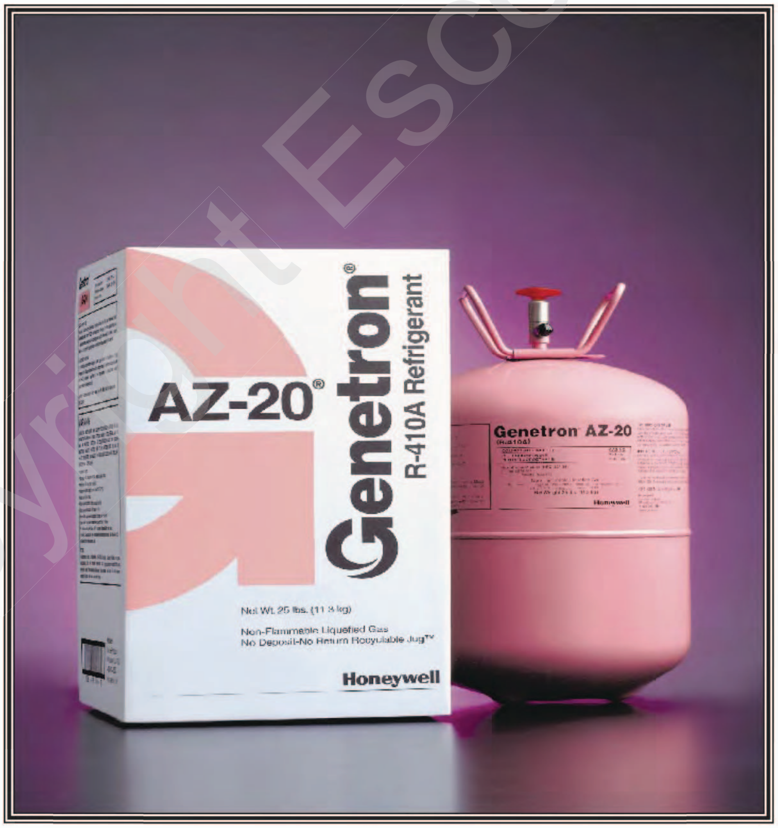
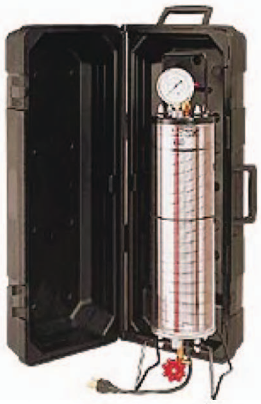
BASIC Refrigeration & Charging Procedures

John Tomczyk





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Mount Prospect, Illinois

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CHAPTER ONE

Refrigerant Pressures, States, and Conditions

The typical vapor compression refrigeration system shown in Figure 1-1 can be divided into two pressures: condensing (high side) and evaporating (low side). These pressures are divided or separated in the system by the compressor discharge valve and the metering device. Listed below are field service terms often used to describe these pressures:

Condensing Pressure	Evaporating Pressure
High side pressure	Low side pressure
Head pressure	Suction pressure
Discharge pressure	Back pressure

CONDENSING PRESSURE

The condensing pressure is the pressure at which the refrigerant changes state from a vapor to a liquid. This phase change is referred to as *condensation*. This pressure can be read directly from a pressure gauge connected anywhere between the compressor discharge valve and the entrance to the metering device, assuming there is negligible pressure drop. In reality, line and valve friction and the weight of the liquid itself cause pressure drops from the compressor discharge to the metering device. If a true condensing pressure is needed, the technician must measure the pressure as close to the condenser as possible to avoid these pressure drops. This pressure is usually measured on smaller systems near the compressor valves, Figure 1-2. On small systems, it is not critical where a technician places the pressure gauge (as long as it is on the high side of the system), because pressure drops are negligible. The pressure gauge reads the same no matter where it is on the high side of the system if line and valve losses are negligible.

EVAPORATING PRESSURE

The evaporating pressure is the pressure at which the refrigerant changes state from a liquid to a vapor. This phase change is referred to as *evaporation* or *vaporizing*. A pressure gauge placed anywhere between the metering device outlet and the compressor (including compressor crankcase) will read the evaporating pressure. Again, negligible pressure drops are assumed. In reality, there will be line and valve pressure drops as the refrigerant travels through the evaporator and suction line. The technician must measure the pressure as close to the evaporator as possible to get a true evaporating pressure. On small systems where pressure drops are negligible, this pressure is usually measured near the compressor (see Figure 1-2). Gauge placement on small systems is usually not critical as long as it is placed on the low side of the refrigeration system, because the refrigerant

