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Btu Buddy's GUIDE TO HVAC TROUBLESHOOTING

by Bill Johnson

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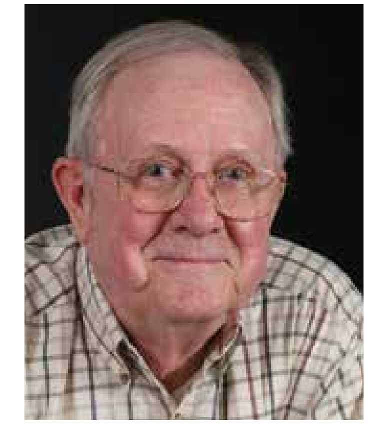
About the Author



Active in the HVACR industry since the 1950s, Bill Johnson graduated in gas fuel technology and refrigeration from Southern Technical Institute, a branch of Georgia Tech (now Southern Polytechnic Institute). He taught at Coosa Valley Vocational & Technical Institute for four years. He moved on to become service manager for Layne Trane. He taught for 15 years at Central Piedmont Community College, part of this time as program director. He had his own business for five years doing installation and service work. Now retired, he is the author of *Practical Heating Technology and Practical Cooling Technology,* and continues as a co-author of *Refrigeration & Air Conditioning Technology,* all published by Delmar Cengage Learning. He can be reached by email at thebillj1@gmail.com.

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High Power Bills With a Heat Pump

Bob was called to a new customer's home that had a 5-ton heat pump. The home was a large ranch style home, all on one floor. The customer met Bob at the door and she explained to him that her power bills were considerably higher than the same months last year. Bob looked at the comparison and agreed. The seasons were similar, but the bills for this year were much higher. Bob then went to the indoor air handler under the house and looked at the filter. All seemed normal with them.

He then went to the outside unit and looked around and nothing stood out to be a problem. He then went inside and checked the outlet temperature at one of the room registers. The temperature was 120°F. He then went to the room thermostat and checked the thermostat to see if the strip heat was calling for heat and it was not. He was looking confused when Btu Buddy appeared and asked, "What is the problem, Bob?"

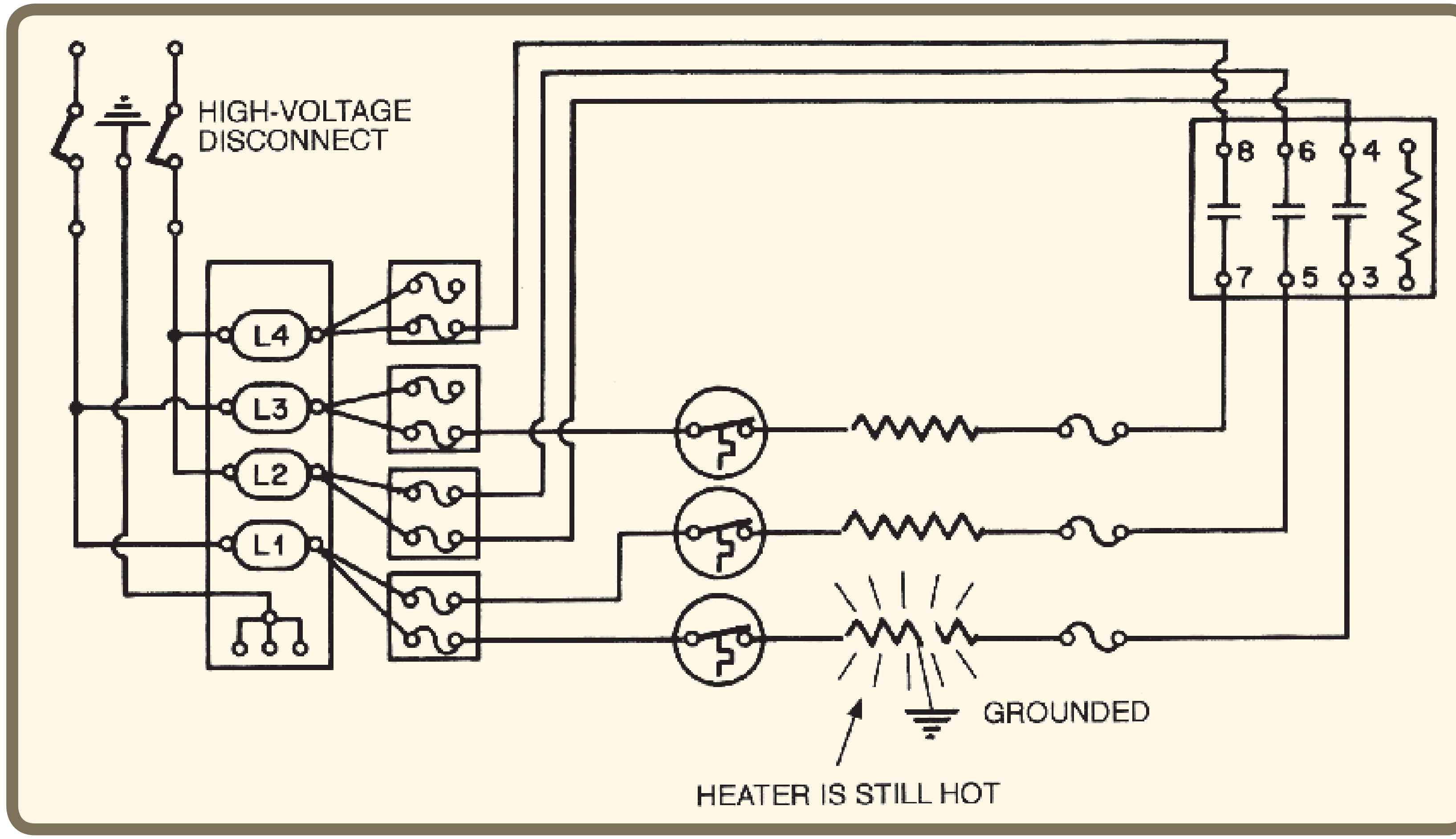


Figure 1. This electric heat element is grounded to the frame of the furnace causing it to produce heat all of the time. *(From Practical Heating Technology by William Johnson, published by Delmar Cengage Learning. ©Delmar Cengage Learning.)*

Bob explained what he knew and asked Btu Buddy for some advice.

Btu Buddy said, "Check for amp draw at the strip heaters on both lines going to the heaters. Remember the time you had a strip heater that was grounded and it was drawing current all the time (Figure 1)?"

Bob got his ammeter from the truck and went under the house and checked all three strip heaters and there was no current flow. Bob then asked, "Now what?"

Btu Buddy then said, "You have ruled out heat from any source except the heat pump refrigerant cycle, so the excess heat must be coming from the heat pump coil itself. With an air discharge temperature like you are getting, I would suggest that you have a reduced airflow. A heat pump should not have a discharge temperature above about 105° and this one is running 120°. Feel the liquid line and tell me if it feels normal."

Bob put his hand on the liquid line and exclaimed, "Boy, that line is really hot. Normally it would be about hand temperature, but that could burn you if you held it for long."

"What does that tell you, Bob?" asked Btu Buddy.

"It tells me that the air stream is not taking the heat out of the refrigerant condenser coil, which is the indoor coil in the heat cycle," said Bob.

Btu Buddy then asked, "What could be some reasons for these symptoms?"

Bob answered, "The filter could be stopped up, the coil could be dirty, the fan may not be moving enough air, there may be trash in the ductwork, insulation may have come loose and dropped down, the supply registers or return grilles may be restricted; those are all possibilities. The duct is insulated on the outside, so there shouldn't be any insulation on the inside that could be loose and cause a restriction."

Btu Buddy then said, "Then you must eliminate those possibilities one at the time. It may be a combination of several of those things."

Bob said, "I never thought of it being more than one thing. Most all of the trouble calls that I have worked on get back to one problem."

Btu Buddy said, "That is usually the case. Let's go do some checking. The simplest things to check would be the supply registers and return air grilles. I noticed that this house has multiple returns, so be sure to check them all."

Bob went from room to room and checked the airflow possibilities and told Btu Buddy, "I found several rooms that both the supply and return fixtures were shut off. I talked to the homeowner and she said she was trying to save money by not heating those rooms. I explained to her that closing those fixtures was at least part of the problem."

Btu Buddy said, "Now check the liquid line temperature."

Bob held the liquid line and said, "That is much better. I think I will check the temperature with my thermistor temperature tester."

After the check, Bob said, "The temperature is still 107°. I am not sure that we have gotten to the bottom of this problem."

Btu Buddy then said, "Good point, check further."

Bob looked at the fan wheel and commented, "The fan wheel has a lot of dirt in the curves of the wheel. I think I will clean the wheel."

"Good point, Bob", said Btu Buddy. "If the fan wheel is dirty, where did the dirt come from?"

Bob responded, "It had to come through the filters. At some point the filters must have been really dirty and let dirt pass."

Btu Buddy then said, "Most filters only get the larger particles of dirt; much of the fine dirt slips through. In the summer, the coil is wet and acts as a super filter. I would suspect that the coil is dirty also."

Bob got set up and cleaned the fan wheel and the coil, and said, "I can't believe how much dirt came out of the core of that coil. It is a good thing I had this pressure washer. It just kept pushing out dirt. That especially made detergent for coils really did the trick."

When Bob got the system back together, he started the unit up and after it had run for about 20 minutes, he looked at the temperature of the liquid line and said, "The temperature is down to 100°. That works for me."

Btu Buddy suggested, "Bob, you need to check the outlet air temperature now that you have made these changes."

Bob went in the house and checked the air temperature at the same place he had checked before and the temperature was 100°.

Bob went back outside with Btu Buddy and told him the results and Btu Buddy said, "Now you have confidence that you got to the complete bottom of the situation. Be sure and talk to the homeowner and tell her what you did. Be sure and mention the outlet air temperatures will be lower, but that the system will be more efficient."

Bob asked, "Why didn't you suggest that we put gauges on the system and check the pressures?"

Btu Buddy explained, "You could have connected your gauges. However, we came to the same conclusions without installing gauges. Remember, every time you fasten your gauges, you let out some refrigerant. The system has a critical charge and you may alter the charge when connecting the gauges. Also, you always have the possibility of leaving a leak behind and then you would be called back to the same job later to add refrigerant."

Bob then said, "None of that would be good."

Bob talked to the homeowner and explained everything to her and she understood to leave all airflows alone.

When riding away, Bob asked Btu Buddy why high head pressure resulted in such a dramatic change in power consumption in a heat pump and Btu Buddy said, "Let's go to lunch and talk about it. Bring your text book so we can discuss some examples."

Head High Pressure and Power Consumption

Bob and Btu Buddy got together for lunch at a place where they could take their time and talk about why high head pressure seems to drive up the power consumption of a compressor. Bob started if off by saying, "I have had several complaints of high power bills, particularly with heat pumps, and have discovered that dirty indoor coils or reduced airflow had driven the head pressure up and the customer discovered it from excess power bills. They then called the company and asked for service. This doesn't seem to happen in the cooling season, only in the heating season. What is the difference and why is this happening?"

Btu Buddy began the explanation: "The simple and easy answer is to say that a compressor in a system is responsible for raising the pressure in the system from the saturated suction pressure to the saturated discharge pressure. The more that it has to raise the pressure, the more it costs. Now for why.

"Let's take this one component at a time. An air conditioner has a 40˚F boiling temperature for R-22 that creates a suction pressure of about 70 psig, rounded up from 68.5 psig, at design conditions. This is the low-pressure side of the system.

"The condenser normally has a condensing temperature of 125˚F that creates a head pressure of 278 psig of head pressure at design conditions. This is considered the high-pressure side of the system.

"The compressor has to lift the refrigerant pressure from the low-pressure side to the high-pressure side. In gauge pressure readings, that is a lift of 209.5 psig (278.5 – 70 = 209.5) (Figure 1, page 7). It can easily be seen that if you raise the amount of lift, you must raise the amount of work done. That is the short version of what happens."

Bob said, "This sounds like it could get serious."

Btu Buddy said, "Yes, it is quite detailed. You remember that we live in an atmosphere of air. Actually, you could say that we live at the bottom of an ocean of air. Air is matter, explained by the fact that it has weight and takes up space. Actually this ocean of air above us creates a pressure at sea level, during standard conditions, of 14.696 pounds per square inch. You notice it when you drive up a mountain; your ears pop. The pressure on the outside of your body becomes less, and your ears pop when the pressures equalize. You will also recall from your technical school days that your manifold gauges read atmospheric pressure as 0 psig. When we start working with the details of compressor lift, we have to take atmospheric pressure into consideration and deal with pounds per square inch absolute (psia). For practical purposes, you just add atmospheric pressure to your gauge reading to get psia."

"Wow," said Bob, "fill me in slowly so I don't get lost."

Btu Buddy then said, "When engineers talk about how a compressor works with pressure, they use a term called compression ratio. Compression ratio is the absolute discharge pressure divided by the absolute suction pressure. In formula form it would look like this: CR = absolute discharge pressure / absolute suction pressure. This is a ratio of the volume of refrigerant in a cylinder at bottom dead center to the volume of refrigerant in the cylinder at top dead center.

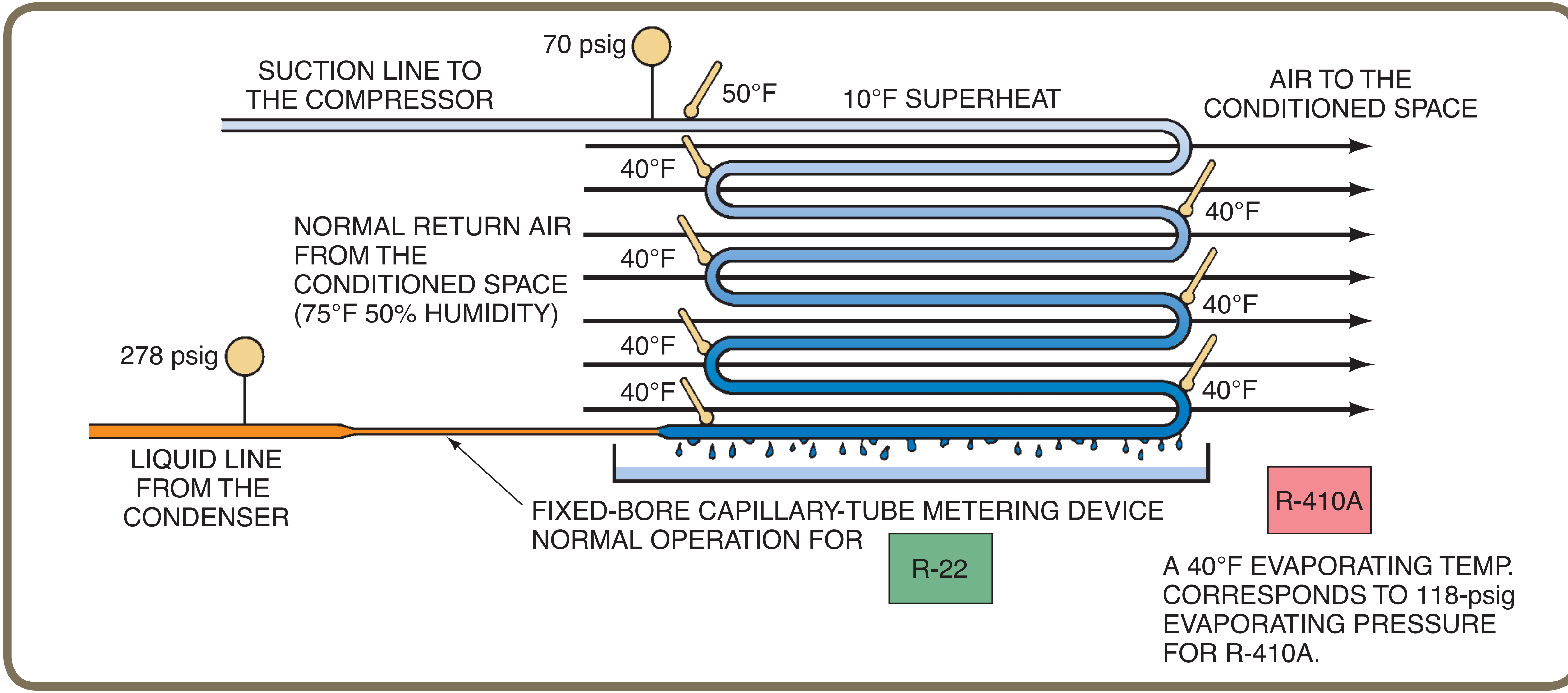


Figure 1. Notice that the suction pressure at the evaporator is 70 psig and the liquid line pressure is 278 psig. The compressor created this pressure difference. *(Figures in this chapter are from Refrigeration & Air Conditioning Technology, 5th Edition, by William Whitman, William Johnson, and John Tomczyk, published by Delmar Cengage Learning.) (©Delmar Cengage Learning.)*

The refrigerant volume is compressed from a large volume to a smaller volume.

"Suppose your gauges read design conditions, 278 psig discharge pressure and 70 psig suction pressure. That would mean that:

- absolute discharge pressure is 278 + 14.696 = 292.7 psia
- absolute suction pressure is 70 + 14.696 = 84.7 psia

"Placing this in the formula:

CR = 292.7 / 84.7 = 3.46:1 ratio of inlet to outlet.

"If this were cubic feet, we would have 3.46 cubic feet of refrigerant compressed to 1 cubic foot during the compression process.

"If we raise the discharge pressure to 350 psig + 14.696 / 70 + 14.696 we get a new CR.

CR = 364.7 / 84.7 = 4.3:1 ratio of inlet to outlet.

"You can say that enough work was done to compress the volume of refrigerant gas from 4.3 to 1 in this compression process.

"The compression ratio can also be changed by lowering the suction pressure. For example, suppose we lower the suction pressure to 60 psig and keep the same design discharge pressure.

CR = 278 + 14.696 / 60 + 14.696

CR = 292.7 / 74.7

CR = 3.9:1 ratio of inlet to outlet.

"If you raise the discharge and lower the suction:

CR = 350 + 14.696 / 60 + 14.696

CR = 364.7 / 74.7

CR = 4.8:1 ratio of inlet to outlet.

"Now, let's look at a heat pump and see what we may get on a cold day. Let's suppose the head pressure is 210 psig and the suction pressure is 21 psig.

CR = 210 + 14.696 / 21 + 14.696

CR = 224.696 / 35.696

CR = 6.3:1 ratio of inlet to outlet.

"That is a lot of conversation that tells you to keep the head pressure as low as practical and keep the suction pressure as high as practical. When either pressure gets out of the design parameters, there will be less efficiency."

Bob asked, "How does that fit in with today's practices for service technicians and their service duties?"

Btu Buddy said, "Our job is to keep coils clean, both indoors and outdoors. Now let's get back to the heat pump that we worked on yesterday that had a dirty coil in the winter. Suppose it had a head pressure of 300 psig and a suction pressure of 21 psig.

CR = 300 + 14.696 / 21. + 14.696

CR = 314.696 / 35.696

CR = 8.8:1 ratio of inlet to outlet.

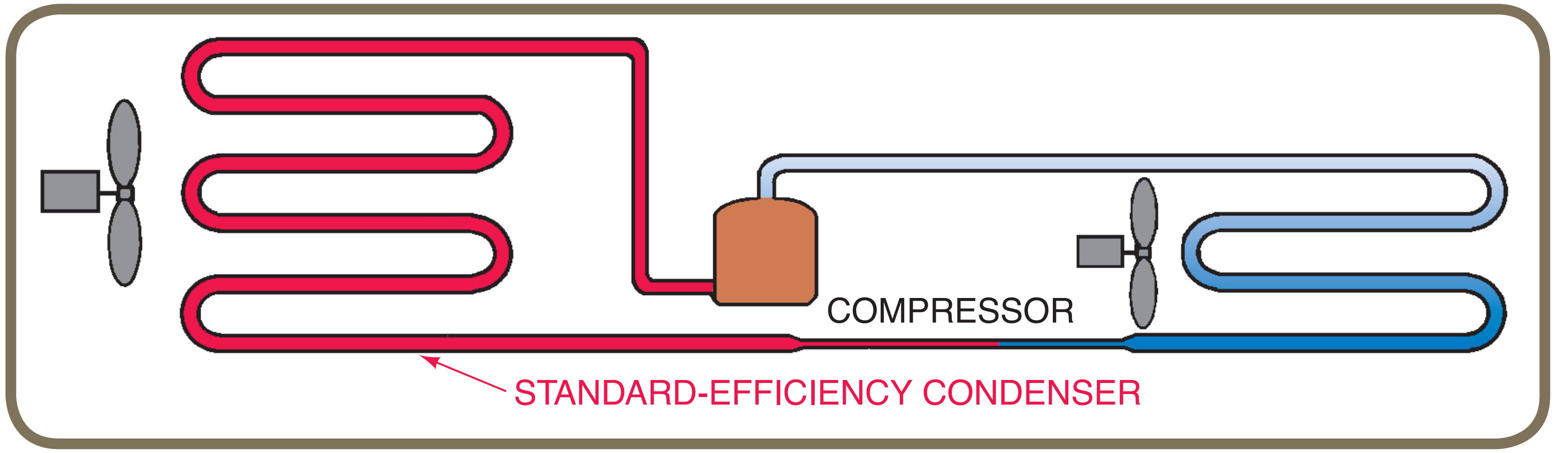
"You finally reach a point that the lift is too much to be practical. The compressor is working very hard and not getting much done so it has to run longer and the strip heat will also be operating more, so the power bill goes up.

