

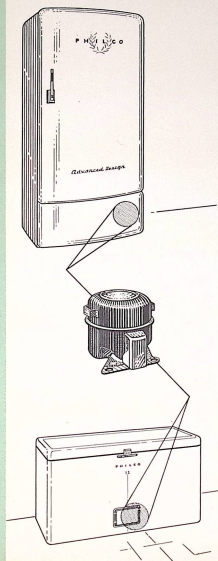
PHILCO

PHILCO
Factory-Supervised
Service

SERVICE

REFRIGERATION

HOME STUDY



SEALED REFRIGERATING SYSTEMS

- Principles
- Types of Systems
- System Components
- Testing Methods

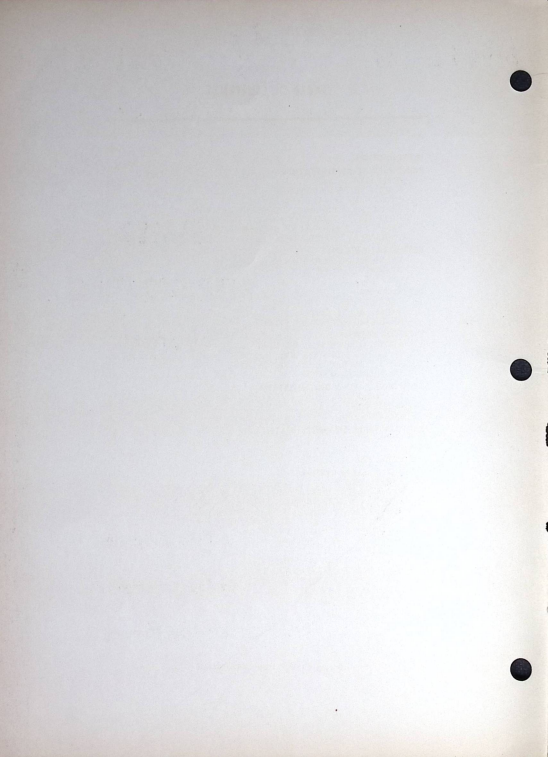


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INTRODUCTION

A Philco factory-supervised serviceman is measured by his accomplishments so it is most important for him to know all about his job. In refrigeration, this includes a knowledge of the behavior of the system and its parts, the ability to recognize and properly diagnose the symptoms of both ordinary and unusual troubles. An understanding of the underlying principles of refrigeration and the functions of the individual parts aids materially in solving unusual problems that might otherwise be baffling.

The skill acquired by experience is all that is necessary to do a routine service job, but to break a tough one, both skill and a sound knowledge of operating principles are required. A command of such knowledge builds confidence and produces an ability to obtain the right answers to unusual problems. This confidence is reflected in the serviceman's conversation and dealings with both customer and employer. Advancement occurs more readily when the skilled serviceman is also equipped with a complete understanding of the operating principles of his job.

This home study booklet was prepared with the above ideas in mind. No attempt has been made to cover the subject on an engineering level. The subjects are presented in a manner felt to be most useful to the serviceman in the analysis of refrigeration problems.

HEAT-REJECTING SYSTEM

PRINCIPLES OF REFRIGERATION

The refrigeration cycle is a thermodynamic cycle that transfers heat from a space or object being cooled to a space or object being cooled. The cycle consists of four main components: a compressor, a condenser, an expansion valve, and an evaporator. The compressor compresses the refrigerant, raising its pressure and temperature. The condenser then rejects the heat from the refrigerant to the surrounding space, causing it to condense into a liquid. The expansion valve then expands the liquid, lowering its pressure and temperature. Finally, the evaporator absorbs heat from the space being cooled, causing the refrigerant to evaporate and return to the compressor.

The refrigeration cycle is a continuous process that repeats itself over and over again. The cycle is driven by the compressor, which is powered by an external source of energy. The condenser is typically located outside the space being cooled, while the evaporator is located inside the space. The expansion valve is located between the condenser and the evaporator. The refrigerant is a substance that can absorb and release heat without changing its chemical composition. Common refrigerants include Freon, R-134a, and ammonia.

The refrigeration cycle is used in a wide variety of applications, including air conditioning, refrigeration, and heat pumps. In air conditioning, the cycle is used to cool and dehumidify the air in a room. In refrigeration, the cycle is used to keep food and other perishable items cold. In heat pumps, the cycle is used to transfer heat from a cold space to a warm space, providing a more efficient way to heat a building.

The refrigeration cycle is a complex system that involves many different components and processes. Understanding the principles of refrigeration is essential for anyone who wants to work in the field of HVAC or related industries.

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SEALED REFRIGERATING SYSTEMS

PRINCIPLES OF REFRIGERATION

Refrigerating systems of any kind make it possible to lower the temperature of substances and to maintain these refrigerated substances at the lower temperature. This is accomplished by preventing the entrance of additional heat by the use of an insulated cabinet and by removing some of the heat from the substances. Since there is no perfect heat insulator, some heat continually leaks back into the refrigerator cabinet as shown in figure 1. Three temperature conditions are represented in this illustration.

A. The inside and outside temperatures are both 75° ; no heat transfer can occur under these conditions.

B. The box temperature is 55° and the outside temperature is 75° ; a considerable amount of heat will pass through the insulation.

C. The box temperature is 35° and the outside temperature is 75° ; much more heat will enter the box.

The arrows represent the relative amount of inward heat leakage. Since heat is continually leaking in under conditions such as B and C above, it is necessary to pump it out at intervals to maintain a lower temperature within the cabinet.

HEAT FLOW

Heat flows naturally from places or substances having higher temperatures to places or substances having lower temperatures. Examples of heat flow are given below:

In cold weather the outer doors of a house are closed and storm windows are installed not to keep the cold out, but to keep the furnace heat inside the house. Clothes made of heavy material are worn in the winter time not to keep the cold out, but to prevent the body from losing its heat to the cold, outside air. If the outside air is colder than the body, the best method of preventing heat loss is to insulate against outward leakage of heat by wearing heavy clothing.

In hot, summer weather, reverse conditions exist. Light-weight clothing with very little heat insulating qualities is worn so that the body heat may be released. If the outside temperature rises higher than the body temperature, the heat flow is reversed and some other method of cooling is necessary. As the outside temperature rises, perspiration increases and it is the evaporation of this moisture that helps to cool the body. Try this experiment to illustrate this point. Hold your hand in the draft from an electric fan. Then wet your hand and repeat the experiment. While the water is evaporating your hand feels cooler. You have just experienced the basic principle of refrigeration, namely, cooling by evaporation.

In the study of refrigeration and refrigerating systems, a form of energy called heat is the primary consideration. The interior of the refrigerator cabinet becomes cold because heat is removed from the cabinet. Cold is the absence of heat, just as dryness is the absence of moisture, and darkness is the absence of light. If a light is turned off in a room, the

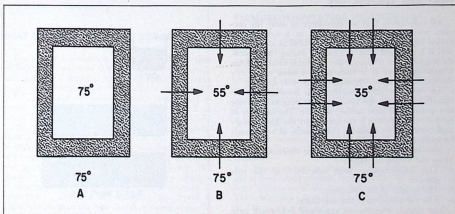
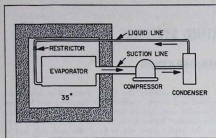


Figure 1. Heat Leakage Through Insulation

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Figure 2. Elementary Refrigeration System

room becomes dark; if moisture is removed from a substance, the substance becomes dry, and if heat is removed from a substance, the substance becomes cold. While we naturally associate the word "cold" with refrigeration, in reality it is not a question of how hot or how cold a substance is, but whether the substance contains more or less heat.

It is apparent from the discussion that, if the interior of a cabinet is to be maintained at a considerably lower temperature than the surrounding air, some method of removing heat must be applied. In other words, heat must be made to travel in a direction opposite to its natural flow. Compare this with the way water acts; it flows downhill naturally, but must be pumped uphill. In the same manner, heat flows into the cold refrigerator cabinet, but it must be pumped out with some type of refrigeration machine. Figure 2, a diagram of an elementary refrigeration system, shows how the heat may be pumped out of an insulated cabinet.

HEAT AND TEMPERATURE

All substances that we encounter in daily life contain heat; the intensity of heat in a substance is called its temperature. If heat is added to a substance and if it does not melt or vaporize during the process, its temperature will increase. If heat is removed from a substance and if it does not condense or solidify during this process, its temperature will decrease.

An ordinary thermometer scale measures the intensity of heat in the room air, but does not measure the quantity of heat in the room air. The intensity of heat or temperature is recognized by the human body and can readily be sensed; the quantity of heat cannot be estimated by the body.

The quantity of heat a substance contains depends upon the following factors:

1. The temperature (heat intensity) of the substance.
2. The weight of the substance.
3. The composition of the substance.

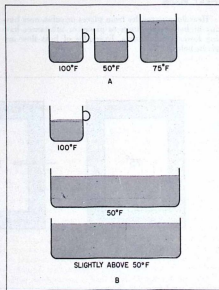
The simple experiment explained below will help to clarify the difference between temperature and heat quantity.

A pint of water at a temperature of 100°F. and a

second pint of water at a temperature of 50°F. are combined, and the temperature of the resulting quart of water is taken. Assuming that no heat is lost by radiation, etc., the observed temperature is 75°F. Part A of figure 3 illustrates the point.

Next, if a pint of water at 100°F. is poured into a bathtub of water (part B of figure 3) at a temperature of 50°F., the resulting temperature rise may not even be noticeable. In both instances, the same amount of heat (one pint of water at 100°F.) was added to a quantity of water having a temperature of 50°F. In the first case, the hand could have sensed the warming effect of the first pint of water; in the case of the bathtub of water, the hand could not have detected whether the pint at 100°F. had been added or not. The conclusion is that a given amount of heat added to different quantities of a substance does not produce the same rise in temperature, for as explained above, the heat a substance contains depends not only on its temperature, but also on its weight and composition. From this experiment, it is evident that the quantity of heat a body contains is not a measure of its temperature.

