CHAPTER 1

BASIC PRINCIPLES OF REFRIGERATION

This is your training section, and it contains all of the theory you will receive while you are learning to service air conditioning and refrigeration equipment. We are not going into the theory of refrigeration in great detail. It is enough that you have a reasonable understanding of the physical laws that are the basis for the refrigeration cycle. This information will not repair any refrigerator or make you one dollar. However, it will lay a foundation for you to build a wonderful trade on. You will be a more efficient trouble shooter if you have this information in the back of your head. Keep it in the back of your head and your hands will travel faster and surer.

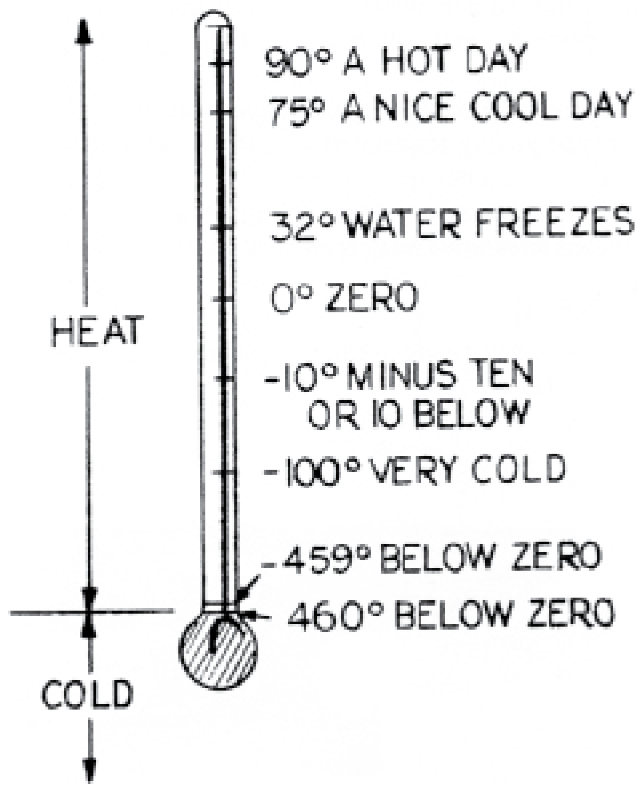
What you are about to read here is contained in books that would fill the shelves of a large library. These books are highly technical and full of scientific words and phrases. With all due respect to the authors of these books and the scientists who furnished the material, we are going to condense the whole lot down to a few pages of readable language. The scientists who contributed the most to this library were Charles, Dalton, and Boyles. These three scientists discovered certain physical laws which cannot be disputed. These laws are much like Newton's Law of Gravity. For the purpose of this course and with due respect for these scientists, we are going to call these laws Doolin's Laws. I will lay down these laws, and we will examine them and tie them into the refrigeration cycle; then we will leave them, for they will not repair refrigeration equipment.

LAW NO. I

There is no such thing as "cold" until the thermometer registers 460 degrees below zero. Everything above this is heat.

We use the term "cold" every day. We say, "The box is getting colder." This is not exactly true. In fact, the box simply has less heat inside.

Here is the temperature scale as we know it plus the lower scale. (Fig. 1-1)



(Fig. 1-1)

In plain language refrigeration is a problem dealing with heat. Since I have already said everything is heat down to 460 degrees below zero, that is where cold begins, there is still some heat at 459 degrees below zero. This is so cold—you notice I use the word "cold;" yet, we know better. This is so cold that if you were exposed to it for a few minutes and I touched you with a screwdriver, your body would shatter like glass.

You may never have given it much thought; but a refrigerator in your home, the one you keep your food in, is a box where there is a mechanical unit taking the heat out of the inside and everything that is stored inside. The unit is not putting something into the box which was not there before. The refrigerating unit is not imparting some quality to the inside. All it is doing is pulling the heat out and getting rid of it on the outside of the box. The insulation in the box keeps heat from getting back in too fast. Then there is a constant struggle for the machinery to get the heat out of the box and to try to keep enough of it out so that there is less heat on the inside than on the outside. The reason water in your ice cube trays turns to ice is that the heat was pulled out of the water until it reached 32 degrees, and then it turned solid. As a matter of fact, an ice cube is very hot if we remember that cold begins at 460 degrees below zero.

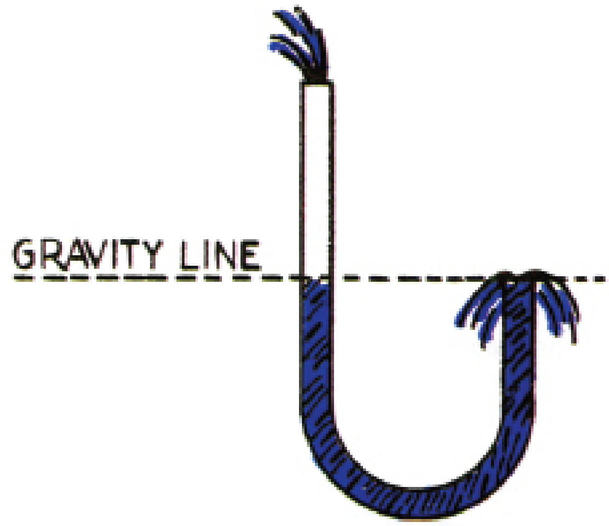
I know this does not repair refrigerators. But again, we are just getting acquainted with some facts that will help you to be a master serviceman.

If you are straight on this first law that to refrigerate means to remove heat, then let's go to *Law No. II*.

LAW NO. II

Heat is ever ready to flow to anything which contains less heat.

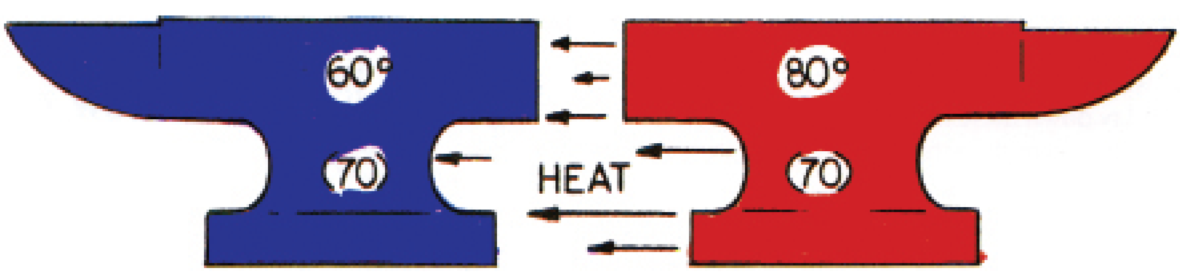
This statement is just as true as your saying that water will run downhill or seek its own level. It's the old law of gravity. For instance, if I pour water into the high end of this tube, you will agree that it will run over on the short end of the "U" until it levels off at the gravity line. You know this will happen, and it is a true law of gravity.



It is just as true as the fact that heat will always start to flow to anything with less heat. If I had two anvils and one had less heat than the other, the heat in the warmer one would flow over to the cooler one until both were the same temperature.

Let's examine the two anvils in **Figure 1-2**.

If one were 60 degrees and the other 80 degrees in temperature, the 80 degree anvil would immediately give up some if its heat to the other until they were both equalized at 70 degrees. You can no more stop the flow



(Fig. 1-2)

of this heat than you can stop water from running downhill. But you can dam water up. Likewise, you can dam up heat with an insulation barrier; but this will not stop the heat flow. It will go on through the insulation if it takes ten years. All the insulation in your home refrigerator is doing is slowing down this flow of heat enough so that the refrigeration unit can get ahead of it. Nothing can stop the flow of heat. All that can be done is to slow it down; that is, the rate at which it moves. Everything is a conductor of heat—air, steel, wood, copper, even flesh. Some materials are better conductors than others.

The Egyptians had an air conditioning system which utilized the law of heat flow in the Pharaoh's palace two thousand years before Christ. Here is the way it worked. Every night 3,000 slaves came down to the palace at sundown and removed the main wall of the palace. The wall was 15 feet high, 10 feet wide and 60 feet long. It weighed over a thousand tons. One side of this huge marble block was polished and fitted into the palace ballroom. The rest was just rough stone. Using rollers, the slaves hauled this huge block out into the Sahara Desert where it stayed all night. The desert was cold at night, and the heat in the stone flowed out into the cold desert air. At the crack of dawn, they dragged the stone back to the palace and cemented it back into place. All day long while it was 130 degrees on the roof of the palace, this stone soaked up the heat in the palace. It is guessed that the temperature in the palace stayed about 80 degrees all day. Imagine, 3,000 men doing what roughly one 100 hp motor would do today.

Actually, we use the same principle today. But instead of 3,000 men to do the job, we use a mechanical system; and the refrigerant gas carries the heat outside where we get rid of it. Simpler yet, modern refrigeration today soaks up heat where it is not wanted and carries it out where it does not matter and gets rid of it. It's the same principle as the stone and the slaves, only we use refrigerant and a pump. The heat is ever ready to flow to anything that has less heat. Your body gets cold when you are improperly dressed not because as grandma always said, "The cold will penetrate!" but because your body heat flows out through your clothes.

Now we have laid down two laws. *Law No. I*, that refrigeration is a problem dealing with heat all the way down to absolute zero at 460 degrees below zero. *Law No. II*, that heat is fluid or in a constant state of motion always ready to move to anything with less heat, or "cooler," if you please. With these two laws in mind, we are going to invent a refrigerator after we get one more law stated.

This third law may give you some trouble, but I believe we can get it across. At first it may not seem to have as good a connection with refrigeration as the first two laws. But after we understand it thoroughly, you will see the possibility of our inventing a simple refrigerator together utilizing these simple three laws.

LAW NO. III

Anytime a liquid changes to a gas or vapor, it must give up its heat; and the heat is carried off in the vapor.

To say it another way, whenever a liquid changes its state from a liquid to a vapor, heat is pulled out of the liquid that is still left; and this heat is carried off in the vapor.

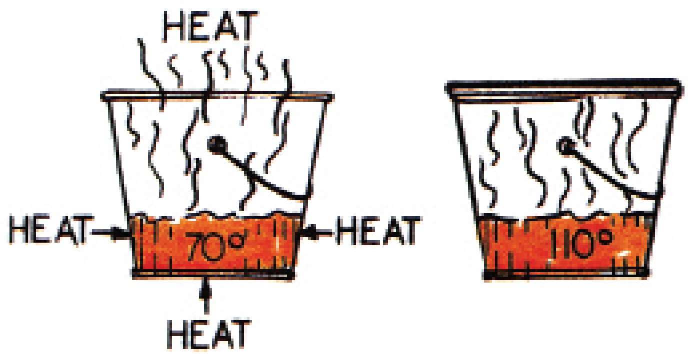
This is the law of changing states of liquid. You may never have given it much thought, but when your skin is wet and you dry off very rapidly, the liquid is changing to a vapor. The heat is being pulled out of the flesh of your body; and you are chilled. The heat has actually left in the water vapor. This law is simple if you will stop and think a minute. Have you ever had gasoline, drip gas, or carbon-tet on your hands? Did you notice the cold (correction, heat loss) from your hands?

At the risk of belaboring a point, I want to be sure you nail this law down. It is the basis of all the refrigeration in the world, natural or mechanical (except the sun and the earth relationship—solar heat).

Take two buckets of water for instance. We put a tight lid on one bucket and leave the other open. Set them both out in the yard. The bucket that is evaporating, that is, drying up, will be 20 or 30 degrees cooler than the closed bucket. Stick a thermometer down in the water in the open bucket. It should read approximately 70 degrees. Take the lid off the other bucket and stick a thermometer in the water. It should be almost as hot as the sun's heat on the lid. The water that was evaporating was cooler because the heat in the residual water left in the bucket was leaving in the water vapor carried off by evaporation .

For example, suppose you set two buckets of gasoline out in the yard. You have the same amount in each bucket. You know that gasoline evaporates even faster than water. The gasoline left in the open bucket just before it all evaporated away would be 40 or 50 degrees cooler than the closed bucket where the vapor could not get out and carry away the heat. **(Fig. 1-3)**

This is an iron bound rule. Any liquid capable of evaporating gives off a vapor, and the heat necessary to make the liquid evaporate is carried off in the vapor.



