pronounced than that of the other belts in a set, the condition indicates that the one belt has stretched in service, and the belt tension should be readjusted before the vibration gets too severe. (19-24)

18. A gradual drop in head pressure over a few hours would accompany a drop in ambient temperature. Over a few days, a continual drop would indicate trouble. To contrast, a sudden drop in pressure usually indicates trouble. (19-24)

19. The purpose of a recording chart is to provide a continuous record of plant operating conditions. (19-24)

20. The purpose of bleed-of water is to get rid of some of the water in which salts are concentrating. (19-25)

21. When makeup water is controlled automatically by a float valve, the rate of bleed-off water will determine the amount of makeup water added. (19-25)

22. In cold weather operation, the best method of capacity control of an evaporative condenser is by means of modulating dampers in the air inlet. (19-25)

23. The disadvantages in operating a cooling tower are (1) scale formation, (2) algae growth, and (3) that it must be protected from freezing in cold weather. (19-25)

24. When making a walk-through inspection of a freezer room, make these checks: (1) Look for unusual sines of frost on expansion valves and extension of frost on the lines. (2) Check to see that fans are operating. (3) Note any unusual noise, vibration, or odor. (19-27-29)

25. A hot gas defrost system may be operated to drive out oil which has accumulated in an evaporator by operating the defrost for a longer period. (19-30)

26. In an ice plant, an agitator is used to keep the brine moving to insure transfer of heat from the ice cans to the evaporator coil. (20-3)

27. Water jackets are used to cool the head of an ammonia compressor because of the high operating temperature of around 250° F. (20-3, 17)

28. Three factors in making a good grade of ice are (1) a brine at 15° F., (2) agitation of the ice water during freezing, and (3) removal of the core water and replacing it with fresh water at the proper time. (20-5)

29. A core sucker is necessary to remove the core water that contains a large concentration of salts which, if left, would take much longer to freeze and would make ice with a disagreeable taste and odor. (20-5, 10)

30. While the brine temperature is 15° F., it must circulate around the evaporator coils which are at 5° F.; consequently, the solution is adjusted low enough to keep it from forming ice around the evaporator. (20-15, 16)

31. Inhibited acid should be prepared in a crock or wooden barrel. Goggles, rubber gloves, and apron must be worn. Inhibitor powder is first dissolved in water at the rate of 3 2/3 ounces of powder for each 10 gallons of water. Muratic acid is added slowly at the rate of 11 quarts of acid to each 10 gallons of water. Use commercial grade acid of 1.190 specific gravity. (20-19)

32. Baking soda should be at hand for instant use to neutralize an acid burn of the skin. It can also be used to check the strength of the acid solution during the cleaning process. (20-19, 20)

CHAPTER 4

1. Capacity control for a variable heat load is obtained by using multiple compressors. (21-1)

2. Two applications are multiple evaporators operated at the same temperature and multiple evaporators at different temperatures. (21-2)

3. Types of evaporator-regulating valves are: (1) bellows, (2) diaphragm, (3) two-temperature, (4) snap-action, and (5) thermostatic. (21-4-9)

4. With multiple evaporators at different temperatures, check valves are installed in the suction line of each of the colder evaporators. (21-10)

5. The coldest evaporator must make up more than half of the heat load or it will not pull down to the desired temperature. (21-11)

6. Since the coldest evaporator has the lowest suction pressure, it will be controlled by the low-pressure cutout. (21-13)

7. When the solenoid valves are closed the evaporators are pumped down, so the receiver must be large enough to hold the total system charge. (21-15)

8. A solenoid valve in the suction line may allow liquid refrigerant to accumulate and flood into the compressor, causing damage when the valve opens. (21-16)

9. The main difficulty with compressors in parallel is insuring equal division of the oil. (22-1)

10. For good operation in parallel, compressors should be the same make and size and all interconnecting lines should be balanced. (22-2)

11. Oil equalizer and gas-equalizer lines must be connected between crankcases of multiple compressors to insure lubrication. (22-4)

12. With multiple compressors, a time delay allows a 10- or 15-second interval between the starting of the first compressor and the second. (22-6)