If the removal of heat from a substance is continued, the substance becomes colder and its temperature continues to drop. If the process of heat removal is carried on long enough, a point will be reached when the substance will contain no heat and its temperature will read 460° below zero on the Fahrenheit scale. This temperature is called "absolute zero," and is a true base for temperature measurements. At all higher temperatures, there is always some heat energy in all substances. Obviously, absolute zero is not a



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Figure 3. Temperature-Heat Quantity Relationship

practical base from which to measure temperature, so arbitrary points, such as the temperature of melting ice and boiling water, are used to establish reference points on the thermometer scale.

MEASUREMENT OF HEAT

A definite quantity of heat can be measured just as a gallon of water or a bushel of potatoes can be measured. The unit that measures the quantity of heat is the British thermal unit (B.T.U.), and one B.T.U. is the amount of heat required to raise one pound (about one pint) of water 1°F .

Since one B.T.U. is required to raise the temperature of one pound of water 1°F ., it follows that ten B.T.U. will be required to raise one pound of water 10°F ., or ten pounds of water 1°F .. Conversely, the same amount of heat removal is required to reduce the temperature of one pound of water 10°F ., or of ten pounds of water 1°F ..

EFFECT OF PRESSURE ON THE BOILING POINT

The effect of pressure is seen in the reduced boiling temperature of water at high altitudes. Because of the reduced atmospheric pressure at high altitudes, water will boil at temperatures considerably below 212°F .. On the other hand, water boils at a temperature well above 212°F ., in the pressure cooker, which is so widely used today.

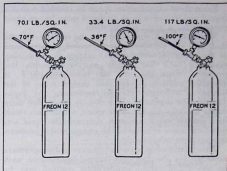
In every case, an increase in pressure on the surface of a liquid raises the boiling point temperature, and a decrease in pressure lowers the boiling point temperature. It follows that a given liquid can be made to boil at any temperature within its range by increasing or decreasing the pressure on its surface.

Liquids used as refrigerants usually have a low boiling point. Under the pressure conditions that are maintained in the evaporator, the liquid refrigerant is made to boil at a lower temperature than that desired in the refrigerator.

HEAT OF VAPORIZATION AND CONDENSATION

The heat of vaporization of a liquid is the number of British thermal units that must be added to change one pound of a liquid at its boiling point into vapor at the same temperature. For example, it takes 970 B.T.U. to change one pound of water from liquid to vapor at atmospheric pressure; for one pound of liquid Freon-12, it requires approximately 69 B.T.U. to change to Freon vapor at atmospheric pressure. Heat of condensation of a vapor is the number of British thermal units that must be removed to change one pound of vapor at its condensing temperature to one pound of liquid at the same temperature. The quantity of heat required for either of these changes is approximately the same, although the amount of heat that is absorbed in vaporizing the liquid is slightly more than the heat that is released when the vapor is condensed.

The amount of heat absorbed during vaporization requires additional explanation. Consider a pan of



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Figure 4. Pressure-Temperature Relationship

water at room temperature that is placed over a gas flame. As heat from the flame enters the water, its temperature increases until it reaches the boiling point (212° at atmospheric pressure). After the boiling point is reached, the temperature of the water remains at 212° , but it is obvious that approximately the same amount of heat continues to enter the water as during the period just before the boiling point was reached. What becomes of this additional heat?

The answer to the above question is that the heat enters the vapor as added energy—that amount of energy that was required to break up the water and change it to a vapor. This is called latent heat and as such it is absorbed in the vapor and remains there until the vapor is condensed, at which time it again becomes sensible heat. Heat that changes the temperature of a substance without changing the substance from a solid to a liquid or from a liquid to a vapor, is called sensible heat.

PRESSURE-TEMPERATURE RELATIONSHIP

A liquid partly filling a closed container will maintain an exact relationship between the vapor pressure and its temperature. Consider a small service tank of Freon-12 arranged so that both the pressure in pounds per square inch, and the temperature in degrees Fahrenheit may be read. See figure 4. Examine this pressure-temperature relationship for the three different conditions shown in the illustration.

1. Assume that the tank is at a room temperature of 70°F .. The pressure-temperature table for Freon-12 in the section on refrigerants shows a pressure corresponding to 70°F ., to be 70.1 lb. per sq. in. gauge pressure.

2. Place the tank of Freon-12 in a refrigerator having a food compartment temperature of 36°F ., and leave it there until the tank temperature is stabilized. The table shows that the gauge pressure will then be 33.4 lb. per sq. in.

3. Similarly, if the tank is then placed in the sun until its temperature reaches 100°F ., the gauge reading will be 117 lb. per sq. in.

From these experiments, it can be concluded that a liquid and its vapor in an enclosed space has an exact pressure for a given temperature.

When the tank was placed in the refrigerator, the tank and the refrigerant were cooled, causing some of the vapor to condense and causing the remaining vapor to have less density and consequently less pressure. When the tank was heated to 100°F., it absorbed additional heat and caused some of the liquid to vaporize, thereby increasing the vapor density. The increased vapor density means that more vapor is occupying the same space, which must result in a greater vapor pressure. Any volatile liquid acts in this manner because of the characteristic pressure-temperature relationship.

This relationship between pressure and temperature accounts for the fact that control instruments, such as the refrigeration temperature control, may be operated equally well from either the actual pressure in the system or from the temperature of a selected position in the cabinet.

COOLING BY EVAPORATION

Cooling by evaporation is not a new process; the people of Southwestern United States and Mexico have long used water coolers, which depend solely upon natural evaporation for cooling. A porous earthen jar, called an *olio*, is filled with water, then hung in the shade. The water soaks slowly through the porous walls of the *olio* and is evaporated on the outer surface. Enough heat is absorbed by evaporation to thoroughly chill the drinking water within, especially if there is any air motion around the container.

Any liquid that vaporizes or boils will absorb heat in the process. In the case of the pan of water on the gas range previously mentioned, heat required to cause vaporization came from the gas range flame.

If a liquid with a much lower boiling point, such as Freon-12 which boils at -21.7°F. at atmospheric pressure, is put in the pan, it will not be necessary to light the gas to cause it to boil unless the temperature of the air in the room is below -21.7°F. If the room air is 70°F., the Freon will boil vigorously, removing heat from the liquid and the pan, thereby cooling itself and the container. The heat that causes continued boiling comes from the air in the room because it is warmer than the pan of Freon. Consider that the pan of boiling Freon is not in an open room, but in an enclosed insulated space, such as a refrigerator cabinet. See figure 5. The heat that enters the Freon will now have to come from within the cabinet. Since heat is being removed from the cabinet, the temperature of the cabinet will be reduced. If no heat enters the cabinet, the temperature of the air inside the cabinet will continue to drop until either the Freon boils away or the cabinet temperature approaches -21.7°F., the boiling point of Freon at atmospheric pressure.

The pan of boiling Freon in the cabinet acts as a good refrigerator while the refrigerant lasts, but, to make the operation continuous, additional equipment must be used to reclaim the Freon vapor and condense it to a liquid so that it can be used over again. To

accomplish this, a compressor and condenser must be added to the evaporator (pan of Freon), and some method of controlling the flow of liquid refrigerant to the evaporator must be employed. A diagram illustrating the major parts of a complete refrigerating system is shown in figure 6.

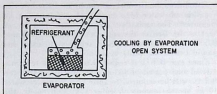


Figure 5. Cooling by Evaporation Without Recovery

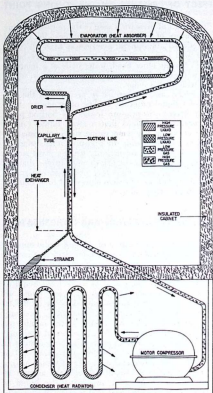


Figure 6. Cooling by Evaporation With Recovery

REFRIGERATION CYCLE

A refrigerating unit operates in a closed cycle, with the entire charge of refrigerant making a complete trip through the system every few minutes. Changes of state and changes in pressure and temperature occur during each cycle. From a high-pressure liquid in the condenser the liquid refrigerant flows through the capillary tube to the evaporator where it is changed to a low-pressure, low-temperature vapor, then to a high-pressure, high-temperature vapor in the compressor and finally to a high-pressure liquid in the condenser.

The portion of the system between the compressor discharge and the entrance to the evaporator contains either vapor or liquid under high pressure and is, therefore, known as the "high side." The portion from the entrance to the evaporator to the compressor discharge contains liquid or vapor under lower pressure and is accordingly known as the "low side."

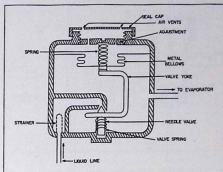
Liquid refrigerant in the high side is held at a pressure sufficiently high to prevent it from boiling. In the Philco System, liquid refrigerant is fed from the condenser into the low side of the system by means of a capillary tube. In the low side of the system, the warm liquid entering the evaporator immediately starts to boil because the pressure on its surface is greatly reduced. As the liquid boils in the evaporator, it absorbs heat from all materials near at hand, including the air inside the refrigerator cabinet. This action depends upon two factors: first, that a sufficiently low pressure is maintained in the evaporator and second, that the temperature of the air in the cabinet is above the boiling point of the refrigerant.

The outlet of the evaporator is connected to the intake of the compressor. As long as the compressor is running, the liquid in the evaporator will continue to boil, since the vapor produced is removed by the pumping action of the compressor. The vapor is compressed in the compressor to a high pressure and discharged into the condenser at a correspondingly high temperature. The heat that was absorbed in the low temperature evaporator by the boiling liquid is now disposed of in the high temperature condenser by dissipating it in the cooler surrounding air. The loss of heat by the vapor in the condenser lowers its temperature sufficiently to cause condensation. A cycle is now completed and another is ready to start.