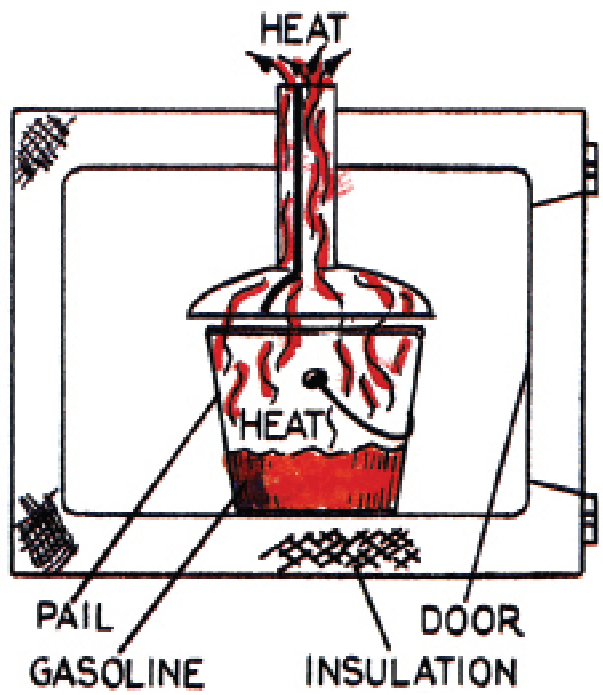
(Fig. 1-3)

The heat necessary to make water boil or evaporate into steam is always contained in the steam. In a steam boiler the heat from the furnace passes on through the water and is carried off in the steam.

Summing this up, any liquid capable of changing into vapor and from vapor back into liquid is a *refrigerant*; that is, it moves or displaces heat. It takes on heat changing from a liquid to a vapor, and it gives up this same heat out of the vapor when it changes back into a liquid.

Men using these three laws as the basis of their experiments invented modern mechanical refrigeration. First, they knew they had a problem dealing with heat—*Law No. 1*. They had to get rid of heat, not put cold inside of a box. Second, they knew that heat was fluid and would always move immediately over into something less hot, like a big hunk of ice. Third, they knew the law of changing states of liquid. With these laws in mind, mechanical refrigeration came into being.

Heat was the problem, not cooling. If the heat could be displaced, it would be cool because there was less heat. The pioneers in refrigeration knew that heat would flow immediately to anything with less heat. They knew also that if there was anything inside of a box colder than the foods stored there, heat would go to this colder thing. They reasoned that if they insulated the box, they could hold back heat trying to get in from outside. They knew that ice would work with these first two laws; but they were after something better. So they brought the third law into action. They reasoned that if all this were true, then what was needed was some kind of liquid in a container which would evaporate carrying the vapor outside of the box through a chimney. This vapor would carry the heat inside of the box to the outside. This was pretty good reasoning since it is almost exactly the basic principle of modern refrigeration. Here is a picture of a refrigerator much like the first one built. **(Fig. 1-4)**



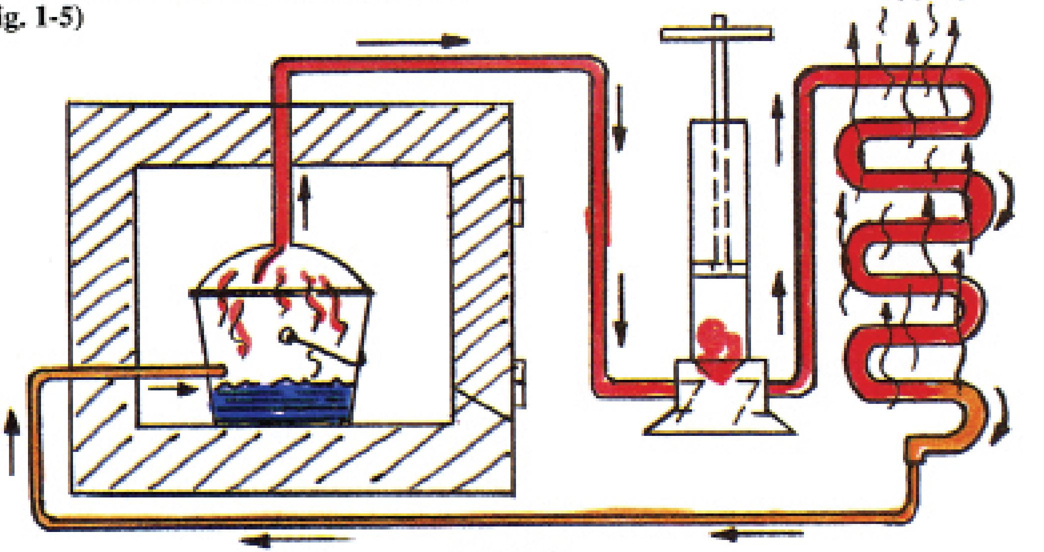
(Fig. 1-4)

The pail is full of gasoline. As the gasoline evaporates, the fumes go up into the hood and out through the chimney. These gasoline fumes are loaded with heat which was pulled out of the liquid left in the pail. More heat is coming through the side of the pail into the liquid and on out in the vapor. This crude box would actually be approximately 20 degrees cooler on the inside than the outside because of the heat being pulled out of the interior.

But what's wrong with this unit? First, it wouldn't keep meat. Second, some escaping fumes might stink up the box. Third, you would always be setting in a fresh bucket of gasoline, so there would be too much waste. You wouldn't want to strike a match to see what was in your refrigerator either. But suppose we solder the hood on top of the bucket. Now we are rid of the stink, but we will have to fill the bucket through the chimney. We have improved our refrigerator; but it still requires that we keep replenishing the gasoline, and it is not cold enough. We can improve that by getting an old plumber's pump and sucking the fumes off at a faster rate. But why waste the vapor fumes which contain the heat? Why not pump the fumes out and then pump them into a coil like a whiskey still and get the heat out. This will condense the vapor back into gasoline.

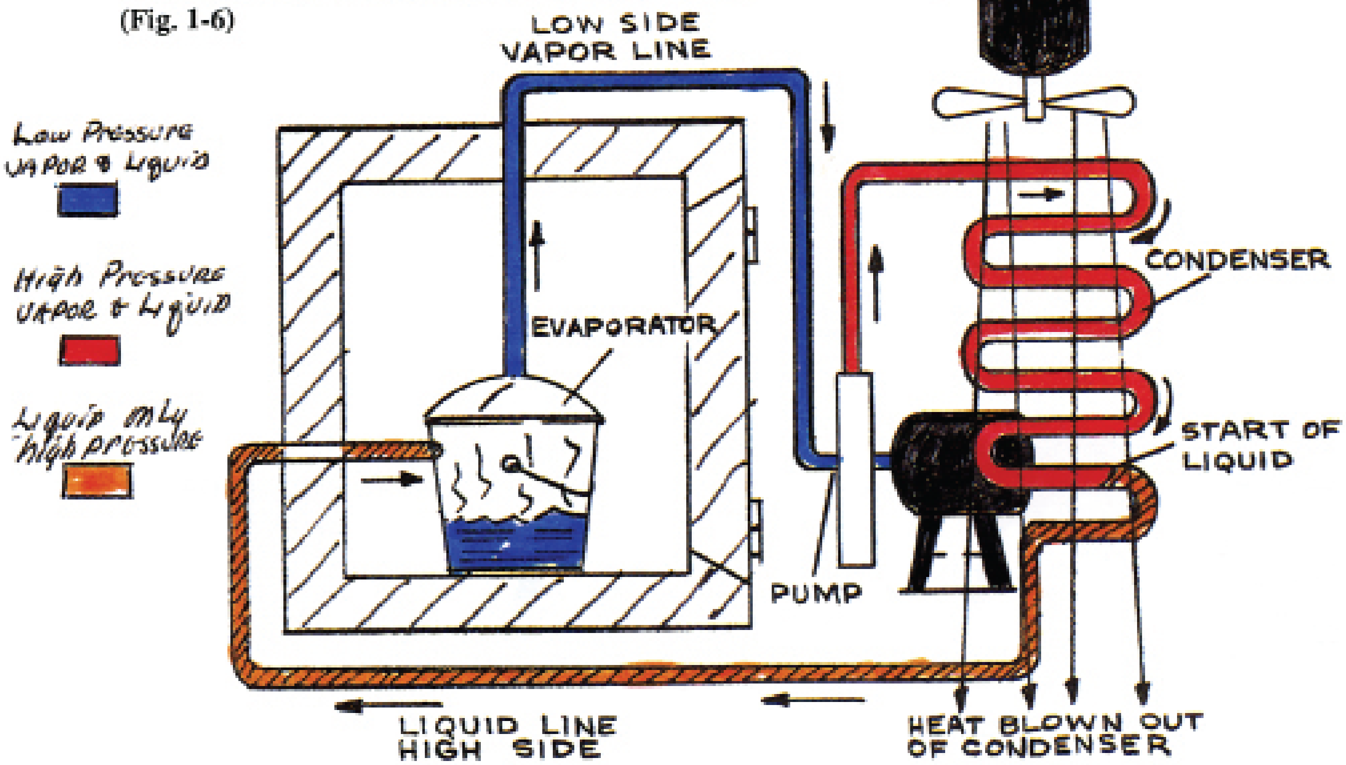
Now we have a refrigeration cycle complete. Of course, we will have to pipe the fumes or vapor to the pump, then to the condenser coil, then back to the pail inside of the box.

Here is our improved version of our original refrigerator. (Fig. 1-5)



(Fig. 1-5)

We have gone this far. Why not improve our refrigerator once more. We will add an electric pump and condenser fan to blow the heat out of the condenser coil. (Fig. 1-6)



(Fig. 1-6)

CHAPTER 8

MOTOR STARTING DEVICES

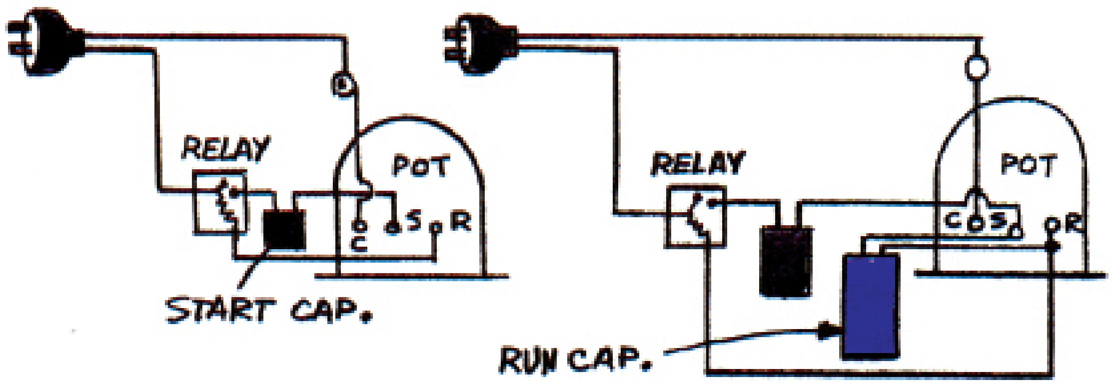
You know that you are not expected to do even minor repair to an open-type motor. You take these motors to the motor repair shop. The motor shop man may be able to loan you a replacement motor until your motor is ready. If not, the customer will just have to wait or buy a new motor.

You are the motor man where hermetics are concerned. You are not expected to open up hermetic pots or rewind any hermetic motor. In fact, you can service hermetic pots for years and never look inside of a hermetic pot or go any further than the terminals on the outside of the pot. However, you are expected to repair or replace all defective hermetic motor starting devices. You will be expected to know whether a pot is good or bad. If you have to make this decision, make it with the knowledge that you are absolutely sure. There is nothing more aggravating than to condemn a pot and later find that it is perfectly good. If this happens, you have failed to test it properly. Take your time and be sure.

The motor starting devices you will be concerned with are the relay and capacitors. You will, of course, be expected to understand the overload device. But rarely does an overload give any trouble. Overloads, line starters, thermostats, pressure controls, and ordinary off-and-on switches are all a part of the electrical devices on refrigerating equipment. These electrical devices are no more complicated than those which you use every day in the modern home, such as hot water tank controls, washing machine controls, iron thermostats and the usual appliance off-and-on controls. The two or three-speed switch on your kitchen mixer is probably twice as complicated as the switches on a window unit air conditioner.

In reviewing the hermetic pot, we know that we have a single-phase motor in the pot. We know that it has a starting winding and that the ends of the windings are tied onto the terminals. We know that we have replaced the centrifugal switch, common to open motors, with the relay. We know that the electrical engineers came up with the starting capacitor to help the ordinary motor to start with more zip and power. We know that this starting capacitor is hooked in so that it is disconnected from the winding when the relay disconnects the starting winding. I have not mentioned another type of capacitor which is being universally used but is not absolutely necessary in order to operate a hermetic pot. However, if the motor designer engineered his pot to use this special capacitor, it will have to be used. This special capacitor is called the running capacitor. Many hermetics use this running capacitor in conjunction with the starting capacitor. Take a look at **Figure 8-1** and note the hook up where the ordinary relay and starting capacitor are the principle motor starting devices. Compare the relay capacitor start pot to the relay capacitor start, capacitor run pot.

