COMFORTGUARD

H.V.A.C.

CORRESPONDENCE MANUAL

PRESENTED
BY
R.V. PRODUCTS

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RV Products
A Division of AIRXCEL, Inc.

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LESSON I

THE REFRIGERATION CIRCUIT AND AIR FLOW

This portion of the course is structured to acquaint the service technician with basic refrigeration theory and operation principals associated with ComfortGuard air conditioners, while providing the knowledge necessary so that when he has a problem he can intelligently analyze and isolate the problem and efficiently correct it. It is not, however, the intention of this course to teach the service technician how to make sealed system repairs, braze refrigerant lines, use vacuum pumps, or charge a/c systems. A study such as this is to intense to be included in a correspondence course and would require a great deal of hands on experience. This type of instruction may be received at your local trade school. Courses are also offered by the Refrigeration Service Engineers Society (R.S.E.S.).

There is nothing new in the following discussion of basic refrigeration! Everything in it is known and stated in many books on refrigeration. As you study this text, it will take you through a basic refrigeration circuit in a logical order one step at a time. Always discipline your study so that you thoroughly understand each word -- each sentence -- each thought --. The next new study idea will then be reasonable, logical, and easily understood.. Upon completion of the following section the Student will be able to:

1) **IDENTIFY BASIC REFRIGERATION COMPONENTS AND EXPLAIN THEIR FUNCTIONS.**

2) **UNDERSTAND BASIC REFRIGERATION TERMINOLOGY.**

3) **DESCRIBE THE REFRIGERATION PROCESS (HEAT TRANSFER).**

4) **EXPLAIN THE EFFECTS OF AIR FLOW ON THE REFRIGERATION SYSTEM.**

5) **CORRECTLY TROUBLESHOOT THE REFRIGERATION SYSTEM.**

A. Compressor
B. Discharge Line
C. Condenser Coil
D. Thermostatic Expansion Valve
E. Evaporator Coil
F. Suction Line
G. Evaporator Motor and Condenser Motor
H. Evaporator Blower Wheel
I. Condenser Fan Blade
J. Refrigerant Charge (Not Shown)
K. Filters (Not Shown)

A. Compressor

A device that uses compression to raise the pressure, temperature, and saturation point of refrigerant vapor. The compressor is called a hermetic compressor which means that is completely sealed (welded together). It is therefore, not internally field serviceable. Inside the compressor housing are basically:

1) an electric motor which drives the compressor

2) a pump which is designed to pump superheated vapor

3) a supply of special refrigeration oil. A small portion of the oil will circulate out through the system with the refrigerant, but will constantly return to the compressor with the refrigerant, so the compressor will not run out of oil

When operating properly, the compressors function is to raise the vapor pressure and corresponding saturation point (condensing point) of the refrigerant. The compressor raises the saturation point (to one that is high enough to allow heat removal) in the condensing coil.

B. Discharge Line

The discharge line carries the refrigerant out of the compressor and to the condenser coil. Remember that as the refrigerant entered the compressor, it was a superheated vapor. As the compressor works on the refrigerant, it adds more heat and also compresses the refrigerant into a smaller space. The refrigerant, therefore, leaves the compressor highly superheated - so if the discharge line is hot to the touch (burns), don't be surprised - it should be.

C. Condenser Coil

The purpose of the finned condenser coil is to transfer heat from the high pressure refrigerant to the warm outdoor air. As the outdoor air passes over the coil, the heat transfer will cause the air temperature to rise. The condenser discharge air will be several degrees warmer than the air entering the condenser. As the refrigerant passes through the first few tubes of the condenser, its temperature will be lowered or it will be desuperheated. After the refrigerant is desuperheated, it will begin to condense or change from a vapor to a liquid and will remain at a nearly constant temperature throughout most of the remainder of the coil. This temperature is called the condensing temperature or high side saturation temperature and will always be higher than the condenser entering air temperature. Near the bottom of the condenser, the refrigerant will all be condensed to a liquid and from there on its temperature will drop to more nearly the temperature of the outdoor air. After the temperature of the refrigerant drops below condensing or saturation temperature, we call its condition sub-cooled liquid. During all of the three processes in the condenser (desuperheating, condensing, sub-cooling), the refrigerant gives up heat; but most of the heat is given up during the condensing process.

D. Thermostatic Expansion Valve

The thermostatic expansion valve (TXV) meters the refrigerant to the evaporator using a thermal sensing element to monitor the superheat. This valve opens or closes in response to a thermal element. The TXV maintains a constant superheat in the evaporator. Remember, when there is a superheat, there is no liquid refrigerant. Excess superheat is not desirable, but a small amount is necessary with this valve to ensure that no liquid refrigerant leaves the evaporator.

E. Evaporator Coil

When the liquid refrigerant passes from the cap tube to the evaporator, it is at low side pressure and will therefore, vaporize at a low temperature as it picks up heat from the air being conditioned. The refrigerant remains at nearly constant temperature (called evaporator temperature or low side saturation temperature) in the evaporator as long as there are both liquid and vapor together. However, near the outlet of the evaporator coil, all of the liquid has boiled (evaporated) away and from there on the temperature of the vapor rises (the vapor becomes superheated). It is necessary that the vapor become superheated because it is headed down the suction line to the compressor and the compressor can only pump superheated vapor. Any liquid (which might be present if the vapor were not superheated) could cause serious mechanical damage to the compressor.

The purpose of the finned evaporator is to transfer the heat from the warm moist indoor air to the cold low pressure refrigerant. As the heat leaves the air the temperature drops and some of the moisture in the air condenses from a vapor to a liquid. The liquid water (condensate) is drained onto the roof of the recreational vehicle. As the heat enters the refrigerant in the evaporator it causes the refrigerant to evaporate (change from a liquid to a vapor). Thus the name - evaporator.

F. Suction Line

Section of copper line connecting the evaporator to the compressor. This line carries low pressure/low temperature refrigerant vapor from the evaporator to the compressor.

G. Evaporator Motor and Condenser Motor

All of these motors are P.S.C. (permanent split capacitor) motors which means it requires a run capacitor to operate efficiently. The fan motors are the heart of the air flow system.

H. Evaporator Blower Wheel

The evaporator blower wheel is driven by the fan motor and is responsible for pulling the air through the return air grille over the filter and through the evaporator coil. The evaporator blower wheel also exhausts the same air through the supply air louvers into the living area of the vehicle.

I. Condenser Fan Blade

The condenser fan blade is driven by the fan motor and is responsible for moving the air flow through the condenser coil and exhausting it out through the louvered area on the sides of the casing.

J. Refrigerant Charge

The systems covered by this manual all use a refrigerant called Monochlorodifluoromethane (better known as R-22).

We know that R-22 is not a deadly gas because many of us have breathed it many times and we are still living. However, no one has said that R-22 is completely safe to breathe; so a wise service technician will always keep his work space well ventilated. IF R-22 IS RAISED TO A HIGH TEMPERATURE IN THE PRESENCE OF WATER (which always exists in the atmosphere), IT DEFINITELY DOES BECOME A TOXIC GAS by changing from virtually harmless R-22 to phosgene, hydrochloric and hydrofluoric acids. If R-22 in the air is exposed to a welding or soldering torch flame, burning water heater burner, burning furnace burner, etc., be sure to avoid breathing it. In addition to being almost non-toxic, R-22 is non-flammable, non-explosive, non-corrosive and miscible (mixable) with oil. It also has a rather high latent heat value. This means that R-22 refrigerant must absorb large amounts of heat per lb. to condense or change from a vapor to a liquid.

K. Filters

The non-allergic natural filters should always be in place when the system is running. More important than their purpose of cleaning the air in the living space is the protection the filters give the evaporator coil. Without filters, a wet evaporator coil will quickly become blocked so that adequate air cannot pass through it. Filters must be installed to completely cover the evaporator coil so that no air can flow around the or by-pass them and carry dust, lint, etc. to the evaporator.

High and Low Side Pressures

It is customary for air conditioning technicians to use the terms high side and low side. In doing so, we refer to the parts of the refrigeration circuit which, when the system is running, contain high pressure refrigerant (high side) and low pressure refrigerant (low side). The high side of these systems exists from the discharge port of the compressor to the expansion valve. The low side is from the expansion valve to the compressor cylinders.

The high side pressure is also referred to as head pressure or condensing pressure, and the low side pressure is also referred to as suction pressure or evaporator pressure.

It is impossible to state the exact pressures that will exist in the high side or low side because those pressures will both vary with different temperature and humidity conditions both inside and outside the sleeper or cab.

REVIEW QUESTIONS FOR LESSON I

FILL IN THE BLANKS:

1. The purpose of the finned condenser coil is to __________________ ___________________ from the high pressure ______________________ to the warm ___________ ___________.

2. The purpose of the finned evaporator coil is to __________________ the _________________ from the warm and moist ___________________ __________________ to the cold pressure _______________________.

3. When operating properly, the compressors function is to raise the ______________________ And corresponding saturation point (condensing point) of the _________________________.

4. Without a ____________________, a wet evaporator coil will quickly stop up so that adequate air ________________________ pass through it.

5. R-22 refrigerant must absorb ____________________ amounts of ___________________ per pound to condense or change from a vapor to a liquid**.**

6. The high side of these systems exists from the _______________________ port of the compressor to the ________________ __________________. The low side is from the ______________________ and compressor _____________________.

LESSON II

REFRIGERATION TERMINOLOGY

1. Refrigeration

Refrigeration as defined in the dictionary, is the process of making or keeping cold. But it involves much more than that. To refrigerate or make something cold, we must remove heat from it. The absence or removal of heat is what produces cold. Notice that we do not say that we destroy the heat – heat cannot be destroyed. Heat can be moved or transferred from one place to another. **WE WILL DEFINE REFRIGERATION AS THE METHOD OF MOVING HEAT FROM ONE PLACE TO ANOTHER.**

2. Refrigeration Machine (Air Conditioner)

A refrigeration machine is actually a heat transfer machine. A mechanical device that produces heat transfer. More specifically, a machine that removes heat from an area where it is not wanted, and transfers it to a different area where the heat is not found to be objectionable.