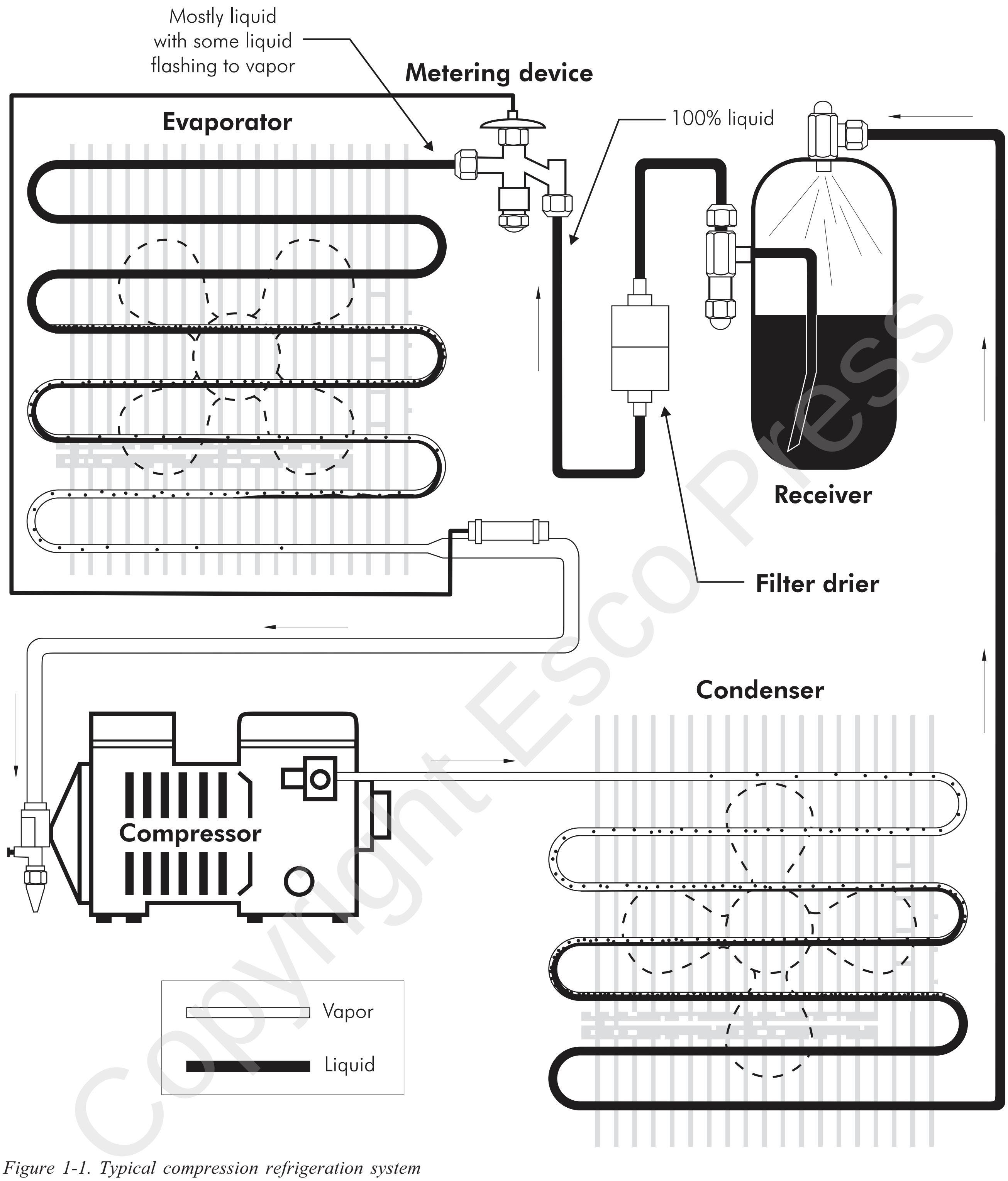

Figure 1-1. Typical compression refrigeration system

vapor pressure acts equally in all directions. If line and valve pressure drops become substantial, gauge placement becomes critical. In larger more sophisticated systems, gauge placement is more critical because of associated line and valve pressure losses. If the system has significant line and valve pressure losses, the technician must place the gauge as close as possible to the component that requires a pressure reading.

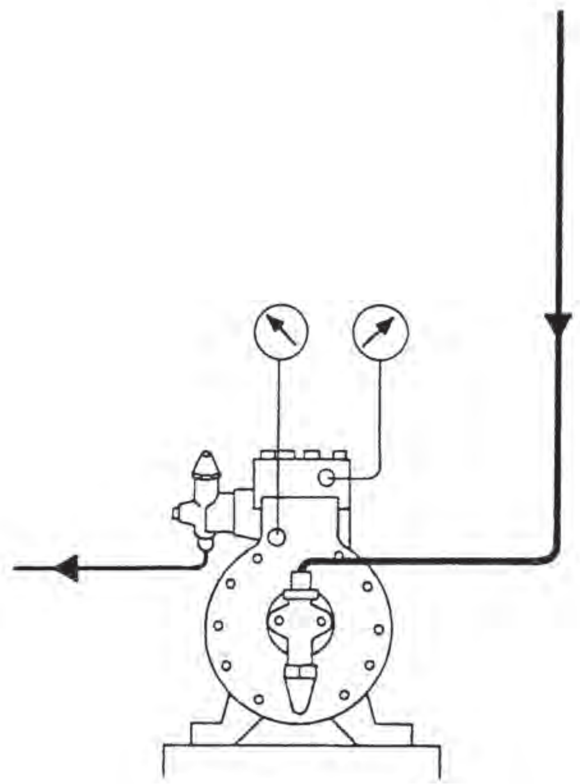

Figure 1-2. Semi-hermetic compressor showing pressure access valves (Courtesy, Danfoss Automatic Controls, Division of Danfoss, Inc.)

Refrigerant States and Conditions

Modern refrigerants exist either in the vapor or liquid state. Refrigerants have such low freezing points that they are rarely in the frozen or solid state. Refrigerants can co-exist as vapor and liquid as long as conditions are right. Both the evaporator and condenser house liquid and vapor refrigerant simultaneously if the system is operating properly. Refrigerant liquid and vapor can exist in both the high or low pressure sides of the refrigeration system.

Along with refrigerant pressures and states are refrigerant conditions. Refrigerant conditions can be *saturated*, *superheated*, or *subcooled.*

Saturation

Saturation is usually defined as a temperature. The saturation temperature is the temperature at which a fluid changes from liquid to vapor or vapor to liquid. At saturation temperature, liquid and vapor are called saturated liquid and saturated vapor, respectively. Saturation occurs in both the evaporator and condenser. At saturation, the liquid experiences its maximum temperature for that pressure, and the vapor experiences its minimum temperature. However, both liquid and vapor are at the same temperature for a given pressure when saturation occurs. Saturation temperatures vary with different refrigerants and pressures. All refrigerants have different vapor pressures. It is vapor pressure that is measured with a gauge.

Vapor Pressure

Vapor pressure is the pressure exerted on a saturated liquid. Any time saturated liquid and vapor are together (as in the condenser and evaporator), vapor pressure is generated. Vapor pressure acts equally in all directions and affects the entire low or high side of a refrigeration system.

As pressure increases, saturation temperature increases; as pressure decreases, saturation temperature decreases. Only at saturation are there pressure/temperature relationships for refrigerants. Table 1-1 shows the pressure/temperature relationship at saturation for refrigerant 134a (R-134a). If one attempts to raise the temperature of a saturated liquid above its saturation temperature, vaporization of the liquid will occur. If one attempts to lower the temperature of a saturated vapor below its saturation temperature, condensation will occur. Both vaporization and condensation occur in the evaporator and condenser, respectively.

The heat energy that causes a liquid refrigerant to change to a vapor at a constant saturation temperature for a given pressure is referred to as *latent heat.* Latent heat is the heat energy that causes a substance to change state without changing the temperature of the substance. Vaporization and condensation are examples of a latent heat process.

Temperature (°F)	Pressure (psig)	Temperature (°F)	Pressure (psig)
-10	1.8		
-9	2.2		
-8	2.6	30	25.6
-7	3.0	31	26.4
-6	3.5	32	27.3
-5	3.9	33	28.1
-4	4.4	34	29.0
-3	4.8	35	29.9
-2	5.3	40	34.5
-1	5.8	45	39.5
0	6.2	50	44.9
1	6.7	55	50.7
2	7.2	60	56.9
3	7.8	65	63.5
4	8.3	70	70.7
5	8.8	75	78.3
6	9.3	80	86.4
7	9.9	85	95.0
8	10.5	90	104.2
9	11.0	95	113.9
10	11.6	100	124.3
11	12.2	105	135.2
12	12.8	110	146.8
13	13.4	115	159.0
14	14.0	120	171.9
15	14.7	125	185.5
16	15.3	130	199.8
17	16.0	135	214.8
18	16.7		
19	17.3		
20	18.0		
21	18.7		
22	19.4		
23	20.2		
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27	23.2		
28	24.0		
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Table 1-1. R-134a saturated vapor/liquid pressure/temperature chart

Superheat

Superheat always refers to a vapor. A superheated vapor is any vapor that is above its saturation temperature for a given pressure. In order for vapor to be superheated, it must have reached its 100% saturated vapor point. In other words, all of the liquid must be vaporized for superheating to occur; the vapor must be removed from contact with the vaporizing liquid. Once all the liquid has been vaporized at its saturation temperature, any addition of heat causes the 100% saturated vapor to start superheating. This addition of heat causes the vapor to increase in temperature and gain *sensible heat*. Sensible heat is the heat energy that causes a change in the temperature of a substance. The heat energy that superheats vapor and increases its temperature is sensible heat energy. Superheating is a sensible heat process. Superheated vapor occurs in the evaporator, suction line, and compressor.

