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System Check Sheets

This chapter compares subcooling amounts in a refrigeration system incorporating an overcharge of refrigerant, a dirty condenser, and air in the system. Note that all of the system check sheets used as samples in this chapter incorporate R-134a as a refrigerant.. These systems are refrigeration systems with a thermostatic expansion valve (TXV) as a metering device with receivers.

Overcharged System

Table 1 shows an R-134a refrigeration system with an overcharge of refrigerant. Notice the 30 degrees of liquid subcooling backed up in the condenser. Because of the overcharge of refrigerant, the condenser will have too much liquid backed up in its bottom, causing high condenser subcooling. By overcharging a system with too much refrigerant, increased liquid subcooling amounts will be realized in the condenser.

However, just because a system has increased subcooling amounts in the condenser doesn't necessarily mean the system is overcharged. This will be explained in the next two system checks. Remember, the condenser is where refrigerant vapor is condensed and liquid refrigerant is formed. This backed-up subcooled liquid at the condenser's bottom will take up valuable condenser volume, leaving less volume for desuperheating and condensation of refrigerant vapors.

Too much liquid subcooling at the condenser's bottom will cause unwanted inefficiencies by raising the head pressure and the compression ratio. Higher compression ratios cause lower volumetric efficiencies and lower mass flow rates of refrigerant through the refrigeration system. Higher superheated

Table 1: Overcharged System

Item to be measured	Measured value
Compressor discharge temperature	240°F
Condenser outlet temperature	90°F
Evaporator outlet temperature	15°F
Compressor inlet temperature	25°F
Ambient temperature	70°F
Box temperature	10°F
Compressor volts	230 V
Compressor amps	High
Low side (evaporator) pressure	8.8 psig (5°F)
High side (condensing) pressure	172 psig (120°F)
Item to be calculated	Calculated value
Condenser split	50°F
Condenser subcooling	30°F
Evaporator superheat	10°F
Compressor superheat	20°F

compressor discharge temperatures will also be realized from the higher heat of compression caused from the high compression ratio.

Remember, most conventional condensers' functions are to:

- Desuperheat compressor discharge vapors,

- Condense these vapors to liquid, and
- Subcool refrigerant at its bottom.

System with Dirty Condenser

Table 2 shows a refrigeration system with a dirty condenser causing restricted airflow over the condenser. A similar condition would be a defective condenser fan motor starving the condenser of air. Both conditions caused the head pressure and thus condensing temperature to increase. Even the liquid at the condenser's bottom will be hotter because of the elevated condensing temperatures. This creates a greater temperature difference between the liquid at the condenser's bottom and the ambient (surrounding air) designed to cool the condenser and its liquid. This will cause the liquid at the condenser's bottom to lose heat faster, causing more condenser subcooling. In this example, high condenser subcooling is not caused from an "amount" of liquid being backed up in the condenser, but from the liquid in the condenser's bottom simply losing heat faster.

This phenomenon happens because the temperature difference between the liquid at the condenser's bottom and the surrounding ambient is the driving potential for heat transfer to take place. As more and more air is restricted from flowing through the condenser, the amount of condenser subcooling will increase.

Notice that the system check sheet shows higher than normal condenser subcooling of 15°. This system check sheet looks very similar to an overcharge of refrigerant because of the increased subcooling amounts, but do not be fooled by it. When a high head pressure and high condenser subcooling is experienced in a refrigeration system, the service technician must not assume an overcharge of refrigerant. The technician must first check to see if the condenser is dirty or a condenser fan is inoperative because of simi-

Table 2: System With A Dirty Condenser

Item to be measured	Measured value
Compressor discharge temperature	250°F
Condenser outlet temperature	110°F
Evaporator outlet temperature	10°F
Compressor inlet temperature	25°F
Ambient temperature	70°F
Box temperature	15°F
Compressor volts	230 V
Compressor amps	High
Low side (evaporator) pressure	6.2 psig (0°F)
High side (condensing) pressure	185.5 psig (125°F)

Item to be calculated	Calculated value
Condenser split	55°F
Condenser subcooling	15°F
Evaporator superheat	10°F
Compressor superheat	25°F

larities of symptoms in both scenarios of an overcharge of refrigerant and restricted airflow over the condenser.

System Containing Air

Another similar scenario would be a refrigeration system containing air, as in Table 3. Air is a noncondensable and will get trapped in the top of the condenser. This will cause high head pressures and high condensing temper-

This phenomenon happens because the temperature difference between the liquid at the condenser's bottom and the surrounding ambient is the driving potential for heat transfer to take place. As more and more air is restricted from flowing through the condenser, the amount of condenser subcooling will increase.

atures because of reduced condenser volume to desuperheat, condense, and subcool. Thus, the liquid at the condenser's bottom will be hotter than normal and will lose heat faster to the ambient. This will result in an increase in condenser subcooling.

Table 3 shows 40° of condenser subcooling, but these amounts will vary depending on the amount of air in the system.

Again, in this example, high condenser subcooling is not caused from an "amount" of liquid being backed up in the condenser, but from the liquid in the condenser's bottom simply losing heat faster. 

Table 3: System Containing Air

Item to be measured	Measured value
Compressor discharge temperature	235°F
Condenser outlet temperature	85°F
Evaporator outlet temperature	17°F
Compressor inlet temperature	40°F
Ambient temperature	75°F
Box temperature	15°F
Compressor volts	230 V
Compressor amps	High
Low side (evaporator) pressure	8.8 psig (5°F)
High side (condensing) pressure	185.5 psig (125°F)

Item to be calculated	Calculated value
Condenser split	50°F
Condenser subcooling	40°F
Evaporator superheat	12°F
Compressor superheat	35°F

Megohmmeters for Preventive Maintenance

Megohmmeters (meggers) are electrical meters used to check the resistance and condition of the motor windings and the condition of the refrigeration and oil environment around the motor windings. A megger is nothing but a giant ohmmeter that creates a very large dc voltage (usually 500 volts dc) from its internal battery. The meter will read out in megohms (millions of ohms). Any motor winding or electrical coil can be checked with a megger. A megohmmeter's main function is to detect weak motor winding insulation and to detect moisture accumulation and acid formations from the motor windings to ground before they can cause more damage to motor winding insulation.

When dealing with HVACR hermetic and semi-hermetic compressor motors, as contaminants in the refrigerant and oil mixture increase, the electrical resistance from the motor windings to ground will decrease. Because of this, regular preventative maintenance checks can be made with a megohmmeter and can signal early motor winding breakdown from a contaminated system when accurate records are kept.

One probe of the megger is connected to one of the motor winding terminals, and the other probe to the shell of the compressor (ground). Note: Make sure metal is exposed at the shell of the compressor where the probe is attached so that the compressor's shell paint is not acting as an insulator to ground. When a button is pushed and held on the megger, it will apply a high dc voltage between its probes and measure all electrical paths to ground. It is important to disconnect all wires from the compressor motor terminals when megging a compressor motor.

Required reading (megohms)	Condition indicated	Required preventive maintenance	Percent of winding in field
Over 100	Excellent	None	30%
100-50	Some moisture present	Change filter-drier	35%
50-20	Severe moisture and/or contamination	Several filter-drier changes; Change oil if acid is present	20%
20-0	Severe contamination	Check entire system and make corrections. Consider an oversized filter-drier, refrigerant and oil change, and re-evacuation. System burnout and clean-up procedures required.	15%

Figure 1.

Also, read the instructions that come with the meter to determine what time interval to energize the megger when checking winding or coils. If possible, it is a good idea to run the motor for at least one hour, disconnect power, disconnect all electrical leads, and then quickly connect the megger to the motor. This will give a more meaningful comparison between readings for the same compressor on different days, because of the approximate same winding temperatures.

Good motor winding readings should have a resistance value of a minimum of 100 megohms relative to ground. In fact, good motor winding resistance should be between 100 megohms and infinity.

Regular preventative maintenance checks can be made with a megohmmeter and can signal early motor winding breakdown from a contaminated system when accurate records are kept.

Figure 1 lists megohm readings with varying degrees of contamination and motor winding breakdown. Because of the very high resistance of the motor winding insulation, a regular ohmmeter cannot be used in place of the megger. A regular ohmmeter does not generate enough voltage from its internal battery to detect high resistance problems like deteriorated winding insula-

tion, moisture, or other system contamination.

Listed below are some other important tips service technicians should know about the use of a megohmmeter:

- Never use a megger if the motor windings are under a vacuum.
- Meggers can be used for other electrical devices other than electric motors.
- Always consult with the meter manufacturer or user's manual for detailed instructions on megging other electrical devices like coils.
- Meggers are often used in preventive maintenance programs, especially before a contractor signs a preventive maintenance contract to determine condition of the electrical devices.
- Any megger with a higher voltage output than 500 volts DC should be used by an experienced technician. A high voltage for too long of a time may further weaken or fail motor windings and the winding insulation could be damaged by the testing procedure. Ⓝ

Bad Compressor Valves

Many servicemen experience service calls where the compressor has both a low head pressure and a high suction pressure. Often, the refrigeration equipment is still running, but the product temperature is suffering about 7 to 10°F. These calls are tough to handle because the compressor is still cooling, but not cooling to its rated capacity. The medium-temperature products will spoil quicker and the low-temperature products are not frozen as solid as they should be.

There are three main reasons why a compressor will simultaneously have a low head pressure and a high suction pressure:

- Bad (leaky) compressor valves (Figure 1);
- Worn compressor rings (Figure 2); and
- Leaky oil separator.

Leaky Compressor Valves

Here are reasons why a compressor's valves may become inefficient because of valve warpage from overheating or lack of lubrication, or from having carbon and/or sludge deposits on them preventing them from sealing properly.

- Slugging of refrigerant and/or oil;
- Moisture and heat causing sludging problems;
- Refrigerant migration problems;
- Refrigerant flooding problems;
- Overheating the compressor which may warp the valves;
- Acids and/or sludges in the system deteriorating parts;
- TXV set wrong — Too little superheat causing flooding or slugging;

- TXV set wrong — Too much superheat causing compressor overheating;
- Undercharge causing high superheat and compressor overheating; and
- Low load on the evaporator from a frozen coil or fan out causing slugging or flooding of the compressor.

Below is a service checklist for a compressor with valves that are not sealing.

Compressor With Leaky Valves (Measured Values)

Compressor discharge temp	225°
Condenser outlet temp.....	75°
Evaporator outlet temp.....	25°
Compressor in temp.....	55°
Ambient temperature	75°
Box temperature	25°
Compressor volts.....	230
Compressor amps	low
Lowside (evaporating) pressure (psig).....	1.6 psig (10°)
Highside (condensing) pressure (psig)	95 psig (85°)

(Calculated values °F)

Condenser split.....	10
Condenser subcooling	10
Evaporator superheat	15
Compressor superheat	45

Symptoms include:

- Higher than normal discharge temperatures;
- Low condensing (head) pressures and temperatures;
- Normal to high condenser subcooling;
- Normal to high superheats;
- High evaporator (suction) pressures; and
- Low amp draw.

Higher than normal discharge temperatures: A discharge valve that isn't seating properly because it has been damaged will cause the head pressure to be low (Figure 1). Refrigerant vapor will be forced out of the cylinder and into the discharge line during the upstroke of the compressor. On the downstroke, this same refrigerant that is now in the discharge line and compressed will be drawn back into the cylinder because the discharge valve is not seating properly. This short cycling of refrigerant will cause heating of the discharge gases over and over again, causing higher than normal discharge temperatures. However, if the valve problem has progressed to where there is hardly any refrigerant flow rate through the system, there will be a lower discharge temperature from the low flow rate.

Low condensing (head) pressures: Because some of the discharge gases are being short cycled in and out of the compressor's cylinder, there will be a low refrigerant flow rate to the condenser. This will make for a reduced heat load on the condenser thus reduced condensing (head) pressures and temperatures.

Normal to high condenser subcooling: There will be a reduced refrigerant flow through the condenser, thus through the entire system because components are in series. Most of the refrigerant will be in the condenser and receiver. This may give the condenser a bit higher subcooling.



Figure 1. Overheating and discoloring of a discharge valve.
(All photos courtesy Ferris State University.)

Normal to high superheats: Because of the reduced refrigerant flow through the system, the TXV may not be getting the refrigerant flow rate it needs. High superheats may be the result. However, the superheats may be normal if the valve problem is not real severe.

High evaporator (suction) pressure: Refrigerant vapor will be drawn from the suction line into the compressor's cylinder during the downstroke of the compressor. However, during the upstroke, this same refrigerant may sneak back into the suction line because the suction valve is not seating properly. The results are high suction pressures.

Low amp draw: Low amp draw is caused from the reduced refrigerant flow rate through the compressor. During the compression stroke, some of the re-

refrigerant will leak through the suction valve and back into the suction line reducing the refrigerant flow. During the suction stroke, some of the refrigerant will sneak through the discharge valve because it is not seating properly, and get back into the compressor's cylinder. In both situations, there is a reduced refrigerant flow rate causing the amp draw to be lowered. The low head pressure that the compressor has to pump against will also reduce the amp draw.

Worn Compressor Rings

When the compressor rings are worn, high-side discharge gases will leak through them during the compression stroke, giving the system a lower head pressure (Figure 2). Because discharge gases have leaked through the rings and into the crankcase, the suction pressure will also be higher than normal. The resulting symptom will be a lower head pressure with a higher suction pressure. The symptoms for worn rings on a compressor are very similar to leaky valves.

Leaky Oil Separator

When the oil level in the oil separator becomes high enough to raise a float, an oil return needle is opened, and the oil is returned to the compres-



Figure 2: Worn compressor rings.

sor crankcase through a small return line. The pressure difference between the high and low sides of the refrigeration system is the driving force for the oil to travel from the oil separator to the compressor's crankcase.

The oil separator is in the high side of the system and the compressor crankcase in the low side. The float-operated oil return needle valve is located high enough in the oil sump to allow clean oil to automatically return to the compressor's crankcase.

Only a small amount of oil is needed to actuate the float mechanism, which ensures that only a small amount of oil is ever absent from the compressor crankcase at any given time. When the oil level in the sump of the oil separator drops to a certain level, the float forces the needle valve closed. When the ball and float mechanism on an oil separator goes bad, it may bypass hot discharge gas directly into the compressor's crankcase.

The needle valve may also get stuck partially open from grit in the oil. This will cause high pressure to go directly into the compressor's crankcase causing high low-side pressures and low high-side pressures. 



Chemical-Free Cooling Tower Treatment

Pure water is a rare commodity. Water, as we know it, contains many dissolved minerals. When evaporation occurs in a cooling tower, only the water evaporates; it exits the cooling tower as water vapor, but leaves the minerals behind to concentrate in the cooling tower's water system.

The concentrations of these dissolved minerals gradually increase until a process called precipitation occurs. Precipitation happens when dissolved minerals such as calcium carbonate (limestone) reach a certain concentration and become solid, usually clinging to equipment and piping surfaces in the cooling tower. HVACR personnel refer to these solids as scale.

Tiny suspended particles exist in large quantities in all city water, or well water that is used for cooling tower or boiler makeup water. Once in the cooling tower water system, these suspended particles neither sink nor float because of their small size. They are transported by the flowing water.

The particles will concentrate during the evaporation process and be attracted to the equipment surfaces in the cooling tower. When the concentration is so great that the water can hold no more minerals, they are forced to find surfaces to precipitate to as a solid, scaling the equipment. This concentration



Figure 1. Signal generator and water treatment module installed in a working cooling tower. (Courtesy of Clearwater Systems Corp.)

and attraction of particles eventually becomes hard, equipment-damaging scale.

Now, a proprietary and patented technology has been developed by an engineering and research team. This chemical-free technology eliminates scale, inhibits bacterial growth, and inhibits corrosion in water purification (Figure 1).

How it Works

When the cooling tower water holding these small suspended particles passes through a water treatment module and is activated by a high-frequency electrical pulse field, the natural electrical static charge on the particle's surface is removed.

