MANUAL 2100-049

BASIC REFRIGERATION TERMS AND PRINCIPLES

REFRIGERATION, HEATING AND AIR CONDITIONING

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BASIC REFRIGERATION TERMS AND PRINCIPLES

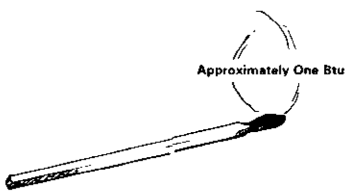
Understanding how a refrigeration system works requires knowledge of some basic principles. The following section discusses the terms and principles used in the air conditioning industry.

HEAT

Heat is a form of energy. Energy is the capacity to do work. Therefore, heat energy is essential to our daily lives. Since heat is a form of energy, it follows the Law of Conservation of Energy. This law states that energy can neither be created nor destroyed but can change form.

BTU

The unit of measurement for heat energy in the English System is the Btu (British thermal unit). It is equivalent to the quantity of heat needed to raise the temperature of 1.0 pound of water 1.0° Fahrenheit. One Btu is approximately the amount of heat given off by the flame of an ordinary wooden kitchen stick match.



HEATING

Heat is the presence of Btus. Heating is the addition of Btus to any matter.

COOLING

If heating is the presence of Btus, then cooling can be defined as the absence of Btus. When Btus are rejected from any matter, the result is a cooling effect.

MATTER

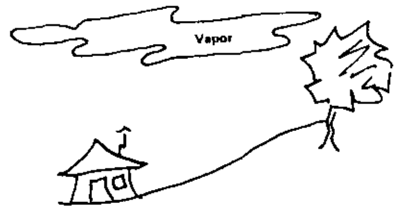
All matter is composed of infinitely tiny particles called molecules or atoms. The heat energy content and the distance between these particles divide matter into three broad categories. They are solids, liquids and gases.

SOLIDS

Matters that maintain their sizes and shapes are called solids. The atoms in these materials are closely packed and have little movement. A brick is an example of a solid.

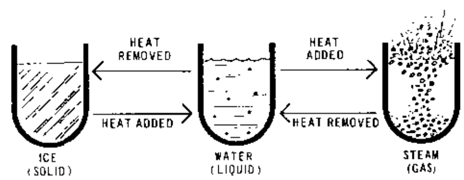
LIQUIDS

Matters that maintain their quantities but take the shape of the container they occupy are called liquids. The molecules in these materials are not so closely packed and are in motion because of their energy.



GASES

Matters that maintain neither sizes nor shapes are classified as gases sometimes called vapors. The molecules or atoms are far apart and in rapid motion.



THE THREE STATES OF MATTER

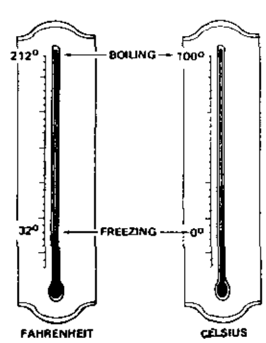
TEMPERATURE

Temperature is the measure of the intensity of heat. A thermometer is normally used to sense or measure temperature.

Heat cannot be seen and has neither weight nor dimension. However, heat can be detected and measured by its effect on other substances. For instance, heat energy causes many substances to expand. Thus, if a tube of mercury is inserted in a substance to which heat energy is added, the mercury expands and rises in the tube. This is how a thermometer works. Two scales of temperature measurement are the Fahrenheit (F) scale and the Celsius (C) scale. While many other parts of the world use Celsius thermometers, temperature is normally measured on Fahrenheit thermometers in the United States.

NOTE: The formula for converting a Fahrenheit reading to Celsius is: °F = 9/5 °C + 32°

The formula for converting Celsius to Fahrenheit is:
°C = 5/9 (°F-32)

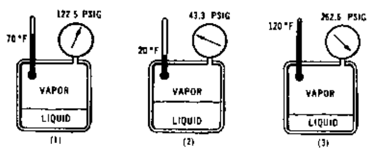


PRESSURE

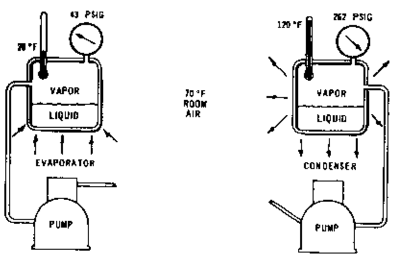
Pressure can be defined as a force per unit area that is exerted on a surface by matter. In the case of a gas in a container, the atoms are in motion and collide with the sidewall. These collisions are a force, just like a ball thrown against a wall, and represent pressure on each square inch of surface area.

