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Recreation Vehicle Industry Association

Recreation Vehicle
Air Conditioning

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- Identify air conditioner components and their functions.
- Identify and measure superheating and subcooling.
- Explain how a refrigeration cycle operates.
- Apply principles of compression refrigeration to an RV air conditioner.
- Convert temperature measurement from Fahrenheit to Celsius and vice versa.
- Identify refrigerant cycle.
- Identify types of RV air conditioning systems (split system, heat pumps, basement models, and roof air).

7-1.1 Properties of Heat Transfer and R22

7-1.1.1 History of Refrigeration

Since mankind has been able to observe and reason, we have noticed that in winter our perishable foods have been preserved from spoilage for a longer period of time because, at lower temperatures, spoilage is retarded. We wanted to copy nature by lowering the temperature of foods all year round. Also, we have wanted to lower the summer temperatures inside our buildings so that we would be more comfortable.

In the U.S.A., our refrigeration industry started when we began harvesting ice from the northern lakes in winter and storing that ice in insulated buildings to be used during summer months. Our society and our system of commerce soon became accustomed to a supply of ice for refrigeration. This is evidenced by the fact that, during the Civil War, the Mississippi River was closed to commerce and the southland was deprived of the ice that had been barged down the river from the northern lakes. The closing of the river was a terrible blow to the cities along the gulf coast, because they could not feed the people in the cities without the supply of ice to which they had become accustomed.

If their very limited and inefficient systems of refrigeration were critical to the people in the 1860s, consider what a critical industry we have now. Without refrigeration, millions of our people would be hungry, and those who did eat would not enjoy the tasty foods that we all take for granted. Once summer air conditioning was a rare luxury that existed only in such places as fine restaurants and theaters. In 1940, we couldn't imagine air conditioning in homes. Now residential air conditioning is considered necessary for wholesome and, in some cases, healthy living.

7-1.1.2 Our Place in the Refrigeration and Air Conditioning Industry

We must strive to provide, install, and properly maintain the highest quality refrigeration and year-round air conditioning equipment possible, and to service and repair that equipment (when necessary) in the most efficient and reliable manner. In order to do that, we must thoroughly understand the principles of refrigeration and air conditioning so that we will know how it works and why it works; then we can install better systems, prevent many problems with the equipment, and reliably repair those problems that do occur.

7-1.1.3 What Is Refrigeration?

Refrigeration is defined in the dictionary as "making or keeping cold or freezing for preservation, as food." But we know that it involves much more. To refrigerate something, we must move the heat from one substance to another. 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.

NOTE: We will define refrigeration as "the method of moving heat from one place to another."

Refrigeration is not always used to cool something. It is also used to control humidity, and it is sometimes used to heat. For instance, an air source heat pump is a refrigeration machine used to move heat from the inside of a building to the outside air in summer. Then, in winter, the same refrigeration machine pumps or moves heat from the outdoor air back into the building to keep us warm and comfortable.

The term "air conditioning" is often misunderstood. The majority of people consider air conditioning to be only the cooling of buildings during warm weather. We must consider air conditioning to be a year-round process, since it is used to control temperature, humidity, ventilation, odor, and so on.

7-1.1.4 Types of Refrigeration Equipment

Recreation vehicle air conditioning equipment removes heat from the air inside the vehicle, where heat is not needed. This heat is absorbed by the refrigerant in the evaporator coil and carried by the pumping action of the compressor outside of the vehicle to the condenser coil where the same heat will be dissipated. There are several types of refrigeration equipment. One type is known as *thermoelectric* refrigeration. Thermoelectric refrigeration is interesting, but it has not proven practical except for a few applications. Another type is *absorption* refrigeration. Still another type is *air cycle* refrigeration, which is mostly used to cool large airplanes while they are on the ground or at low altitude. Finally, there is *compression cycle* refrigeration, which is the most common type. The principles of compression cycle refrigeration apply to absorption and air cycle refrigeration. Typical types of air conditioners used in RVs are rooftop, split system, heat pumps, and packaged basement air conditioners. Although dash air conditioners are used in some RVs, these will not be covered in this textbook.

7-1.1.5 Thermodynamics

"Thermo" relates to heat, and "dynamics" refers to motion or action, so the word "thermodynamics" is the study of the effects of heat and the other forms of energy causing matter to move or be active. The principles of refrigeration and air conditioning are based on thermodynamics. In order to understand refrigeration and air conditioning, we must thoroughly understand that portion of thermodynamics that pertains to those two subjects.

7-1.1.5.1 First Law of Thermodynamics

The first law of thermodynamics states that energy cannot be created or destroyed. For instance, the power companies do not create electrical energy; they convert other forms of energy to electrical energy. The electrical energy is transferred to your home through the power lines. Your electrically powered reading lamp is now converting electrical energy to heat energy. The heat energy raises the temperature of the filament of your light bulb, which makes it glow. When the filament glows, it converts heat energy to a form of radiant energy (light). The radiant energy finally converts back to heat energy that slightly warms the room. Energy is constantly moving and converting from one form to another, but energy is never created or destroyed.

7-1.1.5.2 Second Law of Thermodynamics

The second law of thermodynamics expresses a trend in nature. This trend is that heat tends to flow from hot places to cold places, it never flows from cold places to hot places naturally.

An example is cooling milk from 45°F (7°C) to 35°F (2°C) in a refrigerator. Heat must be extracted from the 45°F (7°C) milk and transferred to the approximately 75°F (24°C) kitchen air. This is moving heat from a cold place to a hot place, and the law states that heat never moves from cold to hot. The refrigeration system must convert the heat to another form and move the heat to the room air in a way that obeys the second law of thermodynamics. There are many other examples of systems that move heat from a cooler to a warmer place: a summer air conditioner moves heat from the cooler indoor air to warmer outdoor air. In winter, a heat pump moves heat from the cold outdoor air to the warmer indoor air.

7-1.1.6 Forms of Energy

There are six forms of energy. They are (1) radiant energy, (2) chemical energy, (3) mechanical energy, (4) electrical energy, (5) nuclear energy, and (6) heat or thermal energy.

7-1.1.6.1 Radiant Energy

Radiant energy is energy that is transferred through space or through transparent matter by wave action without the need for intervening matter. Light is an example of radiant energy.

7-1.1.6.2 Chemical Energy

Chemical energy is energy involved in chemical changes.

7-1.1.6.3 Mechanical Energy

Mechanical energy is the energy that causes matter to move. Anytime anything that has weight (matter) moves, energy is being expended.

When a compressor is compressing refrigerant, or when a fan is moving air, these devices are expending energy (mechanical energy). These devices must get their energy from somewhere, and they get it from the conversion of electricity (another form of energy) to mechanical energy.

7-1.1.6.4 Electrical Energy or Electricity

Electrical energy is a form of energy generated by friction, induction, or chemical change, and having magnetic, chemical, and radiant 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.

7-1.1.6.5 Nuclear Energy

Nuclear energy is generated using heat created by nuclear fusion.

7-1.1.6.6 Heat or Thermal Energy

Heat is created by the friction of moving molecules. The energy that produces molecular motion is called heat or thermal energy.

The conversion of energy will result in the creation of heat. Other things may also result, but heat is the topic to discuss herein. There are two types of heat of concern in refrigeration systems: (1) sensible heat and (2) latent heat.

Sensible Heat

This refers to heat whose effect on matter creates a change in temperature without causing a change in state. It is sometimes described as heat that can be sensed or felt, as with a temperature change.

Latent Heat

"Latent" is Latin for "hidden." This refers to heat that causes a change of state without a change in temperature. It is referred to as *hidden heat,* because the thermometer cannot measure the heat's movement or its effect on matter.

Below are basic discussions of five different types of latent heat.

Latent Heat of Fusion

Fusion is the process in which a solid is changed to a liquid. Fusion is caused by the addition of heat. Since the heat that causes fusion is hidden or latent, it is called the *latent heat of fusion.*

Latent Heat of Freezing

It takes 144 Btu/hr of heat to change 1 lb of 32°F (0°C) ice to 32°F (0°C) water. When liquid water changes to ice, that same amount of heat (144 Btu/hr/lb) must be extracted to cause the water to freeze. That heat is called the *latent heat of freezing*.

Latent Heat of Vaporization

The pressure of vaporization (the process of converting liquid to vapor) must be greater than the vapor pressure on the surface of the liquid before vaporization can occur. The rate of vaporization will increase as the pressure of the vaporization increases. The higher the water temperature, the greater the pressure of vaporization and the quicker the water will vaporize. At 212°F (100°C), the pressure of vaporization is 14.7 psig, which is equal to atmospheric pressure. When water is at 212°F (100°C) and more heat is added, the vapor pressure is sufficient to push both the atmosphere and the liquid out of the way, and bubbling or boiling occurs. Since the 212°F (100°C) water vaporizes as rapidly as the heat is added, all of the added heat is latent heat. It takes 970 Btu/hr of heat to change 1 lb of 212°F (100°C) water to 212°F (100°C) vapor (steam) at standard atmospheric pressure.

Latent Heat of Condensation

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. This process occurs as the high-pressure refrigerant vapor changes to liquid in the air conditioner's condenser coil.

Latent Heat of Sublimation

A solid can change directly to a vapor without going through the liquid state; that process is called sublimation and requires the latent heat of sublimation to cause that change. A common example of sublimation is frozen carbon dioxide, usually called *dry ice,* which sublimates at 109°F (43°C). Dry ice is a very effective refrigerant.

Temperature

In dealing with refrigeration and air conditioning systems, it is important to understand heat and how it is measured. The measurement of heat is the level or intensity of molecular motion. It is not an indicator for a quantity of heat.

When Daniel Fahrenheit developed his thermometer, he mixed salt and snow to obtain what he considered to be the coldest substance in all the world. He arbitrarily established the Fahrenheit scale by placing evenly spaced marks above that zero point on his thermometer. Fresh water freezes and thaws at his 32nd mark or at 32°F (0°C), and water boils at his 212th mark, or at 212°F (100°C). Complete absence of heat occurs at –460°F (–273°C). The ice and salt mixture produces lower temperatures, because the salt causes the ice to melt faster, and this forced absorption of heat causes the lower melting temperature.

The formula to change Fahrenheit to Celsius is:

Subtract 32 from °F and divide by 1.8 [(°F – 32)/1.8].

For example, if the outside temperature is 85°F, the temperature in Celsius would be 29°C.

85 – 32 = 53 divided by 1.8 = 29.44 or 29°C.

The formula to change Celsius to Fahrenheit is:

Multiply °C by 1.8 and add 32 [(°C × 1.8) + 32].

For example, if the interior room temperature is 20°C, the Fahrenheit temperature would be 68°F.

20 × 1.8 = 36 + 32 = 68°F.

British Thermal Unit (Btu)

A British thermal unit is the amount of heat necessary to raise the temperature of one pound of water one degree Fahrenheit at sea level. Many years ago, the British government assigned a group of scientists to come up with a way of measuring an amount of heat. After some thought, they determined a good way would be to measure how heat affects matter. They selected a common sample of matter: water. They decided that the standard measurement of an amount of heat would be that necessary to raise the temperature of a pound of water by one degree Fahrenheit at sea level. They named the unit of measure British thermal unit, abbreviated Btu.