REFRIGERANT CONTROLS

Many types of refrigerant controls have been used as pressure-reducing devices between the high side and the low side of the system. If one part of a completely closed system is to be maintained at high pressure and the other part at low pressure, two pressure-change devices must be used. The compressor produces one of these changes, receiving the refrigerant vapor at low pressure and discharging it at high pressure. Since a low-pressure condition must be maintained in the evaporator, an additional restrictor or pressure-reducing valve must be used where the liquid enters the evaporator.

Older types of refrigerant controls for household refrigerators are mainly of two types, the expansion valve and the float valve. Expansion valves are con-



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Figure 7. Pressure-Operated Expansion Valve

trolled directly from pressure within the evaporator, or in the more advanced type they are operated by the temperature of some portion of the evaporator.

Pressure-Operated Expansion Valve

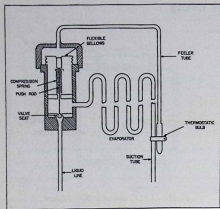
The illustration in figure 7 shows the principal working parts of a pressure-operated expansion valve. The pressure beneath the bellows is the same as the pressure at the entrance to the evaporator. The pressure inside the bellows is at atmospheric pressure. If the pressure in the evaporator is reduced, the bellows expands and opens the valve through the yoke linkage. When the compressor starts, the reduced pressure in the evaporator causes the valve to open and allows liquid refrigerant to enter the evaporator. When the compressor stops, the pressure builds up in the evaporator and the valve closes.

Since this type of expansion valve maintains a fairly constant pressure in the evaporator, it is not materially affected by temperatures outside of the evaporator and is, therefore, not well suited for household refrigerators.

Thermostatic Expansion Valve

If the seal cap in a pressure-operated expansion valve were connected to a feeler tube as shown in figure 8 instead of being subjected to atmospheric pressure, the resulting device would be a thermostatic expansion valve.

When this type of valve is used, the admittance of liquid refrigerant into the evaporator depends upon the temperature at the place where the feeler tube bulb is attached. The feeler bulb contains a small amount of refrigerant vapor which extends through the feeler tube and fills the space on top of the bellows. When the temperature of the evaporator increases, pressure is exerted on the bellows which opens the liquid valve through the push-rod linkage. When the evaporator temperature has decreased sufficiently, the resulting lowered pressure in the feeler bulb allows the compression spring to close the valve.



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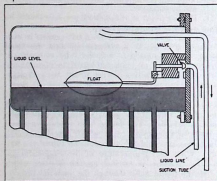
Figure 8. Thermostatic Expansion Valve

Float Valves

In the earlier production of household refrigerators, float valves were used extensively for refrigerant control. Two types of float valves were in general use, namely, the low-side and the high-side.

Low-Side Float Valve

The action of the low-side float valve is clearly illustrated in figure 9. It derives its name from the fact that it is located in the low-pressure side of the system, usually as an integral part of the evaporator. When the compressor starts, the liquid in the evaporator boils away and is removed through the suction tube. When the liquid level in the evaporator is lowered enough to cause the float to drop sufficiently to open the valve, more liquid refrigerant is permitted



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Figure 9. Low-Side Float Valve

to enter. When the compressor stops, the liquid continues to flow into the evaporator until the liquid level is raised enough to cause the valve to close.

High-Side Float Valve

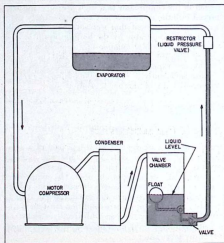
As its name implies, this valve is located in the high-pressure side of the system as shown in figure 10. Condensed liquid refrigerant flows into the valve chamber. As the liquid level rises the float is raised and it opens the refrigerant valve. After a small amount of liquid has passed through the valve, the liquid level drops and the valve closes. With this type of valve, liquid refrigerant is delivered to the liquid line as fast as it is condensed. Since the liquid line is connected directly to the evaporator, some sort of restrictor at the entrance of the evaporator is necessary to prevent the liquid from losing its pressure and vaporizing before it reaches the evaporator. This may be accomplished by some type of spring or weight operated check valve, or a capillary tube may be used.

All of the refrigerant-regulating devices explained above have moving mechanical parts which tend to get out of order. Valve pins and valve seats may become defective and, in the case of the expansion valves, calibrated springs may require occasional adjustment.

Capillary Tube Control

The capillary tube is a more simplified control device; it has no moving parts, needs no adjustment, and will not wear out. In addition to these improvements, the use of a small-bore tube as a refrigerant control allows the pressure in the system to equalize shortly after the compressor stops. Under these conditions the compressor starts easily after a short rest period.

With the capillary system it is necessary to provide



TP2-1342

Figure 10. High-Side Float Valve

enough capacity in the evaporator so that there is no chance for any liquid to be drawn into the compressor. Philco accomplishes this by arranging the parts of the evaporator as shown in figure 11. The liquid starts through the evaporator in a series path, but as it nears the suction line the refrigerant flows through multiple paths. The arrangement thus provides for the excess liquid refrigerant that flows into the evaporator during the pressure-equalizing period.

The capillary tube used in Philco refrigerators is $8\frac{1}{2}$ feet long and has a bore of .031 inch. To allow for this length, the excess tubing is coiled near the evaporator end.

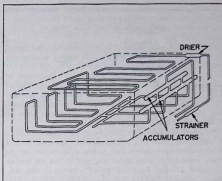
HEAT EXCHANGER

Since the liquid refrigerant in the capillary tube is quite warm, it carries a certain amount of heat into the evaporator. This is a very undesirable condition since the primary object of insulated cabinets is to prevent heat from entering the colder interior. To keep as much of this heat as possible out of the evaporator, the capillary tube is soldered to the suction line as shown in figure 6. The mechanical junction of these two tubes allows a considerable quantity of the sensible heat of the liquid to be transferred to the colder suction-line vapor, thus avoiding additional load on the refrigerating system.

CYCLING

A refrigerating system is said to cycle properly if it starts and stops as required in order to maintain a cabinet temperature corresponding to the temperature control setting.

Under ideal conditions, say 80° room temperature, with ordinary usage, the on-cycle or running time of a home refrigerator in good operating condition should be about 35 percent of the off-cycle, or idle



TP2-1343

Figure 11. Evaporator Duct System

time. In other words, if the refrigerator runs for three minutes it should shut off for about seven minutes, although there are several factors which affect the cycling period. Among the factors are:

1. Extreme weather conditions that cause greater heat leakage into the cabinet and consequently a longer running time to pump it out.
2. Unusual food loads, such as abnormal week-end loading, that introduce large quantities of heat into the cabinet.
3. A cabinet door which is not properly closed or sealed.
4. Defects in the refrigerating system such as defective temperature control, restrictions in the system, or a low-capacity compressor.

REFRIGERANTS

Various individual refrigerants may be used in a refrigerating system. In each case, however, the refrigerant is vaporized and condensed to produce the desired refrigerating effect. Each kind of refrigerant is characterized by properties which may or may not be desirable for the particular type of refrigeration to be accomplished. The variations in the characteristics make some of the refrigerants more suitable than others.

GENERAL CHARACTERISTICS

Some of the desirable characteristics of refrigerants used for household refrigerators and freezers are given below:

1. Non-poisonous.
2. Odorless.
3. Stable; does not decompose under pressure or deteriorate with age.
4. Non-explosive.
5. Non-corrosive; has no effect on the metals with which it comes in contact.
6. Has no objectionable action on the lubricating oils used.

7. Relatively cheap and easy to obtain.
8. High heat of vaporization.
9. Does not absorb water.
10. Vaporization and condensation pressure should not be excessive.
11. Boiling point at atmospheric pressure should be reasonably low.

The four most commonly used refrigerants in over 90 percent of small non-commercial units are listed in the following table:

	Boiling Point Atmospheric Pressure	Typical Suction Line Pressure (lbs./sq.in.)	Typical Head Pressure (lbs./sq.in.)	Latent Heat of Vaporization at 5° F.
Sulphur Dioxide	14°	4 in. vacuum*	70	169
Methyl Chloride	-10.44°	6	110	181
Freon -12	-21.7°	13	130	69
Freon -22	-41.4°	43	198	93

* Pressures below atmospheric pressure are measured in inches of vacuum.

The boiling points at atmospheric pressure are given in the first column and they show the comparative position of the refrigerant with that of boiling water (212°F.).

The second and third columns indicate the usual vaporization and condensation pressures frequently found in typical operating units. The fourth column indicates the latent heat of vaporization measured in B.T.U. per pound and shows the comparative ability of the four refrigerants to absorb heat when vaporizing. A high latent-heat refrigerant is ordinarily desirable since the same refrigerating effect can thus be made with a small quantity of refrigerant.

Sulphur dioxide has the desirable characteristics of high latent heat and relatively low vaporization and condensation pressures, but it has a corrosive action when combined with moisture, and it has an irritating odor. Of the four refrigerants given in the title above, sulphur dioxide ranks second in the latent heat of vaporization.

Methyl chloride requires higher operating pressures and is less corrosive than sulphur dioxide in the presence of water. Methyl chloride has the highest latent heat of vaporization of the four listed. It was a very commonly used refrigerant before the introduction of Freon.

Freon-12 is the most widely used refrigerant of the Freon group. It is nontoxic, noninflammable, colorless, and practically odorless; its operating pressures are only slightly higher than those of methyl chloride. Since the latent heat of vaporization of Freon-12 is quite low compared with methyl chloride, a greater number of pounds must be circulated per minute to obtain the same refrigerating effect. Because Freon-12 is the refrigerant usually found in household refrigerating units, a table of the gauge pressures and latent heat values at the different temperature levels is given below.