The pressure of a gas in a container can be changed. More gas could be added to the volume so there would be a greater frequency of collisions per square inch, increasing pressure. Another way would be to add heat energy to the gas. The atoms would absorb the energy and move faster and faster; therefore, the collisions would be more intense and more often. The pressure again increases.

The earth is surrounded by layers of air or atmosphere. This air exerts a pressure which goes unnoticed to the casual observer. A barometer measures air pressure in pounds per square inch gauge (psig). Standard atmospheric air pressure is 14.7 psig. This is the pressure that exists at sea level. Air pressure decreases as elevation increases; thus, air pressure on a mountaintop is less than 14.7 psig.



EFFECTS OF CHANGING TEMPERATURES



EFFECTS OF CHANGING PRESSURES

EVAPORATION

By definition, evaporation is the process of changing a liquid to a gas (vapor). Heat energy (Btus) must be added to set atoms in rapid enough motion to become a vapor.

CONDENSATION

The condensation of a vapor to a liquid is the opposite process of evaporation. Heat must be withdrawn or rejected from the vapor. When energy is removed from atoms, their motion slows down; they come closer together and form liquid.

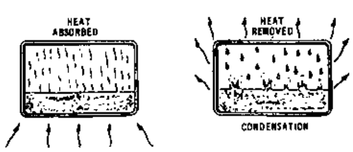
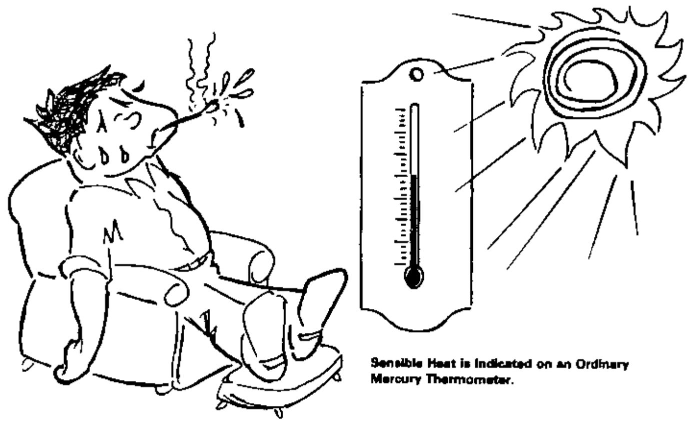


Figure 12
EFFECTS OF ABSORPTION AND REMOVAL OF HEAT

SENSIBLE HEAT

Sensible heat energy can be detected by touch and is indicated on an ordinary mercury thermometer.



MERCURY EXPANDS ON TEMPERATURE RISE

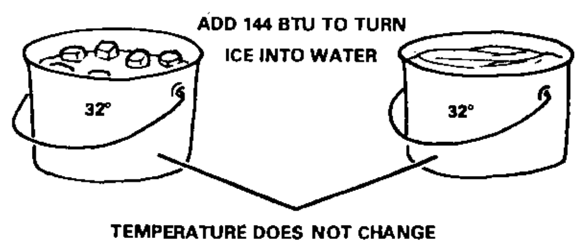
CHANGE OF STATE

Many common substances can exist as either a solid, liquid or gas, depending upon the temperature and pressure to which they are exposed. For example, at sea level atmospheric pressure, water freezes to a solid at 32°F (0°C) and vaporizes or boils to a gas at 212°F (100°C).

A substance that changes from one form to another is said to have undergone a change of state. A transfer of heat energy is required to change the temperature and in turn change the state of that substance.

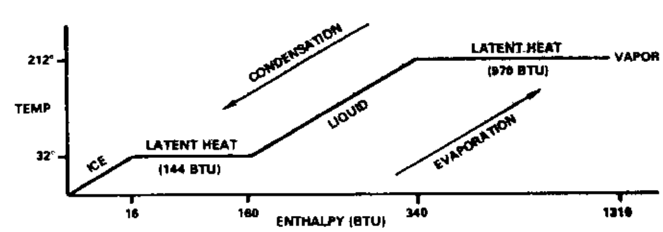
LATENT HEAT

Latent or "hidden" heat is the heat energy that must be absorbed or released in order for a substance to change state. For example, one pound of ice at 32° absorbs 144 Btu of heat energy when changing state from solid to liquid. One pound of water at 32° releases 144 Btu of heat energy when changing from liquid to solid. This heat energy does not change the temperature of the substance; thus, it is sometimes referred to as hidden heat.



