MEASURE 2.7.2 Maintain the proper refrigerant charge.

RATINGS

New Facilities	Retrofit	O&M
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SUMMARY

A fundamental chiller maintenance procedure with a significant effect on efficiency. Finding the level of charge may be tricky. Some inexpensive accessories may help.

SELECTION SCORECARD

Savings Potential .... $ $
Rate of Return .... % % % %
Reliability .... ✓ ✓ ✓ ✓
Ease of Initiation .... ☺ ☺ ☺

The efficiency of all chillers suffers if the system has either too little or too much refrigerant charge. Also, the compressor may suffer damage if the system is overcharged. Some systems have only minimal reservoir capacity, making it important to charge the system precisely. Such systems are more vulnerable to loss of efficiency from small leaks. Other systems have a large amount of reservoir capacity. In these systems, a small leak may persist for a long time before being noticed.

Check the refrigerant charge in your cooling units often enough to keep the charge within proper limits. This Measure gives you procedures for checking and maintaining the proper refrigerant charge and explains the effects of improper refrigerant charge.

Bad Effects of Incorrect Refrigerant Charge

Both the COP and the capacity of a cooling unit suffer if the refrigerant charge is too low. When that occurs, evaporator capacity is reduced because less of its surface is wetted, and the average evaporator temperature differential increases. The compressor must work harder to satisfy the same cooling load.

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Fig. 1 Refrigerant level sight glass in a large chiller The glass is located just below the center of the evaporator shell, to the right of the instrument panel. It is so small that it may not line up with the liquid level. If so, you can't tell whether the liquid level is above or below the glass. In this case, observe the glass when the machine starts.

In hermetic chillers, in which the motor is cooled by the refrigerant gas, low charge can overheat the motor, reducing its life.

If there is too much refrigerant in the system, the excess may back up in the condenser, reducing its effective surface area and increasing the average temperature differential across the condenser. In chillers that have a flooded cylindrical evaporator and no device to regulate the refrigerant level in the evaporator, high refrigerant level reduces the evaporation surface area.

In some types of systems, excess refrigerant can travel through the evaporator in the liquid state, continuing into the compressor. This can destroy a positive displacement compressor immediately, and it can destroy a centrifugal compressor gradually.

How to Measure Refrigerant Charge

The most difficult aspect of maintaining the proper refrigerant charge may be measuring the charge that is presently in the system. In some cases, this can be tricky, tedious, or both. The best method of checking the refrigerant charge depends on the type of system. Use the best method or combination of methods for your system. The following are the various methods that are available.

■ Liquid Level Indicators and Sight Glasses

Some chiller units, and some vessels in a chiller system, may have a means to indicate the refrigerant quantity directly. These work only if a predictable quantity of refrigerant remains in one part of the system. The most common liquid level indicator is a sight glass on the vessel where the refrigerant collects.

Refrigerant level sight glasses are common accessories of packaged water chillers. They are useful on these machines because all the refrigerant remains within the shell of the machine and drains freely into the evaporator. Figure 1 shows a typical sight glass. It can be used when the machine is running or turned off, although the level is more stable when the machine is not running.

Many refrigerant level sight glasses are perversely small, making it difficult to check the level if it is above or below the level of the sight glass. In such cases, it helps to look at the sight glass as the chiller is being started. If the refrigerant surface is above the sight glass, you can probably see bubbles as the chiller starts, or the refrigerant level drops to the level of the sight glass. If the refrigerant level is below the sight glass, you may be able to see splatter on the sight glass, which indicates that the charge is low.

Some older units have a liquid level test cock on the evaporator shell. However, these require venting some refrigerant to test the liquid level. This practice is now considered very bad form, for environmental reasons.

In chiller systems where the components are spread out, refrigerant quantity indicators do not work as well, or they may not work at all. The problem is that refrigerant migrates from one part of the system to another. When the chiller is running, the distribution of refrigerant in the system varies with load. When the chiller is not running, refrigerant migrates to the coldest part of the system. For example, the refrigerant might accumulate in the condenser during winter and in the evaporators during summer.

If a spread-out chiller system has a receiver (refrigerant surge tank) or a shell-and-tube evaporator, it may be practical to use a level indicator in one of these vessels. In such cases, the level indicator provides useful information only when the system is running and stabilized. Even then, the level of refrigerant varies with the cooling load. The refrigerant level indicator should be readable anywhere within the acceptable charge range. When the system is turned off, refrigerant pools in the coldest parts of the system, and the level indicator gives a false reading.