Subcooling

Subcooling always refers to a liquid at a temperature below its saturation temperature for a given pressure. Once all of the vapor changes state to 100% saturated liquid, further removal of heat will cause the 100% liquid to drop in temperature or lose sensible heat. Subcooled liquid results. Subcooling can occur in both the condenser and liquid line and is a sensible heat process. Another method of subcooling liquid, called liquid pressure amplification™, is covered in Chapter Two. This method increases the pressure on subcooled liquid, causing it to be subcooled even more. This creates a liquid with a temperature below its new saturation temperature for the new higher pressure.

A thorough understanding of pressures, states, and conditions of the basic refrigeration system enables the service technician to be a good systematic troubleshooter. It is not until then that a service technician should even attempt systematic troubleshooting.

Basic Refrigeration System

Figure 1-3 illustrates a basic refrigeration system. The basic components of this system are the compressor, discharge line, condenser, receiver, liquid line, metering device, evaporator, and suction line. Mastering the function of each individual component can assist the refrigera-

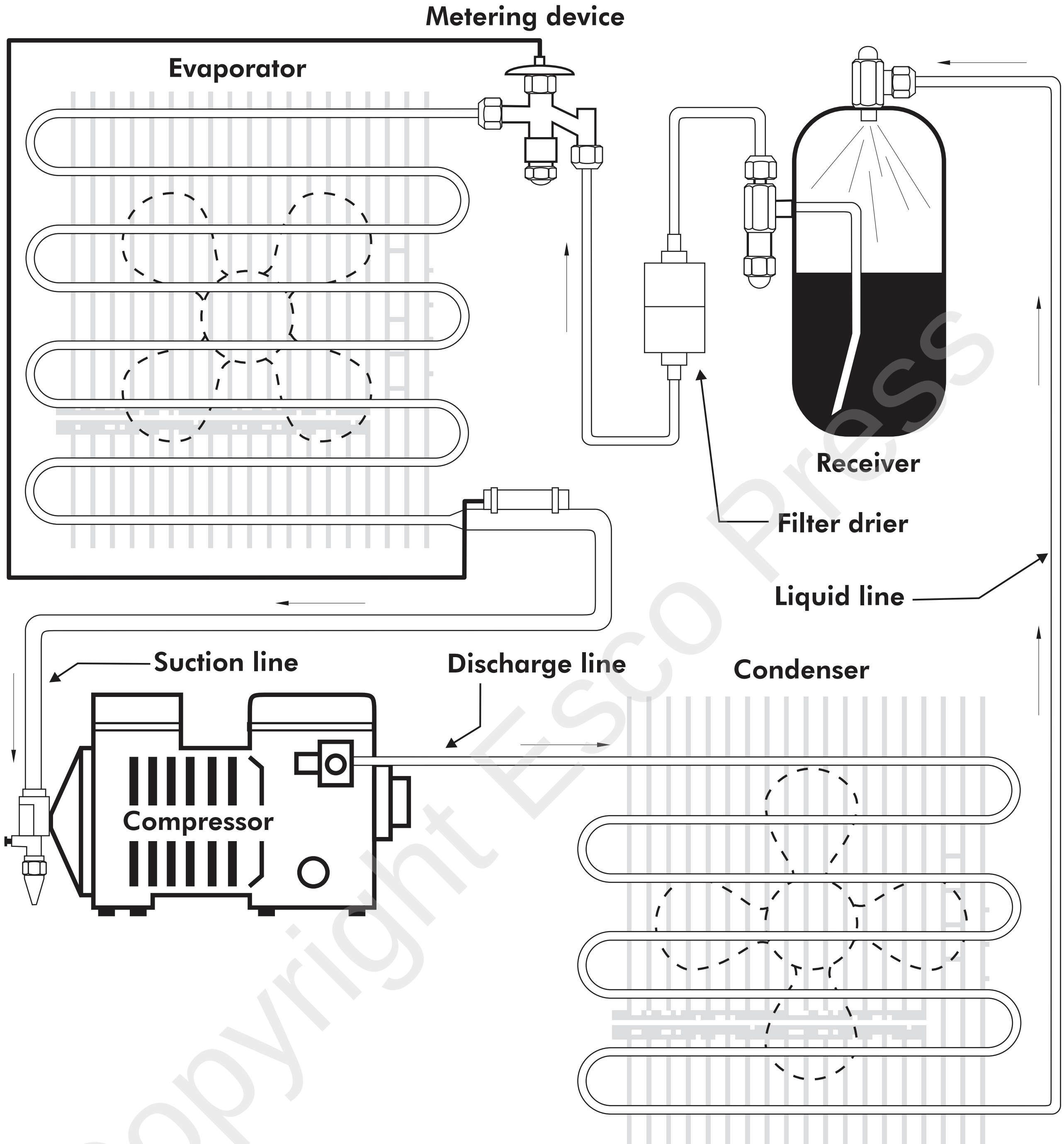

Figure 1-3. Basic refrigeration system

tion technician with analytical troubleshooting skills, saving time and money for both technician and customer.

Compressor

One of the main functions of the compressor is to circulate refrigerant. Without the compressor as a refrigerant pump, refrigerant could not reach other system components to perform its heat transfer functions. The compressor also separates the high pressure from the low pressure side of the refrigeration system. A difference in pressure is mandatory for fluid (gas or liquid) flow, and there could be no refrigerant flow without this pressure separation.

Another function of the compressor is to elevate or raise the temperature of the refrigerant vapor above the ambient (surrounding) temperature. This is accomplished by adding work, or heat of compression, to the refrigerant vapor during the compression cycle. The pressure of the refrigerant is raised, as well as its temperature. By elevating the refrigerant temperature above the ambient temperature, heat absorbed in the evaporator and suction line, and any heat of compression generated in the compression stroke can be rejected to this lower temperature ambient. Most of the heat is rejected in the discharge line and the condenser. Remember, heat flows from hot to cold, and there must be a temperature difference for any heat transfer to take place. The temperature rise of the refrigerant during the compression stroke is a measure of the increased internal kinetic energy added by the compressor.