This running capacitor is hooked in between the run and start terminal, and it stays in the circuit all of the time. I repeat, *even though the relay has cut the starting winding out of the circuit and the starting capacitor is out, the running capacitor is still in the circuit.* This running capacitor can always be identified by its hookup relation to the other starting devices, and it will always be in a metal can since it is an oil-filled transformer or capacitor. You can compare this extra capacitor to the supercharger on a gas engine. The engine will run without the supercharger but not as well as it would run with a supercharger. The electrical engineers have discovered that this oil-filled running capacitor, when used on a hermetic, will actually reduce the amperage load pulled by the motor. But probably more important, the use of the running capacitor permits some savings in the actual construction of the single-phase motor power-



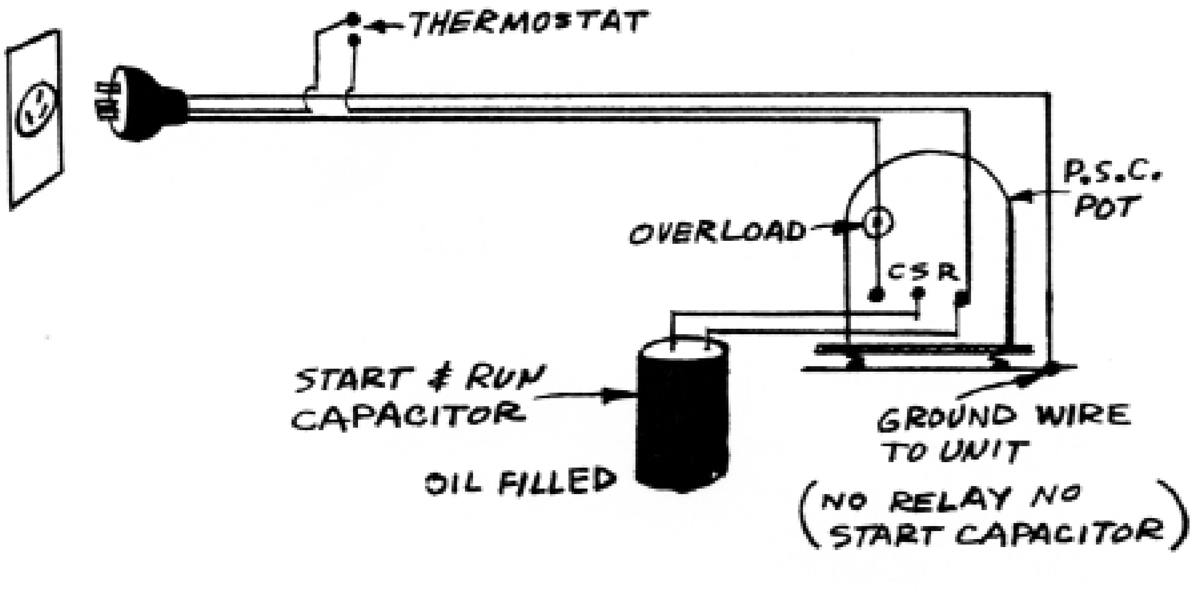
(Fig. 8-1)

wise. There is some question as to whether the actual savings are not off-set by the wear and tear on the running capacitor. Capacitors do blow out and leak their oil. *Do not confuse the running capacitor with the starting capacitor*. One is a dry electrolytic starting device, and the other is an oil-filled running device which stays in the circuit all of the time. What happens electrically within the windings of a single-phase motor when the running capacitor stays in the circuit between the run and start windings is far too complicated to explain here. It is enough that you know when one is bad or good and whether it is the proper size and doing its work. Compare the start capacitor here with the running capacitor in appearance.

Let's briefly review the development of the hermetic pot motor. Originally the engineers had a single-phase no-help pot with run and start windings. Many of these pots are still in use. Then the engineers added the start capacitor between the start windings and the relay. The relay was necessary after the motor was welded up inside of the can. After this system of starting a hermetic pot had been perfected, the electrical engineers discovered that another special device could be added; that is, the running capacitor. They added this capacitor and hooked it between the run and start. The engineers designed this special oil-filled capacitor so there was no necessity to disconnect it from the circuit. So even though the relay cut out the start capacitor and the start windings from the circuit, the running capacitor stayed in the circuit. The manufacturers called this their capacitor start, capacitor run hermetic pot. That is, the pot started by the relay and start capacitor jolting the armature; and still the run capacitor was always in the circuit. This was a pretty good combination and is still used by some manufacturers who favor the capacitor start, capacitor run type pot over the plain capacitor start, single-phase pot.

Just about the time the engineers had perfected the running capacitor to be used in conjunction with the relay and start capacitor, they made another discovery. They discovered that the oil-filled run capacitor could be made to do double service. That is, act as a start capacitor as well as a run capacitor. With this type capacitor on a pot, there was no longer any need for a start capacitor or a relay; and both were eliminated. Here is the new look in pots. Note that this pot is called the *Permanent Split Capacitor Type*. **(Fig. 8-2)**

This PSC motor is very popular with the air conditioning manufacturers using hermetic pots. This is understandable since it eliminated both the start relay as well as the start capacitor. This new run and start capacitor kicks the pot off just like the start capacitor with relay. After the pot reaches its running speed, the new capacitor becomes a run capacitor with the characteristics of a resistor in the circuit through the start windings. The old capacitor start, capacitor run motor with relay has not really changed; it is still the same old single-phase motor; but now it has the new look. In fact, a relay and start capacitor can be added to one of the modern PSC hermetic pumps, and it will function just as it did before with start and run capacitor with relay. We have not discussed this new PSC pot motor until now for a good reason. Had we gone into this new type combination start and run capacitor which eliminates the relay, you might have gotten the impression that the relay was no longer needed nor served any useful purpose in this trade. This is not the case. The relay is very important to the hermetic pot; and even though the new pot uses this combination run and start capacitor which will do everything for the motor, the manufac-



(Fig. 8-2)

turer still reserves the right to go back to the relay in order to get this motor kicked off if the new combination capacitor will not get the job done. You can see that it would be extremely important that you understand the relay if the manufacturer himself has the relay for an ace in the hole in case of the PSC failure. The PSC jobs are wired exactly like the old straight run capacitor hook-ups. That is, between the run and start. To identify a PSC pot, you only have to look for the relay. If it is missing, then it will have to be a PSC pot. Likewise, the start capacitor will be missing since a start capacitor has to be disconnected just like the start winding; and you would never find a plain start capacitor without a relay.

Take a look at this pure PSC hermetic pot wiring diagram:

This special run-start capacitor may be large or in multiples. You will find these PSC pots used in the central system condensing units also.

Just what takes place inside of this oil-filled capacitor used on the PSC pot is of no consequence to us since we will never repair one or do more than test it to see if it is good. The one thing that we are sure of is that it kicks the pot off like a start capacitor, and then it changes into a run capacitor and helps to keep down the amp pull on the line. This new type start and run capacitor is easy to trouble shoot. In fact, it is almost a test device in itself. That is, it can be used to test the pot to see if the pot will respond properly.

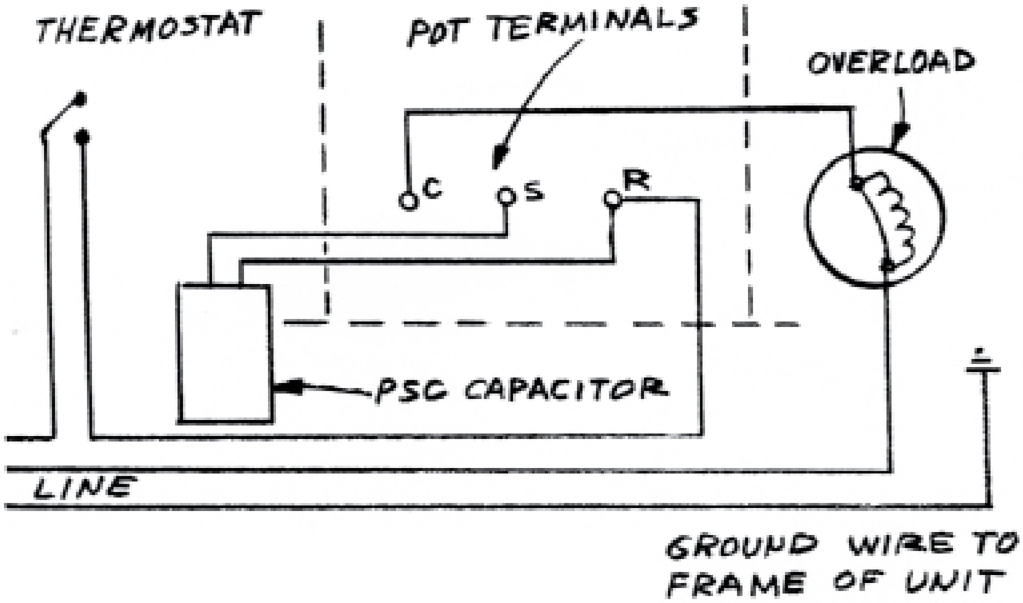
If you have a PSC pot, use a start capacitor with two leads bare at the ends. Touch the bare leads to the start and run terminals. If the compressor is good, it should start. If not, the compressor is bad. If the compressor starts, remove the capacitor and it should run. If a new PSC capacitor does not start the compressor then it is time to put the start relay and capacitor on. The compressor has become a hard starter.

NOTE: When using the PSC capacitor, pressure must equalize between the high and low sides. It takes approximately three minutes on the off cycle for the equalization to take place.

Look at the P.S.C. hook up in **Figure 8-3**.

Summing up all that has been said about hermetic pots, we can say that they will fall in one or the other of the following classes:

1. Single phase with plain starting winding, using a relay for the disconnect device.
   a. Used in household refrigerators and some freezers.
2. Single phase with start winding and capacitor start with relay.
   a. Used in household refrigerators, freezers, window units, and a few small commercial condensing units.
3. Single phase, start winding, capacitor start, capacitor run with relay.
   a. Used in window units, central condensing units, and some hermetic package units.
4. Single phase, start winding, Permanent Split Ca-



(Fig. 8-3)

pacitor type.

a. Used exclusively in window and central units and in some package units.

5. Three-phase pot. No help of any kind needed.

a. Used in package units, central and commercial condensing units.

You must remember that a run capacitor and a start capacitor are two different things. They may be closely related, but they have a different job to do, and they are built differently. The start capacitor is usually enclosed in a hard bakelite case, and it may be of different sizes or capacity. Its size is usually measured by the MFD and the voltage. If the unit is 240, then you use a 330 V capacitor. The MFD may be whatever the motor is designed to use. You can vary this slightly if you cannot get an exact replacement. However, the voltage must be correct for the unit. Run capacitors are almost always encased in a metal oil-filled can, and the MFD is low. The run capacitor's MFD may be as little as three MFD or as high as twenty MFD or thereabouts. MFD stands for microfarad, and that does not tell us anything much. But we are not studying to be electrical engineers. The permanent-type run-and-start capacitor will look just like the ordinary run capacitor but will generally be larger in size. The MFD will be from two to twenty, and the voltage must be correct. Once in a great while, you will find that a manufacturer has used two 120 volt start capacitors in parallel to take the place of one 240 volt start capacitor. This practice has been discontinued in most cases. Even though this will work and two 120 volt capacitors are cheaper than one 240 volt capacitor, you would be constantly changing capacitors, both run and start, if you work on many central systems or window units. These starting aids do go bad, and there is no repair for them. They have to be replaced. One of the most common reasons for a pot to fail to start and run is the breakdown of these capacitors. In fact, it is the first thing you check on a capacitor motor after you have established whether there is a voltage available to the unit and that the thermostat is on. One of the simplest tests is to remove the suspected capacitor, whether it be start or run, and spark it out. Sparking out means to put a charge into the capacitor and jump across the contacts to see if it will unload or if it is capable of taking a charge. There is no quicker or simpler test. If the capacitor does not respond to this treatment or seems to be very weak, do away with it and put in a new one.

Here is the spark test: Take the bare ends of a cord plugged into a 120 volt outlet and very quickly flick the wires across the two capacitor posts. This will charge the capacitor. Pull your cord. *Remember: it is hot.* Now take a screwdriver with an insulated handle and short across the posts of the capacitor. If it is good, there will be a hot spark. It will crack like a firecracker. If you are leery of working with the hot ends of 120 volt service, then use a light bulb in the line to reduce the voltage.

