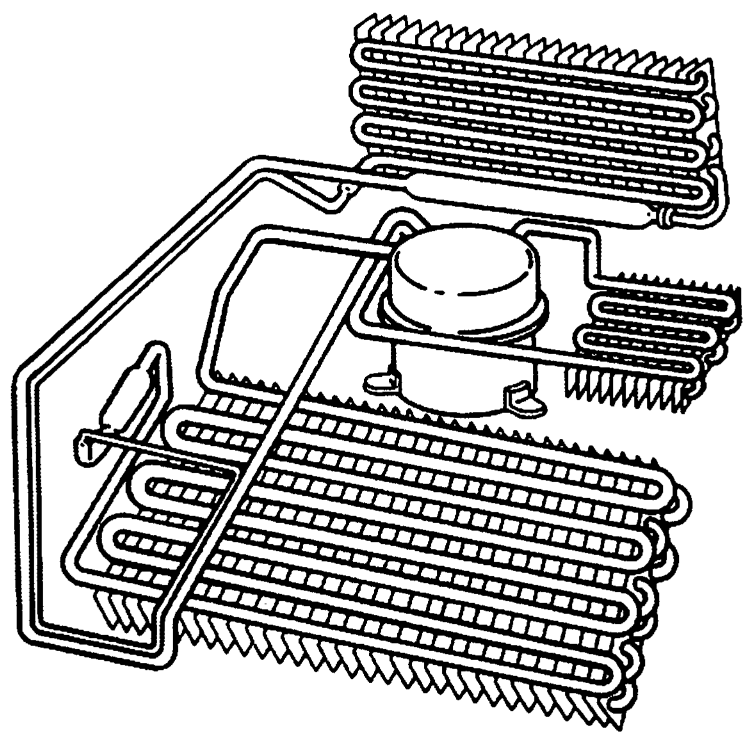
REFRIGERATION

STUDY COURSE

UNDERSTANDING:

- THE REFRIGERATION SYSTEM



MODULE 1

LIT4314331

TABLE of CONTENTS

PAGE

CHAPTER 1 - REFRIGERATION SYSTEM 4
Refrigeration System 5
A Simple System 5
The Refrigeration Cycle 5
High-Pressure Side 6
Low-Pressure Side 6
Compressors 6
Reciprocating 6
Rotary 7
Condensers 7
Static 7
Forced-Draft 8
Warm-Wall 8
Evaporator 8
Capillary Tube 9
Additional System Components 9
Drier (Strainer) 9
Accumulator 9
Precooler 10
Fundamentals Of Refrigeration 10
Atmospheric Pressure 10
Gauge Pressure 11
Absolute Pressure 11
Theory Of Heat 11
Units Of Heat 11

INTRODUCTION

The material presented in this module is intended to provide you with an understanding of the fundamentals of refrigeration servicing.

Major appliances have become more sophisticated, taking them out of the screwdriver and pliers category. Their electrical circuits include several different types of automatic controls, switches, heaters, valves, etc.. Semiconductors, solid-state controls, and other components usually associated with radio and television electronic circuits, are being engineered into automatic washers, dryers, dishwashers and refrigerators.

The appliance technician is emerging into a professional status of his own. He must prepare himself now to be able to perform his duties today as well as to retain his professionalism in the future.

No longer is on-the-job training sufficient to prepare technicians for the complicated procedures required for todays sophisticated appliances. This training can best be obtained through organized classroom study and application. However, much of the knowledge necessary to service todays appliances can be obtained through study courses. Completion of this and other courses will provide you with sufficient understanding of appliances and their operation to enable you to do minor service. It will also serve as a valuable stepping stone to more advanced study and on-the-job training to improve your servicing skills.

Information contained in this module is used on WHIRLPOOL® appliances.

PAGE

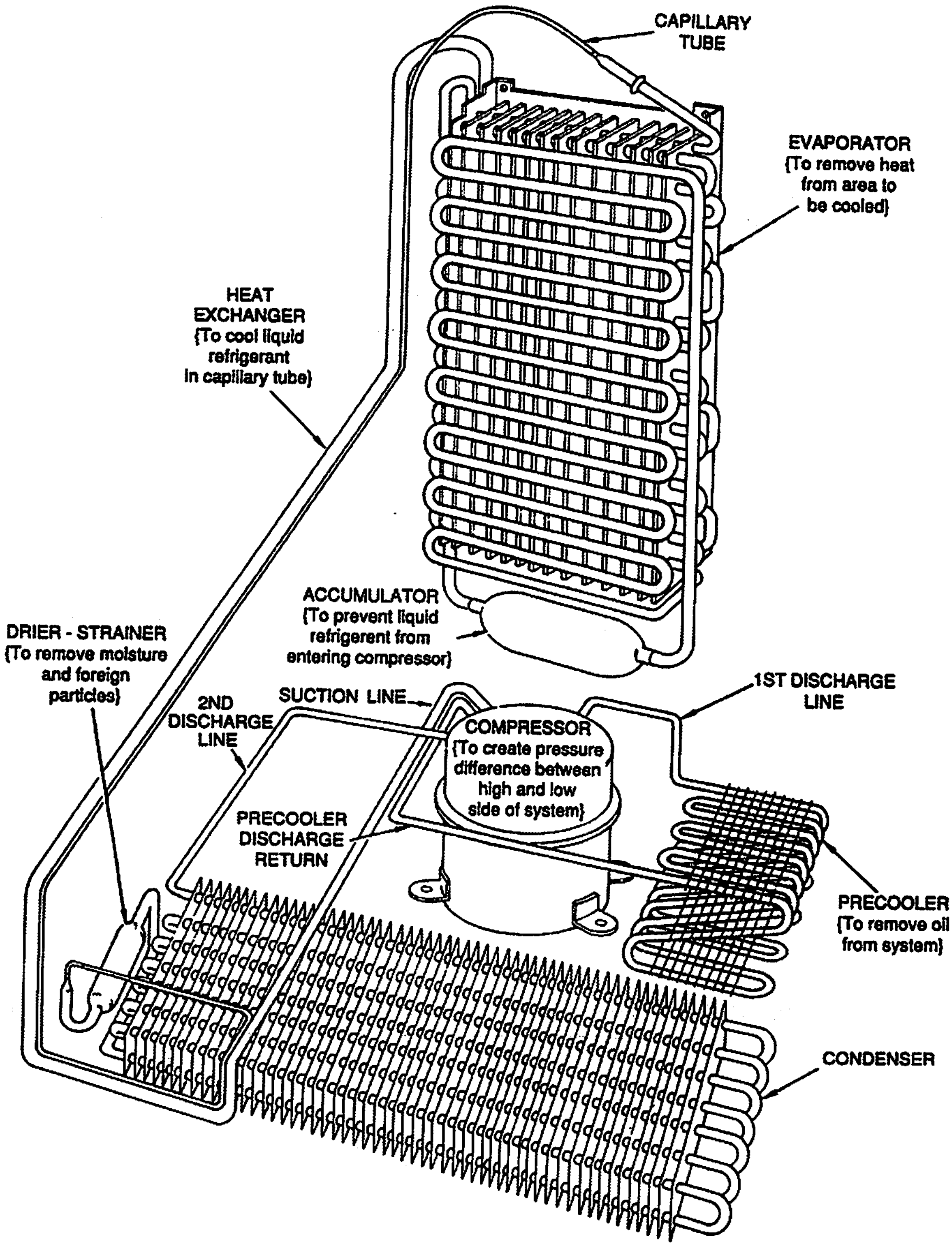
Specific Heat 12
Sensible Heat 12
Latent Heat 12
Heat Transmission 13
  Conduction 13
  Convection 13
  Radiation 14
Refrigerants 14
Desirable Properties 14
Classifications 14
The Chlorofluorocarbon Refrigerants 14
Chemical Properties 15
Operating Pressures 15
Refrigerant-12 {R-12} 15
Refrigerant-22 {R-22} 15
Pressure-Temperature Relationship 15
Care In Handling Refrigerants 16
Handling Refrigerant Cylinders 16