FREON-12 TABLE

TEMPERATURE Degrees F.	PRESSURE lb./sq. in. gauge	LATENT HEAT B.T.U./lb. (Heat of Vaporization)
-30	5.45*	72.67
-25	2.38*	72.25
-20	0.58*	71.80
-15	2.46	71.36
-10	4.30	70.91
-5	6.74	70.44
0	9.17	69.96
2	10.19	69.77

TEMPERATURE Degrees F.	PRESSURE lb./sq. in. gauge	LATENT HEAT B.T.U./lb. (Heat of Vaporization)
6	12.35	69.37
10	14.45	68.97
14	17.10	68.54
18	19.70	68.15
22	22.45	67.72
26	25.37	67.29
30	28.46	66.85
34	31.72	66.40
38	35.18	65.94
42	38.81	65.47
46	42.65	65.00
50	46.69	64.51
54	50.93	64.02
58	55.40	63.51
62	60.07	62.99
66	64.97	62.47
70	70.1	61.92
74	75.5	61.38
78	81.2	60.81
82	87.0	60.23
86	93.2	59.65
90	99.6	59.04
94	106.3	58.42
98	113.3	57.78
102	120.6	57.14

* Note: Pressure is registered in inches of mercury at pressure values below that of the atmosphere.

The value for the latent heat of vaporization becomes slightly less as the temperature and pressure is raised.

Freon-22, one of the newer Freons, has characteristics similar to that of Freon-12; the operation pressure is considerably higher, however. Because of the low boiling point of Freon-22, a system containing it is capable of producing cabinet temperatures lower than those of the other refrigerants mentioned.

REFRIGERANT COOLING EFFECT

In order to show the relation of the refrigerating effect of Freon-12 with that of melting ice, a comparison of the respective latent heats will be made. The latent heat of vaporization for Freon-12 is about 69 B.T.U. per pound, while one pound of ice, when melting, will absorb 144 B.T.U. Therefore, approximately twice as many pounds of Freon-12 must be vaporized to get the same refrigerating effect as from melting one pound of ice. In an average operation, approximately ten ounces of Freon-12 is used, and this amount is circulated about 16 times an hour. At this rate about ten pounds of refrigerant evaporate per hour. By comparison, this is equivalent to melting approximately four and a half pounds of ice per hour, assuming that the system is in continuous operation.

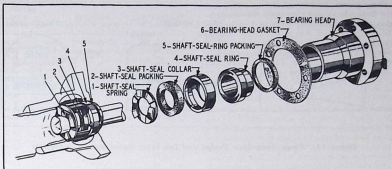
TYPES OF SYSTEMS

ABSORPTION VS. COMPRESSION

While the principle of vaporization is almost universally used in the refrigeration process, the methods employed may vary widely. Two practical methods

are used to circulate the refrigerant through the system and to produce condensation so that the refrigerant can be used over again. These are the absorption system and the compression system.

In the absorption system, heat is employed as the



TP-2863

Figure 12. Compressor-Shaft Rotary Seal, Assembled and Exploded Views

sole agent to circulate the refrigerant and to assist in the refrigeration process. The system is made up of intricate circuits containing water, ammonia, and hydrogen. Water is used because of its ability to absorb large quantities of ammonia vapor; at room temperature one quart of water will dissolve 500 quarts of ammonia vapor. Ammonia is used as the refrigerant. Hydrogen gas is mixed with the ammonia in the evaporator to lower the effective vapor pressure of the ammonia. If liquid ammonia alone is introduced into the evaporator, its vapor pressure is the only pressure exerted on the surface of the liquid ammonia. By introducing hydrogen, which mixes with but does not interact with ammonia vapor, the total vapor pressure must be divided between the two gases. The resulting pressure on the ammonia is now sufficiently low to cause the liquid ammonia to vaporize. In this manner the refrigeration effect is achieved without the use of a mechanical pressure-reducing device so commonly used in most systems. While the absorption system has certain advantages, such as no moving parts and quiet operation, these features are offset by the fact that such a system is considerably lower in over-all efficiency than that of the conventional compression systems.

In the compression system, a mechanical compressor, usually driven by an electric motor, is used to circulate the refrigerant and to raise the pressure of the vapor sufficiently high to cause condensation. The compression system is much more adaptable to various conditions than the absorption system. It can use a wide range of refrigerants having boiling points and other characteristics most suitable for the particular application. For a given refrigeration effect, it is more economical to operate than the absorption system.

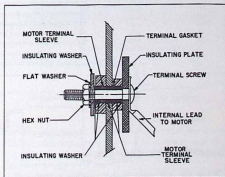
SEALED VS. OPEN SYSTEMS

In the early days of household mechanical refrigeration all systems were open, that is, they had a separate motor and compressor, either directly connected or belt driven. There are many reasons why this type of system is no longer used, except for special application. The motors were exposed to dirt and moisture.

Belts were a constant source of service trouble either because they were worn out or because they were too noisy. Perhaps the greatest disadvantage of the open system was the occurrence of leaks. The greatest possibility of a leak occurred at the rotary seal, where the revolving crankshaft passed through the compressor housing. The seal at this point depended upon a rotating mechanical device like the one shown in figure 12. Other sources of leaks were at the various flare fittings, where the tubing was connected to the parts of the system. Three shut-off valves were a part of the ordinary open system and these were also additional trouble-makers. Moisture in the system, introduced by leaks in the low side or by faulty servicing, was another source of trouble.

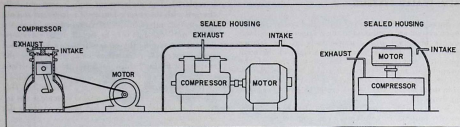
The open system is preferable only when the size of the unit makes the exchanging of the complete system too unwieldy or cumbersome to handle.

All of these factors led to the development of the sealed system with the motor and compressor in a single housing, with no flare-nut tubing connections, and with no valves. All parts of the system, except the



TP2-1345

Figure 13. Terminal-Lead Seal



TP2-1357

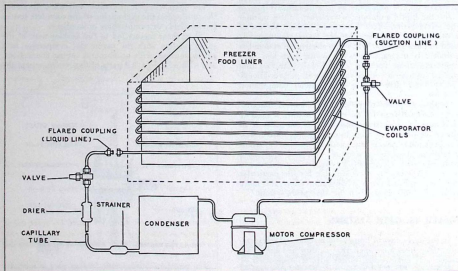
Figure 14. Open, Early-Type Sealed and Late-Type Sealed Motor-Compressors

motor terminal seal shown in figure 13, are hermetically sealed in metal. Figure 14 illustrates the development of the sealed motor-compressor from the open-type units.

ADVANTAGES OF A SEALED SYSTEM

The sealed system is in extensive use because of the many advantages it offers over the open type previously used. Some of the advantages are listed below.

1. Minimum maintenance—Fewer service calls are required.
2. Cleanliness—Motor and compressor are completely dirt and moistureproof.
3. Permanent lubrication—All moving parts are sealed in a lifetime supply of oil.
4. Low noise level—A sealed-in motor-compressor aids in minimizing noise.
5. Simplified servicing—The system does not have to be charged with refrigerants or oils during servicing.
6. No leaks from flare nuts, valves, or rotary seal—The major source of trouble in the open system is eliminated.
7. No belts to wear out or become noisy.
8. No expansion valve to adjust—The function of refrigerant injection into the evaporator is obtained by a simple capillary tube.
9. All defective replacement units are rebuilt and charged at the factory by skilled workers and precision machines. The rebuilt unit represents standards of workmanship and material that are not attainable in most local repair shops.



TP2-1346

Figure 15. Semi-Sealed Refrigeration Unit

SEMI-SEALED SYSTEMS

Some of the advantages of the sealed system and the open system are combined in the refrigeration replacements of larger units, particularly in the freezer groups. The increase of size and weight of the components, and particularly the construction of the evaporator, make it more desirable to have the refrigeration assembly designed so that only the high side need be replaced. A system of this type is shown in figure 15.

When trouble occurs in this type of system only the motor-compressor, condenser, and connecting tubing

is replaced. The replacement unit is sent out fully charged with the exact quantity of refrigerant and oil. The shut-off valves in the refrigerant lines are sealed tightly until the unit is to be installed. An extra service tank containing the same refrigerant as that used in the system is required to completely purge the evaporator tubing before the final tubing connections are made. After the tubes are connected, the shut-off valves are opened to complete the installation. This information concerning semi-sealed systems is not intended as service procedure, but merely explains the general idea.

COMPONENTS OF A SEALED SYSTEM

There are three major parts in a sealed refrigerating system, namely, the compressor, the condenser, and the evaporator. The connecting tubing consists of the capillary tube from the condenser to the evaporator, the return tube from the evaporator to the compressor and a short length of tubing from the compressor to the condenser to complete the circuit. Figure 16 shows a complete refrigerating system, crated for shipment.

The following information explains the function and design of the individual parts of the system.

EVAPORATORS

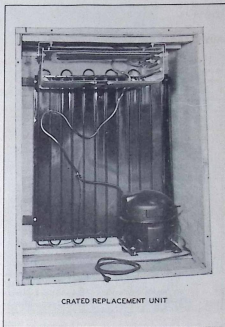
The function of any type of evaporator is to provide a place in the refrigerating system where the liquid refrigerant may be vaporized. The condition that must be maintained is a pressure sufficiently low to reduce the boiling point of the refrigerant to a temperature below the temperature of the air within the cabinet.

Mechanical Design

The design of evaporators varies considerably; some have sufficient capacity to hold a substantial quantity of liquid refrigerant, and others are made entirely of coiled copper tubing that contains a very small quantity of the refrigerant. The evaporators used in Philco refrigerators are of the semi-flooded type, containing only a small quantity of liquid refrigerant.