3. Heat (Thermal Energy)

Heat is molecular motion. Heat is created by the friction of moving molecules. Atoms and molecules are always in motion. This motion requires energy (nothing can move without energy being expended), the energy that produces molecular motion is called heat or thermal energy.

4. Heat Movement

Heat always moves from higher to lower temperatures.

5. Temperature

Temperature is a measurement of the level or intensity of molecular motion (heat). Temperature is not an indicator for a quantity of heat.

6. Refrigerant

In refrigeration systems fluids which absorb heat inside the cabinet and release it outside are called refrigerants. These fluids, in their liquid form, under a reduced pressure absorb heat in the evaporator. In the process of absorbing heat, the liquid changes to a vapor. Now in their vapor form, the refrigerant is taken into the compressor where the temperature and pressure is increased. This allows the heat that was absorbed in the evaporator to be released in the condenser, and the refrigerant is then returned to a liquid state. The refrigerant used in all

ComfortGuard H.V.A.C. air conditioners is R-22 (same refrigerant as in most household air conditioning).

7. Saturated Liquid

Saturated liquid is liquid which is at such a temperature and pressure that if any amount of heat is added, some of the liquid will change to vapor. To say it another way, the liquid that is in contact with vapor is saturated with heat, to the event that if any more heat is added, some of the liquid will be forced into the vapor state. Since this process takes place on the surface of the liquid, it is called evaporation.

In an enclosed cylinder when both vapor and liquid co/exist the vapor will always produce a pressure on the surface of the liquid. The amount of vapor pressure pushing down on the liquid will vary with the gases density and temperature. The molecules at the surface of the liquid are trying to change to a vapor, but if they should, they would raise the pressure of the vapor by increasing its density. The liquid cannot change into a vapor unless the pressure of vaporization is greater than the pressure of the vapor pushing down on the liquid.

In any enclosed cylinder the point when these pressures become equal is called the saturation point. When the pressures are equal the molecules on the liquids surface do not have enough energy to add more pressure to the vapor. The energy that can be added to create more vapor is called thermal energy, molecular motion, or **heat**.

8. Boiling

To boil something is to convert a substance from a liquid to vapor state. This change takes place throughout the liquid and is accompanied by bubbling and turbulence as vapor below the surface rises.

9. Sensible Heat

Sensible heat is heat whose effect on matter creates a change in temperature without causing a change in state. Sometimes described as heat that can be sensed or felt as with a temperature change.

10. Latent Heat

The word latent heat is Latin for hidden heat. It is heat that causes a change of state from a liquid to a gas or gas to a liquid without a change in temperature. It is referred to as hidden heat because the thermometer cannot sense or measure the heats movement or its effect on matter.

11. Latent Heat Of Vaporization or Latent Heat Of Condensation

When a liquid changes to a vapor that process is called vaporization. LATENT HEAT OF VAPORIZATION is what causes that process to occur. When a vapor changes to a liquid that process is called condensation. Condensation is caused by extracting the LATENT HEAT OF CONDENSATION from the vapor. Vaporization is caused by LATENT HEAT OF VAPORIZATION being added. Condensation is caused by LATENT HEAT OF CONDENSATION being extracted. **Note: only a change of state happens no change in temperature.** To cause vaporization or condensation requires a large amount of heat to be added or extracted. Example: The latent heat of vaporization or condensation for H_2O (water) at 212 degrees F. is 970 BTU's per pound.

12. BTU (British Thermal Unit)

A BTU is the amount of heat necessary to raise the temperature of one pound of water one degree Fahrenheit.

13. Tons Of Refrigeration

We often hear of refrigeration capacity referred to in tons of refrigeration. This measure is based on the latent heat of fusion or melting of ice. A ton of refrigeration is the heat removing capacity of one ton of ice melting in 24 hours. Since each pound of ice absorbs 144 BTU's in melting, 2000 pounds (one ton) of ice will absorb 288,000 BTU's per 24 hours, or 12,000 BTU's per hour.

Example: 1 TON = 12000 BTU 2 TON = 24000 BTU 3 TON =36000 BTU ETC.

14. Pressure

Pressure is the weight or amount of force per unit area and is usually stated in pounds per square inch.

REVIEW QUESTIONS FOR LESSON II

FILL IN THE BLANKS:

1. The amount of heat necessary to raise the temperature of one pound of water one degree Fahrenheit is a ______________________________ ______________________________ _________________________________.

2. Heat always moves from ____________________ to ___________________ temperatures.

3. _________________________ _______________________ is heat whose effect on matter creates a change in ___________________ without causing a change in state.

4. We will define refrigeration as a method of __________________ _____________________ from one place to another.

5. A _______________________ ________________________ is a liquid which is at such a temperature and pressure that if any amount of heat is added, some of the liquid will change to vapor.

6. In refrigeration systems, fluids which absorb heat inside the cabinet and release it outside are called _______________________________.

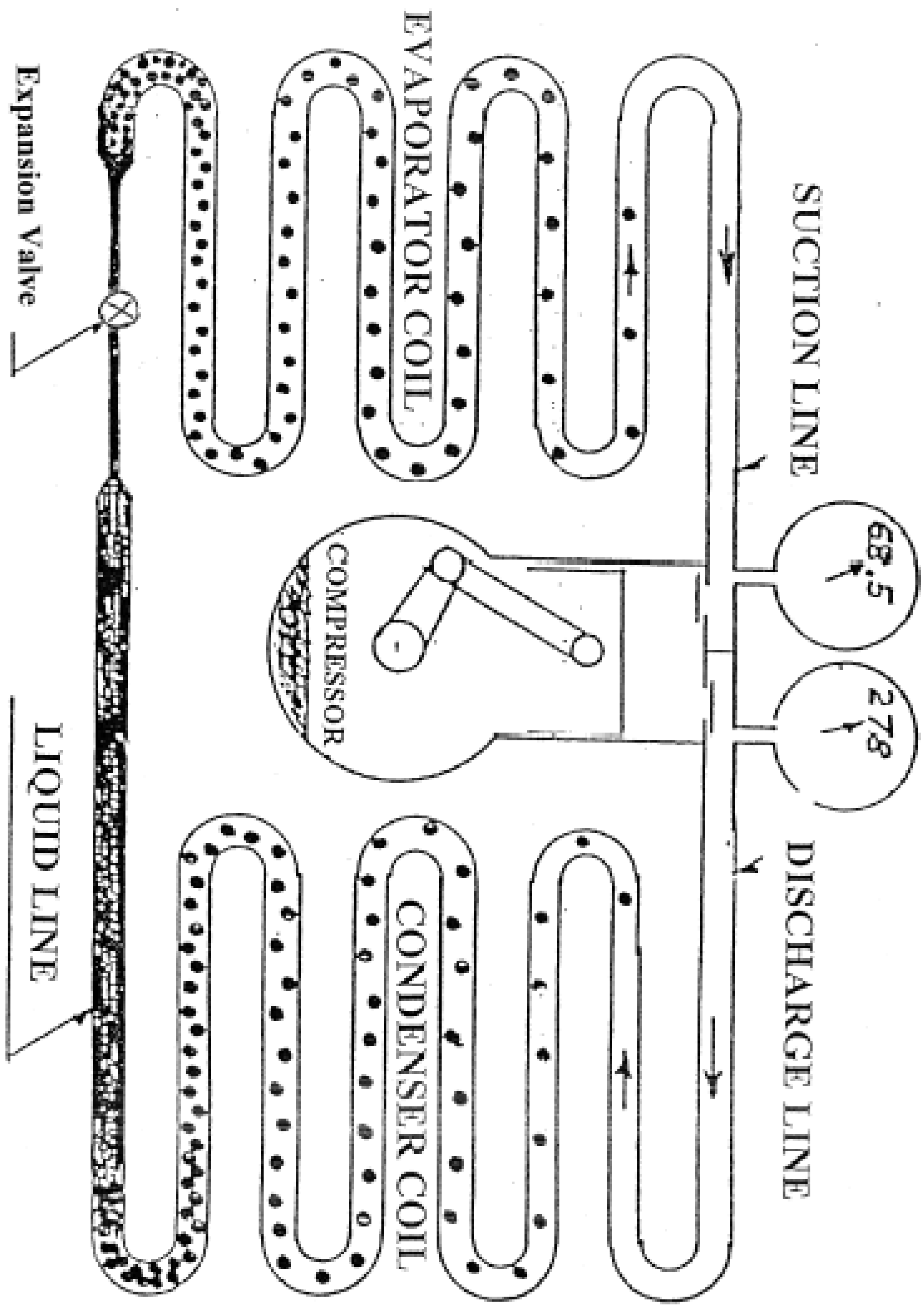
7. ___________________________ _________________________ is heat that causes a change of state from a liquid to a gas, or gas to a liquid without a change in temperature.