*TEST .... See Test Book LIT4314335

NOTE: ***We recommend taking the TEST for MODULE 1, right after studying it.***

CHAPTER 1

REFRIGERATION SYSTEM



REFRIGERATION SYSTEM

The process of refrigeration is most commonly accomplished by the evaporation of a liquid refrigerant, thereby extracting heat from the area to be cooled.

A SIMPLE SYSTEM

The principle of using the latent heat of vaporization of a liquid, such as *R-12*, for producing refrigeration can be illustrated very easily by thinking of a refrigerator of very simple design. The refrigerator is made up of a box that is completely insulated on all six sides to inhibit the entrance of heat by conduction, convection, and radiation. Placed in the top of the cabinet is a series of finned coils, with one end connected to a cylinder charged with *R-12*. Through this end two pounds of *R-12* is charged into the coil, after which the cylinder is sealed and disconnected from the line, with the charging end of the pipe open to the atmosphere.

Since the liquid *R-12* is exposed to the air, the only pressure to which the liquid is subjected is atmospheric pressure, which is approximately 14.7 pounds per square inch *absolute* or zero pounds gage pressure. At this pressure, *R-12* liquid will boil or vaporize at a temperature of -21.6°F, or at any higher temperature. We will say, just for example, that the temperature of the room in which the refrigerator is located is 70°F. If this is the case, the temperature of the cabinet at the time of the addition of the *R-12* in the coils will therefore immediately start boiling and vaporizing because the surrounding temperature is above the boiling point (-21.6°F) of the liquid. As the liquid boils away, it will absorb heat from the cabinet because, for every pound of *R-12* liquid vaporized, 71 BTU's of heat will be extracted from the cabinet. As soon as the temperature of the cooling coil is reduced to a point lower than the cabinet temperature, the air in the cabinet will start circulating. Remember heat always flows from the warmer to the colder object.

With this method, however, the two pounds of *R-12* liquid would soon be vaporized and the gas given off to the air outside the cabinet and refrigeration would then stop until a new charge was placed in the cooling coil. *R-12* is expensive and difficult to handle and some means must therefore be used to reclaim the vapor in order to use the original charge continuously. The inconvenience of recharging the coil must also be eliminated, and the refrigerator must be built so that it will automatically maintain proper food-preservation temperatures at all times with absolutely no inconvenience to the customer. This can be accomplished by a compressor pulling the heated *R-12* gas from the cooling coils and pumping it into a condenser where it will be changed to a liquid ready to return to the cooling coils.

The principle components of a compression type of refrigeration system are

- Compressor
- Condenser
- Evaporator
- Refrigerant metering device (i.e., capillary tube)

THE REFRIGERATION CYCLE

A thorough understanding of the cycle of operation, that is, what takes place inside a refrigerator, is necessary before a correct diagnosis of any service problems can be made. Thus, only by a thorough study of the fundamentals will one be able to master the field of refrigeration. A cycle, by definition, is *an interval or period of time occupied by one round or course of events in the same order or series.* The word *cycle* as applied here, means a series of operations in which heat is first absorbed by the refrigerant, changing it from a liquid to a gas, then the gas is compressed, further raising its temperature, and forced into a condenser where the heat absorbed by the refrigerant is dissipated into the room air surrounding the condenser, thus bringing the refrigerant back to its original or liquid state. The cycle of operation consists of the following steps.

1. The compressor pumps the refrigerant through the entire system. It draws refrigerant gas in through the suction line from the evaporator coils. It then compresses the gas and pumps it into the condenser where its temperature and pressure are greatly increased.
2. The condenser performs a function similar to that of the radiator in an automobile; that is, the condenser is the cooling coil for the hot refrigerant gas. From the surface of the condenser, the heat is dissipated into the cooler air in the room outside the cabinet. During this process, the refrigerant gas gives up the heat it absorbed from inside the cabinet, and changes into a liquid.
3. The high-pressure liquid leaves the condenser and enters the metering device (capillary tube).

4. The capillary tube is carefully calibrated in length and inside diameter to meter the exact amount of liquid refrigerant flow required for each system. A predetermined length of the capillary tube is usually soldered along the exterior of (or enclosed within) the suction line, forming an assembly (commonly called a *heat exchanger)* which helps to further cool the liquid refrigerant in the capillary tube. The capillary tube then connects to the larger diameter tubing of the evaporator.

5. As the refrigerant leaves the capillary tube and enters the larger tubing of the evaporator, the sudden increase in tubing diameter causes a *low-pressure* area, and the temperature of the refrigerant drops rapidly as it changes from a liquid form to a mixture of liquid and gas. In the process of passing through the evaporator, the refrigerant absorbs heat from the warmer items within the cabinet and is gradually changed from a liquid to a gas.

6. As the refrigerant leaves the evaporator, it returns to the compressor through the suction line which is a part of the heat exchanger, thus completing the cycle.

HIGH-PRESSURE SIDE

The high-pressure side of the system is that part containing the high-pressure and high-temperature refrigerant, and includes everything between the inlet to the condenser and outlet of the capillary tube.

LOW-PRESSURE SIDE

This is that part of the system containing the low-pressure and low-temperature refrigerant, and consists of the evaporator and suction line.