Review and Define Kinds of Heat

Let's now review and define the kinds of heat: (1) sensible heat and (2) latent heat.

1. Sensible heat: the heat that causes a change in temperature with no change in state.
2. Latent heat: the heat that causes a change in state with no change in temperature.

   There are three kinds of latent heat in standard air conditioner applications:

   1. Latent heat of fusion or freezing: the heat that causes a solid to change to a liquid, or vice-versa.
   2. Latent heat of vaporization or condensation: the heat that causes a liquid to change to a vapor, or vice-versa.
   3. Latent heat of sublimation: The heat that causes a solid to change to a vapor without going through the liquid state.

In each of the above explanations of latent heat, it was pointed out that the cause of a change of state was the addition or extraction of latent heat. Nothing else causes a change of state.

The latent heat of condensation of water vapor is 970 Btu/hr/lb at 212°F (100°C). That is a fact, but at lower temperatures, the latent heat of condensation is greater. For instance, at 58°F (14°C), which is commonly the temperature of the surface of an air conditioning cooling coil where water vapor condenses to liquid water, the latent heat of condensation is 1060 Btu/hr/lb. This means that, when a pound of water drips out the condensate drain of an air conditioner, the system has extracted 1060 Btu/hr of heat from the water vapor. Therefore, if 10 lb of water per hour drips out the condensate drain of a 30,000 Btu/hr air conditioner, 10,600 Btu/hr or 35 percent of the system's total capacity is being used to condense the water vapor. This example is a very common percentage of latent heat capacity in relation to total capacity of a normally operating air conditioner. A well designed system can expect to operate at approximately 35 percent latent heat capacity when the indoor conditions are reasonably comfortable (indoor temperature 75°F (24°C) to 80°F (27°C) and indoor relative humidity approximately 50 percent). Notice that only 65 percent of the capacity of a normally operating air conditioning system is being used to lower the temperature of the air in the building; 35 percent of the capacity is being used to control the humidity without affecting the temperature of the air.

Notice, too, that when matter changes state, a large amount of heat is always involved. For instance, 144 Btu/hr of latent heat is required to change one pound of ice to water with no change in temperature, while

144 Btu/hr of sensible heat will raise the temperature of one pound of water from 32°F (0°C) to 176°F (80°C). Additionally, 970 Btu/hr of latent heat of condensation must be extracted from one pound of 212°F (100°C) water vapor to condense it to liquid with no change in temperature, but it only requires the extraction of 180 Btu/hr of sensible heat to lower the temperature of one pound of liquid water from 212°F (100°C) to 32°F (0°C).

Methods of Heat Transfer

Heat may be transferred or moved from one body to another by one of three methods: radiation, conduction, or convection. Some systems of heat transfer use a combination of these three methods.

Conduction

Conduction is the flow of heat between parts of a substance. The flow can also be from one substance to another substance in direct contact.

Radiation

Radiation is the energy transmitted by waves through space or some medium. Heat flow without contact between the hot (sun) and cold (earth) materials. This includes heat flow by electron flow, even across a vacuum.

Convection

Convection is the transfer of heat by the circulation of fluids due to differences in temperature and density.

Variations in the Rate of Heat Transfer

Substances differ in their ability to conduct heat. In general, substances that are good conductors of electricity are also good conductors of heat. Substances that conduct poorly are called *insulators.*

7-1.1.7 Comparison of Steam Heating to Refrigeration

Figure 7-1 depicts a very basic steam heating system. Keep in mind that there is nothing in the sealed loop except water and steam. Since the loop is vented, the pressure inside the loop is equal to atmospheric pressure. Heat from the flame enters the water in the boiler and causes it to vaporize. The steam is condensing back to liquid water in the radiator by giving up heat to the occupied room, and the water returns to the boiler by gravity. With this system, we are moving heat from the fire of the boiler to the occupied room. Each pound of steam that condenses gives up 970 Btu/hr of latent heat of condensation. If 10 lb of water is circulated each hour, the heating capacity of the system is 9,700 Btu/hr.

Figure 7-2 is identical to *Figure 7-1* except the names of the parts have been changed. The boiler is now the evaporator. The water in the boiler is now replaced by liquid R22 refrigerant at a low pressure and temperature. The heat from the flame is replaced by warmer airflow pulled through the evaporator by means of a fan or blower wheel. As this air is pulled through the evaporator, the heat will be absorbed from the air into the cooler refrigerant (hot to cold), causing the refrigerant to boil (latent heat of vaporization). This heat is carried to the condenser coil where the heat can be given or dispensed into the outdoor air. Notice that the air conditioner refrigeration system is a sealed system with no vents to the outside.

There are two parts missing that are usually found in a refrigeration system. One part is the compressor, and the other is the metering device, generally a capillary tube. These two parts are necessary to create the pressure and temperature differences throughout the refrigeration sealed system.

Figure 7-1 Basic Steam Heating System

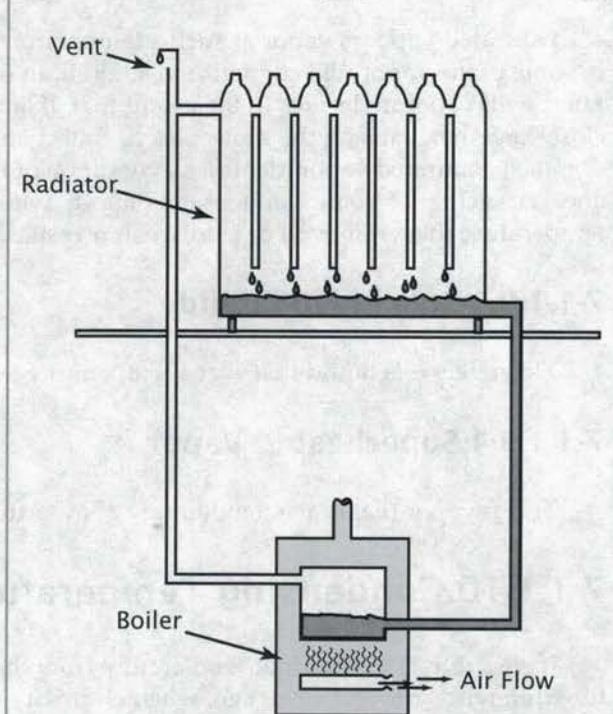
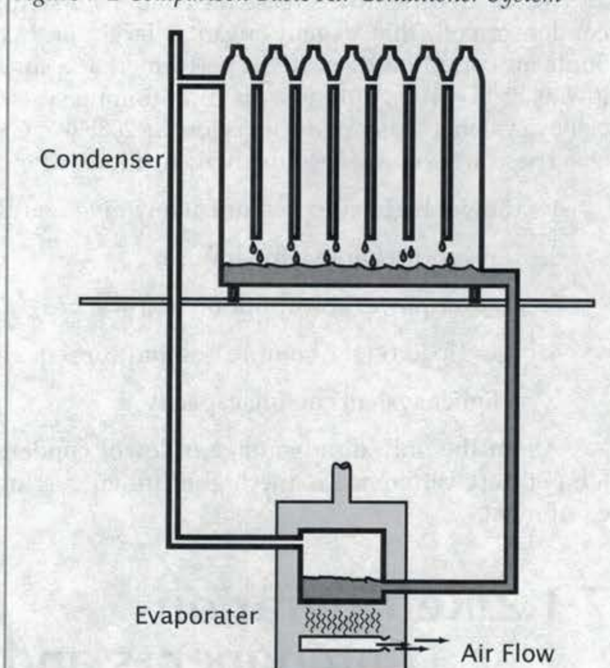


Figure 7-2 Comparison Basic Air Conditioner System



7-1.1.8 Refrigerants

In refrigeration systems, fluids that absorb heat inside the cabinet and release it outside are called *refrigerants*. These fluids, in their liquid form under reduced pressure, absorb heat in the evaporator and in absorbing heat change to a vapor. In their vapor form, the fluids are taken into the compressor, where the temperature and pressure are 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.

7-1.1.9 Conditions of Refrigerant

7-1.1.9.1 Saturated Liquid

This is liquid that is at such a temperature and pressure that, if any amount of heat is added, some of the liquid will change to vapor. In other words, the liquid that is in contact with vapor is saturated with heat to the extent 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 any enclosed cylinder, the point at which these pressures become equal is called the *saturation point*. When the pressures are equal, the molecules in the liquid's 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*. So when the surface of the liquid is holding all the heat it can while still remaining a liquid, it is called *saturated liquid* or at the liquid's *saturation point*.

7-1.1.9.2 Saturated Vapor

Saturated vapor is vapor at such a temperature and pressure that, if any amount of heat is removed from it, some of the vapor will condense to a liquid. In other words, the vapor that is in contact with liquid is saturated with vapor molecules to the extent that, if any heat is removed, some of the vapor will contract or draw closer together, causing the molecules to collect and condense into the liquid state. The process is called *condensation*. Saturated vapor identifies a condition of balance on an enclosed quantity of vaporized fluid. The balance is such that some condensate (liquid) will be produced if there is even the slightest lowering of temperature (heat removal) or increase in pressure.

7-1.1.9.3 Subcooled Liquid

This refers to a liquid that is at a temperature below saturation.

7-1.1.9.4 Superheated Vapor

This is vapor that is at a temperature above saturation.

7-1.1.10 Condensing Temperature Difference

If we subtract the outdoor temperature from the condensing temperature, we get the condensing temperature difference. Several years ago, when electricity was cheap and considered inexhaustible, it was stated that the condensing temperature difference would be from 20°F (-7°C) to 35°F (2°C). Many systems ran as high as 35°F (2°C). In order to decrease the condensing temperature difference, one would need either a more efficient condenser coil (that usually meant a larger and consequently more expensive coil) or a more efficient fan. Some air conditioning systems performed at a condensing temperature difference of 35°F (2°C), and some as low as 25°F (-4°C), but most air conditioning systems performed at approximately 30°F (-1°C). Our high-efficiency systems today perform as low as 20°F (-7°C) condensing temperature difference, and a few even lower.

These are some of the advantages of lower condensing temperature difference:

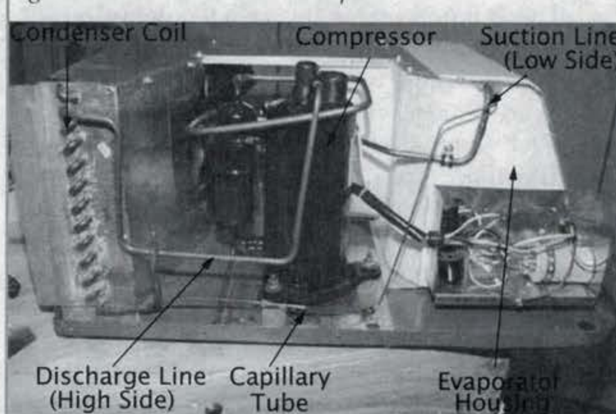
1. Lower high-side pressure at any given outdoor temperature
2. Lower discharge temperature
3. Lower power consumption or lower cost of operation
4. Less load on the compressor and consequently longer compressor life
5. Higher system cooling capacity

About the only disadvantage of lower condensing temperature difference is the higher initial cost of the equipment.