Philco evaporators are designed to be strong and rigid, and they are constructed from two steel sheets. Before the sheets are joined a continuous groove is pressed into the lower sheet. After the grooving process is completed, the two sheets are brazed together to form a continuous path for the refrigerant through the evaporator. The assembly is then formed into the conventional evaporators shown in figures 17 and 18.

Under certain conditions, it is necessary to spread the cooling effect over a larger area than would be possible if only one evaporator were used. Some freezer

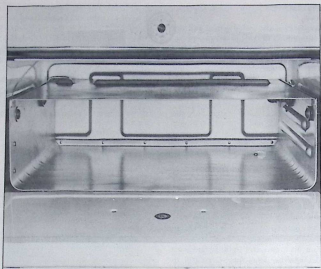


TP9-1294

Figure 16. Sealed Refrigerating System

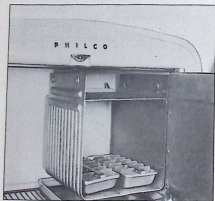
systems, like the one shown in figure 19, make use of this arrangement. Here the two evaporators are connected as if only one were used, that is, the two sections are joined in series.

The two-door Philco refrigerator uses a specially designed evaporator to permit it to pass through the rear cabinet cutout when installation or replacement



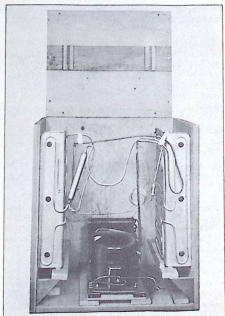
TP1-2500

Figure 17. Full-Width Evaporator



TP-4927

Figure 18. U-Type Evaporator



TPQ-708

Figure 19. Twin Evaporators

is necessary. Since the vertical dimensions of the evaporator are slightly greater than those of the rear cutout, the evaporator is designed so that its top may be lowered for removal. Figure 20 shows the channels that support the top of the evaporator when it is mounted in the cabinet. When the channel mounting screw is removed, the top of the evaporator may be lowered sufficiently to permit it to pass out through the rear cutout.

Cooling Capacity

An evaporator must have enough exposed surface to transfer the cabinet heat to the refrigerant. In general, the greater the heat load the evaporator must handle the larger the exposed surface should be. To produce a definite cooling effect, the evaporator must be able to vaporize liquid refrigerant at a given rate.

Effect of Frost

The evaporator walls must conduct heat freely to maintain continuous boiling. Anything that tends to obstruct this free flow of heat, such as a heavy coating of frost, cuts down on the refrigerating effect. An accumulation of ice or frost on the evaporator acts like a heat insulator and impairs economical operation. If the interior of the cabinet is to be maintained at the proper temperature, heat must flow through the evaporator walls at a given rate. If this action is retarded by frost, a reduced cooling effect must result.

Air Currents Within the Cabinet

Most of the heat in the cabinet that arrives at the evaporator is carried by air currents. If the entire interior of the cabinet is to be cooled, heat must be removed from every part of the cabinet. If the air movements within the cabinet are restricted or blocked off with foods crowded on the shelves, the transfer of heat will be slowed down and a loss of refrigerating capacity will result.

CONDENSERS

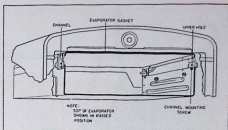
The function of the condenser in a refrigerating system is to maintain conditions that will cause the refrigerant vapor to condense to a liquid. Since a vapor must release some of its heat to cause it to condense, one of the conditions is that the whole condenser must be at a higher temperature than the surrounding medium, usually air. The other condition is that the pressure must be high enough to cause condensation.

Mechanical Design

The mechanical design of condensers covers a wide range; condensers are classified by the method of cooling, that is, whether they are air-cooled or water-cooled. If they are air-cooled, condensers may again be classified by their mechanical design; they may be of the plate type, or may consist of finned copper tubing. A third classification in the air-cooled types depends upon whether the condenser cooling is accomplished with natural or forced draft.

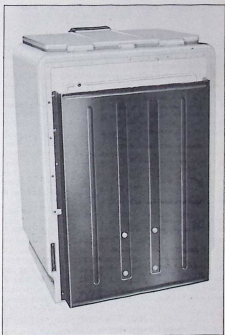
Air-Cooled Condensers

All Philco refrigerators and freezers use air-cooled condensers, but they may be of either the plate or finned-tube type. The plate-type condenser shown in



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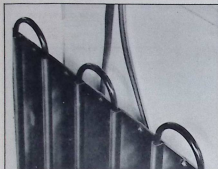
Figure 20. Collapsible Evaporator



TP-7913

Figure 21. Plate-Type Condenser

figure 21 is used on all of the present models of Philco refrigerators. This condenser has several advantages over the older finned-tube type as explained below. The plate-type condensers cannot become clogged with dirt because the air merely passes by them, not through small openings as it does in the finned type. When installed on the rear of the cabinet, they act as a flue to create a natural air draft. They are more



TP1-2402

Figure 22. Detailed View of Plate Condenser

economical to build than the finned copper-tube condensers. A detail of the mechanical structure of the plate condenser is shown in figure 22.

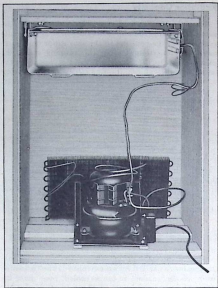
While several advantageous features of the plate condenser have been pointed out, there are certain types of systems used in Philco freezers where the use of the finned-tube condenser serves best. Where space is restricted, a very small finned-tube condenser may be used and the heat removal hastened by using forced draft. This consists of a small fan that blows the cooling air through the condenser. If forced draft were not utilized a much larger condenser like the one shown in figure 23, would be required. To gain sufficient heat radiation surface without the use of forced draft, two separate condensers may be used, as shown in figure 24. The two condensers are connected the same as if one were used, that is, they are connected in series.

The natural draft caused by the heat of the condenser and motor-compressor, provides sufficient condenser cooling in Philco refrigerators. In older models using finned-tube condensers, a flue was provided on the rear of the cabinet to assist in removing the hot air from the condenser. Remember that all of the heat that is absorbed at the evaporator is released at the condenser in the form of sensible heat. This heat is either removed by surrounding air currents, by natural or forced draft, or by water as explained below.

Water-Cooled Condensers

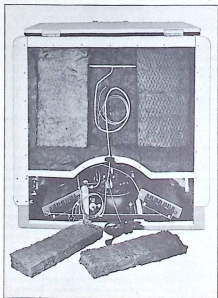
This type of condenser is used extensively in commercial installations. The simplest water-cooled condenser is known as the shell-and-coil type and is illustrated in figure 25. Refrigerant vapor from the compressor enters the closed drum or shell and is cooled by contact with the coiled tubing through which the cooling water flows. The lowered temperature resulting from the heat that is removed by the circulating water causes the vapor to condense.

Water-cooled condensers are not used in Philco refrigerators or freezers but are utilized in some of the larger Philco air conditioners.



TP-5528

Figure 23. Finned-Tube-Type Condenser



TP-1255

Figure 24. Twin Finned-Tube-Type Condensers

Radiation Capacity

A condenser that is designed for a given refrigerating system must be able to radiate heat at a definite rate in order to cool the refrigerant vapor enough to cause condensation. During the running cycle, the evaporator absorbs a certain amount of heat from the interior of the cabinet. It follows that, during the same running cycle, the condenser must be able to radiate a similar amount of heat.

The ability of a condenser to radiate heat depends mainly upon the following factors:

1. The surface area exposed to the cooling agent, usually air or water.
2. The temperature difference between the cooling agent and the condenser.
3. The amount of cooling agent used.

COMPRESSORS

The compressor in a refrigerating system receives the low-pressure, low-temperature vapor from the evaporator and compresses the vapor so that it occupies a much smaller space. After compression has occurred, each cubic inch of vapor contains the heat that was formerly contained in several cubic inches. As explained previously, the addition of heat to a substance always results in a rise in temperature if no change of state occurs. Since we merely raised the pressure of the vapor, without condensation, the temperature of the compressed vapor must rise accordingly. It can be seen from the process described above that the function of the compressor is to take the vapor from the evaporator, raise its pressure and temperature, then discharge the vapor to the condenser. The temperature of the vapor discharged from the compressor must be *higher* than the condenser-cooling medium in order that the condenser can cool the refrigerant sufficiently to cause condensation. There are two types of refrigerating compressors in general use; the reciprocating compressor shown in figure 26 and the rotary compressor shown in figure 27.

Displacement and Clearance

The amount of refrigerant a compressor circulates through the system depends upon the speed (R.P.M.) of the compressor and its displacement. The displacement of a compressor is a measure of the quantity of vapor it can handle during each revolution and is usually expressed in cubic inches. When the piston of a reciprocating compressor reaches the top, the space left in the top of the cylinder is called clearance volume. The clearance volume in a compressor is one of the new factors that determines the amount of compression efficiency. When the design of the compressor allows for a very small clearance, the compressor efficiency will be high accordingly.

Reciprocating Compressor

The reciprocating or piston-type compressor is used in all Philco refrigerators and freezers. Before the description of the detailed construction and operation of the Philco compressor, a discussion of compressor action in general, will be given.

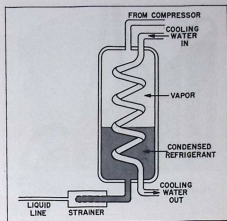


Figure 25. Shell-and-Tube-Type Water-Cooled Condenser

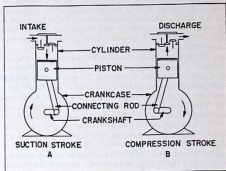


Figure 26. Typical Reciprocating Compressor

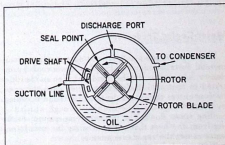


Figure 27. Typical Rotary Compressor



Figure 28. Motor-Compressor, External View

The compressor shown in figure 26 is designed for an open system, that is, a compressor with a separate motor drive, usually belt connected. This type of compressor requires a rotary seal to prevent leaks where the rotating shaft passes through the compressor housing.