Heat energy in the form of latent heat is also involved when a substance changes state from a liquid to a vapor (called evaporation) or from vapor to liquid (called condensation).

In order for one pound of 212° water to evaporate to steam at sea level atmospheric pressure, 970 Btu of latent heat must be absorbed. 970 Btu must be released for one pound of 212° steam to condense to water at sea level.

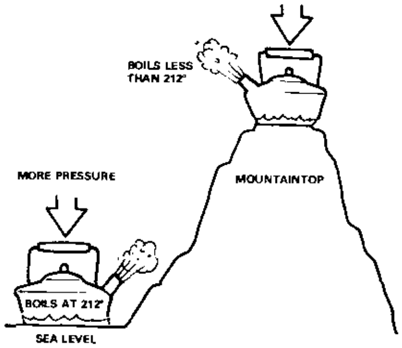


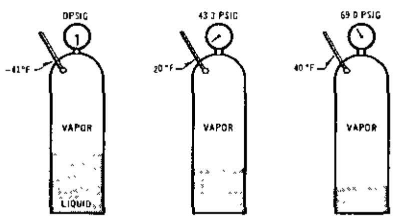
CHANGES OF STATE FOR WATER

VAPOR PRESSURE

The pressure exerted by a vapor on a surface is vapor pressure. Vapor pressure is especially important on the surface of a liquid. This is because vapor pressure affects the boiling point of a liquid. Water at sea level boils at 212°F. Air (vapor) pressure pushes down on the surface of the water. Enough heat has to be added to the water to give the molecules enough energy (212°F) to overcome the atmospheric pressure as the water boils. When water is boiled on a mountaintop, less heat energy is required. Since there is less atmospheric pressure on the surface of the water, the water will boil at less than 212°F.

In general, if the vapor pressure increases on a liquid, the boiling point increases as in a pressure cooker. If the vapor pressure decreases on a liquid, the boiling point decreases.





R-22 BOILING TEMPERATURE UNDER VARYING PRESSURES

SATURATED CONDITIONS (SATURATION)

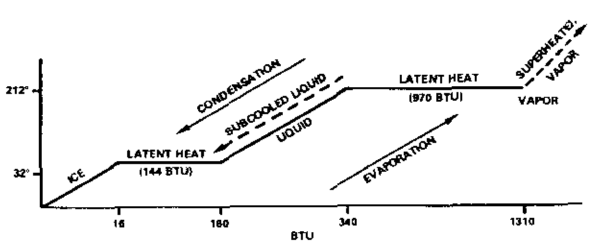
Saturated conditions occur when liquid and vapor of that liquid are present in the same container. Also, for a given heat energy level the liquid and vapor phases are in equilibrium with each other. (As temperature increases, counter vapor pressure increases on the surface of the liquid.)

SUPERHEATED VAPOR

Superheated vapor is the term used to describe a vapor that is heated to a temperature above its vaporization point.

SUBCOOLED LIQUID

Any liquid which is cooled to a temperature lower than its condensation temperature is said to be subcooled.



CHANGES OF STATE FOR WATER

ENTHALPY

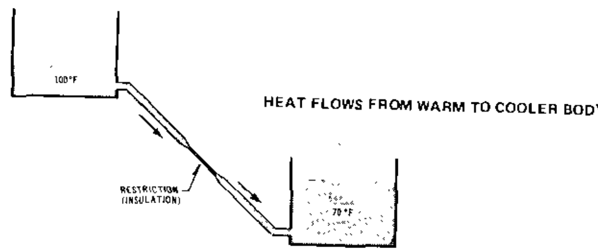
Enthalpy is a measure of the total heat content of matter. It is expressed in Btu per pound of substance. It accounts for both sensible heat and latent heat. As an example, the more moisture there is in a pound of air the greater the enthalpy. This is because additional heat is required to change a liquid to a vapor. The heat energy of the water vapor contributes to the overall heat content.

HEAT TRANSFER

Since heat is a form of energy, it cannot be created or destroyed. However, it can be moved or transported from one place to another through many varied mediums.

In order to understand how a cooling system works, one must first understand the ways in which heat transfer can occur. Water always flows downhill, never uphill, always from a higher level to a lower level. In a similar way, heat can be thought of as always flowing in one direction, from a position of higher temperature to one of lower temperature.