7-1.2 Refrigeration Components and Their Functions

Figure 7-3 shows an air conditioner with its components identified.

Figure 7-3 Air Conditioner Components



7-1.2.1 Compressor

A compressor is a device that uses compression to raise the pressure, temperature, and saturation point of refrigerant vapor. When operating properly, the compressor's function is to raise the vapor pressure and corresponding saturation point (condensing point) to one that is high enough to allow heat removal and condensation when the vapor is passed through the condensing coil of a compression refrigeration machine.

7-1.2.2 Discharge Line

This is a section of the copper line connecting the compressor and condenser. This line carries high-pressure, high-temperature refrigerant vapor from the compressor into the condenser.

7-1.2.2.1 High Side

The "high side" is that portion of the machine that manipulates refrigerant vapor with high pressure and a corresponding high-temperature condensing point. It allows outside air to extract heat from refrigerant vapor and returns it to a liquid state. The high side consists of the compressor, discharge line, condenser, liquid line, and capillary tube.

7-1.2.3 Condenser Coil

A condenser coil is a heat exchanger in which vapor is changed to liquid through the process of heat removal.

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 its heat will be removed (desuperheating). After the heat is removed from the refrigerant, 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, its condition is called a *sub-cooled liquid*. During all of the three processes in the condenser (desuperheating, condensing, sub-cooling), the refrigerant gives up heat, but the majority of the heat is given up during the condensing process.

7-1.2.4 Liquid Line

The liquid line (not shown in *Figure 7-3*) is the section of copper line connecting the condenser and the metering device. It carries high-pressure, high-temperature refrigerant liquid from the condenser to the capillary tube.

7-1.2.5 Metering Device

This refers to a device designed to control the flow of refrigerant to the evaporator. Metering can be accomplished by the use of a capillary tube, fixed orifice, or expansion valve.

7-1.2.5.1 Capillary Tube or Fixed Orifice

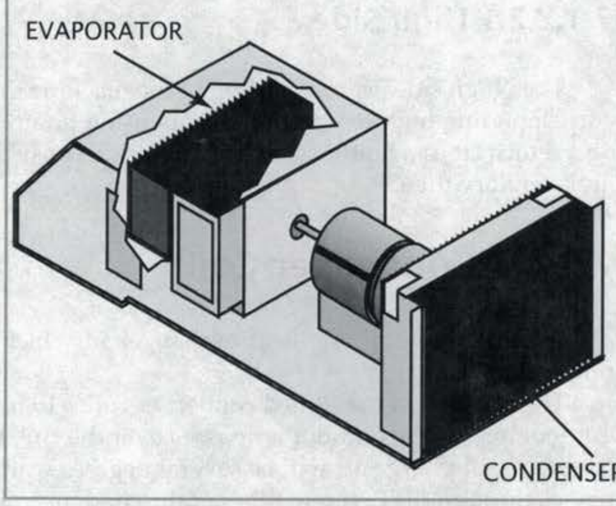
This is a small-diameter tube or opening designed to meter refrigerant into the evaporator of a refrigeration machine. It reduces refrigerant pressure and flow through friction that is controlled by the tube size or the orifice opening.

7-1.2.5.2 Expansion Valve

The expansion valve (not shown in *Figure 7-3*) is a device to control the flow of refrigerant to the evaporator. This valve automatically adjusts the flow rate by the temperature of the suction line.

7-1.2.6 Evaporator

Figure 7-4 Condenser/Evaporator



An evaporator is a heat exchanger in which liquid is changed into a vapor through the process of heat absorption.

When the liquid refrigerant passes from the capillary 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 liquid and vapor together. However, near the outlet of the evaporator coil, all of the liquid has boiled (evaporated) away and, from that point 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, as the pump is designed to compress vapor, not liquid.

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 often drained onto the roof of the recreation 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*. An example of a condenser/evaporator is shown in *Figure 7-4*.

7-1.2.7 Suction Line

The suction line is the 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.

7-1.2.7.1 Low Side

The *low side* is the portion of the machine that manipulates refrigerant liquid with low pressure and a corresponding low-temperature boiling point. It allows the system to absorb heat from inside air and, in the process, converts liquid to vapor refrigerant. The low side consists of the evaporator, suction line, and compressor intake.

7-1.3 How an Air Conditioner Works

7-1.3.1 Refrigerant Cycle

7-1.3.1.1 Refrigerant Changing States in Unit

Warm air is drawn into the air conditioner by the evaporator blower from the living area through the return air grill and filter over the cold evaporator. The cold refrigerant extracts heat and moisture from the traveling air. The warm air changes the state of the refrigerant from a liquid to a low-pressure gas. The cooler air is returned to the living area. The low-pressure gas passes through the accumulator to the compressor, where it is compressed to a hot/high-pressure gas. The hot/high-pressure gas enters the condenser coil, where cooler outside air is pulled in through louvers in the shroud of the air conditioner over the coil. The cooler air transforms the hot gas into a liquid that is metered into the evaporator.

7-1.3.1.2 Removal of Heat from Inside and Moving to Outside

Whenever a gas is compressed and heat removed (as in the air conditioning condenser), the gas will lose heat as it liquefies. As the pressure on the liquid is reduced (entering the evaporator), it returns to the vapor state, minus the heat that was lost in the condenser. The absence of heat makes the evaporator cold. And since the laws of physics make heat travel to cold, heat from the interior of the RV is absorbed by the refrigerant in the cold evaporator and carried to the compressor, which forces it into the condenser, where it gives up the heat to the outside air. The air is sucked from the living area by the spinning evaporator blower wheel that also passes the cooled air back into the RV. That's a complete cycle: the refrigerant picked the heat out of the interior air (where it was objectionable) through heat absorption and released it using the properties of evaporation and condensation.

7-1.3.1.3 Delta-Temperature Relationship (ΔT)

This is the drop in air temperature across the evaporator coil. The amount of this change in temperature, or the *delta,* is used to determine if the air conditioner is properly functioning.

7-1.3.2 Btu/hr Ratings

Air conditioners are generally rated by their Btu/hr capacity. RV furnaces are rated by the same Btu/hr method. Instead of measuring an amount of heat produced, the capacity of an air conditioner is measured in the amount of heat removed and given a Btu/hr value. One Btu/hr is enough heat to raise one pound of water one degree Fahrenheit. Since the rating for air conditioners is stated in Btu/hr, a 12,000 Btu/hr air conditioner can remove enough heat from the air to raise 12,000 lb of water (about 1,428 U.S. gallons) one degree Fahrenheit each hour.

7-1.3.2.1 Size of RV Air Conditioner Units

RV air conditioners are usually sized from 7,000 to 15,000 Btu/hr. The size of the air conditioner unit should be sized to the RV's electrical system. A larger air conditioner will draw up to 16 A at 120 VAC during normal operating conditions and will generally be protected by a 20 A circuit breaker.

7-1.3.2.2 Relationship of RV Size to Proper Air Conditioner Unit Size

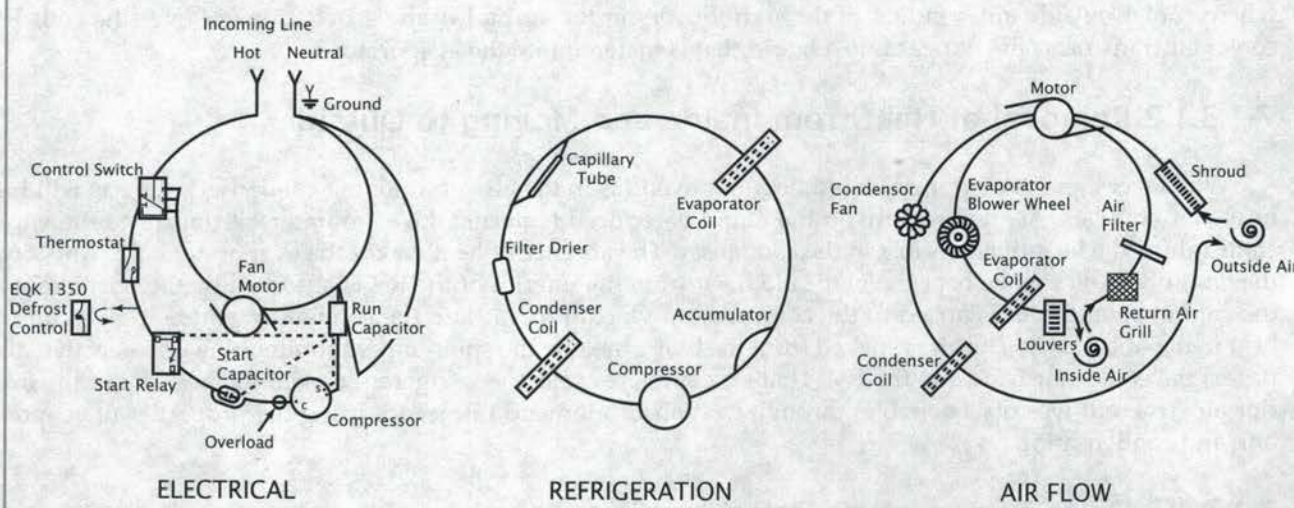
The size of an air conditioner unit is typically determined by the number of Btu/hr that can be removed from the RV. A 15,000-Btu/hr air conditioner can remove 15,000 Btu in a single hour. No specific criteria for sizing air conditioners have been developed because of the differing climatic conditions. Efficiency can be affected by the RV's insulation, size, number and placement of windows, number of people in the unit, and relative humidity. **Generally, the air conditioner should be as large as the RV electrical supply system will allow.**

NOTE: Amperage draw of air conditioners must not exceed capability of the RV electrical system (branch circuit and/or generator circuit).

7-1.3.2.3 Three Systems of an Air Conditioner

The three systems of an air conditioner are shown in *Figure 7-5* and detailed in the lists that follow.

Figure 7-5 Circles of Air Conditioner Components



1. Electrical system contains:
   - Control switch
   - Thermostat
   - EQK 1350 defrost control
   - Start relay
   - Start capacitor
   - Fan motor
   - Overload
   - Compressor
   - Run capacitor
2. Refrigeration system (proper charge volume from data plate) contains:
   - Capillary tube
   - Filter drier
   - Condenser coil
   - Compressor
   - Accumulator
   - Evaporator coil
3. Airflow system contains:
   - Motor
   - Condenser fan
   - Condenser coil
   - Shroud
   - Evaporator blower wheel
   - Evaporator coil
   - Louvers
   - Return air grill
   - Air filter

7-1.3.3 RV Air Conditioner Refrigeration Cycle Review

Earlier, an air conditioner was defined as a machine that transfers heat from one place to another. A simple law of physics (second law of thermodynamics) 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 refrigerant 22 (R22) within the system. (Other refrigerants such as R12 and R134a will vary.) Take a few minutes and look over *Table 7-1*. As the pressure of the refrigerant increases, so does the temperature; 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 R22. Most of us know that refrigerant exists in this air conditioner 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 *Table 7-1* will indicate that, by adding heat to the saturated refrigerant at 68.5 lb of pressure, the heat will cause the refrigerant to boil at 40°F (4°C), and it will continue to boil at 40°F (4°C) until the last drop of liquid is gone and all of the refrigerant is changed to a vapor.