The action of the piston-type compressor is quite simple. In figure 26, part A, as the crankshaft turns, the piston is pulled downward, thus creating a partial vacuum in the space above the piston. The vapor pressure in the suction line pushes the intake valve open and permits vapor to enter the cylinder during the down trip of the piston. After the piston reaches bottom center and starts upward as shown in part B of figure 26, the increasing vapor pressure within the cylinder allows the intake valve to close and also opens the exhaust valve when the pressure in the cylinder becomes greater than the pressure in the exhaust line. The intake and exhaust valves in these compressors are opened by vapor pressure and closed by spring action. With the upward travel of the piston, vapor under high pressure passes through the exhaust valve, and is discharged to the condenser. The piston travel discussed above represents one revolution of the crankshaft.

Rotary Compressor

Figure 27 shows a typical rotary compressor in which there are four sliding blades carried by the rotor. The sliding blades operate in slots in the rotor and are held against the compressor housing by centrifugal force or as shown in the figure by compression springs.

The rotor is offset or eccentric in relation to the housing in which it revolves, causing the rotor to seal against the housing at one point as shown.

The action of this particular rotary compressor is explained below. Vapor from the suction line passes through the intake to the space between the rotor, the

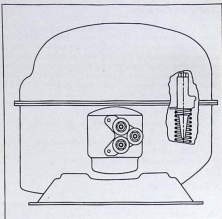


Figure 29. Internally Spring-Mounted Motor-Compressor

housing, and two adjacent blades. As the rotor revolves in the direction indicated by the arrow, the vapor is trapped between two adjacent rotor blades. As the rotation continues, the vapor-filled space between the blades becomes smaller and smaller, compressing the vapor to a smaller space and consequently raising its pressure. As the rotor blade approaches the exhaust port the high-pressure vapor is forced out through the discharge port since it cannot pass the seal point where the rotor and housing meet. Lubrication oil is essential in producing a seal between the rotor blades and the housing as well as the rotor seal point.

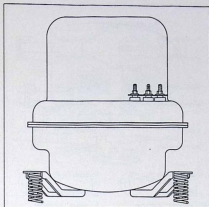
Connecting Rod Type Motor-Compressor

This type of reciprocating compressor is used by Philco; two design variations being the connecting rod type and the scotch yoke type. The connecting rod type will be discussed first.

In the Philco sealed system the motor is directly connected to the compressor, that is, the compressor crankshaft is a continuation of the motor shaft. The entire assembly is sealed in the steel housing, shown in figure 28, and is supported with coil springs located either under the entire assembly or within the housing supporting the motor-compressor only.

Internally Spring-Mounted Motor-Compressor

If the spring supports are within the housing, the unit is known as an internally spring-mounted motor-compressor. Three mounting springs are used, one of which is shown in figure 29. The main advantage of this type of support is that there is no external vibration. The suction and liquid lines are entirely free from vibration because the entire housing is mounted rigidly on the refrigerator base. Internal mounting of motor-compressors is used on all current models of Philco refrigerators.



TP2-1351

Figure 30. Externally Spring-Mounted Motor-Compressor

Externally Spring-Mounted Motor-Compressor

Earlier models of Philco refrigerators are equipped with externally spring-mounted motor-compressors; see figure 30. This mounting was effective in cushioning vibratory noises, but it also permitted the entire motor-compressor assembly to vibrate during operation and especially during starting. This caused the connecting tubing to vibrate, but this condition was entirely overcome when internal mounting was adopted.

COMPRESSOR PARTS

Figure 31 shows a cutaway view of a Philco standard internally spring-mounted, motor-compressor with numbers designating the principal parts.

1. **SUCTION MUFFLER.** Since all Philco compressors have but one cylinder the muffler is used to cushion, or smooth out, the refrigerant flow.

2. **CRANKSHAFT.** What is called the crankshaft is also the motor shaft because both motor and compressor operate as one unit.

3. **CRANKCASE.** The crank case is that part of the compressor that houses the crankshaft.

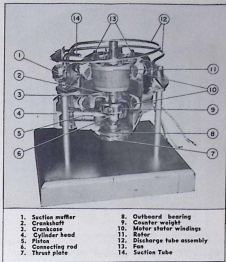
4. **CYLINDER HEAD.** The cylinder head covers the end of the cylinder, and is divided into two sections as shown, one for the vapor inlet and the other for the discharge of the compressed vapor. The valve plate, located under the cylinder head, contains the intake and discharge valve.

5. **PISTON.** The function of the piston is to take vapor into the cylinder on the inward stroke and to compress it on the outward stroke.

6. **CONNECTING ROD.** The connecting rod, as the name suggests, connects the piston to the crankshaft. It converts the rotary motion of the crankshaft to the "back and forth" motion of the piston.

7. **THRUST PLATE.** The thrust plate assembly acts as a support for the crankshaft.

8. **OUTBOARD BEARING.** The outboard bearing is the lower crankshaft bearing.



TP1-1418

Figure 31. Motor-Compressor, Cutaway View

9. **COUNTERWEIGHT.** The counterweight serves to balance the crankshaft. The unbalanced condition is caused by the weight of the crank offset and the connecting rod.

10. **MOTOR WINDING.** The motor winding in all Philco refrigerators and freezers is of the split-phase induction type. Two separate sets of coils are used in the stator winding; one set is the starting winding and the other, the running winding. To start the motor both windings must be energized, but once it comes to its rated speed, only the running winding is required. A relay is used to disconnect the starting winding when the rotor reaches about 80 percent of full load speed.

11. **ROTOR.** The rotor, or the part of the motor that rotates, consists of laminated silicon steel discs piled to form the body of the rotor, with metal conductors imbedded in the laminations. These conductors are all joined at each end of the rotor with the metal rings shown in the illustration.

With this construction of the motor, all windings and moving parts are exposed to the refrigerant.

12. **DISCHARGE TUBE ASSEMBLY.** Since the internally spring-mounted motor-compressor is free to vibrate inside the housing, the discharge tube must have some provision to absorb this motion. Since one end of this tube is fastened to the vibrating motor-compressor and the other to the stationary housing, the coiled tubing is used for this purpose.

13. **FAN.** Small vanes on the rotor serve to circulate the return gas and apply its cooling effect to the motor winding.

14. **SUCTION TUBE.** The suction line from the evaporator, not shown in the illustration carries the refrigerant vapor to the interior of the motor-compressor.

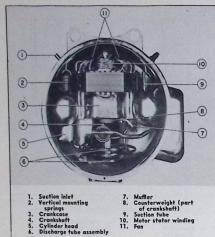


Figure 32. Scotch Yoke-Type Motor-Compressor

sor housing, from which point it is picked up by the suction intake and passed on to the compressor. Since the intake is not a continuous tube, no extra coil is necessary to absorb vibration.

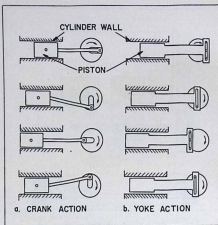
Scotch Yoke-Type Motor Compressor

The scotch yoke-type compressor is used in some of the Philco 7-cubic foot refrigerators. While it is a reciprocating compressor, its mechanical design differs radically from the piston-type compressor. It is often called a "compact" type because of its shape. Figure 32 shows an exposed view of the yoke-type compressor with the directly-connected motor mounted above it. This compressor has a crankshaft but no connecting rod, as the piston is operated directly by the action of the yoke block. The yoke block and piston are either fastened rigidly together or made in one piece.

The operation of the yoke-type compressor is illustrated graphically in figure 33. The piston and crankshaft positions in a standard reciprocating compressor shown in part A are compared with similar positions in the yoke type, shown in part B.

An inspection of figure 34 shows the rotor mounted above the compressor, and illustrates the major operating parts.

The cross-slide pin fits into the yoke block and the crank pin is inserted in the hole in the cross-slide pin. The cross-slide pin is fitted so that it slides freely in the yoke block when the crankshaft revolves. The rotation of the crankshaft moves the cross-slide pin in the yoke block, and the combined cross-slide pin motion together with the rotating crankshaft motion causes the entire yoke block and piston assembly to move back and forth in the cylinder. In this manner a reciprocating motion is transmitted to the piston without the usual connecting rod and piston pin. The cross-slide pin is at the center of the yoke block when the piston is at either top center or bottom center.



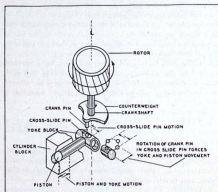
TP2-1352

Figure 33. Piston Movement, Connecting Rod vs. Scotch Yoke Type

Compressor Oil

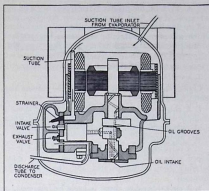
Oil for refrigerator compressors must have special characteristics to make it suitable for such use. A refrigerator oil must have a specified viscosity, which is a measure of whether an oil is "heavy" or "light." It must have an extremely low pour-point temperature; below this point the oil becomes too heavy to be poured. Above all, it must be thoroughly clean and dry. All refrigeration oils are hygroscopic, meaning that they readily absorb moisture. If oil has been exposed to the atmosphere for a considerable length of time, it should never be used in a refrigerating system.

Philco refrigerating systems are charged with an exact quantity of oil at the factory and since the oil



TP2-1353

Figure 34. Operating Parts of Yoke-Type Compressor



TPI-1626A

Figure 35. Cross-Sectional View of Connecting Rod Type Motor-Compressor

is sealed in the motor-compressor housing, no additional lubrication is required for the life of the refrigerator.