If your chiller system does not have an easy-to-read refrigerant level indicator, consider adding one, if possible. If you do, install a placard at the sight glass or gauge that indicates the normal range of readings, and the conditions under which the readings are valid. For example, the placard might say, "Refrigerant level indicator valid only if the compressor is running, or if the receiver temperature is at least 10°F colder than the outside air temperature." (See Reference Note 12, Placards, for tips on how to create an effective placard.)

Any kind of refrigerant level gauge or sight glass should be strong and well protected. A broken sight glass or gauge connection would vent the entire refrigerant charge into the surrounding space. With high-pressure refrigerants, the blowout continues at full pressure as long as there is liquid in the system, which is a dangerous situation.

■ Discharge and Suction Pressures

With all types of compression cooling equipment, you can check the state of refrigerant charge by measuring the discharge and suction pressures in the system. Do this while the compressor is operating and the system is in stable operation.

Larger machines usually have gauges installed that indicate the evaporator and condenser pressures at all times. Figure 2 shows a typical example. Use portable gauges if the machine does not have gauges installed.

The normal discharge pressure depends on the condensing temperature. To check system charge, use a table of refrigerant pressures and temperatures. This tells you what the condensing pressure should be at the current condensing temperature. If the discharge pressure is lower than it should be at that temperature, the system is low on charge.

Refrigerant pressure gauges often have the corresponding saturation temperatures printed right on the gauge dials. This saves you the trouble of finding a refrigerant pressure chart. Portable refrigerant gauges typically show the saturation pressures for several of the most common refrigerants. If you need to use a refrigerant table, you can find one in many reference books. Also, refrigeration supply houses common give away refrigerant tables that are printed on handy cards. If the type of refrigerant used in the chiller system has been changed, be sure to use a refrigerant table for the current refrigerant.

If the refrigerant charge is low, both the discharge and suction pressures will be lower than normal. The discharge pressure is low because there is not enough gas in the system for the compressor to squeeze to the normal discharge pressure. The suction pressure drops

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Fig. 2 Evaporator and condenser gauges These tell you immediately whether the machine has the minimum amount of refrigerant for efficient operation. They do not tell you the actual amount. The condenser pressure provides an uncertain indication of excessive charge.

because there is not enough liquid refrigerant in the evaporator to boil off vapor at the normal vapor pressure. As a result, the vapor expands into the compressor suction, lowering its pressure. In other words, the compressor starts to act like a vacuum pump.

Low suction pressure also creates abnormally low suction temperature. This occurs because the refrigerant gas is cooled below its saturation temperature by the greater expansion. The suction temperature can eventually fall enough to freeze the evaporator coil. In a water chiller, this can cause major damage.

Suction pressure could be lower than normal for other reasons, such as obstructed air flow through an air-cooled evaporator. For example, opening the evaporator coil access panel in an air handling unit short-circuits the flow of air around the coil, causing its refrigerant pressure to drop.

Discharge pressure is much less reliable as a clue to excessive refrigerant charge. If the condenser floods from excess charge, its cooling capacity is reduced, so the discharge pressure rises. A noticeable pressure rise occurs only under high load. A condenser that is heavily flooded with excess refrigerant will also cause cooling water or cooling air temperatures that are lower than normal, because the condenser is not rejecting as much heat. However, this symptom is subtle.

(If the discharge pressure is lower than normal and the suction pressure is higher than normal, the compressor may be worn out, or the compressor or system may have an internal leak from the discharge side to the suction side, or the system may have hot gas bypass.)

So, the suction and discharge pressures are a reliable indicator of low charge, and the discharge pressure is a less reliable indicator of excessive charge. However, system pressure cannot tell how much refrigerant is in the system within the normal range of charge. As long as there is enough liquid within the system to keep the evaporator supplied, the readings are normal. In systems without refrigerant quantity indicators, you have to check the refrigerant pressure at appropriate intervals to detect the first sign of inadequate charge. When leakage finally causes liquid starvation in the evaporator, pressures start to decline. The rate of decline depends on the leakage rate and on the volume of refrigerant in the system.