Table 7-1 Pressure/Temperature Table for R22 at Saturation

Temp. °C	Temp. °F	Pressure PSIG	Temp. °C	Temp. °F	Pressure PSIG	Temp. °C	Temp. °F	Pressure PSIG
-7	20	43.0	8	46	77.6	22	72	125.7
-6	21	44.1	8	47	79.2	23	73	127.8
-6	22	45.3	9	48	80.8	23	74	130.0
-5	23	46.4	9	49	82.4	24	75	132.2
-4	24	47.6	10	50	84.0	24	76	134.5
-4	25	48.8	11	51	85.7	25	77	136.7
-3	26	50.0	11	52	87.4	26	78	139.0
-3	27	51.2	12	53	89.1	26	79	141.3
-2	28	52.4	12	54	90.8	27	80	143.6
-2	29	53.6	13	55	92.6	27	81	146.0
-1	30	54.9	13	56	94.3	28	82	148.4
-1	31	56.2	14	57	96.1	28	83	150.8
0	32	57.5	14	58	97.9	29	84	153.2
1	33	58.8	15	59	99.8	29	85	155.7

Table 7-1 Pressure/Temperature Table for R22 at Saturation

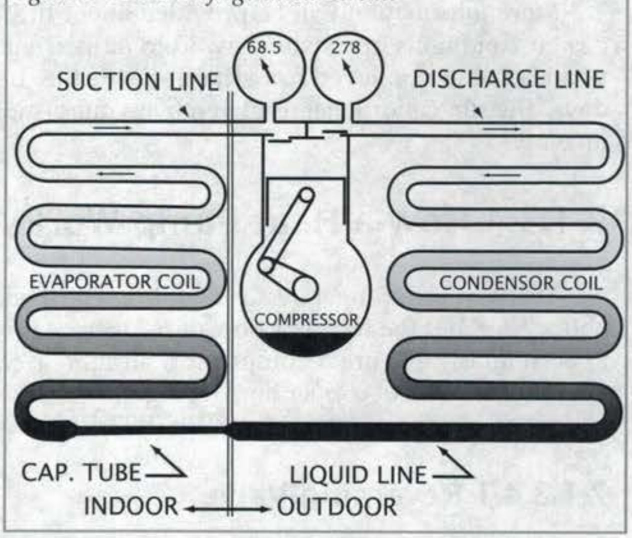
Temp. °C	Temp. °F	Pressure PSIG	Temp. °C	Temp. °F	Pressure PSIG	Temp. °C	Temp. °F	Pressure PSIG
1	34	60.1	16	60	101.6	30	86	158.2
2	35	61.5	16	61	103.5	31	87	160.7
2	36	62.8	17	62	105.4	31	88	163.2
3	37	64.2	17	63	107.3	32	89	165.8
3	38	65.6	18	64	109.3	32	90	168.4
4	39	67.1	18	65	111.2	33	91	171.0
4	40	68.5	19	66	113.2	33	92	173.7
5	41	70.0	19	67	115.2	34	93	176.4
6	42	71.5	20	68	117.3	34	94	179.1
6	43	73.0	20	69	119.4	35	95	181.8
7	44	74.5	21	70	121.4	36	96	184.6
7	45	76.0	22	71	122.5	36	97	187.4
37	98	190.2	48	119	256.4	60	140	337.3
37	99	193.0	49	120	259.9	61	141	341.5
38	100	195.9	49	121	263.5	61	142	345.8
38	101	198.9	50	122	267.0	62	143	350.1
39	102	201.8	51	123	270.6	62	144	354.4
39	103	204.7	51	124	274.3	63	145	358.9
40	104	207.7	52	125	278.0	63	146	363.4
41	105	210.8	52	126	281.7	64	147	367.8
41	106	213.8	53	127	285.4	64	148	372.4
42	107	216.9	53	128	289.2	65	149	376.9
42	108	220.0	54	129	293.0	66	150	381.5
43	109	223.2	54	130	296.8	66	151	386.2
43	110	226.4	55	131	300.7	67	152	390.9
44	111	229.6	56	132	304.6	67	153	395.6

Table 7-1 Pressure/Temperature Table for R22 at Saturation

Temp. °C	Temp. °F	Pressure PSIG	Temp. °C	Temp. °F	Pressure PSIG	Temp. °C	Temp. °F	Pressure PSIG
44	112	232.8	56	133	308.6	68	154	400.4
45	113	236.1	57	134	312.6	68	155	405.2
46	114	239.4	57	135	316.6	69	156	410.0
46	115	242.7	58	136	320.7	69	157	414.9
47	116	246.1	58	137	324.8	70	158	419.9
47	117	249.5	59	138	328.9	71	159	424.8
48	118	253.0	59	139	333.1	71	160	429.9

NOTE: Large amounts of heat are required to boil liquid refrigerant into a vapor.

Figure 7-6 Basic Refrigeration Circuit



A sketch of a basic refrigeration circuit is shown *Figure 7-6*. This may be considered a normally operating air conditioning refrigeration circuit. The only accessories shown that are not needed are the gauges. The only thing that is essential for operation, but not shown, is the motor to drive the airflow over the evaporator and condenser coils. Let's start analyzing it at the evaporator coil. The evaporator has liquid R22 slowly feeding into it at the bottom. The pumping action of the compressor pushing the liquid through the cap tube has reduced the pressure of the R22 in the evaporator. Consequently, the boiling temperature of the liquid R22 has been lowered. We can see by reading our gauge that the pressure in the evaporator is 68.5 pounds per square inch gauge (psig). At that pressure (68.5 psig), the R22 liquid will boil at 40°F (4°C) (refer to *Table 7-1*). There is return air at approximately 75°F (24°C) passing over the evaporator, so heat will transfer by conduction from the 75°F (24°C) air through the walls of the tubes to the 40°F (4°C) R22; thus heat is being extracted from the air. The heat going into the R22 liquid causes the R22 liquid to absorb the latent heat of vaporization. Notice that the liquid R22 is all vaporized away before it leaves the evaporator, so the compressor is pumping only R22 vapor. The portion of the evaporator that 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 icewater). 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 coach's interior air.

At this point, we have shown the important part of the air conditioner's job. We have drawn the warm, moist air from the coach, pulled it through the evaporator coil, and returned this air cooler and drier to the coach 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 coach 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 *Figure 7-6*, 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 that is to be removed is all sensible heat.

At 278 psig vapor pressure (refer to the *Table 7-1*), R22 vapor will condense at 125°F (52°C). 125°F (52°C) is called the *condensing temperature* at which this system is now performing. A fan pulls 95°F (35°C) outdoor air over the condenser coil so heat will conduct from the 125°F (52°C) R22 vapor through the walls of the tubing to the 95°F (35°C) air. This process allows the R22 vapor to give up its latent heat of condensation to the outdoor air. Liquid R22 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 R22 liquid to the capillary tube. The capillary tube is the metering device—so-called because it is so small that it reduces the pressure and meters the right amount of R22 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 once.

In the preceding example of a basic refrigeration cycle, we have described 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 vary with different temperature and humidity conditions both inside and outside of the recreation vehicle. For example, as the temperature of the air increases, there is more 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 *Chapter 7-4*. Humidity also adds load to the system. At design conditions approximately 30 to 40 percent of the capacity is dedicated to humidity removal. Every pound of water removed from the air inside the coach takes approximately 1060 Btu/hr. On extremely humid days, the air conditioner unit removes more moisture from the air so that portion of the total capacity increases.

7-1.3.4 How a Heat Pump Works

The heat pump operates in two different modes: cooling and heating. The same mechanism is used for both cycles, but the travel or flow of refrigerant is reversed to change from cooling to heating. The items used to accomplish this are a compressor, an indoor coil, an outdoor coil, capillary tube or tubes (the metering device(s), a series of copper lines (refrigerant-grade tubing), a reversing valve, an air movement system (motor and wheel or blades), and refrigerant (R22).

7-1.3.4.1 Reversing Valve

The reversing valve is the main component of a heat pump that allows the heat pump to heat or cool. Depending on the position of the reversing valve, the high pressure of the refrigerant vapor can be diverted to the indoor coil or the outdoor coil, causing the heat pump to heat or cool. The following is a thorough review of how the cooling and heating functions work.

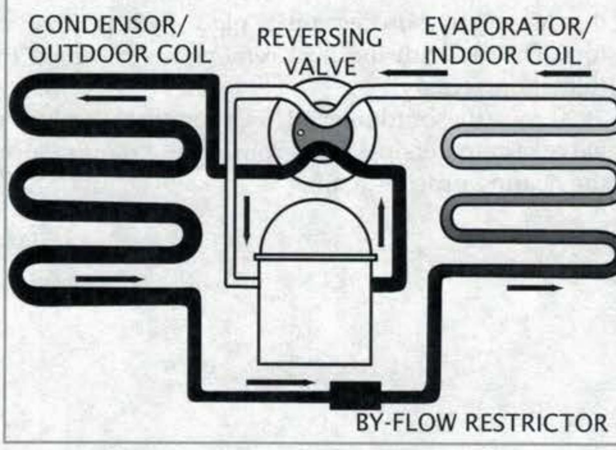
7-1.3.4.2 Cooling Mode

To cool the air inside a structure, heat is removed from the indoor air and released to the outdoor air or ambient. To accomplish this, first airflow is established to pass over both coils (indoor and outdoor). The process is shown in *Figure 7-7*. Next, a refrigerant cycle is established to cause refrigerant (R22) to flow through both coils.

The refrigerant cycle starts at the compressor. Its function is to take the low-pressure R22 vapor and discharge it as high-pressure vapor. As the refrigerant (R22) is compressed, it gives off heat, causing the discharge line to be quite warm or hot to the touch in hot weather.

The R22 high-pressure vapor leaves the compressor through the discharge line and enters the reversing valve. The reversing valve routes the high-pressure vapor to the outdoor coil. In the cooling mode, the outdoor coil is a condenser coil.

Figure 7-7 Cooling Mode



The high-pressure R22 vapor enters the outdoor coil (condenser). Here it is cooled and condensed into liquid R22 by passing through the coil. The heat removed from the refrigerant is expelled to the outdoor air. The refrigerant leaves the outdoor coil as high-pressure liquid.