COMPRESSORS

There are two types of compressors, they are:

- Reciprocating compressors
- Rotary compressors

The function of the compressor is to establish a pressure difference and thus cause the refrigerant to flow from one part of the system to the other. It is this difference in pressure between the high and low sides that forces liquid refrigerant through the capillary tube and into the evaporator.

Modern refrigeration compressors are usually of the hermetically-sealed type, either rotary or reciprocation although numerous early refrigeration systems used open-type compressors. The open type is one in which the motor is connected to the compressor by means of a belt or coupling. In the sealed type, the motor and compressor are directly connected to the same shaft and sealed in the same compartment. A typical reciprocating-type sealed compressor provides a compact assembly with the advantage of the elimination of a belt and pulley, resulting in a lower noise level and reduced maintenance.

Reciprocating Compressors

The reciprocating compressor consists of one or two cylinders mounted either horizontally or vertically. The motion of the piston in the cylinder is accomplished by the crankshaft arm which is fastened to one end of a connecting rod. The other end of the connecting rod is fastened to the piston by means of a piston pin. It is in this manner that the connecting rod and crank arm converts the rotation of the crankshaft to the reciprocating or back-and-forth motion of the piston.

The passage of the refrigerant gas to and from the compressor is controlled by means of suction and discharge valves located on a specially designed valve plate which forms the lower part of the cylinder head. The flapping action of the valves permits the flow of refrigerant gas out through the discharge valve port only, and in only through the suction valve port. Thus, when the piston moves away from the valve plate (suction stroke), the pressure in the cylinder is below that in the suction line, and a flow of refrigerant gas occurs that pushes open the suction valve and permits a certain quantity of the gas to enter the compressor.

As the motion of the piston reverses and moves toward the valve plate (compression stroke), it increases the pressure, which causes the suction valve to close. A further compression, as the piston moves close to the valve plate, opens the discharge valve and forces the refrigerant gas into the discharge line, thus causing what is known as the high-side pressure of the refrigerant. It is in this manner that the suction stroke fills the cylinder with vaporous refrigerant. The compression stroke compresses it and forces it out of the cylinder; the valves are actuated only by the difference in pressure.

The servicing of hermetic refrigerating systems using hermetically-sealed compressors does not differ in any important respect from those systems in which the compressor and motor are separately mounted. Because the unit is completely sealed and tested at the factory, trouble is seldom found with the compressor-motor assembly. The source of the trouble in most cases is found in other parts of the system. The motor, located above the compressor, operates in a vertical position, whereas the compressor operates horizontally. The construction of the motor-compressor permits operation of the compressor in oil, simplifying lubrication problems. The dome of a reciprocating compressor is under low pressure.

Rotary Compressors

Rotary compressors have a set of rotating vanes that are closely fitted into an eccentric cylinder. The vanes or blades push the refrigerant vapor around ahead of them into a narrowing area of the eccentric cylinder, compressing the vapor and forcing it into the high side of the system. Refrigerant vapor flows from the low side into the void behind the moving blades.

The overall efficiency of a rotary compressor is higher than that of the reciprocating type. Rotary compressors are also more compact and can produce a deeper vacuum than a reciprocating compressor. It is for this reason that a rotary compressor is used as a vacuum pump for evacuating a refrigeration system for servicing. However, a reciprocating compressor can handle larger volumes of refrigerant.

Oil within the rotary compressor not only lubricates the moving parts, but it also serves to cool the compressor. The dome of a rotary compressor is under high pressure.

CONDENSERS

There are three types of condensers, they are:

- Static condensers
- Forced-draft condensers
- Warm-wall condensers

Since the refrigerant leaves the compressor in the form of high-pressure vapor, some method must be found to change the vapor back into a liquid. It is the function of the condensing unit to condense the vapor to a liquid so that it can be re-used in the refrigeration cycle.

As the refrigerant vapor is pumped into the condenser by the compressor, its temperature and pressure increase. This high temperature allows an effective transfer of heat to the surrounding room air from the surface of the condenser. A large portion of the heat transferred to the room air is the latent heat which was absorbed by the refrigerant in the evaporator. The loss of heat to the room air is sufficient to condense the refrigerant vapor to a liquid.

Condensers are of three main types: air-cooled by natural air circulation, air-cooled by means of a forced fan draft, and indirectly air-cooled through being in thermal contact with (and inside the exterior wall of) the cabinet.

Static Condensers

The most common condenser construction is the static type. This type is usually physically larger than a forced-draft condenser, and is constructed of either finned tubing or tubing interlaced with wire. It is located on the back of the refrigerator cabinet (fig. 1) and relies on the thermal expansion of the surrounding room air to create a draft (convection currents) over the tubing.

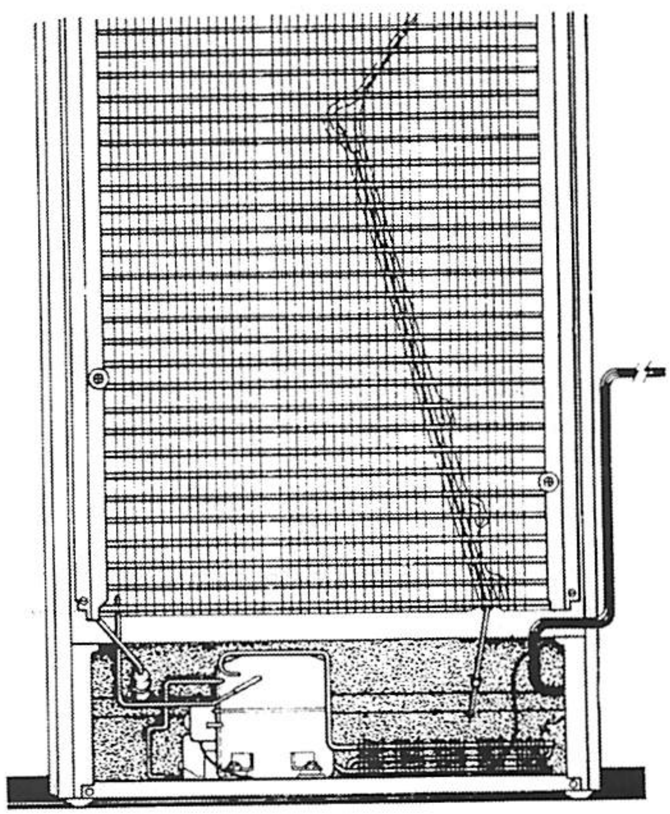


FIGURE 1

Forced-Draft Condensers

Forced-draft condensers are usually constructed with finned tubing. A fan is used to move air over the condenser (fig. 2). The fan is wired into the circuit in such a way that it tuns only during the time the compressor is running. This type of condenser is located in the machine (compressor) compartment and will have the necessary air baffles to direct the air over the finned tubing.