See these tests for capacitors in **Figure 8-4**.

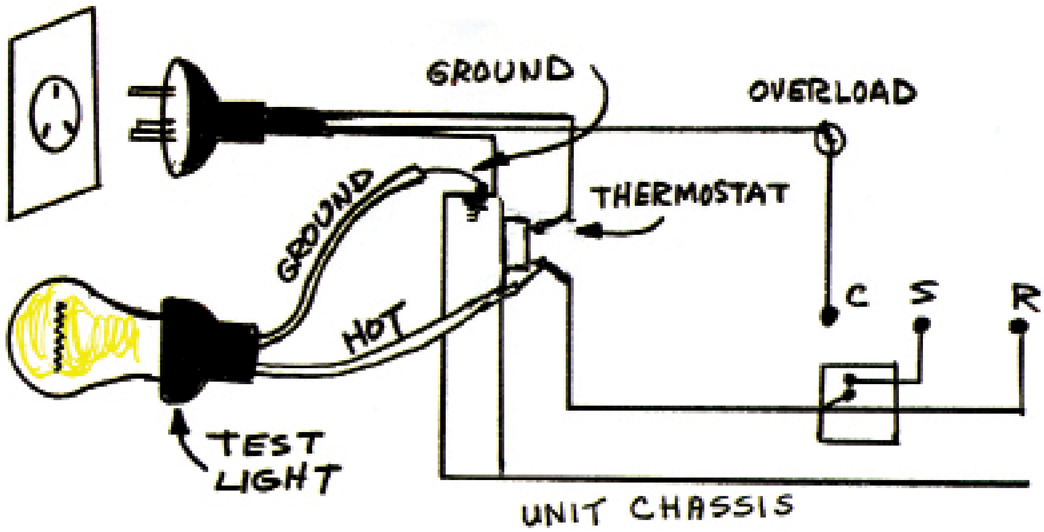
What if you were out in the field servicing air con-

CHAPTER 9

TROUBLE SHOOTING WINDOW UNITS

You never charge a household refrigerator while the box is in the customer's home. You might change out a relay or a capacitor if that is all the unit needs. The size of the box and unit will dictate your policy. Where some freezers are concerned, it may be more practical to charge them on the premises than to attempt to bring them to the shop. However, if the freezer is small enough to be transported, take it to your shop. Only in case of emergency should you charge a freezer in the home. If you have to charge it right where it is located, come back over a period of two or three days to finish the job. Do not attempt to make major repairs to any household unit, whether freezer or refrigerator, on short notice or on one call.

Take all window units to your shop, if possible. Explain to the customer that you already have a service charge for coming out, and it will cost him no more for you to take it in and check it properly. Tell him that you will call him and let him know exactly what you find and how much it will cost to repair. Remember, if you do a quick job in his home and you overlook some small thing that had nothing to do with the work you were paid for performing, you are still held to make your work good. The customer does not understand that the relay and capacitor are two different things. All he knows is that he has paid you for working on his window unit; and if the job does not hold up, he wants you to make it good. Had you taken the box to your shop in the first place, you would probably have caught the bum relay along with the bad capacitor. It is always tough to have to explain to a customer that you did not look at the capacitors and that all you did was fix the bad relay which was in need of replacing. The main thing that is on his mind is that you did not do your job in the first place. Remember this, charge for your work and give good service and careful workmanship. If you give your work away for nothing and it does not hold up, you will always be remembered for being a poor mechanic. Never will you be remembered as having been charitable. If you charge, and your work holds up, you will always be known as the man who charges but does good work. The very man who may say your charges are high will come back to you, for he wants the best. When you are dealing with the customer in his home, make sure that you both have a distinct understanding as to what is going to be done. Do not take anything for granted. Don't ever be guilty of having to say, "I thought you knew that this was our policy." Make sure that he knows your policy. When dealing with the customer in reference to what is wrong with the unit, always state what you believe to be wrong and tell him that you do not know what caused this failure until you make a more careful examination. Don't give a customer a lecture on the refrigeration cycle. You will only succeed in convincing him that you are trying to find out yourself what is going on. The more you talk, the more you will convince him that you are inexperienced. Be thorough. Be brief. Be sincere. Collect your money when you are finished and be on your way. Don't hang around full of good tidings and joy because you have his money in your pocket. He will become aware of it soon enough after you are gone. If you do your job and do it well, there will be no need to make a high powered sales pitch. The job will hold up or it won't hold up. For this reason, you are again cautioned not to get caught in the trap of doing a fine job on the main trouble and overlooking a small thing that will give the customer the impression that you have never touched the unit simply because it quits again. If you have the unit in your shop, it will offer greater chances for you to find anything that



(Fig. 9-1)

might cause a failure after you have declared the job complete.

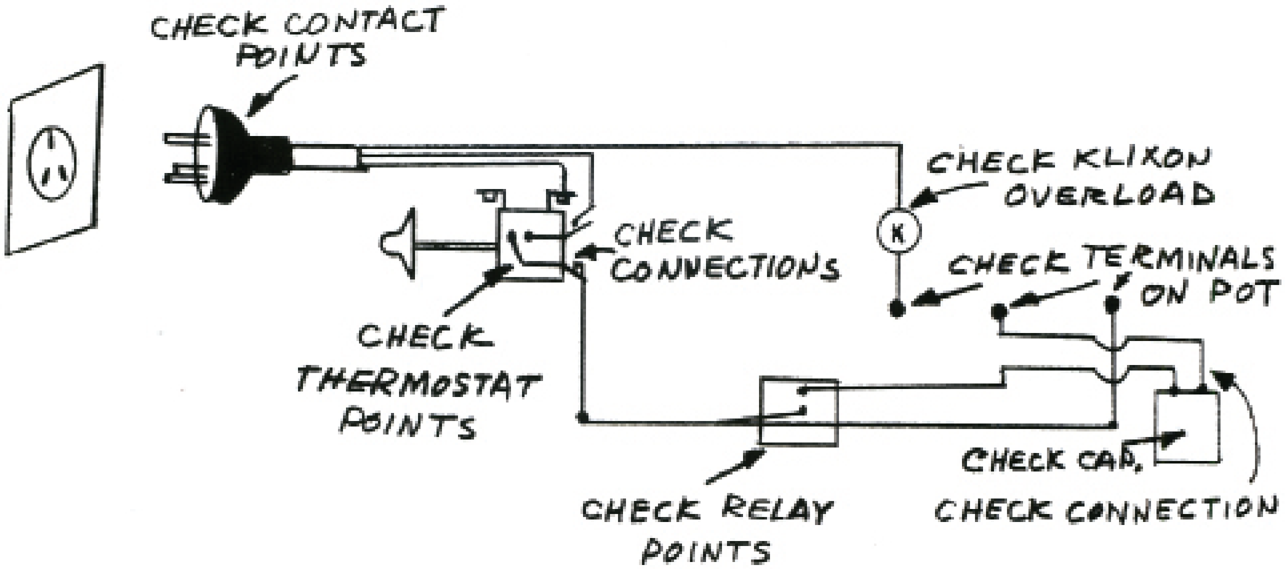
Let's take a call together on a window unit. We arrive at the home and take in a box of tools. Actually, we really do not need the tools since we do not plan to do any work in the home. But we have to take in the tools since the public expects us to be prepared to work, even if we do not intend to make more than an examination. *Do not set tool boxes down on carpeting.* The bottom of the tool box may be dripping with oil. Watch that wall-to-wall carpeting. Now we are in front of the window unit. We ask the lady of the house a few simple questions which have nothing to do with the technical aspects of air conditioning. A good opening question is, "When did it run last?" If the owner does not seem to know anything whatsoever about the unit, then your job is to find out why she called you. What is the complaint? Suppose the unit won't run. You would immediately check the wall plug to see whether the cord cap is plugged in tightly. The cord being plugged in tightly you jiggle the thermostatic switch, and if the unit attempts to start and dies again, take it into the shop. It probably has a bad thermostat, but that isn't all. It may have run long enough for the thermostat to break down the relay. The unit could be a hard starter because one start capacitor was out and the original unit came with two.

You might also find loose terminals had caused the line from the thermostat to run hot and this had contributed to the thermostat's break-down. But suppose it was simply a defective thermostat, and you change it out right in the home. If it holds up, fine. If not, you will be called back. You were paid to fix the unit. Now fix it. Back to our unit, suppose it is still dead after jiggling the thermostat. Now you can look to your relay if you have no other way of checking to see if you have any voltage at all. Suppose you do have a pig tail socket and lamp with you, and you check the screw terminals on the thermostat to ground.

See the check for voltage in **Figure 9-1** and see the check points in **Figure 9-2.**

You find that there is juice through the thermostat and on to the relay. There is no use going any further here. You cannot fix this in the home, so just break it off right there. Declare yourself, don't quibble. Say, "I know that there is a defective relay, and I will replace it, but I would like to find out if something caused this relay to go bad or not." Actually, you plan to change the relay, blow out the condenser and evaporator, change the filter, check the pot terminals and the capacitors for leakage. Oil-filled cans can rust out, and the oil will leak out. If this happens, the capacitor is ruined, even though it might start or operate for a few times during the day.

Suppose a customer says that the pump seems to be running, but the fan does not. This will be an observant customer. You will have to check to make sure that he doesn't have it backwards; that is, the pump is out and the fan is on. However, most customers will miss the air flow of the fan very quickly. Now this fan motor is a two-speed capacitor run-and-start type. It may look just like a shaded pole motor; and for all purposes, it doesn't make much difference. This motor is two-speed and

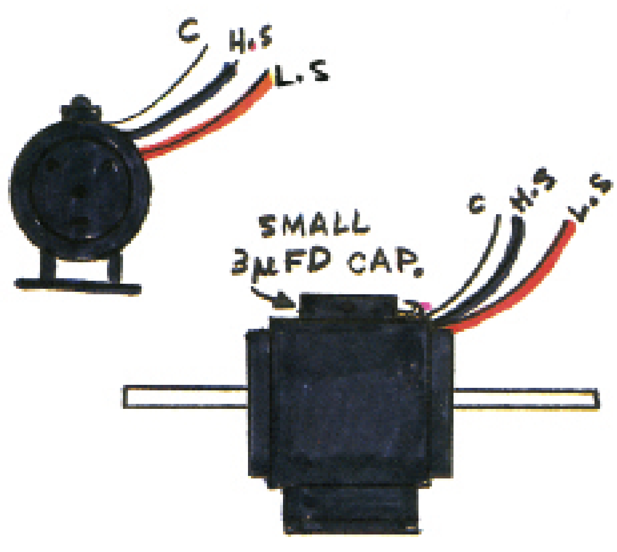


(Fig. 9-2)

looks like this in **Figure 9-3**.

You will note that a two-speed motor has three lead wires. When this is the case, one of the wires will always be on the line. It will be known as the common; that is, common to both the low and high speed windings. See this high-low speed hookup in **Figure 9-4**.

You can always bet that if there are three wires coming in and out of a window unit fan motor, it is two-speed. It will have a two-speed switch, and it will run on either speed. So, if the fan motor changes speed, it simply means that the system operates nicely or correctly on one certain speed and is unbalanced on the reduced speed.



(Fig. 9-3)

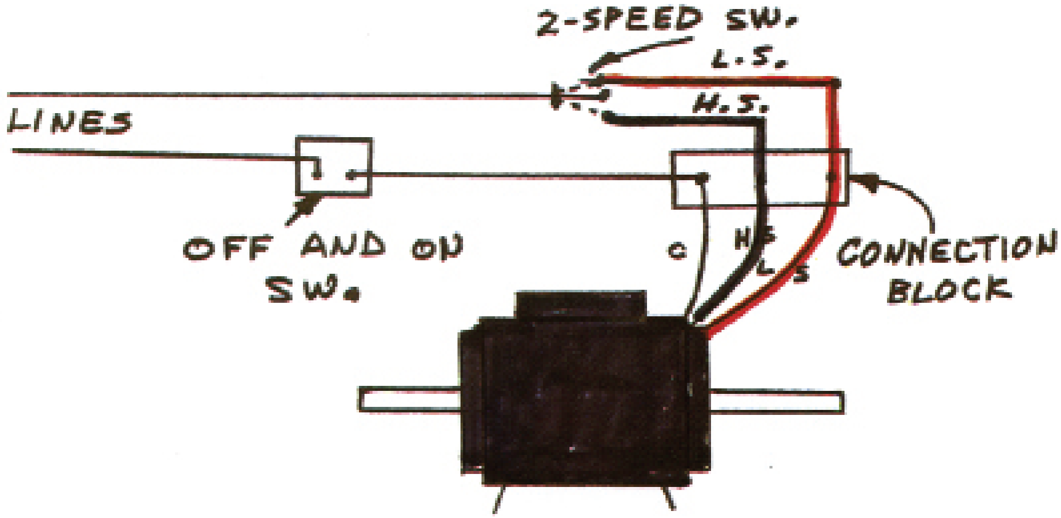
Once in a while you will run into a fan motor that uses a transformer in the circuit in order to reduce the speed of the motor. See this hookup with the transformer acting as a resistor in the line in order to reduce the speed of the motor. **(Fig. 9-5)**

Fan motors are easy to deal with. They either run or don't run, and there is seldom any middle ground. If the motor does not run properly, it will have to be replaced or rewound.