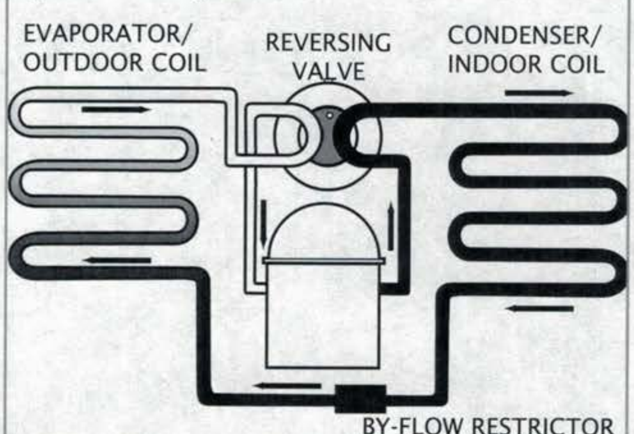
As the high-pressure liquid R22 leaves the outdoor coil (condenser), it passes through the small capillary tube or tubes. This is the metering or flow control device in the sealed system. It determines the amount and force of which the R22 enters the indoor coil. It is **imperative** that the capillary tube's length and diameter not be altered. If the tube is altered, the unit will not operate as efficiently as it should.

The high-pressure liquid R22 then enters the indoor coil in a controlled amount from the capillary tube. When the liquid enters the low-pressure atmosphere of the indoor coil (evaporator), it evaporates into vapor. When the evaporative process takes place, heat is removed from the air flowing through the indoor coil (evaporator). The air with the heat removed is returned to the inside of the structure via the air movement system (blower assembly).

From the indoor coil (evaporator), the low-pressure refrigerant (R22) vapor returns to the reversing valve. The reversing valve routes the low-pressure vapor to the compressor through the suction line to start the cooling process again.

7-1.3.4.3 Heating Mode

Figure 7-8 Heating Mode



To heat the air inside a structure, heat is removed from the outdoor air or ambient and released to the indoor air. The process is shown in *Figure 7-8*.

To accomplish this, first airflow is established to pass over both coils (indoor and outdoor). Next, a refrigerant cycle is established to cause the refrigerant (R22) to flow through both coils.

The refrigerant cycle starts at the compressor. Its function is to take the low-pressure R22 vapor and discharge it as high-pressure vapor. As the refrigerant (R22) is compressed, it gives off heat causing the discharge line to be quite warm to the touch. The R22 high-pressure vapor leaves the compressor through the discharge line and enters the reversing valve. The reversing valve routes the high-pressure vapor to the inside coil. In the heating mode, the inside coil is a condenser coil.

The high-pressure R22 vapor enters the indoor coil (condenser). Here it is cooled and condensed into liquid R22 by passing through the coil. The heat removed from the refrigerant is expelled to the inside air. The refrigerant leaves the indoor coil as high-pressure liquid.

As the high-pressure liquid R22 leaves the indoor coil (condenser) it passes through the small capillary tube or tubes. This is the metering or flow control device in the sealed system. It determines the amount and force of which the R22 enters the outdoor coil. It is imperative that the capillary tube's length and diameter not be altered. If the tube is altered, the unit will not operate as efficiently as it should.

The high-pressure liquid R22 enters the outdoor coil in a controlled amount from the capillary tube. When the liquid enters the low-pressure atmosphere of the outdoor coil (evaporator), it evaporates into vapor. When the evaporative process takes place, heat is removed from the air flowing through the outdoor coil (evaporator). The air with the heat removed is returned to the outdoor air (ambient) via the air movement system (blower assembly).

From the outdoor coil (evaporator), the low-pressure refrigerant (R22) vapor returns to the reversing valve. The reversing valve routes the low-pressure vapor to the compressor through the suction line to start the heating process again.

7-1 Review

1. Heat cannot be destroyed. It can only be transferred from one place to another.

   True False

2. Refrigeration is only used to cool something.

   True False

3. RV air conditioning equipment pumps cold air into the vehicle.

   True False

4. List four types of refrigeration equipment.

   A.

   B.

   C.

   D.

5. List four typical types of air conditioners used in RVs.

   A.

   B.

   C.

   D.

6. The first law of thermodynamics states that:

   A. Energy cannot be created or destroyed.

   B. Heat cannot be created or destroyed.

   C. Energy can be created or destroyed.

   D. Heat can be created or destroyed.

7. The second law of thermodynamics states that:

   A. Energy moves from stationary to moving.

   B. Energy moves from moving to stationary.

   C. Heat always moves from cold to hot.

   D. Heat always moves from hot to cold.

8. List the six forms of energy.

   A.

   B.

   C.

   D.

   E.

   F.

9. Identify the following:

   A. ________________ : Energy that causes matter to move

B. ____________ : Energy transferred through space

C. ____________ : Energy that produces molecular motion

D. ____________ : Energy consisting of electrons and protons

10. List the two types of heat we are concerned with in refrigeration systems.

    A.

    B.

11. Which of the following is not a type of latent heat?

    A. Fusion

    B. Radiant

    C. Freezing

    D. Vaporization

    E. Condensation

    F. Sublimation

12. Btu/hr stands for:

    A. Bradford Technical University

    B. British Technical University

    C. Bradford thermal unit

    D. British thermal unit

13. The amount of heat necessary to raise the temperature of one pound of water one degree Fahrenheit at sea level is called a ____________.

14. Identify the three methods of heat transfer.

    A.

    B.

    C.

15. Identify the following:

    A. ____________ : Flow of heat transmitted by waves

    B. ____________ : Flow of heat from one place to another by way of fluid or air

    C. ____________ : Flow of heat between parts of a substance

16. Substances that conduct heat poorly are called:

    A. Insulators

    B. Isolators

    C. Conduits

    D. Conductors

17. Liquid that is at such a temperature and pressure that, if any amount of heat is added, some of the liquid will change to vapor, is called ______________.
18. The process of liquid changing to vapor is called ______________.
19. Vapor that is at such a temperature and pressure that, if any heat is removed some of the vapor will turn to liquid, is called ______________.
20. The process of vapor turning to liquid is called ______________.
21. Refrigerant changes from liquid to low-pressure vapor at the:
    A. Evaporator
    B. Condenser coil
    C. Compressor
    D. Capillary tube
22. Refrigerant changes from a low-pressure vapor to a high-pressure vapor at the:
    A. Evaporator
    B. Condenser coil
    C. Compressor
    D. Capillary tube
23. Refrigerant changes from a high-pressure vapor to a high-pressure liquid at the:
    A. Evaporator
    B. Condenser coil
    C. Compressor
    D. Capillary tube
24. In an air conditioner unit, the component in which the heat is absorbed from the living area is:
    A. Evaporator
    B. Condenser coil
    C. Compressor
    D. Capillary tube
25. In an air conditioner unit, the refrigerant forces heat to the ______________ air in the ______________.
26. The term ______________ is used to identify the change in air temperature across the evaporator coil.
27. The size of an RV air conditioner unit should be determined by:
    A. The size of the electrical system
    B. The propane pressure
    C. Cost
    D. The owner's wishes

28. Which of the following can affect air conditioner efficiency?
    - A. Insulation
    - B. Size of unit
    - C. Numbers of windows
    - D. Placement of windows
    - E. Number of people in unit
    - F. Relative humidity
    - G. Power voltage
29. The main difference between the heating and cooling modes of a heat pump is:
    - A. The type refrigerant must be changed.
    - B. The flow of the refrigerant is reversed.
    - C. Power source changes from electricity to propane.
    - D. There is no difference.
30. The main component of a heat pump that allows the heat pump to heat or cool is the ________________.

Chapter

7-2 Montreal Protocol

- Explain properties of refrigerants (R22, R12, R134a).
- Identify safe handling and environmental concerns of refrigerant.
- Identify Montreal Protocol.

An international agreement, known as the Montreal Protocol on Substances that Deplete the Ozone Layer, controls the production and consumption of substances that can cause ozone depletion. The Clean Air Act of 1990 set guidelines in the United States in regard to recapturing or disposition of refrigerants, based on the directive of the Montreal Protocol.

7-2.1 Introduction to Recycling Refrigerants

7-2.1.1 History of Refrigerants and Uses

In 1930, Du Pont Chemical Co. announced a newly developed refrigerant with the chemical name dichlorodifluoromethane. Instead of using the chemical name, Du Pont called their new refrigerant "Freon®." Later, Du Pont developed other refrigerants that they also called Freons, so they assigned numbers to each refrigerant (Freon 11, Freon 12, Freon 13, Freon 22, and so on). After the Freon patents expired, several other companies started marketing refrigerants under their own brand names: Racon, Isotron, Kaiser Refrigerants, Ucon, Genetron, and so forth, but the industry has continued to use the Freon numbers.

7-2.1.1.1 Chemical Composition of Refrigerants

Many refrigerants are compounds of chlorine, fluorine, and carbon, so the generic identification for them is chloro fluoro carbons, abbreviated CFCs. We now identify each of these refrigerants by calling it refrigerant (abbreviated "R") and its number, i.e., R12, R22, R11, R502, and so forth.

Chemical Makeup of Refrigerants

Many refrigerants are composed of the following types of chemical compounds:

1. Chlorofluorocarbons
2. Hydrochlorofluorocarbons
3. Hydrofluorocarbons

7-2.1.1.2 Atmospheric Effects of Refrigerants

Historically, refrigerants have been responsible for negative effects on the atmosphere (ozone layer depletion). The development of refrigerants that have less negative effects on the atmosphere is continuing.

7-2.2 Montreal Protocol

7-2.2.1 History and Participants

Global cooperation for the protection of the stratospheric ozone layer began with the negotiations of the Vienna Convention for the Protection of the Ozone Layer, which concluded in 1985. The details of the international agreement were defined in the Montreal Protocol on Substances that Deplete the Ozone Layer. The Montreal Protocol was signed in September 1987 and became effective in 1989. It contains provisions for regular review of the adequacy of control measures based on assessments of evolving scientific, environmental, technical, and economic information.

7-2.3 Recovering, Reclaiming, and Recycling

7-2.3.1 Recovery Methods and Requirements

Check with the state or local authorities for the proper handling of evacuation of refrigerants. The evacuation and recharge of the sealed refrigerant system must be done only by a technician trained by EPA, HRAI, or other governing-body-approved organizations and instructors in the procedure and equipped with the necessary items.

7-2.4 Certification

The Clean Air Act of 1990 addresses refrigerants. RV technicians handling refrigerants must be certified as at least a Type I. Refrigerant handlers certification can only be administered by EPA, HRAI, or other governing-body-approved organizations and instructors.

7-2 Review

1. Historically, refrigerants have been responsible for negative effects on the atmosphere known as ________________.

2. The evacuation and recharge of the sealed refrigerant system must be done only by a technician trained in the procedure and equipped with the necessary items.

   True False

3. Refrigerant handlers certification can only be administered by EPA, HRAI, or other governing-body-approved organizations and instructors.

   True False

4. RV technicians handling refrigerants must be certified as at least a Type I.

   True False

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Chapter
7-3 Airflow

- Identify airflow cycle.
- Visually inspect for blockage.
- Determine proper system operation.
- Test the systems function.
- Inspect filters.
- Inspect evaporator coil.
- Determine airflow and ducting requirements.
- Verify airflow proper operation.