In removing this surface charge on the suspended particles, they are now the preferred site for precipitation of minerals to occur, instead of the equipment surfaces. The suspended particles now act as seeds for precipitation of dissolved minerals. Thus, the hard scale is prevented from forming on the equipment's surfaces and instead bonds to the tiny suspended particles in the water.

The minerals in the water now adhere to and coat the suspended particles. As more and more minerals bond to the suspended particles, they become heavier and can no longer suspend themselves in

the water stream. They eventually make their way to the cooling tower's basin as a harmless fluffy powder or tiny coated particle.

This powder or coated particle can easily be removed from the cooling tower's basin by manual means, filtration, or centrifugal separation. The quantity of powder is typically about 15 percent of normal blow-in dirt in a cooling tower.

Particle Separator

Particles can be removed from the bottom of the cooling tower's basin using a centrifugal separator (Figure 2). Water from the basin is pumped to a centrifugal separator, where it enters the separator tangentially. This gives the water the proper inlet velocity and causes a constant change of direction to generate an initial vortexing action.

Internal tangential slots located on the inner separation barrel causes the water to accelerate further and magnify the vortex

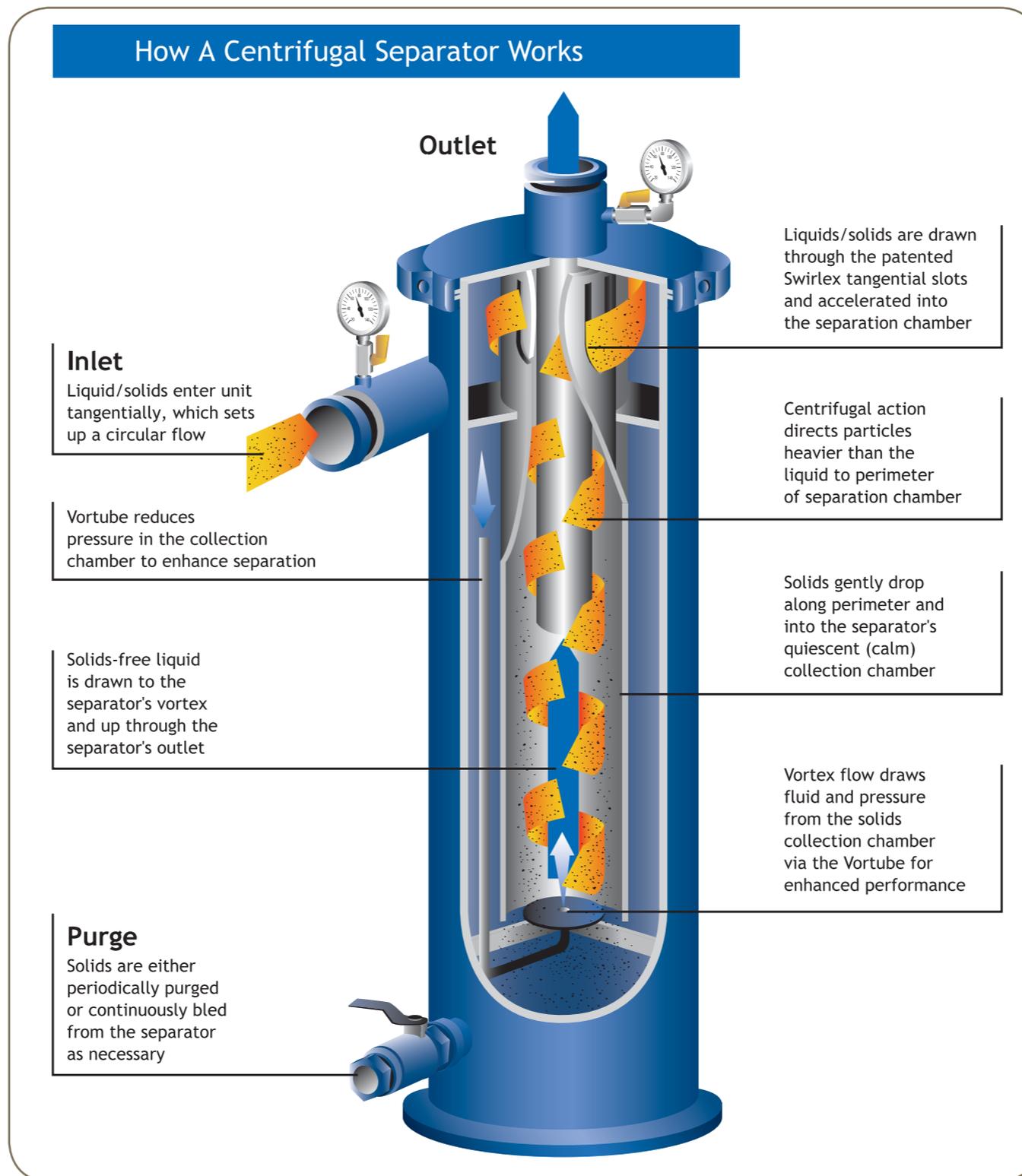


Figure 2 (left). The removal of particles at the bottom of the cooling tower's basin can be accomplished using a centrifugal separator. (Courtesy of Lakos Separators and Filtration Solutions)

strength. Particles in the water are now separated through centrifugal action caused by the vortex. The particles spiral downward along the perimeter of the inner separation barrel and are deposited in a collection chamber below the vortex deflector plate, where they can be automatically purged.

Free of separable particles, the water spirals up the center vortex in the separation barrel and upward to the outlet. A vortex-driven pressure relief line draws fluid from the separator's solids-collection chamber and returns it to the center of the separation barrel at the vortex deflector plate. This allows even finer solids to be drawn into the solids-collection chamber that would otherwise be re-entrained in the vortex.

Bacterial Control

There are two methods of controlling bacteria or microbial population in cooling tower systems: encapsulation and electroporation.

Normally, bacteria form a biofilm or slime layer on equipment surfaces. The slimy bacterial secretion forms a protective canopy to protect the bacteria beneath it from chemical biocides. It is very slimy to the touch, four times more insulating to heat transfer than mineral scale, and is the primary cause of microbial-influenced corrosion on equipment.

The bacteria that live in a biofilm and adhere to the equipment surfaces are called Sessile bacteria; they represent 99 percent of the total bacteria in a system. However, this slime layer can be eliminated through a process of nutrient limitation.

The suspended particles in the water of a cooling tower incorporate most of the free-floating planktonic bacteria. Normally, since like charges repel one another, the bacteria are repelled by the suspended particles in cooling tower water due to the fact that nearly all tiny particles have similar negative static electrical charges on their surfaces. However, after being activated by the high-frequency electrical pulse field at the water treatment module by the signal generator, the natural electrical static charge on the particle's surface is removed.

The repulsion to the bacteria is eliminated; therefore, the bacteria are attracted to the powder and become entrapped in it. The powder, in effect, sweeps the water clean of planktonic bacteria and renders them incapable of reproducing. This process is referred to as encapsulation.

The high-frequency, pulsing action of the signal generator also damages the membrane of the planktonic bacteria by creating small pores in their outer membrane. The condition weakens the bacteria and inhibits their capabilities to reproduce. This process is referred to as electroporation. Microbial life has

a 24- to 48-hour life span. Any microbe not captured in the forming powder are zapped by the secondary pulse of the signal generator, forcing them to spend their lives repairing cell wall damage rather than reproducing.

All of the living organisms in a cooling tower system depend on one another for their food supply. Thus, when the nutrients from the planktonic bacteria are diluted by both encapsulation and electroporation, the biofilm cannot be sustained and it will disintegrate.

The biofilm will never be created if the cooling tower system is installed using a high-frequency electrical pulse field and creating encapsulation and electroporation processes. The combined effects of encapsulation and electroporation result in exceptionally low total bacterial counts (TBC) in cooling tower water.

Corrosion Control

Most corrosion in cooling tower systems or boilers comes from:

- Chemical additives;
- Softened water;
- Biofilm; and
- Mineral scale.

So, by removing chemicals, avoiding the use of softened water, and using the chemical-free water treatment module and signal generator in cooling tower and boiler water applications, corrosion concerns can be eliminated.

The calcium carbonate that coats the suspended particles is in a state of saturation while it precipitates, and will act as a powerful cathodic corrosion inhibitor. It will greatly slow the corrosion process by blocking the reception of electrons that are thrown off by the corrosion process. With no place for the electrons to go, the corrosion process is physically, very effectively controlled. 

Loss of Air Conditioning Cooling

For this chapter I want to discuss a real life situation regarding poor cooling in a residence and reduced airflow coming from the registers in the house. The air conditioner is a three ton (36,000 btuh), HCFC-22, split type, air conditioner with the A-coil in the plenum of the furnace located in the basement. The evaporator has an orifice for a metering device. The condensing unit is located on the east end of the house. The residence is a 1,800-square-foot ranch house located in a subdivision in Flint, Mich. The homeowners are an elderly couple and rely on air conditioning for health reasons. It has been an unseasonably hot summer and temperatures in the house are reaching 80°F. In fact, the homeowners said that temperatures inside the house have been rising steadily in the last two weeks. They try to keep the house at 72° throughout the entire summer. They are also complaining of high humidity inside the house.

A service technician soon arrives. After introducing himself and his company, the technician converses with the two homeowners for about 10 minutes trying to get as much information and history about the a/c problem as possible. The technician then goes outside to the condensing unit and installs both of his gauges. He instantly notices that the suction pressure is reading 50 psig (26°). The normal suction pressure should be about 70 psig (41°) for the outdoor temperature and humidity conditions that day. The head pressure is also low at 190 psig for the 90° day. The head pressure should be in the 255–265 psig range. The technician also notices the compressor sweating heavily from top to bottom.

The technician then touches the crankcase area or bottom to the compressor and finds that it is extremely cold. This means that the compressor has been suffering from liquid floodback during the day at some point during its

Compressor Inlet Temperature	28°F
— Saturated Evaporating Temperature ...	26°F
Compressor Superheat	2°F

Equation 1.

run cycle. Floodback is liquid refrigerant entering the crankcase of the compressor during the running cycle. The technician then installs a temperature probe on the suction line about 6 inches from where it enters the compressor. The temperature reads 28°. The technician then subtracts the saturated evaporating temperature of 26° from the compressor inlet temperature 28° and finds out that there is only 2° of compressor superheat (See Equation 1).

This reinforces that there is a floodback problem during the running cycle. Floodback can ruin a compressor by diluting the compressor’s oil with liquid refrigerant. This has a tendency to ruin the lubricity of the oil and score bearing surfaces in the compressor. Floodback also causes oil foaming, which can cause oil to be pumped out the discharge valve and into the system. Discharge valve damage can also occur from the oil foam/refrigerant rich mixture.

Finding a Cause

The technician then checks the airflow problem and agrees with the homeowners that there is a reduced airflow problem. The technician then takes a cur-

rent reading of the fan motor and finds it to be 4.2 amps. This is far from the nameplate current of 8 amps. This tells the technician that the fan motor is only partially loaded and is not moving the proper amount of air it is designed to move.

The technician then decides to check the air filter located in the return air cabinet before the evaporator or A-coil. He notices that it is completely filled with dust and lint. However, even with the air filter pulled, there still is a restricted airflow problem and the fan motor continues to pull low current. He then decides to have a look at the A-coil itself. He shuts off power to the unit and removes the plenum. He finds that the A-coil is completely covered with a blanket of ice and frost. The technician then melts the iced coil with a large wattage blowdryer. After putting the plenum back on the unit and installing a new air filter, the technician starts the air conditioner. The proper airflow has been established and the suction pressure is normal at 70 psig. The fan motor is now drawing normal current of about 7 amps.

The technician then explains to the homeowner that a dirty air filter has caused a restricted airflow to the A-coil. He then explains the importance of keeping the air filter clean. This restriction in the airflow has caused a low suction pressure because of a reduced heat load entering the evaporator coil. This caused a slower vaporization rate of refrigerant in the evaporator. The low suction pressure made the refrigerant flowing through the evaporator below freezing (26°). This finally froze the evaporator coil solid with ice. The restricted airflow also unloaded the fan motor causing it to draw low current.

Once the evaporator coil froze solid, the refrigerant saw very little heat

and humidity load. This caused a low vaporization rate and some of the liquid refrigerant (R-22) trickled down the suction line to the compressor's crankcase causing floodback. This is why there were only 2° of compressor superheat and the crankcase area was cold to the touch.

The low heat and humidity load on the evaporator also caused the head pressure to be low. This happened because if there was very low heat being absorbed in the evaporator section, there will be hardly any heat to be rejected into the condenser section of the system. This will keep condensing (head) pressures down.

Talk Is Good

Many technicians will try to add refrigerant when they experience low suction and low head pressures simultaneously. This is not always the answer. It is true, an undercharge of refrigerant will cause low head and low suction pressures, but that is not the only thing that will cause both pressures to be low. An undercharge will have low subcooling readings on the high side, where a dirty air filter for the evaporator will not produce low subcooling readings.

In this case, something as simple as a dirty air filter was the culprit in freezing the coil and causing low head and suction pressures. In this case, the low airflow was the major clue to the problem, and it wouldn't have been noticed if the technician did not converse with the homeowner before troubleshooting. Hopefully, the service technician would have eventually taken a subcooling reading if the low airflow problem was not noticed. 📍

Condenser Splitting

This chapter focuses on the concept of condenser splitting. But first, here's a quick review of condenser flooding before covering condenser splitting to help the reader better understand both of these concepts and their particular advantages and disadvantages.

Condenser Flooding

A pressure-actuated holdback valve is installed at the condenser outlet. This valve is often referred to as an ORI (Open on Rise of Inlet) valve. The valve will throttle shut when the condenser pressure reaches a preset minimum pressure in a cold ambient condition (Figure 1). This throttling action will back up liquid refrigerant in the bottom of the condenser, causing a flooded condition. The condenser now has a smaller internal volume, which is what is needed for a colder ambient condition. The condenser pressure will now rise, giving sufficient liquid line pressures to feed the expansion valve. Larger receivers are needed for these systems to hold the extra refrigerant for condenser flooding in the summer months.