The compressor also compresses the refrigerant vapors, which increases vapor density. This increase in density helps pack the refrigerant gas molecules together, which helps in the condensation or liquification of the refrigerant gas molecules in the condenser once the right amount of heat is rejected to the ambient. The compression of the vapors during the compression stroke is actually preparing the vapors for condensation or liquification.

Discharge Line

One function of the discharge line is to carry the high pressure superheated vapor from the compressor discharge valve to the entrance of the condenser. The discharge line also acts as a desuperheater, cooling the superheated vapors that the compressor has compressed and giving that heat up to the ambient (surroundings). These compressed vapors contain all of the heat that the evaporator and suction line have absorbed, along with the heat of compression of the compression stroke. Any generated motor winding heat may also be contained in the discharge line refrigerant, which is why the beginning of the discharge line is the hottest part of the refrigeration system. On hot days when the system is under a high load and may have a dirty condenser, the discharge line can reach over 400°F. By desuperheating the refrigerant, the vapors will be cooled to the saturation temperature of the condenser. Once the vapors reach the condensing saturation temperature for that pressure, condensation of vapor to liquid will take place as more heat is lost.

Condenser

The first passes of the condenser desuperheat the discharge line gases. This prepares the high pressure superheated vapors coming from the discharge line for condensation, or the phase change from gas to liquid. Remember, these superheated gases must lose all of their superheat before reaching the condensing temperature for a certain condensing pressure. Once the initial passes of the condenser have rejected enough superheat and the condensing temperature or saturation temperature has been reached, these gases are referred to as 100% saturated vapor. The refrigerant is then said to have reached the 100% saturated vapor point, Figure 1-4.

One of the main functions of the condenser is to condense the refrigerant vapor to liquid. Condensing is system dependent and usually takes place in the lower two-thirds of the condenser. Once the saturation or condensing temperature is reached in the condenser and the refrigerant gas has reached 100% saturated vapor, condensation can take place if more heat is removed. As more heat is taken away from the 100% saturated vapor, it will force the vapor to become a liquid or to condense. When condensing, the vapor will gradually phase change to liquid until 100% liquid is all that remains. This phase change, or change of state, is an example of a latent heat rejection process, as the heat removed is latent heat not sensible heat. The phase change will happen at one temperature even though heat is being removed. *Note: An exception to this is a near-azeotropic blend of refrigerants where there is a temperature glide or range of temperatures when phase changing (see Chapter Eight on blend temperature glide)*. This one temperature is the saturation temperature corresponding to the saturation pressure in the condenser. As mentioned before, this pressure can be measured anywhere

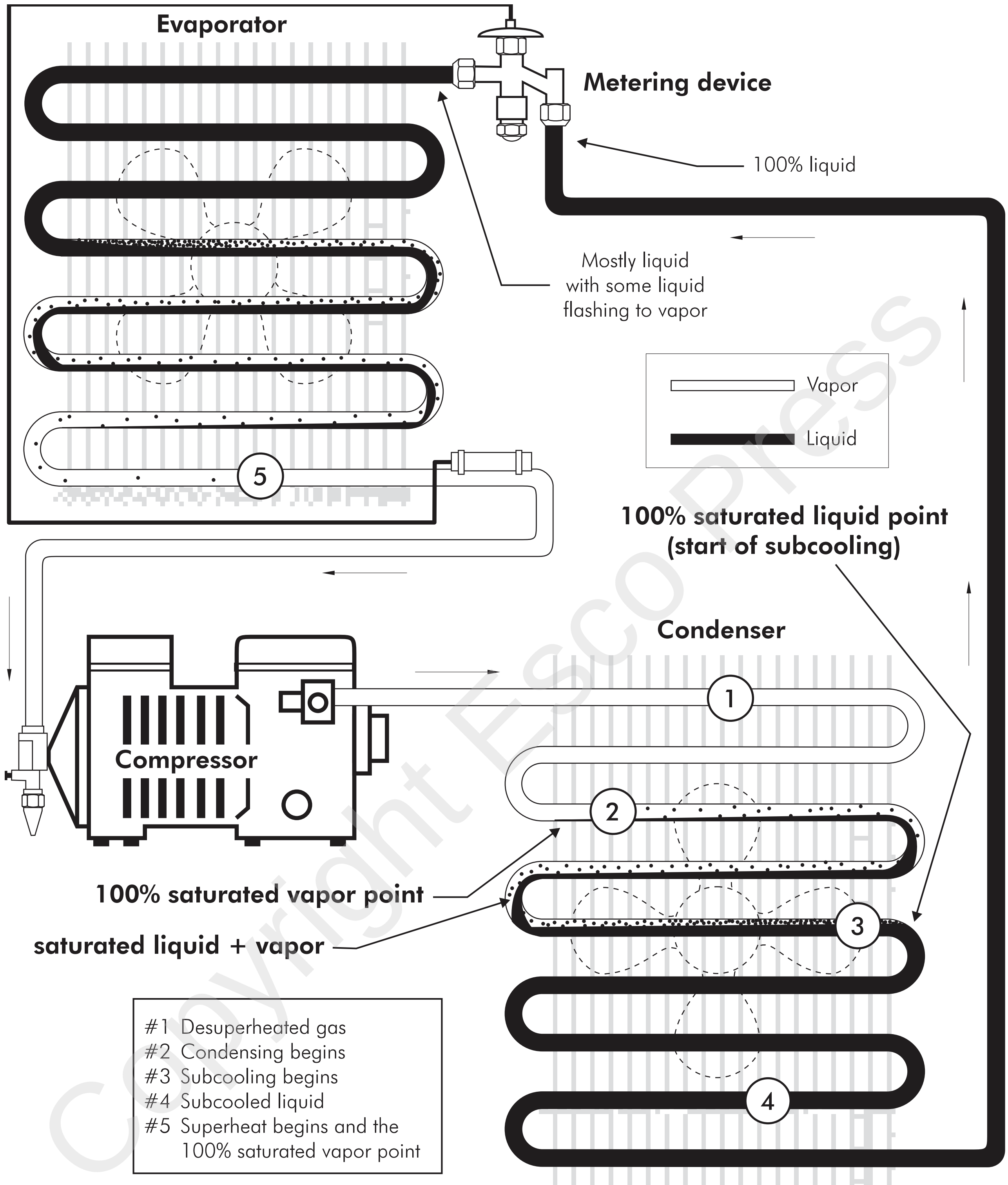

Figure 1-4. Basic refrigeration system showing 100% saturated vapor and liquid points

on the high side of the refrigeration system as long as line and valve pressure drops and losses are negligible.