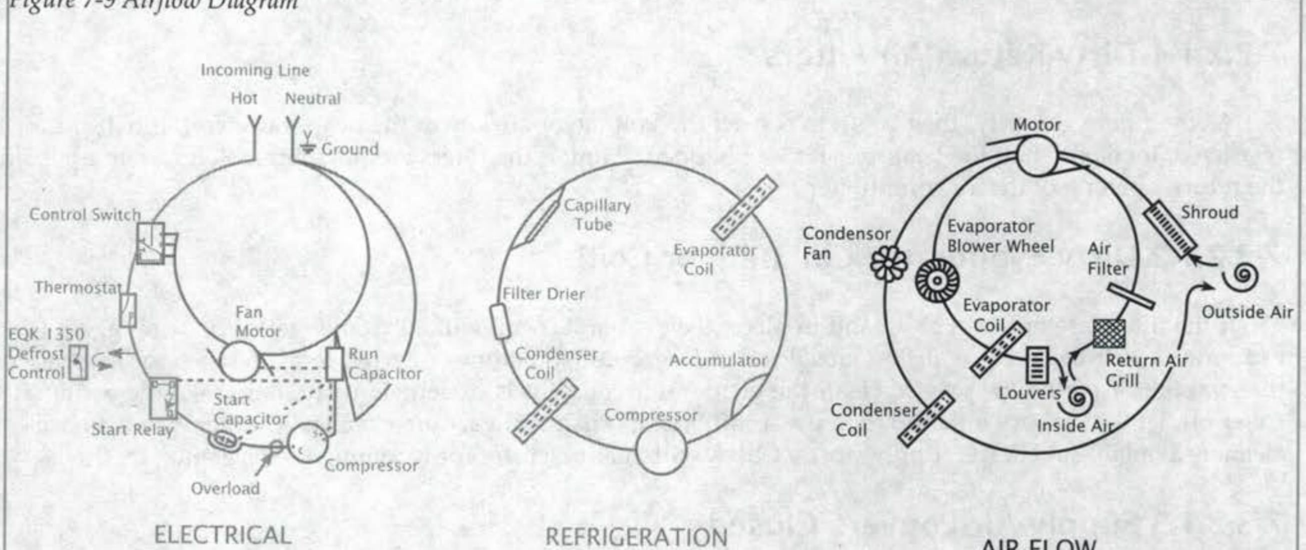
7-3.1 Condenser Coil and Evaporator Coil Airflow

7-3.1.1 Airflow and Effect

The proper operation of any RV air conditioning system is highly dependent upon proper volume and temperature of indoor and outdoor air circulation through the coils. An airflow diagram, *Figure 7-9*, shows the components that relate to the air circulation system within the air conditioner. In fact, airflow is so important to the air conditioner that it is well deserving of its own individual chapter. After electrical problems, improper or insufficient airflow through the coils is the second most common reason why air conditioners cease cooling. Low return air temperatures and/or insufficient evaporator coil airflow contribute to almost 100 percent of the air conditioner freeze-up problems, especially when these conditions are combined with cool outdoor ambient temperatures. On the other hand, dirty condenser coils contribute to air conditioners tripping circuit breakers and compressor overload.

The amount of air and the temperature or heat content in the air are the factors controlling the operating pressures within the air conditioner system. As the pressures go up or down, so do the evaporative and condensing temperatures. The main condition in which an air conditioner freezes up is when the evaporating or boiling temperature of the refrigerant in the evaporator coil drops below freezing. How could this happen? Contrary to popular belief, the primary reason for this is that the evaporator coil is not picking up enough heat to keep the pressure/temperature relationship above 32°F (0°C) (57 psig).

Figure 7-9 Airflow Diagram



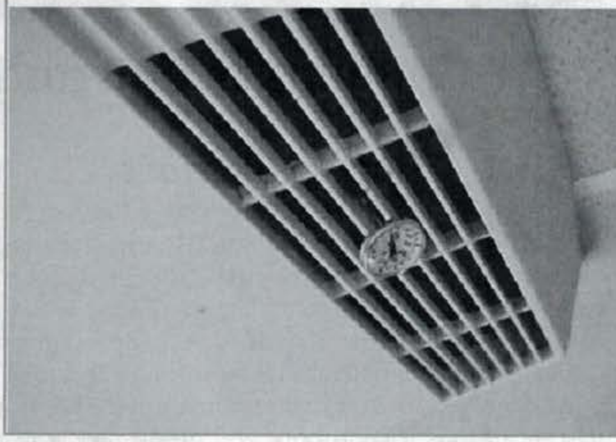
7-3.1.1.1 Room Air Dehumidification

As air conditioning systems cool the air, they also dry the air. This occurs when moisture in the air contacts the cold evaporator coil and turns to water droplets. The air leaving the evaporator coil has less moisture than when it entered. Water dripping from air conditioning units is actually moisture that was removed from the coach's interior air.

7-3.2 Measuring Airflow Temperatures

Measuring the airflow temperatures is a good way to determine if the air conditioner is in good working order. To do this, the air temperature is measured as the air enters the evaporator coil and as the air leaves the evaporator coil area. Simply insert a thermometer in through the return air filter, as in the *Figure 7-10*, and compare it to the temperature of the cooler air measured at the outlet duct(s), thereby determining the temperature difference between each side of the evaporator. With the indoor air at about 50 percent relative humidity, the temperature drop (ΔT) across the evaporator coil should be approximately 20°F (11.1°C). The air temperature differential of the air across the coil will be less if the relative humidity inside the RV is greater than 50 percent. If the relative humidity is less than 50 percent, the change in temperature (ΔT) should increase.

Figure 7-10 Thermometer in Return Air Filter



7-3.2.1 Evaporator Airflow

Obstructions reduce the amount of air passing through the coils. Dirt acts as an insulator, reducing the heat transfer across the fins. This could lead to a lack of airflow and eventually a frozen evaporator. A blocked evaporator also can result in lower than normal amperes at the compressor.

Some of the most common causes for lack of airflow/heat transfer are described below.

7-3.2.1.1 Dirty Return Air Filters

As the filters get dirty, they begin to restrict the volume of airflow to the evaporator coil. If half the air is restricted, then only half the heat transfer will happen. (Hint: if the filters are missing, look for them up inside the return opening of the air conditioner.)

7-3.2.1.2 Dirty Evaporator Coil (Indoor Coil)

If the filters are not kept clean and in place, the evaporator coil will inevitably get dirty or plugged. Dirty evaporator coils can reduce airflow, resulting in freeze-up (sometimes referred to as *frost-over* or *freeze ice* on the evaporator coil). One way to clean the evaporator coil, if it is extremely dirty, is to take the evaporator cover off, let the coil dry out, and then use a soft bristle brush and vacuum cleaner. Another way is to use coil cleaners available at HVAC supply stores. Check with manufacturer for recommended cleaning methods.

7-3.2.1.3 Supply Air Louvers Closed

Some retail customers will shut the supply air louvres off when they get cold instead of turning the thermostat to a warmer setting. Any air conditioner will freeze up if the airflow is restricted enough.

7-3.2.1.4 Low Ambient Temperatures

As the temperatures outside drop off, so does the high-side discharge pressure. Now less refrigerant is pushed through the capillary tube into the evaporator coil. Consequently, the evaporator temperature is lower. If this is combined with return air temperatures, freeze-up is likely.

7-3.2.1.5 Restricted Ductwork

This can be a difficult problem to identify, because the ductwork is often hidden in the ceiling. Airflow from air conditioner systems may be affected by duct systems that are not sized correctly. Ducts that are too small can adversely affect airflow. The air conditioner installation instructions will address the proper sizing of duct systems for the air conditioner used. To check proper airflow, use an anemometer and compare the reading to manufacturer specifications.

NOTE: Quite often, freeze-up 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, anytime water is condensed from the air, this adds load to a system. See *Chapter 7-8*.

7-3.3 Evaporator Discharge Duct and Air Separation

7-3.3.1 Ceiling Assembly Models

Short cycle is caused by cold air being drawn back into the intake side of the air conditioner before it is mixed with the warmer room air. This may cause the evaporator coil to freeze up, causing the cold control to open the circuit to the compressor. Two possible causes of this condition are the air box and the discharge duct. If the air box is not sealed tightly against the ceiling, it will allow cold air to cross over into the return air portion of the air conditioner. The correct discharge duct must be selected for the thickness and rounding of the roof. All problem areas should be sealed. Tape may be needed to seal the discharge duct.

7-3.3.2 Ducted Assembly Models

Short cycle could be caused by air being circulated directly on the remote sensor. Make sure registers are not too close to the remote sensor. Verify that the duct connection at the unit is not leading into the return air. Seal all problem areas.

7-3.4 Condenser Airflow

7-3.4.1 Air Space around Condenser Coil

The condenser section is either a blow-through or a suck-through type. The condenser section is gasketed to separate the intake from the hot air discharge. This prevents hot air from being recirculated. Visually check to ensure that the gasket is not damaged or missing.

7-3.4.2 Effects of Blocked Condenser Coil

The condenser coil must release the heat that was absorbed in the system's evaporator coil. If it doesn't, the pressures and temperatures of the refrigerant on both the high and low sides increase, and the air conditioner will cease cooling. Environmental blockages such as dirt, sand, leaves, and spider webs reduce the airflow across the coil and impact the heat transfer at the condenser coil. This will cause the condenser coil to work harder, requiring higher ampere draws, and can possibly overload the condenser coil and trip breakers. Crushed or damaged fins will reduce airflow and affect the heat transfer.

NOTE: Not all environmental blockages, such as wood smoke, paint overspray, and smog residue, are readily visible.

7-3.5 Other Causes of Lack of Airflow

7-3.5.1 Blower Motors

Blower motors with insufficient current in amperes or speed in rotations per minute (rpm) will cause unsatisfactory airflow. Check that the rpm and amperes are as specified on the blower motor or by the blower motor manufacturer.

7-3.5.2 Blower Wheels and Fans

Dirty or rubbing blower wheels and fans can also negatively affect airflow. Visually check and remove dirt and debris if present. Also ensure that the fan is centered in its shroud.

7-3.6 Inspecting for Blockage

7-3.6.1 Method of Inspection

Make sure the coils are clean and unclogged. Remove the exterior cover shroud and/or the evaporator housing as needed, and vacuum or blow out the coils to remove dirt. The primary method of inspection is visual. Coil fins should be examined and, if necessary, cleaned and straightened. A fin coil comb, typically available from the air conditioner parts supplier or manufacturer, can be used.

Many blockages, as stated before, are created by the environment. These includes dirt, leaves, and insect webs or similar causes.

7-3.7 Checking System Pressures

Checking the system pressure of an air conditioner is not a typical procedure. This is because it requires the sealed system to be opened. Checking the system pressure should be done only as a last resort, when all other troubleshooting efforts lead to this action.

7-3.7.1 Conducting a Very Basic Cooling Performance Test

After proper airflow 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. (see *"Compressor" on page 7-36*)
2. Check the air temperature drop (ΔT) across the evaporator coil. Note: before this can be done effectively, the air temperature inside and outside the coach should be above 75°F (24°C). [Operating temperatures cooler than 75°F (24°C) could promote coil freeze-up problems.]