LESSON III

HOW YOUR AIR CONDITIONER WORKS

In an earlier chapter we defined an air conditioner as a machine that transfers heat from one place to another. A simple law of physics states that "heat travels to cold." By passing heat-laden air over a cold object, heat is transferred from the air to the object. The air leaving the cold object does so with less heat, hence it feels cold. Almost all of the heat transferred is done through a process of boiling or evaporating the liquid refrigerant in the evaporator. The evaporator gained heat is then taken outside to the condenser coil where the refrigerant now gives off all of the heat that was absorbed in the evaporator to the outside air. How can this be done? The answer is simple - it all comes down to a basic pressure temperature relationship of the R-22 within the system. Take a few minutes and look over the PRESSURE - TEMPERATURE chart located at the end of this lesson. As you might have noticed as the pressure of the refrigerant increases so does the temperature and likewise as temperature increases so does the pressure in a direct relationship. So what does this chart mean? To understand this chart we must look at the different characteristics of R-22. Most of us know that refrigerant exist in this A/C system as a liquid and secondly as a gas or vapor. We also know the refrigerant constantly circulates within the system as long as the compressor is running. So if this is true it is reasonable to believe that at some point the liquid will boil to a vapor and at another point in the system the vapor will condense to a liquid. This condition is called the saturation point. The corresponding evaporating or condensing pressures and temperatures are indented on the saturation chart. Another look at the PRESSURE -TEMPERATURE chart will indicate to you that by adding heat to the saturated refrigerant at 68.5 pounds of pressure the heat will cause the refrigerant to boil at degrees F. and it will continue to boil at degrees F. until the last drop of liquid is gone and all of the refrigerant is changed to a vapor. **Note large amounts of heat are required to boil liquid refrigerant into a vapor.**

Now let’s take a look at the sketch of a basic refrigeration circuit on the following page. This may be considered a normally operating air conditioning refrigeration circuit. The only accessories shown which are not needed are the gauges. The only thing that is essential for operation but is not shown is the motors to drive the air flow over the evaporator and condenser coils. Let's start analyzing it at the evaporator coil. The evaporator has liquid R-22 slowly feeding into it at the bottom. The pumping action of the compressor pushing the liquid through the expansion valve has reduced the pressure of the R-22 in the evaporator, and consequently, the boiling temperature of the liquid R-22 has been lowered. We can see by reading our gauge that the pressure in the evaporator is 68.5 PSIG (pounds per square inch gauge). At that pressure (68.5 PSIG,) the R-22 liquid will boil at 40 degrees F. (refer to the PRESSURE - TEMPERATURE chart). There is return air at approximately 75 degrees F. passing over the evaporator so heat will transfer by conduction from the 75 degrees F. air through the walls of the tubes to the 40 degrees F. R-22; thus heat is being extracted from the air. The heat going into the R-22 liquid causes the R-22 liquid to absorb the latent heat of vaporization. Notice that the


SUCTION LINE
68.5
278
DISCHARGE LINE
EVAPORATOR COIL
COMPRESSOR
CONDENSER COIL
Expansion Valve
LIQUID LINE

liquid R-22 is all vaporized away before it leaves the evaporator so the compressor is pumping only R-22 vapor. The portion of the evaporator which contains boiling liquid is called the active portion.

As air conditioning systems cool the air, they also dry the air. This occurs when moisture in the air contacts the cold evaporator and turns to water droplets (the same way water droplets form on a glass of ice water). The air leaving the evaporator has less moisture than when it entered. Water that is seen dripping from air conditioning units is actually moisture that was removed from the sleeper.

We have at this point managed to do the important part of the air conditioners job. We have drawn the warm moist air from the sleeper pulled it through the evaporator coil and returned this air cooler and drier to the sleeper only because we took heat and moisture out of the air.

Now it would be impossible for us to continue to remove heat from inside the sleeper without putting the heat somewhere. As the refrigerant returns to the compressor it is still relatively cool and still at approximately 68.5 PSIG. According to our gauge in the above example, the compressor raises the pressure to 278 PSIG which causes the refrigerant to flow through the entire system. When the vapor refrigerant leaves the compressor it is highly superheated; so the first thing that occurs to the refrigerant in the condenser is to remove the superheat or to desuperheat it. To desuperheat the refrigerant takes only a small portion of the condenser because the superheat which is to be removed is all sensible heat.

At 278 PSIG vapor pressure (refer to the PRESSURE -TEMPERATURE chart), R-22 vapor will condense at 125 degrees F. The 125 degrees F. is called the condensing temperature at which this system is now performing. A fan pulls 95 degrees F. outdoor air over the condenser coil so heat will conduct from the 125 degrees F. R-22 vapor through the walls of the tubing to the 95 degrees F. air. This process allows the R-22 vapor to give up its latent heat of condensation to the outdoor air. Liquid R-22 is more dense than vapor so gravity pulls the liquid to the bottom of the condenser coil. At the bottom of the condenser the liquid flows into the liquid line which carries the R-22 liquid to the expansion valve. The expansion valve is the metering device, it meters the right amount of R-22 liquid into the evaporator coil to cause the active portion of the coil to extend to near the top.

We have now been around this refrigeration circuit one time.

In the preceding example of a basic refrigeration cycle, we have stated some temperature and pressure relationships that might exist within the air conditioning system. However it is impossible to state the exact pressures that will exist in either the high side or the low side because those pressures will both vary with different temperature and humidity conditions both inside and outside of the recreational vehicle. For example, as the temperature of the air increases there is more heat content involved. The air conditioner has to work harder to remove the heat so consequently the pressures and temperatures increase. **Note: As the load on the air**

conditioner increases so will the compressor amperage in a direct relationship. More information will be provided about this in the chapter on electricity. Humidity also adds load to the system. At design conditions approximately 30-40% of the capacity is dedicated to humidity removal. Every pound of water removed from the air inside the coach takes approximately 1060 BTU's. On extremely humid days the A/C unit removes more moisture from the air so that portion of the total capacity increases.

PRESSURE TEMPERATURE TABLE FOR R-22 AT SATURATION

Temp. Degree F.	Pressure PSIG	Temp. Degree F.	Pressure PSIG	Temp. Degree F.	Pressure PSIG
20	43.0	67	115.2	114	239.4
21	44.1	68	117.3	115	242.7
22	45.3	69	119.4	116	246.1
23	46.4	70	121.4	117	249.5
24	47.6	71	122.5	118	253.0
25	48.8	72	125.7	119	256.4
26	50.0	73	127.8	120	259.9
27	51.2	74	130.0	121	263.5
28	52.4	75	132.2	122	267.0
29	53.6	76	134.5	123	270.6
30	54.9	77	136.7	124	274.3
31	56.2	78	139.0	125	278.0
32	57.5	79	141.3	126	281.7
33	58.8	80	143.6	127	285.4
34	60.1	81	146.0	128	289.2
35	61.5	82	148.4	129	293.0
36	62.8	83	150.8	130	296.8
37	64.2	84	153.2	131	300.7
38	65.6	85	155.7	132	304.6
39	67.1	86	158.2	133	308.6
40	68.5	87	160.7	134	312.6
41	70.0	88	163.2	135	316.6

42	71.5	89	165.8	136	320.7
43	73.0	90	168.4	137	324.8
44	74.5	91	171.0	138	328.9
45	76.0	92	173.7	139	333.1
46	77.6	93	176.4	140	337.3
47	79.2	94	179.1	141	341.5
48	80.8	95	181.8	142	345.8
49	82.4	96	184.6	143	350.1
50	84.0	97	187.4	144	354.4
51	85.7	98	190.2	145	358.9
52	87.4	99	193.0	146	363.4
53	89.1	100	195.9	147	367.8
54	90.8	101	198.9	148	372.4
55	92.6	102	201.8	149	376.9
56	94.3	103	204.7	150	381.5
57	96.1	104	207.7	151	386.2
58	97.9	105	210.8	152	390.9
59	99.8	106	213.8	153	395.6
60	101.6	107	216.9	154	400.4
61	103.5	108	220.0	155	405.2
62	105.4	109	223.2	156	410.0
63	107.3	110	226.4	157	414.9
64	109.3	111	229.6	158	419.9
65	111.2	112	232.8	159	424.8
66	113.2	113	236.1	160	429.9

REVIEW QUESTIONS FOR LESSON III

FILL IN THE BLANKS:

1. Air Conditioners draw the warm moist air from the sleeper, pull it through the ________________ ________________ and return this air cooler and drier to the sleeper only because we took the ________________ and __________________ out of it.

2. By passing heat-laden air over a cold object, __________________ is transferred from the ___________________ to the ___________________. The air leaving the cold object does so with less heat, hence it feels cold.

3. Large amounts of heat are required to _____________________ liquid refrigerant into vapor.

4. A fan blows outdoor air over the condenser coil so that heat will conduct from the _______________ _________________ through the walls of the tubing to the __________________.

5. As the pressure of the refrigerant ______________________, so does the temperature and likewise as temperature ___________________, so does the pressure in a ______________________ relationship.

6. As air conditioning systems cool the air, they also _______________ the air.

7. Return air passing over the ________________________ will transfer heat by conduction from the air through the wall of the tubing to the refrigerant thus heat is being _____________________ from the air.

8. It is impossible to state the exact pressures that will exist in either the high side or the low side because those pressures will both ___________________ with different ___________________ and _____________________ conditions both inside and outside of the sleeper or truck.

LESSON IV

AIR FLOW

The proper operation of any ComfortGuard air conditioning system is highly dependant upon proper volume and temperature of the indoor and outdoor air circulation through the coils. In fact, air flow is so important to the air conditioner that it is well deserving of its own individual lesson. Improper or insufficient air flow through the coils is the number one reason why air conditioners seem to quit cooling. Low return air temperatures and or insufficient evaporator air flow contribute to almost 100% of the air conditioner freeze up problem, especially when these conditions are combined with cool outdoor ambient temperatures. On the other hand dirty condenser coils contribute to air conditioners kicking circuit breakers or tripping the compressor overload. Lets find out why!

As we previously mentioned, the amount of air and the temperature or heat content in the air is what controls the operating pressures within the A/C system. As the pressures go up or down, so does the evaporative and condensing temperatures. The only reason an air conditioner freezes up is if the evaporating or boiling temperature of the refrigerant drops below freezing. How could this happen? Contrary to popular belief there is only one logical reason why, and that is: The evaporator is not picking up enough heat to keep the pressure-temperature relationship above 32 degrees F. (approximately 57 PSIG).