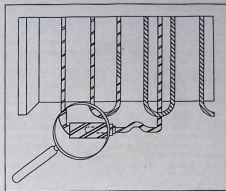
Oil absorbs or takes up an appreciable amount of Freon-12 and some oil particles are carried with the refrigerant vapor throughout the entire system.

Figure 35 shows the usual method of lubricating all moving compressor parts. The vertical crankshaft has an oil duct as indicated by the dotted lines. The duct starts at the lower end of the crankshaft and is so designed at this point that it acts like a small centrifugal pump, forcing oil to flow up the shaft to the connecting rod and main bearing. The connecting rod also contains a duct that carries oil to the piston wrist pin.

Oil-Cooling Condenser

An oil-cooling condenser is used in the larger of the Philco two-door refrigerators to assist in cooling the motor compressor. This auxiliary condenser is located between the bottom of the plate condenser and the rear of the cabinet. Its action is as follows:

The discharge line from the motor compressor carries the high-pressure, high-temperature vapor to the oil-cooling condenser, where enough heat is radiated to produce partial condensation. From this point the semi-liquid refrigerant is returned by a tube through the oil in the motor compressor base. Since the oil is now warmer than the refrigerant in the tube, enough heat enters the refrigerant to completely vaporize it



TPI-2595

Figure 36. Strainer Location in Liquid Line

and produce a refrigerating effect inside of the motor compressor. After the refrigerant tube has passed through the oil, it again leaves the motor compressor and carries the refrigerant through the system in the regular manner.

STRAINERS

When the liquid refrigerant moves from the condenser, it passes through the fine mesh strainer shown by the dotted line in figure 36. Such a device is used as a precaution in case small quantities of scale or dirt are left in the system during manufacture. A very small amount of foreign matter will clog the capillary tube and retard or stop refrigeration.

DRIER (DEHYDRATORS)

A drier is placed in the system where the capillary tube enters the evaporator. When refrigerators are assembled at the factory, extreme care is used to prevent moisture from entering the system and to make sure that all parts are absolutely dry before and during assembly. But in case a slight amount of moisture remains in the system, a drier, shown in figure 6, is inserted in the liquid line. The drier contains silica gel which has the ability to absorb a considerable quantity of water. Silica gel, a hard crystalline substance, is very porous, but the pores are so small that they cannot be seen with an ordinary microscope.

FACTORY TESTS ON ENTIRE SYSTEM

The Philco unit assemblies, which make up the essential operating portion of the refrigerator, are given a series of tests to ensure their proper performance and compliance with established production specifications.

An assembly-line method of handling the units, through use of an overhead conveyor system is used. The units, attached to the conveyor, are given a series

of tests as they move along, the results being marked on a "history" tag attached to each unit. At the end of the run, the units successfully passing the tests are approved, and any which do not meet the requirements are sent back for reprocessing. Service replacement unit assemblies receive the same tests as the original factory assemblies.

PRESSURE TEST

Before the unit assembly is charged with Freon-12 and oil, it is subjected to an immersion test in an aquarium-type dunk tank to check for leakage. While immersed in the heated water bath, the unit is subjected to an internal air pressure of from 235 to 250 pounds per square inch. Sufficient time is allowed to make adequate observation for leaks.

LEAK TEST

After the unit-assembly has been found to be free of leaks by the air-pressure water-immersion method, the complete unit is thoroughly dehydrated to remove all traces of moisture and noncondensable gases and then charged with carefully measured Freon-12 and oil. Then a leak test is made with a halide torch and also with an electronic leak detector for possible refrigerant leakage from the unit.

OPERATIONAL TEST

The unit assembly, now fully charged, is ready for a performance test and is placed in an operating condition on the test line (using the overhead conveyor previously mentioned). The test includes the following items.

1. A check on the proper refrigerant charge by observation of the frost distribution on the evaporator and suction line when it is operating under conditions which will permit obtaining evaporator temperatures within the normal operating range of the evaporator.

2. A leakage check to determine tightness of the refrigerating unit after all connections have been sealed.

3. A wattage check on the motor.

Checks on the electrical portion of the unit are also made. They include:

1. A check on the overload and relay operation is made by starting the unit at maximum voltage, when cold, to insure that the relay operates when the motor comes up to speed.

2. A relay check is made by starting the unit at reduced voltage, when the unit is hot, to determine whether the relay operates and the unit starts normally.

3. A circuit-breaker check is made by impressing a reduced voltage so as to prevent the unit from starting and by noting the time for the circuit breaker to reset.

4. A noise check is made by comparing the amount of noise made by an operating unit with that of an accepted noise standard.

5. A high potential voltage check is made for possible insulation failure or grounds.

TESTING A SEALED SYSTEM

The service man should familiarize himself with the operation of refrigeration units by occasionally checking the performance of one known to be in good condition. In this way he will become familiar with the temperatures of the various parts of the system when it is operating properly. By making these checks, he will develop the ability to determine how a unit is performing by merely feeling various parts of the system and noting the comparative temperatures. Such information, along with a checkup of the normal evaporator frosting, permits the service man to make a comprehensive study of each unit in a very short period of time.

It is advisable to make two or more checks on a unit before reaching any definite conclusion. If the unit has been standing idle for an extended period, it should be operated for some time to stabilize temperatures before a final check is made. When checking for the cause of trouble in a sealed unit, the following conditions in the system should be noted.

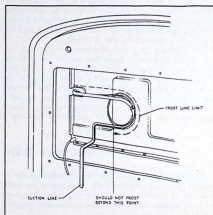
FROST ON LINES

If the unit has been running long enough so that its temperature is stabilized, frost on the suction line should not extend beyond the point shown in figure 37. Frost should never occur on the capillary tube if the unit is operating properly.

PRESSURE-EQUALIZING TIME

Determine the pressure-equalizing time as follows: Shut the unit off and allow it to remain off for about

four minutes. At the end of this period the unit should start, indicating that the pressures in the system are equalizing through the capillary tube at the proper speed. In cases of a partial restriction in the system, the time required for the pressure to equalize will be



TPI-2749

Figure 37. Location of Normal Frost-Back Point

considerably longer, depending upon the amount of restriction.

TEMPERATURE CONDITIONS IN THE SYSTEM

Evaporator. The evaporator should be uniformly frosted over its entire surface.

Discharge Line (Compressor to Condenser). This line should be decidedly warm at any time that the unit is operating properly.

Suction Line (Evaporator to Compressor). The suction line should be cold but not frosted.

Condenser. Since the compressor pumps hot vapor into the condenser, the first pass of tubing should be quite warm, perhaps 135 to 200 degrees. This portion of the condenser is radiating the heat necessary to reduce the temperature of the refrigerant vapor to its condensing temperature. At some point in the condenser tubing, perhaps after the first two loops, enough heat will have been dissipated to start condensation. The remainder of the condenser tubing will be 20 to 35 degrees above room temperature.

RESTRICTION IN THE HIGH SIDE (LESS CAPILLARY)

Restriction in the system, caused by foreign matter lodged in the tubing, is usually apparent for one or more of the following reasons:

In the case of a restriction in the high side, other than in the capillary tube, the only effect is that of slowing down the entire movement of refrigerant. This condition applies to all cases, except those in which there is an almost complete restriction. If enough refrigerant passes the restrictions, the evaporator may frost evenly, but the extent of cooling would depend upon how much the circulation is slowed down.

Because the flow of refrigerant is slowed down, there is a tendency to fill the condenser, or at least the lower passes (loops) of the condenser, with liquid. This liquid reduces the efficiency of the condenser by cutting down the amount of area of the condenser that is devoted to removing heat from the vapor that is being pumped into it. The ultimate result is that less heat radiation takes place which results in reduced refrigerating capacity. Under these conditions, the condenser outlet temperature may be only slightly above room temperature and the evaporator may be only partially frosted. Even with the reduced capacity, it is entirely possible that the unit will lower the temperature of the evaporator enough so that the unit will shut off if the temperature control is set on one of the warmer positions. If the unit does shut off, the evaporator warms rapidly. However, since warm liquid refrigerant trapped in the condenser continues to flow past the restriction through the capillary to the evaporator, the pressure will not equalize as rapidly as it would under normal conditions.

If the evaporator warms rapidly or the pressures equalize slowly, it is probable that the unit will stall at the beginning of each cycle.

With the reduced capacity it is quite likely that the unit will never pull down to a point where the temperature control will shut off on the colder tempera-

ture settings. If it does shut off, the on-cycle will be unusually long as compared to the off-cycle. In either case the motor-compressor may stall at the next start.

RESTRICTION IN THE CAPILLARY TUBE

There is one definite indication of restriction in the capillary tube and that is frost or sweating on the tube at and beyond the restriction point. In the case of a restriction in the strainer, there may be a certain amount of frost along the capillary tube, the reason being that expansion takes place within the tube itself.

RESTRICTION IN THE LOW SIDE

An indication of restriction in the low side of the system is very much the same as a restriction on the high side. In this case there will be reduced capacity with the result that the evaporator temperature will never be as low as it would be on a normal unit. A restriction in the suction line will raise the evaporator temperature because the pressure will tend to build up in that part of the system.

MOISTURE IN THE SYSTEM

Extreme caution is used in manufacturing sealed refrigerating units to ensure that the interior of the system is completely dehydrated, since even a trace of moisture may cause trouble at some later date. In the event that there is moisture in the system, the moisture will be carried along with moving refrigerant until it reaches the upper end of the capillary tube. Since rapid evaporation occurs at this point, the temperature drops sufficiently to freeze the water into ice and restrict the flow of refrigerant. Enough ice may form at the upper end of the capillary tube to completely stop the refrigerant flow. This may cause intermittent operation because after the refrigerant flow stops, the evaporator will warm up enough to melt the ice and allow refrigeration to start again, only to be stopped when more ice forms. This intermittent operation is largely due to tripping of the motor circuit-breaker.