Rewinding window unit fan motors is a gambling proposition. Even if the motor rewind man believes he can do the job and is willing to guarantee his motor rewind, you must consider that it is more work to take a motor in and out than it is to rewind it. It is better to replace burned out fan motors with new motors. Rewinds to these motors are not too satisfactory; and if you have to take a motor out again because it will not hold up, you are risking your reputation with your customer notwithstanding the loss of labor.

You must change a fan motor to the correct voltage, and it would be a good idea to try your very best to get an exact replacement. Do not use substitutes where horsepower and amperage are concerned. Fan blades put just as positive a load on a motor as a piston and crankshaft.

Never take wire colors for granted. There will be a factory wiring diagram on the motor. Take a good look at the diagram to be sure the new motor does not take on

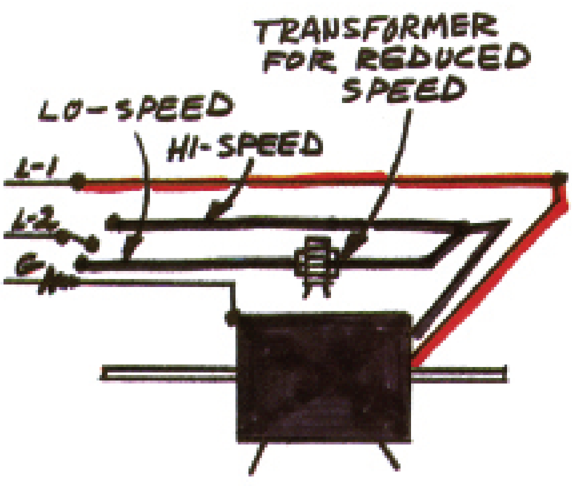


(Fig. 9-4)

a new wire coloring. Do not accidentally hook the line to high and low together. The motor will burn faster than the leads can be removed. See **Figure 9-6**.

Most new two-speed replacement motors will have diagrams with the motor. If a drawing is not packed with the motor then you should check speed to be sure. Run the fan motor on both speeds, and you will know that you have the common located. When the fan connections are made to the switch block or terminal block around somewhere on the unit, the common will always be in the line. The two-speed switch will always be working across the two-speed ends of the motor. **(Fig. 9-7)**

Now let's go back to our original fan motor complaint. The customer has said that the fan wouldn't

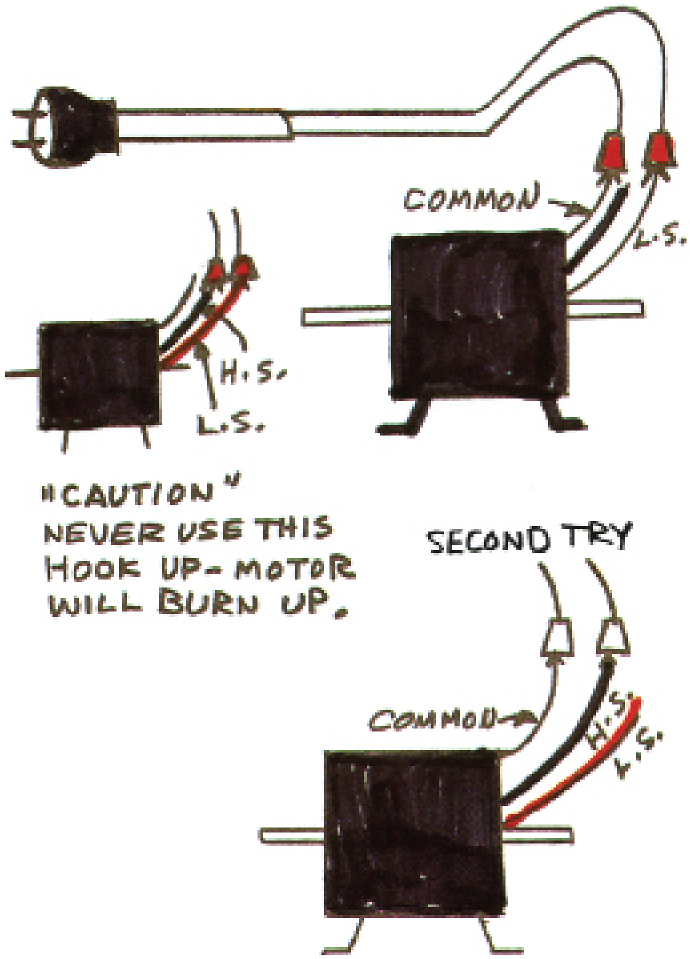


(Fig. 9-5)

work, and you found that he was right. It will not work. You check all of the connections, and you find that the fan motor is apparently burned out or has an open winding. In some cases, it is possible for the fan to work on one winding when the other winding is burned out. Where this is the case, all you can do is to have the whole motor rewound, or replaced with a new one.

You should own a long Allen wrench for taking loose the squirrel cage blower on the evaporator end of double shaft motors. This is a tough screw to take loose, and it will require you to own this particular wrench. See this approach to the Allen screw in the squirrel cage blower in **Figure 9-8**.

Many of the fan blades on window unit fan motors are so designed that they stay in the housing of the condenser or evaporator even though you take out the motor itself. When this is the case, you should be careful not to bend or damage the fan blade when sliding it off the motor shaft. The motor will have to be tilted or turned so you can slide the fan off the motor shaft without putting any undue strain on any part of the fan itself. A bent fan will wobble and cause vibration and in time will loosen on the shaft. Keep fan blades clean, and they will turn better with less load on the motor. Dirt is a drag on a fan. It will cause an overload on the fan motor, and the fan will not deliver enough air if it is dirty. Where double motors are used in a window unit, the motor problem is much simpler; and taking out the motor will be an easier matter. You must always be careful in giving estimates for labor on taking out and replacing fan motors. This work can become very involved. You may find that you will have to charge



(Fig. 9-6)

twice as much as you estimated in order to break even on your labor.

The same practice applies to the fans used in commercial and package units. Clean the blades occasionally. Keep the fan motor oiled. You should pay special attention to squirrel cage blowers which can accumulate enough dust and dirt to become almost a solid disc of dirt. In many cases, where you cannot get to these blowers, you will have to use high pressure air or even a steam cleaning outfit.

But let's go back to our trouble shooting. We can make a quick check on any fan motor by taking the motor leads loose and using a clip cord.

See this check method to be sure that the fan is all right as shown in **Figure 9-9**.

In most cases, if you make the original call and pick up the window unit, you will have some idea as to what happened; or at least you will know what the complaint is. For instance, it won't run, no refrigeration, runs noisy, lets water drip on the floor, etc. But suppose you have a helper who picked up a unit and asked no questions. He brings the unit to your shop. You are ready to proceed. First you would take a good look with a flashlight to see if you could locate anything which would tell you why the unit went bad. You would not touch the unit with your hands. While you are having this look around, you would note that the unit is 240 volts and the refrigerant is F-22. If you do not see any metal data tag and you have nothing to go by, you can take a look at the pronged cap that plugs the unit into the wall. If this cap is three pronged or polarized, then you could almost say for sure that the unit is 240. One way or another you can generally determine the voltage. Here is the procedure you can follow to tell you the voltage: See the specification tag, metal data, or name plate. If there is no name plate, look on or about the pot itself for a stenciled letter designating that this pot is F-22. If it is F-22, you can bet it will be 240. Take a look at the cord plug. If it's three pronged, it will be polarized and for use on a 240 volt unit. Another good indicator is to note the horsepower on the pot. If it is one horsepower or better, you can almost bet the unit is 240. Look at the data tag on the fan motor. It may tell you the fan motor voltage, and it will always be the same as the pot. Finally, if you are still in doubt, try running the unit on 120 and see how it responds. Never try 240 volts first. If it is not left on for any great length of time, no harm will be done even if it is a 240 unit. If you have an amp meter, you can always check the amperage against the pot size. If it is not correct for the motor rating, you will have the wrong voltage. This is no problem; forget it. Just note the voltage when you first check a pot. The kind of refrigerant will likewise be found on the name plate of the pot; and if there is absolutely no indicator of the gas, here, too, you can use your own judgment. In most cases, if the pot is one horsepower, it may be F-12. So what? If you put the wrong gas in a unit, it will not run properly, if it will run at all. But no harm will be done. It will take you only a minute to know that you must switch to the other gas. As a general rule, you can say that 99 percent of all window units will use F-22; and 99 percent of all fractional horsepower window units, like 1/2 and 3/4 horsepower, will use F-12.

We noted that this unit was 240 and F-22. You look carefully with your flashlight and find nothing to indicate trouble. Everything looks clean and operative.

CHAPTER 10

HOUSEHOLD REFRIGERATORS AND AUTO AIR CONDITIONING

Dry air itself does no particular damage to a refrigeration system other than taking the place of the refrigerant. Big rocks in the gas tank of your automobile would do no particular damage; but if there were enough of them, they would take up the space normally occupied by gas; and you would have an undersize gas tank. Air will fill up the condenser space where the Freon normally condenses, and this will cause a condition that is equal to cutting down the size of the condenser. If you will remember that the manufacturer has already cut the size of the condenser to the minimum to meet competition, then you will be acutely aware of the fact that if any air is let into a refrigeration system, the normal head pressure will be increased in proportion to the amount of air in the system. Said in another way, air in the condenser of a unit is equal to putting rocks in the radiator of your automobile. You will agree that if you put enough rocks in the radiator of your automobile, the temperature of the cooling water may be increased to the danger point. Air displaces the normal condensing refrigerant. The air contained in the charging hoses and gauge manifold could be enough to effect the head pressure of a small system like a household box, home freezer, a window unit if this air is permitted to enter the system. The manufacturer has made the condenser just big enough to get the condensing job done and no more; therefore, if the condenser capacity or efficiency is effected by an alien gas, it would not operate properly if it operates at all.

Never confuse air with water. Air is made up of many gases like oxygen, nitrogen, hydrogen, and so on. Some of these gases contained in air will condense under extremely high pressure, but not at the pressure of the normal refrigerating unit. For this reason, we call air a non-condensable gas. Water will condense, and it will in turn change into a vapor and from a vapor back into a water state. Water is actually a refrigerant like Freon, but it is of no value as a refrigerant like Freon, simply because it does not evaporate fast enough to do any work in the temperature range that we humans live in.

There is a good chance that you will never let enough air into a system to do any appreciable damage by reason of the air alone; however, air will and does carry large amounts of water. In one cubic foot of air on a humid day, there may be as much as one teaspoon full of plain water. Air soaks up water and becomes saturated. This is something that you already know; however, it would be a wise refrigeration man who remembers that any air that he lets into a system may carry some water in the form of an invisible vapor. This water vapor will condense out of the air when it is put under pressure in the condenser of a unit. Likewise, moisture will condense out of the air if it is cooled to the right dew point in the evaporator. You know this from having taken something cold out of the refrigerator and having water or sweat form on the surface. This sweat was the water condensing out of the air in the kitchen onto the surface of the cold vessel taken out of the refrigerator. If this same air were inside of a unit circulating with the gas and it came into contact with the cold evaporator, the water would condense out of the air, even though the dry air would keep on circulating or end up trapped in the top of the condenser. It is possible to get water into a system by carelessness, and it is possible that a water-cooled condenser could rupture and let water into a system when the gas was all leaked out. Likewise, a serviceman could be using water around a system when he was working and let water in accidentally. However, as a general rule, you can say that when a system is saturated or has moisture in it, the moisture came from a leak. That is, a leak developed and the gas escaped; and when the gas pressure was all gone, the unit continued to run and sucked in air. The moisture in this air is condensed out inside of the system. The unit now has water in it as a result of a gas leak. The colder a system is, the more likely it is to accumulate moisture as a result of a leak; therefore, whenever you open up any system that is still cold or frosty, you must be doubly careful that you do not let any air into the system. In fact, a cold evaporator will condense water just as fast as the air carrying the water enters the coil.