Some of the most common causes for lack of heat transfer are:

A) Dirty Return Air Filters

As the filters get dirty, they begin to restrict the volume of airflow to the evaporator. If half the air is restricted, then only half the heat transfer will happen.

B) Dirty Evaporator Coil

If the filter is not kept clean and in place, the evaporator coil will inevitably get dirty or plugged. One of the easiest ways to clean the evaporator coil if it is extremely dirty, is to remove the filter, let the coil dry out and then use a soft bristle brush and vacuum cleaner.

C) Supply Air Louvers Closed

A large portion of the retail customers will shut the supply air louvers off when they get cold instead of turning up the thermostat. Many people use their car air conditioners in this manner. Any air conditioner in the world will freeze up if you restrict the airflow enough.

D) Low Ambient Temperatures.

As the temperatures out side drop off so does the high side discharge pressure. Now less refrigerant is pushed through the expansion valve into the evaporator. Consequently the evaporator temperature is lower. If you combine this with low return air temperatures you have a sure freeze up situation.

E) Restricted Duct Work

Inspect duct work to insure it is pulled tight, and it is not kinked or collapsed. The less bends and/or nineties in the duct work, the less the duct work is restricted.

F) Recirculation Of Cold Air Across The Evaporator

The cold supply air could be recirculating through the evaporator coil. This condition is usually a installation problem. Examples: A ripped or torn duct connecting the A/C unit to the supply register, or a supply register pointed right at the return air grill.

Note: Quite often a freeze up situation is attributed to a combination of any of the above mentioned problems. High humidity by itself will not cause an air conditioner to freeze up. Remember any time you condense water from the air this adds load to a system.

Air conditioners freeze up because of a lack of heat transfer from the air to the refrigerant in the evaporator coil. What do you suppose happens if the reverses is true and for some reason we do not transfer the heat in the condenser coil back to the outside air? The condenser coil must release the heat that was absorbed in the systems evaporator. If it doesn't, the pressures and temperatures of the refrigerant on both the high and low sides increase and the air conditioner will quit cooling. The most common reason for this is a dirty condenser coil. As the coil becomes even more restricted the pressures and temperatures will keep climbing. Eventually this may drive the compressor amperage up enough to kick the overload or the circuit breaker, especially if the ambient temperatures are already very warm. Over a period of time this may also cause serious damage to the compressor motor windings.

Absolutely one of the single most important things you can do to insure proper cooling performance from your air conditioner is <u>keep it clean</u>! When you don't it cost you more to operate it and you get less cooling.

REVIEW QUESTION FOR LESSON IV

FILL IN THE BLANKS:

1. High ________________ by itself will not cause an air conditioner to freeze up.

2. Low return air temperatures and/or insufficient evaporator air flow contribute to almost ____________________ of the air conditioner _____________________ up problems.

3. Absolutely one of the single most important things you can do to insure proper cooling performance from your air conditioner is to _____________ ____________ ___________.

4. One of the easiest ways to clean the evaporator coil if it is extremely dirty is to remove the filter, let the coil dry out and then use a _________________ ______________ and a _________________ __________________.

5. The proper operation of any ComfortGuard system is highly dependant upon the _________________ and _________________ of the indoor and outdoor air circulation.

6. As the temperatures outside drop off so does the high side discharge ___________________.

7. As the filters get dirty, they begin to _________________ the volume of air flow to the evaporator.

8. Air conditioners freeze up because of ___________ ____________ _____________ _____________ in the evaporator coil.

LESSON V

REFRIGERATION SYSTEM TROUBLESHOOTING

As you may have noticed very little has been said up to this point about the amount of refrigerant charge in the system, this has not been by accident. Our Goal is to prevent service technicians from putting manifold gauges on the system as much as possible, and only as a last resort. **CHARGE IS VERY RARELY EVER THE PROBLEM.** The refrigerant charge in a ComfortGuard type air conditioner is very critical, the charge is usually plus or minus 1/4 ounce. If you are not specifically trained to do so, do not attempt to add or subtract charge or do any type of sealed system repairs. Should system repairs become necessary, the refrigerant charge must be weighed in when repairs are done. Never attempt to charge by pressures, temperatures, or compressor amperage. Note: The Clean Air Act of 1990 has set Guidelines with regard to recapturing refrigerants, check with your local E.P.A. authorities for Proper Refrigerant Handling Procedures.

Service Problems And Solutions

Problem

1. Inadequate Cooling

Customer complains his A/C does not cool like it did when it was new.

Question: "Should we check the refrigerant charge?"

Answer: "No, generally speaking if an air conditioner had a refrigerant leak it would be completely empty and doing absolutely no cooling."

Question: "What should we check."

Answer: (Possible Causes and Repair)

1. "The filter could be dirty." This is a very probable cause and can be corrected by washing the filter with detergent and water then replacing them after they dry.

2. "The evaporator coil could be covered with lint or dirt." Dirt will reduce the air flow and slow down the heat transfer from the air to the refrigerant.

3. "Condenser coil could be coated with dirt or leaves." The coil may even be damaged by hail. When the condenser air flow is obstructed the pressures and temperatures go up and heat transfer slows down. The condenser coil may be washed out with a garden hose. The condenser coil should be washed from the inside out. Caution should be taken to insure “not

to" collapse the fins on the coil i.e. no pressure washers. (Be sure to remove all electrical power).

4. "The Condenser air flow could be recirculating". Make sure the path of air flow into and out of the A/C unit is not obstructed. (Some trucks have a headache rack or some other obstruction mounted too close to the condenser).

CONDUCTING A VERY BASIC COOLING PERFORMANCE TEST

After proper air flow has been determined and the coil surfaces have been checked and cleaned the following test may be run:

1. Check the compressor voltage and amperage. Correct operating voltage should be between 103.5 and 126.5 VAC. Note: Compressor Rated Load Amps (RLA) as published on the rating plate is determined at design conditions only. That condition is 95 degrees outdoor temperature, 80 degree indoor temperature, and approx. 50% relative humidity. Since outdoor air temperature has by far the largest effect on compressor amperage, the actual expected current draw must be adjusted up or down. Actual compressor amperage will change approximately .7 amp. For every 5 degrees up or down from 95. i.e.95 degrees = RLA, 90 degrees = RLA-.7 amp. 100 degrees = RLA +.7 amp.

2. Check the air temperature drop across the evaporator coil as follows. Note: Before this can be done effectively the air temperatures inside and outside of the truck should be above 75 degrees F. (Operating temperatures cooler than 75 degrees F. could promote coil freeze up problems).

PROCEDURE FOR CHECKING AIR TEMPERATURE DROP ACROSS EVAPORATOR COIL

1. Start the air conditioning unit and allow it to run for at least ½ hour. Possibly longer if is extremely warm outside (the objective is to saturate the evaporator coil before we begin running a temperature test).

2. With a standard dial type or digital thermometer measure the temperature of the air immediately entering the return air grille of the A/C unit.

3. Subtract from this temperature the temperature of the air immediately leaving the supply air louvers (Use the closest discharge register and make sure the temperature sensing device is measuring supply air temperature only).

4. A properly running A/C unit should have a temperature difference of approximately 16 to 22 degrees F. Note: Slightly less temperature differences are possible under extremely humid conditions. (The unit may have to run longer to remove moisture.)

5. Temperature differences greater than 22 degrees are possible in warm dry weather. Restricted air flow over the evaporator may also cause greater than 22 degree temperature differences.

Problem

2. Inadequate Cooling

The customer says he gets inadequate cooling for a while after he turns the system on and then it seems to quit cooling completely. As soon as the top is removed from the evaporator section with the system running, we observe that the suction line is coated with frost.

Question: "Could the system be low on charge or the expansion valve plugged?"

Answer: "No"

Question: "Why not?"

Answer: "Because, if it were low on charge or if the expansion valve was even partially plugged, the low side would be starved for refrigerant and therefore, the suction line would be warm. Also, the compressor housing would be hot."

Question: "Then why isn't it cooling properly?"

Answer: "Because the evaporator is not picking up the heat load."

Question: "What could cause the evaporator to not pick up the heat load?"

Answer: (possible causes and repairs)

1. "The filter could be dirty." This is the most probable cause and, of course, the easiest to check and correct.

2. "Supply air discharge louvers could be completely closed." This problem is easy to find and it is usually corrected by opening the discharge louvers.

3. "The fan could be at fault." A mechanical problem such as the wheel or squirrel cage blower may be loose on the shaft, this is usually rather obvious. Checking why a fan motor does not come up to speed is a little more involved.

4. "The evaporator coil face could be coated with lint, dirt, etc." Dirt or lint on the coil will restrict the flow of air through the coil. To clean, simply let the coil dry then use a soft bristle brush and a vacuum cleaner. Before system is put back into operation, be sure the filters are

properly installed to prevent recurrence of dirty coil.

5. "The cold supply air could be recirculating through the evaporator coil". This condition is usually a installation problem. Examples: A ripped or torn duct connecting the A/C unit to the supply register, or a supply register pointed right at the return air grill.

Problem

3. Compressor cycling off and on.

The customer says he gets inadequate cooling even though he has several times set the thermostat down to call for a lower temperature until it is now all the way down to the lowest possible setting. On investigation, we find that the compressor is cycling off and on.

Question: "What could cause the compressor to cycle off and on?"

Answer: "Two things".

1. "Cold air recirculating across the evaporator coil-Improper discharge/return air separation" This cold air back across the evaporator coil may be causing the freeze sensor to cycle the compressor off and on.

2. "The compressor is cycling on the thermal current overload."

Question: "What could cause the overload switch to open and close?"

Answer: "Compressor is running hot or compressor is drawing excess current or both."

Check by:

1. Carefully feeling the compressor dome - it will normally (during warm weather - above 85 degrees) be too hot to be comfortable if you keep your hand on it. If it is burning hot, it is probably overheating. The normal compressor housing temperature varies with outside temperature and evaporator load so determining whether or not it is too high is a matter of judgement based on experience.