7-3.7.2 Procedure for Checking Air Temperature Drop (ΔT) across Evaporator Coil

1. Completely open all supply (discharge) air registers.
2. Start the air conditioning unit and allow it to run for at least half an hour on high. The objective is to saturate the evaporator coil before running a temperature test.
3. With a standard dial-type or digital thermometer, measure the temperature of the air immediately entering the return air grill of the air conditioner unit. This is the return air temperature.
4. With a standard dial-type or digital thermometer, measure the temperature of the air immediately leaving the supply (discharge) louvres. This is the supply air temperature.
5. Subtract the supply air temperature from the return air temperature. (If it is a ducted air conditioner unit, use the closest discharge register and make sure the temperature sensing device is measuring supply air temperature only.)
6. A properly running air conditioner unit should have a nominal temperature difference of 20°F (11.1°C).

NOTE: Slightly lower temperature differences are possible under extremely humid conditions. (The unit may have to run longer to remove moisture.)

7. Temperature differences greater than 22°F (–5.5°C) are possible in warm, dry weather. Restricted airflow over the evaporator coil or low fan speed may also cause greater than 22°F (–5.5°C) temperature differences.

NOTE: When using two thermometers, one for intake and one for discharge, be certain they are calibrated to each other.

7-3 Review

1. The proper operation of any RV air conditioning system is highly dependent upon proper ____________ and ____________ of indoor and outdoor air circulation through the ____________.
2. The reason air conditioners seem to quit cooling is ____________ and ____________.
3. As operating pressures within the air conditioner system go up or down, so does the ____________.
4. As air conditioner systems cool the air, they also ____________.
5. To measure airflow temperatures, the air temperature is measured as the air enters the ____________ and as the air leaves the ____________.
6. List five causes for airflow/heat transfer.

   A.

   B.

   C.

   D.

   E.
7. List the two types of condenser coil.

   A.

   B.
8. Checking system pressure of an air conditioner requires the sealed system to be opened.

   True False
9. Checking system pressures is one of the first troubleshooting steps a technician should take.

   True False
10. Proper airflow has been determined and coil surfaces are checked and cleaned. What are the next two steps in a very basic cooling performance test?

    A.

    B.

Chapter 7-4 Electrical Circuitry

- Identify electrical cycle.
- Read wiring diagram for the RV air conditioner.
- Measure operations of air conditioner circuits.
- Measure operations of air conditioner components.
- Diagnose air conditioner electrical systems.
- Repair air conditioner electrical connections and circuits.
- Test the air conditioners electrical systems function.
- Determine electrical requirements.

7-4.1 Components, Functions, and Interactions

7-4.1.1 Manual Control Air Conditioners

7-4.1.1.1 Selector Switch

There are four different selector switches used in the manufacture of the RV air conditioner. They are the ten-position, eight-position, six-position, and five-position switches. The air box decal will indicate which type is used.

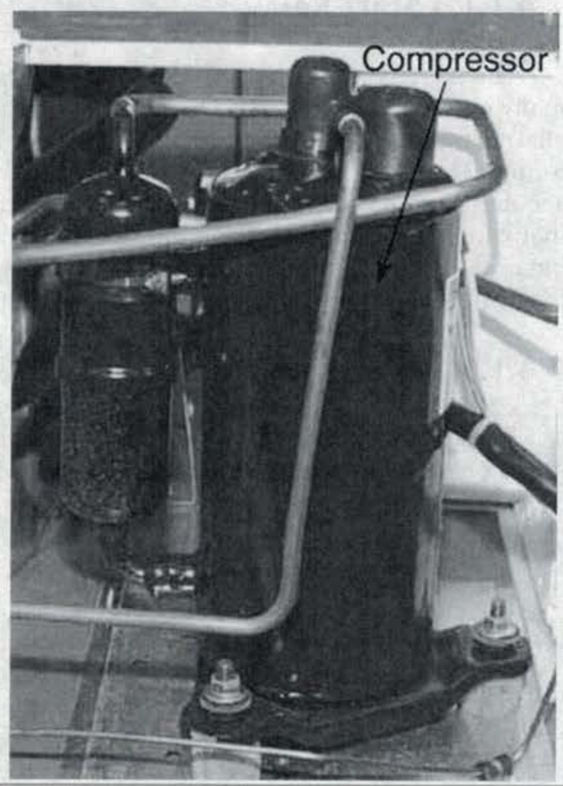
7-4.1.1.2 Thermostat

Two types of thermostats have been used in the manufacture of air conditioners: cooling only and heat/cool.

7-4.1.1.3 Compressor

The compressor, as shown in *Figure 7-11*, pumps the refrigerant vapor through the system.

Figure 7-11 Compressor



Open or Shorted Compressor, Start or Run Windings

There is an excellent way of checking compressors by checking the windings, as depicted in *Figure 7-12*. Since the start and run windings are connected to the common terminal of the compressor, a simple test with a multimeter set to measure resistance in ohms will determine the electrical condition of the compressor.

To begin with, disconnect all leads to the compressor. Be sure to unplug the coach from electrical power or shut down the generator.

NOTE: Be sure to discharge all capacitors before disconnecting wires, as described in *"Start Capacitor" on page 7-37.*

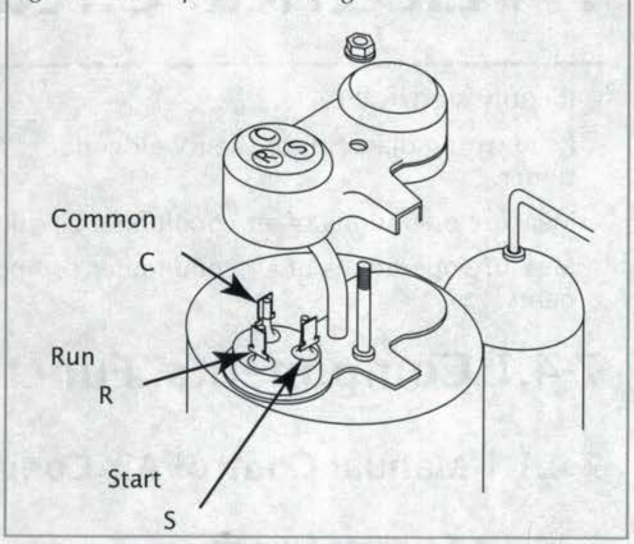


Figure 7-12 Compressor Windings

Now, with the three leads disconnected and marked (including the overload), check and record the following ohm readings at these terminals on the compressor: S + C (start + common), R + C (run + common), and S + R (start + run). Because the start and run windings are both connected to the common terminal, a little arithmetic will yield the answer. Add the S + C ohm reading to the R + C reading, and the sum should equal the S + R reading. The equation is: (S + C) + (R + C) = (S + R).

Check with the multimeter for continuity between the case and all terminals. There should be no continuity (infinity) between the compressor case and any terminal; if there is continuity (no resistance), the compressor is shorted to the case and needs to be replaced.

The last item to be checked is the compressor overload. This is done by making sure there is continuity between the two terminals of the overload device. The windings shorted to ground or the compressor case could cause an open compressor overload or tripped 120 VAC circuit breaker.

7-4.1.1.4 Start Relay


Figure 7-13 Start Relay

The start relay, as shown in *Figure 7-13*, is a normally closed relay that connects the start capacitor parallel to the run capacitor for increased motor starting torque. The contacts on the relay open as the compressor starts and reaches approximately 75 percent of normal running speed, thus dropping the start capacitor out of the circuit. The relay contacts stay open as long as the compressor is running above 75 percent of normal.

7-4.1.1.5 Positive Temperature Coefficient Resistor (PTCR)

PTCR stands for positive temperature coefficient resistor, a solid state device that may replace the compressor start relay on some models. Check this device for continuity.

7-4.1.1.6 Start Capacitor

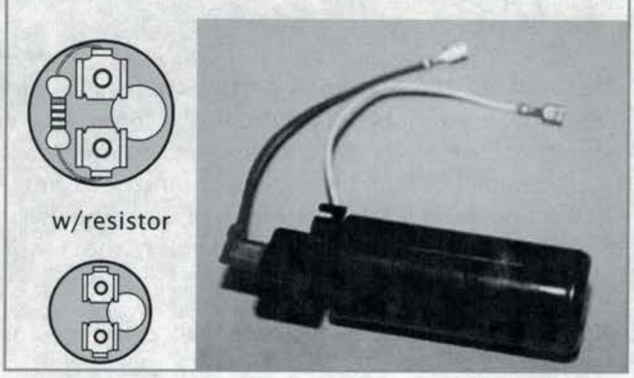


Figure 7-14 Capacitors

The capacitor-start/capacitor-run motor generally uses two capacitors, as shown in *Figure 7-14*. Both are in the start winding circuit, but only one is controlled by the relay switch. When the motor is started, the capacitors turn the motor power surges into two-phase power and produce a high starting torque. After the motor reaches 75 percent of its rated speed, the relay opens the circuit to the starting capacitor.

7-4.1.1.7 Run Capacitor

The run capacitor may be one of two different kinds: a single capacitor for the fan or compressor, or a combination capacitor for both the fan and compressor. The purpose of a run capacitor is to give the motor starting torque and maintain a high power factor during operation. The run capacitor is always connected between the start and run terminals of the motor. A voltage much higher than the live voltage may be observed across the terminals on a run capacitor during motor operation. This is due to the electromotive force generated within the motor as it turns.

7-4.1.1.8 Circuit Breaker

A circuit breaker is a manually operated device designed to open and close an electrical circuit. More important, the circuit breaker is designed to open the circuit automatically on a predetermined overload of current, without injury to itself when properly applied within its rating.

7-4.1.1.9 Overload Switch

Mounted on the outside of the compressor housing is a two-terminal overload switch.

NOTE: There are some compressor models with internal overloads that are non-serviceable. 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. An overload switch is normally closed.

High Amperes (Current)

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

High Temperature (Thermal)

The switch is clamped tightly against the compressor housing and located close to the windings. As the windings reach a high temperature, it takes less current to cause the switch to open. The switch is always affected by a combination of current to the compressor and winding temperature.

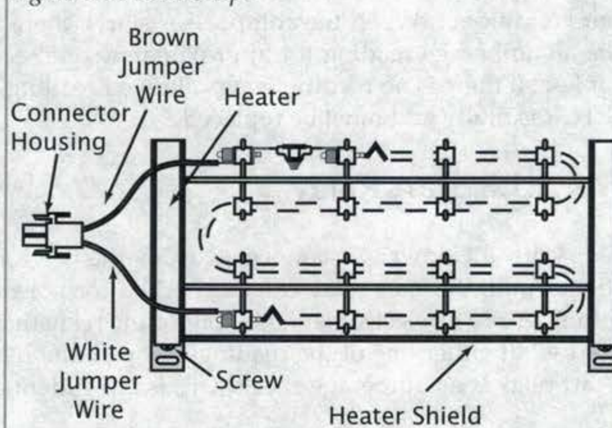
7-4.1.1.10 Defrost/Cold Controls

A preset switching device senses suction line or coil surface temperature and shuts down the compressor if the temperature drops to freezing.