The last function of the condenser is to subcool the liquid refrigerant. Subcooling is defined as any sensible heat taken away from 100% saturated liquid. Technically, subcooling is defined as the difference between the measured liquid temperature and the liquid saturation temperature at a given pressure. Once the saturated vapor in the condenser has phase changed to saturated liquid, the 100% saturated liquid point has been reached. If any more heat is removed, the liquid will go through a sensible heat rejection process and lose temperature as it loses heat. The liquid that is cooler than the saturated liquid in the condenser is subcooled liquid. Subcooling is an important process, because it starts to lower the liquid temperature to the evaporator temperature. This will reduce flash loss in the evaporator so more of the vaporization of the liquid in the evaporator can be used for useful cooling of the product load (see Chapter Two on the importance of liquid subcooling).

Receiver

The receiver acts as a surge tank. Once the subcooled liquid exits the condenser, the receiver receives and stores the liquid. The liquid level in the receiver varies depending on whether the metering device is throttling opened or closed. Receivers are usually used on systems in which a thermostatic expansion valve (TXV or TEV) is used as the metering device. The subcooled liquid in the receiver may lose or gain subcooling depending on the surrounding temperature of the receiver. If the subcooled liquid is warmer than receiver surroundings, the liquid will reject heat to the surroundings and subcool even more. If the subcooled liquid is cooler than receiver surroundings, heat will be gained by the liquid and subcooling will be lost.

A receiver bypass is often used to bypass liquid around the receiver and route it directly to the liquid line and filter drier. This bypass prevents subcooled liquid from sitting in the receiver and losing its subcooling. A thermostat with a sensing bulb on the condenser outlet controls the bypass solenoid valve by sensing liquid temperature coming to the receiver, Figure 1-5. If the liquid is subcooled to a predetermined temperature, it will bypass the receiver and go to the filter drier.

Liquid Line

The liquid line transports high pressure subcooled liquid to the metering device. In transport, the liquid may either lose or gain subcooling depending on the surrounding temperature. Liquid lines may be wrapped around suction lines to help them gain more subcooling, Figure 1-6. Liquid/suction line heat exchangers can be purchased and installed in existing systems to gain subcooling. The importance of liquid subcooling will be covered more extensively in Chapter Two.

Metering Device

The metering device meters liquid refrigerant from the liquid line to the evaporator. There are several different styles and kinds of metering devices on the market with different functions. Some metering devices control evaporator superheat and pressure, and some even have pressure limiting devices to protect compressors at heavy loads.

The metering device is a restriction that separates the high pressure side from the low pressure side in a refrigeration system. The compressor and the metering device are the two components that separate pressures in a refrigeration system. The restriction in the metering device causes liquid refrigerant to flash to a lower temperature in the evaporator because of its lower pressure and temperature.

Evaporator

The evaporator, like the condenser, acts as a heat exchanger. Heat gains from the product load and outside ambient travel through the sidewalls of the evaporator to vaporize any liquid refrigerant. The pressure drop through the metering device causes vaporization of some

Refrigeration & Charging Procedures

Refrigerant pressures, states and conditions are covered, as well as how they apply to the refrigeration system. Vapor pressures, subcooling, superheat, saturation, latent heat, and sensible heat are explained and applied to the refrigeration cycle. Basic system components, their functions and applications are included. Detailed explanations of each point in the refrigeration cycle will clarify questions the reader may have.

Definitions and system applications of subcooling and superheat are also included in this module. Condenser subcooling, total subcooling, evaporator superheat and total superheat are explained with examples as they apply to the basic refrigeration cycle. Friction and static pressure losses, with examples and applications, gives the reader a thorough understanding of how much sub-cooling is needed in any system.

Advanced topics such as; liquid pressure amplification, superheat suppression, floating head pressure, and refrigerant control systems are included.

This module includes a detailed explanation of refrigerant metering devices which include; thermostatic expansion valves, automatic expansion valves, and capillary tubes. Application, sizing, and troubleshooting under varying system operating conditions are explained.

System charging procedures as they apply to these various types of air conditioning and/or refrigeration systems are included. Charging charts and charging curves with examples of system applications give the reader a thorough understanding of system charging when reading this module.

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CHAPTER
ONE

Refrigerant Pressures, States, and Conditions

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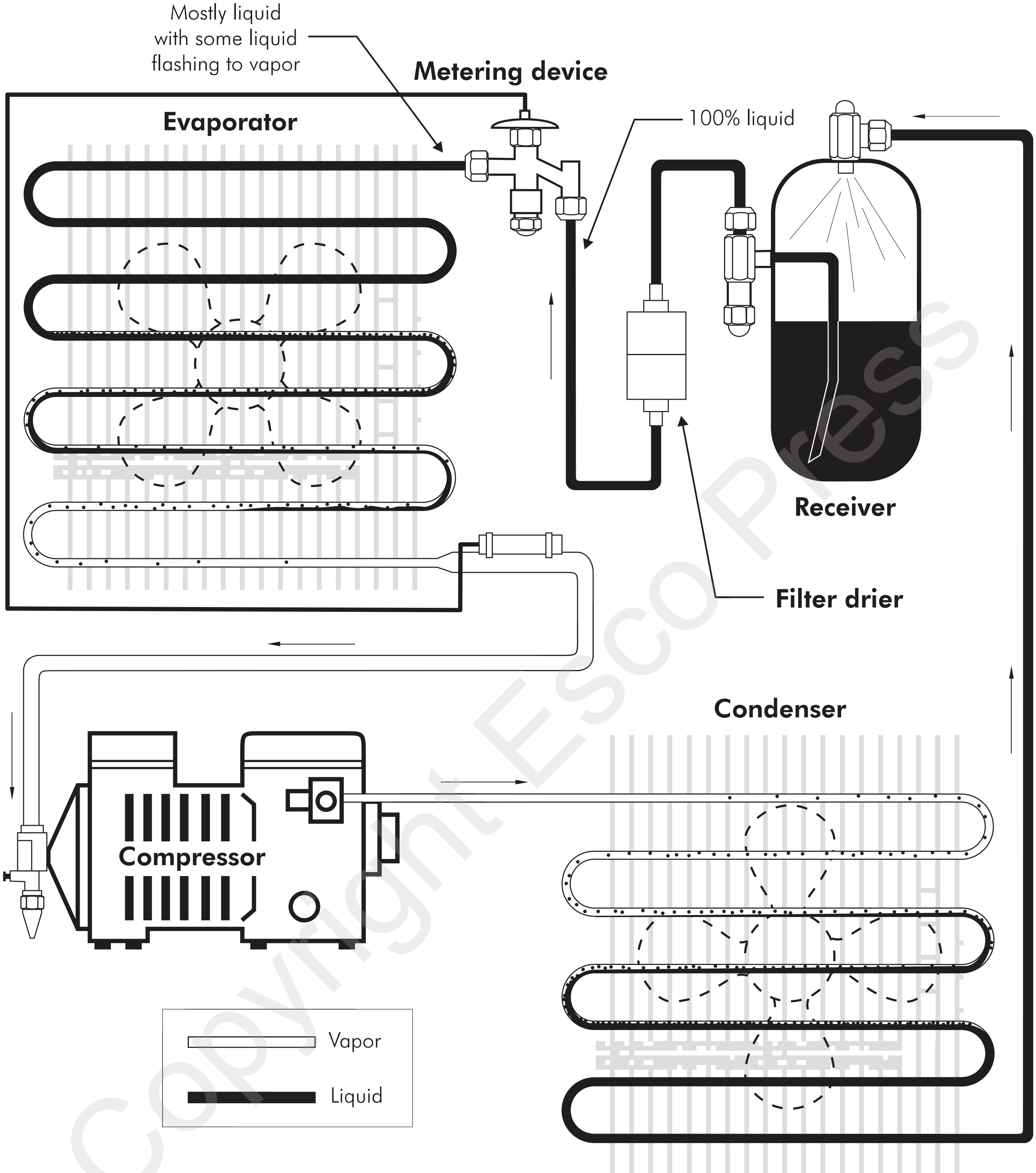