2. Measuring the current (amperes) through the purple wire to the compressor. This current may be compared to the unit FLA rating as described in the Electrical section on compressors.

   Remember that the overload switch is sensitive to both high temperature and high current. We can't specify a definite temperature or amperage at which the switch will open. As the temperature rises, the current at which the switch will open goes down. As the temperature goes down, the current at which the switch will open goes up.

Question: "What could cause the compressor to draw over current or to overheat?"

Answer:

1. "Dirty condenser coil." This is by far the number one reason for higher than normal current draw. Check the appearance of the coil. If it is coated with lint, cottonwood fuzz, leaves, etc., it is insulated and it cannot give up its heat to the outside air. A dirty condenser will cause high head pressure which will in turn cause both high current draw and high temperature at the compressor.

2. "Condenser fan does not come up to speed." Check fan blade, fan motor and capacitor.

3. "High or low voltage." High voltage can drive excessive current through the motor windings. Low voltage can cause the compressor to slow down, overload and draw excessive current. Check the voltage between "C" and "R" terminals on the compressor while it is running. The volt meter must read between 103.5 volts and 126.5 volts (plus or minus 10% of 115 VAC).

4. "Overcharge or non-condensables in the system." Either an overcharge of refrigerant non-condensables in the system will cause high head pressure and consequently excessive current. Be especially suspicious if you discover that this system has been charged or some other refrigerant work has been performed in the past).

THE INDICATIONS OF OVERCHARGE ARE:

a) Over current may be checked as outlined in the electrical section on compressors.

b) Cooler than normal discharge line. The discharge line should be highly superheated and therefore at a high temperature.

Feeling lines with your fingers is a very inexact method of gathering information and cannot be considered accurate. So use this information only to form preliminary judgements in your diagnosis.

THE INDICATIONS OF NON-CONDENSABLES IN THE SYSTEM ARE:

a) Over current

b) Higher than normal discharge line temperature

c) Higher than normal liquid line temperature

d) Higher than normal compressor temperature

5. "Low charge." This very rarely occurs and should be considered only after all other possible causes have been positively eliminated.

   The compressor is dependant on a good supply of cool suction gas for cooling. If the system charge is low, there will be less than a normal amount of refrigerant vapor passing through the compressor. Less heat will be carried away by the refrigerant, and therefore, the compressor will overheat. Note - LOW CHARGE **WILL NOT** CAUSE OVER CURRENT. It will, in fact, cause the current to be low.

INDICATORS OF LOW CHARGE ARE:

a) The evaporator will be starved for liquid refrigerant so the suction line and a portion of the evaporator coil will be warmer than normal. This is the condition we refer to as too much superheat. How much of the evaporator will be starved for liquid refrigerant depends on the degree of undercharge.

b) The active portion of the evaporator coil which does have some liquid refrigerant will be colder than normal and many times will frost because the suction pressure will be low. How much of the coil is active depends on the degree of undercharge.

c) The compressor temperature will be noticeably higher than normal. Note: Low charge situations may be mimicked by problems such as dirty filters, dirty evaporator coils, air flow restrictions and low load conditions. **Do not attempt to put manifold gauges on the system unless you are specifically trained in refrigeration system repairs.**

REVIEW QUESTIONS FOR LESSON V

FILL IN BLANKS:

1. When considering problem #1, Inadequate Cooling; list 4 possible causes.
   ____
   ____
   ____
   ____

2. Charge is very ______________________ ever the problem.

3. The correct procedure for checking air temperature drop across the coil is to subtract the leaving air temperature from the temperature of the outside air.
   True or False

4. When searching for an inadequate cooling problem, the first thing to check is the refrigerant charge.
   True or False

5. When considering problem #2, Inadequate Cooling; list 5 possible reasons for evaporator freeze up.
   ____
   ____
   ____
   ____
   ____

6. Low charge will cause high compressor amperage (overcurrent).
   True or False

7. List 4 possible causes for the compressor to overheat or draw excessive current.
   ____
   ____
   ____
   ____

8. List 3 indicators of a low charge:
   Small portion of the evaporator coil may _________________________.
   Suction line will be ____________________ than normal.
   Compressor temperature ____________________ than normal.

CHAPTER VI

115 VAC A/C CONTROL CIRCUITS

INTRODUCTION

The one aspect of air conditioning which we most often work with is electricity. Although electricity itself is a study that would require several books just to cover only the basics, in the next several lessons we will discuss electricity and how electricity relates to ComfortGuard air conditioning.

The purpose of the following section is to acquaint the service technician with 115 VAC a/c circuits. Upon the completion of the following section the student will be able to:

1) UNDERSTAND BASIC ELECTRICAL TERMINOLOGY AND BRIEFLY EXPLAIN WHAT ELECTRICITY IS AND HOW IT WORKS.

2) UNDERSTAND ELECTRICAL METERS AND THEIR USES.

3) IDENTIFY AND CHECK THE ELECTRICAL COMPONENTS IN 115 VAC A/C ELECTRICAL CIRCUITS.

4) DETERMINE PROBLEMS AND LOGICAL SOLUTIONS THAT MAY OCCUR IN 115 VAC A/C ELECTRICAL CIRCUITS.

WARNING - SHOCK HAZARD

TO PREVENT THE POSSIBILITY OF SEVERE PERSONAL INJURY OR EQUIPMENT DAMAGE DUE TO ELECTRICAL SHOCK, ALWAYS BE SURE THE POWER SUPPLY TO THE APPLIANCE IS DISCONNECTED. THIS CAN NORMALLY BE ACCOMPLISHED BY SWITCHING THE BREAKER FOR THE AIR CONDITIONER TO "OFF", DISCONNECTING ALL EXTERNAL ELECTRICAL CONNECTIONS AND CORDS, SWITCHING "ON BOARD" ELECTRICAL GENERATORS AND INVERTERS TO "OFF", AND REMOVING THE CABLE FROM EACH POSITIVE TERMINAL ON ALL STORAGE AND STARTING BATTERIES.

DANGER

SOME DIAGNOSTIC TESTING MAY BE DONE ON ENERGIZED CIRCUITS. ELECTRICAL SHOCK CAN OCCUR IF NOT TESTED PROPERLY. TESTING TO BE DONE BY QUALIFIED TECHNICIANS ONLY.

What is Electricity

It is not enough to know what electrical parts look like and where they are located. When we encounter an electrical problem, we must be able to determine why the problem occurred, what caused the problem, and what should be done to correct the problem. Too many so called Service Technicians risk their reputations and the reputations of their employers by just trying on new parts until they find one which makes the equipment work again and they don't have the knowledge to determine what caused the problem. If the cause of the problem is not corrected , the problem probably will, in fact surly will, occur again.

Lets now ask what is electricity? The definition found in Websters New World Dictionary of the American League, "Electricity - A form of energy generated by friction, induction, chemical, and having magnetic, chemical, and (heat) effects; it is a property of the basic particles of all matter, consisting of protons (positive charges) and electrons (negative charges), which attract each other." That's a pretty difficult definition to understand so probably a better place to start is with a few basic electrical concepts.

1. **Voltage** is a description of electrical force or pressure. Pressure that causes electrons (electricity) to move. Sometimes voltage is referred to as potential or electromotive force. For example a light switch always has the potential of pushing electricity (electrons) to and through a light bulb to make them glow even if the switch is off the unit used to measure this

pressure is a **volt**. Through an electro mechanical process, the electrical company supplies us with the electrical energy to serve our needs.

2. **Electrical Current** is the movement of electrons (electricity) flowing through a conductor. In the above example voltage or electrical pressure was applied at all times to the light switch. **The quantity or amount of electrical movement consumed by the bulb when the switch is turned on is known as current or amperage**. Two of the by-products created from electrical current flow are: (1) heat from friction, (2) magnetism. The strength of the magnetic field created by moving electrons varies in direct proportion to current flow. The higher the current flow (amps) the stronger the magnetic field.

   The **Ampere** is the unit used to measure the quantity of electrons passing a given point in a specific period of time. There are two type of current:

   a) Direct Current (DC) travels in one direction usually at a constant value. Electrons have a negative charge and travel to atoms with a positive charge. Direct current flows from negative to positive.

   b) Alternating Current (AC) is electrical current that flows in one direction for a definite length of time and then reverses and flow in the other direction for the same period of time.

3. The **Load** or work to be done in an electrical circuit controls the amount of power consumed by the component in an electrical circuit and is measured in **Watts**. When electrons move through a wire, light filament or any other conductor, they bump into other electrons, impurities in the metal, or other obstructions. All of these obstructions tend to resist the flow of electrons. Resistance to electrical flow is measured in **Ohms**. All elements which consume electrical power are referred to as the load in the circuit. there are two types of loads:

   a) **Inductive Loads** are devices that use the electrical energy by converting this energy to magnetic energy for the creation of a magnetic field. These type of loads are generally motors. The amperage drawn in inductive load devices are limited by the opposing electrical pressure or voltage generated in the coil in the device. This opposing electrical pressure is called back EMF (electromotive force) which is generated by the motor.

   b) **Resistive Loads** are resistance devices sized to convert the total electrical pressure to heat. The amperage draw of these loads depends directly on the resistance of the conductor within the device and the amount of voltage applied. Typical resistance loads are light bulbs, heating elements, etc.

4. The measurement unit of **power** is the **Watt**, it is equal to the voltage across the circuit multiplied by the current through the circuit. The total amount of electrons (electricity) moved from one point to another may be different over a given period of time depending on the rate at which the are moved. Ultimately the consumer pays for electricity in Kilowatt/hrs which is equal to 1000 watts consumed for 1 hour.

5. A **Conductor** (wire) is the path through which electrical charges are transferred from one point to another. Conductors are made out of materials that have a low resistance. Copper, for example, offers a low resistance to the flow of electrons. Insulation, such as rubber or plastic coverings on the surface of conductors, confines the flow of electrical charges along a desired path.