"The job was a heat pump and heat pumps have a little different slant on the problem. Typically an air conditioner condenser is about 25 percent larger than the evaporator because the condenser must eliminate about 25 percent more heat than the evaporator absorbs into the system (Figure 2, page 9). This heat is called 'heat of compression.' Compression ratios of over 12:1 are prohibitive for compressors because as the compression ratio rises, the discharge gas temperature rises. Oil is always present in discharge gas and oil particles begin to break down at temperatures of over 250°F. These high compressor temperatures are asking for a problem.

"I don't know if you have noticed, but heat pumps use the same indoor and outdoor sizes as air conditioners."

Bob then said, "When they reverse the cycle for winter time operation, the condenser area is automatically 25 percent smaller than the evaporator. That can't be good."

Btu Buddy said, "It works out that it is good because it is harder to extract heat from the colder outdoor air and the coil really needs to be larger. The



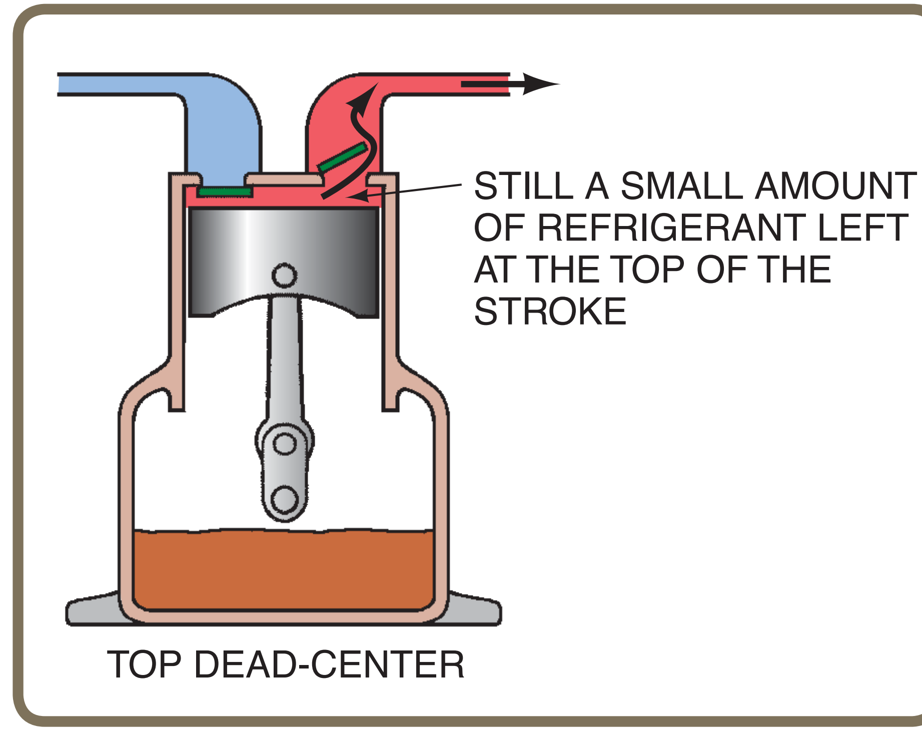


Figure 2 (above). Notice the size of the evaporator and the condenser. The condenser must reject the heat of compression from the compressor as well as the heat absorbed by the evaporator. *(©Delmar Cengage Learning.)* **Figure 3 (right).** There is always volume left at the top of the cylinder (clearance volume) in a reciprocating compressor. The refrigerant compressed into this clearance volume will expand when the piston starts back down. No refrigerant will enter the compressor cylinder until the pressure in the cylinder is less than the pressure in the suction line. *(©Delmar Cengage Learning.)*

indoor coil being smaller is good because it raises the air temperature to the structure. Typically, the supply air from a heat pump is no greater than 100°F. You have been on a service call where the customer complained about drafts. If the outlet air were any cooler, even though it was heating the house, there would be more complaints."

Bob asked, "What else do I need to know about this?"

Btu Buddy then explained, "The heat pump we were working on yesterday was a reciprocating compressor. High compression ratios are even worse on reciprocating compressors because of the clearance volume at the top of the cylinder on the upstroke of the piston. When a reciprocating compressor piston reaches the top of the stroke, there is a little refrigerant trapped at the top, between the piston and the cylinder head (Figure 3). All reciprocating compressors have this clearance volume so the piston will not hit the cylinder head. When the piston starts down, this tiny bit of gas re-expands in the cylinder on the down stroke. The cylinder cannot start filling until the pressure in the cylinder is less than the pressure on the low side of the system. When the head pressure is higher than normal, there is more than normal refrigerant gas trapped in the clearance volume of the compressor. The compressor efficiency just went down even more than what was caused by the compression ratio."

Bob said, "Boy, this is really a lot of information."

Btu Buddy said, "When you buy a huge cup of iced tea in the summer at lunch, you drink it a sip at a time. It is hot outside and you are really thirsty. I bet it takes awhile to drink it all. This is how your education is. You take it a little at a time and over time you really become educated; just like the cup of tea, you keep reaching for the bottom, only with education, there is no bottom. This keeps you interested all of your life."

Bob then said, "Thank goodness for good resources, such as other technicians, books, and the Internet." N

Charging an Overcharged System

The day was starting off all wrong for Bob. He received a call from the dispatcher that a system was not cooling properly. It was a small office with a 4-ton unit that used a capillary tube metering device. When he arrived, the office thermostat was set to control at 72˚F and the thermometer was reading 76˚. The office felt warm and humid. The office manager told Bob, "Back in the spring, we had a service company check the system and they found a leak and repaired it, then added refrigerant. For some reason I did not have confidence in that company or technician. His truck looked like it needed to be sent to the landfill and dumped. The back end was full of old wire and pipe and junk. Not a very professional look."

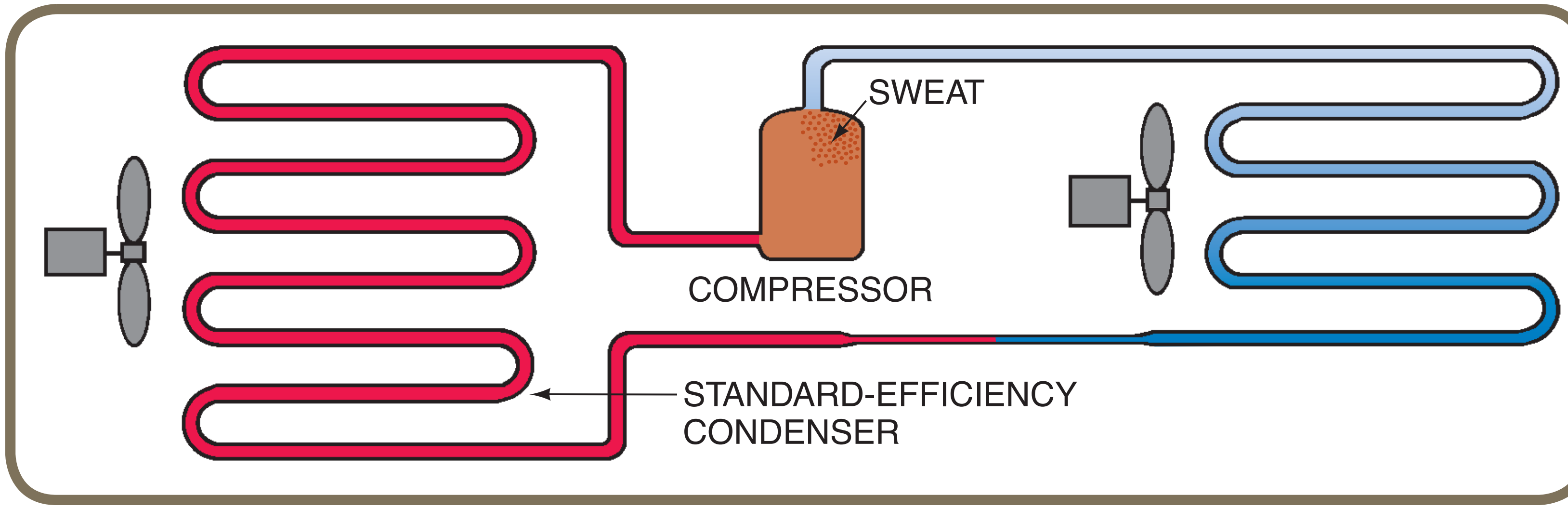


Figure 1. This compressor is sweating all over because liquid refrigerant or saturated vapor is entering the compressor. *(Figures in this chapter are from Refrigeration & Air Conditioning Technology, 5th Edition, by William Whitman, William Johnson, and John Tomczyk, published by Delmar Cengage Learning.) (©Delmar Cengage Learning.)*

Bob went to the outdoor unit and felt the suction line and it was really cold. This seemed like it should cool the place. He thought the filters were restricted so he went to the air handler and removed the filter and discovered that it was clean. He used his flashlight to examine the coils and they looked really good.

Bob then went back to the condensing unit with gauges and fastened them to the suction line. The temperature outside was 94˚ so the unit really had a load on it. The low-pressure gauge read 85 psig and the high-side gauge read 375 psig; the refrigerant was R-22. These readings were much too high.

Bob then removed the cover to the compressor compartment and discovered the compressor was sweating all over (Figure 1). It was evident that the system had too much refrigerant. The last technician had charged the system in mild weather without taking the low outdoor temperature into consideration.

Bob went to the truck and got his temperature tester and recovery setup to remove refrigerant from the system.

An hour later, Bob was standing there scratching his head when Btu Buddy appeared and asked, "What is the problem, Bob?"

Bob then said, "I have a problem charging this system and you showed up — what a timely visit. I need help. I have been removing refrigerant for an hour, a little at a time, and cannot seem to get the charge correct, according to the superheat method."

Btu Buddy then explained, "It is almost impossible to charge a system correctly by removing refrigerant. You either take out too much or too little. I am

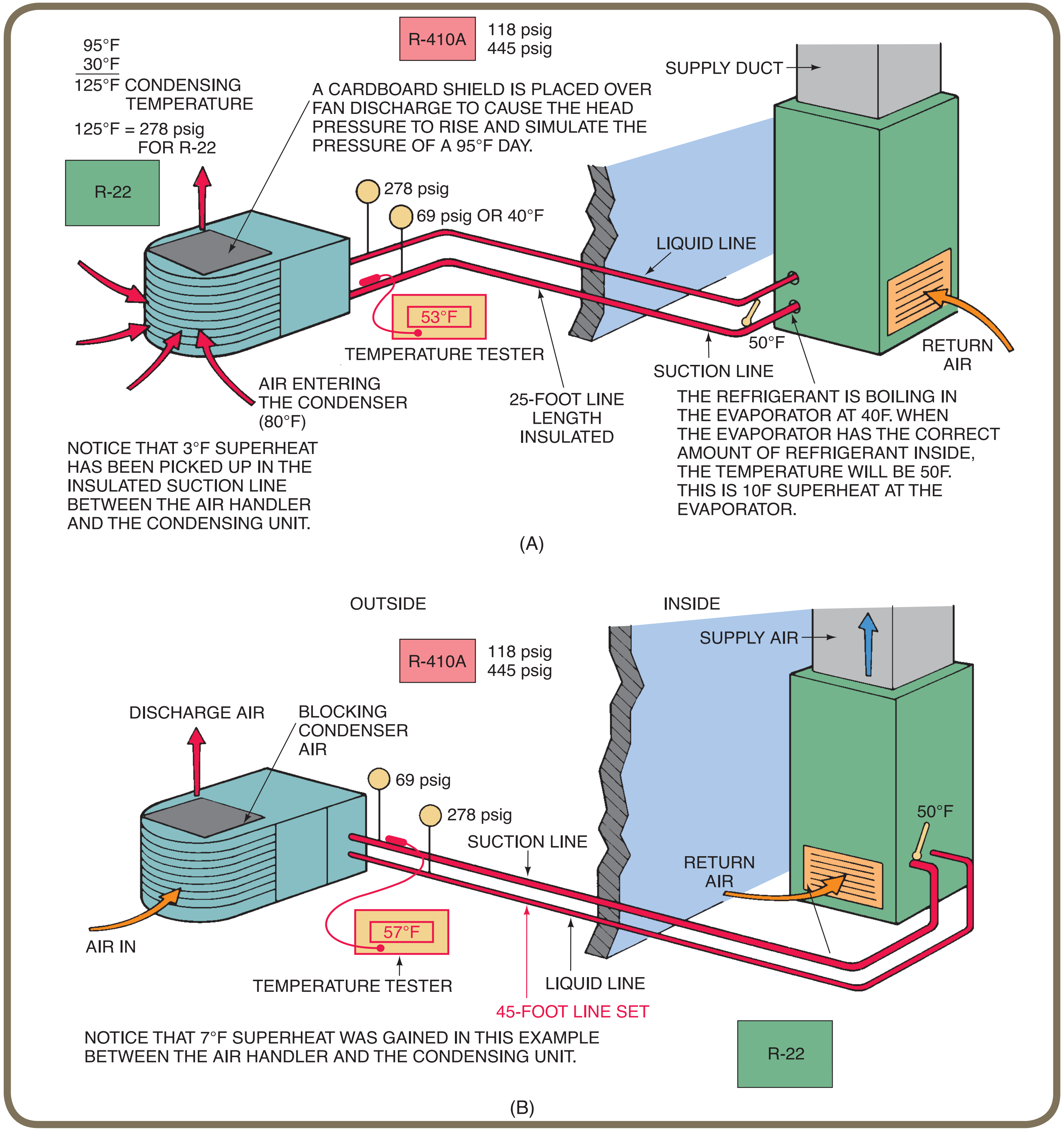


Figure 2. These two systems are being charged on a mild day. The line lengths are used to decide the amount of superheat for the different systems. Charging a system on a 95˚F day is the ideal time to use this procedure. When the temperature is less than 95˚, the technician can cover the condenser to cause the head pressure to rise and simulate the conditions of a 95˚ day. *(©Delmar Cengage Learning.)*

going to recommend that you use the recovery unit and remove refrigerant until you are sure that the charge is short. Then add vapor back to the system to arrive at the correct charge based on the superheat."

Bob then said, "I was removing liquid from the system and I guess it really would be hard to get that just right."

Bob removed refrigerant until the suction pressure was about 65 psig and the head pressure was reduced to 250 psig. Then he started adding vapor back to the system and watched the superheat. The system had a line set of about 20 feet, so he charged the system to a superheat of 12˚ (Figure 2 shows how this was calculated).

Bob went to the manager's office and reported what he had done, and the manager said, "I can already feel the difference. Thanks."

Bob then asked Btu Buddy a question, "When I checked the system using the touch test, the suction line was really cold. It seemed like the system should have been really cooling. What exactly was the problem that it was not cooling?"

Btu Buddy answered with a question, "What was the coil boiling temperature of the evaporator when you checked the pressure?"

Bob then said, "I asked you a question and you answered with a question. I guess you are trying to get me to think again. The suction pressure was 85 psig. That equated to a suction boiling temperature of about 55˚."

Btu Buddy then asked, "What should the boiling temperature be for an air conditioning coil?"

Bob then said, "I see what you are getting at. The suction boiling temperature should be about 40˚. The coil was not cold enough, but the suction line was really cold."

Btu Buddy said, "It was actually 50˚ because there was 0˚ superheat, about the temperature you had with a 40˚ coil with 10˚ superheat. The big difference in the feel of the line was that with 0˚ superheat it had liquid in the line. When there is liquid in a suction line, it will remove heat from your hand much faster than vapor. With vapor in a line at 50˚, you can feel it change temperature when you grip it very tight. If there is liquid in the line and you grip it tight, it will actually be so cold that it seems to hurt your hand."

Bob then said, "That is why you have always told me to grip the line tight, to see if I can detect liquid that conducts heat faster than vapor."

Btu Buddy said, "That is correct. Now, there was one other sign that you didn't seem to notice about this system. There was a large puddle of water under the condensing unit. Where did it come from?"

Bob said, "You are right. I should have noticed that without having to remove the compressor compartment door. The compressor sweating created the puddle. In this hot weather, the suction line would sweat up to the compressor, but it shouldn't create a puddle like this unit had. I could have probably diagnosed an overcharge of refrigerant from the outside, if I had been thinking."

Btu Buddy said, "That was a sure sign of overcharge. If you walk by a unit in hot and dry weather and see a big puddle, you should expect an overcharge on a capillary tube system. I can remember one time I was asked to quote doing the maintenance for an office building. I walked up on the roof and there were about 50 condensing units on the roof. The building manager was with me. I looked around and there were empty refrigerant cylinders all over the roof. Also, there were about 10 compressors that had been changed and were just sitting on the roof. I could tell that some very poor service had been performed on the place. As we walked around, I felt each suction line and observed the units. Many of them had large puddles of water under them and it was hot and dry. I explained to the manager what was going on and told him that before I could take over the maintenance, my technicians would need to get the system charges correct. It took two men four days just to regulate the charges to the correct charge. All of the preliminary diagnostics were done with looking and touching the system components."

Bob said, "Boy, that seems like a lot of time."

Btu Buddy said, "It was, but I was not willing to take over 50 systems that were out of order. The first thing that would have happened is our company would start getting the blame for the problems. I believed that the systems should be brought up to standard before we assumed the responsibility."

Bob then said, "You didn't mention what the liquid refrigerant getting back to the compressor could do."

Btu Buddy said, "I was getting around to that. The liquid refrigerant that was flowing back to the compressor was probably wet gas. By that I mean there was not a steady stream, but just a trickle of liquid or a saturated gas mixture. If you were looking at it like it was water, you will notice that you cannot see water vapor in the air until it becomes saturated and then we call it fog. The small amount of liquid getting back to the compressor was mostly boiled to a vapor by the warm motor windings. If any of the liquid trickled back as real liquid, it would drop down in the oil. When the oil is mixed with liquid refrigerant, it will dilute the oil and it will not be a good lubricant. Long running times would eventually score the bearing surfaces due to poor lubrication."

Bob then said, "You can really learn a lot about the system by looking and touching. The gauges will verify what you see and are used to tune the system to the best performance."

Btu Buddy then said, "You are learning a lot from these calls. Keep up the good work."

Chiller With High Head Pressure

The day was scorching hot and Bob got a call to go to an office building because the air conditioning system was off. It was a water-cooled chiller located in the basement with the water tower on the roof of the building. The refrigerant was R-22. When Bob arrived, he was met by the building manager who said, "We have been using another service company for several years and they say they cannot get to our call for three days, and we are without cooling. Everybody in the building is hot and irritable."

Bob said that he would do what he can to get the system back on-line as soon as possible. He explained that all local service companies were busy because of the heat wave, then he went to the equipment room where he found a 100-ton reciprocating chiller that was not running. He looked the system over and saw that the flag on the high-pressure control was out, signaling that the unit was off because of high pressure.

Bob was about to reset the control when Btu Buddy showed up and said, "Why don't you look at the tower before you reset the control. You may find the problem there."

Bob said, "I should have known that I was headed in the wrong direction when you showed up."

They went to the roof and looked at the water tower. The condenser water pump was running and the tower looked clean with clean water running through the tower.

Bob said, "This all looks good to me. I wonder if the tower fan will run. If it won't run, the unit would cycle off because of high pressure, and with the water still running, it would eventually cool the water down."

Btu Buddy said, "That was a good observation. The motor starter for the tower fan is over there. Turn the starter to 'manual on' and see if the fan will start."

Bob turned the fan to on and the fan started so he said, "Well, the fan will run, but it has to be controlled by a water temperature thermostat. I wonder if it is starting the fan. I am going to set the starter back to the automatic position and start the chiller and see what happens."

Btu Buddy then said, "That is the next logical step."

Bob pushed the button and the chiller started up. It had its own gauges for the operator to watch. As they were standing watching the chiller run, all seemed normal. Btu Buddy said, "Watch the thermometers in the condenser water lines. The water from the tower is showing 85°F in and 90° out (Figure 1, page 14). What does that tell you?"

Bob said, "The temperature rise should be about 10° and it is only 5°. The chiller doesn't seem to be doing but half capacity (Figure 2, page 14)."

Btu Buddy then said, "What is the chilled water side of the system doing?"

Bob looked at the thermometers in the chilled water circuit and said, "The inlet water is 70° and the outlet water is 60°. The chiller seems to have a 10° drop, which is normal, but the condenser only has a 5° rise. It seems that the evaporator is operating at 100 percent and the condenser is only operating at 50 percent capacity."

Btu Buddy said, "Great observation. You are really catching on."

Bob said, "Thanks, experience is teaching me how."

Btu Buddy then said, "Feel the liquid line going to the expansion valve and tell me what you feel."