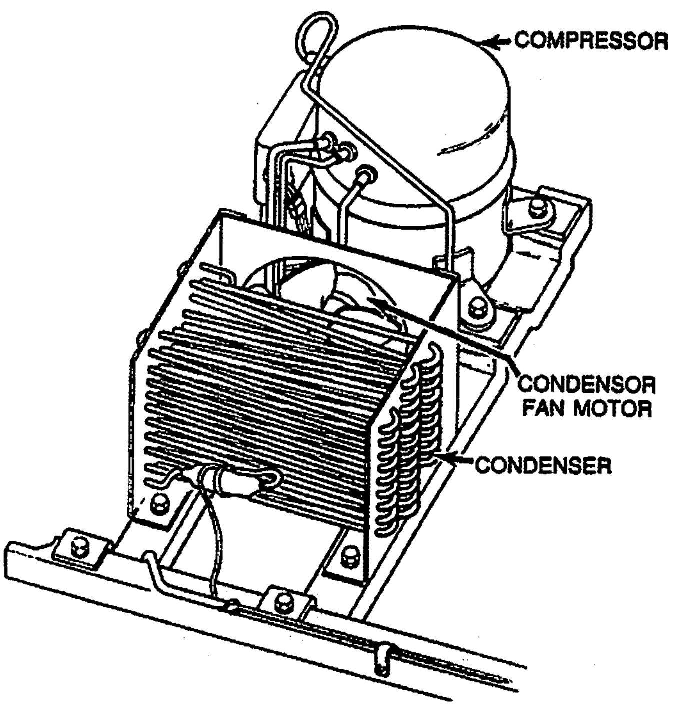


FIGURE 2

Warm-Wall Condensers

A warm-wall condenser is actually another type of static condenser. This type has the condenser tubing fastened directly to, and in thermal contact with, the inside of the outer wall of the cabinet (fig. 3).

Heat is transferred to the cabinet wall from the tubing and from the wall to the surrounding room air. In a warm-wall condenser, the outside of the cabinet will feel warm to the touch when this type of condenser is used and is in operation.

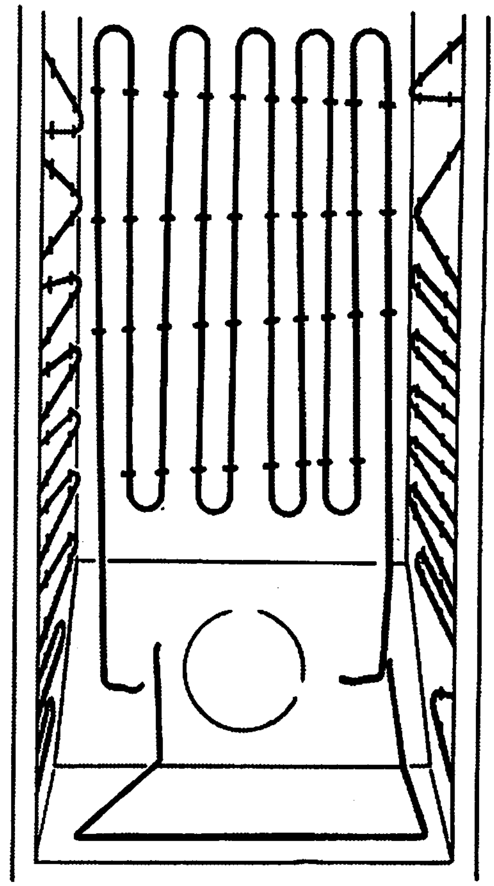


FIGURE 3

EVAPORATOR

The function of the evaporator in a refrigerator is to absorb heat from the air surrounding it, the heat being introduced by food placed in the refrigerator, by heat introduced through the insulation, and by heat entering the refrigerator when the door is opened. Evaporators used in present-day designs are of the direct-expansion type. The are simple to construct, low in cost, and compact, and also they provide a more uniform temperature and rapid cooling. The evaporator consists simply of metal tubing or passages through which the refrigerant flows.

In operation, when the liquid refrigerant leaves the capillary tube and enters the larger tubing of the evaporator, the sudden increase in tubing diameter creates a low-pressure area which causes the *boiling point* of the refrigerant to drop, allowing a more rapid absorption of heat units, In the process of passing through the evaporator, the refrigerant will absorb heat from the surrounding cabinet air and will gradually change from a liquid to a mixture of liquid and vapor, and finally to a vapor.

CAPILLARY TUBE

The capillary tube is essentially a metering device used as a part of the refrigerant circuit. It consists normally of a miniature tube, the length and bore of which depends on the size of the condensing unit and the kind of refrigerant used. The bore or inner diameter is very small and the length varies greatly from a few inches up to several feet. Since the capillary tube offers a restricted passage, the resistance to the flow of refrigerant is sufficient to build up a high enough head pressure in the condenser to change the vapor to a liquid. The operating balance is obtained by properly proportioning the size and length of the tube to the particular system on which it is to be used.

The inside diameter of the tube must, in any event, be such as to keep the tube full of liquid under normal operating conditions. Due to the tiny size of the tube bore, it is important to keep the refrigerant circuit free from dirt, grease, and any kind of foreign matter, since these obstructions may close up the tube and thus make the system inoperative. If the capillary tube becomes plugged, the evaporator will defrost and the unit may run continuously.

ADDITIONAL SYSTEM COMPONENTS

The previous discussion described the basic of fundamental components necessary for any refrigeration system. Other components are sometimes added to the system for various reasons. They are:

- Drier-strainer
- Accumulator
- Precooler

Drier-Strainer

The function of the drier-strainer is to remove any moisture and impurities from the refrigeration system. A typical drier-strainer consists essentially of a tubular metal container, or housing, arranged for connection into the refrigerant circuit. The drying agent, along with an inlet screen, provides the drying and filtering action. Each time the system is entered, the drier-strainer *must* be replaced. If the system did not contain a drier-strainer originally, one *must* be installed. The drier-strainer may be found (fig. 4) (or may be installed) in either the high or low side of the system. However, the drying agent used will be different, depending on which side the drier-strainer is installed.