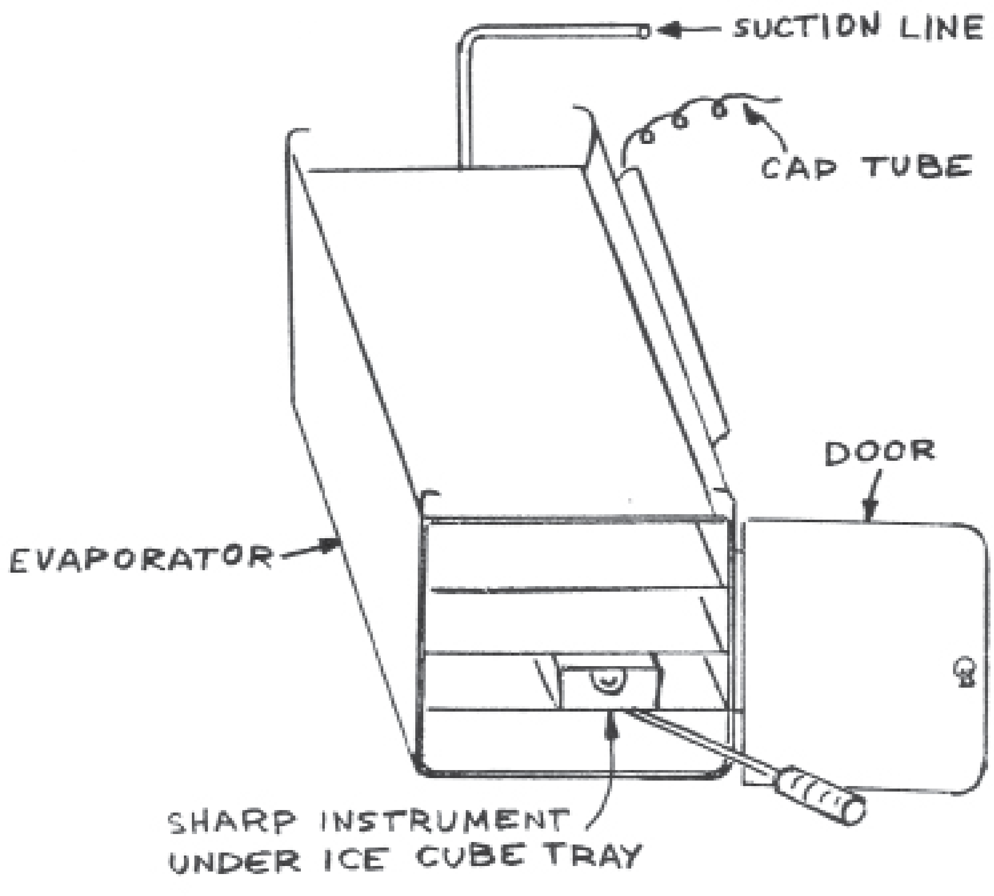
It is important that you know that even though you get the air out of a system, it may have given up its moisture inside the system. This is the case where you let air get into a cold space like a frosted up evaporator. The moisture would condense out of the air very quickly; and when you purge the air out, all you would be getting out would be dry air.

Up to this point we have discussed air and moisture in general terms. Now, it can be nailed down to specific units. Start with a household refrigerator.

These boxes are the worst kind to quit because of moisture. Any water that is in this system will freeze into a solid plug of ice right where the cap tube feeds the refrigerant into the evaporator (ice cube maker). This plug of ice will stop up the flow of liquid refrigerant. The unit will pull down to a vacuum and defrost and will not freeze again until this ice plug is melted and the water pulled out with a vacuum pump. Step by step, let's take a look at a box in a home that is getting a full slug of water.

One of the most common ways that water gets into a household box system is by punching a hole in the evaporator with an ice pick or sharp instrument. Much of the repair work you will do on a household box that has lost its gas is the result of someone trying to defrost the evaporator with an ice pick or trying to pry out a frozen ice cube tray with a sharp instrument.

See this drawing in **Figure 10-1**:



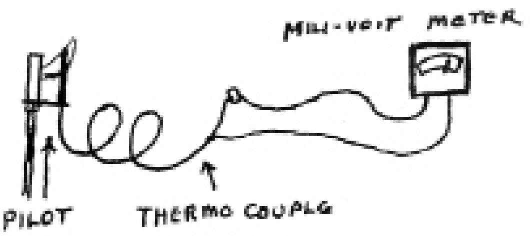
(Fig. 10-1)

CENTRAL HEATING SERVICE CHECK LIST FOR FALL LIGHT-UPS

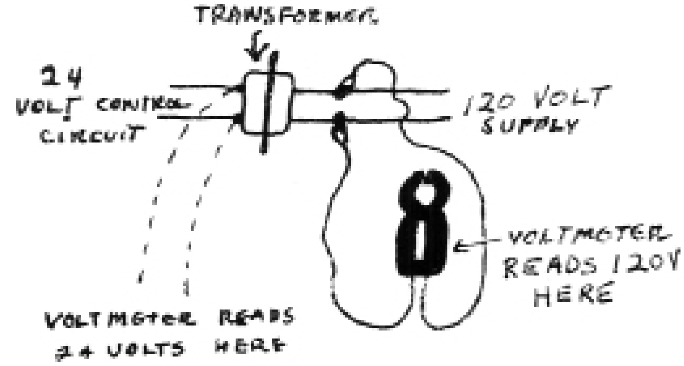
1. Check air filter. If the filter is dirty, be sure to clean or replace.
2. Inspect fan and blower motor. Oil both if not self-lubricated.
3. Inspect belt. If the belt is frayed or cracked, replace it.
4. Clean pilot burner and light. Be sure to have a clear blue flame.
5. Check safety pilot and be sure it is operating properly.
6. Check the operation of the solenoid valve and be sure it will open and close properly.
7. Check the differential and make changes on the heat anticipator if needed.
8. Check out the operation of the fan control. Be sure that the fan will come on and go off properly.
9. Check and be sure the limit switch will operate. This can be done by removing the belt or removing the common wire on direct drive motors and turning on the main burner.
10. Let the heater operate through several heating cycles. You can do this by changing the setting on the thermostat manually.

SERVICE POINTERS FOR CENTRAL HEATING

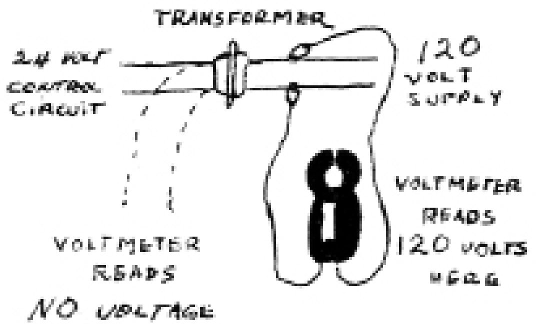
1. Heater will not come on.
   A. Check pilot light. If it is off, clean and light.
   B. When pilot light all right, check thermocouple. It may be bad and need to be replaced.
   C. Check voltage supply to transformer; if all right, check transformer to be sure of voltage to the control circuit.
   D. Check and see if solenoid valve will open.
   E. Check thermostat and be sure the points are making contact.
2. Heater cycles off-and-on too often.
   A. Check heat anticipator settings.
   B. Check the setting of the limit control. If set too low, it would cause the fire to cycle often.
3. Heater takes too long to heat the house.
   A. Check for dirty filter which would cause a restriction to the air flow.
   B. Check for loose fan belt, fan not running at full speed.
4. Heater will not cut off, house overheating.
   A. Check thermostat to see that the points are opening.
   B. Check and make sure the solenoid valve is not stuck open. If it is, be sure to replace it.
   C. Check the control circuit and be sure there is no short circuit.
5. Fan runs constantly.
   A. Fan control stuck closed; replace it.



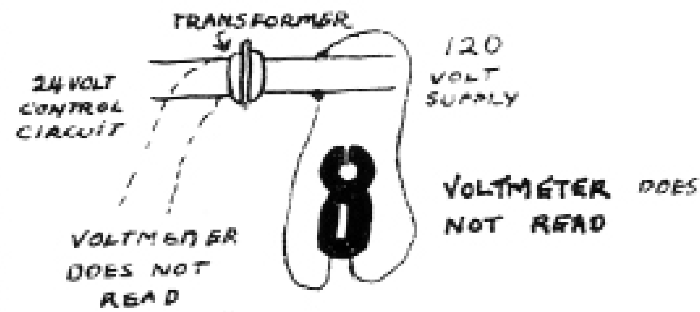
Checking thermocouple with milivolt meter. A reading of around 30 millivolts indicates good thermocouple.



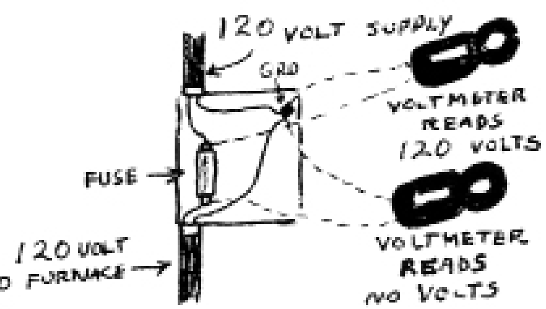
Transformer Checks OK



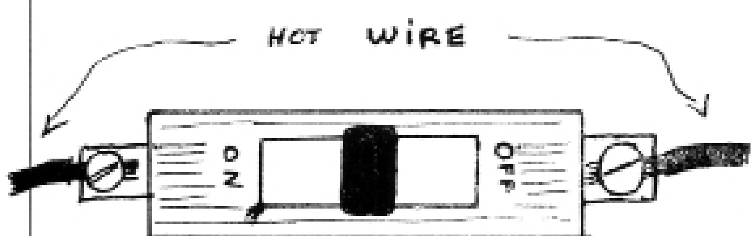
Transformer Checks Bad



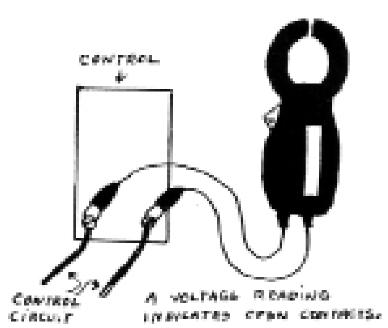
No Power To Transformer



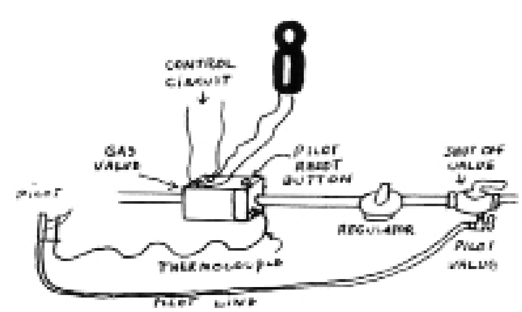
Fuse Shows Blown if top meter reads 120 volts and bottom meter reads no voltage fuse is blown



When breaker is in half way position, breaker is tripped. Turn to off position then back on, to reset breaker.



A reading of no voltage indicates contacts are closed.



If voltmeter reads 24 volts with pilot reset good gas valve is bad

HEATING TROUBLE SHOOTING GUIDE

COMPLAINT	CAUSE	REMEDY
A. No heat.	1. Pilot light off.	1. Check and see if pilot is on 100° shut off.
	2. Thermocouple bad.	2. Replace thermocouple.
	3. Milivolt coil in pilot reset bad.	3. If milivolt coil is built into valve replace valve. If pilot safety is remote, replace pilot safety only.
	4. Pilot orifice dirty not letting enough flame burn across the thermocouple.	4. Clean pilot orifice.
	5. Draft in furnace burner, causing thermocouple to fail. Pilot blows away from the thermocouple in this case.	5. Check for cracked heat exchanger first. If OK, eliminate unusual draft.
	6. No power to furnace.	6. Replace fuse or reset breaker, and find reason for failure of either.
	7. Bad transformer.	7. Check size and voltage of transformer. Check for shorted 24 volt circuit.
B. Burner will come on but fan will not run.	1. Fan control contacts not closing.	1. Replace fan control
	2. Setting of fan control too high.	2. Set fan to cut in at approximately 140 degrees.
	3. Fan motor defective.	3. Check power at fan motor terminals, and replace if defective.
	4. Fan motor will come on but fan will not run.	4. Check for broken fan belt.
C. Burner cycles on thermostat normally but fan will not cut off.	1. Fan control contacts stuck.	1. Remove one wire of fan control. If fan cuts off, replace stuck control.
	2. Fan control cut out set too low.	2. Set fan control to cut out at approximately 110 degrees.
	3. Fan set in manual position.	3. Check to see if fan has manual position. Turn to automatic.
	4. Thermostat set on continuous fan.	4. Set thermostat to auto position.
	5. Fan relay stuck.	5. Replace fan relay.