Bob felt the liquid line and said, "This line is hot, and it should only be warm."

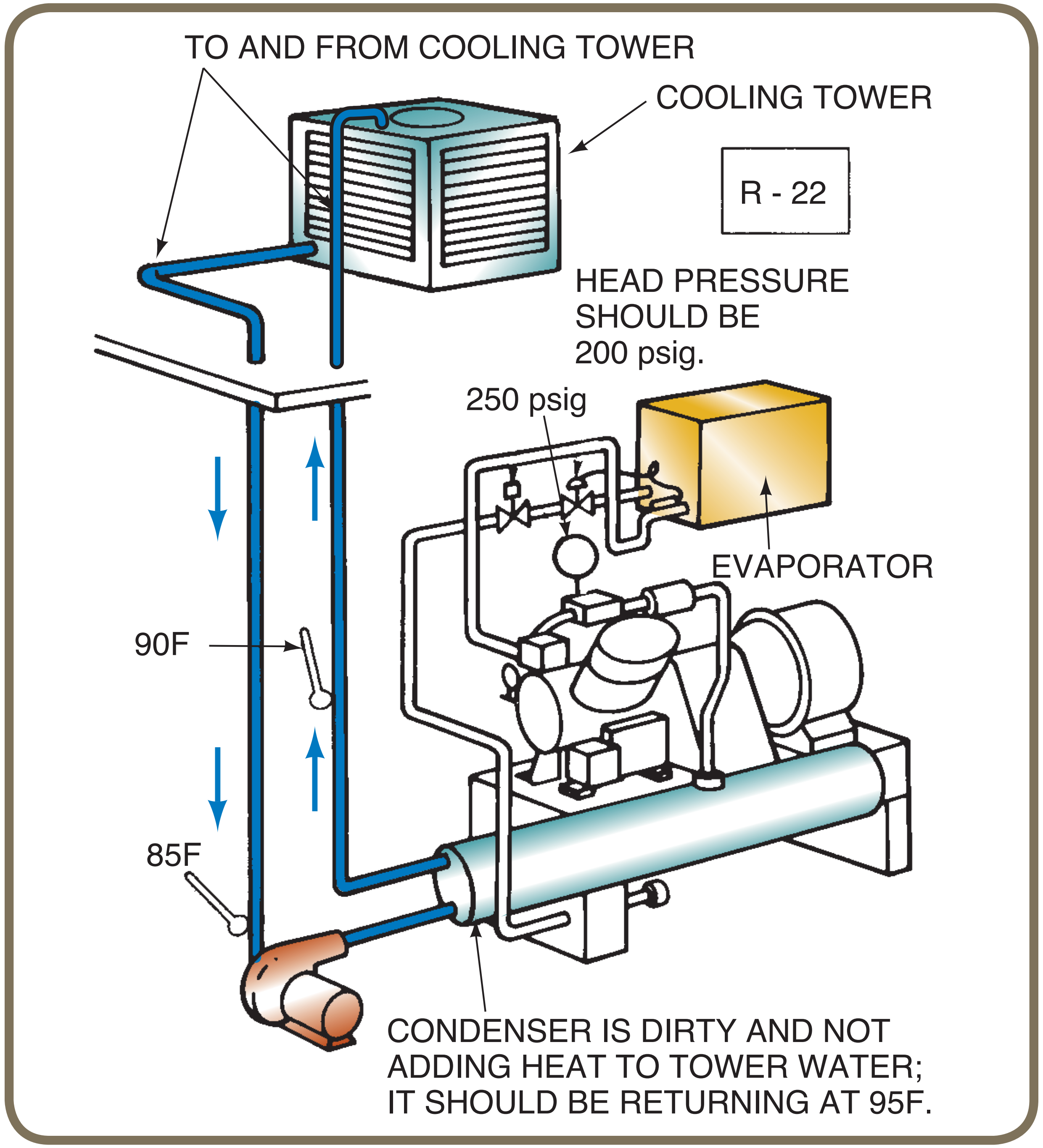


Figure 1. This condenser has dirty tubes. The water returning to the tower from the condenser should be about 95°F. *(Figures in this chapter are from Refrigeration & Air Conditioning Technology, 5th Edition, by William Whitman, William Johnson, and John Tomczyk, published by Delmar Cengage Learning.) (©Delmar Cengage Learning.)*

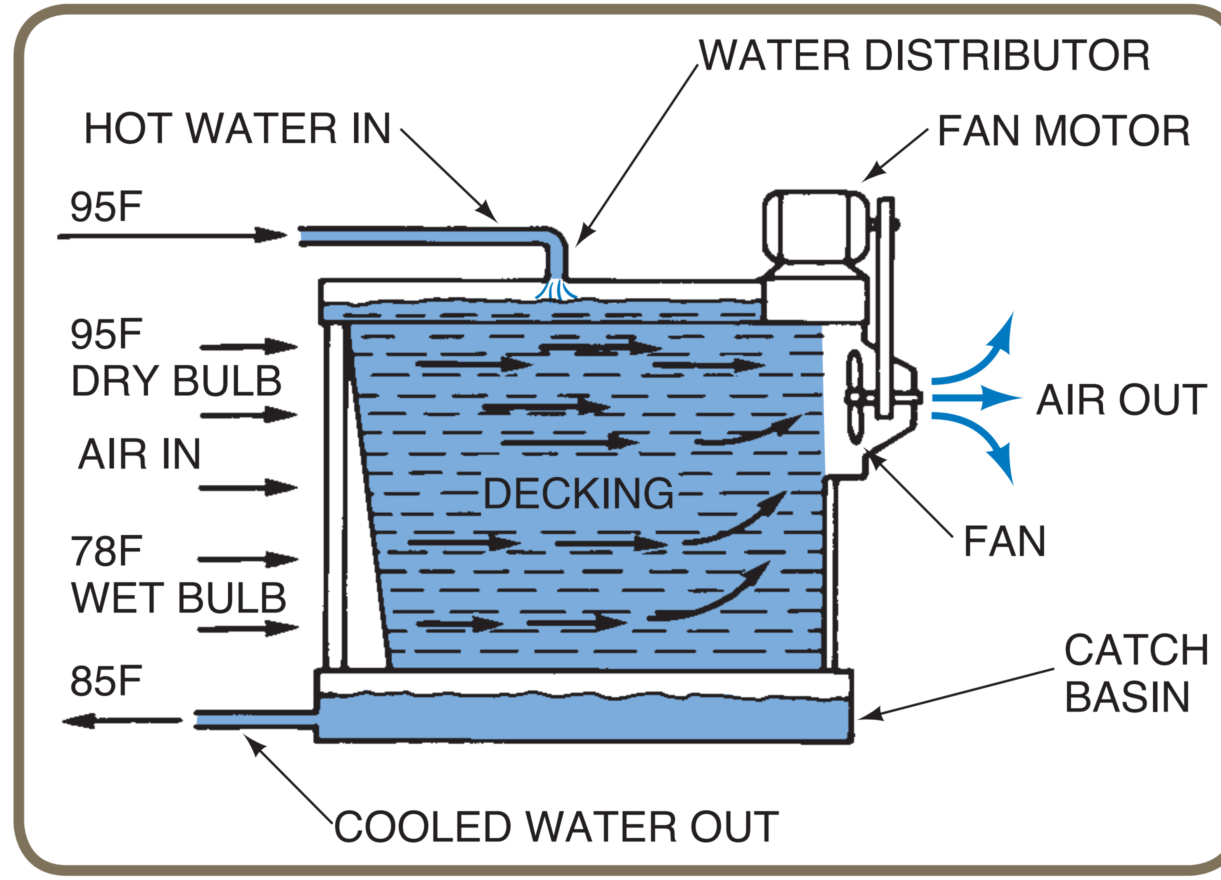


Figure 2. This cooling tower is operating at full load, 95°F water in and 85° water out. The condenser for this tower is operating correctly. *(©Delmar Cengage Learning.)*

Btu Buddy then explained, "The system has a condenser water temperature of 85° entering the condenser and should condense the refrigerant at about 105° with 95° leaving water. It should have about 10° of subcooling, so the liquid line temperature should be about 95° when it is operating normally. What is your observation at this point?"

Bob said, "It looks like the condenser tubes are dirty and not taking the heat out of the refrigerant. Look, the head pressure is up to 260 psig. The high-pressure control is going to shut the chiller off. I think it should be set at

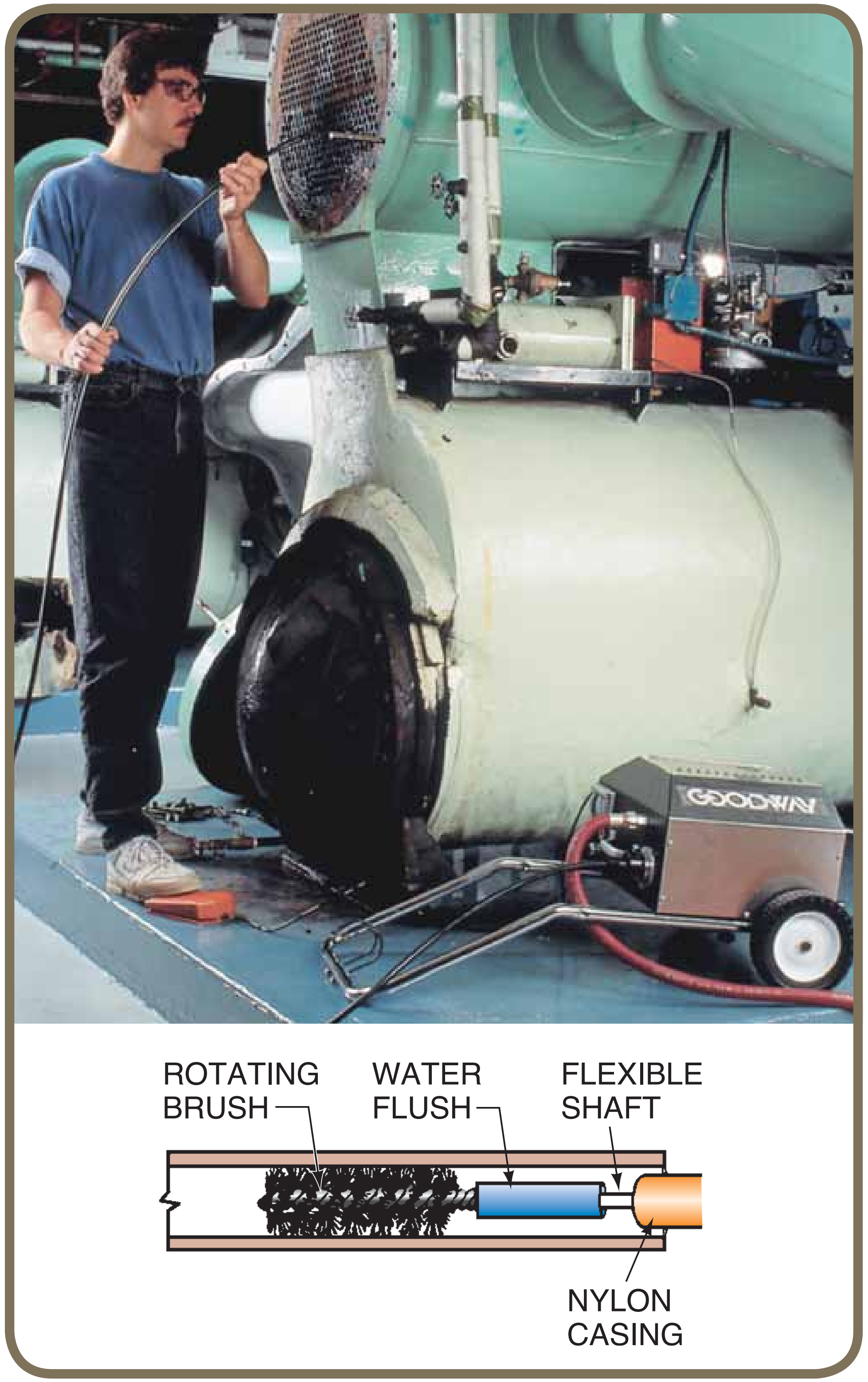


Figure 3 (left). The man above is cleaning the condenser tubes on a large chiller using a machine that turns a nylon brush and flushes the tube with water at the same time. *(©Delmar Cengage Learning.)*

about 275 psig. We need to get set up to clean the condenser tubes as soon as possible. I am going to call the shop and ask for someone to bring me the condenser tube cleaning machine and someone to help me clean the tubes."

Bob called the office and got equipment and help on the way. Then he told Btu Buddy, "I am going to start removing heads from the condenser and maybe we can have this system back on in a few hours."

Btu Buddy then said, "You are really organizing this job to save the customer downtime. They will thank you for that."

Bob turned off the condenser water pump, closed the valves on each side of the condenser, drained the condenser, and removed the heads and looked at the tubes. They were dirty and really needed cleaning. When the tube cleaning machine arrived, he and the helper cleaned and rinsed the tubes (Figure 3) and then put the heads back on the condenser. He was ready to open the valves and let the water back in the condenser when the building manager appeared and asked, "How long will it be before you can turn the system on?"

Bob said, "In about five minutes we will be ready to start the chiller back up."

The manager said, "I was afraid you were going to say sometime tomorrow."

Bob opened the valves and let the water fill the condenser, then he started the condenser water pump and, assured that water was flowing, he started the chiller.

He watched the high-pressure gauge and it settled down at 210 psig. The system was working correctly. He kept observing as he cleaned up the equipment room and picked up all of his tools. In about 30 minutes, the chiller was putting out 45° water and the head pressure was still 210 psig. The system was performing normally.

The manager came back to the equipment room again and said, "Thanks for getting this job done in a reasonable time. I noticed that you worked right through the lunch hour to provide service for us. I called the restaurant down on the corner and you and your helper have the lunch of your choice on us. Thanks for doing such a good job."

As Bob got in his truck and the helper got in his truck to leave for lunch, Btu Buddy said, "You really did a great job here today. It will be noticed by management and they will reward you for doing good work."

Bob then said, "Thanks for all of your help. It feels good when a job goes as good as this one."

Then Bob remarked, "I wonder why those condenser tubes were dirty? The tower had a water bleed off system and the water was clean."

Btu Buddy said, "You don't know if the other company did regular maintenance on the system. The water could have been really dirty for a long time, then the other service company could have cleaned up the tower and not checked to see if the condenser was performing correctly."

Was the Charge Really Low?

The dispatcher sent Bob to a new customer for a routine system tune-up. The system was a 3-ton cooling unit with a capillary tube metering device. Bob looked the system over and thought everything was in good shape. The customer was not really complaining about system performance, but the weather was not really hot, only 85°F. Bob felt the suction line and it did not feel quite as cool as it should be, so he fastened a temperature tester to the suction line and it read 60°. Bob thought that was a little high so he decided to increase the head pressure by blocking the condenser and see what happened to the suction line temperature.

Bob blocked the condenser until the air coming out the top was really warm (Figure 1). He gave the unit a few minutes to settle down and felt the suction line again. It seemed to have cooled down some. The temperature tester showed it to be 55°. That was some improvement, but not what Bob expected.

Bob then decided to fasten gauges to the system. The high-side gauge read 275 psig with the condenser still blocked and the low-side gauge read 51 psig. Bob knew this was not right since the low-side temperature in the evaporator corresponded to 27° for 51 psig suction pressure. The system used R-22 for the refrigerant.

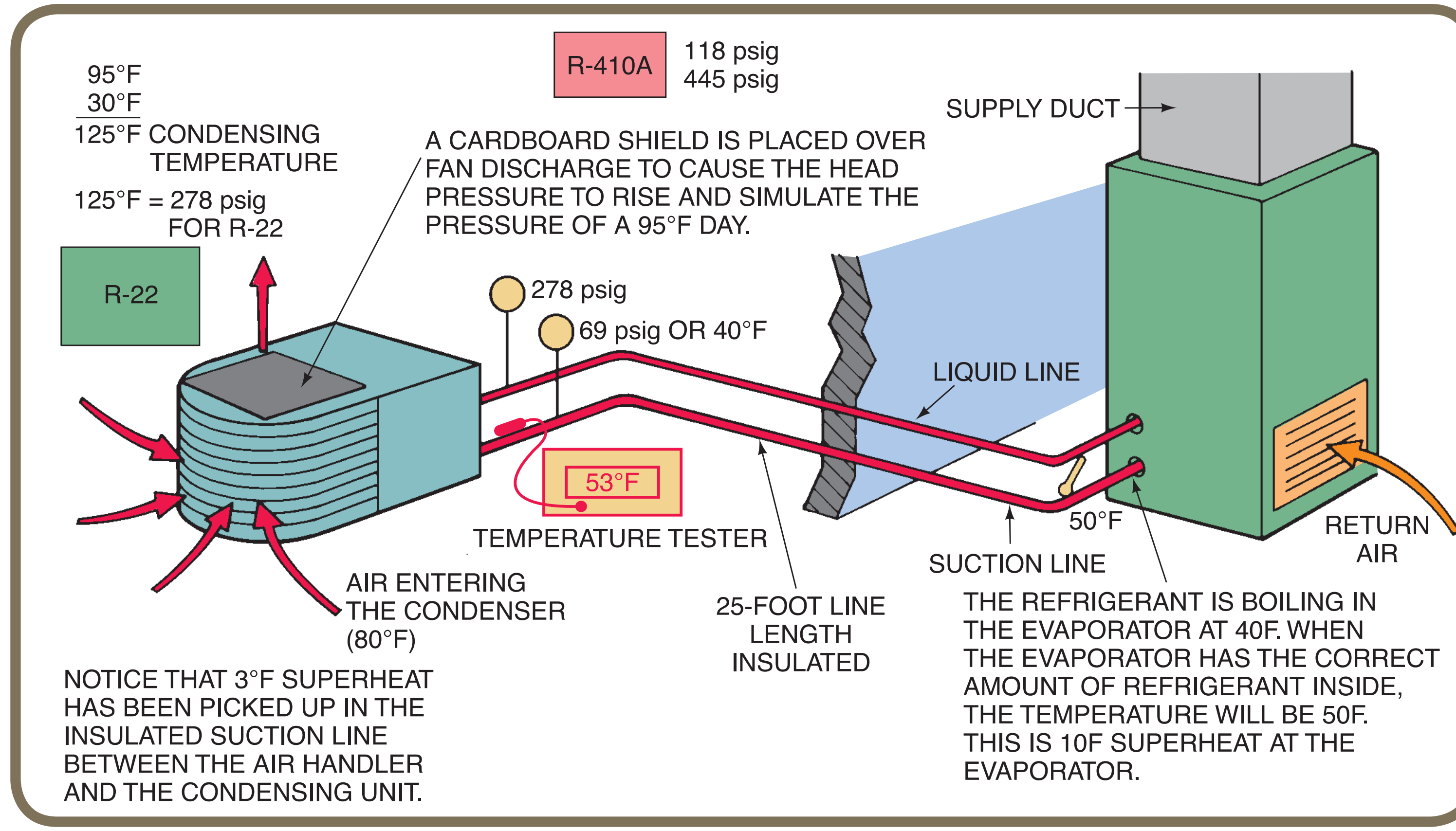


Figure 1. Blocking some of the airflow across the condenser causes the head pressure to rise. This will make sure the condenser is not backing up refrigerant and the metering device will get the correct amount of liquid only. This illustration shows normal conditions when the condenser is blocked on a cool day. (From Refrigeration & Air Conditioning Technology, 5th Edition, by William Whitman, William Johnson, and John Tomczyk, published by Delmar Cengage Learning.) (©Delmar Cengage Learning.)

Bob was scratching his head when Btu Buddy appeared and asked, "What is the problem, Bob?"

Bob said, "This system's pressures don't add up. With a head pressure of 275 psig, the suction pressure should read about 70 psig."

Btu Buddy asked, "What is the superheat at these conditions?"

Bob said, "It is 28° with the condenser blocked. The suction pressure is low; the super heat is high with a normal head pressure for a hot day. The low-side symptoms show a low charge."

Btu Buddy then asked, "What are you going to do?"

Bob said, "Add refrigerant."

Btu Buddy then suggested, "The symptoms for the low side are a low charge, and normal on the high side. Could there be any other causes for the low-side pressure to be low?"

Bob then said, "Well, a partially plugged capillary tube would starve the evaporator and act like this system."

Btu Buddy then said, "You may be on the right track. Start looking for reasons that the low side is starved of refrigerant. Are there other reasons?"