While the condenser is being flooded with liquid refrigerant, a CRO (Close on Rise of Outlet) valve, located between the compressor's discharge line and the receiver inlet, will bypass hot compressor discharge gas to the receiver inlet when it senses a preset pressure difference between the discharge line and the receiver (Figure 1). The 'T' symbol means the valve comes with a built-in pressure tap for ease in taking a pressure reading for service purposes and for setting the valve. The pressure difference is created from the reduced flow of refrigerant to the receiver because of the throttling action of the ORI valve. The bypassed hot gas

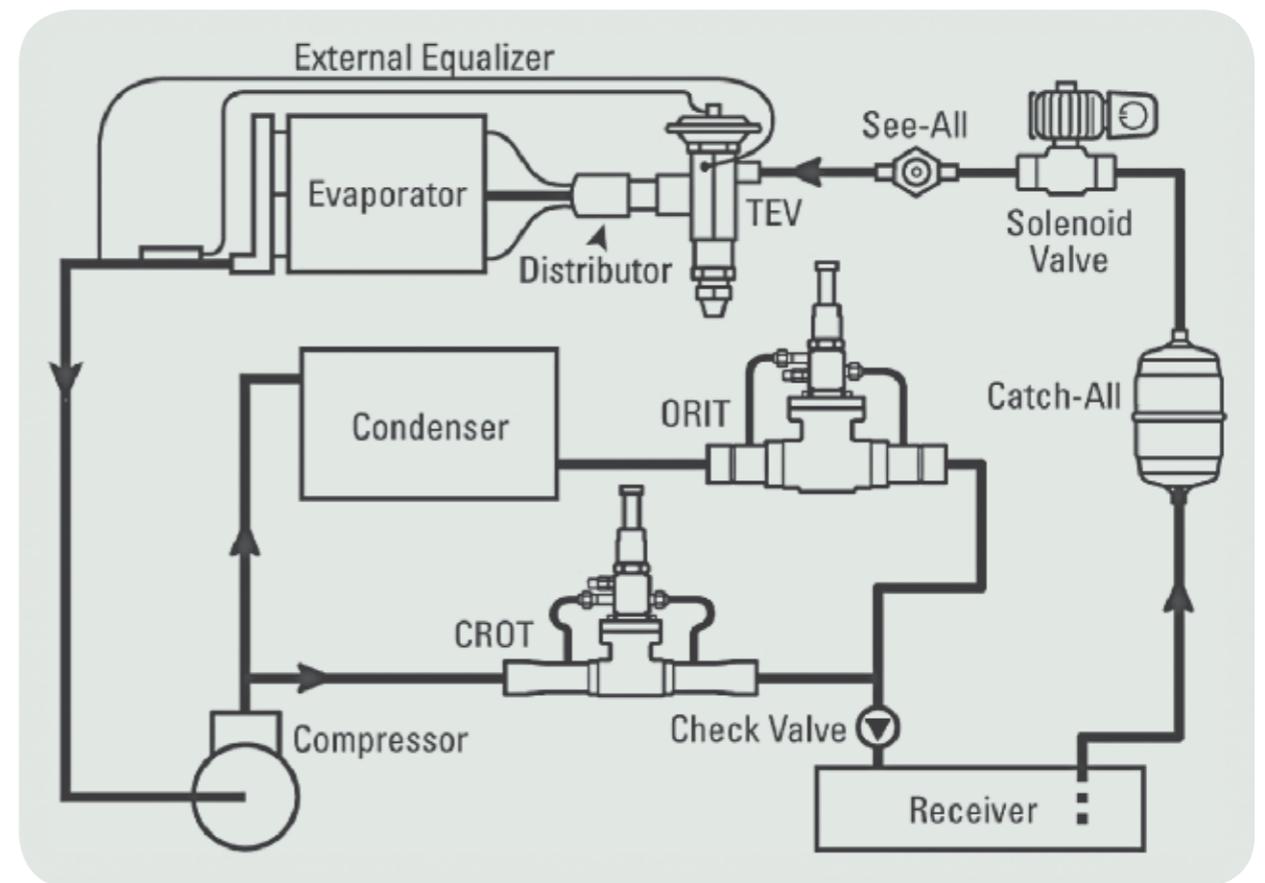


Figure 1. The Close on Rise of Outlet (CRO) valve is located between the compressor's discharge line and the receiver inlet. (All artwork courtesy Sporlan Division, Parker Hannifin Corp.)

through the CRO valve serves to warm up any cold liquid coming from the ORI valve at the receiver's inlet, and it will also increase the pressure of the receiver so metering devices will have the proper liquid line pressure feeding them.

One of the main advantages of condenser flooding is to keep consistent liquid pressure feeding the metering device in low ambient conditions. Manufac-

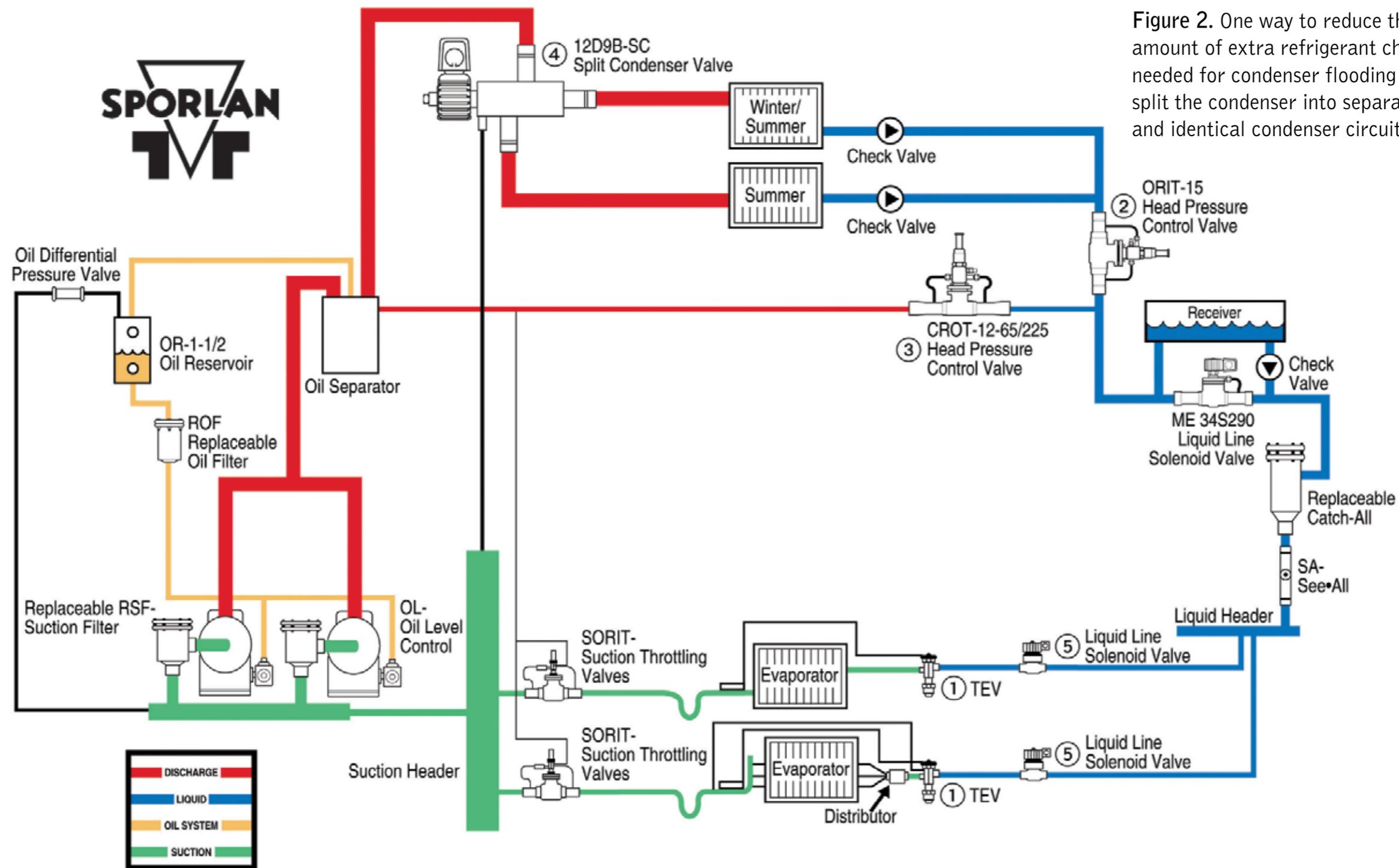


Figure 2. One way to reduce the amount of extra refrigerant charge needed for condenser flooding is to split the condenser into separate and identical condenser circuits.

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THIS SYSTEM DIAGRAM HAS BEEN DEVELOPED ONLY TO ILLUSTRATE SPECIFIC SPORLAN PRODUCTS AND THEIR TYPICAL APPLICATION. THE DIAGRAM IS NOT INTENDED AS A PIPING DRAWING AND/OR RECOMMENDATION.

turers do supply technical information on how much extra refrigerant is needed for flooding a condenser for a certain low ambient condition. However, in extreme low ambient conditions, it may be necessary to flood 80 to 90 percent of the condenser. On larger systems, this could mean several hundred pounds of refrigerant. This is the main disadvantage of flooding a condenser for low ambient operations. With the rising price of refrigerant and the environmental concerns of global warming and ozone depletion, condenser flooding can become quite expensive and environmentally unsound if not managed and serviced properly.

Condenser Splitting

As mentioned above, the main disadvantage of condenser flooding is that larger refrigeration systems may hold hundreds of extra pounds of refrigerant needed to properly flood a condenser at extremely low ambient conditions. One way to reduce the amount of extra refrigerant charge needed for condenser flooding is to split the condenser into two separate and identical condenser circuits (Figure 2 on the previous page). This method is referred to as condenser splitting. The splitting of the condensers is done with the addition of a pilot-operated, three-way solenoid valve installed in the discharge line from the compressors (Figure 3). The splitting of the identical condensers is done in such a way where only one-half of the condenser is used for winter operation, and both halves are used for summer operation. The top half of the condenser is referred to as the summer-winter condenser, and the bottom half of the con-

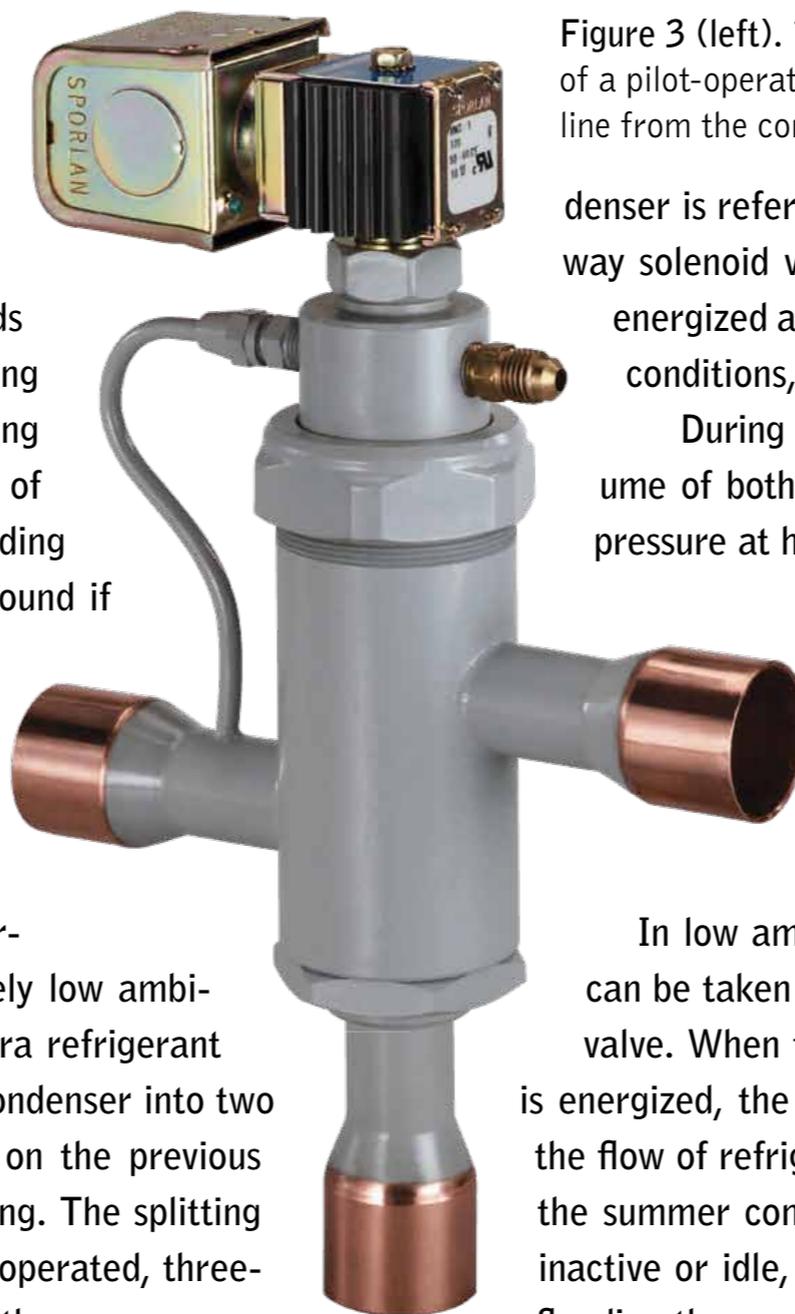


Figure 3 (left). The splitting of the condensers is done with the addition of a pilot-operated, three-way solenoid valve installed in the discharge line from the compressors.

denser is referred to as the summer condenser (Figure 2). The three-way solenoid valve controlling the splitting of the condensers can be energized and de-energized by a controller sensing outside ambient conditions, an outdoor thermostat, or a high-side pressure control.

During summertime operations, the added surface area and volume of both condensers are needed to maintain a reasonable head pressure at higher ambient conditions. The pilot-operated, three-way solenoid valve is then de-energized. This positions the main piston inside the valve to let refrigerant flow from the compressor's discharge line to the three-way valve's inlet port, and then equally to the valve's two outer ports. In other words, the flow of refrigerant will flow to both of the condenser halves equally.

In low ambient conditions, the summer portion of the condenser can be taken out of the active refrigeration system by the three-way valve. When the coil of the pilot-operated, three-way solenoid valve is energized, the sliding piston inside the valve will move and close off the flow of refrigerant to the port on the bottom of the valve that feeds the summer condenser. This action will render the summer condenser inactive or idle, and the minimum head pressure can be maintained by flooding the summer-winter half of the condenser with conventional refrigerant-side head pressure control valves, as explained in the condenser flooding section of this chapter.

In fact, during winter operations, the system's head pressure is best maintained with a combination of condenser splitting, refrigerant-side head pressure

controls, and air-side controls like fan cycling or fan variable-speed devices. This combination of refrigerant-side and air-side controls will minimize the refrigerant charge even more while splitting the condenser. These combinations will also maintain the correct head pressure for better system efficiencies.

The refrigerant that is trapped in the idle summer condenser during low-ambient conditions will flow back into the active system through a bleed hole in the piston of the three-way valve. This trapped refrigerant will flow through the piston's bleed hole, into the valve's pilot assembly, and back to the suction header through a small copper line which feeds all parallel compressors (Figure 2).

Another scheme to rid the idle summer condenser of its refrigerant is to have

a dedicated pump-out solenoid valve, which will open when energized and vent the trapped refrigerant to the common suction header through a capillary tube restriction. Both the bleed hole in the piston or the capillary tube ensure that the refrigerant experiences a restriction, and is mostly vaporized before reaching the common suction header which is under low side (common suction) pressure.

A check valve is located at the summer condenser's outlet to prevent any refrigerant from entering it while it is idle and under a low pressure condition. While not needed for backflow prevention, a check valve is also located at the outlet of the summer/winter condenser simply to make the pressure drops equal in both halves of the condenser when both are being used simultaneously in summertime operations. 

Helical Oil Separators

Because refrigerants and refrigeration oils are miscible in one another, there will always be some oil that leaves the compressor with the refrigerant being circulated. Also, any time flooding or migration occurs, crankcase oil is sure to be diluted with refrigerant. This will cause oil foaming at start-ups. Crankcase pressures will build often forcing oil and refrigerant around the rings of the compressor's cylinders to be pumped into the discharge line. Oil separators remove oil from the compressor's discharge gas, temporarily store the oil, and then return it to the compressor's crankcase. Oil separators are located close to the compressor in the discharge line. Even though most oil separators are designed to be mounted vertically, there are some horizontal models available on the market. Oil separators are essential on low and ultra-low temperature refrigeration systems and on large air conditioning systems up to 150 tons. Most compressor manufacturers require oil separators on all two-stage compressors. Oil separators can also act as discharge mufflers to quiet compressor pulsation and vibration noises.

Unusual conditions occur at times to compressors and rapid removal of oil from the compressor's crankcase happens. A lot of times these occurrences happen beyond the control of both the designer and installer. The velocity of the refrigerant flowing through the system should return oil to the compressor's crankcase. Even though proper refrigerant system piping designs maintain enough refrigerant velocity to ensure good oil return, sometimes this added pressure drop, which assists in getting the right refrigerant velocity for oil return, hampers the system's efficiencies. A lot of times, a higher than normal pressure drop is intentionally designed into a system for better oil return. This will cause higher compression ratios and lower volumetric efficiencies, leading to lower capacities.



A helical oil separator. (Courtesy Ferris State University)

Detrimental Effects of Oil in a System

Oil that gets past the compressor and into the system not only robs the compressor's crankcase of vital lubrication, but it coats the walls of the condenser and evaporator. Oil films on the walls of these important heat exchangers will reduce heat transfer. The condenser will not be able to reject heat as efficiently as it should with an oil film coating its walls. Even though this oil

film will be hotter and thinner than if it were in the evaporator, system efficiencies will suffer. Head pressures will rise causing higher compression ratios and lower volumetric efficiencies with lower than normal system capacities.