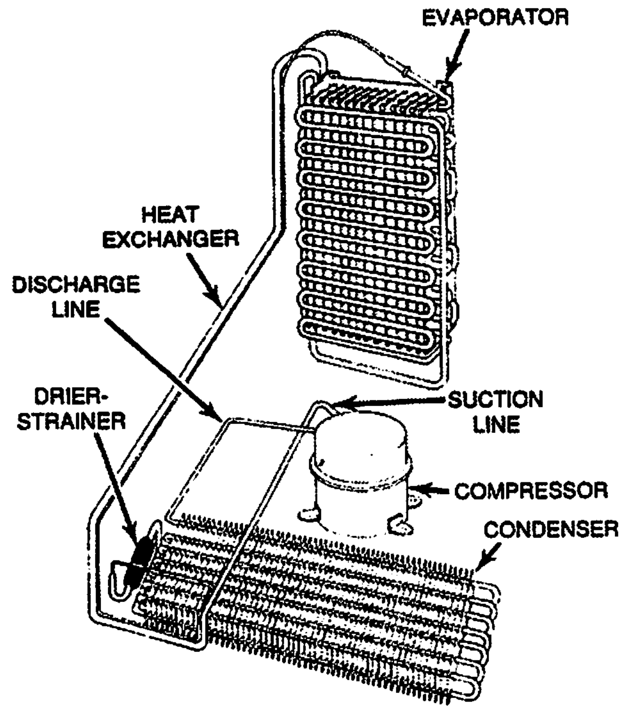


FIGURE 4

Accumulator

The accumulator is added as part of the evaporator in some systems, and is a large cylindrical vessel (fig. 5) designed to hold any liquid refrigerant which may not have changed to a vapor in the evaporator. It is in this manner that any liquid refrigerant remaining in the low side of the system is prevented from entering the suction line and causing damage (slugging) to the compressor. The accumulator must therefore be positioned so that the outlet is always higher than the inlet.

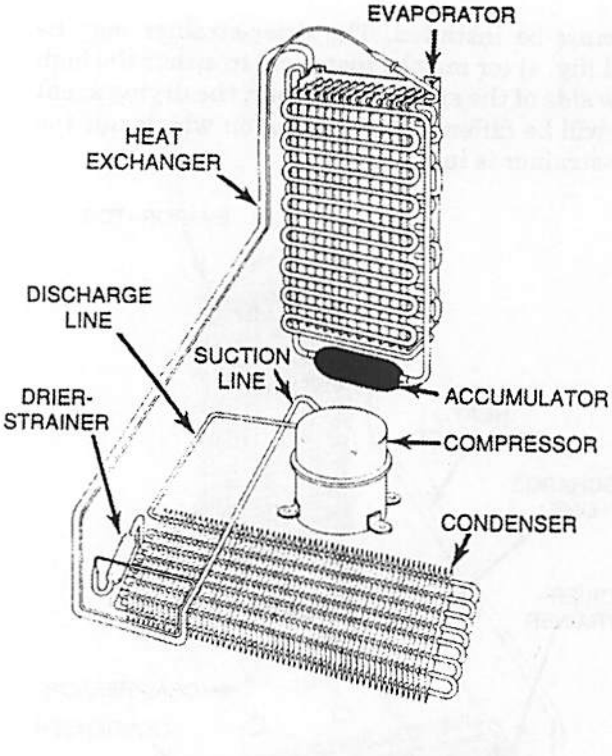


FIGURE 5

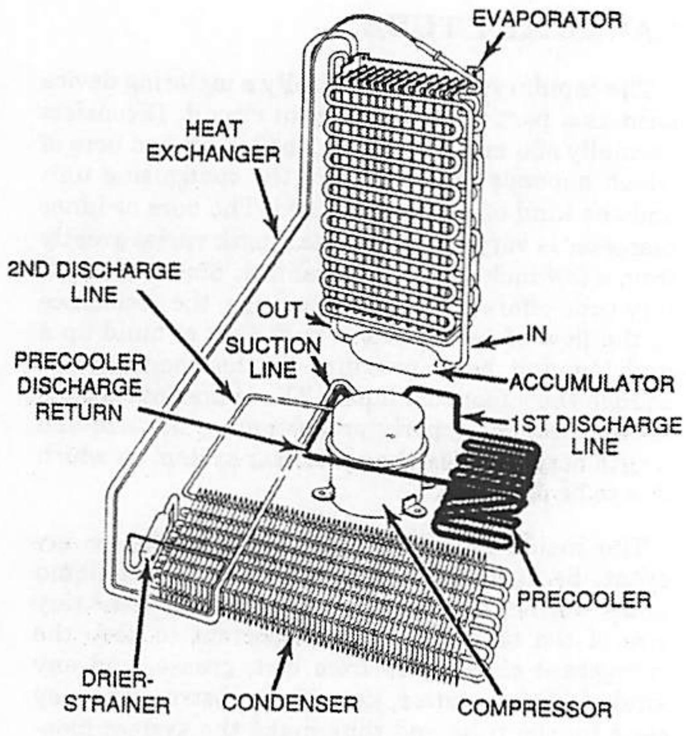


FIGURE 6

Precooler (Rotary Compressor)

With the use of rotary high-side dome compressors, the lubricating oil may become vaporized and leave the compressor as a high-temperature vapor in quantities large enough to either damage the compressor or cause oil restrictions further along in other parts of the system. To minimize the amount of oil circulated through the system, a precooler coil is used (fig. 6). The precooler coil is connected between the 1st discharge port and the discharge return port on the compressor, thus, the oil vapor condenses and is returned to the compressor.

FUNDAMENTALS OF REFRIGERATION

It is of the utmost importance that the refrigeration student understand the meaning of the various kinds of pressure as related to refrigeration. They are:

- Atmospheric Pressure
- Gauge Pressure
- Absolute Pressure

Atmospheric Pressure

Atmospheric pressure is that pressure which is exerted by the atmosphere in all directions. Standard atmospheric pressure is considered to be 14.695 pounds per square inch (psi) at sea level.

This figure is usually rounded off to 14.7, which is sufficiently accurate for the majority of calculations.

Altitude has a definite and predictable effect on atmospheric pressure. The pressure (or weight) of a 1-inch square column of air at the top of a mountain will be less than at sea level. Also, this same column of air will weigh more (exert a greater pressure) at some point below sea level, as in Death Valley in California, than it will at sea level.

Gauge Pressure

Gauge pressure is that pressure in addition to atmospheric pressure. It is the usual reading in psi obtained on a gauge that reads zero when disconnected from any pressure source. In some instances this reading is referred to as pounds per square inch gauge (psig). In the refrigeration industry, however, the term *psi* always means gauge pressure unless otherwise stated.

Absolute Pressure

Absolute pressure is the sum of gauge pressure and atmospheric pressure at any particular time. For example, If the pressure gauge reads 53.7 psi, then the absolute pressure is 53.7 + 14.7 (atmospheric pressure) or 68.4 psi. Remember, this is at sea level and will vary with other altitudes.

These definitions can be written as follows:

Absolute Pressure = Gauge Pressure *plus* Atmospheric Pressure

or

Gauge Pressure = Absolute Pressure *minus* Atmospheric Pressure

THEORY OF HEAT

The concept of heat that is generally accepted is the so-call *molecular theory* because it is based on the theory that all matter is composed of innumerable, separate, and minute particles called *molecules.* The molecule is so tiny that it is considered to be the smallest independent particle of matter that can exist, so tiny that even powerful microscopes cannot reveal it.