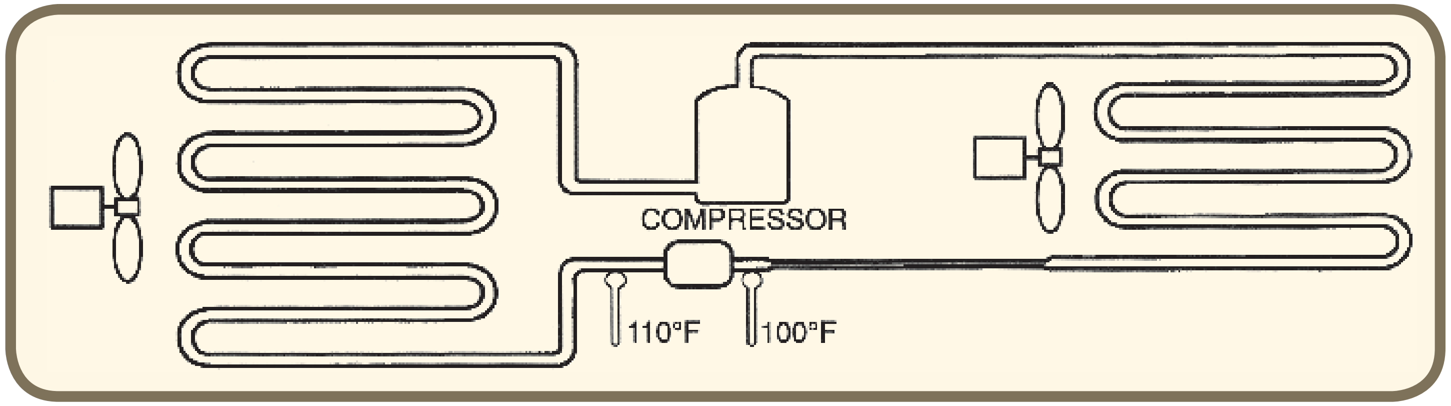


Figure 2. The liquid entering the drier is 110˚F and it is 100˚ when it leaves. There is a 10˚ temperature drop across the drier. When there is a temperature drop, there is a pressure drop. The drier is partially restricted. *(From Practical Cooling Technology by William Johnson, published by Delmar Cengage Learning.) (©Delmar Cengage Learning.)*

Bob then said, "The capillary tube must have a good quality of liquid refrigerant entering it for it to perform correctly."

Btu Buddy said, "You may have something there. How would you check for that?"

Bob said, "The system doesn't have a sight glass, so I am not sure."

Btu Buddy then suggested, "How about temperature of the liquid line. You can use your infrared thermometer to check the liquid line temperature."

Bob used his infrared thermometer and scanned the liquid line starting where the line went under the house back to the condensing unit. Entering the liquid line drier, the line was 110˚, while coming out of the drier, the line was 100˚ (Figure 2).

Bob said, "Wow, there is a temperature drop across the drier. It must be partially plugged."

Btu Buddy said, "See if you can tell the difference in temperature across the drier with your hands."

Bob felt both sides of the line to and from the drier and said, "No, they feel the same to me. I would think that I could feel a 10˚ temperature difference."

Btu Buddy said, "Some people may be able to feel the difference, but the difference is hard to detect with just your touch. Now what?"

Bob said, "It is going to be hard to explain to a customer that there is a problem when they don't see a symptom."

Btu Buddy said, "You are right about that, but you owe it to the customer to try."

Bob explained to the customer that the drier was partially plugged and that it was hard on the compressor to operate without proper cooling, and that the first time hot weather came, the system would not cool the home.

The customer said to go ahead with the repair.

Bob recovered the refrigerant from the system, changed the filter drier, and recharged the system. He used scales to recharge the system to the correct charge and then checked the system again. The condenser was still blocked and the evaporator showed 12˚ of superheat with 278 psig of head pressure. The condensing temperature was 125˚ and the liquid line temperature was 113˚, which is 12˚ of subcooling. The system was in good working order.

Btu Buddy suggested, "Leak check all connections, including the service port where you removed the gauges, before you count the job completed."

Bob completed the leak check and all was well.

As they were riding away, Bob said, "Well, another lesson learned."

Btu Buddy added, "The lessons go on and on, that is why this is such an interesting profession. I have heard people say that this is a profession for people who don't have the intellect to go to college. That service call was for a thinking person."

Smoking Gas Package Unit

Bob got a call about a new customer who complained about their gas package unit smoking and smelling bad. Bob called the customer who explained that the unit could be smelled at the street about 60 feet away when the wind was blowing in that direction. The customer also said that smoke was coming out of the unit's vent. Bob advised the customer to shut the unit off until he could get there. He explained that there should not be any fumes entering the house, but to be safe, turn it off.

When Bob arrived, he talked to the customer and then turned the unit off at the disconnect switch at the unit. He then went inside and turned the thermostat up to call for heat. He then went outside to the unit and started it with the disconnect switch. Sure enough, a light black smoke was coming out of the vent. Bob removed the burner compartment panel and looked at the flame and it didn't look all that bad. He was scratching his head when Btu Buddy showed up.

Btu Buddy asked, "What is the problem, Bob?"

Bob said, "I have never seen a gas appliance smoke like this, and it really smells bad."

Btu Buddy then asked, "What would cause a gas flame to smoke?"

Bob said, "Maybe too much fuel, or not enough air. The vent seems to be working and I can hear the vent fan turning, so it must be good. Maybe there is too much pressure on the gas manifold causing too much gas for the amount of combustion air."

Btu Buddy then said, "Why don't you take off the vent cover and see if there could be a blockage at the fan outlet?"

Bob removed the cover and took a light and looked inside and said, "Here is the problem. The fan wheel is all torn up. I don't see how it could move any air, but something is moving the air."

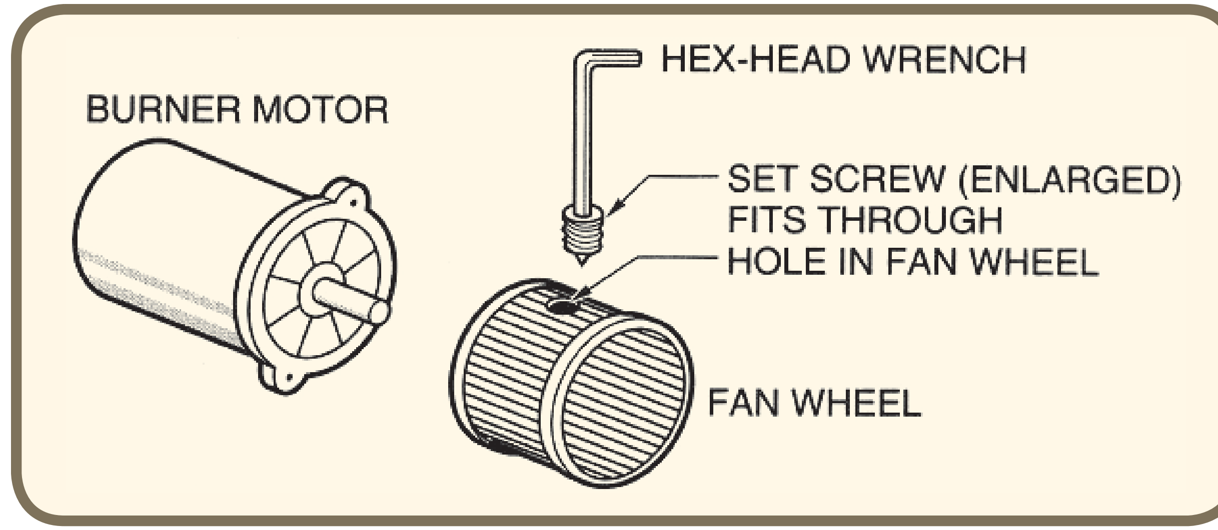


Figure 1. This is a motor and fan assembly similar to the one that Bob replaced. *(From Practical Heating Technology by William Johnson, published by Delmar Cengage Learning.) (©Delmar Cengage Learning.)*

Bob removed the fan and wheel and looked it over. He then said, "I don't see how that worked at all. There is no sign of the rest of the fan wheel. I wonder where it went. I think I need to talk to the customer and see if she knows anything."

Bob talked to the customer and the customer said, "We had problems with this unit last spring, just at the end of the heating season. The contractor is no longer in business. The contractor told me that the heat exchanger had a hole in it and changed it out in warranty. It only cost us for the labor. He didn't mention what could have caused it."

Bob showed her the fan wheel and she wanted to know what it should look like, so Bob showed her a picture of a new motor and fan wheel (Figure 1). He explained to her that there was no sign of the rest of the wheel.

She told Bob to make the repair.

Bob was making the repair when Btu Buddy suggested, "I think the contractor last year found the defective fan wheel when he installed the heat exchanger and just threw the missing pieces away and didn't mention it. It was going to cost even more, so he just didn't do his job because he didn't want to go back to the customer for more money than his estimate. He must have noticed that the vent smelled bad, but assumed it was venting good enough. Probably the old fan wheel was what caused the heat exchanger to fail. If the unit had operated for long, the heat exchanger would have failed again and then the customer would have really been mad."

Bob decided to see if he could change just the fan wheel and tried to remove it from the fan motor shaft. Then he discovered the hex head nut holding the fan wheel on the shaft was rusted out inside and an Allen wrench would not get a grip to turn it. He then said to Btu Buddy, "I am going to have to change the motor and the fan wheel — even more expense."

Bob went to the supply house with the old motor and fan wheel where the counter man said, "You are doing the right thing. I have noticed that nobody can remove these old fan wheels from the shaft because of the rusty Allen screw."

Bob had the new fan assembly and went back to the job to install it.

Btu Buddy said to Bob, "Shine your flashlight into the heat exchanger at the top where the fan mounts and at the bottom where the burners are and look closely for signs of soot deposits."

Bob used his light and examined the heat exchanger from both ends and said, "There are no signs of soot. We are good to go forward."

Btu Buddy then said, "Thank goodness the homeowner got right on this, before it had enough running time to accumulate soot."

Bob asked Btu Buddy, "Why was there so much rust in the fan section?"

Btu Buddy explained, "The unit is about 11 years old. Every time it starts up, it gets a blast of moist air from combustion and that air is slightly caustic, about like a soft drink. After years of exposure, it just accumulates rust. I have never seen one that is rusted out like this one. Notice, the new fan wheel is coated with a galvanized zinc coating. The original one should have been coated the same way. It is possible that it did not get a good thick coat of galvanizing for proper protection."

Bob then asked a crucial question, "How come combustion was allowed to keep going when there was not enough airflow? It seems like it should have shut the unit down."

Btu Buddy then said, "Let me start by saying, there are three methods of proving airflow in a forced combustion system:

1. Some systems have a pressure switch across the blower that proves airflow.

2. Some systems have a 'sail switch' that moves to make a set of contacts to verify combustion.

3. Some combustion motors have an 'end switch' built into the motor to assure the combustion fan is turning. This assumes that the fan will move air when the motor is turning.

"All of these systems open the gas valve when airflow is established. I guess your vote would be for either number 1 or 2, after today's experience."

Bob said, "Yes, this system sure didn't function as expected. Who would have expected a fan wheel to completely come apart? It seems like it would have made a noise."

Btu Buddy said, "The last technician did not do a professional job. You know better than to leave a job like this when it still had problems." Ⓝ

Dry House Problem

Figure 1 (left). This is a photo of a cabinet door that is showing shrinkage due to low humidity. *(Photo by Bill Johnson)* **Figure 2 (above).** A sling psychrometer uses the wet-bulb/dry-bulb principle to provide humidity readings. *(From Refrigeration & Air Conditioning Technology, 5th Edition, by William Whitman, William Johnson, and John Tomczyk, published by Delmar Cengage Learning.) (©Delmar Cengage Learning.)*

Bob got a call from a customer who said her house was so dry that the wood was shrinking. He wasn't sure what she was talking about until he arrived at the house and talked to her. She explained that the painted surfaces on some of her cabinets were shrinking to the point that she could see the unpainted surfaces (Figure 1).

Bob looked around the house and could see signs of wood shrinkage in several places. He was standing there scratching his head when Btu Buddy made an appearance and asked, "What is the problem, Bob?"

Bob said, "Boy am I glad to see you. This house is so dry that the wood is drying up and shrinking. I have never noticed that before, until the homeowner showed it to me. I don't know why a house would be so dry."

Btu Buddy then asked Bob if he knew what level of humidity the house was maintaining.

Bob said, "No, but I can take a reading and find out."

Bob went to the truck and brought in his sling psychrometer (Figure 2) and took some readings. He then said, "This house is very dry; the humidity is down to about 15 percent. What should the humidity be?"

Btu Buddy said, "Most people in the industry would like to hold the humidity somewhere between 40 percent and 60 percent for a typical home. Below 40 percent is uncomfortable and the wood in the house will begin to suffer. If the humidity is above 60 percent, mold can grow in some places in the house."

Bob then said, "I wonder why the humidity in this home is so low."

Btu Buddy said, "This house is about 25 years old, so we should look for several things. To start with, I would think that the house is not nearly as tight as modern homes. If there is too much infiltration, the humidity will be low. For example, when outdoor air at 35°F at 50 percent humidity enters through infiltration, and it is mixed with indoor air at about 70°, the indoor humidity level drops to about 19 percent. That is a large drop in humidity (Figure 3, page 22).

Houses of older construction have much more infiltration than the newer constructed houses. Many of the older houses have 50 percent of the air changed out

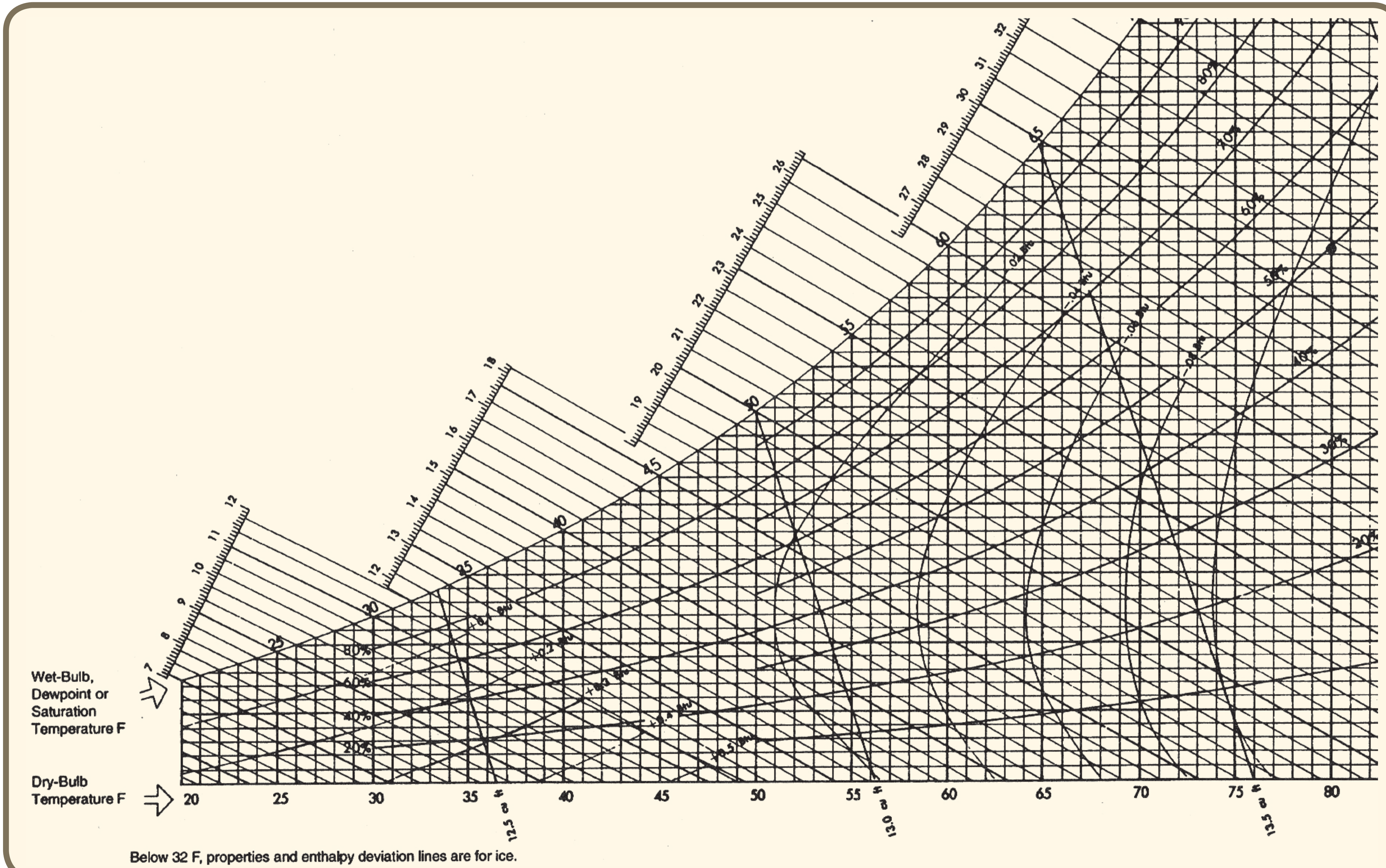


Figure 3. An excerpt from a psychrometric chart showing air entering at 35°F and 50 percent humidity mixing with air in the home at 70° and the humidity of that air dropping to 19 percent. *(From Practical Cooling Technology by William Johnson, published by Delmar Cengage Learning.) (©Delmar Cengage Learning.)*

in the house every hour; certainly an older house would have at least 25 percent of the air changed every hour. It is easy to see from the chart, that would easily lower the humidity in the house."

Bob then asked, "How in the world can that much air change out in a house? It would seem like it would be like a wind tunnel."

Btu Buddy explained, "All houses are subject to the prevailing breeze or wind. The air is rarely still. The wind causes a positive pressure on one side of the house, and when it drops off of the other side of the house, it creates a negative pressure (Figure 4). This causes air to enter on the positive side and exit on the negative side. The house is a vessel, but it is not an air tight vessel."

Bob then asked, "Now what do we do?"

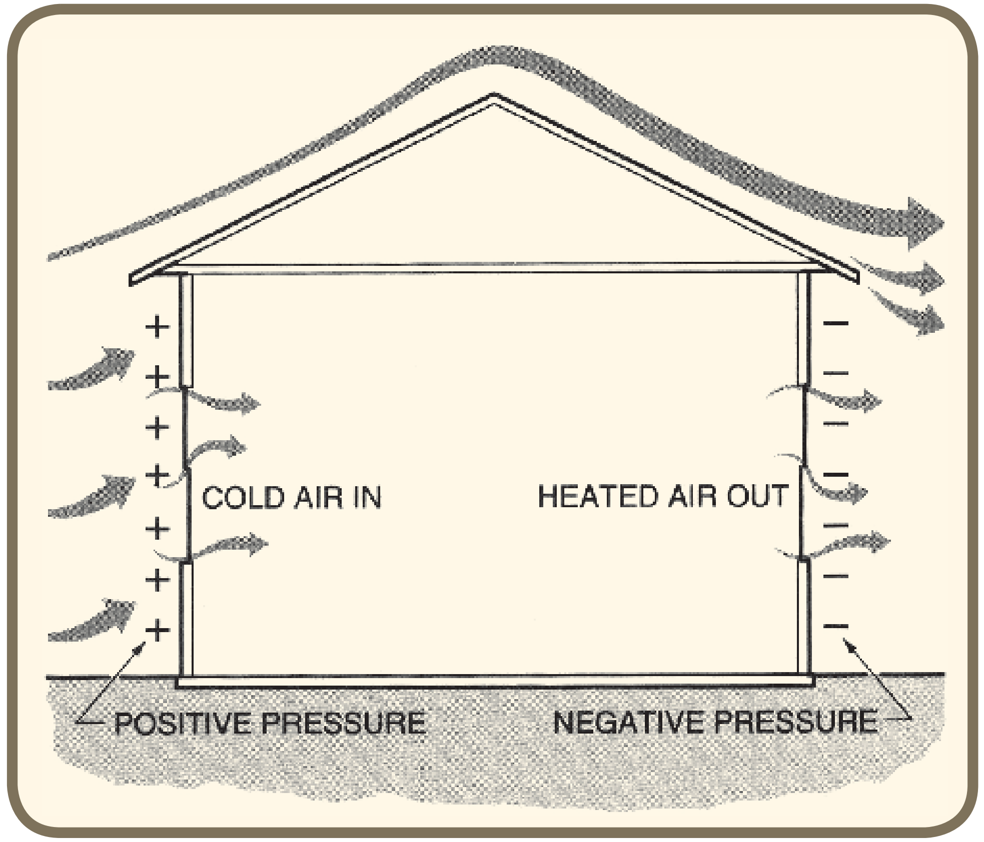


Figure 4. This illustration shows how infiltration air enters a structure from the prevailing breezes. *(From Practical Heating Technology by William Johnson, published by Delmar Cengage Learning.) (©Delmar Cengage Learning.)*

Btu Buddy then suggested, "I think you should show the owner what is going on with the structure and suggest that she get a general contractor to offer suggestions. Your company can explore and repair some of the problems. The air distribution duct system can also cause excess outdoor air to be pulled into the structure. If the supply duct leaks, the return air will cause the home to go into a slight vacuum, sucking in outdoor air. If the return duct leaks, it will suck in outdoor air from either under the house or the attic when the duct is routed in these locations. This will force air into the structure and put it into a positive pressure. You can check those yourself and initiate a repair. Meanwhile, you can install a humidifier in the central duct system and a humidistat to help stabilize the humidity in the house."

Bob explained all of this to the homeowner and she told him to go ahead with the duct examination and repair and to add a humidifier.