Oil that coats the walls of the evaporator will decrease heat transfer to the refrigerant in the evaporator. A film of oil bubbles, which acts as a very good insulator, will form on the inside of the evaporator. The evaporator will now see a reduced heat load, which will cause the suction pressure to be lower. Lower suction pressures cause higher compression ratios and lower volumetric efficiencies. The result is a lower system capacity with much longer running times.

Most metering devices including thermal expansion valves (TXV) and capillary tubes will also experience inefficient performance due to the presence of oil filming. Capillary tubes may experience wide variation in flow rates. Usually, reduced refrigerant flow rate with higher head pressures and lower suction pressures are experienced. TXV remote bulbs may not sense the correct refrigerant temperature at the evaporator outlet, causing improper superheat control. TXV hunting can also occur.

If an oil separator isn't employed, the compressor often sees slugs of oil that are returning from the evaporator. The compressor's pistons can momentarily pump slugs of liquid oil which can build tremendous hydraulic forces because of the incompressibility of most liquids. Serious compressor valve and drive gear damage can result.

How Helical Oil Separators Work

Helical oil separators offer 99 to 100 percent efficiency in oil separation with low pressure drop. Upon entering the oil separator, the refrigerant gas and oil fog mixture encounter the leading edge of a helical fighting. The gas/oil mixture is centrifugally forced along the spiral path of the helix, causing the heavier oil particles to spin to the perimeter where impingement with a

screen layer occurs. This screen layer serves as an oil stripping and draining medium. The separated oil now flows downward along the boundary of the shell through a baffle and into an oil collection area at the bottom of the separator. The specially designed baffle isolates the oil collection and eliminates oil re-entrainment by preventing turbulence.

Virtually oil-free refrigerant gas exits the separator through an exit screen just below the lower edge of the helical fighting. A float activated oil return valve allows the captured oil to return to the compressor's crankcase or oil reservoir. When the level of oil gets high enough to raise a float, an oil return needle is opened and the oil is returned to the compressor's crankcase through a small return line connected to the compressor's crankcase.

The pressure difference between the high and low sides of the refrigeration or air conditioning system is the driving force for the oil to travel from the oil separator to the crankcase. The oil separator is in the high side of the system, and the compressor's crankcase is in the low side. This float operated oil return needle valve is located high enough in the oil sump to allow clean oil to be automatically returned to the compressor's crankcase.

Only a small amount of oil is needed to actuate the float mechanism. This ensures only a small amount of oil is ever absent from the compressor's crankcase at any given time. When the oil level in the sump of the oil separator drops to a certain level, the float will force the needle valve closed.

On larger parallel compressor systems, the oil separator gives the oil to an oil reservoir for temporary storage until a compressor calls for it. The oil reservoir is usually kept at a pressure at about 20 psi above the common suction header pressure by a special pressure regulating valve. Many times there may be a combination oil separator/reservoir. In this case, the oil is distributed to each compressor's oil level regulator at a reduced pressure before entering a compressor's crankcase. 

Frost on the Compressor's Head

Many service technicians believe that if there is frost on the compressor's head, there is cause for alarm. This is simply not true. Frost is simply frozen dew. Usually on lower temperature refrigeration applications, the suction line and part of the compressor's head will get cold. The part of the compressor's head that gets coldest is where the suction vapors enter before they are compressed. These parts often get cold enough to reach the dew point of the surrounding air. When the air's dew point temperature is reached from coming in contact with the cold suction line and compressor head, water vapor in the air is cooled to its dew point and will condense on the suction line and head of the compressor. When this condensed water vapor reaches 32°F, it will freeze into frost (Figure 1). So, frost is simply condensed water vapor or dew, which has reached 32° or below.

System Specifications

Consider a low temperature commercial refrigeration application operating with 7° of evaporator superheat and 40° of compressor superheat (Figure 2, page 23). The refrigerated box temperature is 0° with an evaporator temperature of -13°. It is an R-404A system. With an evaporator temperature of -13° and the system having 40° of compressor superheat, the temperature of the refrigerant coming into the compressor is 27° (-13 plus 40). The 27° temperature coming into the compressor is lower than the surrounding air's dew point, and it is also lower than the freezing point of water (32°), so the dew on the suction line and compressor's head will form frost. These frost lines are completely normal for this low temperature application refrigeration machine.



Figure 1. Condensed water vapor freezes into frost.
(Courtesy of Ferris State University.)

Compressor Flooding or Slugging?

Because the system has a compressor superheat of 40°, there is no worry about whether the compressor is flooding or slugging. In review, flooding is liquid refrigerant coming back to the compressor's crankcase during a run cycle. Slugging is liquid refrigerant or oil actually entering the compressor's cylinders and/or valve arrangement and being pumped. Again, because the system has superheat at the compressor of 40°, flooding and slugging cannot exist.

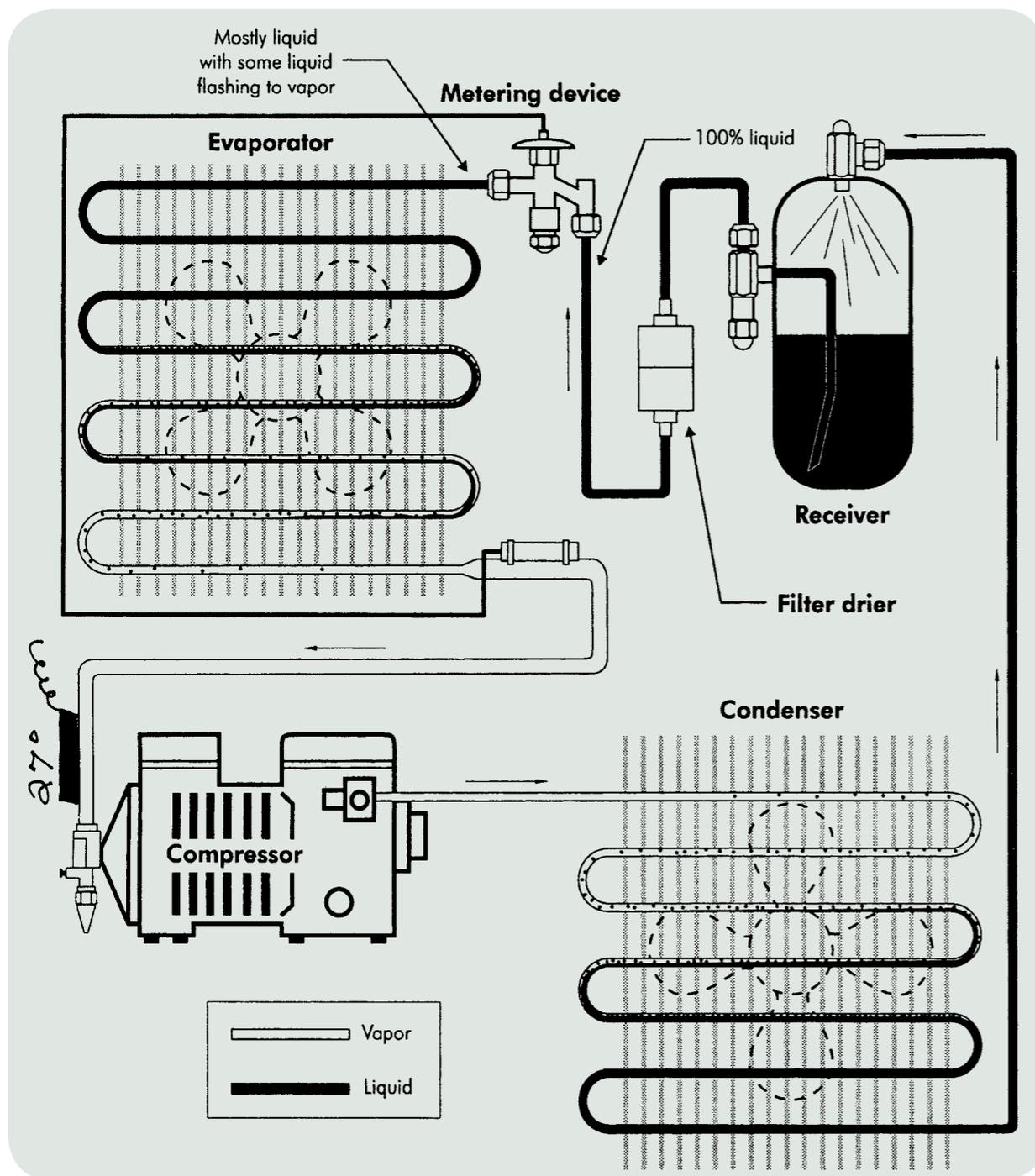


Figure 2. Low temperature commercial refrigeration application.
(Figure from *Troubleshooting and Servicing Modern Air Conditioning and Refrigeration Systems* by John Tomczyk)

In order for slugging or flooding to occur, the compressor would have to be experiencing no superheat. In other words, the temperature coming into the compressor would be the same as the evaporator temperature (-13°). This would indicate that there was no compressor superheat and liquid refrigerant was entering the compressor.

The amp meter on the air cooled, semi-hermetic compressor (Figure 1) is reading 5.87 amps. The rated load amps (RLA) of the air-cooled, semi-hermetic compressor is 6.5 amps. We are still quite below the RLA of the compressor. However, if liquid was coming back to the compressor, the amp meter would be above the RLA rating of the compressor. A mixture of high-density vapors and liquid is hard for the compressor to pass, causing high amp readings. Valve plate damage usually occurs in these situations. Air-cooled, semi-hermetic compressors bring the refrigerant gas right back to the head of the compressor and then to the suction valves directly. This is why it is very important to have some superheat to ensure that vapor and not liquid is returning to the compressor. This is not the case for refrigerant cooled compressors where suction gases come into the end bell of the compressor and then pass through the motor windings before entering the valve arrangement (Figure 3, page 24).

In either scenario, whether the system has compressor superheat and doesn't have compressor superheat, both the suction line and compressor's head would still be frosted. This is why it is of utmost importance for service technicians to measure superheat at both the evaporator and compressor to make sure the compressor is protected from slugging and flooding.

Measuring Compressor (Total) Superheat

In review, compressor superheat or total superheat is all of the superheat in the low side of the refrigeration system. Compressor superheat consists of evaporator superheat and suction line superheat. A service technician can

measure total superheat by placing a thermometer, thermocouple, or thermistor at the compressor inlet and taking the temperature. A pressure reading will also be needed at this same location.

For example, consider the example below for a R-404A system with a low side pressure taken at the compressor of 21 psig or -13° and a compressor inlet temperature of 27° . The pressure gauge reading on the low side of the system of 21 psig tells the service technician that there is a -13° evaporating temperature. The compressor superheat calculation is as follows:

Compressor inlet temp. — Evaporator temp. = Compressor superheat
 $27^{\circ}\text{F} - (-13^{\circ}\text{F}) = 40^{\circ}\text{F}$

In this example, the compressor superheat is 40° . It is possible to have a TXV adjusted to control the proper amount of evaporator superheat at the coil and still return liquid refrigerant to the compressor at certain low load conditions. It is recommended that all TXV controlled refrigeration systems have some compressor superheat to ensure that the compressor does not see liquid refrigerant (flood or slug) at low evaporator loads. The TXV, however, should be set to maintain proper superheat for the evaporator. This will ensure that the compressor will always see refrigerant vapor, and not liquid. 

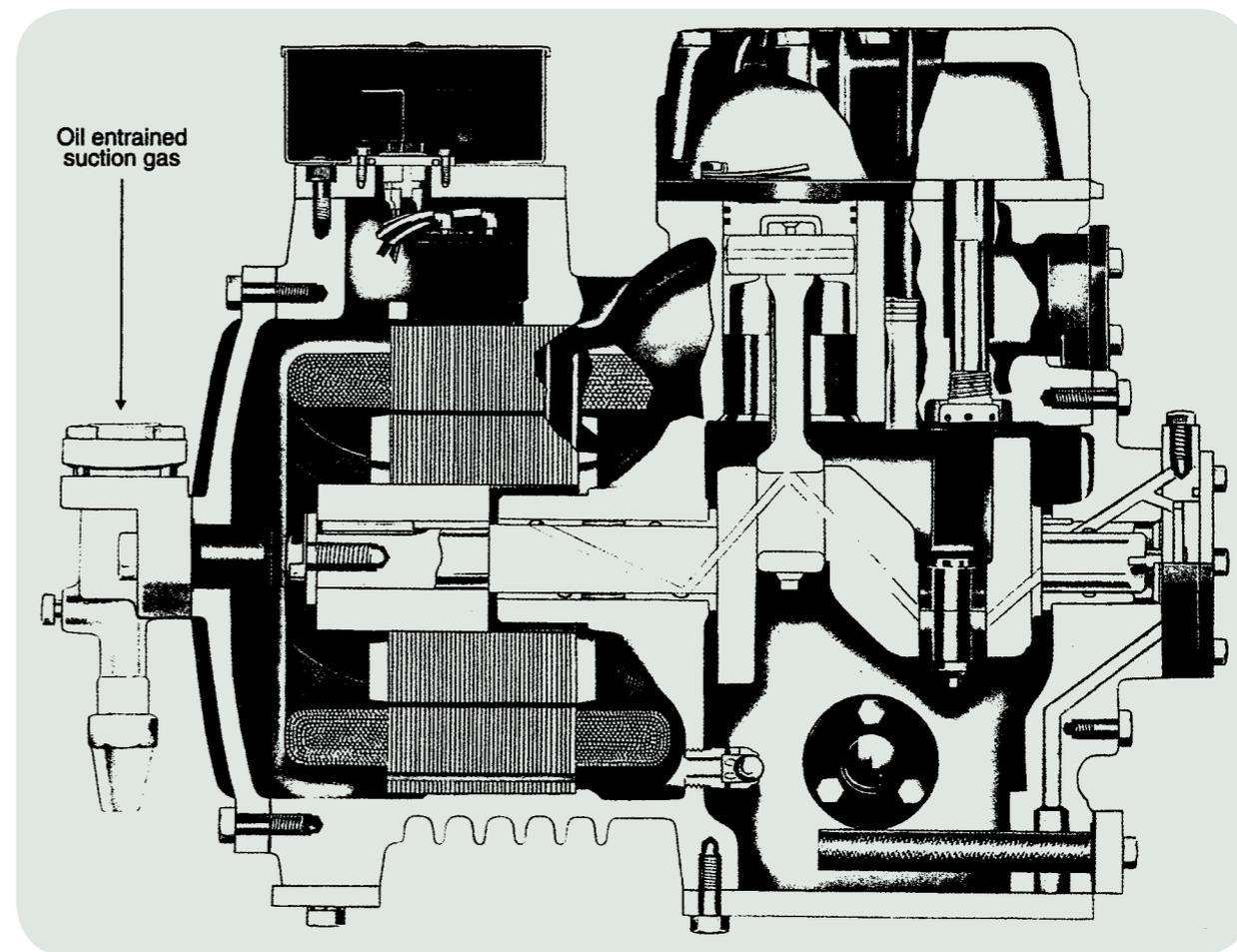


Figure 3. Refrigerant cooled semi-hermetic compressor.
 (Figure from *Troubleshooting and Servicing Modern Air Conditioning and Refrigeration Systems* by John Tomczyk)

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Ice Flake Machine Troubleshooting

Many ice flake machines employ an auger rotating within an insulated freezing cylinder or evaporator. The auger, which is driven and geared down by a gear motor and gear box to about 8-16 rpm, has cutting edges or flights. The flights shave ice from the walls of the freezing cylinder (evaporator) which is flooded with water and has refrigerant lines wrapped around its outer circumference (Figure 1). The refrigerant lines have vaporizing refrigerant in them which will freeze the water that is in close proximity or contact to the inside of the freezing cylinder.

A water reservoir supplies the right height or level of water to the freezing cylinder. Because water will seek its own level, the water level or height in the water reservoir will also be the level in the freezing cylinder (Figure 2 on the next page). Water level in the reservoir is usually controlled by a single float mechanism, or a dual-float mechanism which controls an electric solenoid valve to bring water to the reservoir. The water-logged shaved ice is then carried through the water to the top or head of the freezing cylinder where it is squeezed, extruded, shaped, cut and eventually falls to an insulated ice storage bin for use (Figure 3 on the next page).