Figure 1-1. Typical compression refrigeration system

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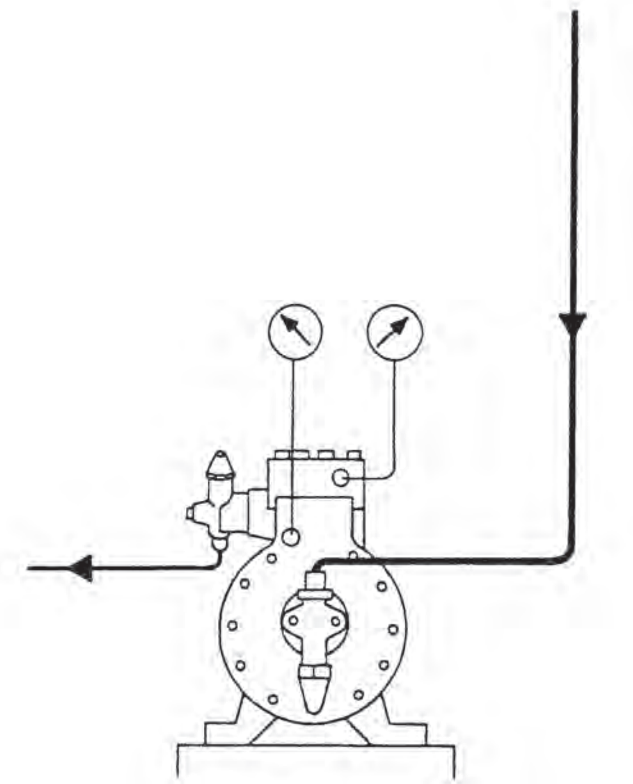

Figure 1-2. Semi-hermetic compressor showing pressure access valves (Courtesy, Danfoss Automatic Controls, Division of Danfoss, Inc.)

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Along with refrigerant pressures and states are refrigerant conditions. Refrigerant conditions can be *saturated*, *superheated*, or *subcooled.*

Saturation

Saturation is usually defined as a temperature. The saturation temperature is the temperature at which a fluid changes from liquid to vapor or vapor to liquid. At saturation temperature, liquid and vapor are called saturated liquid and saturated vapor, respectively. Saturation occurs in both the evaporator and condenser. At saturation, the liquid experiences its maximum temperature for that pressure, and the vapor experiences its minimum temperature. However, both liquid and vapor are at the same temperature for a given pressure when saturation occurs. Saturation temperatures vary with different refrigerants and pressures. All refrigerants have different vapor pressures. It is vapor pressure that is measured with a gauge.

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27	23.2		
28	24.0		
29	24.8		

Table 1-1. R-134a saturated vapor/liquid pressure/temperature chart

Superheat

Superheat always refers to a vapor. A superheated vapor is any vapor that is above its saturation temperature for a given pressure. In order for vapor to be superheated, it must have reached its 100% saturated vapor point. In other words, all of the liquid must be vaporized for superheating to occur; the vapor must be removed from contact with the vaporizing liquid. Once all the liquid has been vaporized at its saturation temperature, any addition of heat causes the 100% saturated vapor to start superheating. This addition of heat causes the vapor to increase in temperature and gain *sensible heat*. Sensible heat is the heat energy that causes a change in the temperature of a substance. The heat energy that superheats vapor and increases its temperature is sensible heat energy. Superheating is a sensible heat process. Superheated vapor occurs in the evaporator, suction line, and compressor.

Subcooling

Subcooling always refers to a liquid at a temperature below its saturation temperature for a given pressure. Once all of the vapor changes state to 100% saturated liquid, further removal of heat will cause the 100% liquid to drop in temperature or lose sensible heat. Subcooled liquid results. Subcooling can occur in both the condenser and liquid line and is a sensible heat process. Another method of subcooling liquid, called liquid pressure amplification™, is covered in Chapter Two. This method increases the pressure on subcooled liquid, causing it to be subcooled even more. This creates a liquid with a temperature below its new saturation temperature for the new higher pressure.

A thorough understanding of pressures, states, and conditions of the basic refrigeration system enables the service technician to be a good systematic troubleshooter. It is not until then that a service technician should even attempt systematic troubleshooting.

Basic Refrigeration System

Figure 1-3 illustrates a basic refrigeration system. The basic components of this system are the compressor, discharge line, condenser, receiver, liquid line, metering device, evaporator, and suction line. Mastering the function of each individual component can assist the refrigera-