Electrical Power Circuits

Now let's put these terms into perspective. An electrical circuit must have a power source, a conductor to carry the current, and a load or device to use the current and usual some sort of device for turning electrical current flow on and off. Let's examine a simple electrical circuit. A simple light switch and light bulb circuit will be sufficient in this example. Figure 2-1 shows the 115 volts power source between **L1** and **N** when the switch is closed. Voltage pushes electrons (current) through the wire (conductor) and through the light bulb (load) allowing the current to flow. The amount of current (amps) is determined by the resistance of load in this electrical circuit. Some light bulbs offer more resistance to electrical flow than others, this varying resistance in 2 different light bulbs determines how bright the bulb will be assuming the voltage at each bulbs is the same. This popular conception for electrical current as the flow of electrons through a circuit reflects the common attempt to make electrical phenomena understandable by direct comparison to the flow of water. For our purpose, it would be correct in saying that when electrons move through a material, we have electricity. This is a very simplified version of how electricity works but it gives us a good basis for what we about to discuss in the following lessons.

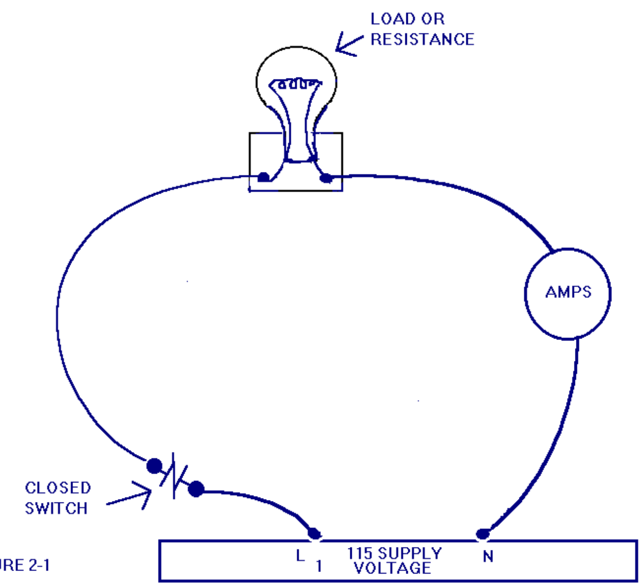


FIGURE 2-1

REVIEW QUESTIONS FOR LESSON VI

FILL IN THE BLANKS:

1. ______________________________ is the movement of electrons flowing through a conductor.

2. Electrical force or pressure is known as ____.

3. ______________________ is the unit used to measure the quantity of electrons past a given point in a specified period of time.

4. The path through which the electrical charges are transferred from one point to another is known as a ___________________________.

5. The two types of electrical current are known as ___________________ and ___________________.

6. ____________________ is the unit used to measure the resistance to electric flow.

7. The opposing electrical pressure generated by a motor is called ______________________.

8. The three things an electrical circuit must have for current to flow is __________________, _____________________ and ______________________.

(Circle Correct Answer)

9. The unit used to measure electrical force or pressure is:

   a. watt
   b. volt
   c. ampere

10. Power consuming devices in an electrical circuit are called:

   a. wires
   b. watts
   c. loads

LESSON VII

ELECTRICAL METERS AND THEIR USE

From Lesson 1 we now have a basic understanding of what electricity is. In the following lesson we will become familiar with the electrical meters used to check electrical circuits. Before the service technician ever attempts any electrical checks he or she must be aware of how electricity may be harmful or fatal.

Safety
Voltage (electrical pressure) whether high or low, will not hurt you. It's the current through vital parts of your body that does the damage, and under the right conditions, 115 volts is plenty to drive a deadly dose of current (amperage) through your body. Remember that electricity can be very dangerous, but you can safely work with it. In order to be safe, you must know what you are doing. You must work deliberately and carefully. **You must think safety before each move**.

1. Ammeter And Its Use

An ammeter is an instrument for measuring electric current. Current electricity is actually electrons moving from one atom to another through a conductor. In order to intelligently use electricity, we must have a measurement of a quantity of electrons.

The instrument we use to measure the number of amperes is called an **ammeter**. The handiest ammeter to use in our business is an **AMPROBE**. These instruments have snap-around jaws that will allow you to read the current through a wire without detaching the wire from the system. Always buy an energizer with the instrument so that you can accurately read low current circuits. These meters also have volt meter and ohm meter attachments so they are an excellent multi-purpose meter. **NO TECHNICIAN SHOULD EVER ATTEMPT A SERVICE CALL WITHOUT ONE.**

2. Ohm Meter And Its Use

An ohm meter or resistance meter indicates the resistance of a circuit to current flow. Just as every water pipe or hose has a resistance to water flow or every air duct has resistance to air flow, so does every wire have resistance to the flow of electric current. There is no such thing as a conductor with zero resistance to electron flow although sometimes we will be measuring the resistance of a conductor and find it so low that we cannot detect any resistance; so we call the resistance zero. What we mean is that the resistance is so low that we can't find it. The amount of resistance or holding back force of the wire or conductor depends on:

a) The material the conductor is made of; silver, copper and aluminum are good conductors. This means that in any given size wire, these materials will have low resistance. Silver has the lowest resistance, but its price is too high, so we use copper.

b) The diameter of the wire. The longer the wire, the greater the resistance because there is more metal to carry the current.

c) The length of the wire. The longer the wire, the greater the resistance. In fact, the resistance of any wire varies in direct ratio with its length.

d) The temperature of the conductor. The resistance of most - but not all - conductors increases as the temperature of the conductor rises. Hence, the resistance of the filament of a light bulb is rather low when it is turned off and cooled down; but when the power is turned on, the filament temperature increases until it glows and the resistance increases.

Resistance to electron flow is measured in units called ohms. An ohm is actually the amount of resistance that will hold the current down to one ampere if there is one volt of pressure.

An ohm meter is really a resistance meter that is calibrated in ohms. The ohm meter has its own power source, a small dry cell, which forces a small amount of current through a conductor via the meter probes. The meter must be calibrated to read 0 ohms when the probes are touched together each time it is used because as the dry cell loses its charge. Consequently the meter will need to re-calibrated regularly

If the probes of an ohm meter are attached to the terminals of a closed switch, the meter will read 0. This means that there is virtually no resistance to current flow through the switch. Now, if the switch is turned off, the contacts will be open and there will be very high resistance. In fact, the resistance is so high it is an infinite number of ohms so we call this reading infinity.

With the switch open, there is not a continuous conductor through it so we say there is no continuity. If the ohm meter reads anything other than infinity, we say we do have continuity. As can be seen from the above example, an ohm meter is a good instrument for checking to see if the contacts of a switch, thermostat, relay, overload, etc. are closing properly or creating **continuity**.

The previous examples show two conditions that can be detected by an ohm meter; (1) a closed, 0 resistance conductor and (2) an open circuit which reads infinity or no continuity. Now let's consider something in between – the windings of a compressor. If we attach the ohm meter probes to the common and run terminals of the compressor, we can read the resistance of the main or run winding. The winding is a solid and continuous copper wire so there will be continuity through it; but instead of 0 ohms, as there was through the closed switch, this winding is of such small wire and so long that there is resistance. Now let's attach the probes to the common and start terminals to get the resistance of the start of phase winding. Since this winding is made of even smaller and longer wire, its resistance will be greater than the main winding. Now let's attach the probes to the start and run terminals to read the resistance through both windings. This reading is the same number of ohms as the total of the two previous readings.

If the reading between any two terminals is infinity, we can determine that the winding is open – the wire is broken or burned in two. If the reading between any two terminals is 0 ohms, the insulation is burned off the winding and we can determine that the compressor motor is shorted. If the reading between any terminal and the compressor housing is anything except infinity, we can determine that the compressor motor is grounded. An open, shorted or grounded compressor must be replaced. The fan motor windings can be checked by the same method as the compressor motor winding. The only difference being that the windings are made of smaller gauge wire and the resistance will be higher. The fan motor has no push on terminals, but we know by referring to the wiring diagram, that the purple wire is the common terminal, the red wire is the start terminal and the white wire is the run terminal.

Notice that when we are using an ohm meter, the **power must be turned off**. It is also important to disconnect all wires from a conductor being checked with an ohm meter to prevent any chance of feedback.

An Amprobe is an essential instrument to have and use, and is a real bargain because it is three instruments in one.

3. Volt Meter And Its Use

A volt meter measures the amount of electrical pressure in an electrical conductor just as a tire gauge measures the amount of air pressure in an automobile tire. If we attach one volt meter probe to the hot line and the other probe to the neutral line of a standard circuit, the meter reading will be the electromotive (electron moving) force or pressure difference between the two lines. This is the amount of pressure we have available to push electricity (electrons) through the light bulbs to make the motors turn, etc. In the above example, we should find approximately 115 volts (domestic USA models) or units of electrical pressure. Remember, a volt meter always registers the voltage pressure difference between two points.

CAUTION
A volt meter is used on live circuits so use extreme care.

THINK SAFETY!

REVIEW QUESTIONS FOR LESSON VII

FILL IN THE BLANKS:

1. An __________________________ is an instrument used for measuring electrical current.

2. A ___________________________ is used for measuring the amount of electrical pressure.

3. When using an ohm meter to check a wire for continuity and the meter reads infinity, this indicates the wire is _____________________________.

4. When using an ohm meter to check the compressor windings and the meter reads continuity from any terminal to the compressor casing, this indicates the compressor is ___________________________________.

5. A ____________________________ is an instrument used for measuring the resistance of a circuit.

LESSON VIII

115 VAC COMFORTGUARD AIR CONDITIONING COMPONENTS

In Lesson I we discussed basic electrical concepts and what requirements are needed to make an electrical circuit. now we can take these concepts and incorporate them with ComfortGuard air conditioning electrical components. In Lesson III we will consider basic components and electrical power requirements found in a ComfortGuard air conditioner.