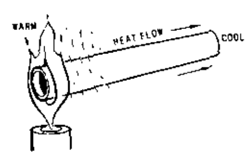
When water is flowing downhill, the steeper the hill the faster the water travels. Likewise in the transfer of heat, the greater the temperature difference the greater the quantity of heat that will flow in a unit of time. The transfer of heat takes place in three main ways—conduction, radiation and convection.



HEAT FLOW AS COMPARED TO WATER FLOW

CONDUCTION

This is the flow of heat through a substance caused by the transfer of heat energy from particle to particle. Heat energy flows from the warmer region to the colder region. For example, if a rod is heated over an open flame, heat travels by conduction from the hot end to the cooler end. Conduction heat transfer occurs not only within an object or substance but between different substances which are in contact with one another as well.

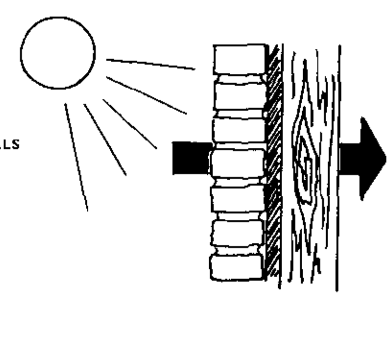


HEAT TRAVELS BY CONDUCTION FROM HOT TO COLD

HEAT FLOW IN METAL BAR

A good example of this is house construction. In house construction, there is a combination of wood, insulation, plaster, brick and even concrete. These materials are often touching each other. If it is hotter in the house than outdoors, heat by conduction will pass through these materials. If it is hotter outdoors than it is in the house, heat will flow into the house.

CONDUCTION CAN TAKE PLACE BETWEEN DIFFERENT MATERIALS



RADIATION

Radiation is the transfer of heat through space just as light travels through space. Radiant heat passing through air does not warm the air through which it travels. All objects radiate heat—the higher the temperature of the object, the greater the quantity of heat which it radiates. The amount of radiant energy given off in a unit of time depends not only on the temperature of the radiating body, but also on the extent and type of its surface. At the same temperature, a rough dark surface, for example, radiates much more heat than another surface which is smooth and bright.

CONVECTION

Convection is the transfer of heat due to the movement of fluid. The simplest definition of fluid is anything that flows. Gas and liquids are both fluids. Air is a mixture of several gases, so it is a fluid. As the air flows or moves, it carries heat from one place to another.

TEMPERATURE - PRESSURE RELATIONSHIP

The principles of temperature and pressure are directly related when applied to a gas in a confined space. If temperature increases, then the pressure will increase. If temperature decreases, then the pressure will, likewise, decrease.

Absolute pressure of a confined gas at constant volume is proportional to absolute temperature. Thus, if a given volume of gas is confined in a container and subjected to changes in temperature, the pressure of the gas will change so the quotient of pressure divided by absolute temperature is always the same.

NOTE: A cylinder containing a given weight of liquid varies in volume of liquid and volume of gas with changes in temperature.

Stated Mathematically:

$$\frac{Po\ Vo}{To} = \frac{Pn\ Vn}{Tn} = \text{Constant}$$

BEHAVIOR OF GASES

A basic understanding of the behavior of gases under various conditions is necessary for the refrigeration mechanic. Pressures within the system must be maintained and abnormal pressures must be diagnosed for effective troubleshooting. Throughout much of our refrigeration cycle, our refrigerant is in the form of a gas, and this gas is subjected to varying pressures, temperatures, and volumes. Let us see how our gas is affected by these three factors. Much research has been conducted in this field through the years and two men named Boyle and Charles formulated laws hundreds of years ago which stand to this day as the rule-of-thumb. Boyle found that if he maintained a constant temperature and increased the pressure on a confined gas, the volume would decrease. (Figure 1). Charles added to Boyle's findings by discovering that if he maintained a constant pressure and increased the temperature of a confined gas the volume would increase. (Figure 2).

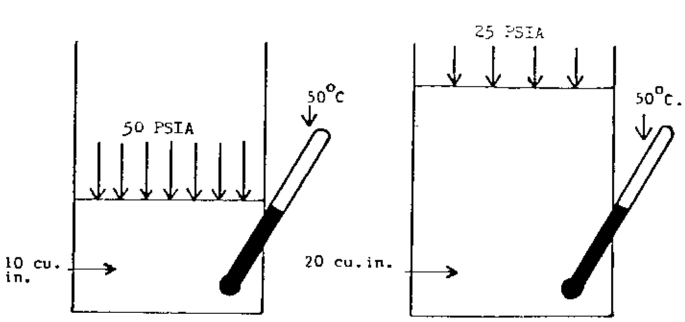


Figure 1 - Boyle's Law

AT A CONSTANT TEMPERATURE, A DECREASE IN PRESSURE = AN INCREASE IN VOLUME.