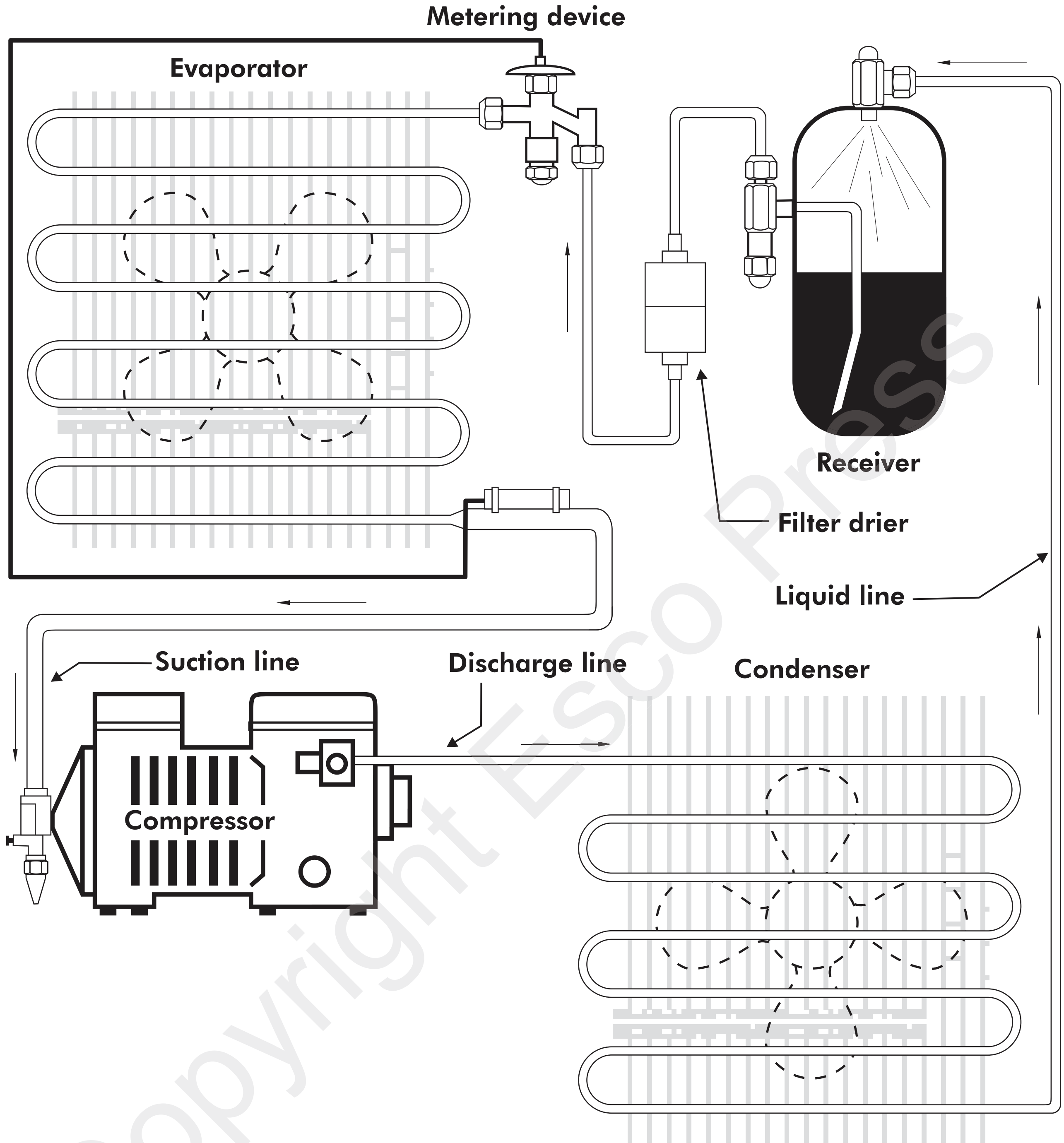

Figure 1-3. Basic refrigeration system

tion technician with analytical troubleshooting skills, saving time and money for both technician and customer.

Compressor

One of the main functions of the compressor is to circulate refrigerant. Without the compressor as a refrigerant pump, refrigerant could not reach other system components to perform its heat transfer functions. The compressor also separates the high pressure from the low pressure side of the refrigeration system. A difference in pressure is mandatory for fluid (gas or liquid) flow, and there could be no refrigerant flow without this pressure separation.

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Discharge Line

One function of the discharge line is to carry the high pressure superheated vapor from the compressor discharge valve to the entrance of the condenser. The discharge line also acts as a desuperheater, cooling the superheated vapors that the compressor has compressed and giving that heat up to the ambient (surroundings). These compressed vapors contain all of the heat that the evaporator and suction line have absorbed, along with the heat of compression of the compression stroke. Any generated motor winding heat may also be contained in the discharge line refrigerant, which is why the beginning of the discharge line is the hottest part of the refrigeration system. On hot days when the system is under a high load and may have a dirty condenser, the discharge line can reach over 400°F. By desuperheating the refrigerant, the vapors will be cooled to the saturation temperature of the condenser. Once the vapors reach the condensing saturation temperature for that pressure, condensation of vapor to liquid will take place as more heat is lost.

Condenser

The first passes of the condenser desuperheat the discharge line gases. This prepares the high pressure superheated vapors coming from the discharge line for condensation, or the phase change from gas to liquid. Remember, these superheated gases must lose all of their superheat before reaching the condensing temperature for a certain condensing pressure. Once the initial passes of the condenser have rejected enough superheat and the condensing temperature or saturation temperature has been reached, these gases are referred to as 100% saturated vapor. The refrigerant is then said to have reached the 100% saturated vapor point, Figure 1-4.

One of the main functions of the condenser is to condense the refrigerant vapor to liquid. Condensing is system dependent and usually takes place in the lower two-thirds of the condenser. Once the saturation or condensing temperature is reached in the condenser and the refrigerant gas has reached 100% saturated vapor, condensation can take place if more heat is removed. As more heat is taken away from the 100% saturated vapor, it will force the vapor to become a liquid or to condense. When condensing, the vapor will gradually phase change to liquid until 100% liquid is all that remains. This phase change, or change of state, is an example of a latent heat rejection process, as the heat removed is latent heat not sensible heat. The phase change will happen at one temperature even though heat is being removed. *Note: An exception to this is a near-azeotropic blend of refrigerants where there is a temperature glide or range of temperatures when phase changing (see Chapter Eight on blend temperature glide)*. This one temperature is the saturation temperature corresponding to the saturation pressure in the condenser. As mentioned before, this pressure can be measured anywhere