Bob found several places in the supply duct that needed attention. He also applied mastic to all of the duct connections that he could access. He then turned his attention to the return duct and found several places where it was obvious that air was leaking in and repaired them. He then called his company and asked for a duct pressure test technician to come out and test the duct for leaks. He did this by taping all duct outlets and returns and applied a fan to the furnace fan section and pulled room air into the duct system pressurizing it. He then measured the amount of leakage and told Bob that he had done a good job of sealing the system. It had very little leakage.

Meanwhile, the general contractor showed up and Bob explained what was going on. The contractor looked around and told the homeowner that she had storm windows that were not great, but adequate. He looked under the sinks on the outside walls and suggested that all penetrations to the home be sealed, including plumbing and electrical (Figure 4). He explained to her that it would take a few materials and only a few hours to complete this job.

Btu Buddy then said, "We are not going to install the humidifier today. We'll go back to the shop, decide on the best system for this job, and come back tomorrow with the humidifier and a humidistat."

Bob said, "Well, this simple job turned into a learning experience, but I love it."

Freezing Evaporator

Warmer spring weather was here and Bob was beginning to get calls about units that were not cooling. He just received a call from an old customer who said that her unit cools fine during the morning and daytime, but at night, it stops cooling. She then shuts it off for the evening at bedtime and opens the windows.

Bob arrived at the job at about 3 p.m. to look at the unit. He listened to what the housewife had to say, then went to the room thermostat and saw that it was set at 70°F and the unit was running. He went out to the unit and looked it over. It was a 4-ton split system that used an orifice for a metering device. A gas furnace furnished the heat and the fan for cooling (Figure 1).

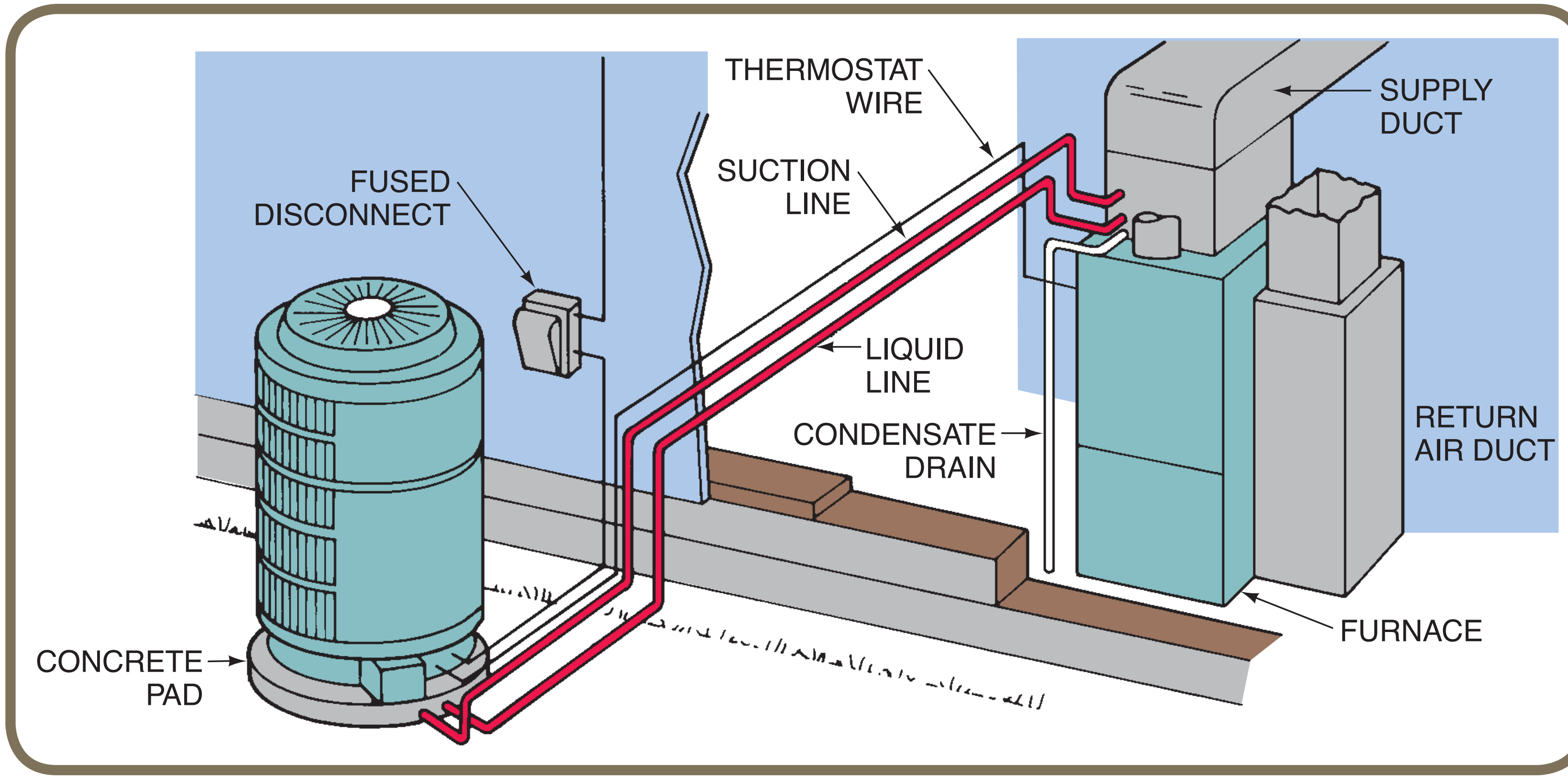


Figure 1. This illustration shows a complete installation, similar to the one discussed in the service call. *(Figures are from Refrigeration & Air Conditioning Technology, 5th Edition, by William Whitman, William Johnson, and John Tomczyk, published by Delmar Cengage Learning.) (©Delmar Cengage Learning.)*

It was 80° outside and the unit was operating. Bob felt the suction line and noticed that it was really cold. He looked in at the compressor and the side of the compressor was sweating. He thought a minute and decided that the unit had too much refrigerant in it and started getting set up to remove some of the refrigerant when Btu Buddy arrived and asked, "What's up Bob?"

"The unit's suction line is really cold back to the compressor and it is only 80° outside. It appears to me to have too much refrigerant," Bob said.

Btu Buddy then told Bob, "Put your gauges on and see what the pressures are running. What do you think they should be running?"

Bob then looked at his temperature and pressure card and said, "The unit uses R-22. I would suspect that the suction pressure would be about 65 psig and the head pressure would be about 226 psig, corresponding to a condensing temperature of about 110° (80° + 30° = 110°). This seems to be a standard efficiency condensing unit and it is about 15 years old. How does that sound?"

Btu Buddy said, "That is some quick thinking on your part. You are getting used to calculating the head pressure. You are about right. Why did you decide on 65 psig for the suction pressure?"

Bob explained, "Well, the home thermostat is set at 70°, which is a little on the cool side, and it is spring. There is not enough humidity in the air to put a humidity load on the coil and the head pressure should be a little below normal because it is not a hot 95° summer day."

Btu Buddy said, "Those are some good deductions. Now let's put the gauges on and see what the pressures read."

Bob fastened his gauges to the gauge ports and noted the pressures to be 51 psig low side and 225 psig high side.

Bob then said, "Well, so much for speculation. Now what?"

Btu Buddy asked, "What would cause a low suction pressure with a low superheat?"

Bob then said, "Well, it looks like there is enough refrigerant in the system. Maybe the coil is dirty, or the filters are dirty. I think I will have a look. The coil is over the furnace in the garage."

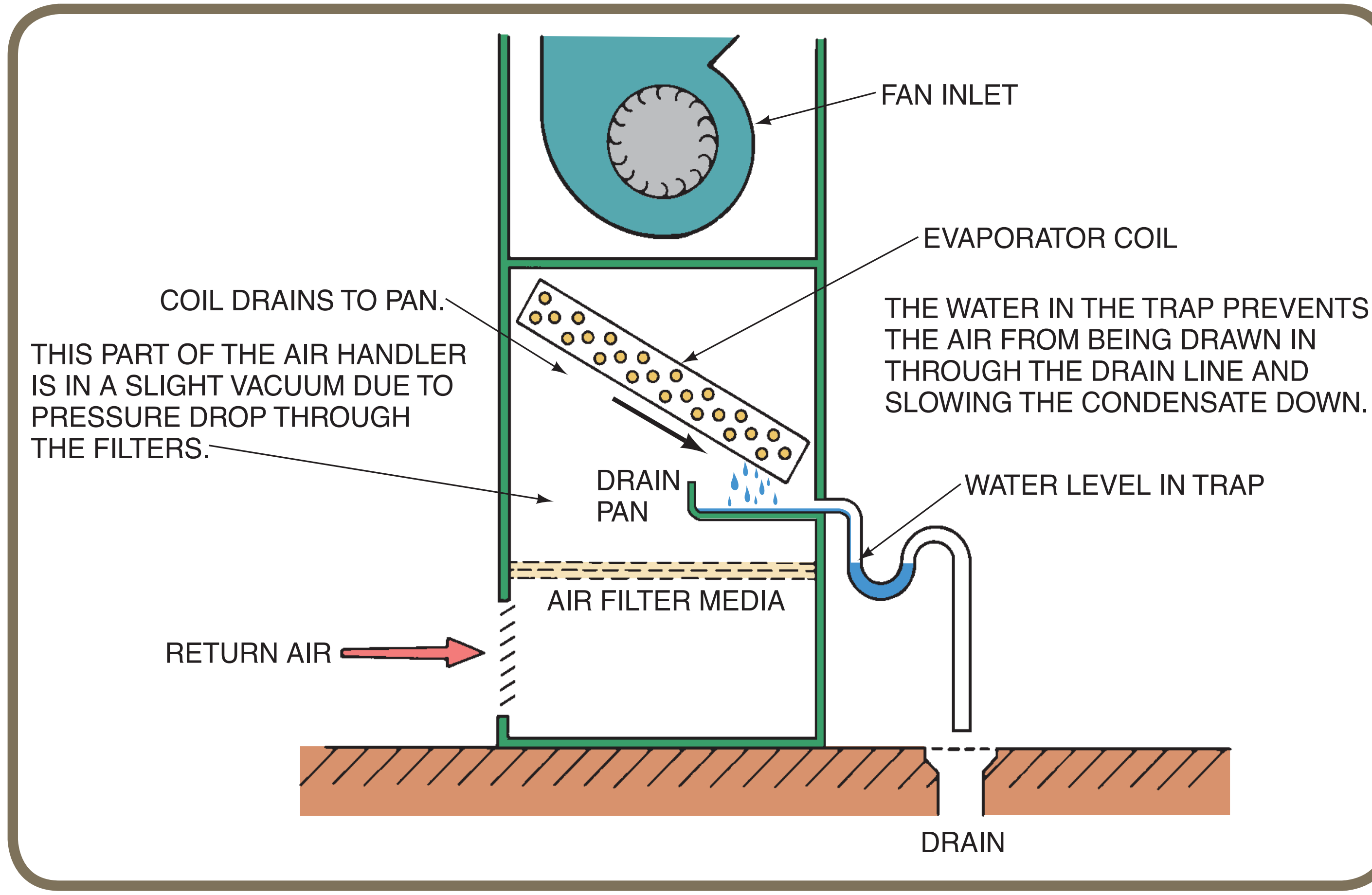


Figure 2. This coil can be washed slowly and the water should all go down the condensate drain line. Then the drain line should be flushed to push all dirt to the drain. *(©Delmar Cengage Learning.)*

Bob and Btu Buddy went to the coil and Bob felt the suction line at the coil and said, "This line has some ice on it. We either don't have enough airflow or the coil is dirty."

Btu Buddy then asked, "What is next for you?"

Bob said, "I am going to check the filter first, then the coil and fan for dirt."

Btu Buddy said, "That sounds like a good plan."

Bob turned off the breaker to the furnace, which stopped the whole system, then he removed the cover to the filter and it was clean. The owner had been changing the filter every 60 days and had a record of it written down on a page close by.

Bob said, "Well, I guess we can rule out dirty filters. The owner seems to really keep them clean."

Bob then removed the cover to the fan housing and took his light and shined it at the fan wheel, and he said, "Look at that fan wheel. It has a lot of dirt caked into the wheel."

Btu Buddy then said, "If there is that much dirt built up on the fan wheel, you can bet the coil is also dirty. What is going to be your plan of action?"

Bob said, "I am going to remove the fan wheel and clean it in the driveway using a screw driver to scrape deposits out of the wheel and detergent to wash it. Then I am going to wash the coil with detergent that is approved for copper and aluminum. I will have to wash the coil slowly so that the dirt and water will go down the condensate drain line. Then I will flush the condensate drain line from the coil to the outlet to push the dirt down the drain (Figure 2)."

"That is a good plan, Bob. You are covering all the bases," said Btu Buddy.

Bob then said, "Now explain to me why the system was not cooling at night."

Btu Buddy explained, "The system had reduced airflow and the coil was freezing during the running cycle, as you observed. However, the thermostat would satisfy and the coil would thaw between cycles. When evening came, the outdoor air temperature dropped even further, causing the evaporator pressure and temperature to drop to the point that the coil would freeze up all the way. I would suspect that airflow dropped to practically nothing with the coil frozen. There would be no cooling during the evening hours and there would still be some heat load in the house from lighting and other activity. When she shut the system down at bedtime, the coil would thaw overnight and the process would repeat itself the next day. The system seems to have enough refrigerant. Cleaning the fan and coil should solve the problem."

Bob then asked, "The filters were clean. How did the fan and coil get so dirty?"

Btu Buddy responded, "Typical filters are good for taking out large particles. There is a certain amount of air that goes through a typical hardware store filter. This bypass air is dirty and, over the years, it will build up. Particularly on a wet cooling coil in the summer, it is a super filter. It was a dead giveaway when you found that the fan wheel was dirty. The coil must be dirty also."

Bob then said, "Well, another day, another lesson."

Condenser Fan Motor Problems

The day had been very hot and Bob was really tired after spending all day on rooftops working on equipment when he received a call from the dispatcher telling him about a restaurant that was having difficulties. The restaurant expected a big crowd in the dining room that night and the air conditioning was off.

Bob arrived at the restaurant to discover yet another unit on a rooftop that had a problem. Bob checked the thermostat and it was set at 72°F and the room temperature was 80°. Bob turned the thermostat fan switch to fan-on and the fan started. This verified the indoor power supply was working. He then set the thermostat fan switch back to auto and went to the truck for his ladder to go on the roof where the air-cooled condenser was located.

When he got on the roof he noticed that the fan motor was turning, but seemed to be very slow. As he approached the condensing unit, the fan stopped. A few seconds later the compressor shut off because of high pressure.

Bob was sure that the fan capacitor must be the problem, so he turned off the power and removed the old capacitor and went down to the truck for a replacement.

While at the truck, he used his capacitor tester to check the capacitor. He was surprised that it checked out OK. He carried the new capacitor up to the unit anyway and installed it. He started the unit again and the fan was still turning slowly and ran for a few minutes and stopped again. He let the unit sit for a few minutes and placed his clamp-on ammeter on the condenser fan wire and started the unit again. The fan was supposed to draw 6 amps and it was drawing 7 amps. Now the picture was getting clear. Then Btu Buddy appeared and Bob explained what was happening.

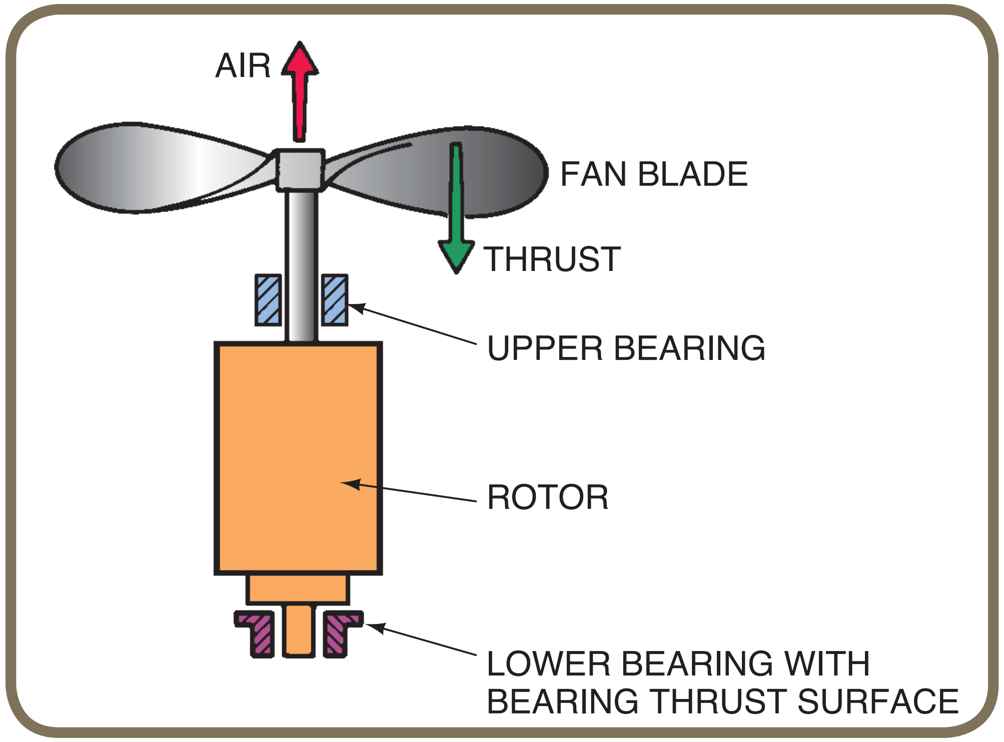


Figure 1. This illustration shows the two bearings that support a vertical condenser fan motor. *(Figures in this chapter are from Refrigeration & Air Conditioning Technology, 5th Edition, by William Whitman, William Johnson, and John Tomczyk, published by Delmar Cengage Learning.) (©Delmar Cengage Learning.)*

Bob asked, "What could be wrong that would cause the motor to draw 7 amps? That is only slightly more than the 6 amps that it is rated at."

Btu Buddy explained, "The unit is a top discharge fan unit. As this motor moves the air, it is causing a downward thrust on the bearings (Figure 1). I would suspect that the thrust bearing is worn out. This calls for a new fan motor and the supply houses are closed."

Bob then asked, "What is the difference in the type of wear on a fan that blows out the side?"

Btu Buddy explained, "When a prop type fan is a side discharge, it has a small amount of thrust towards the back of the motor, but most of the wear is on the bottom of the bearing because the fan shaft is laying in the bearing.

You might say that the shaft is cradled in the bearing."

Bob then said, "It seems like that is the best bearing and fan combination. Why use top discharge fans?"

Btu Buddy then explained, "All equipment was side discharge in the beginning (Figure 2). As time went on, some people wanted top discharge fans to move the hot air upward. This moved the hot air and the sound upward and allowed you to place units closer together. With the side discharge units, there was always the problem of one unit blowing hot air into another unit unless they were arranged correctly. Side discharge units can also kill shrubbery with the hot air blowing on it. Placing multiple units is easier with top discharge fans. Top discharge fans also must be protected from rain dripping in the motor and leaves and pine needles falling into the unit. That was not a problem with side discharge units. Times and applications change and manufacturers adapt to them."

Btu Buddy then asked, "What are you going to do now?"

Bob said, "I have a night number for a supply house that is close to this job. I am going to call them and get a fan motor. The owner will have to pay an extra fee for night duty, but under the circumstances, I am sure that will be OK."

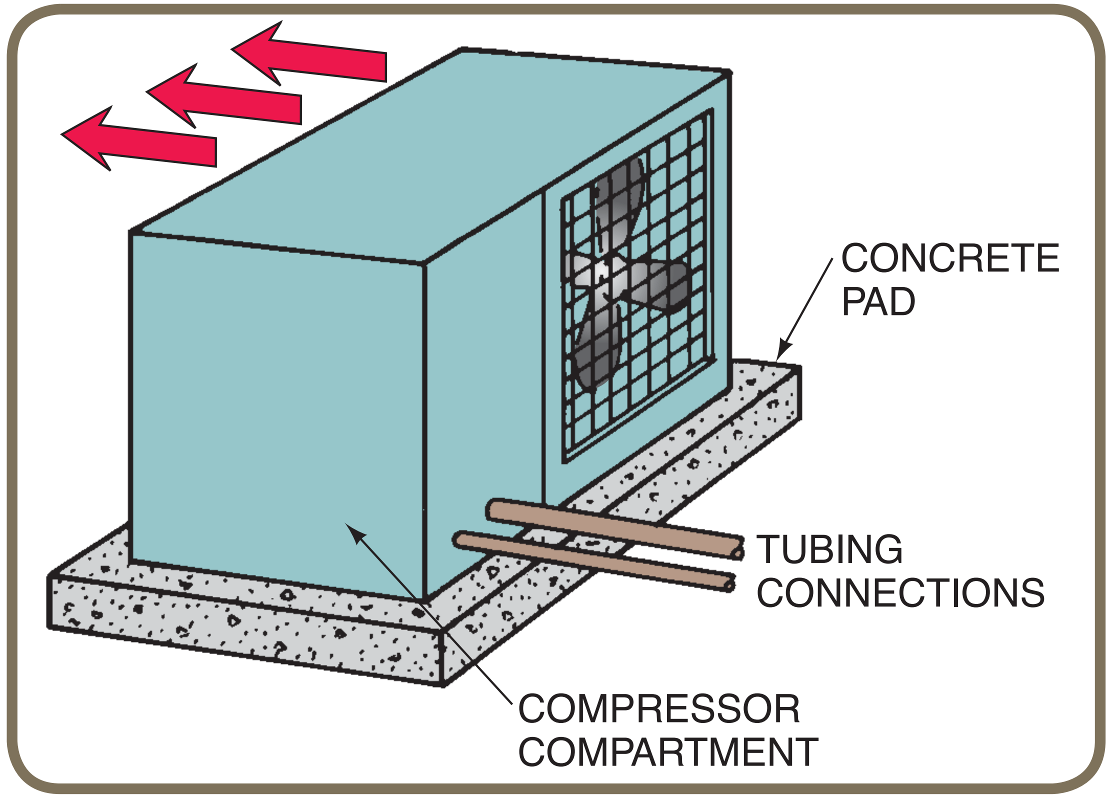


Figure 2. This illustration shows a side discharge air-cooled condensing unit. Notice that the hot air and the noise are discharged out the side of the unit.