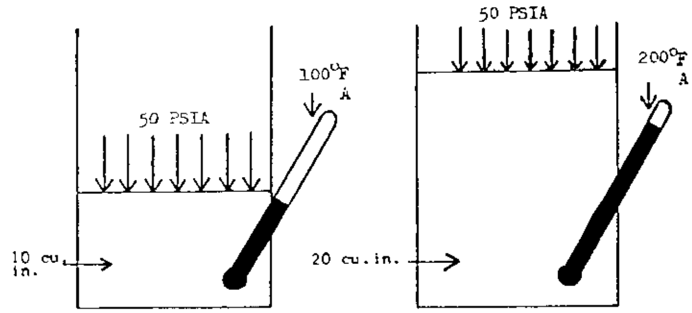


Figure 2 - Charles' Law

AT A CONSTANT PRESSURE, AN INCREASE IN ABSOLUTE TEMPERATURE = AN INCREASE IN VOLUME.

VOLUMETRICS

When heat is added, liquid evaporates. This causes the molecules to move faster and occupy an increased volume or space. The gas of a liquid will expand to larger volumes.

Pressure can be used to "squeeze" molecules of a gas closer together. Depending upon the heat energy content of these molecules, the pressure may be great enough to push them close together and form a liquid.

REFRIGERANT CHARACTERISTICS

Most cooling applications today use either Refrigerant 12 or 22. These are frequently referred to as R-12 and R-22. In order for a refrigerant to efficiently and economically transfer large quantities of heat, it must satisfy several major requirements.

1) It must readily absorb heat when evaporated and reject heat when condensed.

2) It must be capable of being used over and over again in a continuous cycle.

3) It must evaporate at temperatures low enough for normal cooling purposes.

Refrigerants are stored and transported in drums or cylinders. The refrigerant exists at saturated conditions in these drums. There is a liquid level and above the surface of the liquid is vapor. The liquid and vapor are in equilibrium. When the valve on an upright drum is opened, vapor refrigerant escapes. If the valve is opened on an inverted drum, then liquid refrigerant escapes. The valve also consists of a safety fusible metal plug. Its purpose is to help guard the cylinder from over-heating. Refrigerant cylinders are color-coded to aid in identification.

Refrigerant Color Codes

R-12	White
R-22	Light Green
R-11	Orange

R-22 is the standard refrigerant for residential and commercial air conditioning. R-22 is virtually colorless, odorless, non-toxic and non-irritating. R-22 has a much greater refrigeration capacity than R-12. R-12 and R-22 must never be interchanged or substitued for one another.

PHYSICAL PROPERTIES OF REFRIGERANTS

Refrigerants are clear, water-white and practically odorless. They are non-irritating, non-toxic, non-combustible and non-explosive. Because R-22 boils at -41.4°F, it may produce a burn much like that of dry ice if it comes in contact with the skin. The latent heat value of 86.5 Btu/lb is not as great as the 970 Btu/lb for water, but is sufficient for the cooling process.

Refrigerants conform to the temperature and pressure relationships. Charts have been made that depict corresponding pressures for given temperatures. That is, if a drum of refrigerant (R-22) is at 100°F, the pressure inside the drum is nearly 200 psig.

REFRIGERANT CHARACTERISTICS

	Refrigerant-22	Refrigerant-12
Chemical Formula	$CHCl\ F_2$	CCl_2F_2
Boiling Point at Atmospheric Pressure	—41.4°F.	—21.6°F.
Latent Heat of Vaporization @ 45°F.	86.5 Btu/#	65.1 Btu/#
Net Refrigeration Effect	69 Btu/#	51 Btu/#
Specific Heat of Liquid	0.335 Btu/# /°F.	0.24 Btu/# /°F.
Specific Heat of Vapor at Constant Pressure	0.152 Btu/# /°F.	0.145 BTU/# /°F.