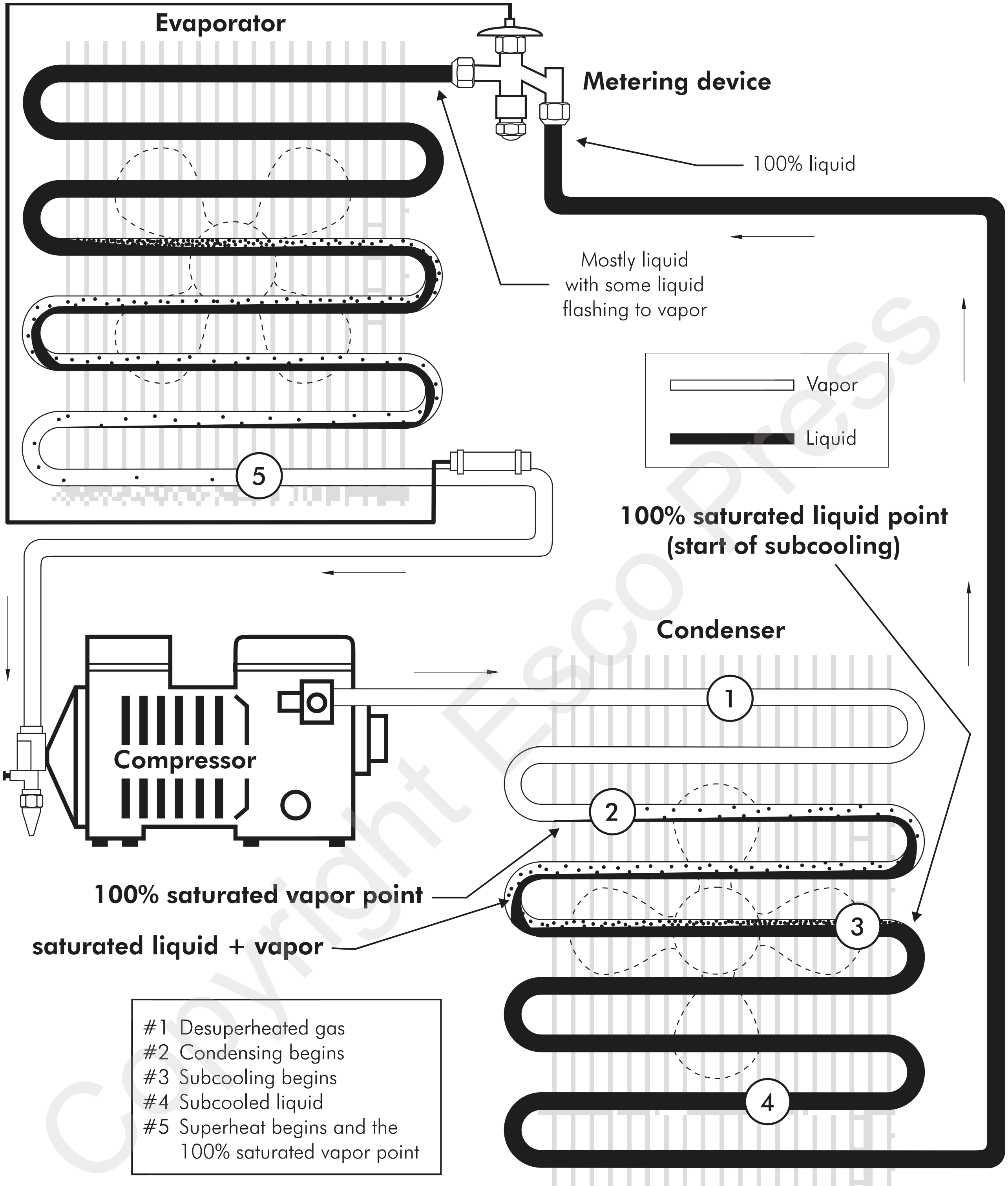

Figure 1-4. Basic refrigeration system showing 100% saturated vapor and liquid points

on the high side of the refrigeration system as long as line and valve pressure drops and losses are negligible.

The last function of the condenser is to subcool the liquid refrigerant. Subcooling is defined as any sensible heat taken away from 100% saturated liquid. Technically, subcooling is defined as the difference between the measured liquid temperature and the liquid saturation temperature at a given pressure. Once the saturated vapor in the condenser has phase changed to saturated liquid, the 100% saturated liquid point has been reached. If any more heat is removed, the liquid will go through a sensible heat rejection process and lose temperature as it loses heat. The liquid that is cooler than the saturated liquid in the condenser is subcooled liquid. Subcooling is an important process, because it starts to lower the liquid temperature to the evaporator temperature. This will reduce flash loss in the evaporator so more of the vaporization of the liquid in the evaporator can be used for useful cooling of the product load (see Chapter Two on the importance of liquid subcooling).

Receiver

The receiver acts as a surge tank. Once the subcooled liquid exits the condenser, the receiver receives and stores the liquid. The liquid level in the receiver varies depending on whether the metering device is throttling opened or closed. Receivers are usually used on systems in which a thermostatic expansion valve (TXV or TEV) is used as the metering device. The subcooled liquid in the receiver may lose or gain subcooling depending on the surrounding temperature of the receiver. If the subcooled liquid is warmer than receiver surroundings, the liquid will reject heat to the surroundings and subcool even more. If the subcooled liquid is cooler than receiver surroundings, heat will be gained by the liquid and subcooling will be lost.

A receiver bypass is often used to bypass liquid around the receiver and route it directly to the liquid line and filter drier. This bypass prevents subcooled liquid from sitting in the receiver and losing its subcooling. A thermostat with a sensing bulb on the condenser outlet controls the bypass solenoid valve by sensing liquid temperature coming to the receiver, Figure 1-5. If the liquid is subcooled to a predetermined temperature, it will bypass the receiver and go to the filter drier.

Liquid Line

The liquid line transports high pressure subcooled liquid to the metering device. In transport, the liquid may either lose or gain subcooling depending on the surrounding temperature. Liquid lines may be wrapped around suction lines to help them gain more subcooling, Figure 1-6. Liquid/suction line heat exchangers can be purchased and installed in existing systems to gain subcooling. The importance of liquid subcooling will be covered more extensively in Chapter Two.

Metering Device

The metering device meters liquid refrigerant from the liquid line to the evaporator. There are several different styles and kinds of metering devices on the market with different functions. Some metering devices control evaporator superheat and pressure, and some even have pressure limiting devices to protect compressors at heavy loads.

The metering device is a restriction that separates the high pressure side from the low pressure side in a refrigeration system. The compressor and the metering device are the two components that separate pressures in a refrigeration system. The restriction in the metering device causes liquid refrigerant to flash to a lower temperature in the evaporator because of its lower pressure and temperature.

Evaporator

The evaporator, like the condenser, acts as a heat exchanger. Heat gains from the product load and outside ambient travel through the sidewalls of the evaporator to vaporize any liquid refrigerant. The pressure drop through the metering device causes vaporization of some

Refrigeration & Charging Procedures

Refrigerant pressures, states and conditions are covered, as well as how they apply to the refrigeration system. Vapor pressures, subcooling, superheat, saturation, latent heat, and sensible heat are explained and applied to the refrigeration cycle. Basic system components, their functions and applications are included. Detailed explanations of each point in the refrigeration cycle will clarify questions the reader may have.

Definitions and system applications of subcooling and superheat are also included in this module. Condenser subcooling, total subcooling, evaporator superheat and total superheat are explained with examples as they apply to the basic refrigeration cycle. Friction and static pressure losses, with examples and applications, gives the reader a thorough understanding of how much sub-cooling is needed in any system.

Advanced topics such as; liquid pressure amplification, superheat suppression, floating head pressure, and refrigerant control systems are included.

This module includes a detailed explanation of refrigerant metering devices which include; thermostatic expansion valves, automatic expansion valves, and capillary tubes. Application, sizing, and troubleshooting under varying system operating conditions are explained.

System charging procedures as they apply to these various types of air conditioning and/or refrigeration systems are included. Charging charts and charging curves with examples of system applications give the reader a thorough understanding of system charging when reading this module.

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