On the other hand, air in the system causes all pressures to be higher than normal. This can mask a

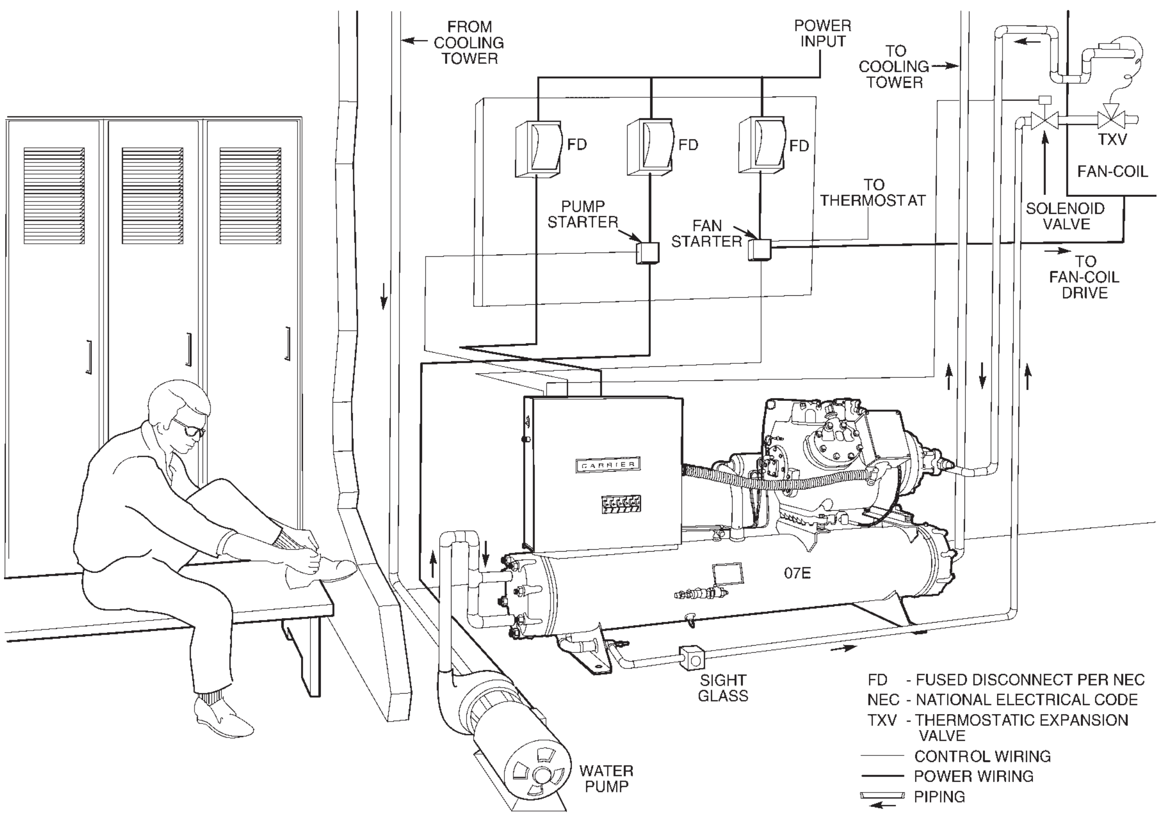

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Fig. 3 Evaporator liquid line sight glass It is generally located as shown here, close to where the refrigerant liquid enters the evaporator. Bubbles in the sight glass while the system is running probably indicate low refrigerant charge, but they may also indicate an obstruction of the refrigerant line in the direction of the condenser.

low refrigerant charge. Keep air out of the system at all times. This is covered by Measures 2.7.1 and 2.7.3.

■ Evaporator Liquid Line Sight Glass

In chillers that use a throttling type of refrigerant metering device (an "expansion valve," capillary tubes, etc.) to control the flow of refrigerant to the evaporator, a sight glass may be installed in the refrigerant line leading to the evaporator. Figure 3 shows where to look for the sight glass.

Bubbles in the sight glass indicate that there is not enough liquid in the system to keep the line filled. Bubbles first appear under high cooling load, when liquid is being drawn out of the line most rapidly. Bubbles that occur when the system first starts may be normal, and do not indicate low charge.

Bubbles in a sight glass are not a foolproof indication. If the sight glass is located upstream of a partially obstructed filter or dryer, the back pressure may keep bubbles from forming even when the charge is low. Conversely, if the sight glass is downstream of a clogged filter or dryer, the reduced pressure at the sight glass may cause bubbles to form even though the amount of refrigerant in the system is proper. Adding more refrigerant based on this false indication may overcharge the system and cause compressor damage.

A liquid line sight glass cannot reveal excessive refrigerant charge.

■ Suction Gas Superheat

In direct-expansion chiller systems (which send the refrigerant directly into the cooling coils), low charge is indicated by high superheat in the gas leaving the evaporator, especially when the compressor is operating at full load. Superheat is the excess of the gas suction temperature above the gas saturation temperature. When the evaporator becomes "starved" for refrigerant, the available refrigerant boils off quickly and the unsatisfied heat load of the evaporator superheats the refrigerant gas excessively.