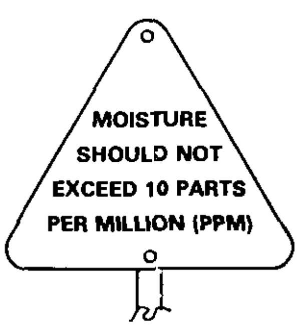
PRESSURE TEMPERATURE CHART
(PRESSURE PSIG)

DEG. F	R-12	R-22	DEG. F	R-12	R-22
-40	11.0"	0.6	55	52.1	93.3
-30	5.5"	4.9	60	57.7	102.4
-20	0.6	10.2	65	63.8	112.2
-10	4.5	16.6	70	70.2	122.5
0	9.2	24.1	75	77.0	133.4
10	14.6	32.9	80	84.2	145.0
12	15.8	34.9	85	91.8	157.2
14	17.1	36.9	90	99.8	170.0
16	18.4	39.0	95	108.3	183.6
18	19.7	41.1	100	117.2	197.9
20	21.0	43.3	105	126.6	212.9
22	22.4	45.5	110	136.4	228.6
24	23.9	47.9	115	146.8	245.2
26	25.4	50.3	120	157.7	262.5
28	26.9	52.7	125	169.1	280.7
30	28.5	55.2	130	181.0	299.7
32	30.1	57.8	135	193.5	319.6
34	31.7	60.5	140	206.6	340.3
36	33.4	63.3	145	220.3	362.0
38	35.2	66.1	150	234.6	384.6
40	37.0	69.0	155	249.5	406.3
45	41.7	76.6	160	265.1	433.3
50	46.7	84.7			

CHEMICAL PROPERTIES OF REFRIGERANTS R-22

Moisture in the form of water or water vapor is the worst enemy of any refrigeration system. At the temperature pressure ranges in a refrigeration system, water reacts with the refrigerant to produce hydrochloric and hydrofloric acids. These strong acids can damage all parts of a cooling system. Another hazard is that the temperature at certain areas in the system is low enough to freeze water. Ice will restrict or block the flow of refrigerant through the lines.

The moisture content of refrigerant in a system should not exceed 10 parts per million (ppm.).



If Refrigerant 22 is placed in the presence of an open flame or even an arcing wire, phosgene gas will be formed. This is a toxic deadly gas which is extremely dangerous. Phosgene was used in chemical warfare during World War I.

An air conditioning system requires a specific amount of refrigerant (also called "charge"). The exact amount of charge a system should contain is determined by making temperature and pressure checks at certain points. "Charging the system" is a term which means injecting new refrigerant into a system whose charge is found to be low. Since charging an air conditioning system requires transporting and removing refrigerant from a drum, and therefore potential direct contact, a number of safety considerations need to be understood.

SAFETY PRECAUTIONS FOR REFRIGERANTS

In order to assure the cleanliness and dryness of refrigerants, strictly adhere to the following:

1. Always purchase refrigerants in factory filled containers to assure clean, dry refrigerant.
2. Avoid transferring refrigerants from one container to another because:
   a. It is virtually impossible to keep out all moisture and air.
   b. Generally, the receiving container will not be chemically or physically clean enough for the purpose.
   c. Over-filling can easily occur, which is dangerous.

Facts to remember about cylinders containing refrigerants:

1. Fusible metal plugs are designed to protect the cylinder in case of fire. They may not protect the cylinder from gradual and uniform overheating.
2. The Interstate Commerce Commission requires that the liquefied compressed gas container shall not be full of liquid at 130F.
3. Above 130F, liquid refrigerant will completely fill a cylinder and hydrostatic pressure will build up rapidly with each degree of temperature rise.
4. Fusible metal plugs begin to soften at 157F and melt completely at 165F. The hydrostatic pressure developed at 157F is far in excess of the cylinder test pressure. Excessive pressure can cause the cylinder to rupture.
5. Never apply a direct flame to a refrigerant cylinder.
6. To provide a margin of safety, never heat a cylinder above 125F. If it is necessary, use a hot water bath.
7. Do not place a resistance heater in direct contact with a refrigerant cylinder.
8. Never transfer refrigerant from one cylinder to another.
9. Do not drop, dent or otherwise abuse refrigerant cylinders.
10. Always replace valve cap and hood cap when cylinder is not in use.
11. Use suitable valve wrench for opening and closing cylinder valve. Loosen valve packing nut before turning valve stem.
12. If not mounted in a suitable stand for withdrawal of refrigerant, all cylinders should be secured in an upright position with the help of a chain or strap. A refrigerant drum that is not secured may roll and shear off the valve. Drum pressure could put it in uncontrolled motion.
13. Always keep refrigerant drums out of direct sunlight, especially on roofs.
14. Safety glasses should be worn at all times when working around refrigerants. This is a cheap insurance policy that pays big dividends if your eyesight is saved.
15. It is a good idea to wear cotton gloves when connecting and removing charging hoses. They afford protection for the skin.