As Bob was going down the ladder, the owner came around the building and Bob explained the situation. The owner said to go ahead because he really needed the dining room to be cool for this evening's party in that dining room.

Bob met the supply house agent and purchased the fan motor and went back and installed it. The unit started up and ran just as it should. He went into the dining room and made sure the thermostat was set correctly and the owner said, "Thanks, Bob, this really saved the party. It is a party for a really good customer and it would be hard to explain why the air conditioning is not working. They will be here in about an hour and the dining room will be cool by then."

As they were riding away, Btu Buddy said, "Well, Bob, you now have another very satisfied customer for yourself and your company. Good loyal customers are not easy to get and your company will notice this. It is not easy to work these service calls after-hours and after a hard workday, but you are in the emergency service business. Other peoples' problems are your income."

Bob said, "Boy, this has really been a long, hot, and tiring day, but very rewarding."

Starved Evaporator, TXV

This service call was for a routine checkup on an old 7 ½ ton unit using R-22. The call was going well until the owner mentioned to Bob that the unit had never cooled well. He said that late in the afternoon the unit would run all the time and the store temperature would begin to rise. The manager just never mentioned it to the service people before, but he asked Bob to look into this and see if the system was performing up to capacity.

Bob had checked the system out, changed the filters, and oiled the motors. He had given the system the touch test and everything seemed fine. The suction line seemed cool enough and the liquid line felt warm, but not hot.

Bob then decided to fasten gauges to the system and check it out all the way. He fastened a temperature tester to the suction line and to the liquid line.

The readings for the R-22 system were:

- Suction pressure — 64 psig, evaporator temperature 37˚F
- Suction line temperature at the outdoor unit — 60˚
- Superheat — 23˚ (60 – 37 = 23)
- Outdoor ambient temperature — 96˚
- Head pressure — 226 psig, condensing temperature 110˚
- Liquid line temperature — 95˚
- Subcooling — 15˚ (110 – 95 = 15)

The condensing temperature should really be about 126˚ (96˚ outdoor temp + 30 = 126) for a head pressure of 278 psig.

Bob was sitting down and looking over the figures and studying them when Btu Buddy showed up.

Bob said, "I must be in trouble. You always show up when I am confused or have a problem."

Btu Buddy said, "I am not sure you have a problem. Tell me what you know."

Bob then explained that the suction pressure was low, with a high superheat. The head pressure was low; it was 226 psig when it should be about 278 psig. The subcooling temperature was about right, so the refrigerant charge must be about right. The only thing Bob could think of was that the evaporator coil must be starved of refrigerant, causing a low capacity.

Btu Buddy said, "Bob, you are on the right track. What can you do to increase the superheat?"

Bob said, "I will have to see what kind of expansion device it has."

Btu Buddy said, "Let's go and look."

The indoor unit was in a closet in the back of the store. When they got there, Bob remarked, "The unit has a TXV (thermostatic expansion valve). This should be easy. It is adjustable and I can just decrease the superheat and it will be good to go."

Btu Buddy then said, "Look around before you make an adjustment. It is very seldom that a TXV is out of adjustment. They come from the factory adjusted correctly and they shouldn't drift out of adjustment."

Bob looked over the system and said, "The valve does have an adjustment. Maybe the valve is defective and should be changed."

Btu Buddy then said, "Check the way the bulb is mounted and the location of the external equalizer."

Bob looked at the bulb and said, "It is under the insulation, but it seems like it is tight on the line."

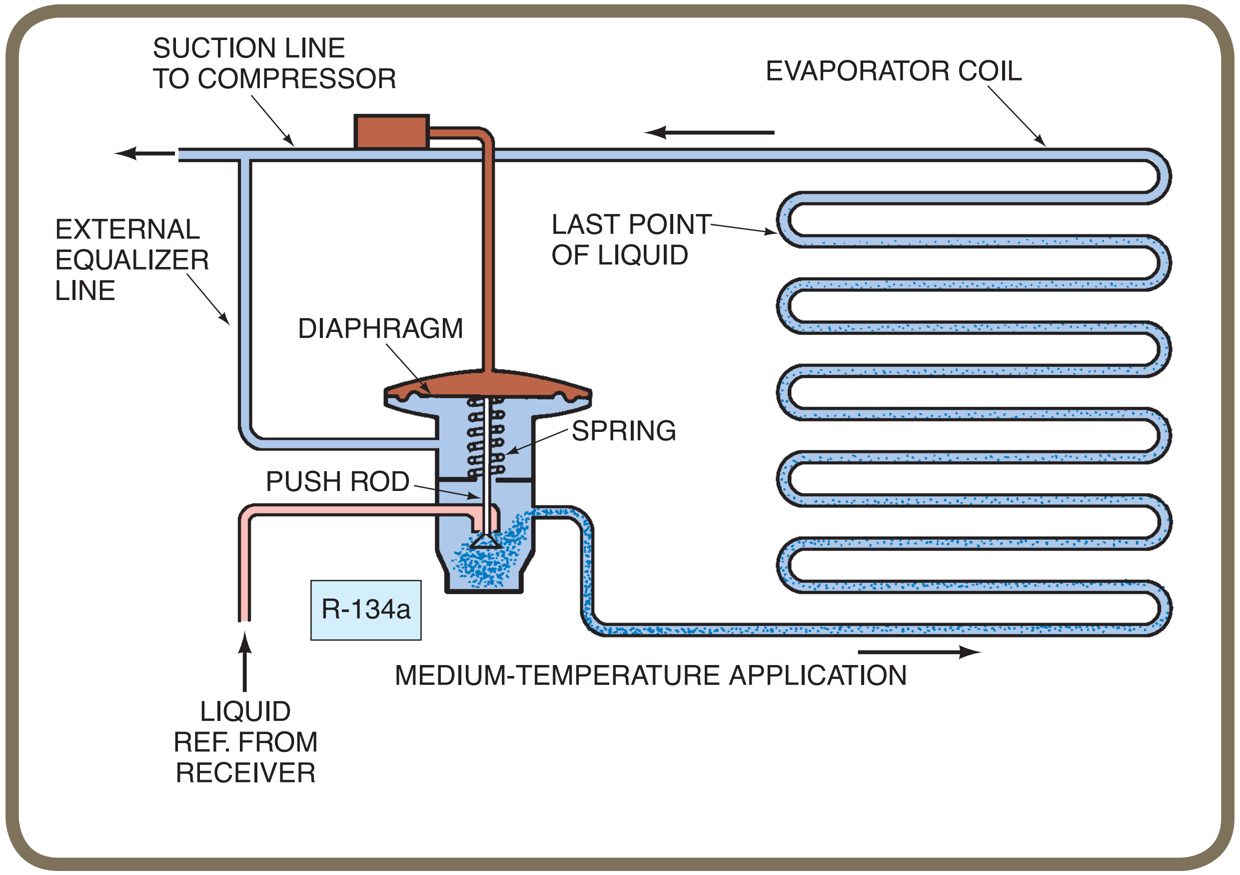


Figure 1. This example shows how a TXV sensing bulb should be mounted in relation to the external equalizer line. *(Figures in this chapter are from Refrigeration & Air Conditioning Technology, 5th Edition, by William Whitman, William Johnson, and John Tomczyk, published by Delmar Cengage Learning.) (©Delmar Cengage Learning.)*

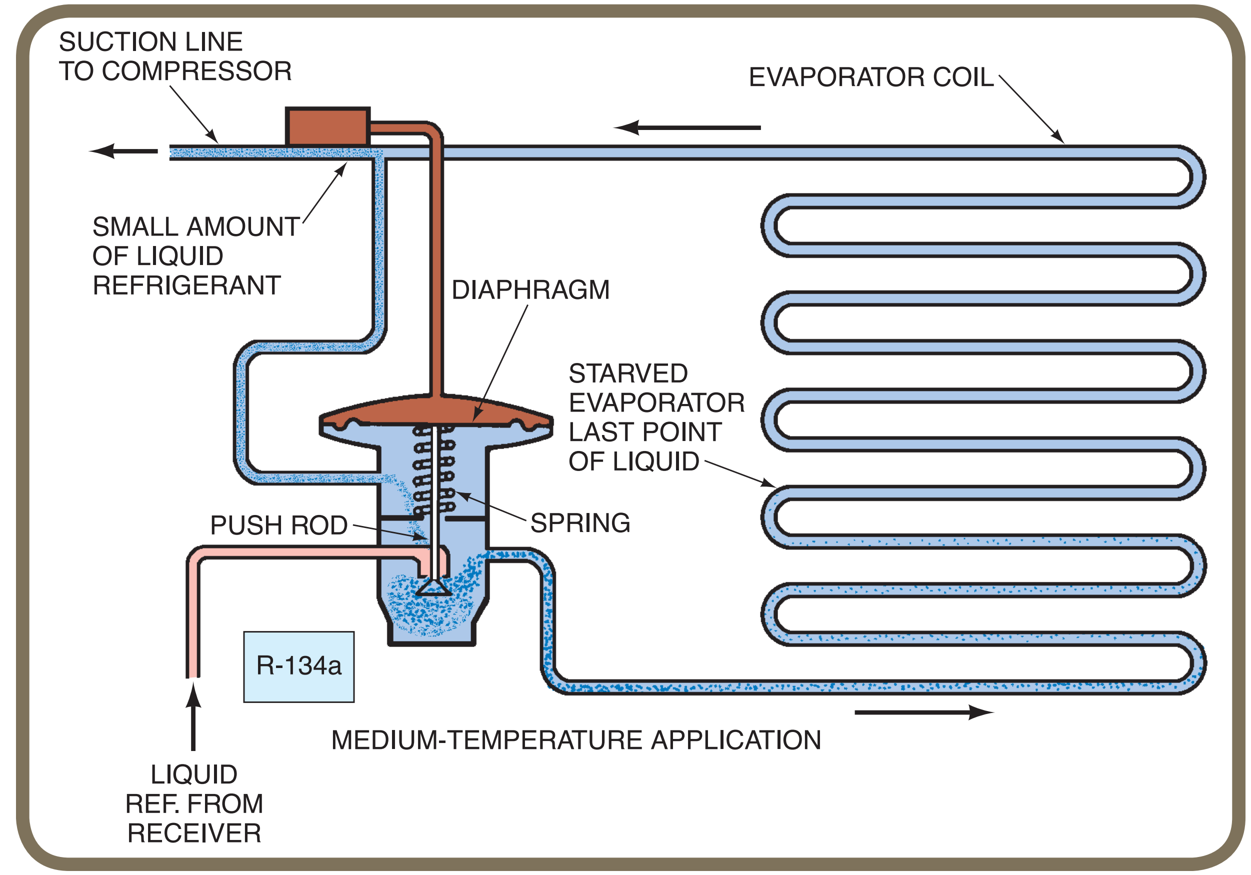


Figure 2. This figure shows a leaking TXV that is allowing a small amount of refrigerant liquid to influence the TXV metering. The small amount of liquid is not enough to flood back to the compressor and cause harm. *(©Delmar Cengage Learning.)*

Btu Buddy then asked, "Do you see anything different about the external equalizer line?"

Bob said, "It is mounted right under the expansion valve bulb and it is really sweating."

Btu Buddy then said, "You are really on the right track now. The external equalizer line should be mounted after (downstream of) the bulb (Figure 1)."

Btu Buddy went on to explain, "If the valve has an internal leak, liquid refrigerant will be pushed into the low side and it will be right on the bulb, the sensor for the valve. This will cause the valve to throttle back because it thinks there is liquid in the suction line (Figure 2)."

Bob then said, "All we should need to do is move the bulb upstream like it should be."

"That is correct," said Btu Buddy. "We have to make sure there is room for the bulb on the line. Remember, the bulb should be mounted on a straight section of the line, several inches from any elbow."

Bob said, "There is plenty of horizontal line between the external equalizer and the first elbow."

Bob then shut the unit off and moved the bulb back toward the evaporator and cleaned the line with sand tape and cleaned the bulb element and mounted it on the suction line with approved strapping.

When all was complete, Bob turned on the power and started the unit. After about 15 minutes of running time, he took the following readings:

- Suction pressure — 69 psig, evaporator temperature 40°
- Suction line temperature — 52°
- Superheat — 12° (52 – 40 = 12)
- Head pressure — 278 psig, condensing temperature 125°
- Liquid line temperature — 115°
- Subcooling — 10° (125 – 115 = 10)

Bob then said, "I would say that all is well with this system."

Btu Buddy said, "I would say that you are correct. A call back to the customer late this afternoon should confirm that the system is performing up to capacity."

Bob said, "It really pays to get the system running correctly. I am surprised that someone else hadn't found this out."

Btu Buddy then said, "Probably the owner never mentioned it to another technician, or maybe the other technicians just never decided to look into it, like you did. Good job."

Btu Buddy added, "There is help everywhere. Some technicians just don't take a real interest in being professional and learning all they can. The better technicians will always be in demand."

Frosting Heat Pumps

The day had been cold and damp. The temperature was in the high 30s and it had been misting rain for three days when Bob was called to do a routine checkup on a heat pump in a condominium complex. From where he was standing, he could see 12 heat pumps and there was something disturbing about what he saw. They all had different frost patterns. Most of them were frosted all over, but the heat pump on which he was to do routine service had a very different frost pattern (Figure 1).

He was trying to figure out what was going on when Btu Buddy asked, "What is the question, Bob?"

Bob said, "You always appear when I am confused. You catch me every time."

"That could be good," said Btu Buddy.

Bob then said, "I am lucky that I have you to give me help."

"Well, what is the confusion, Bob?" asked Btu Buddy.

"I am standing here looking at all of these heat pumps and a few of them have a really different frost pattern. It seems to me that they should all look alike. I realize that this kind of weather will really build frost on heat pumps. But it seems like it should be uniform," said Bob.

Btu Buddy then said, "Like conditions will produce like frost patterns. There are some things that we should consider before we draw conclusions here. One of the variables would be how long it has been since the heat pump has been running after the last defrost. If it had been 30 minutes, for example, since all of them had been through a defrost cycle, they should all have the same frost pattern, if they were all correctly charged. But suppose one of them were to be undercharged, it would have a frost pattern that would show

Figure 1. This frosted heat pump does not have enough refrigerant. You can see the various refrigerant circuits in the coils. *(Photo by Bill Johnson)*

that the coils were not filled to the correct level of refrigerant. The timers for defrost are not all set at the same time. Look at the unit that you are servicing, you can count the actual refrigerant circuits in the unit. All of them are starved of refrigerant. But that may not be the whole story. If it had just come out of the defrost cycle, we should let it run for at least 30 minutes to see if the coils will fill with refrigerant. The defrost cycle redistributes the refrigerant and we must give it time to get in balance."

"What would I do if I wasn't prepared to wait 30 minutes?" asked Bob.

Btu Buddy said, "You do want to use your time wisely. You could change the air filter and give the unit a general looking over and use the touch test to feel the lines and check the air temperature during this time. If you are really in a hurry to know, you fasten your gauges to the unit. I personally believe the unit is low on refrigerant charge. Go ahead and fasten the gauges and see what you see."

Bob fastened his gauges to the unit and found the pressures to be low for the conditions. The suction pressure was 30 psig, corresponding to 7°F.

Bob said, "No wonder the coil is freezing. It is running very cold and the humidity is high."

Btu Buddy said, "Check the charging chart for this unit and see what the suction pressure should be."

Bob looked at the charging chart in the cover of the unit and said, "Looks like the suction pressure should be about 42 psig. The outdoor wet bulb is 33° and the indoor dry bulb is 70°. The high pressure should be about 210 psig for these conditions. I think this unit is definitely low on refrigerant charge."

Btu Buddy said, "I agree, get set up to charge. Be sure to add refrigerant very slowly. It is very easy to overcharge a unit in the winter. Do not add liquid refrigerant because some of it will likely move to the suction line accumulator in the liquid state (Figure 2). Many a service technician has overcharged a system by getting liquid refrigerant in the accumulator while charging liquid refrigerant only to discover later that liquid refrigerant was holding back in the accumulator. It may take quite awhile for it to boil out of the accumulator."

Bob asked, "How am I going to keep the pressure up in my refrigerant cylinder charging vapor in this cold weather?"

Btu Buddy said, "Go to the laundry room with your five-gallon bucket and fill it about two-thirds full of warm water. You should be able to comfortably hold your hand in the water. If it is too hot for your hand, it is too hot. Then, start charging vapor into the system. When the pressure starts to drop, set the cylinder into the water for a few minutes to keep the pressure up. Again, I caution you to just use warm water. You can use a thermometer to check the temperature and don't let it rise over 105° and you will be safe. Remember all of

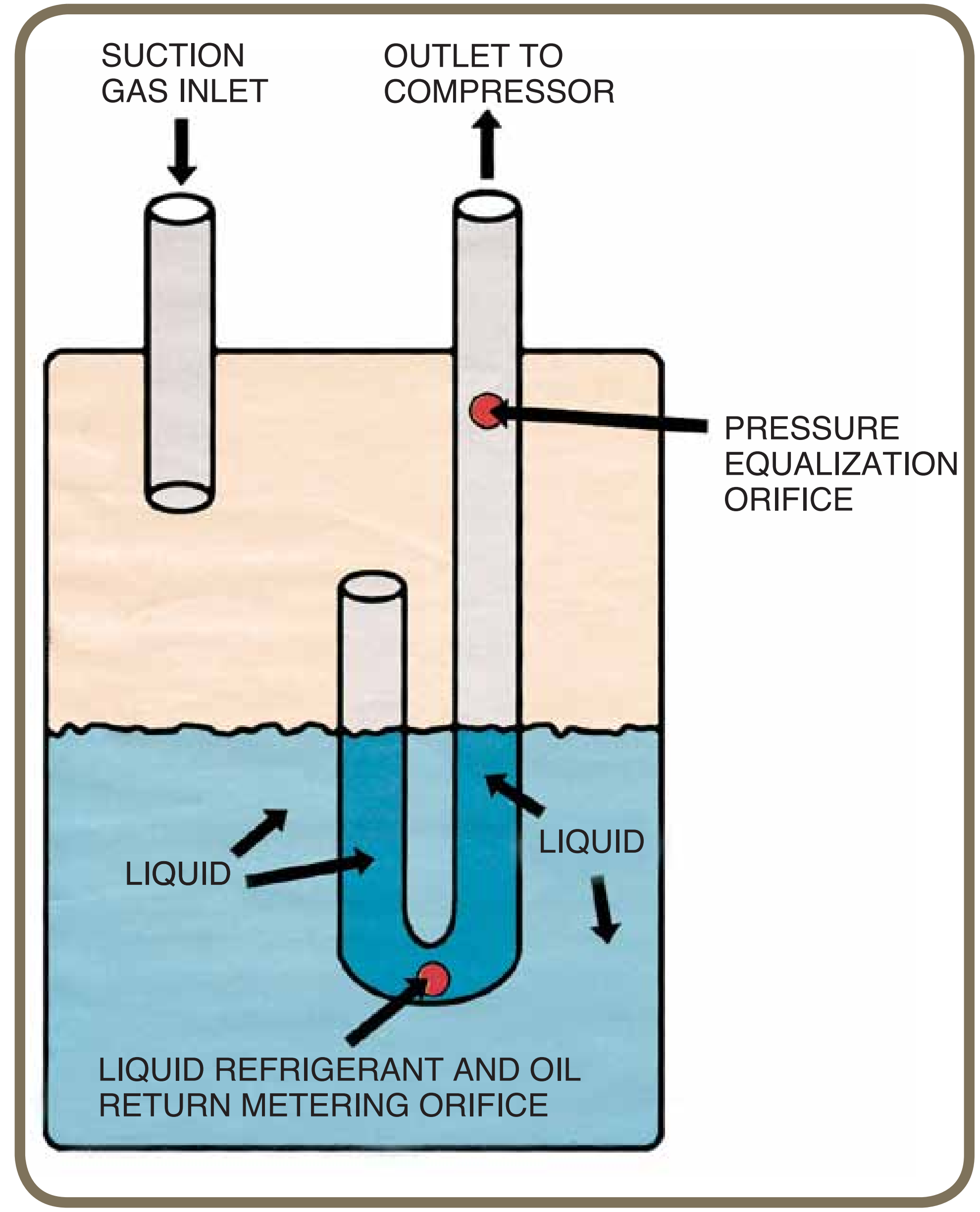


Figure 2. This is one style of suction line accumulator. Notice that it has a very small orifice in the bottom of the suction tube that allows oil to return to the compressor. It will also allow liquid refrigerant to return to the compressor very slowly so that no damage will be done. *(From Refrigeration & Air Conditioning Technology, 5th Edition, by William Whitman, William Johnson, and John Tomczyk, published by Delmar Cengage Learning.) (©Delmar Cengage Learning.)*

the days that your refrigerant sat in the back of your truck and it was 100°? The refrigerant cylinder is safe to about 115° so you will be safe."