It is of utmost importance that the water level in the reservoir and freezing cylinder are at the proper levels for the ice flake machine to operate effectively. What follows are some scenarios for improper water levels in the freezing cylinder, and how they affect other components of the ice flake machine.

Low Water Levels

If a float mechanism in the water reservoir is adjusted wrong and the water level is low in the reservoir, it will also be low in the freezing cylinder



Figure 1. A cutting edge, or flight, is shown to the right in this photo of an auger. (Courtesy of Ferris State University.)

because of water seeking its own level. Since water is the refrigerating load for an ice flake machine, low water level in the freezing cylinder means low load on the evaporator. This condition will cause lower than usual evaporator pressures, thus lower evaporator temperatures.

These low evaporator temperatures will produce harder and colder ice for the auger to cut. This will put an extra load on the auger, gears, and gear motor. Often, the gear motor will trip on its overload and sometimes has to be manually reset. Water reservoirs should have a line indicating the correct water level for that particular machine.

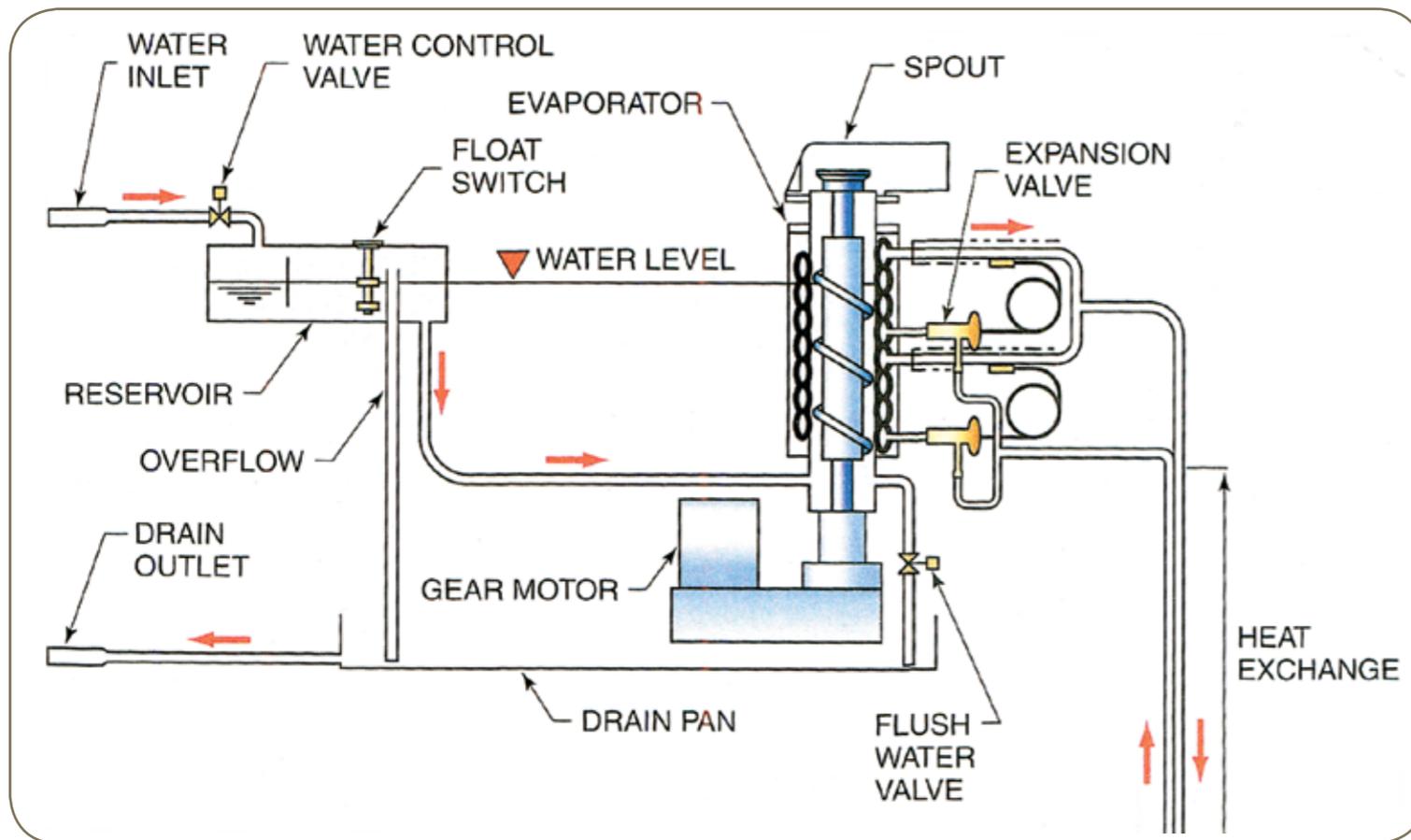


Figure 2. This schematic shows the relationship of the water level with the freezing cylinder in a flake ice machine. (Courtesy of Hoshizaki America.)

High Water Levels

If the float mechanism in the water reservoir is adjusted wrong, or the seat in the float chamber is leaking and the water level is too high, the freezing cylinder will experience high water levels. This will cause stress on the gear motor from the auger doing more work because there is more surface area of ice to cut.

Again, the overload may trip on the gear motor. When the gear motor's overload reset button must be reset often, a service technician should suspect water level problems as a possible cause. Often, high water levels will cause water to pour over into the ice storage bin and cause a large melting depression in the stored flaked ice. Also, this new water constantly coming into the freezing cylinder will impose extra heat load on the evaporator and cause higher than normal evaporating pressures and poor ice quality and quantity. This happens because the higher quantities of new water will have to be refrigerated to the freezing point to start making ice. [Ⓝ]

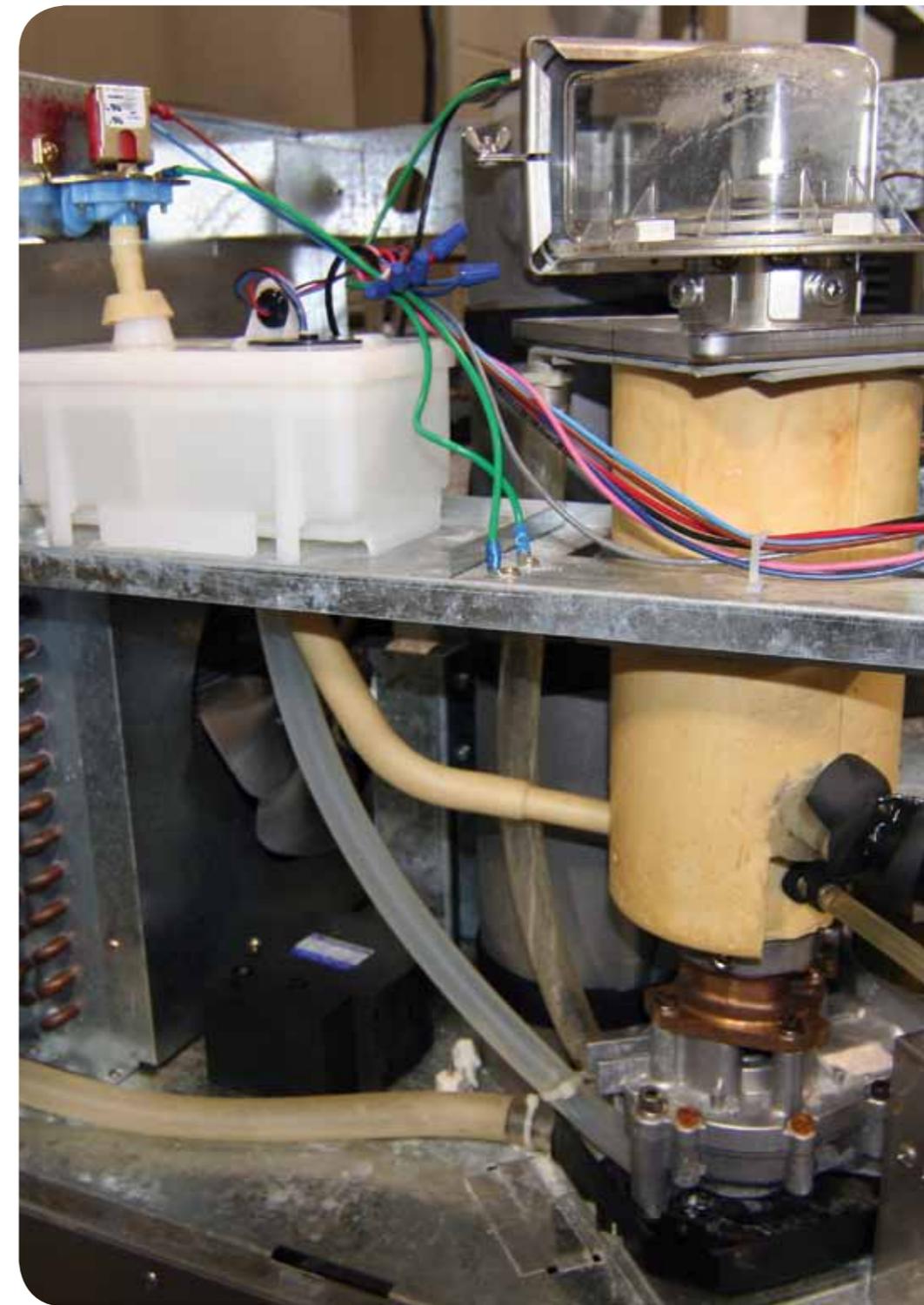


Figure 3. Water-logged shaved ice is carried through the water to the top or head of the freezing cylinder where it is squeezed, extruded, shaped, cut and eventually falls to an insulated ice storage bin for use. (Courtesy of Ferris State University.)

More Ice Flake Machine Troubleshooting

This chapter is part two of our discussion on ice flake machine troubleshooting. The previous chapter examined troubleshooting low and high water levels. This chapter will examine problems associated with water impurities as well as mechanical problems.

When water is frozen in an evaporator flooded with water, minerals in the water will often build up on the walls of the evaporator. This mineral buildup will cause added resistance for the ice cutting auger. Mineral buildup (scale) is a porous material and is a good insulator to heat transfer. The refrigerant will now see less heat load from the water in the cylinder and the evaporator pressure will drop. A drop in evaporator pressure will cause a colder evaporator and harder ice. The cutting auger's flights now have to cut harder ice along with minerals that have built up on the evaporator surface. The result is a loud crunching or squealing noise coming from the evaporator compartment. This added resistance of cutting ice and mineral buildup will also add extra load on the gear motor. A higher amp draw will be the result.

Drive Train (Gears + Shafts)

When the ice-cutting auger is stressed, so is the gear motor and drive train. The ice-cutting auger, drive train with gears, and the gear motor are all connected (Figure 1). When the gear motor is stressed from cutting hard ice and minerals, the extra torque generated from the motor will cause excessive heat. This may cause the gear motor's overload to open and shut the unit down until a service person manually resets the overload on the gear motor. Cleaning the ice flake machine according to the manufacturer's recommendations with an

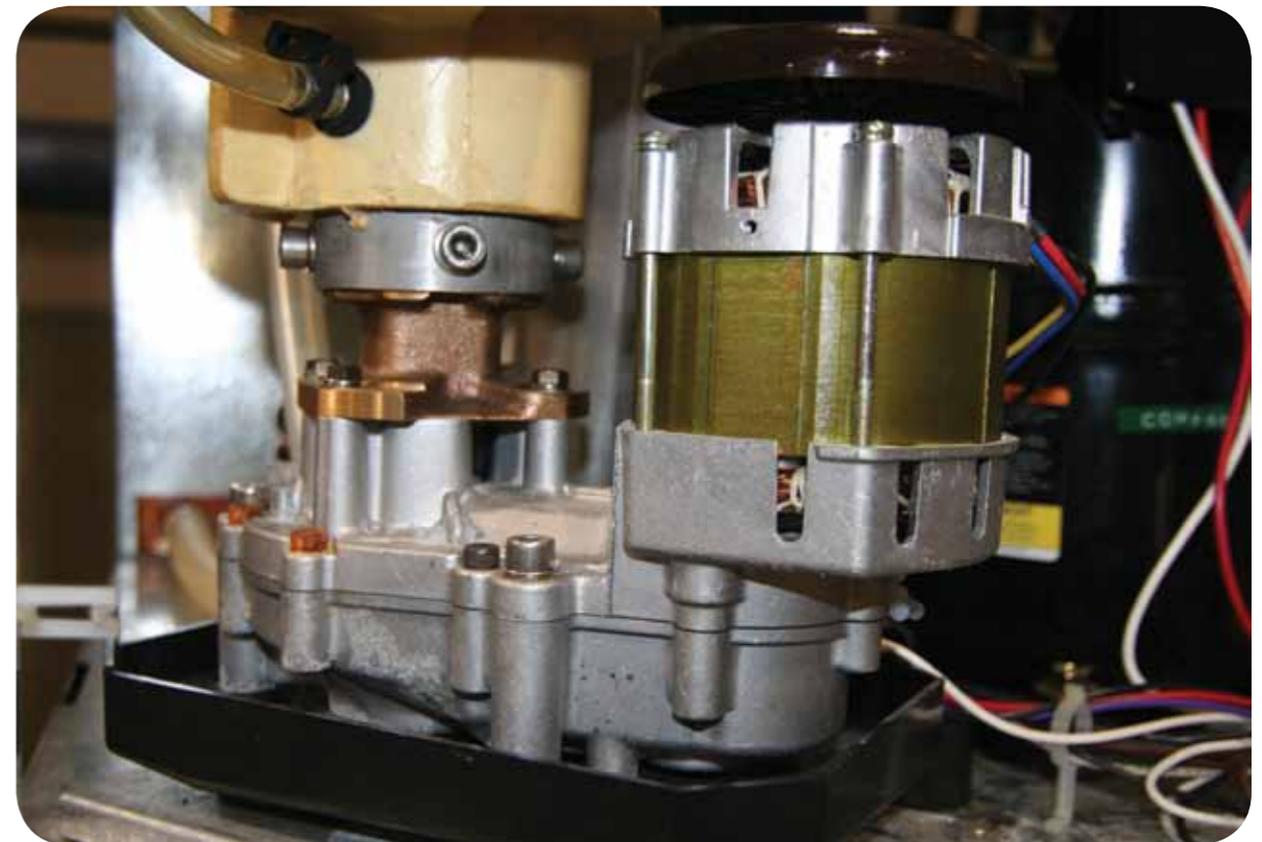


Figure 1. The ice cutting auger, drive train with gears, and the gear motor are all connected. (Courtesy of Ferris State University.)

approved cleaner, and inspecting the bearings connecting the cutting auger with the drive train will prevent mineral buildup on the freezing cylinder's surface and keep the ice flake machine operating quieter and longer.

Often, grease can leak out of a bearing housing and start a bearing failure. If a bearing has started to fail, the cutting auger may wobble from the added clearance in the worn bearing. This wobbling as the auger rotates may cause the auger to touch the freezing cylinder (evaporator) and scar its surface. If

scarring of the evaporator surface or auger's cutting surface has occurred, one of the components will, for sure, have to be replaced. Always follow the manufacturer's recommendation when replacing a cutting auger or freezing cylinder. It is this gear motor assembly that is more susceptible to failure than any other part of the ice flake machine.

Remember, as the auger rotates and cuts ice and mineral deposits, the gear motor and gear assembly senses all of these stresses and strains. It is for this reason that some manufacturers have manufactured open-type gear case housing assemblies. This means the gear assembly has a vent and is exposed to the atmosphere, usually with a soft plastic plug holding the gear lube

(grease) from escaping. When excessive heat occurs from gear motor stress, expanded hot grease can escape through the vent. However, one has to be careful to keep the vent hole plugged or moisture can enter. This will deteriorate the lubricating effect of the grease, and excessive gear wear will result.