The molecular theory is based on the supposition that the molecules of a substance are not attached to each other by any bond or cement, but are held together by a force known as cohesion or mutual attraction, a phenomenon somewhat similar to the attraction offered by a magnet for iron filings. The molecules, however, are not physically bound or in contact with each other, like the iron filings, but are actually separated to such an extent in some instances (and usually so at higher temperatures) that the space separating two adjoining molecules is larger than either particle. Furthermore, the molecules are not fixed or stationary, but revolve and vibrate within the limits of their allotted space.

Each substance on this earth is composed of different ingredients or various combinations of molecules, and therefore each particular kind and mixture, together with additional peculiarities in physical assembly, have a structure differing from all other materials. It is the rapidity of the motion of the molecules composing a body or mass that determines the intensity of its heat. As an example to point out the connection between the theory of heat and the molecular theory, a bar of lead may be used for illustration. When cold, the molecules undergo comparatively slow motion. But if the bar is heated, the molecular activity becomes more rapid, until its temperature has been increased to a point where molecular motion becomes so rapid and the individual particles so far separated from each other that, with further absorption of heat, they become so weakly cohesive they no longer can hold the body in a rigid or solid mass, and it changes into a liquid.

Further application of heat forces the molecules to greater separation and speeds up their motion to such an extent that the liquid becomes more mobile and finally results in a gas or vapor being produced. The vapor thus formed no longer has a definite volume, such as it had in either the solid or molten (liquid) form, but will expand and completely fill any space that is provided for it. The vapor, of course, contains the same number of molecules that were in the original solid. The difference is that molecular action is extremely active in the vapor phase, comparatively slow in the instance of the liquid, and slowest in the solid form. The motion of the molecule is somewhat like a bicycle rider; at a slow speed a very small turning circle can be adhered to, but with each advance in the rate of travel, larger turning circles are required.

UNITS OF HEAT

The *quantity* of heat contained in a body is not measurable by a thermometer, which indicates only the temperature or *intensity.* For example, a gallon of water and a pint of water may both have the same temperature, but we are certainly aware that the larger body must have more heat within it than the smaller.

The unit of heat measure employed in this country is called the *British Thermal Unit,* more commonly referred to as the BTU, and it is that quantity of heat required to be added to one pound of pure water initially at a temperature of its greatest density (that is, 39°F) to raise its temperature one degree on the Fahrenheit thermometer (in this case to 40°F). Roughly, a BTU may be said to be the quantity of heat required to raise the temperature of one pound of water one degree on the Fahrenheit scale.

Just as the thermometer is used as a measure of the intensity of the heat of a body, the BTU is used to represent the quantity of heat energy. For instance, one body at 50°F may contain twice as many BTU's as another body at the same temperature, because the bodies may be different in size or weight and, of great importance, may have different capacities for absorbing heat.

SPECIFIC HEAT

It could be said that each and every substance on the earth has a different capacity for absorbing heat. Some identical materials, especially natural formations, even give different values for samples secured in different localities. As an illustration of the difference in the heat capacities of materials, let us consider a pound of iron and a pound of water, both at 80°F. If the heat is removed from these bodies, and the number of BTU's extracted in cooling each mass to the same temperature is recorded, it will be found that each will give up a different amount. If each body had been at a temperature of 80°F, and was cooled to 60°F (a reduction of 20°F on the Fahrenheit scale), it would be found that 1 pound of water at 80° cooled to 60° would give up 20 heat units or 20 BTU.

If the iron (of the same weight) is cooled over the same range, only 2.6 BTU will be extracted (approximately 1/8 of that taken from the same weight of water under identical conditions). We therefore come to the conclusion that all materials absorb heat in different capacities, and by comparing the heat-absorbing qualities with a standard, we have a standard of measure, a gauge to compare all substances. This measure is the amount of heat, expressed in BTU's required by one pound of a substance to change its temperature 1 degree Fahrenheit. Since water has a very large heat capacity, it has been taken as the standard, and since one pound of water requires 1 BTU to raise its temperature 1 degree, its rating on the specific-heat scale is 1.00. Iron has a lower specific heat, its average rating being 0.130; that of ice, 0.504; of air, 0.238; and of oak 0.570. The more water an object contains, as in the case of fresh food or air, the higher the specific heat. Materials usually stored in a refrigerator have a high specific heat, averaging about 0.80.

Table 1. Average Specific Heats

Water	1.000
Copper	0.095
Vinegar	0.920
Alcohol	0.659
Air	0.238
Mercury	0.033
Coal	0.241
Brass	0.094
Pine	0.650
Strong Brine	0.700
Oak	0.570
Ice	0.504
Glass	0.194
Iron	0.130
Sulphur	0.202
Zinc	0.095

Table 1 lists the average specific heats of a number of common substances. With this table, their relative heat capacities can be compared with water. Observe that metals have limited heat storing powers as compared with water. This is one of the reasons why scalds from hot water burn so deeply, for the water contains so much heat energy that a considerable amount is released and will cause a worse burn than molten metal at a much higher temperature.

SENSIBLE HEAT

The specific heat of various foods and their containers are of interest to the refrigeration engineer when estimating the amount of heat to be extracted by a cooling or refrigeration system. The heat that can be felt and measured with a thermometer is termed *sensible heat,* its name denoting it as the heat we can sense or feel. It is the sensible heat which forms the greater part of the heat load that the refrigeration system is called on to remove in cooling.

LATENT HEAT

One of the most mystifying laws to understand is that of latent heat. The word itself, *latent*, expresses it aptly enough, for it means hidden or not apparent.

We are aware that most substances are capable, under proper conditions, of assuming two or more physical states. For instance, lead, when cold, is a solid, and when heated and molten, a liquid. Water gives us an outstanding example, for it can assume three states; that is, solid, liquid, and vapor within a relatively short temperature range. Ice, of course, represents the solid state; water, the liquid; and steam, the vaporous or gaseous state. Latent heat is also defined as that heat which brings about a change of state with no change in pressure or temperature. Latent heat cannot be measured on a thermometer.

HEAT TRANSMISSION

In refrigeration, we are interested in getting the heat contained in a room or refrigerator to a medium that will cause its removal. Ice is a simple method and was at one time widely used. The more modern refrigerators are equipped with a cooling apparatus that takes the place of ice and provides for more constant and cooler temperatures. Before we can study how heat is taken up (absorbed) and removed mechanically, it is imperative to learn all we can about the characteristics and behavior of heat.