Safety.

Remember that electricity can be very dangerous, but you can safely work with it. In order to be safe, you must know what you are doing. You must work deliberately and carefully. **You must think safety before each move.**

THINK SAFETY

Power Supply - from Commercial Utility

1) Wire Size

The power supply to the air conditioner must come through a circuit breaker or time delay fuse. The power supply must be 20 amperes and 12 AWG wire minimum. Any size larger at any time may be used and **should** be used if the length of the wire is over 32 feet.

2) Color Code

The electric power from the electric service panel should be delivered through a 3 conductor cable and the Service Technician should check to be sure the color code is correct. The electrician probably installed the cable with the colors according to code, but don't bet your life on it.

a) The wire with black insulation is the hot wire and there should be 115 volts between it and either of the other wires. All switches, fuses, circuit breakers, disconnects, etc. should be in this line.

b) The wire with the white insulation is the neutral. There should be 115 volts between the neutral and the hot (black) wire, but there should be 0 volts between the neutral and the ground (the green wire or the frame of the air conditioner). **There must be no switches, fuses, disconnects, etc.** of any kind in the neutral wire.

c) The third wire may be covered with green insulation or it may be a bare metal wire. It is the ground wire. There must be 115 volts between this wire and the hot (black) wire and 0 volts between it and the neutral (white) wire. The ground wire must be securely fastened to the air conditioner cabinet. A ground screw is provided for this purpose.

1) Voltage

The voltage (electrical pressure) at the unit should be 115 volts and all electrical components will perform best at the correct voltage. However, the voltage will vary and the air conditioning system will perform satisfactorily within plus or minus 10% of the rated (115) voltage. Therefore, the voltage has to be between 103.5 volts and 126.5 volts.

Power Supply - Generated By ComfortGuard A.P.U.

WARNING: The service technician must keep in mind when checking to make sure that the power is turned off. Check only between the hot (black) lead and the neutral (white) lead.

Components

1. Compressor Motor

The compressor motor is located inside the hermetic compressor housing and therefore not accessible for service or visual observation in the field. However, the motor winding condition can be analyzed by using an ohm meter. Be sure to remove all the leads from the compressor terminals before making this check.

a) If the resistance between any two terminals is 0 ohms, the motor windings are shorted.

b) If the resistance between any terminal and the compressor housing is anything but infinity, the winding is grounded.

c) If the resistance between any two terminals is infinity, the winding is open.

On a good compressor, the highest resistance will be between the R (run) and S (start) terminals. The lowest resistance will be between the C (common) and R (run) terminals. The intermediate resistance will be between the C (common) and S (start) terminals. Notice that compressors have the identification of the terminals marked on either the terminal cover or on the compressor housing.

2. Overload Switch

Mounted on the outside of the compressor housing is a two terminal overload switch. The switch is connected in series with the common terminal, so if the switch opens, it will cut the power to the compressor motor. The switch will open as the result of either or both of two conditions that could be harmful to the compressor.

a) High Amperes (Current)

The switch contains a heater which increases in temperature as the current increases. The higher temperature warps the switch and will cause it to open before the windings reach a dangerous temperature.

b) High Temperature (Thermal)

The switch is clamped tightly against the compressor housing and located close to the windings. Therefore, as the windings reach a higher temperature, it takes less current to cause the switch to open.

As can be seen, the switch is always affected by a combination of current to the compressor and winding temperature.

3. Fan Motor

Fan Motor Check Procedure

If a fan motor refuses to perform properly, it can be checked in the following manner:

1. Be sure the motor leads are connected to the proper points – follow the wiring diagram provided with the unit.

2. To check the motor winding resistance carefully, check the resistance between each of the wires and ground (preferably a copper refrigerant tube for a good connection). These readings must be infinity. Any continuity means the windings are grounded.

   If there is a reading of 0 between any two leads, the motor is shorted and is no good. If there is a reading of infinity (no meter reading at all) between any two leads, the winding is open and the motor is no good.

   Note: A motor with 2 brown leads will have an O reading between 1 brown wire and either the black or white wire.

4. Run Capacitors

The purpose of the run capacitors is to give the motors starting torque and to maintain high power factor during running. The run capacitors are always connected between the start and run or main terminals of the motor.

CAPACITORS

Capacitor Check

There are several capacitor test devices available. The ohm meter is one of them. The ohm meter cannot verify a capacitors MFD (microfarad) value. However, the following procedures will show you how to use an ohm meter to determine if the capacitor is good, open, shorted or grounded. To check a capacitor's MFD or UF, a digital meter with a MFD or UF setpoint must be used. The MFD or UF of the capacitor must be within plus or minus 10% of the MFD or UF rating of the capacitor.

Before testing any capacitor, always perform the following procedure:

* This test must be done with a analog type meter.

a) Disconnect all electrical power to the air conditioner.

b) Discharge the capacitor with a 20,000 ohm (approx. 3 watt) resistor or larger.

c) You may discharge capacitors with a standard volt meter if you use a scale over 500 volts and touch the leads (one lead to each side of the capacitor). The volt meter will discharge the capacitor.

d) Identify and disconnect the wiring from the capacitor.

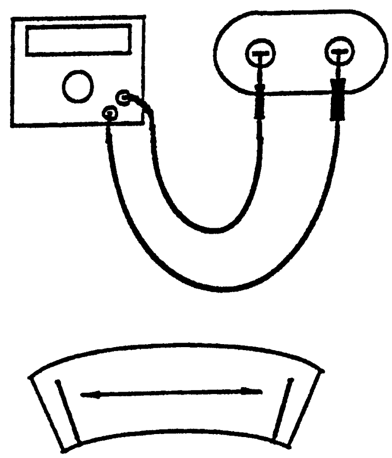
e) Set and zero the ohm meter on the "highest" scale.

When testing for a good, open or shorted capacitor, perform the following checks: Place the ohm meter leads across the capacitor terminals (one lead on each terminal) and perform a continuity test. Then observe the action of the meter needle or indicator. Reverse the leads and test again. The result should be the same. Note: If the capacitor had not been properly discharged, a false reading could be indicated on the first test. Always test several times (reversing the leads with each test). This will verify the capacitors condition.

Good Capacitor

If the capacitor is good, the indicator will move from infinity (the left side), up towards zero ohms and slowly return back to infinity. Reverse the leads and test again. The result should be the same.

OHM METER CAPACITOR

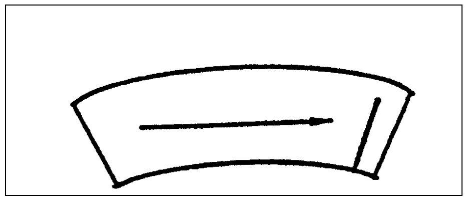


Indicator sweeps back and forth as shown above the capacitor is good

Open Capacitor

If the capacitor is open, the indicator will show no deflection or movement. Reverse the leads and test again. If there is no indicator movement on the second test, the capacitor is open. Open capacitors are defective and must be replaced.

OPEN

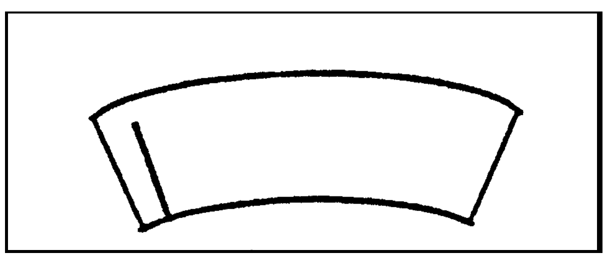


Indicator shows no movement
Needle stays to the left side
(indicating an incomplete circuit)
The capacitor is open

Shorted Capacitor

If the capacitor is shorted, the indicator will move towards and sometimes hit zero ohms, and will stay there. This indicates a completed circuit through the inside of the capacitor (shorted). Shorted capacitors are defective and must be replaced.

SHORT

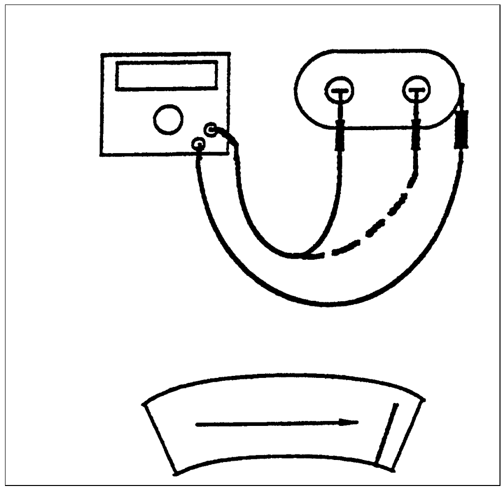


Indicator moves to the right side of
the scale and stays there
(indicating a completed circuit).
The capacitor is shorted.

Grounded Capacitor

When testing for a grounded capacitor, perform a continuity check between each terminal on the capacitor and the bare metal of the capacitor case. Any indication of a circuit (constant resistance) from either terminal to case, indicates a grounded capacitor. Grounded capacitors are defective and must be replaced. Note: (Plastic case capacitors cannot short to ground)

OHM METER CAPACITOR



Indicator moves to the right side of the scale and stays there
(indicating a completed circuit).
The capacitor is grounded.

Start Capacitor

ComfortGuard air conditioners use a start capacitor to give the compressor high starting torque. The compressor will, therefore, start against normal pressure difference (head pressure minus suction pressure) even when shut down for a short period of time. The start relay will disconnect the start capacitor from the compressor circuit when the motor reaches approximately 75% running speed. All start capacitors used in conjunction with a potential start relays have bleed off resistor. The resisters function is to discharge the capacitor as soon as the electrical circuit becomes open.

Start capacitor test procedures are the same as previously outlined in the “CAPACITOR CHECK” section.