Usually, a regular clicking sound will be heard from the drive train if a gear is chipped from poor lubrication or too much stress. However, if the auger motor is starting to fail, a loud, higher pitch noise will be heard. Cleaning the ice flake machine with an approved cleaner and inspecting the bearings connecting the cutting auger with the drive train will prevent mineral buildup on the freezing cylinder's surface and keep the ice flake machine operating quieter and longer. 📌

Restricted TXV Metering Device

This chapter explores how a restricted metering device will affect system performance and efficiency. The system is a commercial refrigeration system with a TXV as the metering device. The refrigerant being used is HFC-134a. Very similar results will occur if an automatic expansion valve (AXV) is used. However, because different refrigerant system configurations may apply when using capillary tubes as metering devices, different system symptoms may occur. The intent of this chapter is to explore how a partially restricted TXV will affect system performance and efficiency and what symptoms will occur.

Listed below are ways the metering device (TXV) can become restricted:

- Plugged inlet screen;
- Foreign material in orifice;
- Oil logged from refrigerant flooding the compressor;
- Adjusted too far closed;
- Wax buildup in valve from wrong oil in system;
- Sludge from the byproducts of a compressor burnout;
- Partial TXV orifice freeze-up from excessive moisture in the system; and
- Manufacturer's defect in the valve.

A system with a restricted metering device has the very same symptoms as a system with a liquid line restriction that occurred after the receiver. This is because the TXV is actually part of the liquid line. A TXV being restricted will cause the evaporator, compressor, and condenser to be starved of refrigerant. This will cause low suction pressures, high superheats, low amp draws, and low head pressures.

Also, the symptoms of a restricted TXV system are very similar to a system with a refrigerant undercharge. However, the undercharged system will have low condenser subcooling levels. Service technicians often confuse an undercharged system with a restricted metering device.

Adding refrigerant to a system with a restricted metering device will only raise the condenser subcooling amounts to a level where the head pressure may elevate. This is caused from a lack of internal volume in the condenser to hold the added refrigerant. Even the receiver may overflow if too much refrigerant is added.

Table 1 on the next page shows a system checklist for a system with a restricted metering device. Symptoms can include:

- Somewhat high discharge temperature;
- Low condensing (head) pressure;
- Low condenser split;
- Normal to a bit high condenser subcooling;
- Low evaporator (suction) pressure;
- High superheats;
- Low amp draw; and
- Short cycle on low-pressure control (LPC).

Symptoms

High discharge temperature: Somewhat high discharge temperatures are caused by the higher superheats from the evaporator being starved of refrigerant. The compressor is now seeing a lot of sensible heat coming from the evaporator and suction line, along with its heat of compression and mo-

tor heat. The compressor will probably overheat from the lack of refrigerant cooling if it is a refrigerant-cooled compressor.

Low condensing (head) pressures: Since the evaporator and compressor are being starved of refrigerant, so will the condenser because these components are in series with one another. There will be little heat to eject to the ambient surrounding the condenser. This allows the condenser to operate at a lower temperature and pressure.

Low condenser splits: Since the condenser is being starved of refrigerant, it can operate at a lower temperature and pressure. This is because it does not need a large temperature difference between the ambient and the condensing temperature to reject the small amount of heat it is getting from the evaporator, suction line, and compressor. This temperature difference is referred to as the condenser split. If there were large amounts of heat to reject in the condenser, the condenser would accumulate heat until the condenser split was high enough to reject this large amount of heat. High heat loads on the condenser mean large condenser splits. Low heat loads on the condenser mean low condenser splits.

Normal to a bit high condenser subcooling: Most of the refrigerant will be in the receiver, with some in the condenser. The condenser subcooling will be normal to a bit high because of this. The refrigerant flow rate will be low through the system from the restriction. This will cause what refrigerant that is in the condenser to remain there longer and subcool more. Note that an undercharge of refrigerant will cause low subcooling.

Low evaporator pressures: Since the evaporator is starved of refrigerant, the compressor will be starving also and will pull itself into a low-pressure situation. It is the amount and rate of refrigerant vaporizing in the evaporator that keeps the pressure up. A small amount of refrigerant vaporizing will cause a lower pressure.

Restricted Metering Device

(Measured Values)

Compressor discharge temperature	200
Condenser outlet temperature.....	70
Evaporator outlet temperature	30
Compressor in temperature.....	65
Ambient temperature.....	70
Box temperature	30
Compressor volts	230
Compressor amps	low
Low side (evaporating) pressure (psig).....	1.8 psig (-10°)
High side (condensing) pressure (psig).....	104.2 psig (85°)

(Calculated Values °F)

Condenser split.....	15
Condenser subcooling	15
Evaporator superheat	40
Compressor superheat	75

Table 1. This is a system checklist for a system with a restricted metering device.

High superheats: High superheats are caused again from the evaporator and compressor being starved of refrigerant. With the TXV restricted, the evaporator will become inactive and run high superheat. This will cause the compressor superheat to be high. The 100 percent saturated vapor point in the evaporator will climb up the evaporator coil causing high superheats.

Low amp draw: High compressor superheats and low suction pressures will cause low density vapors to enter the compressor. Also, the compressor will be partly starved from the TXV being restricted. These factors will put a



very light load on the compressor causing the amp draw to be low.

Short cycle on the low-pressure control (LPC): The compressor may short cycle on the LPC depending on how severe the restriction in the TXV is. The low suction pressures may cycle the compressor off prematurely. After a short period of time, the evaporator pressure will slowly rise from the small amounts of refrigerant in it and the heat load on it. This will cycle the compressor back on. This short cycling may keep occurring until the compressor overheats. Short cycling is hard on controls, capacitors, and motor windings. 📌

A system with a restricted metering device has the very same symptoms as a system with a liquid line restriction that occurred after the receiver. This is because the TXV is actually part of the liquid line. (Courtesy of Sporlan Division, Parker Hannifin Corp.)

Basic Leak Detection Methods

Every environmentally conscious service technician should spend time learning how to check for refrigerant leaks in refrigeration and/or air conditioning systems. Ozone depletion, global warming, and the increasing price of refrigerants are forcing technicians to become better and more thorough leak detectors. This chapter will cover some basic methods of leak detection in refrigeration and air conditioning systems. The next chapter will look at some of the more advanced methods.

Leak Detection Methods

All sealed systems leak. The leak could be 1 pound per second or as low as 1 ounce every 10 years. Every pressurized system leaks because “flaws” exist at every joint fitting, seam, or weld. These flaws may be too small to detect with even the best of leak detection equipment. But given time, vibration, temperature, and environmental stress, these flaws become larger detectable leaks.

It is technically incorrect to state that a unit has no leaks. All equipment has leaks to some degree. A sealed system which has operated for 20 years without ever needing a charge is called a “tight system.” The equipment still has leaks, but not enough leakage to read on a gauge or affect cooling performance. No pressurized machine is perfect.

A leak is not some arbitrary reading on a meter. Gas escapes at different times and at different rates. In fact, some leaks cannot be detected at the time of the leak test. Leaks may plug, and then reopen under peculiar conditions. A leak is a physical path or hole, usually of irregular dimensions. The leak may be the tail end of a fracture, a speck of dirt on a gasket, or a microgroove between fittings.

Exposing the Leak

Refrigerant vapor can flow under layers of paint, flux, rust, slag, and pipe insulation. Often the refrigerant gas may show up quite a long distance from the leak site. This is why it is important to clean the leak site by removing loose paint, slag, flux, or rust. Remove any pipe insulation. Oil and grease must also be removed from the site because they will contaminate the delicate detection tips of electronic detectors.

There are six classifications of leaks.

1. Standing leaks: Standing leaks are leaks that can be detected while the unit is at rest or off. This includes freezer evaporator coils warmed up by defrost. Standing leaks, fortunately, are the most common of all leaks.

2. Pressure-dependent leaks: Pressure-dependent leaks are leaks that can only be detected as the system pressure increases. Nitrogen is used to pressurize the low sides of systems to around 150 psig, and high sides to 450 psig. Never use air or pure oxygen. Often, a refrigerant trace gas is introduced into a recovered and evacuated system along with the nitrogen. The trace gas enables electronic leak detectors to be used to detect the vicinity of the leak. Refrigerant trace gas will be covered in more detail later in the article. Pressure-dependent leak testing should be performed if no leaks are discovered by the standing leak test. Bubbles or a microfoam solution can also be used to locate pressure-dependent leaks.

Warning: Mixtures of nitrogen and a trace gas of refrigerant, usually of the system’s refrigerant, can be used as leak test gases because, in these cases, the trace gas is not used as a refrigerant for cooling. However, a technician cannot avoid recovering refrigerant by adding nitrogen to a charged system. Before nitrogen is added, the system must be recovered and then evacuated to appropriate

levels. Otherwise, the HCFC, or HFC refrigerant trace gas vented along with the nitrogen will be considered a refrigerant. This will constitute a violation of the prohibition on venting. Also, the use of CFC as a trace gas is not permitted.

3. Temperature-dependent leaks: Temperature-dependent leaks are associated with the heat of expansion. They usually occur from high-temperature ambient air, condenser blockages, or during a defrost period.

4. Vibration-dependent leaks: Vibration-dependent leaks only occur during unit operation. The mechanical strain of motion, rotation, refrigerant flow, or valve actuation are all associated with vibration-dependent leaks.

5. Combination dependent leaks: Combination dependent leaks are flaws that require two or more conditions in order to induce leakage. For example, temperature, vibration, and pressure cause the discharge manifold on a semi-hermetic compressor to expand and seep gas.

6. Cumulative microleaks: Cumulative microleaks are all the individual leaks that are too small to detect with standard tools. The total refrigerant loss over many years of operation slightly reduces the initial refrigerant charge. A system having many fittings, welds, seams, or gasket flanges will probably have a greater amount of cumulative microleaks.

Spotting Refrigerant Oil Residue for Standing Leaks

Successful leak detection is solely dependent on the careful observation made by the testing technician. Fortunately, all refrigeration systems internally circulate compressor oil with the refrigerant. Oil will blow off with the leaking refrigerant gas and “oil mark” the general area of leakage. Oil spots appear wet and have a fine coating of dust (Figure 1). The technician must determine that the area wetness is oil and not condensate. This can be accomplished by rubbing the area with your fingers and feel for oil slickness. However, what is the reliability of oil spotting? Oil spotting is the technician’s

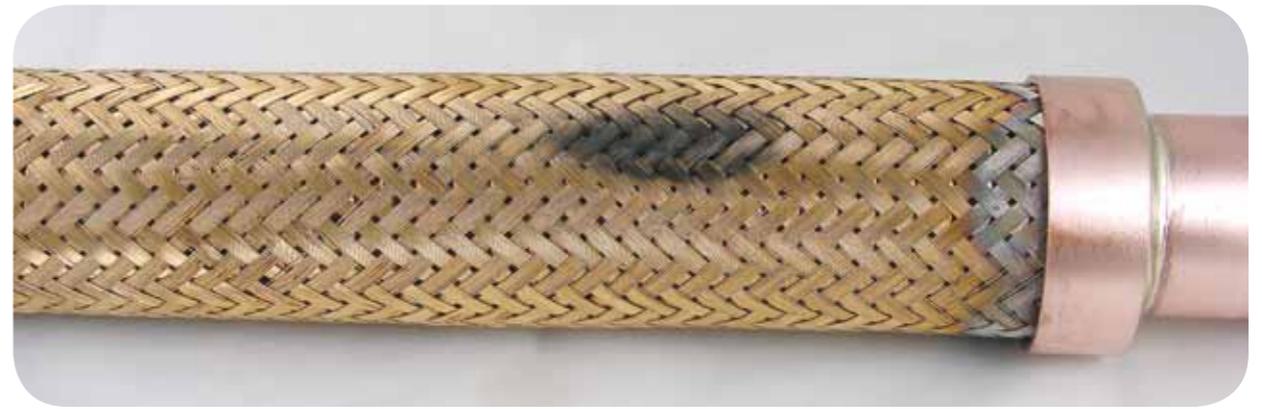


Figure 1. In leaking systems, oil spots can appear wet and have a fine coating of dust. (Photo courtesy of Refrigeration Technologies, Anaheim, Calif.)

first quick-check, but is not always reliable for the following reasons:

- Oil is always present at Schrader valves and access ports due to the discharging of refrigerant hoses on the manifold and gauge set. (Figure 2, next page). Often these parts are falsely blamed as the main point of leakage.
- Oil blotches can originate from motors, pumps, and other sources.
- Oil residue may be the result of a previous leak.
- Oil is not always present at every leak site. It may take months, even years of unit operation to cause enough oil blow-off to accumulate on the outer side.
- Oil may not be present with micro-leaks.
- Oil may not reach certain leak positions.
- Oil may not be present on new start-ups.

Testing for Evaporator Section Leaks

Many leaks that go undetected are in the evaporator coil. This is because most evaporator sections are contained in cabinets, buttoned-up, or framed into areas that do not allow easy access. In order to avoid time-consuming labor to strip off covers, ducting, blower cages, or the unloading of product, an easy electronic screening method is outlined on the next page.



Figure 2. Oil is always present at Schrader valves and access ports due to the discharging of refrigerant hoses on the manifold gauge set. (Photo courtesy of Refrigeration Technologies, Anaheim, Calif.)

1. Turn off all system power including evaporator fan motors.
2. Equalize high- and low-side pressures in the refrigeration or air conditioning system and defrost any frozen evaporator coils. (If the system does not have any pressure, evacuate to the required levels and then add a refrigerant trace gas. Nitrogen is then added to generate a practical test pressure). Most low sides of systems have a working pressure of 150 psig, but always read the nameplate on the evaporator section for test pressure specifications.

3. Calibrate an electronic leak detector to its highest sensitivity.
4. Locate the evaporator drain outlet or downstream drain trap.
5. Position the electronic leak detector probe at the drain opening. Be careful that the leak detector probe does not come into contact with any water.
6. Sniff with the electronic detector for a minimum of 10 minutes or until a leak is sensed. Recalibrate the device and test again. Two consecutive "positive" tests confirm an evaporator leak. Two consecutive "negative" tests rules out an evaporator section leak.

Remember, refrigerant gas is heavier than air. Gravity will cause the gas to flow to the lowest point. If the evaporator section tests positive, the technician should expose the coil and spray coat all surfaces with a specially formulated bubble/foam promoter. Bubble/microfoam solutions have been very successful in leak detection because of their price and effectiveness. Leaks can be easily pinpointed with these solutions. Often, a mild soap and water solution is used for bubble checking. Research has shown that soap and water does not have the same properties as do the micro-foam solutions that contain coagulants and wet adhesives. Household detergents often contain chlorides and will pit and corrode brass and iron.

The specially formulated and patented bubble solutions have entered the market with remarkable results. These new solutions will form a foam "cocoon" when in contact with a leak. All that is required is for the solution to be applied over the suspected leak area. When a leak is found, bubbles or foam will tell the technician of its location. The technician must be patient and let the bubbles stand for at least 10-15 minutes if small leaks are suspected.

Another advantage of bubble testing is that bubbles can be used with nitrogen or refrigerants pressurizing the system. Small, significant leaks of less than a couple ounces per year can often be found with special formulated microfoam solutions. If the evaporator section tests negative for leaks, continue on to leak testing the condensing unit.

Testing for Condensing Section Leaks

To test for condensing section leaks:

1. Calibrate an electronic leak detector to its highest sensitivity and place the probe at the base of the unit, usually under the compressor. The unit should be fully pressurized.

2. Cover the condensing unit with a cloth tarp or bed sheet to serve as a barrier against any outside air movement and to trap refrigerant gas (Figure 3). Do not use a plastic material because some plastics may set off some electronic leak detectors and give a false reading.

3. Monitor for leakage for 10 minutes or until a leak is sensed. Recalibrate and test again. Two consecutive positive tests confirm condensing section leakage. Two consecutive negative tests rule out a detectable leak.

4. Use the electronic leak detector to check for leaks on the bellows of the pressure controls. Remove the control box cover and place the probe within the housing. Cover the control tightly with a cloth barrier and monitor for 10 minutes as above.