One of the most important laws has already been mentioned, that which refers to the flow of heat from a body at a higher temperature to one having a lower sensible heat. Never of its own accord will heat or water flow up hill or in the opposite direction. Therefore, heat in a refrigerator or room will flow to the cooler object, such as ice or the cooling device.

The transmission of heat may be accomplished in three ways:

- By conduction
- By convection
- By radiation

Conduction

This is the transfer of heat by molecular impact from one particle of a material to another. For instance, if the end of a bar of iron is heated in a fire, (fig. 7) some of the heat will pass through the bar to the cooler portion. Heat traveling in a body, or from one body to another where the two are in intimate contact, is termed *conduction.*

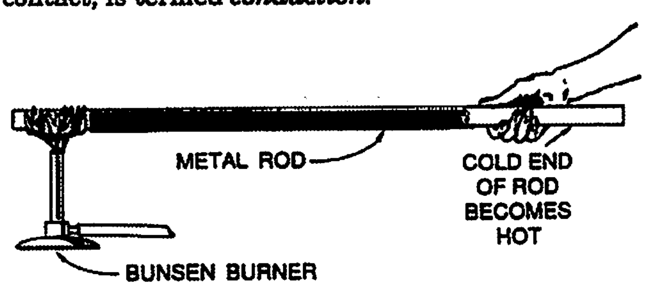


FIGURE 7

Metals are usually very good conductors of heat. Each and every material has a conduction value, some good like the metals, others fair, and a few very poor. For instance, heat will quickly pass through a piece of copper but will have considerable difficulty in passing through a piece of cork. The materials that have very low heat conductivities are termed heat insulators. Even the very poorest conductors, or insulation materials, allow a certain amount of heat to pass through. There is no material which offers a perfect barrier or resistance to the passage of heat. Insulators will slow down the transfer of heat but cannot completely stop it.

Convection

Convection is the principle used in hot-air heating. Air that is free to circulate, such as in any air body of appreciable size, will be set into motion when a difference of temperature occurs, for it will absorb heat from the warmer wall, become heated, expand and become lighter. The heated air will rise and the cooler air will move into its place, which in turn will become heated. The heated air eventually moves over to the colder wall, and the heat flows from the air to the colder wall. Thus, any body of air capable of motion will transmit heat by convection (fig. 8). Hot-air and hot-water heating systems work on the convection principle. They convey heat by bodily moving the heated substance from one place to another.

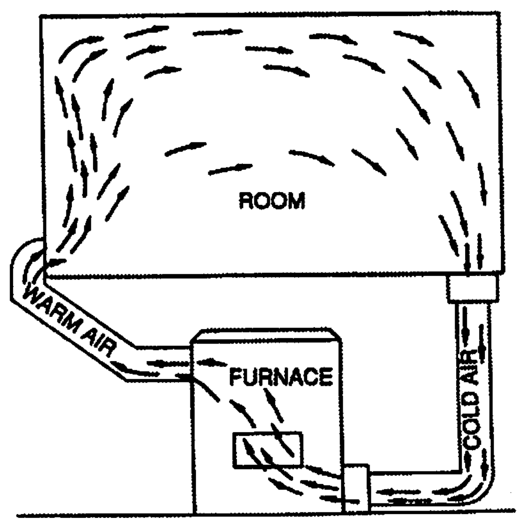


FIGURE 8

The most efficient heat insulation known is a vacuum, but except for very small containers, it is structurally impractical to employ it commercially. The next best insulating medium is air subdivided into the smallest possible units so that is does not move, or is stagnant. Air that is contained in spaces of appreciable size, such as between the double walls of refrigerators, will circulate and transmit heat by convection. Fiberglass is an insulation material of a high order and has great resistance to the passage or transmission of heat because of its air content. The air cells in fiberglass are of such a small size that the air trapped in them is so restricted that only a little circulation is possible and is, for all practical purposes, still air, so that little or no convection occurs. Polyurethane foam is another excellent insulation that is now being used extensively.

Radiation

Heat energy transmitted through the air in the same way light is sent out by a lighted lamp, a radiant heater, or the sun, is called radiant energy (fig. 9). Large cold-storage warehouses, auditoriums, theaters, and homes are built with consideration of the heat absorbed through radiant energy from the sun. Small household appliances rarely have to consider any radiant-heat factor, for they are used in existing structures without any change in building design and are sheltered from direct heat.

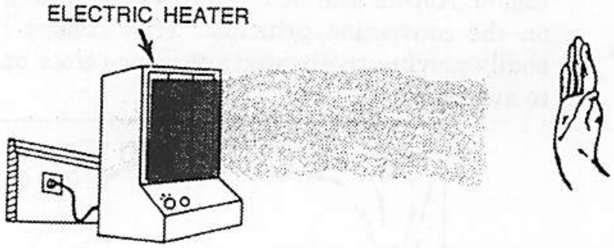


FIGURE 9

REFRIGERANTS

Refrigerants are heat-carrying mediums which absorb heat at a low temperature level and can be compressed (increased in pressure) to a higher temperature where they are able to give off the absorbed heat. The ideal refrigerant would be one that could discharge all of the heat it is capable of absorbing.

DESIRABLE PROPERTIES

The requirements of a good refrigerant are:

- Low boiling point.
- Safe and nontoxic
- Easy to liquefy at a moderate pressure and temperature.
- High latent-heat value (able to absorb a large quantity of BTU heat units).
- Capable of changing state under normal pressure changes.
- Able to mix well with oil.
- Noncorrosive to metal.
- Nonflammable.

CLASSIFICATIONS

Refrigerants may be divided into three classes according to their manner of absorption or extraction of heat from the items to be refrigerated.

Class 1 - This class includes those refrigerants that cool materials by the absorption of the latent heat. These include *R-12, R-22,* ammonia, methyl chloride, etc..

Class 2 - The refrigerants in this class are those that cool substances by absorbing their sensible heat. These include air, calcium-chloride brine, sodium-chloride (salt) brine, alcohol, and similar solutions.

Class 3 - This group consists of solutions that contain absorbed vapors of liquefiable agents or refrigerating media. These solutions function by their ability to carry the liquefiable vapors that produce a cooling effect by the absorption of latent heat. An example of this group is aqua ammonia, which is a solution composed of distilled water and pure ammonia.

The refrigerants in Class 1 are used in the standard *compression* type of refrigerating systems, such as home refrigerators, dehumidifiers, and air conditioners.