CHAPTER 13

HEAT PUMPS

Heat pumps are an intricate piece of machinery, requiring more knowledge than what the average serviceman has. Refrigerant charges have to be accurate and the heat pump is more complex than the common Central Heating and Cooling systems.

Heat pumps have been around for many years especially making a big show around the late 1950s and early 1960s. At this time they were more popular in warmer winter climates such as Florida, Southern California and deep southern states.

Today, heat pumps are making big advances in all climates. High fossil fuel costs (butane, propane and heating oil) have turned people's interests in its direction. Where only electricity is available heat pumps are common, since the electrical cost to operate a heat pump is as much as 30% less as compared to heating with electrical resistance heat.

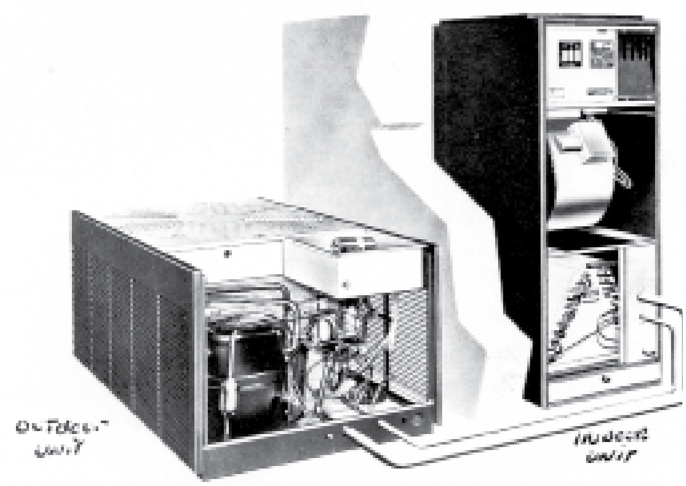
Heat pumps can be complicated when servicing them. If you do not have a complete understanding of how the heat pump operates and you can't readily answer questions by the customer, they will quickly diagnose you as inexperienced. This section will give you the savy to answer questions, make quicker observations and more knowledgeable in making the repair.

HOW THE HEAT PUMP WORKS

Cooling — During cooling season, the heat pump works like any other summer air conditioner. It uses an indoor coil, a compressor and an outdoor coil to remove heat from inside the home or office to outside. Fans move air across the coils and circulate air in the conditioned space. A thermostat turns the fans and compressor on and off as cooling is needed. Hotter weather means more cooling is required, so the unit will run longer. When the temperature is highest, the unit may run continuously for several hours.

Heating — In the heating season, the use of the coils are reversed. The outdoor coil picks up heat from outside air (remember there is heat in air down to absolute zero -460°F) and the indoor coil releases this heat to warm the conditioned area. Colder weather increases heat needed and the unit runs longer. In most areas the temperature will sometimes drop low enough that the heat pump will run continuously. This outdoor temperature, at which the heat needed is equal to the heat pump's capacity, is known as the system's "Balance Point." This temperature will vary with each installation, depending on the heat loss of the area and the size of the heat pump selected. Below the "Balance Point," the heat pump will run continuously and the auxiliary resistance heat will be cycled on and off by the thermostat. Heat pumps can continue to operate effectively at outdoor temperatures below 0°F.

Always remember this, and be sure the customer knows that discharge air temperatures in the conditioned area, using heat pumps, will only operate 15° to 30° warmer than room temperature. The air will feel drafty if blown directly on a person. People who have used gas heat or some other type of heat will have difficulty in understanding this. However, the temperature of the conditioned area should have no problem maintaining its temperature set point at the thermostat. At this point you will find it better to refer to the condenser as the *outdoor coil* and the evaporator as



the *indoor coil*. The outside unit should be referred to as the *outdoor unit* and the inside fan and coil the *indoor unit*. This terminology will make heat pump conversations easier to understand.

Defrost Cycle — When the outdoor temperature drops below 45°F, frost may occur on the outdoor coil. Frost build up will be heaviest on damp days with the temperature at 35° to 40°F. The heat pump has an automatic control which will reverse the system and stop the outdoor fan to defrost the coil when needed. When the reversal takes place, we are actually going back to an air conditioning cycle whereas the outdoor coil becomes the condenser and melts the ice away. Some units operate on a timer at 45 to 90 minute intervals. Others have an electronic control, which senses coil and air temperatures to determine when a defrost cycle is needed. They may go as long as 6 hours between defrost. The coil may be almost completely covered with frost at times. Don't worry unless it continues to build up a thick layer with areas of hard clear ice. If excessive ice build-up occurs, then service is needed.

When the heat pump is defrosting, a cloud of steam may rise from the outdoor unit for a short time. This is normal and harmless, but may be diagnosed as smoke by the customer, more especially if they have never experienced this before. The water, which runs from the defrosting coil, must be drained away from the unit. In areas where snow is common, the unit must have legs long enough to be kept above the snow level.

IMPORTANT THINGS TO REMEMBER ABOUT THE HEAT PUMP

1. Water must drain away from the outdoor coil.
2. The outdoor unit must be above snow level.
3. Install the unit so roof dripping will not build up on the outdoor coil.
4. Do not install the unit where snow most commonly drifts.
5. Select the sunny side of a building, away from the north wind to make use of the sun's radiant heat.

THE THERMOSTAT

The heat pump thermostat is much different than the conventional heating and cooling stat. It will have switches to select some or all of the following functions **(Fig. 13-1)**.

Cool — Turns cooling on when temperature rises above the set point. Contact is made through a sealed mercury bulb in the stat.

Heat — Turns heat pump heating on where temperature drops below set point. If room temperature drops another 2°, turns on auxiliary resistance heat with heat pump continuing to run.

Auto — Turns on cooling or heating as required to maintain set points. Most thermostats have at least 4° separation between heating and cooling settings.

Off — Turns heating and cooling modes off (fan may still run in Fan/On).

Fan/On — Turns fan on for continuous operation (leave in auto for best electrical conservation and humidity control).

Fan/Auto — Fan cycles on and off with cooling or heating operation.

Emergency Heat — Turns heat pump compressor and outdoor fan off and provides heat from electric resistance heat only. Use this switch to manually turn the heat pump off and change to auxiliary heat in case of heat pump problems.

A lever is used to set the temperature desired. Some stats have two levers, one for heating and one for cooling.

Lights may be used to indicate that the auxiliary electric heat is operative. The lights may be different colors on different types of stats. Typical lights will be blue or green for normal auxiliary heat and red for emergency heat.

To operate most economically, do not change the temperature setting up more than 2°. Above 2° will bring on the auxiliary heat with the heat pump operating. If a higher temperature is required, be patient and go 2° at a time.

Night Setback Thermostats — Night setback thermostats are available to automatically turn the temperature down at night and back up in the morning.

(Fig. 13-1)

Only setback thermostats with gradual, incremental or intelligent recovery should be used with heat pumps. Setback stats without gradual recovery will use the auxiliary heat strips to warm air in the morning, and may use more electricity than was saved at night. Ask your parts supplier for recommendations before installing a setback or "Energy Saving" stat.

Heat Pump Monitor — A control called a heat pump monitor may be installed with the heat pump system. If so it will check the performance of the heat pump and turn it off if a problem occurs. It will switch to auxiliary heat and turn on the emergency heat light on the thermostat to tell you that the system requires attention.

Operating Economically — To prevent nuisance calls from your customer and to help the customer economically, here are some tips to improve system efficiency.

1. Keep all grilles and registers open and clean of obstructions. The system is designed to deliver 450 CFM of air per ton. Restricting that air could damage the unit or cut off on a safety control.
2. Keep doors and windows closed. Fresh air is not needed.
3. Be sure all air ducts are well insulated (2 inches minimum) and all joints taped tight.
4. Advise the customer to let sun through windows in winter and keep out in summer.
5. Be sure clothes driers are vented to outside away from outdoor unit.
6. Fireplaces are pleasant, but fireplaces infiltrate more outside air for combustion and flue draft than they heat. The heat pump may actually run more. Even though the thermostat setting may be keeping the area warm, the excessive draft may make the occupant feel cold. This is even more common with a heat pump since the registry air discharge is cooler than most heating systems.
7. Use kitchen and bathroom exhaust fans only when necessary.
8. Add insulation, storm windows and insulate outside doors. Seal cracks to prevent air leaking. This is advise you would give to the customer.
9. Keep filters clean. Reduced air flow reduces efficiency.
10. Operate the indoor fan on "AUTO." It will cost less and will provide better humidity control in the summer.
11. Keep lamps, TV and other heat sources away from the thermostat.

EFFICIENCY

EER — Most people are very conscious of the EER or energy efficiency ratio, and rightly so. The higher the EER the more savings received from operation. The EER is used when the compressor is used and is nothing more than how many Btu you are getting out of every watt of power put in. It is determined by dividing the total capacity (in Btu/hr) of the system by the total electric power consumed in watts/hour. For example, if a three ton heat pump operating on a 40°F outdoor temperature has a heating capacity of 39,000 Btu/hr and is using 4,380 watts per hour, then the EER would be 39,000 Btu/hr over 4,380 watts/hr= 8.9 Btu/watt or EER = 8.9.

$$EER = \frac{39{,}000}{4{,}380} = 8.9$$

It would be easy to understand that an EER of 10.0 is more desirable than an EER of 7.0, because the EER of 10.0 means that you are getting 10 BTU's of cooling for each watt consumed.

Heat pumps are more economical than straight electric heat. We can measure this economy using either of the following rating methods.

One method is the energy efficiency ratios or EER, which is used to rate any air conditioning system. Another method, which has been used for years when discussing the efficiency of a heat pump, is the coefficient of performance or COP. No matter which method is used, a knowledge of how they are determined is important.

COP — This is the coefficient of performance for a heat pump. To determine COP of a heat pump, the following formula can be used. COP = Btu/hr capacity over unit wattage X 3.413 Btu/watt. If we use the same three ton unit as in the last example, the COP would be 39,000 Btu/hr over 4,380 watt X 3.413 Btu/watt = 2.6.

$$COP = \frac{\text{Btu hr}}{\text{Watts} \times 3.413} \quad \text{or}$$

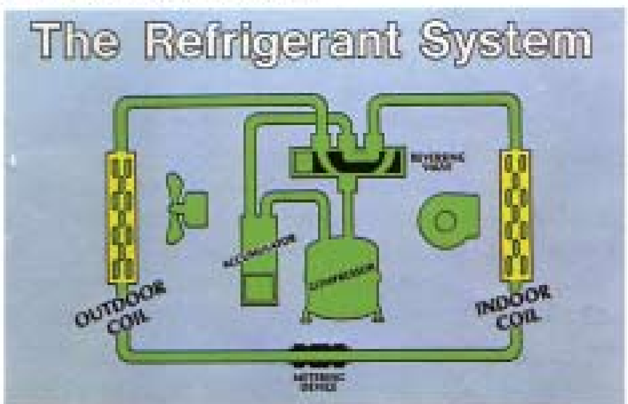
$$COP = \frac{39{,}000}{4{,}380 \times 3.413} = 2.6$$

This indicates just how efficient the unit is when compared to electric resistance heat. When electric heat is used it generates 3.413 Btu of heat for each watt. Therefore, the COP of straight electric heat is (1.0) and can never be any higher. When comparing the COP of the heat pump with that of an electric heater, we find that the heat pump can deliver more heat per watt of power used. The heat pump is therefore more efficient.

Under the operating conditions in our example, the heat pump will deliver 2.6 times as much heat as our electric resistance heater using the same wattage.