Bob charged the system with vapor and the pressures fell in line with the charging chart.

Bob then told Btu Buddy, "That went really smooth. It did take a little time. What other alternatives would I have?"

Btu Buddy explained, "You could have recovered all of the refrigerant and charged it by weighing it in. That is probably the most accurate method. You could also switch the unit to cooling and charge by the superheat method. It has worked well for me. To do that, leave the thermostat in the heating mode and switch the heat pump section over to cooling by removing the four-way coil wire if it is energized in heating or jump it out if it is not energized in heating. Do what it takes to change the four-way valve to cooling and charge using the superheat method. By leaving the unit in heating, the strip heat will start up and will not over-chill the house. The owners will remain comfortable to some extent. This charging method does not take into account the indoor wet bulb temperature, or the load on the evaporator coil, but will get the charge very close."

Bob then said, "I can't believe there are so many ways to do a job, and all of them work."

Btu Buddy responded, "Yes, there are several ways to do many things. It is up to you to use the one that is quickest and keeps the customer comfortable. These decisions will become easier the more you work in the field. You also must ask yourself, where did the refrigerant go. The unit had a low charge. I would suspect that the last service technician did not get the correct charge into the unit."

Bob said, "The owner said that the unit had not cooled correctly during the last part of the cooling season when it was serviced by another company."

Btu Buddy then said, "Let's assume that the charge was not correct and make note of that on your service ticket so the next technician will be aware of what has been done."

Bob said, "Well, the call is complete now and we have left a paper trail as to what we did. If I am the one to come back, I will be able to review this service ticket. If the charge is low again, I will know to really give the unit a good leak test."

Condensing Furnace Problems

The first call of the day already had Bob confused. It started with a call from the dispatcher who described a gas heat customer who had no heat. It was a new installation and the customer was upset because the new system was not heating. It was up to Bob to make the customer as happy as possible. The weather was really cold, 10˚F at night and only 20˚ during the day.

Bob arrived to find an angry housewife. It was hard to be polite, but he had to. He assured the woman that he would do all in his power to get the system started quickly. Meanwhile, he recommended that she take the two children to the kitchen and put a pan of water on each stove eye to boil. This would keep the electric cooking elements from getting too hot and put some humidity in the air. He then went to the furnace in the garage.

When he got to the garage and the furnace, the first thing that he noticed was that the furnace was cold. It had not been operating. He decided to check the power supply and found that he had 24 volts at the low voltage power supply. This proved that both the low and high voltage power was on. He then checked from the common terminal to the "W" terminal to see if the thermostat was calling for heat and it was not. Now Bob was sure that the thermostat was defective.

Bob then went to the thermostat and removed it from the sub-base. He then jumped from the "R" terminal, which is the hot terminal, to the "W" terminal for heat. He was expecting the heat to come on so he went to the furnace and was surprised the furnace was not running. He was standing there confused when Btu Buddy arrived and said, "What is the problem, Bob?"

Bob explained what he had done and Btu Buddy said, "Why don't you jump from 'R' to 'W' on the furnace (Figure 1, page 37)?"

Bob then said, "When I get confused, my thinking ability seems to stop."

Bob jumped the terminals and the furnace started.

"What does that tell you, Bob?" asked Btu Buddy.

Bob said, "It tells me that the furnace will operate and the signal telling it to operate is not getting through. It has to be in the field wiring somewhere. I am going to let the furnace run while I try to figure it out."

Bob then said, "I know the problem is in the field wiring. I think I will trace it out and try to find the problem by just observing."

Bob then started with the wire that connected to the "W" terminal and followed it. It went for a ways and then went up in the wall towards the room thermostat. There was no visible problem.

He then started following the wire on the "R" terminal. It went to the other side of the furnace to a terminal on the condensate pump. He turned to Btu Buddy and asked, "Why would the wire go to the condensate pump? Also, the pump seems to be running. What is that all about? I thought that pump was for the air conditioning only."

Btu Buddy then explained, "I thought you would hear that pump running when we walked in. Probably you only had your mind on why the furnace was not running and did not notice what else was happening.

"This is a condensing furnace and it actually generates condensate. It is a 96 percent efficient furnace. It gets some of that extra efficiency by running the flue gases through an extra coil that is mounted where the cool return air passes over it. This cools the flue gases enough that the water in the flue gas condenses. This furnace makes enough condensate that it must be dealt with like you would with air conditioning condensate. This system has to pipe the

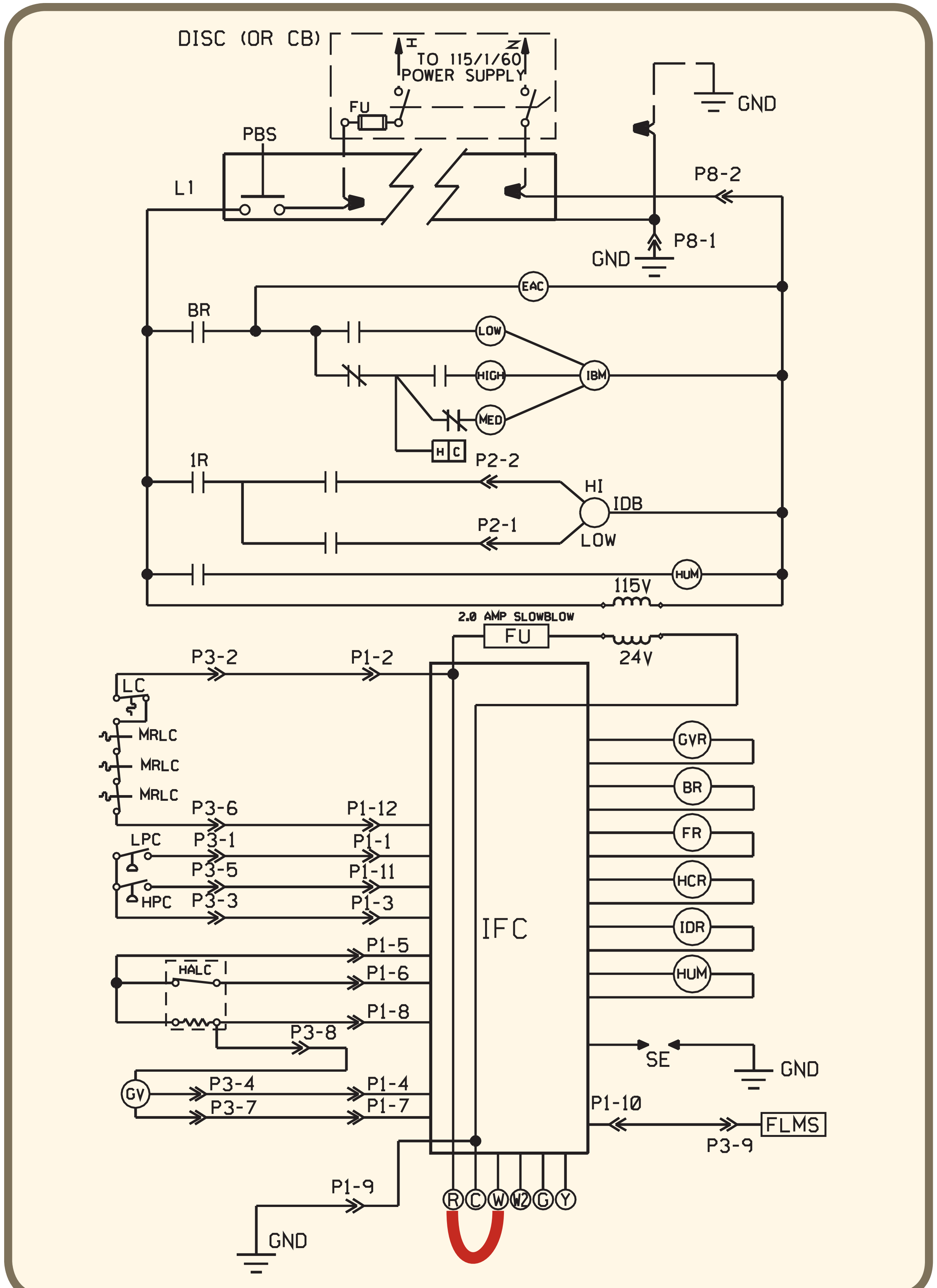


Figure 1. This wiring diagram shows where a jumper can be applied to temporarily operate the furnace. Don't forget to remove the jumper. It is recommenced to use a long jumper that will be obvious so you won't forget it. *(From Refrigeration & Air Conditioning Technology, 5th Edition, by William Whitman, William Johnson, and John Tomczyk, published by Delmar Cengage Learning.) (©Delmar Cengage Learning.)*

condensate outside since the furnace is below ground level. Now you need to find out where the condensate pump line terminates."

Bob followed the condensate line to the end and said, "The line terminates about four feet from the house under a bush."

Btu Buddy then asked, "Is there any water on the ground?"

Bob said, "No, everything is frozen including the condensate line. I am going to cut it off closer to the house and see what happens."

Bob then said, "Wow, water is rushing out of the line."

Btu Buddy said, "Now take your jumper off of the furnace terminal board and see what happens."

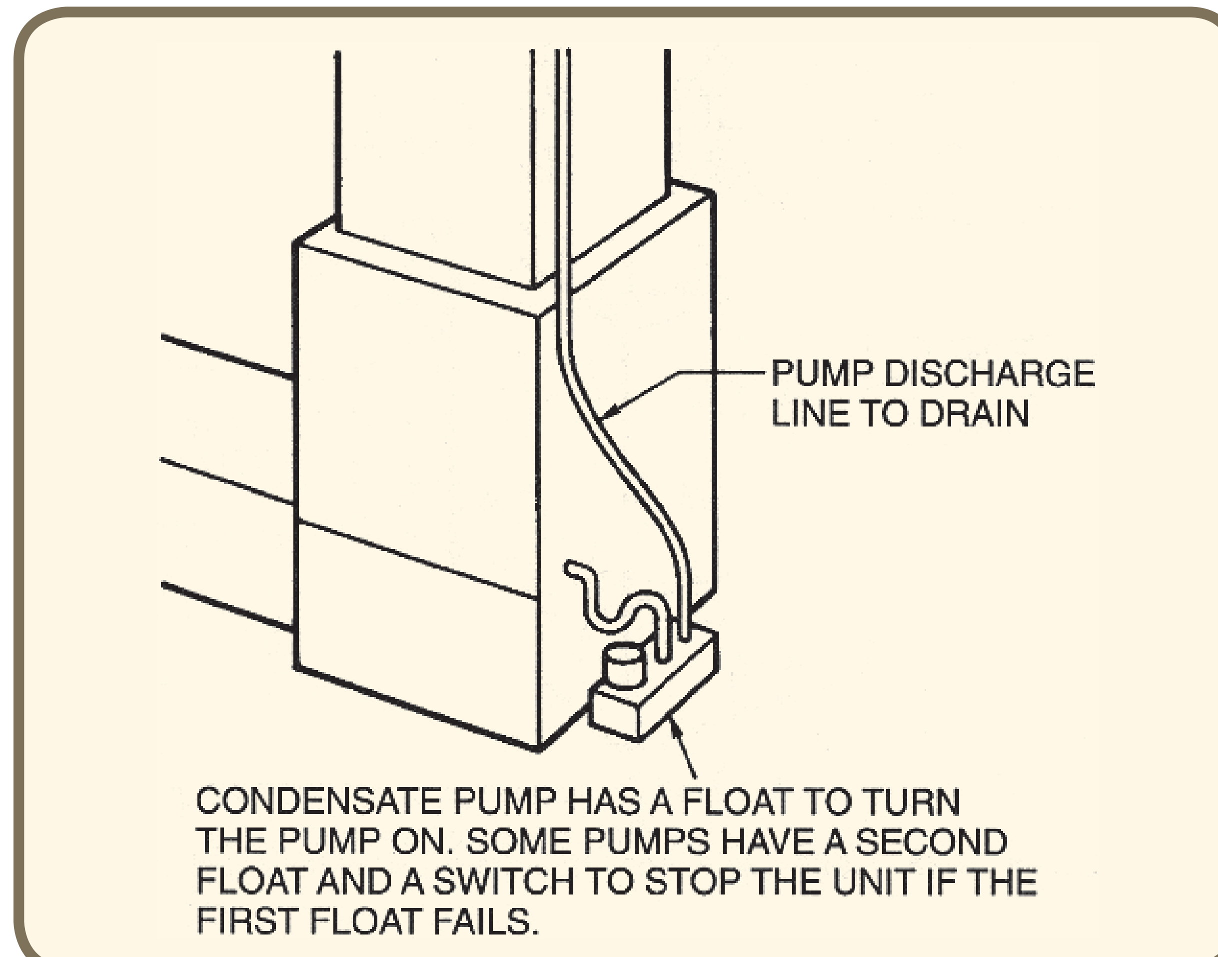


Figure 2. This shows a condensate pump that may be used for air conditioning and heating to move the condensate to a proper drain. *(From Practical Cooling Technology, by William Johnson, published by Delmar Cengage Learning.) (©Delmar Cengage Learning.)*

Bob removed the jumper and said, "The furnace is still running. I don't get it."

Btu Buddy explained, "The condensate pump has two float switches in it. The first one is supposed to start the pump. The second switch is wired into the hot side of the control wiring and interrupts the signal to the thermostat and neither heating or cooling will start. That is why the pump was running but the furnace would not start. It also prevented condensate from getting all over the floor. When the outlet froze solid, the next time it called for pumping out the pump reservoir, the pump started and just ran, but did not pump. It is a centrifugal pump so no damage occurred (Figure 2, page 37)."

Bob told the homeowner what had happened and she was relieved and thankful that it wasn't a whole system failure.

As they were leaving, Bob said, "That was another brain twister. What should I have noticed first to shorten the call?"

Btu Buddy said, "The pump running was the first sign. It doesn't make much noise, but it shouldn't have been running all of the time. You really did the right thing by keeping the furnace running while figuring out the problem. It helped make the homeowner more comfortable as the service procedure was figured out."

Bob then said, "Thanks again. You can't teach me how to think, but your guidance sure helps."

Superheat Problem With Three Coils

Bob was on his way to a job at a new customer for his company. He was anxious to make a good impression because this customer has several properties. He wanted to be part of helping build the customer base. The job was a three-story office building with an air handler on each floor with a refrigerant coil in each air handler. A 75-ton condensing unit served the three 25-ton air coils. This was an old system that has still been doing a good job. The complaint was that the second floor unit was not holding the conditions that the thermostat was set for. It has been running 2°F higher than the set point on the thermostat.

Bob went to the building manager and they looked at the thermostat and Bob saw what he was talking about. The manager showed Bob where the air handler was and the roof hatch to the top of the building where the condensing unit was.

Bob asked the manager if there have been any other complaints about the system and the manager said, "I have been to both of the other floors and the thermostats are set at 72° and both of those floors are running at the set point."

Bob then went to the room where the air handler was and looked around. Bob found a place on the suction line were he could touch it and it seemed plenty cool to the touch. He went to his truck and got an electronic thermometer and checked the temperature of the supply air and was surprised to find it was 59°. He was expecting it to be about 55°.

Bob was scratching his head when Btu Buddy showed up and asked, "What is the matter, Bob? You look confused."

Bob told him what was going on and said, "I am going to one of the other air handlers and see what the discharge air is."

Btu Buddy said, "That is a good idea. It might lead you to an answer."

Bob went to the first floor and took a measurement and it was 56°. Then he said, "That is interesting, I think I will go to the third floor. I am confused."

Bob went to the third floor and the temperature of the discharge air was 56°.

Bob said, "I don't get it. There must be an excess heat load on the second floor."

He went to the manager and asked him if anything had changed on the second floor and the manager said no. This temperature change just happened today.

Bob was now scratching his head for sure.

Btu Buddy then said, "Why don't you look into what kind of heat this system has. Maybe the system is picking up heat out of the heating system. It is the season change and oftentimes calling for heat at night."

Bob looked over the air handler and a building print that was in the room where the air handler was located and found that the system had a hot water heating system with a boiler on the top floor. He went to the boiler and found it up to temperature. He was sure he had solved the problem now. He went back to the second floor air handler and felt the inlet and outlet to the hot water coil. It didn't seem to be warm at all. He shut off the valves just to be sure and waited about 15 minutes and checked the coil outlet temperature and the temperature hadn't changed a bit.

Bob then said, "I can't imagine what is going on."

Btu Buddy said, "If there is not excess heat, maybe the refrigerant coil is not performing. Let's go and look at the compressor and see what the conditions are there."

They went to the roof and removed the compressor compartment door and found the compressor sweating on the motor and the crankcase (Figure 1, page 40).

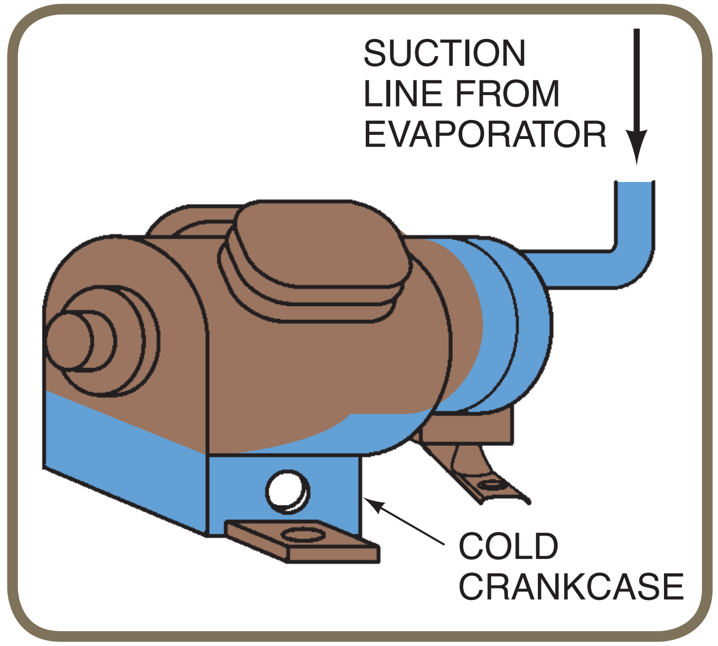


Figure 1. This compressor is sweating at the motor housing and on the crankcase. It is a sure sign that liquid is getting back to the compressor. *(From Refrigeration & Air Conditioning Technology, 5th Edition, by William Whitman, William Johnson, and John Tomczyk, published by Delmar Cengage Learning.) (©Delmar Cengage Learning.)*

Bob said, "We have a problem here. This compressor is sweating all over the motor housing and crankcase. Liquid refrigerant must be coming from somewhere. I think we should start with the second floor air handler."

Btu Buddy said, "I think you are on the right track now. You have found something that is wrong."

They went to the second floor air handler and Bob took a close look at the expansion valve bulb mounting. He had to peel back the insulation. He then said, "Would you look at this; this bulb was mounted using two nylon straps and both of them are broken. The bulb is loose on the suction line."

Btu Buddy said, "Those straps can hold a bulb down tight, but they may eventually fatigue and break. You should make the repair using the correct fasteners."

Bob shut the system down and it went through a pump down cycle and pumped the refrigerant into the condenser and receiver.

Btu Buddy said, "That was a good idea to shut the system down and let it pump down. If you had just shut off the breaker, when you started it back up, there was probably going to be some liquid slugging."

Bob repaired the bulb fastening according to the manufacturer's recommended method, then he said, "I bet the other coils have the same problem and it just hasn't broken loose yet. I am going to check them while I have the system off."

Btu Buddy suggested, "You may want to tell the manager what you are doing. He is surely going to have some calls."

Bob let the manager know what was going on and he told Bob to go ahead and repair the system to proper standards.

The system had been off for nearly an hour when Bob turned it back on. The building had warmed up some. Bob then said, "I think we should go to the roof and see how that compressor is doing."

They went to the roof and the compressor was running just fine. Bob felt the motor housing and the crankcase, and said, "This feels more normal. I believe we got to the bottom of the problem."