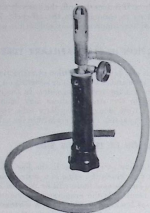
To prevent the possibility of this action in the Philco refrigerators and freezers a small drier or dehydrator is placed in the liquid line at the upper end of the capillary tube.

LEAK DETECTORS

When testing for leaks, the pressure in both sides of the system must be above atmospheric pressure. Turn the temperature control to OFF and allow the pressure to equalize before making a leak test on the low side of the system.

Soap Lather or Oil Test

To make this test, prepare a soap lather and apply to all brazed or soldered connections in the tubing and at the motor-compressor terminal seal. Look for bubbles to form at the point where the gas is escap-



TP-247

Figure 38. Halide Torch

ing. Light oil or liquid soap may also be used when making the test.

Halide Torch

A common type of test torch available for leak testing is a self-contained alcohol burner and is shown in figure 38. The halide torch is constructed so that the flame heats a copper disc mounted in the upper end of the torch. A flexible detecting tube is provided with the torch, to carry traces of Freon gas to the flame when the open end of the tube is held near a leak. If the torch is burning normally, it produces an almost colorless flame. In detecting a small gas leak (Freon), the flame changes to a pale green color; when the leakage is large, the flame becomes a brilliant blue or purple. In case of a severe leakage, the torch flame may be extinguished. The room where the torch is used should be well ventilated; if not, the air from any section of the room may contain sufficient Freon vapor to cause the flame to burn green. The flame should be kept in the dark as much as possible so that slight changes in its color may be easily noticed.

Carbon tetrachloride, often used in washing equipment parts, produces fumes which give the same indication as Freon when the leak detector is used.

UNDERCHARGE OF REFRIGERANT

If the unit is undercharged, there may not be sufficient refrigerant to carry all the way through the evaporator. The result is that the evaporator is partially frosted; it is frosted only on that section of the evaporator that is in contact with the vaporizing liquid.

However, since there is not the usual amount of liquid vaporizing, the compressor will produce a less-than-normal pressure in the evaporator. The lowered pressure results in a lower than normal temperature on that portion of the evaporator that is being frosted. This accounts for two things; one, the variation in the

frost deposits on the evaporator, and the other, the fact that in many cases the unit of refrigerant will actually cycle, the cycles frequently being of short duration.

If that portion of the evaporator to which the temperature control feeler tube is attached is frosted, it is readily apparent why the unit will shut off. The off-cycle, however, may be shorter than the on-cycle in many cases. After the unit has shut off, the frosted portion of the evaporator warms up very rapidly because the entire interior of the refrigerator is considerably warmer than it would be under ordinary circumstances.

The procedure for making checks for undercharge are described below.

Visual Check for Undercharge

Open the refrigerator door, and check for uniform distribution of frost over the entire evaporator. The system is not undercharged if the evaporator is completely frosted. If the evaporator is not completely frosted, make the following operational check.

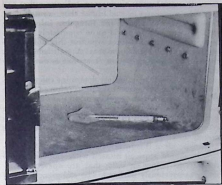
Operational Check for Undercharge

1. Turn the temperature control to OFF and allow the evaporator to warm up until it is entirely defrosted, then set the temperature control to its coldest position.
2. Allow the unit to operate until the frost pattern on the evaporator ceases to change.
3. If the evaporator is not completely frosted at this time, the system is undercharged (or otherwise defective) and should be replaced.

OVERCHARGE OF REFRIGERANT

Overcharge means that the system contains too much refrigerant, but a great deal depends upon the extent of overcharge. Overcharge causes the evaporator to be so full of liquid refrigerant that some of this liquid finds its way into the suction line and vaporizes there. When this happens, heat is being absorbed, not only from the interior of the refrigerator, but also from the room to which the suction line is exposed. Therefore, if the overcharge is slight, it is readily apparent that there will be very little effect on the unit. However, if there is an appreciable overcharge and a great deal of vaporization is taking place outside of the insulated cabinet in temperatures that are quite warm, the result will be a considerable increase in the heat load on the unit and the evaporator pressure will be quite high.

In extreme cases, the evaporator pressure may remain high enough so that the boiling liquid in the evaporator itself will never reach a low enough temperature to cause the temperature control to shut off. Because of the increased load on the unit, the line from the compressor to the condenser as well as the condenser itself will all be at a higher temperature than they would be if these parts were only dissipating the heat that was removed from the interior of the refrigerator.



TP-1157

Figure 39. Thermometer Frozen to Floor of Evaporator

Another effect of frost-back is the resulting frost which collects on that portion of the suction line which passes through the insulation layer in the cabinet wall. When the unit stops, the frost on this section of the suction line will melt and set up a condition in the insulation that is very undesirable.

The procedure for making checks for overcharge is described below:

Visual Check for Overcharge

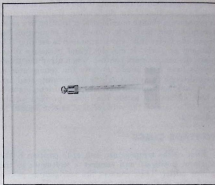
Check for signs of sweating or frosting on the suction line. If no sweating is observed, it is a good indication that the system is not overcharged. If sweating or frosting is observed, check for overcharge as follows:

Operational Check for Overcharge

1. Set the temperature control to its coldest position.
2. Remove the outer cover plate on the rear of the cabinet and remove sufficient insulation to uncover the suction line.
3. Operate the unit until the frost-back on the suction line ceases to increase. At this time, the frost-back must not exceed the maximum limit shown in figure 37.

LOW-CAPACITY COMPRESSOR

In a low-capacity compressor, it merely becomes a case of not being able to remove vapor from the boiling refrigerant in the evaporator fast enough to bring about a sufficiently low temperature. This condition is largely due to defective valves, worn cylinder walls, or worn moving parts. With sufficient refrigerant in the evaporator, the temperature in the evaporator will be fairly uniform, whether it is actually frosting or is merely cooling off enough to cause condensation.



TP-8129

Figure 40. Vertical Mounting of Thermometer

The type of cycle will naturally be governed by the extent of the reduction of capacity of the compressor. In extreme cases, the unit may never be pulled down to allow enough temperature to cause the unit to shut off. It may, in some cases, cause the unit to cycle on the warmer settings. If it does cycle, it is probable that the on-cycle is extremely long as compared to the off-cycle.

With a low-capacity compressor, a less-than-normal amount of heat is removed from the interior of the refrigerator. Accordingly, a less than normal amount of heat is released from the vapor at the condenser. The result is that the condenser operates at a temperature which may be only lukewarm.

TEMPERATURE CHECK

The evaporator temperature is checked by means of a thermometer which is usually frozen to the bottom center of the evaporator as shown in figure 39. In some instances the instructions may require the thermometer to be fastened to a vertical cold wall by means of a moistened fabric as shown in figure 40. However, the instructions for the thermometer placement, as well as the cut-off and cut-on temperatures are to be obtained from the appropriate service manual or other available data source which applies to the unit being checked.

If the cut-on and cut-off temperatures are not maintained, the reason may be due to one or several of the following conditions:

1. Temperature control not functioning properly.
2. Line voltage too low.
3. Incorrect connection between feeler tube and evaporator.
4. Trouble within the refrigerating system.

Before checking the system for abnormal temperature conditions, see that the condenser is clean and free of dust or other accumulation. Check the line voltage. If the voltage varies more than 10 percent of the rated voltage, it may be the main cause of im-

proper operation of the unit. If the refrigerator is located in a section of the room where the temperature is excessive, a change in refrigerator location to a more favorable spot may help. Check the connection between the feeler tube and evaporator to see that it is clamped properly. It may be found necessary to replace the temperature control. When all of the above checks have been made, operate the refrigerator at least through two cycles, taking temperature readings. If the unit continues to have evaporator temperatures which do not fall within the limits specified for the particular model, the refrigeration system should be replaced.

WATTAGE CHECK

First set the temperature control to position 1 (the warmest position) and connect a wattmeter to the power outlet. Then connect the refrigerator power-cord plug to the wattmeter receptacle. The running wattage indicated will vary with: (1) line voltage (2) room temperature and (3) the particular part of the running cycle in which the unit is operating.

Check with the appropriate data, and note whether the wattage reading falls within the maximum and minimum values specified. A considerably greater than maximum reading is a certain indication of trouble within the unit. However, slight deviations from the specified values should not require removal and replacement of the unit.

The wattage reading will be lower than normal if there is a heavy restriction in any part of the system. It will also read less than normal if the system is undercharged. An overcharge of refrigerant is the only

factor discussed under testing a sealed system that will cause the wattmeter to read higher than normal.

It will be noted from the foregoing information, that the unit can be tested quite completely with no equipment except a pocket type test thermometer to check evaporator temperatures. A wattmeter check may be required in certain cases, but is not usually essential.

It is impossible to definitely determine the temperature of the various parts of the units referred to in the checks, since all of these temperatures are relative to surrounding temperatures. Nevertheless, there is a definite temperature difference between the points referred to, and these differences have a direct bearing on any unit test being made.

Because all of this information is relative, the serviceman should acquaint himself with temperatures of the various points on units that are operating normally as previously outlined. The experience gained by making periodic checkups on normal units will be most valuable, since the results obtained from tests of this nature depend to a great extent upon experience. Certain things are taken for granted in supplying information for tests of this nature; for example, it is assumed that the units are operated for the period of time required for stabilization, and this time varies with conditions. Refrigerators that have been stored in a cold place for some time will not reach normal performance until the entire motor-compressor dome assembly has warmed up, indicating that most of the Freon has left the oil. On the other hand, if the refrigerator has been stored in a hot warehouse it may take three or four hours for the temperature to stabilize throughout the cabinet.

NOTES

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