13. An ultralow-temperature chamber is used to test aircraft and weapons. (23-2)

14. A test chamber which makes rapid changes to ultralow temperatures must have an insulation such as Ferrotherm, which has a low heat capacity. (23-3)

15. Two methods of staging are compound compression and compressors in cascade. (23-5)

16. A direct compound system has two compressors in series with an intercooler between, for better efficiency. (23-6, 7)

17. Since there are two separate systems in a cascade system, two refrigerant having different temperature ranges may be used. (23-9)

18. Three refrigerants for ultralow temperatures are R-12, R-13, and R-22. (23-11)
19. At ultralow temperatures, an ordinary expansion valve requires excessive superheating at the bulb location to operate the valve. (23-12)

20. Ultralow temperature requires a special cutout because a conventional model is not satisfactory for a vacuum over 20 inches Hg. (23-14)

21. To avoid problems from wax in an ultralow-temperature system, a high grade oil and oil separator are used. (23-15)

22. Warm the frozen valve carefully and if it is released at a temperature colder than 32° F., the difficulty is the result of wax formation. (23-16)

CHAPTER 5

1. Trucks which must transport perishable foods require refrigeration to prevent spoilage. (24-1)

2. The primary source of power may be either a small gasoline engine or the main engine which powers the truck. (24-3, 4)

3. Using the main engine as the primary power source is less advantageous, since the compressor stops when the truck engine is stopped. (24-3, 4)

4. When engine speed is governed for 2400 r.p.m., the compressor is driven at 1800 r.p.m. (24-7)

5. Heat may be furnished by a blower and an electric heating coil, or it may be supplied from operating the unit, with the defrost valve open so that hot gas flows through the evaporator. (24-8)

6. Yes. All of the controls operate automatically, except the starter switch, the heat-cool switch, and the defrost switch. (24-9-13)

7. Liquid CO2 is released into a trailer as a fog, which removes cargo heat very quickly. (24-15-20)

8. Yes. While blast chilling can cool a trailer in a few minutes, the atmosphere will have too little oxygen for breathing, and protective clothing should be worn to protect against frost burns. (24-15-21)

9. The liquid CO2 vaporizes faster than dry ice, so it will cool a given area in less time than the water. Also, the liquid can be controlled easily by a valve. Finally, the liquid is stored in tanks for use at any time, while it is impractical to store dry ice for an extended period of time. (24-22)

10. The liquid CO2 refrigeration of a trailer is more reliable because it has a minimum of moving parts and reduces temperature faster. (24-23)

11. The manufacturer's warranty may be void if a compressor fails while operating with an unrecommendable oil. (25-3)

12. You should wear goggles when opening the refrigeration system and when using a hole saw or portable jig saw. (25-4)

13. Failure of the radiator cap to maintain pressure can cause an engine to overheat. (25-7)

14. Vibration causes copper to harden and become brittle. (25-8)

15. You would look for a sight glass in the receiver-drier-strainer, located in the liquid line. (25-9)

16. An expansion valve operates by means of a thermo-bulb to control liquid refrigerant to the evaporator. A RoboTrol valve operates by means of suction line pressure to control evaporator pressure and volume flow to the compressor. (25-10-12)

17. Either fuses or a circuit breaker may protect the electrical system. (25-19)

18. A magnetic clutch may use a stationary field coil or a rotating field coil with brushes and collector ring. (25-21)

19. Always install grommets on a line where it passes through a metal wall. (25-23)

20. Failure to clean dirt from the shaft or hub may prevent proper mating causing a pulley to wobble. (25-29)

21. A magnetic clutch can be removed without a puller if its hub is threaded. Screw a 3/8-inch NC capscrew into the bulb and tighten it against the crankshaft until the clutch comes free. (25-30)

22. Two causes of belt failure are damaged pulley grooves and separation of belt material because of being stretched too tight. (25-31)

23. When you suspect improper operation of an expansion valve, check the thermobulb to see that it is securely clamped and makes metal-to-metal contact with the suction line. (25-32)

24. Never use sealant compounds on fittings as the sealant may clog the strainer and void the warranty on the unit. (25-35)

25. When connecting lines to charge a system, always purge the lines with refrigerant before you tighten the fittings. (25-38)