Btu Buddy then suggested to Bob, "I think you should talk to the manager about a service contract now. I believe he would want to talk about it after this service call."

Bob went to the manager and suggested that he let a representative call on him and give him a quote.

The manager said, "We have always had service when we needed it. The last service company never mentioned a service contract. I think that might be good."

Bob explained, "The problem that this system was having would have shown up at a routine service checkup. The compressor probably has been operating with small amounts liquid refrigerant in the crankcase for some time. That is really not good. I believe a regular look at the system will be a good idea."

As Bob and Btu Buddy were riding away, Bob asked, "Why didn't that liquid getting back to the crankcase ruin that compressor?"

"Good question, Bob," said Btu Buddy. "Let's meet for breakfast in the morning and talk about it. Meanwhile, see if you have any more questions."

Bob then said, "I think it was not explained why that didn't effect the total system suction pressure and cause the other two coils to perform the same way."

Flooded Compressor Discussion

Bob and Btu Buddy have gotten together for breakfast to discuss their last service call, which concerned a compressor that had liquid refrigerant flooding back to it. Btu Buddy said, "Bob, you asked two questions yesterday while we were leaving the job. The first was: Why did liquid flooding back to the compressor not destroy the compressor? The other question was: Why didn't the flooded coil affect the other two coils in this multi-evaporator system?"

Bob said, "Yes, that compressor looked like it had been flooded for awhile. It looks like that would have done major damage."

Btu Buddy explained, "You have to think about what was going on inside the compressor. There were not great quantities of liquid getting back or the compressor would have been making noises. The season is mild and the liquid may have been getting back to the compressor for quite awhile. We cannot tell what damage was occurring inside the compressor. If this were a critical job, it would probably pay to open that compressor during an off time and examine it for problems."

Bob asked, "What kind of problems would you look for?"

Btu Buddy said, "Probably only saturated refrigerant vapor was getting back to the compressor with small amounts of liquid."

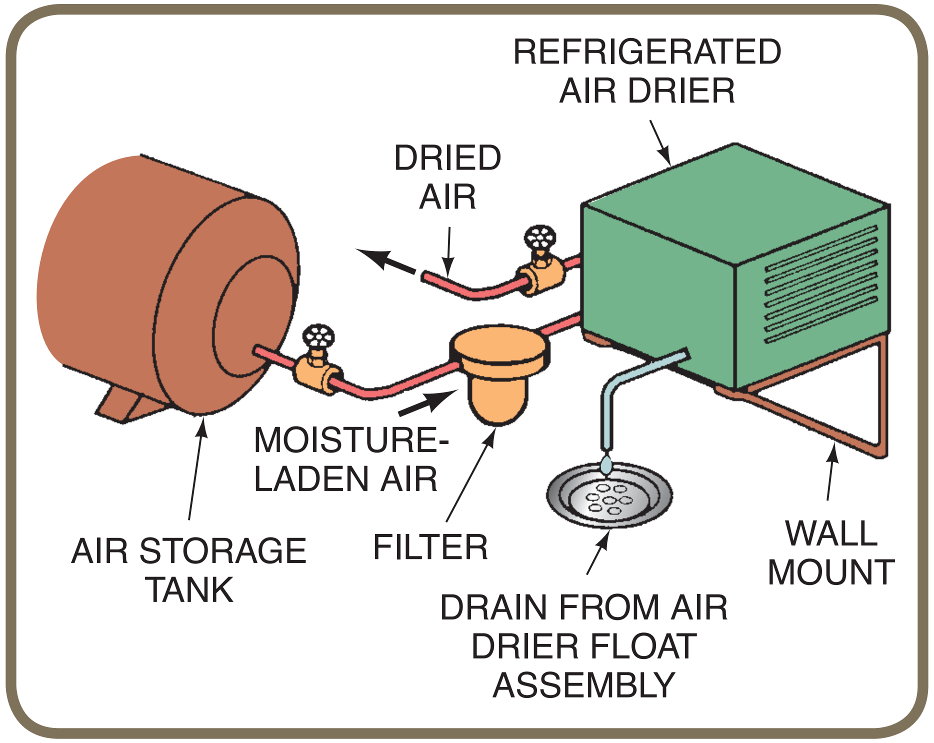


Figure 1. This is a refrigerated air drier that removes moisture from air that is used for pneumatic controls. This air must be moisture free. *(From Refrigeration & Air Conditioning Technology, 5th Edition, by William Whitman, William Johnson, and John Tomczyk, published by Delmar Cengage Learning.) (©Delmar Cengage Learning.)*

Bob said, "I don't understand."

Btu Buddy responded, "Let's suppose we explain it like an air compressor. The air compressor pulls air out of the atmosphere and compresses it. Suppose the air was saturated, 100 percent humid. It would be like pulling fog into the compressor. Would it do damage?"

Bob said, "I never thought of it, but I guess not."

Btu Buddy then said, "You are correct. The heat from the compression would probably boil the saturated air to a vapor. The air leaving the compressor would be full of moisture. This is why you oftentimes see refrigerated aftercoolers on critical air systems, such as air that is used for pneumatic controls (Figure 1). Control air has to be very dry because if there is any free moisture, it will plug the tiny passages in the controls. Now back to the refrigerant system. If the suction gas is 100 percent saturated, it will be like a fog returning to the compressor."

Bob said, "It looks to me like the compressor would boil that saturated vapor off, like the air compressor example."

Btu Buddy remarked, "You are correct. The compressor could probably handle saturated vapor because it has to pass across the motor windings and into the cylinders. But let's take it a step further. A system like you worked on yesterday had three different coils on three different floors. Each is supposed to control its own refrigerant flow. The one on the second floor had a loose sensing bulb on the suction line. That valve was letting more than saturated vapor move towards the compressor. Remember, oil and refrigerant are circulating in the system. The liquid that was moving down the line was staying in the oil in the bottom of the suction line. This liquid will reach the compressor and pour out in the motor housing and some of it will stay with the oil as it moves to the compressor crankcase by gravity. The refrigerant that is in the oil will do the damage in this case."

Bob then said, "I don't understand why or how."

Btu Buddy explained, "We have determined that not enough liquid refrigerant has returned to the compressor for liquid slugging. We would hear the compressor hammering, trying to compress it, which it cannot do."

"True," said Bob, "tell me more."

Btu Buddy then explained, "Let's use a car engine for this explanation. What weight oil do you use in your car?"

Bob said, "I use 20W-40 oil. How does this figure into a refrigerant compressor?"

"Well," said Btu Buddy, "a car engine is much like a compressor. It has to have the proper lubrication. Suppose you changed the oil in your car and decided to mix the crankcase oil with fuel oil. They are both oils, they just ignite and burn at different temperatures. They will both lubricate."

Bob said, "I would think that the oil would be too thin to lubricate and that would cause engine wear."

Btu Buddy said, "You have the picture now. The system would continue to run, but with marginal lubrication. Where do you think that would show up in a compressor?"

Bob said, "I am getting it now. It would show up where the most stress is occurring, at the cylinder walls, the pistons and rod connections, and the crankshaft."

Btu Buddy then said, "If you opened that compressor, that is exactly where you would look. You would feel the surfaces for how smooth they were and use instruments to check to make sure the dimensions were correct. If that compressor ran for a short while it is probably good to go. Every hour that it runs in that atmosphere it is doing some damage. In this case, all sounds good so it is best to just let it run."

"Now for the other question: Why did this only effect one of the three coils?" Bob said.

Btu Buddy said, "There is no doubt that the coil that was flooding affected the common suction pressure. The saturated gas from the coil on the second floor mixed with the superheated gas from the other two coils. This helped boil off some of the returning liquid, but not all of it. Remember the liquid mixed with the oil is much harder to boil to a vapor. The suction pressure in the coil on the second floor was high enough to affect coil performance and the coil outlet air temperature went up enough that it wouldn't properly cool that floor."

"Boy," exclaimed Bob, "there is still a lot to learn."

Btu Buddy agreed, "There really is a lot to learn. Your education never stops in any technical field. The good part about it is you don't have to learn it all at once. Some of the best help you can get comes from good books, manufacturers, and the people behind the parts counter, particularly the ones with grey hair." Ⓝ

Condenser Under Water

The dispatcher called Bob and sent him to a job that really sounded like a problem. There had been a hard rain and a customer had a condensing unit that had been under water that morning due to high water from a creek behind his house. The condenser was at the lower end of the car port. The house did not get any water inside it. The water had never been this high at this house, and the owners had lived there for 51 years. The owners were on a fixed income and wanted to get the repair at the best possible price.

Bob arrived at the residence and could see that the water had in fact been up over the fan motor and the controls. Fortunately, the water looked to have been fairly clear, not muddy.

Bob talked to the homeowner and discovered that the condensing unit was the only thing that was flooded. The man had seen the water coming up and pulled his car to higher ground and shut off the breaker to the condensing unit.

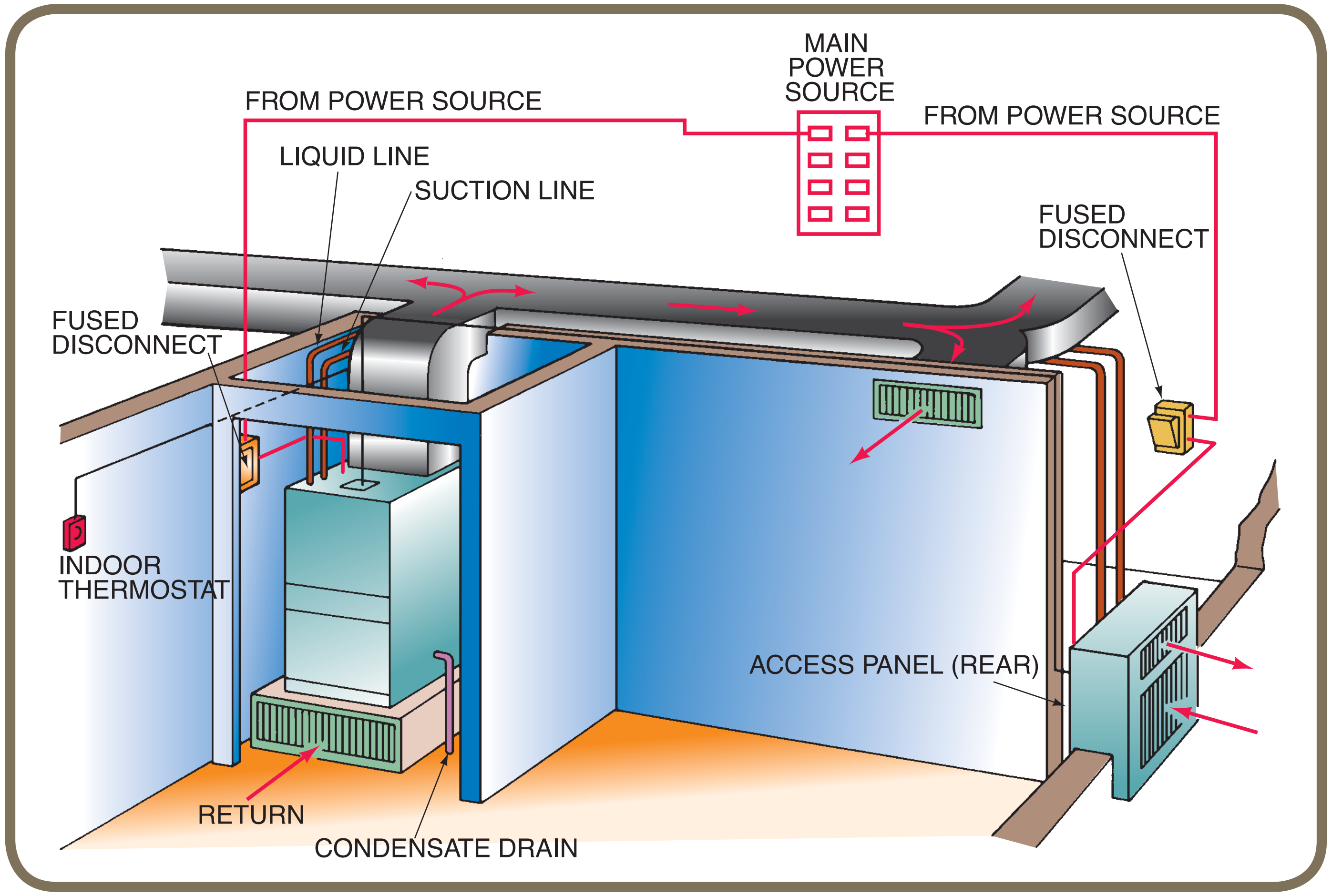


Figure 1. This is a similar arrangement to the service call in that it has two shutoff switches, a breaker at the main panel and a fused disconnect switch at the unit. *(Figures are from Refrigeration & Air Conditioning Technology, 5th Edition, by William Whitman, William Johnson, and John Tomczyk, published by Delmar Cengage Learning.) (©Delmar Cengage Learning.)*

The owner again expressed the need for economy. Bob explained, "I will do everything I can to reduce the expenses. By the way, is there a breaker for this unit at the main breaker box? I think that the disconnect at the unit may be wet and I want to be careful."

The owner showed Bob the main disconnect and he found the breaker for the condensing unit had been shut off so he taped it in place (Figure 1).

Bob pulled his truck down to the area close to the condensing unit. He checked the voltage at the condensing unit breaker and found no power. He shut that breaker off and looked for signs of water. This breaker was above the water line of the flood.

Bob removed the cover to the control panel of the unit and saw where the water level had been above the controls. He looked at the condenser fan and it had been under water, too. He was standing there scratching his head when Btu Buddy appeared and asked, "What is the problem, Bob?"

Bob explained the situation as well as the financial burden it would put on the customer to properly fix this system by replacing the controls, capacitors, and the fan motor. He really did not like what he was seeing.

Btu Buddy said, "I am glad that you feel the need of this customer. I think that we can take some precautious short cuts and get many more years of service out of this unit. If you stop and think about it, probably every component in this system has probably been wet at some time during manufacturing. How are they working together now?"

Bob said, "Well, of course they were dried. They are assembled now and I don't see how they can be dried while assembled."

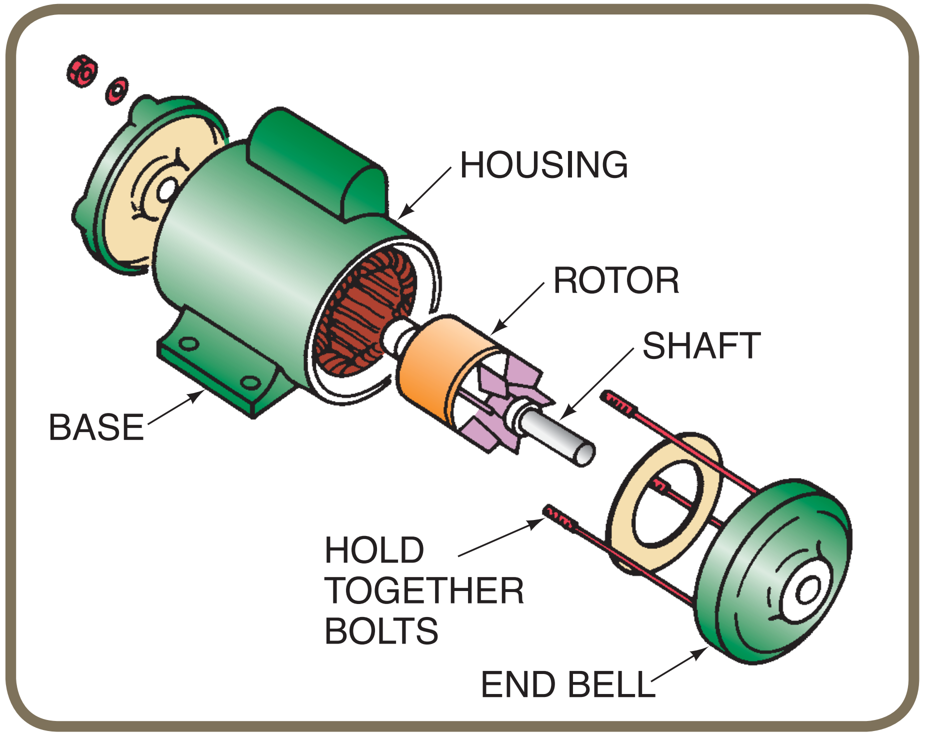


Figure 2. This is an illustration of a disassembled motor. *(©Delmar Cengage Learning.)*

Remember that when you get the contact dry, that is the only high voltage component in the contactor. The coil is low voltage."

Bob did as directed by removing the cover to the contacts. When he got to the coil, he commented, "This coil in encased in plastic. It would be hard for water to get inside."

Btu Buddy then said, "Disconnect the wiring to the contactor and check the coil to ground using your ohmmeter and the Rx10,000 scale. If it is digital, use the highest ohm scale. You can test it by holding one lead in each hand and it will read through the resistance in your body. If it will read a resistance through your body, it will read any ground in that coil."

Bob checked the coil and said, "This coil shows no resistance to ground. I think it is good. That is a relief."

Btu Buddy said, "Make a list of the components that you think would be hard to dry."

Bob made a list:

1. The contactor coil and contacts
2. The circuit board
3. The capacitors
4. The condenser fan motor
5. The compressor motor terminals
6. The crankcase heater

Btu Buddy said, "Let's start with the contactor. Remove the cover and use your air hose and blow out the contacts and the coil as best as you can.

Btu Buddy then said, "It shows no resistance to ground, but there may be some water in the coil and still have a circuit from coil to coil. Now use your air hose and blow the circuit board down, both front and back. Also blow down the connections to the board."

Bob then did this job.

Btu Buddy said, "Use the air hose to blow off the tops of the capacitors. Those are high voltage connections."

Bob blew down the capacitor connections.

"Now," Btu Buddy said, "we saved the hardest for last. We need to take out the fan motor and take the fan off of the shaft (Figure 2). Now, mark the end bells where they attach to the motor housing so that you can get them back into the same position. Now remove the end bell on the shaft end and slide it out the shaft. Be sure there is no rust or burrs on the shaft and oil it as you slide the end bell over the shaft. We don't want to damage the bearing. Now remove the end bell on the opposite end. Take your air gun and blow out any water in the windings and end bells. Leave them laying out in the sun while we do the next step."

Bob disassembled the motor and blew it as dry as he could and then asked, "What about the bearing oil cavities? They are probably wet."

Btu Buddy said, "I was hoping you would see that as a problem. The water came up on this unit and went down in a matter of hours and the water was not very dirty. We got to this unit before it sat very long. My guess and our gamble on this job is that those bearing cavities can be purged of water with WD-40. Remember, the WD stands for water displacement. I think we can risk a good flush job. The motor may fail at another time, but I think we can get more years out of the motor. You can tell the homeowner what we did and that the fan motor is no guarantee. I think he will be willing to take the chance."

Bob flushed the oil cavities until he thought they must be clean. He followed it up by flushing it with regular motor lubricating oil.

Btu Buddy said, "The motor has been disassembled and laying in the sun for awhile. Check the motor leads to the motor housing for a ground circuit."

Bob checked and said, "It is not showing a circuit to ground. I believe it is good. I am going to assemble it back together."

Btu Buddy said, "I think you are right. Be sure to oil the shaft and the inside of the bearings as you assemble the motor. When you get it back together, remove the terminal cover for the compressor and blow the terminals out with air."

Bob said, "I think everything is ready to run. The fan motor went back together and is in place."

Btu Buddy then said, "Let's make one more check to ground from the line side of the contactor. We have not checked the crankcase heater, but if it is grounded, it will show up in this check. If we don't see a ground there, I think we are ready to start the unit."

Bob made the check from both line side wires to ground and everything looked good.

Btu Buddy then said to Bob, "Go in and tell the owner that you are going to turn the thermostat to the 'off' position and put power on the unit. Explain to him that he shouldn't start the unit for at least 10 hours to give the crankcase heater time to boil any liquid out of the crankcase. The unit has been sitting for several hours with no crankcase heat."

When Bob came back, he turned all of the power on to the unit and all seemed well.

As they were driving away, Bob said, "That call was all about knowing the equipment and its limitations. I sure am learning a lot. I was sure that I would need to change a lot of components on that unit."

Btu Buddy noted, "A lot of the reason that we were able to do that call so economically was that the components did not stay under water for long and we checked them all electrically before turning power on to the components."

Bob called the customer the next morning and the homeowner said the unit was running great and he thanked Bob for the great savings on the service call.

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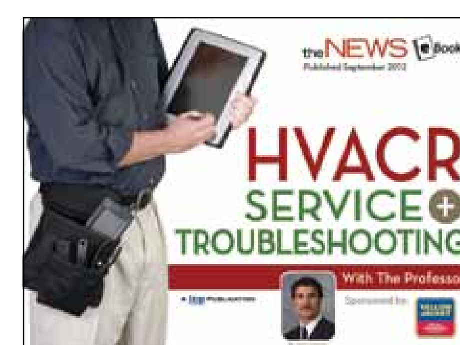
HVACR Service + Troubleshooting with The Professor

BY JOHN TOMCZYK



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