THE CHLOROFLUOROCARBON REFRIGERANTS

The chlorofluorocarbon* family of refrigerants is presently used almost universally in household type refrigeration appliances. In the past, refrigerants selected for use were chosen principally for their boiling points and pressures, and their stability within the system or unit regardless of other important and necessary properties such as nonflammability and nontoxicity. Of course, there are many factors that must be taken into account when selecting a chemical compound for use as a refrigerant other than boiling point, pressure stability, toxicity, and flammability. They must include molecular weight, density, compression ratio, heat value, temperature of compression, compressor displacement, design or type of compressor, etc., to mention only a few of the major considerations.

*The chlorofluorocarbon family of refrigerants originally designated as *Freon-12, Freon-22,* are presently listed under various trade names simply as *Refrigerant-12, Refrigerant-22,* or merely as *R-12, R-22* or *F-12, F-22.*

CHEMICAL PROPERTIES

The chlorofluorocarbon refrigerants are colorless, almost odorless, and boiling points vary over a wide range of temperature. The chlorofluorocarbon refrigerants that are in general use are nontoxic, noncorrosive, non-irritating, and nonflammable under all conditions of usage. (*CAUTION: Even though nonflammable, chlorofluorocarbon gas, when exposed to open flame, will produce phosgene gas which is highly toxic).* They are generally prepared by replacing the chlorine or hydrogen molecules with fluorine. Chemically they are inert and are thermally stable up to temperatures far beyond conditions found in actual operation.

OPERATING PRESSURES

Operating pressures will vary with the temperature of the condensing unit, amount of condenser surface, operating back pressure, condition of the condenser surface, extent of superheating of the refrigerant gas, and other factors. NOTE: Superheat is that condition in which a gas is heated to a temperature higher than it would normally be at the pressure under which it is existing.

REFRIGERANT-12 (R-12)

R-12 has a boiling point of -21.6°F and is extensively used as a refrigerant in air-conditioning systems as well as in refrigerators and freezers. The health hazards resulting from exposure to R-12 when used as a refrigerant are remote. R-12 is in a class of specially nontoxic gases. Vapor in any proportion will not irritate the skin, eyes, nose, or throat, and being odorless and non-irritating, it eliminates all possibilities of panic hazards should it escape from a refrigeration system. A pound of R-12 liquid expands to 3.8 cu. ft. of vapor at 68°F room temperature. R-12 is a stable compound capable of undergoing, without decomposition, the physical change to which it is commonly subjected to in service, such as vaporization, compression, and high temperatures.

REFRIGERANT-22 (R-22)

R-22 has a boiling point of -41.4°F and is used as a refrigerant in industrial and commercial low temperature refrigerating systems to -150°F and also in window-type and free-standing room coolers and central air-conditioning units. R-22 is also used in locker and processing plants where lower temperatures result in quicker freezing of foods, greater volume of products handled by the quick freezing units, and countless numbers of other low temperature industrial applications.

PRESSURE-TEMPERATURE RELATIONSHIP

The relations between pressure and corresponding temperatures in Fahrenheit degrees of *R-12* and *R-22* are given in Table 2. For example, at a pressure of 21 psi, the temperature of *R-12* will be 20°F. If the pressure is increased to 77 psi, the temperature will increase to 75°F.

The reason why a torch *should not* be used to heat a tank of refrigerant is evident. The torch flame temperature is so high that pressures above the tank safety capacities can too easily be reached. The tank could rupture and explode.

Pressures at or below the tank safety limits may still be too high for the connection hoses when the tank valve is opened. For safety's sake, use nothing warmer than hot water if you wish to warm a refrigerant drum or tank.

Table 2. Pressure-Temperature Relationship (Vapor Pressure-psig)

Temp. °F	R-12	R-22
-60	19.0	12.0
-55	17.3	9.2
-50	15.4	6.2
-45	13.3	2.7
-40	11.0	0.5
-35	8.4	2.6
-30	5.5	4.9
-25	2.3	7.4
-20	0.6	10.1
-15	2.4	13.2
-10	4.5	16.5
-5	6.7	20.1
0	9.2	24.0
5	11.8	28.2
10	14.6	32.8
15	17.7	37.7
20	21.0	43.0
25	24.6	48.8
30	28.5	54.9
35	32.6	61.5
40	37.0	68.5
45	41.7	76.0
50	46.7	84.0
55	52.0	92.6
60	57.7	101.6
65	63.8	111.2
70	70.2	121.4
75	77.0	132.2
80	84.2	143.6
85	91.8	155.7
90	99.8	168.4
95	108.3	181.8
100	117.2	195.9
105	126.6	210.8
110	136.4	226.4
115	146.8	242.7
120	157.7	259.9
125	169.1	277.9
130	181.0	296.8
135	193.5	316.6
140	206.6	337.3
145	220.3	358.9
150	234.6	381.5
155	249.5	405.1
160	265.1	429.8

CARE IN HANDLING REFRIGERANTS

It has been observed that one of the requirements of an ideal refrigerant is that it must be nontoxic. In reality, however, all gases (with the exception of pure air) are more or less toxic or asphyxiating. It is therefore important that wherever gases or highly volatile liquids are used, adequate ventilation should be provided, because even nontoxic gases can produce a suffocation effect, by displacing the oxygen in the air.

R-12 is not irritating and can be inhaled in considerable concentrations for a short period without serious consequences. *It should be remembered, however, that liquid refrigerants will freeze or remove heat from anything with which they come in contact when released from a container,* as in the case of an accident. In other words, liquid refrigerant spilled on any part of the body will produce freezing. A physician should be called immediately to treat the affected area.

HANDLING REFRIGERANT CYLINDERS

It is of the utmost importance to handle cylinders of refrigerant with care and to observe the following precautions:

- Never drop cylinders nor permit them to strike each other violently.
- Never use a lifting magnet or a sling (rope or chain) when handling cylinders.
- Caps for valve protection, when provided, should be kept on the cylinders except when the cylinders are in actual use.
- Never overfill cylinders. Never recharge throw away type cylinders. To do so may result in serious injury or possible death. Whenever refrigerant is discharged from or into a cylinder, immediately thereafter weigh the cylinder and record the weight of the refrigerant remaining in the cylinder.
- Never mix refrigerants in a cylinder.
- Never use cylinders as rollers, for supports, or for any purpose other than to carry refrigerants.
- Never tamper with the safety devices in valves or cylinders.

- Open cylinder valves slowly. Never use wrenches or tools except those provided or approved by the manufacturer.
- Make sure that the threads on regulators or other unions are the same as those on cylinder valve outlets. Never force connections that do not fit.
- Regulators and pressure gauges provided for use with a particular gas must not be used on cylinders containing other gases.
- Never attempt to repair or alter cylinders or valves.
- Never store cylinders near highly flammable substances such as oil, gasoline, waste, etc.
- Always wear safety goggles when working with refrigerants.
- Never heat cylinders with an open flame to remove refrigerant; tank rupture or explosion could result.

NOTES