5. Start (Potential) Relay

The start relay consists of –

1) Normally closed contacts internally between terminals #1 and #2 which switch in the start capacitor in parallel to the run capacitor during shut down and then switch out the start capacitor when the motor reaches approximately 75% normal running speed.

2) A high voltage coil internally between terminals #5 and #2 to actuate the contacts. The coil is too weak on line voltage to actuate the contacts, but it is connected in series with the start winding and it gets the generated voltage of the start winding portion of the compressor motor. This generated voltage is much higher than line voltage and varies with the speed of the motor. Therefore, since the relay is designed to open the contacts at 75% of normal running voltage (measured between terminals #5 and #2), the contacts will open (thus disconnect the start capacitor) at approximately 75% of normal running speed.

   The relay coil (terminals #1 & #2) may be checked out by using an ohm meter and checking for continuity. However, the opening action of the relay can only be checked by using an amp meter, and placing this meter on one of the wires going to the start capacitor. Amperage on the start capacitor wires should only be detected for a fraction of a second. If amperage continues longer than one second either the compressor did not start (see compressor section) or the relay contacts did not open.

6. Heating Element

The heating element is a resistance heater of 1172 watts in low heat (4000 BTUH) and 2344 watts in high heat (8000 BTUH). The current draw of the heater (element only) will be 10.0 amperes in low heat and 20.0 amperes in high heat.

The heating element may be checked with an amp meter while running or use an ohm meter to check the element for continuity if it has been disconnected from the power source.

7. Limit Switch

The limit switch is a safety switch and is mounted in the heating element frame. It will open and break the circuit on temperature rise in case the air flow through the heater becomes low enough to cause the heater to overheat. This is a normally closed switch, check with an ohm meter for continuity.

REVIEW QUESTIONS FOR LESSON VIII

FILL IN THE BLANKS:

1. The voltage at the air conditioner should be ___________________ volts and all electrical components will perform satisfactorily within plus or minus _____________ of the rated (115) voltage.

2. The power supply to the air conditioner must be ________________ amperes and _______________ ___________________ wire minimum.

3. The three terminals on top of the compressor housing which are connected to the compressor motor windings are designated as __________ __________ __________.

(CIRCLE THE BEST ANSWER)

4. An overload switch opens on both high amperes and high temperature.
   True or False

5. A ComfortGuard air conditioner fan motor uses a start capacitor and relay.
   True or False

6. The contacts on a start (potential) relay will open and take the start capacitor out of the circuit at approx. 75% of the normal running voltage.
   True or False

7. Start capacitors are used to give starting torque to:
   a. compressors
   b. fan motors
   c. heating elements
   d. all of the above

8. When checking a capacitor and the needle indicator on the ohm meter sweeps back and forth, this means the capacitor is:
   a. open
   b. shorted
   c. good
   d. all of the above

9. When checking a run capacitor, what 4 possible conditions may you expect to find?
   a. ______________________
   b. ______________________
   c. ______________________
   d. ______________________

10. A start relays job is to remove the ________________ __________________ from the circuit after the compressor comes up to approx. 75% of its running speed.

LESSON IX

SERVICE PROBLEMS AND THEIR SOLUTIONS

In the previous lessons we've become familiar with electricity, electrical meters, and electrical components found in ComfortGuard air conditioners. In Lesson IV we will consider some of the problems and solutions that sometimes occur in these air conditioners.

When a ComfortGuard owner calls for service on his air conditioner, let him explain exactly what has happened; when the air conditioner first gave him trouble, what it sounded like, how hot was the weather, what time was it, etc. He is a rich source of information. Listen to everything he says. You will compliment him and he will help you to identify the problem.

Always be alert for a customer who has been working on his own equipment. Check all wiring and visually inspect all motors, fans, capacitors, tubing, etc.

When a Service Technician gets all the information he can from the customer, he then examines the equipment for more facts that might lead to the root cause of the problem. **(always be on the alert for loose or burned wires, smoke stains, - those things which would obviously cause a malfunction or would indicate a malfunction).**

After the service technician gets all the available information together, he starts asking himself questions:

"What causes has the information eliminated and why?" (For instance, if the compressor is running, that eliminates a tripped circuit breaker as the cause of the problem.)

"What are the possible causes?"

"Which of the possible causes are the most probable ones?"

"How should I check them out?"

For each of his questions, he expects an answer. Since there is no one else around qualified to answer his questions, he must supply the answers himself.

As his questions and answers eliminate the possible causes one by one, he will soon identify the reason for the malfunction. Then he can repair it.

ISOLATE THE PROBLEM – THE SOLUTION IS SIMPLE.

Problem

1. Nothing runs.

The customer turns the thermostat to the “Cool” position and nothing happens. This is surely a serious problem, but it is usually the easiest to correct.

Question: “What are the possible causes?”

Answer:

1. “The power supply could be dead.” Check for open circuit breaker. Check for 115 volts between hot line (black) and neutral (white) at power entrance at unit.

2. “The power supply to the thermostat could be dead”. Check for 12 VDC at the thermostat between (Red) 12 VDC positive (+), (Blue) 12 VDC negative (-).

Problem

2. No Cooling.

The customer turns the thermostat to “Cool” and the fan runs OK, but the unit does not cool. We observe that the compressor does not run; however, it periodically hums for 1 to 30 seconds.

Question: “Could the cause of the trouble be the circuit breaker or the thermostat?”

Answer: “No - because we know that power is getting to the common and run terminals of the compressor to make it hum and the Thermal-Current Overload switch is breaking the circuit to protect the compressor from burn out.”

Question: “What are the possible causes of the problem.”

Answer: The possible causes are –

1. “The voltage could be low – ”

   a) The voltage must be 115 volts. No less than minus 10% is allowable.

   b) Check the voltage from “C” or “R” of the compressor while it is humming (trying to start). The latter reading will probably be lower, but it still must be 103.5 volts.

If the first reading is above 103.5V and the second is under 103.5V, there is too much voltage drop in the lines - a situation which must be corrected for the air conditioner to perform safely and satisfactorily.

2. "A capacitor could be shorted, weak or open."

Turn the power off.

Caution – There is always a chance that a capacitor is holding a residual charge, so before touching a terminal, discharge the capacitor as explained earlier in this booklet.

Remove capacitors, visually examine them and test them per instructions given in earlier section on capacitor testing.

If the capacitors test OK, replace them and carefully reconnect the wires. Be sure the wires are connected to the right terminals.

3. "Compressor start winding could be open or grounded."

   Check compressor windings per instructions. See the section on the compressors.

4. "Compressor could be mechanically stuck."

   This very rarely occurs and when it does, it is usually after a lengthy shutdown. This should be considered **only** after **all** the above possible causes have been positively eliminated.

Problem

3. Compressor trips breaker or thermal current overload.

Compressor trips circuit breaker or thermal current overload immediately (no hum). Note that this problem is different from the previous one in that in the previous problem, the compressor did hum for several seconds.

With the thermostat in "Fan Only" position, the fan works OK.

Question: "What are the possible causes?"

Answer:

1. "The compressor winding is shorted or grounded, or"

2. "The circuit breaker or thermal current overload is weak, (this rarely occurs, but it can occur

after the switch has tripped out many times. The only repair is to replace the circuit breaker or overload)."

Question: "How do I repair it?"

Answer:

1. "With the power turned off, check the resistance between all three compressor terminals and ground. If any continuity is found, locate the ground and correct it."

2. "Check compressor windings per instructions."

3. "If the above checks are OK, replace the switch that is tripping out."

Problem

4. Compressor makes loud growling noise.

Customer has turned the unit off and called for service because he believes the air conditioner is surely burning up since it makes such a loud noise. On inspection, we find that the compressor starts but draws high current and continues to make the growling noise until the thermal current overload trips out.

Question: "Which components can we determine are working OK from the symptoms?"

Answer:

1. "The power is getting to the compressor."

2. "The start circuit is starting the compressor OK."

3. "The capacitors and relay are providing the starting torque."

Question: "Then why the noise?"

Answer: "The start capacitor is staying in the circuit and the compressor is running with too much capacitance. This condition is caused by; 1) the compressor does not come up to speed and does not supply adequate voltage to actuate the potential relay, or 2) the potential relay contacts are welded shut, or 3) the potential relay coil is open."

Question: "How do I repair it?"

Answer:

1. “Check the voltage between “C” and “R” terminals of the compressor. Low voltage can cause the compressor to not come up to speed.”

2. “Check out the potential relay with hermetic analyzer or try a new potential relay.”

3. “Check compressor windings per instructions.”

Problem

5. Fan won’t run.

The customer turns the thermostat to fan and nothing happens. When he turns the thermostat to “Cool”, the compressor starts but still no fan.

Question: “What could cause the fan to be dead?”

Answer:

1. “Fan motor windings could be open, shorted or grounded.”

   Be sure power is off. Check motor windings per instructions.

2. The electrical circuit to the fan motor leads could be open. Check all connections (including wire nuts) to the fan motor red, black and white wires.

3. “Fan capacitor may be shorted, weak or open.”

   To check fan capacitor, follow same procedure that is outlined for compressor run capacitors.

REVIEW QUESTIONS FOR LESSON IX

1. If a customer complains that his air conditioner does not cool but the fan runs, it could mean he has a tripped circuit breaker.
   True or False

2. Customer complains his air conditioner keeps tripping breakers every time he turns the air conditioner on to cool, the compressor could have a start winding grounded.
   True or False

FILL IN THE BLANKS:

3. List three possible causes why a fan motor may not run.

   ____

(Circle The Best Answer)

4. The two correct terminals for checking voltage to the compressor are terminals “R” and “C”.
   True or False

5. Low voltage may cause the compressor to cycle on the overload.
   True or False

6. If the fan motor will not run, the problem could be a bad start capacitor.
   True or False