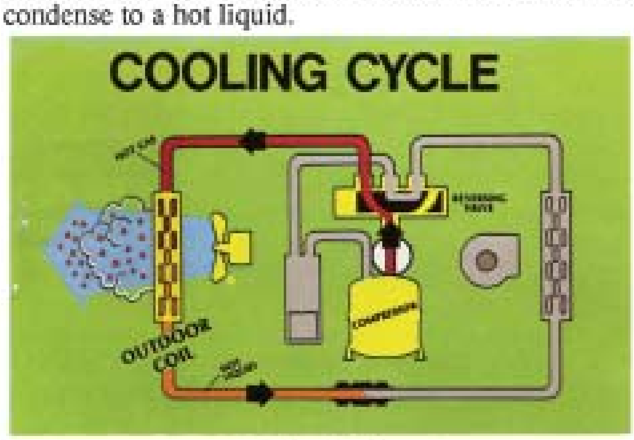
THE REFRIGERATION CIRCUIT

The first step in understanding the heat pump is to know how the refrigeration system works. Since the basic concept used for changing the unit from cooling to heating cycle is to reverse the refrigerant flow, each coil will act as a condenser or as an evaporator depending on the direction the refrigerant is flowing, so the coils are referred to by their location in the air stream rather than their function (**Fig. 13-2**). The indoor coil is located in the indoor air stream and the outdoor coil is in the outdoor air stream.



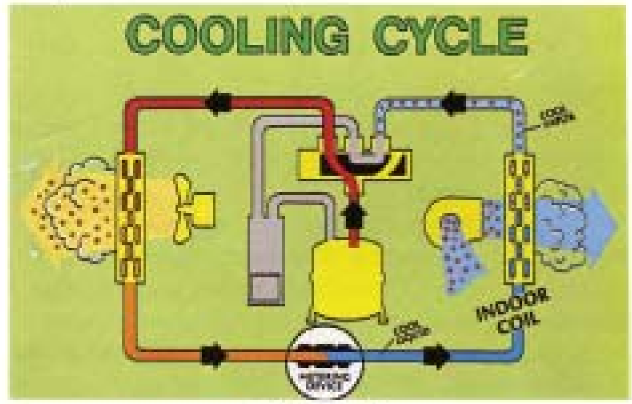
(Fig. 13-2)

Let's trace the flow of refrigerant through a typical heat pump during the cooling cycle when the unit is removing heat from the conditioned space and rejecting it outdoors (**Fig. 13-3**). Starting at the compressor discharge, the hot gas is discharged to the reversing valve, which directs it to the outdoor coil. The outdoor coil acts as a condenser. Outdoor air circulated over the coil removes heat from the refrigerant and causes it to condense to a hot liquid.



(Fig. 13-3)

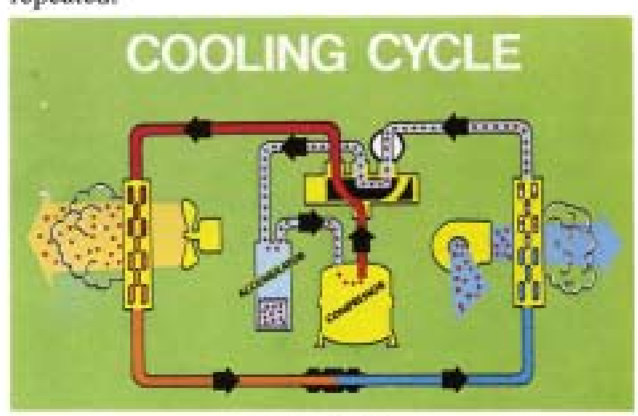
The liquid refrigerant now passes through a metering device (**Fig. 13-4**), where the pressure is reduced causing some of the liquid to flash off and cool the remaining liquid to a lower temperature. This cool liquid passes to the indoor coil which acts as an evaporator. The liquid boils and absorbs heat from the indoor air passing over the coil causing the refrigerant to evaporate into a cool vapor.



(Fig. 13-4)

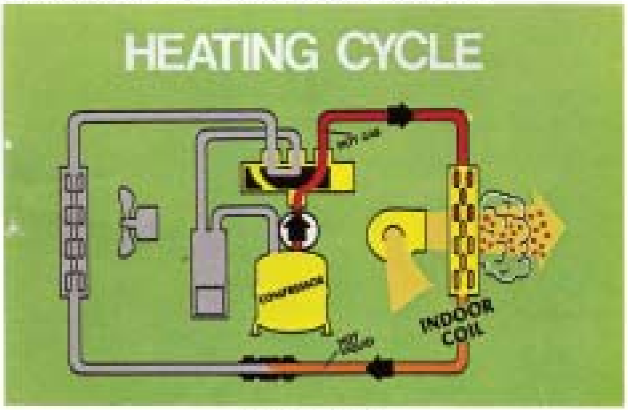
It is important at this time to know that heat from the air crossing the evaporator is enough to make a refrigerant boil since the boiling points of refrigerants are lower than air temperatures and therefore absorb heat.

In Figure 13-5 the cool vapor now passes through the reversing valve which directs it to the accumulator, where any liquid refrigerant will be trapped and then back to the compressor where the gas is compressed to a high pressure, high temperature gas and the cycle is repeated.



(Fig. 13-5)

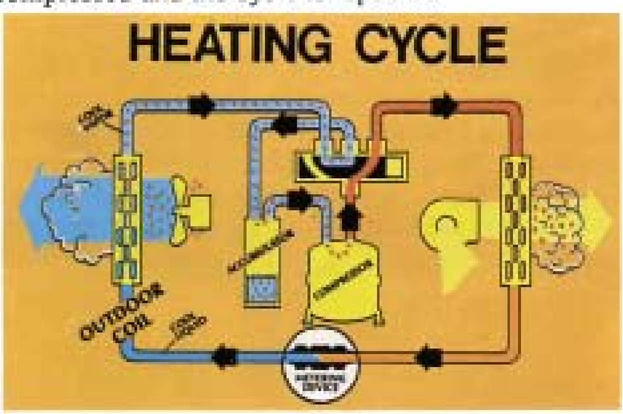
During the heating cycle, (**Fig. 13-6**) when heat is removed from the outside air and rejected indoors, the hot gas discharge from the compressor is directed by the reversing valve to the indoor coil. The indoor coil now acts as a condenser. The indoor air picks up heat from the refrigerant as it passes over the coil and causes the refrigerant to condense to a hot liquid.



(Fig. 13-6)

In **Figure 13-7** the liquid refrigerant now passes through a metering device where it flashes to a low pressure, low temperature mixture of liquid and vapor. The mixture now passes to the outdoor coil.

The outdoor coil acts as an evaporator. Heat from the outdoor air is absorbed into the refrigerant as it boils into a cool vapor. The refrigerant gas goes through the reversing valve which directs it to the accumulator and back to the compressor where it is compressed and the cycle is repeated.

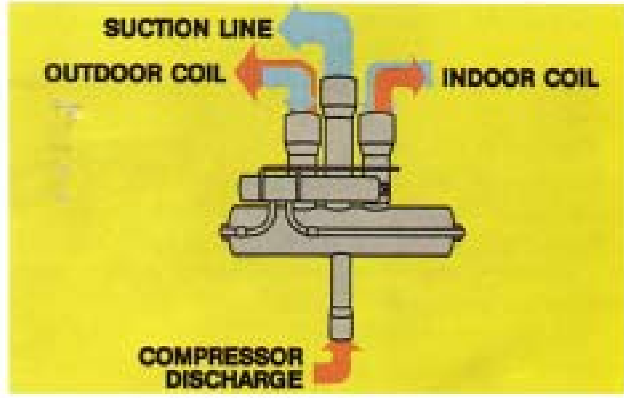


(Fig. 13-7)

From the cycle diagrams, you can see that heat is in fact moved by the heat pump. The total amount of heat rejected by the coil, (indoor coil) which is acting as a condenser, is equal to the total heat absorbed into the system plus the heat of compression.

When a heat pump is operating in the higher temperature range, the heat of compression is only a fraction of the total capacity of the system.

As the outdoor temperature drops, so does the heat pump's ability to absorb heat. This results in a decrease in capacity of the unit. For example: A three ton heat pump may be capable of putting out 39,000 BTU's of



(Fig. 13-8)

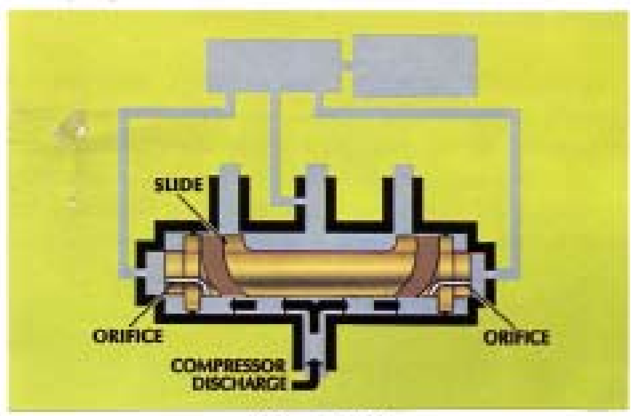
heat with the outdoor temperature being at 45°, but on a 20° day, it may only put out 22,000 Btu of heat. At some temperature, the heat pump will not be able to supply enough heat to maintain comfort conditions, so some form of supplemental heat must be provided, generally electric resistance heat. This will be discussed in detail later.

In order to make the process of transferring heat work for both heating and cooling cycles, the direction of refrigerant flow must be controlled. The device that controls the direction of refrigerant flow in a heat pump is called the reversing valve **(Fig. 13-8)**.

There are four piping connections on the reversing valve. There are two directions of flow that are never changed and they are the hot gas discharged from the compressor and the suction line back to the compressor.

The remaining two ports connect to the outdoor and indoor coils. The direction of flow depends on the cycle.

The valve is solenoid controlled. A typical reversing valve directs the refrigerant flow by using a free floating slide inside a cylinder **(Fig. 13-9)**. The slide changes position by refrigerant pressure. As this slide



(Fig. 13-9)

Doolins Trouble Shooters Bible

T e s t Q u e s t i o n s

These test questions have been developed for use by those who are using the trouble shooters bible as a text book or study guide.

The Publishers
Doolco, Inc.

CHAPTER ONE

1. Heat is always present until
   A. a substance becomes cold
   B. the freezing point of 32⁰F is reached
   C. absolute temperature is reached

2. Absolute zero is considered as the temperature in which
   A. freezing of water occurs
   B. absolute temperature is reached
   C. there is no longer a sense of heat felt by touch

3. Heat will always flow
   A. from a warmer body to a colder one
   B. as long as a substance is at its freezing point
   C. as long as a refrigeration device is in operation

4. The purpose of a home refrigerator is
   A. to store foods and dairy products
   B. to remove the heat present in stored products
   C. to remove some of the heat in products down to a desired temperature for food preservation

5. Any time a liquid changes to a vapor it must
   A. absorb heat
   B. absorb heat up to its boiling point
   C. cool it down

6. The purpose of a mechanical refrigeration system is to
   A. remove heat
   B. run long enough to cool
   C. remove heat from one confined area and reject it into the atmosphere

7. Freon refrigerants are used in refrigeration machines because
   A. it is easy to contain in the system
   B. it has a low boiling point
   C. it does not contaminate the atmosphere

8. The purpose of the evaporator is to
   A. give up heat
   B. absorb heat
   C. to freeze water

9. The purpose of the condensor is to
   A. give up heat
   B. absorb heat
   C. lower the volume of refrigerant

10. When a liquid refrigerant absorbs heat it
   A. boils and gets hot
   B. starts the refrigerant moving in a cycle
   C. boils and gets cold

11. Refrigerant 12 (Freon 12) boils at a temperature of
   A. -21.7 below zero
   B. at212^{O}F
   C. as soon as vapor appears

12. In considering pressure and temperature relationship we should always assume that
   A. wherever there is pressure there will be temperature
   B. for every given pressure, refrigerants will always boil below zero
   C. for every given pressure, the temperature will always be in direct relationship to that pressure

13. Using your pressure-temperature chart, let's say you have a pressure of 37 PSI using refrigerant 12. What will be the refrigerant temperature?
   A. 40^{0}F
   B. at freezing point
   C. 32^{0}F

14. Answer the same question as before, but use refrigerant 22.
   A. around freezing
   B. it would be the same as R-12
   C. around 15^{0}F

15. The purpose of the metering device (capillary tube) is to
   A. make a connection between the condensor and evaporator
   B. have a certain length of small tubing to maintain a constant amount of refrigerant to be fed into the evaporator
   C. to maintain a constant load on the compressor

16. The three main components in the refrigeration cycle are
   A. the evaporator, capillary tube and the condensor
   B. the evaporator, connecting tubing and the condensor
   C. the evaporator, the condensor and the compressor

17. The refrigeration cycle connects and flows as follows
   A. from the compressor to the condensor - condensor to the metering device to the evaporator - then back to the compressor
   B. from the compressor to the evaporator - into the capillary tube - into the condensor and back to the compressor
   C. from one component to the other until depending on the size of the capillary tube

18. When a refrigeration system is low on refrigerant, you can expect the evap-orator pressures to be
   A. just about right
   B. a little too high
   C. lower than normal