MECHANICAL REFRIGERATION

GENERAL

Refrigeration is the process of removing some undesired heat from a confined space.

BASIC MECHANICAL CYCLE

The basic mechanical refrigeration cycle consists of four stages:

a. Expansion
b. Evaporation
c. Compression
d. Condensation

These stages occur over and over again—always in the same sequence.

CYCLE COMPONENTS

METERING DEVICE. The metering device is a valve or flow meter which regulates the flow of liquid refrigerant from the liquid receiver into the evaporator. This device also produces a great pressure and temperature drop in the refrigerant.

EVAPORATOR. The evaporator is the component in which the actual cooling effect is produced. It is composed of a series of coils of refrigerant tubing located inside the space to be cooled.

COMPRESSOR. The functions of the compressor are to establish the pressure differential required for refrigerant flow and to raise the refrigerant gas pressure and temperature so that it may be condensed easily.

The compressor is driven by an electric motor. The two most common types of compressors used in refrigeration are reciprocating and rotary.

CONDENSER. The condenser is composed of a series of coils of refrigerant tubing. The condenser MUST be located outside of the conditioned space. The two most common condenser cooling mediums are air and water.

FUNDAMENTAL LAWS OF REFRIGERATION

There are three fundamental laws upon which all refrigeration is dependent.

Law No. 1: Heat will flow only from a hot body to a colder body.

Law No. 2: To change the physical state of any substance, (latent) heat MUST be added or subtracted.

Law No. 3: The temperature at which any liquid boils, can be controlled by varying the pressure acting upon its surface.

BASIC CYCLE OPERATION

We'll begin our discussion of the cycle's operation with the metering device.

The metering device acts as a constriction in the refrigerant line (similar to a nozzle in a garden hose) and causes a great pressure temperature drop. This is known as the expansion stage, for while the pressure is being reduced, the volume of the refrigerant is expanded rapidly. The metering device regulates the flow of the now low-pressure, low-temperature liquid refrigerant into the evaporator.

As the refrigerant circulates through the evaporator coils a number of things happen. Heat is transferred from the air from the confined space to the refrigerant (Fundamental Law No. 1); because the refrigerant pressure is low, its boiling point is low (Fundamental Law No. 3). As a result the heat absorbed by the refrigerant will produce boiling and subsequent evaporation to gas. This heat which is absorbed by the refrigerant is latent heat, and results in a refrigerating effect inside the confined space.

The refrigerant leaves the evaporator, as a low temperature, low pressure gas. It is now sucked into the compressor. In this compression stage the gas pressure and temperature is increased.

The now high temperature, high pressure gas is passed into the condenser, where the latent heat previously absorbed (by the refrigerant) in the evaporator, is given off to the surrounding air. The refrigerant boiling point is now quite high because of its pressure (Fundamental Law No. 3). In the condenser, the direction of heat transfer is from the refrigerant to the atmosphere, (cooling medium) and the gas condenses to liquid. This high pressure, high temperature liquid is now passed to the metering device where the cycle will repeat itself.

SYSTEM COMPONENTS

LIQUID LINE. Refrigerant line connecting the condenser and metering device.

SUCTION LINE. Refrigerant line connecting the evaporator and compressor.

DISCHARGE LINE. Refrigerant line connecting the compressor and condenser.

AUXILIARY DEVICES

ACCUMULATOR. Storage tank which receives liquid refrigerant from evaporator during periods of light load and prevents it from flowing into compressor before vaporizing.

DRIER. Water is the enemy of refrigeration systems. Any entrapped moisture will cause corrosion and a reduction in output of the system. The drier, located in the liquid line, contains a chemical which can absorb large amounts of water. Driers should be replaced whenever the unit is opened for repair.

SUMMARY

METERING DEVICE: Meters flow of refrigerant, and lowers temperature by allowing refrigerant to expand. Bard uses a capillary tube restriction type metering device.