In systems that use a thermostatic expansion valve, the valve is designed to maintain a fixed amount of superheat. The purpose of the superheat is to ensure that liquid refrigerant does not enter the compressor. Do not let this superheat fool you into believing that the charge is low. If the superheat setting of the valve is unknown (it is typically 10°F to 20°F, or 5°C to 11°C), the charge is probably not low if the superheat remains essentially the same at all loads.

■ Condensate Subcooling

In systems with air-cooled condensers, excessive charge is indicated by excessive subcooling of the refrigerant. Subcooling is cooling of the liquid refrigerant below its saturation temperature. When the system is overcharged, the condenser fills with liquid refrigerant, the condenser capacity drops, and the liquid lingers in the condenser long enough to become excessively subcooled.

The difference in temperature between normal and subcooled refrigerant from a condenser is small. This makes the test too subtle for any but experienced technicians. Look for condenser subcooling as confirmation of excess charge if the discharge pressure is too high.

This symptom is accompanied by abnormally high condenser pressure, especially at high cooling load.

■ Bleeding Refrigerant Pressure

As a last resort, you can bleed refrigerant from the system until the operating pressures drop, and then add the recommended amount of extra refrigerant. Do not use this method with any environmentally harmful refrigerant unless you have the equipment to salvage the refrigerant.

Should You Add a Receiver?

All chiller systems have a certain amount of storage volume for liquid refrigerant, but the amount varies widely. Ample refrigerant storage capacity ensures that refrigerant is available to the evaporator. It compensates for accumulation of refrigerant in different parts of the system under different operating conditions. It prevents back-flooding of refrigerant into the condenser. And, it provides a reserve to make up for leakage.

Some chillers inherently have large storage volume. For example, packaged centrifugal water chillers store a large amount of refrigerant in their evaporator shells. On the other hand, direct-expansion chillers may have little storage capacity, because air coils have small liquid volumes. In the past, it was common practice to install a "receiver" in such systems, which is simply a storage tank, or surge tank. Different chiller system designs may have receivers in different parts of the system.

It has become commonplace to eliminate the receiver from chiller systems as a cost saving measure. In such systems, storage volume is limited to the condenser itself and to the piping downstream of the condenser. Therefore, a relatively small overcharge may cause refrigerant to back up into the condenser, and a relatively small undercharge may starve the evaporator of refrigerant. For example, a difference of a few ounces of refrigerant charge may affect chiller performance in a small split system.

In systems that lack refrigerant storage capacity, it may be desirable to add a receiver to the system. The mechanical installation is usually not complicated, but it should be done by a refrigeration specialist familiar with proper piping practices and other aspects of assembling cooling systems. Finding the proper location for the receiver in the system requires a clear understanding of chiller system design.

Installing a receiver is not a substitute for keeping the system free of leaks. If the system operates properly when it is properly charged, it probably does not need a receiver. Instead, put your emphasis on proper charging procedure and checking for leaks.

How to Add Refrigerant

Follow the refrigerant charging procedures specified by the manufacturer. If your system does let you measure the refrigerant charge directly, find the point of minimum charge as described previously. Then, add refrigerant in the amount specified by the manufacturer. If you use a large bulk container of refrigerant, put it on a portable scale as you charge the system. Calculate the amount of refrigerant added from the change in weight.

Be careful to keep air from entering the system when you recharge it. This requires great care if the refrigerant in the chiller is below atmospheric pressure. Even with high-pressure refrigerants, be careful to purge all the refrigerant gauge and filling hoses before opening the chiller service ports.

If you are filling a chiller system that has been opened to the atmosphere, you have to use a vacuum pump to remove all air and vapor from the system before recharging. Don't try this without training. Chiller servicing should be done only by technicians who fully understand what they are doing. Inadequate training of maintenance personnel is a common cause of chiller damage and inefficiency.

ECONOMICS

SAVINGS POTENTIAL: *Up to 20 percent of chiller operating cost.*

COST: *Usually minimal.*

PAYBACK PERIOD: *Short.*

TRAPS & TRICKS

SKILLS AND TRAINING: *Understand how refrigerant travels in your chiller system. Know the best methods of checking the charge in that type of system. Invest in training the right person for this responsibility. Keep unqualified people from messing with refrigerant charge. They can do a lot of harm.*

SCHEDULING: *This is another function that tends to be forgotten. If the charge in your chillers can be checked easily, put a column for refrigerant level on the chiller operating log. Otherwise, schedule checks in your maintenance calendar. (You do have a chiller operating log and a maintenance calendar, right?)*