5. If the results are positive, uncover the equipment and begin spray coating with a microfoam solution. If the results are negative, continue to the suction/liquid line leak test that follows.

Suction + Liquid Line Leak Test

The longer the tubing runs are between the evaporator and condensing unit, the greater is the odds for defects. Count on all possibilities whether it be a typical sight glass-drier connection leak to a poor solder joint hidden under pipe insulation.



Figure 3. In testing for leaks, cover the condensing unit with a cloth tarp or bed sheet to serve as a barrier against any outside air movement and to trap refrigerant gas. (Photo courtesy of Refrigeration Technologies, Anaheim, Calif.)

The suction line can be screened by calibrating an electronic leak detector to its highest sensitivity. Tuck the probe underneath the pipe insulation. Monitor for 10 minute intervals while the system is at rest and fully pressurized to equalization. It may be necessary to insert the probe at several downstream points.

If a leak is sensed, strip off insulation and apply a bubble/foam promoter to all surfaces. If no leak was positively screened, test the liquid line. 📍

Advanced Leak Detection

The last chapter introduced the topic of leak detection and provided details on basic detection methods. This chapter will look at more advanced methods. You may recall that the previous chapter outlined various classes of leaks with standing leaks as the most common. How to deal with such leaks was covered in that chapter as the first classification of leaks.

Pressure-Dependent Leaks

The second classification was the pressure-dependent leaks which can only be detected as the system pressure increases. So we will begin with a discussion of how to test for pressure-dependent leaks.

First, you need to pressurize the low side to 150 psig and the high side to 450 psig using dry nitrogen. The equipment rating plate usually states the maximum pressure permissible. Also, always make sure that valving and other components can take these pressures whether they are original equipment or not. If the high side and low side cannot be split by ways of isolation valves, pressurize the entire system to about 350 psig if permissible.

Warning: Never use pure oxygen or air to raise the pressure in a refrigeration system. Pure air contains about 20 percent oxygen. The pure oxygen and/or the oxygen in the air can combine with refrigerant oil and cause an explosive



Figure 1. In using a micro-foam solution for leak testing, allow up to 15 minutes reaction time. (Photo courtesy of Refrigeration Technologies, Anaheim, Calif.)

mixture. Even some refrigerants when mixed with air or oxygen can become explosive under pressure. Pure oxygen and the oxygen in the air will oxidize the system's oil rapidly. In a closed system, pressure from the oxidizing oil can build up rapidly and may generate pressures to a point of exploding.

The second step in testing for pressure-dependent leaks is to always conduct proper bubble testing by thoroughly saturating all surfaces with a micro-foam solution. Allow up to 15 minutes reaction time for the microfoam to expand into a visible white "cocoon" structure (Figure 1 and Figure 2, shown on the next page). Use an inspection mirror to view any undersides and a light source for dark areas.

Third, starting at the compressor, coat all suspected surfaces. Continue to coat all suction line connections back to the evaporator section.

Fourth, spray coat all fittings starting at the discharge line at the compressor to the condenser coil. Spray coat all soldered condenser coil U-joints.

Fifth, from the condenser, continue to spray coat all liquid line connections including the receiver, valves, seams, pressure taps, and any mounting hardware. Continue the liquid line search back to the evaporator section.

Sixth, any control line taps to the sealed system must be spray coated the entire length of their run all the way back to the bellows device.

Seventh, expose the evaporator section and coat all connections, valves,



Figure 2. Proper bubble testing for leaks includes thoroughly saturating all surfaces. (Photo courtesy of Refrigeration Technologies, Anaheim, Calif.)

and U-joints.

Notice that the first sequence of searching started with the compressor and suction line due to their large surface areas.

The next sequence began with the discharge line, went across the condenser to the liquid line connection, and then to the evaporator section. The evaporator section is the last and least desirable component to pressure test in the field.

Temperature-Dependent Leaks

The third classification of leaks is temperature dependent. All mechanical connections expand when heated. The connections on refrigeration and air conditioning systems are usually of soft metals such as copper, brass, or aluminum.



Figure 3. An example of a micro-foam solution used for leak testing. (Photo courtesy of Refrigeration Technologies, Anaheim, Calif.)

special fittings available from the chiller manufacturer to equalize pressure inside and outside of the rupture disc to prevent rupture. Please consult with the chiller manufacturer before attempting to service or leak check any chiller.

An electronic leak detector may be used while the system is running. However, running a system usually causes a lot of fast air currents from fans and motors that may interfere with electronic detection. It helps to cover the unit with a blanket or sheet to try to collect escaping refrigerant gases. The leaking refrigerant will be easier to pick up with an electronic detector if it can collect somewhere, instead of being dissipated by air currents.

2. Spray coat all metal connections with a microfoam solution (Figure 3)

These metals actually warp when heated, then contract and seal when heat is removed.

The procedures to deal with that are:

1. Place the unit in operation and raise the operating temperature by partially blocking the condenser's air intake.

Warm water may also be used for system pressurization. Water chillers are usually pressurized using controlled warm water. When dealing with chillers, valve off the condenser and evaporator water circuits. Controlled warm water is now introduced on the evaporator tube bundle. This causes the rate of vaporization of the refrigeration to increase, causing higher pressures in the evaporator.

One must slowly control the amount of warm water introduced to avoid temperature shock to the evaporator. The rupture disc on the evaporator may open if the pressures are raised too high. There are

one at a time and observe for leakage. Rewet any extremely hot surfaces with water to keep the fluid from evaporating too quickly.

3. When testing evaporator components, you may induce heat by placing the unit into defrost.

Vibration-Dependent Leaks

The fourth classification of leaks is vibration dependent. Leaks that only occur while the unit is in operation are the rarest of all leaks. They are cracks that open and close from physical shaking. However, studies have shown that certain components and piping on refrigeration units will develop vibration leaks.

An electronic leak detector or a microfoam solution can be used while the unit is running. Again, drafts have to be minimized when the unit is running for use of an electronic detector. If an electronic detector is used first, a blanket or sheet should be used to help collect escaping gases and minimize air currents.

If a microfoam solution is used, place the unit in operation and spray coat the following areas with the solution. Look for large bubbles or foam cocoons formations. Large bubbles will form on larger leaks (Figure 4) and foam cocoons will form on small leaks.

Below are areas to spray coat:

- All compressor bolts and gasket edges;
- Suction line connection at compressor;
- Suction line connection at evaporator;
- Discharge line connection at compressor;
- Discharge line connection at condenser;
- Vibration eliminators;
- Any joint or fitting on unsupported pipe runs;
- Expansion and solenoid valves;



Figure 4. Large bubbles form on larger leaks. (Courtesy of Refrigeration Technologies, Anaheim, Calif.)

- Capillary tube connections; and
- Sight glass.

Combination-Dependent Leaks

Dealing with combination-dependent leaks — the fifth classification of leaks — involves overlapping the procedures already mentioned. At least two, and usually three, procedures should be merged into one procedure. This type of testing requires a high order of skills and observation techniques. Each suspected component must be isolated and tested in the following manner:

Such superfine leak testing is beyond the normal operations of the service technician. Microleaks are considered an acceptable amount of leakage in our industry at this point in time.

1. A valve or fitting is subjected to high pressure.
2. Spray coat the valve or fitting.
3. Tap the component repeatedly with a rubber mallet to induce vibration.

If there's no leakage, then go to step 4.

4. Gently add heat to the component. If no leakage, continue on to another component.

Cumulative Microleaks

The sixth and final classification of leaks discussed over these past two chapters was a cumulative microleak that is measured using a helium mass spectrometer. Such superfine leak testing is beyond the normal operations of the service technician. Microleaks are considered an acceptable amount of leakage in our industry at this point in time.

Note: The technical information and photographs contained in this chapter and the previous chapter on leak detection were used with the permission of Refrigeration Technologies, Anaheim, Calif. ©

Checking on Refrigerant Overcharge

This chapter will discuss refrigerant overcharge. The check sheet shown on this page depicts a refrigeration system with an overcharge of refrigerant. The system in this example is a low-temperature HFC-134a refrigeration unit with a TXV/receiver. (See the chart at right.)

Symptoms

Symptoms can include:

- High discharge temperature
- High condenser subcooling
- High condensing pressures
- Higher condenser splits
- Normal to high evaporator pressures
- Normal superheats
- High compression ratio

High Discharge Temperatures: With an overcharged system, the high compressor (superheated vapor) discharge temperature of 240° is caused from the high compression ratio. A discharge temperature of 225-250° is considered the maximum discharge temperature in order to prevent system breakdown from excessive heat. Liquid backed up in the condenser from the overcharge of refrigerant will flood some of the condenser's internal volume at its bottom causing high head pressures. All of the heat being absorbed in the evaporator and the suction line, along with motor heat and high heat of compression from the high compression ratio, has to be rejected into a smaller condenser's internal volume because of the backed up (overcharged) liquid refrigerant.

Refrigerant Overcharge

(Measured Values)

Compressor Discharge Temperature	240°
Condenser Outlet Temperature	90°
Evaporator Outlet Temperature	15°
Compressor In Temperature	25°
Ambient Temperature	70°
Box Temperature	10°
Compressor Volts	230
Compressor Amps	High
Low Side (Evaporating) Pressure (PSIG)	8.8 (5°)
High Side (Evaporating) Pressure (PSIG)	172 (120°)

(Calculated Values °F)

Condenser Split	50
Condenser Subcooling	30
Evaporator Superheat	20
Compressor Superheat	10

High Condenser Subcooling: Because of the overcharge of refrigerant in the system, the condenser will have too much liquid backed up at its bottom causing high subcooling. Remember, any liquid in the condenser lower than the condensing temperature is considered subcooling. You can measure this at the condenser outlet with a thermometer or thermocouple. Subtract the condensing out temperature from the condensing temperature to get the amount of liquid subcooling in the condenser. A forced-air condenser used in refrigeration should have at least 6-8° of liquid subcooling in the condenser. However, subcooling amounts do depend on system piping configurations and liquid line static and friction pressure drops. Condenser subcooling is an excellent indicator of the system's refrigerant charge. The lower the refrigerant charge, the lower the subcooling. The higher the charge, the higher the subcooling.

High Condensing Pressures: Subcooled liquid backed up in the condenser causes a reduced condenser internal volume and raise condensing pressures. Now that the condensing pressures are raised, there is more of a temperature difference between the surrounding ambient and condensing temperature, causing greater heat flow. This compensates for the reduced condenser's internal volume. The system will still reject heat, but at a higher condensing pressure and temperature.

High Condenser Splits: Because of the higher condensing pressures, thus higher condensing temperatures, there will be a greater temperature difference (split) between the ambient and condensing temperature. A dirty condenser will also give a system high condenser splits, but the condenser subcooling will not be as high as with an overcharged system.

Normal to High Evaporator Pressures: Since this system has a TXV metering device, the TXV will still try to maintain its evaporator superheat, and the evaporator pressure will be normal to slightly high depending on the amount of overcharge. If the overcharge is excessive, the evaporator's higher

pressure would be caused by the decreased mass flow rate through the compressor from high compression ratios causing low volumetric efficiencies. The evaporator would have a harder time keeping up with the higher heat loads from the warmer entering-air temperature. The TXV will also have a tendency to overfeed refrigerant to the evaporator on its opening stroke due to the high head pressures.

Normal Evaporator Superheats: The TXV will try to maintain superheat even at an excessive overcharge. As mentioned above, the TXV may overfeed slightly during its opening strokes, but then should catch up to itself if still in its operating pressure ranges.

High Compression Ratios: The condenser flooded with liquid during the overcharge will run high condensing pressures. This causes high compression ratios and causes low volumetric efficiencies causing low refrigerant flow rates.

Overcharged Capillary Tube Systems

If we are dealing with a capillary tube metering device, the same symptoms occur with exception to the evaporator superheat. Remember, capillary tube systems are critically charged to prevent liquid floodback of refrigerant to the compressor during low evaporator loads. The higher head pressures of an overcharged system incorporating a capillary tube as a metering device will have a tendency to overfeed the evaporator, thus decreasing the superheat.

If the capillary tube system is severely overcharged, liquid can enter the suction line and get to the suction valves or crankcase. This will cause compressor damage and eventually failure.

Again, it is the system check sheet that will tell the service technician whether a system is overcharged or not. Service technicians must install pressure gauges and thermistors or some other sort of temperature sensing devices in order to systematically troubleshoot a refrigeration system correctly. 

Refrigerant Migration

Refrigerant migration is defined as refrigerant, either liquid or vapor, traveling to the compressor's suction line or crankcase during the off cycle. During the off cycle, or especially during a long shutdown, refrigerant will want to travel, or migrate, to a place where the pressure is the lowest.

In nature, most fluids travel from a place of higher pressure to a place of lower pressure. The crankcase usually has a lower pressure than the evaporator because of the oil it contains. Oil has a very low vapor pressure and refrigerant will flow to it whether the refrigerant is in the vapor or liquid form. In fact, refrigerant oil has such a very low vapor pressure it will not vaporize even when a 100-micron vacuum is pulled on the refrigeration system.

Some refrigeration oils have a vapor pressure of as low as 10 microns. If the oil did not have a very low vapor pressure, it would vaporize every time a low pressure exists in the crankcase, or a vacuum was pulled on it.

If refrigerant migration does occur, and the crankcase is lucky enough to have a crankcase heater, the vapor will be forced away from the crankcase and end up in the suction line. This refrigerant may condense in the suction line and cause slugging in the compressor's cylinders on start-up. Slugging is liquid refrigerant or liquid oil actually trying to be compressed in the cylinders of the compressor. Slugging happens during the compressor's on-cycle. As we know, liquids cannot be compressed, and tremendous reversal forces are generated often resulting in broken parts. Slugging can especially happen if the compressor is located in a cold ambient outdoor setting. The cold ambient will amplify the lower vapor pressure area and help condense the refrigerant vapor to liquid. The crankcase heater does help keep the oil in the crankcase free of refrigerant from refrigerant migration.

Because refrigeration migration can occur with refrigerant vapor, the migration can occur uphill or downhill. Once the refrigerant vapor reaches the crankcase, it will be absorbed and condense in the oil. Refrigerant and oil have a strong attraction for one another and mix very well. Since liquid refrigerant is heavier than oil, the liquid refrigerant will be on the bottom of the oil in the crankcase.

On short off cycles, the migrated refrigerant does not have a chance to settle under the oil, but does still mix with the oil in the crankcase. When the compressor does turn on, the sudden pressure drop on the crankcase containing liquid refrigerant and oil will cause the refrigerant in the oil to flash to a vapor. This causes violent foaming in the crankcase.

The oil level in the crankcase will now drop and mechanical parts will be scored from inadequate lubrication. The crankcase pressure will now rise and the mixture of refrigerant and oil foam can now be forced through compressor passages and around piston rings and be pumped by the compressor.

Not only does this situation cause loss of oil from the crankcase to the system, but it can also cause a mild form of slugging in the compressor's cylinders. High compressor current draw, which will lead to motor overheating usually, follows. Also, broken or warped valves can occur as a result of overheating and/or slugging.