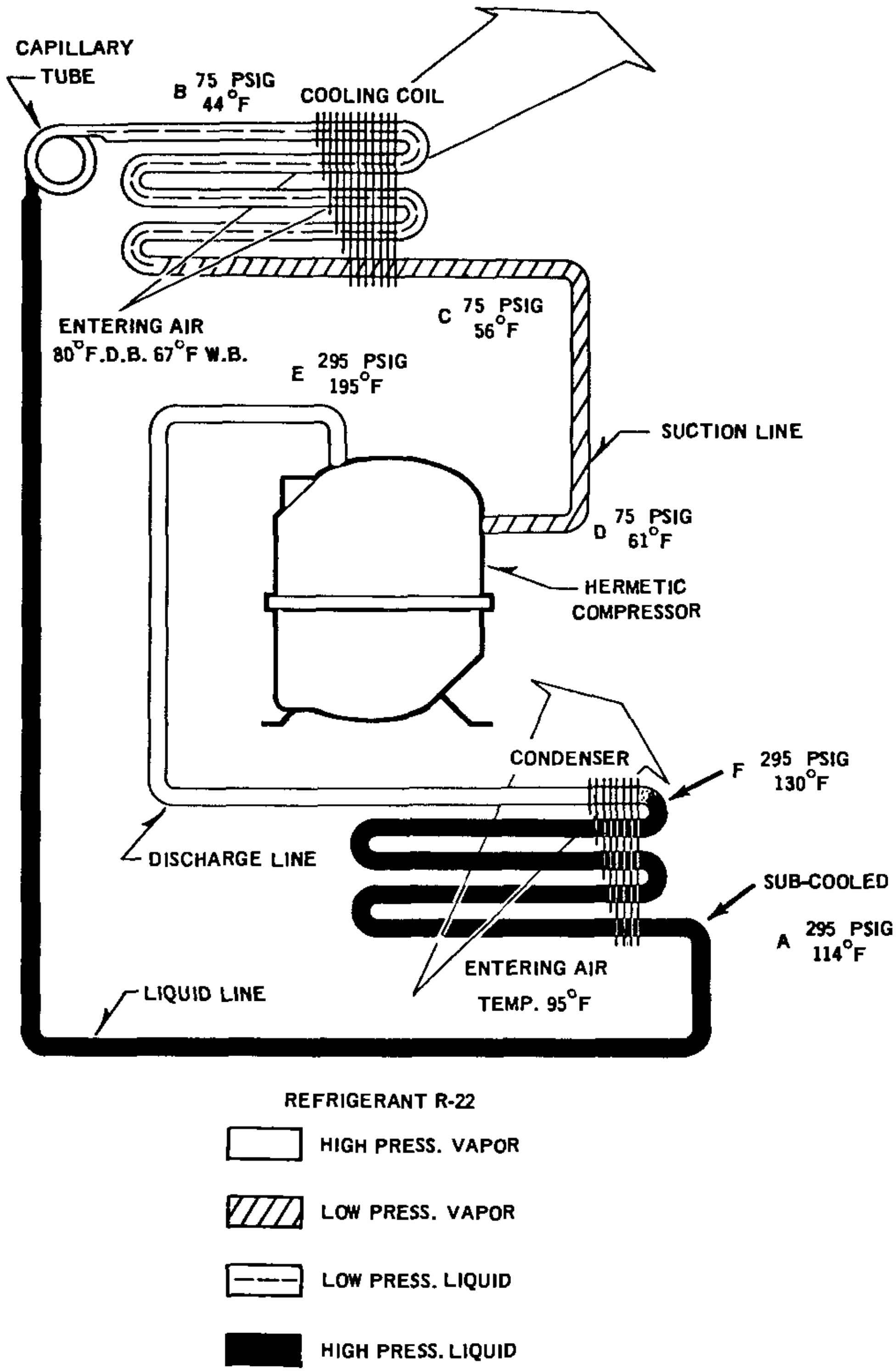
EVAPORATOR(Indoor Cooling): Coils provided for the boiling off, of evaporation (vaporization) of the refrigerant (changing from a liquid to a gas).

COMPRESSOR: Two-fold purpose; help move refrigerant through the system, raise pressure and temperature of refrigerant by compression. *NO LIQUID REFRIGERANT SHOULD EVER GET TO THE COMPRESSOR!!*

CONDENSER: Coils provided for the condensation of the refrigerant (changing from a gas to a liquid).

STEP	DEFINITION	PART
Expansion	Reduction of pressure and temperature and increase in volume	Metering Device
Evaporation	Change of state from a liquid to gas. (Refrigerant absorbs heat)	Evaporator
Compression	Decrease in volume, increase in pressure and temperature.	Compressor
Condensation	Change of state from a gas to a liquid.(Refrigerant gives off heat)	Condenser
LINE	**CONNECTS**	**TEMPERATURE**
Liquid Line	Condenser and Metering Device	Room temperature and above
Suction Line	Evaporator and Compressor	A little cooler than room temperature
Discharge	Compressor and Condenser	Hot

REFRIGERANT CYCLE
CAPILLARY TUBE



REFRIGERATION CYCLE