Solution

The only sure solution in avoiding migration is to get rid of all the refrigerant in the evaporator, suction line, and crankcase before the off-cycle. An automatic pump down system can accomplish this. A thermostat controlling box temperature is wired in series with a liquid line solenoid. When the box tem-

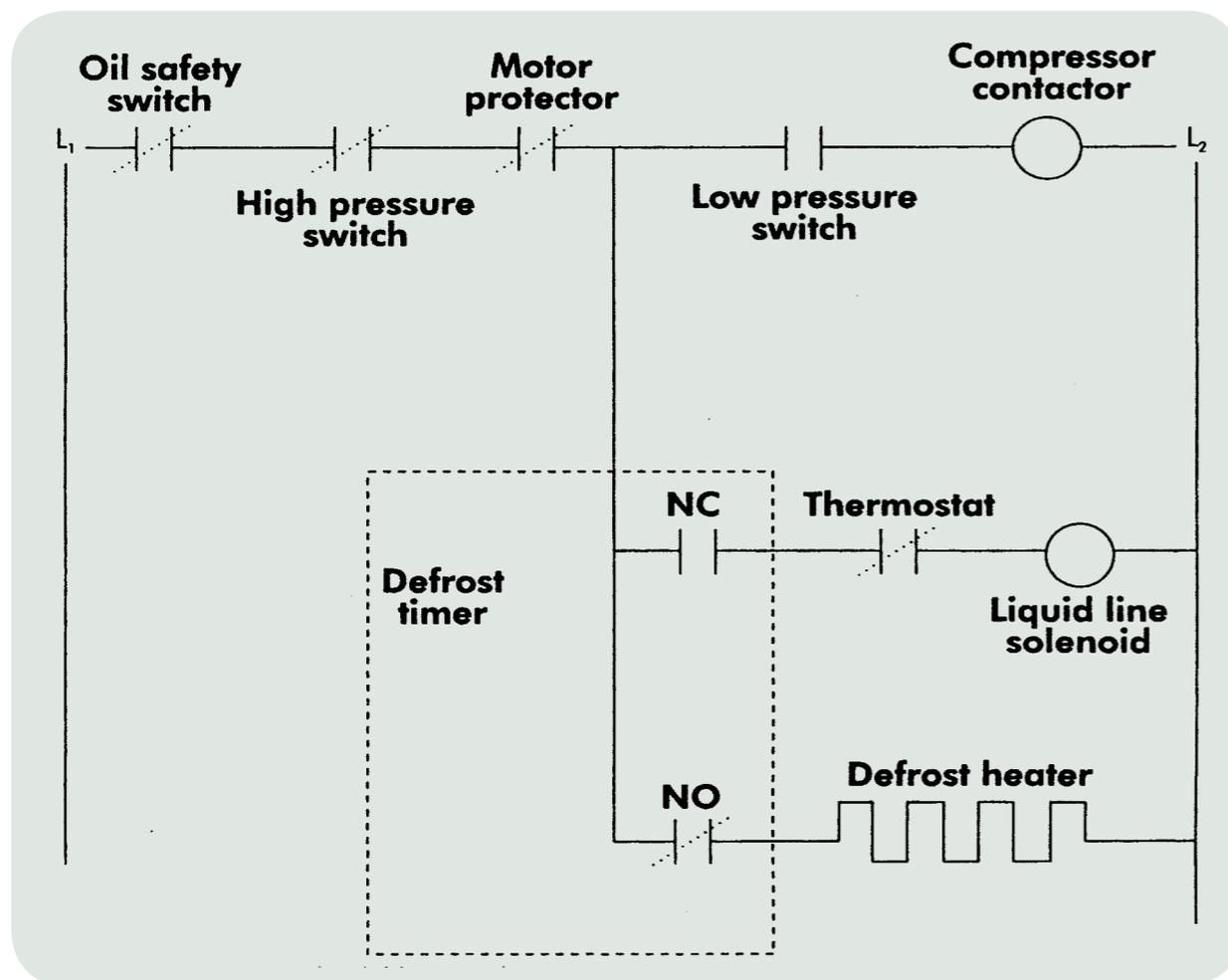


Figure 1. Schematic diagram of an automatic pump down system. (Figure from *Troubleshooting and Servicing Modern Air Conditioning and Refrigeration Systems* by John Tomczyk)

perature is satisfied, the thermostat contacts will open. This will de-energize the liquid line solenoid and a pump down cycle will be initiated. Soon all the liquid and vapor refrigerant from the solenoid forward through the compressor will be pumped into the high side (condenser and receiver) of the system.

Once the low-side pressure reaches about 10 psig, a low-pressure controller will interrupt the compressor circuit initiating an off cycle. The system is now pumped down and migration cannot occur because of lack of refrigerant vapor

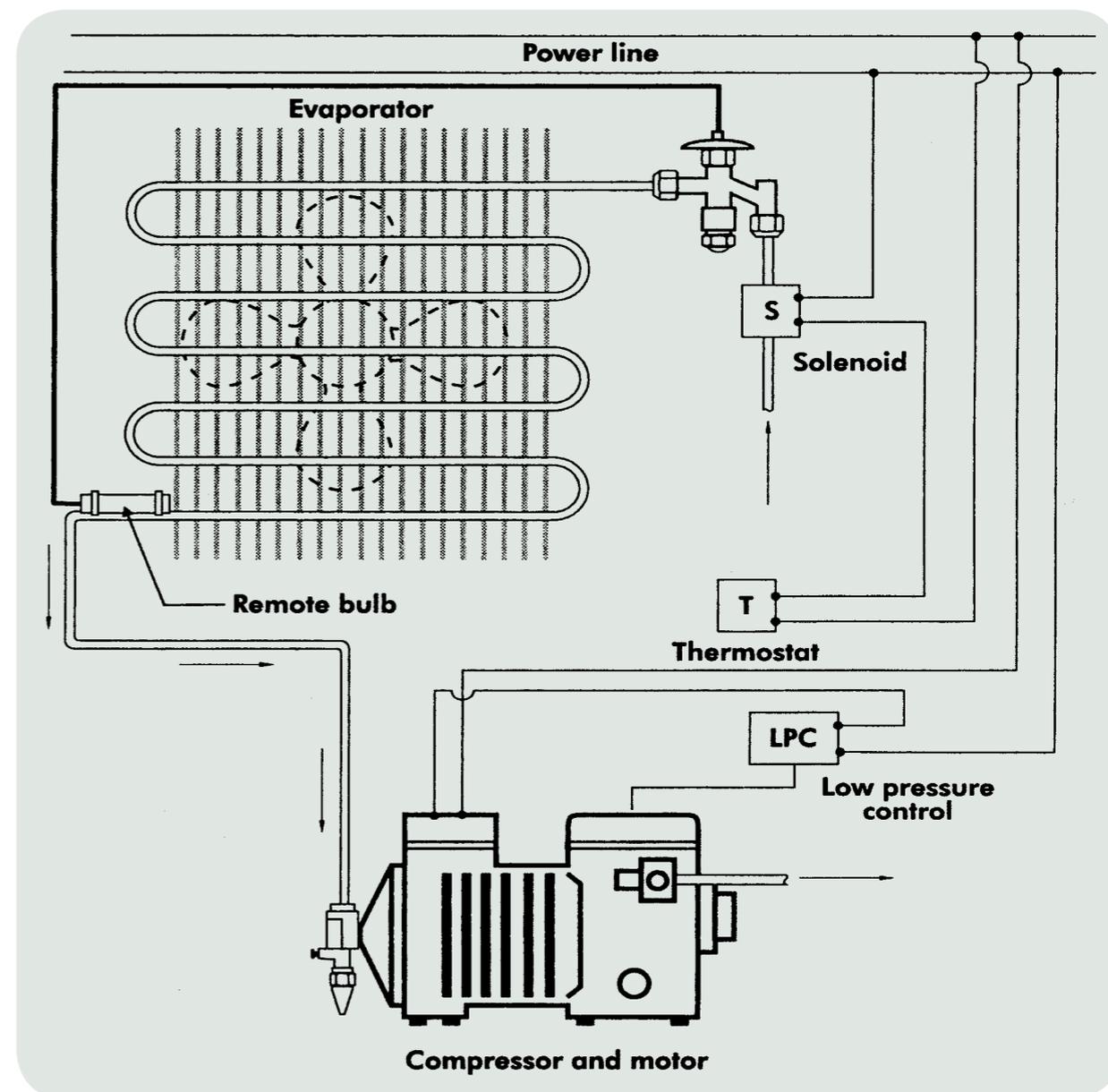


Figure 2. Pictorial diagram of an automatic pump down system. (Figure from *Troubleshooting and Servicing Modern Air Conditioning and Refrigeration Systems* by John Tomczyk)

and liquid in the evaporator, suction line, and crankcase. When the box thermostat then calls for cooling, the liquid line solenoid is energized; refrigerant pressure will now travel through the metering device to the low side of the system.

This pressure will cause the cut-in pressure of the low-pressure control to close its contacts and bring the compressor to another on-cycle. The cut-in pressure for the low-pressure control is system and refrigerant dependent. It has to be high enough to prevent any short cycling of the compressor during an on-cycle, but low enough to allow the low side pressure to reach it when the box thermostat initiates an on-cycle. Actual trial and error will allow a service technician to determine the low-pressure control's settings.

Figures 1 and 2 (both shown on the previous page) show an automatic pump down circuit and system in both schematic and pictorial forms respectively. It

is important not to let the low-side pressure get too low before shutting off the compressor. If the low-side pressure was allowed to drop to 0 psig before the low-pressure control terminated the cycle every off cycle, damage could occur to the compressor from lack of refrigerant mass flow rate and high compression ratios. This severely unloads the compressor and may cause overheating from loss of the cooling effect on the compressor's windings. A cutout pressure of 10 psig is low enough to ensure most of the liquid and vapor refrigerant has been cleared from the evaporator, suction line, and crankcase to prevent refrigerant migration during the off cycle. 

Flooding and Slugging

HVACR field service terminology is often confusing and misused even by the most seasoned service veterans. Clarification of terminology among service technicians is of utmost importance in order to clarify the real problem and efficiently find the correct remedy. Clear, concise, and accurate communication between service technicians, part suppliers, customers, and the home shop is rapidly gaining importance as the HVACR field transitions become more technically oriented.

The previous chapter on refrigerant migration discussed how this issue can damage the compressor's mechanical parts. It also covered remedies to migration using automatic pump-down systems. This chapter will cover flooding and slugging of compressors. Two important service terms that are often misunderstood and misused by service technicians are "flooding" and "slugging." Each one will be thoroughly defined and explained as they apply to refrigeration and air conditioning compressors.

Flooding

Flooding is liquid refrigerant entering the compressor's crankcase while the compressor is running. Flooding occurs to a compressor only during the on cycle.

Causes could be:

- Wrong TXV setting (no compressor superheat);
- Overcharge;
- Evaporator fan out;
- Low load on evaporator;
- End of cycle (lowest load);

- Defrost clock or heater out (iced coil);
- Dirty or blocked evaporator coil;
- Capillary tube overfeeding;
- Capillary tube system overcharged;
- Expansion bulb loose on evaporator outlet;
- Oversized expansion valve;
- Flooding after hot gas termination;
- Heat pump changeover; and
- Defrost termination.

Since liquid refrigerants are heavier than refrigeration oils, liquid refrigerant returning to the compressor will settle under the oil in the bottom of the compressor's crankcase. This liquid refrigerant will gradually be boiled off from the low pressures in the crankcase. However, since the liquid refrigerant being boiled off is under the oil in the crankcase, very small oil particles will be entrained in this vaporization process. The oil level in the crankcase will now drop and rob mechanical parts of vital lubrication.

Often, refrigerant-cooled semi-hermetic compressors have check valves located on a partition between the crankcase and motor barrel to prevent oil and liquid refrigerant from mixing. Air-cooled semi-hermetic compressors and hermetic compressors are often more prone to flooding. Suction accumulators can help a flooding condition, but if the situation is severe, accumulators can also flood.

Crankcase pressures can become excessively high from liquid refrigerant boiling in the crankcase. These high crankcase pressures can cause refrigerant and entrained oil particles to escape around the rings of the pistons during its down stroke. Once in the compressor's cylinders, the refrigerant and oil

will be pumped by the compressor into the discharge line. The compressor is now pumping oil and refrigerant and robbing the crankcase of lubrication.

Oil in the system and not in the crankcase will coat the inner walls of the tubing and valves and cause unwanted inefficiencies. Higher than normal crankcase pressures caused from the higher density refrigerant and oil mixture being pumped through the compressor's cylinders will cause high compressor current draw. This may overheat and even trip the compressor. Broken valves can also occur from this phenomenon. A telltale sign that a compressor's crankcase is being flooded with refrigerant will be a cold, frosted, or sweaty crankcase. A foaming compressor's oil sight glass with a low oil level are also signs of flooding. Higher than normal current draws will also be present.

Slugging

Slugging is liquid refrigerant, or liquid refrigerant and oil, entering the compressor's cylinder during an on cycle. Causes could be:

- No compressor superheat;
- Migration (off cycle);
- Bad TXV;
- TXV hunting;
- Low load;
- End of cycle (lowest load);
- Evaporator fan out;
- Iced evaporator coil;
- Defrost timer or heater out;
- Dirty evaporator;
- Capillary tube overfeeding; and
- Overcharge.

Air-cooled semi-hermetic compressors are more prone to slugging liquid than

refrigerant-cooled semi-hermetic compressors. This is because refrigerant is often drawn directly into an air-cooled semi-hermetic compressor's cylinder without passing through the motor barrel. Slugging can result in broken valves, broken head gaskets, broken connecting rods, and other major compressor damage.

Refrigerant-cooled semi-hermetic compressors will often draw liquid from the suction line through hot motor windings in the motor barrel, which will assist in vaporizing any liquid. Even if liquid refrigerant gets past the motor windings, the check valve in the partition between the crankcase and the motor barrel will prevent any liquid refrigerant from entering the crankcase. High current draws will be noticed here from dense refrigerant vapors entering the compressor's cylinder.

Most hermetic compressor's suction lines end at the shell of the compressor. If liquid refrigerant is entering the compressor, liquid will fall directly into the crankcase oil and eventually be flashed. As mentioned earlier, this is referred to as flooding. This causes oil foaming and excessively high crankcase pressures. Refrigerant and oil droplets will soon reach the compressor's cylinder and slugging will soon occur.

Slugging in hermetic compressors can also occur from a migration problem. As mentioned before, foaming oil and refrigerant in the crankcase due to migration will generate excessive crankcase pressures when the on-cycle occurs. These oil and refrigerant droplets can now get past piston rings and other small openings and enter the compressor's cylinder. The end result is slugging of refrigerant and oil. Slugging can damage reed valves, piston rods, bearings, and many more mechanical parts.

Conclusion

Clarification and understanding of these two technical terms can help technicians troubleshoot and remedy even the most complex compressor breakdowns. 

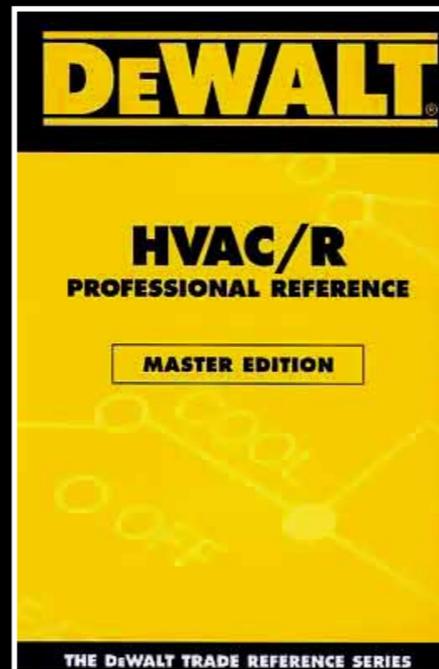
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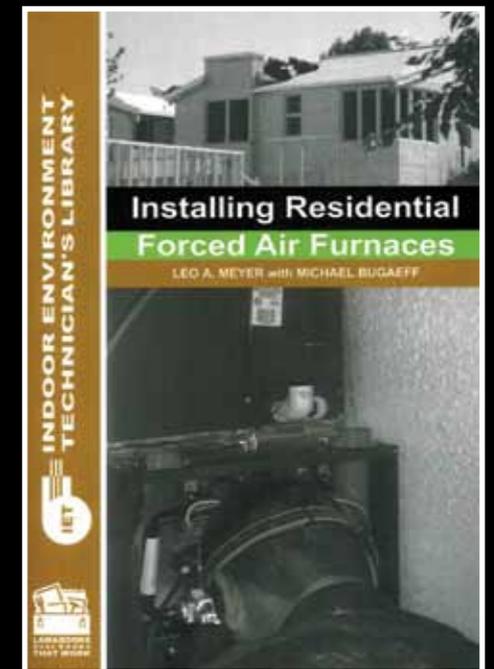
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