7-4.1.1.11 Heat Strips

Many air conditioning units are equipped with heat strips, as shown in *Figure 7-15*, connected to a thermostat temperature control system with the air conditioner. The heat strip consists of a heating element and a limit switch to open the circuit in the event of an overheating situation. Heat strips operate on 120 VAC power.

Figure 7-15 Heat Strips



7-4.2 Component Testing

7-4.2.1 Individual Tests for All Components

7-4.2.1.1 Compressor

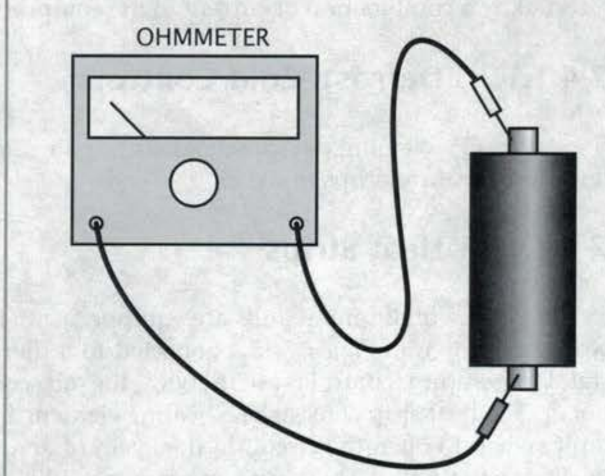
To check the integrity of the compressor motor windings, turn the air conditioner circuit breaker to OFF. Disconnect the wires from the common, start, and run terminals. With the volt-ohmmeter (VOM) set on the ohm scale, check for continuity among all three terminals. Lack of continuity indicates faulty windings in the compressor, and the compressor should be replaced. Next, scrape some paint off the casing of the compressor and check for continuity between each terminal and the casing. If a reading is obtained, the windings are shorted to the casing, and the compressor must be replaced. The second compressor check would be made while the compressor and fan motor are in operation, after it has been running for 30 minutes. Using an ammeter, we can check the compressor (FLA) or (RLA) to see if it is operating at the correct amperage. The data plate on the air conditioner unit itself will show what the FLA should be. For example, a standard 13,500 Btu/hr compressor should draw 11.4 FLA at rated conditions. The rated conditions are defined as 95°F (35°C) ambient temperature, 80°F (26.6°C) indoor temperature, 50 percent relative humidity, and 120 VAC. The amperage on the data plate was established during design engineer cell testing. When the outdoor or indoor ambient temperature rises, the load conditions change, and the amperage increases. The opposite happens when the outdoor or indoor ambient temperature decreases. There is less of a load, and the amperage decreases. For example, at 75°F (24°C), the compressor amperage could be from 7 to 8 A. At 95°F (35°C) outdoor, it might be 11 to 12 A, and at 115°F (46°C) outdoor (desert conditions), it could be as much as 15 to 16 A.

To check the compressor amperage, place the pickup of a clamp-on ammeter around the compressor wire.

To check the compressor running voltage, set a VOM to the correct scale, and place the leads on the R and C terminals.

7-4.2.1.2 PTCR

Figure 7-16 Checking PTCR



The first check to be made on the PTCR device is continuity, as shown in *Figure 7-16*. Turn the air conditioner circuit breaker to OFF. Disconnect the PTCR from the circuit. Check for continuity. If there is no continuity, the device should be replaced. The second check is an amperage reading. Clamp an ammeter around the wire from the PTCR to the capacitor. Turn the air conditioner circuit breaker to ON and start the air conditioner. When the compressor starts, there will be an amperage reading for approximately one second or less. If there is no reading or a prolonged reading, the PTCR is faulty and must be replaced.

7-4.2.1.3 Start Relay

With all power disconnected from the air conditioner unit, the start relay can be checked for normally closed contacts between terminals #1 and #2 with an ohmmeter. The electromagnetic coil for the relay may also be checked with an ohmmeter between terminals #5 and #2. If either one of the readings is open, the relay is faulty and must be replaced. A second check for the start relay is an amperage check. This is done identically to the amperage check made on the PTCR device.

7-4.2.1.4 Start Capacitor

The start capacitor should be checked with a capacitor tester following the tester manufacturer's procedures. If a tester is not available, an analog VOM may be used. A digital VOM may be used if the meter is capable of testing capacitors.

Turn the air conditioner's circuit breaker off. Verify that there is no 120 VAC to the air conditioner before doing any tests.

Manually discharge the start capacitor. To discharge, use an AC voltmeter set at the highest AC scale (500V minimum) and connect meter leads to the terminals of the capacitor. To ensure that the capacitor has discharged, the leads should be reversed and the procedure repeated.

To test, disconnect the wires to the capacitor. Set the VOM to the highest ohm scale and connect the probes to the capacitor terminals. The reading should rapidly move toward continuity and slowly return to infinity. Then the leads should be reversed and the procedure repeated. If there is no reading or a prolonged reading, the start capacitor should be replaced. When replacing the capacitor, make certain the replacement capacitor is to manufacturer's specifications. The specifications can be found on the side of the capacitor.

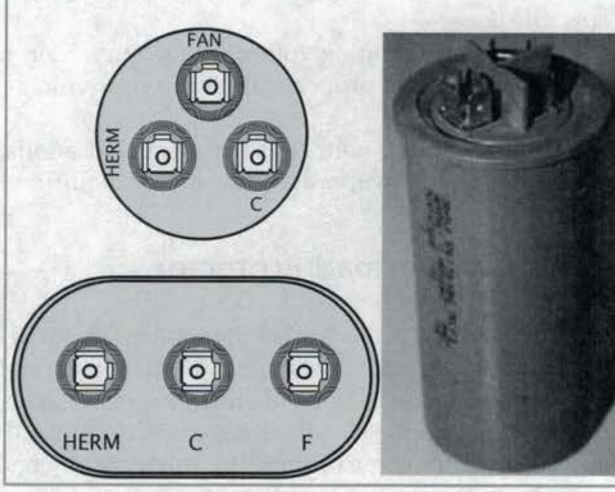
NOTE: Some start capacitors have bleed-off resistors soldered between the terminals; if so, when using the VOM to check this type of capacitor, the reading will rapidly move toward continuity and slowly return to approximately 15,000-3/4. A scale higher than 15,000-3/4 must be used for this test.

Open start capacitors can cause the compressor overload protector or the air conditioner circuit breaker to trip. Open capacitors are defective and must be replaced.

If the capacitor is shorted, the indicator will move toward, and sometimes hit, zero ohms and will stay there. Shorted capacitors are defective and must be replaced. When testing for a grounded capacitor, perform a continuity test between each terminal on the capacitor and the bare metal of the capacitor case. Any indication of a circuit from either terminal to case indicates a grounded capacitor. Grounded capacitors are defective and must be replaced.

7-4.2.1.5 Run Capacitor

Figure 7-17 Run Capacitor



The checking of a run capacitor must also be done with an analog VOM. A digital VOM may be used if the meter is capable of testing capacitors.

Turn the air conditioner's circuit breaker off. Verify that there is no 120 VAC to the air conditioner before doing any tests.

Manually discharge the run capacitor. To discharge, use an AC voltmeter set at the highest AC scale (500 volt minimum) and connect meter leads to the terminals of the capacitor. To ensure that the capacitor has discharged, the leads should be reversed and the procedure repeated.

After the capacitor has been discharged, remove the wire from the terminals and inspect the casing. If it is bulged, cracked, or split, the capacitor is defective and should be replaced.

To test for a good, open, or shorted capacitor, place the ohmmeter leads on 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. If the capacitor is good, the indicator will move from infinity up toward zero ohms and slowly return to infinity. Reverse the leads and test again: the result should be the same. 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 run capacitors can cause the compressor overload protector or the air conditioner circuit breaker to trip. Open capacitors are defective and must be replaced.

If the capacitor is shorted, the indicator will move toward and sometimes hit zero ohms, and it will stay there. Shorted capacitors are defective and must be replaced.

When testing for a grounded capacitor, perform a continuity test between each terminal on the capacitor and the bare metal of the capacitor case. Any indication of a circuit from either terminal to case indicates a grounded capacitor. Grounded capacitors are defective and must be replaced. When replacing the capacitor, make certain the replacement capacitor is to manufacturer's specifications. The specifications can be found on the side of the capacitor. An example of a run capacitor is shown in *Figure 7-17*.

7-4.2.1.6 Fan Motor

To check the fan motor, turn the air conditioner circuit breaker to OFF. With a VOM, verify that the circuit has no 120 VAC. On most air conditioners, the wires from the fan motor connect directly into a six- or nine-pin connector. The fan motor leads are white (common), black (high), red (low), and yellow (medium). Some air conditioners are two-speed units. When checking a two-speed system, disregard the yellow wire.

To check resistance in the fan motor windings, set your VOM to the ohms scale and measure resistance between the white wire and each of the other wires (yellow, red, and black). Lack of continuity between the white wire and any of the specified wires indicates an open circuit and requires the fan motor to be changed.

To check for a grounded fan motor, test for continuity between each wire and the green/yellow wire. Any continuity reading indicates a grounded fan motor, and it must be replaced.

On some models, the fan motor leads do not go into a connector. On these air conditioners, disconnect the wires from the AC power module and perform the previous tests between the fan motor leads.

To measure the running amperage of the fan motor only, turn the air conditioner circuit breaker to ON. With a VOM, verify that the circuit has 120 VAC. Turn the fan motor selector switch to the high speed setting. Place the pickup of a clamp-on ammeter around the black fan motor wire. Verify amperage against manufacturer's specifications.

To measure the total amp draw (fan and compressor), turn the fan motor selector switch to the high speed setting and turn the thermostat to the lowest setting. Once the compressor starts, place the clamp-on ammeter around the black wire at the air conditioner junction box. Verify the total amperage against the manufacturer's specifications.

To measure running voltage of the fan motor, turn the fan motor selector switch to the high speed setting. Set the VOM to the proper scale. Take your voltage reading across the white wire and black fan motor wire at the selector switch.

If the incoming voltage is within specifications, and the amp draw is higher than specifications, check for dirty filters, dirty evaporator, or a motor requiring lubrication. Also check the run capacitor.

7-4.2.1.7 Overload Protector

An overload protector is a component that will open the 120 VAC circuit to the compressor if the compressor overheats due to an electrical problem such as low voltage, or if the fan fails. Some compressors have the overload protector built inside the compressor. This type, if defective, requires a complete compressor replacement. Most compressors have the overload protector mounted on the exterior of the compressor casing.

To check this type of protector, turn the air conditioner circuit breaker OFF. Make sure that the overload is at ambient temperature and measure continuity across its terminals. If open, it should be replaced. A weak overload protector in the electrical system will cause the compressor to start and stop rapidly or short-cycle. This situation would be difficult to test. An exact replacement overload protector should be used whenever a replacement is required.

7-4.2.1.8 Freeze Control

The cold (freeze) control is used on some RV air conditioner systems (see *Figure 7-18* and *Figure 7-19*). There are various ways to provide freeze protection, including a normally open switch, a normally closed switch, and a thermistor.

Figure 7-18 Coleman Freeze Control

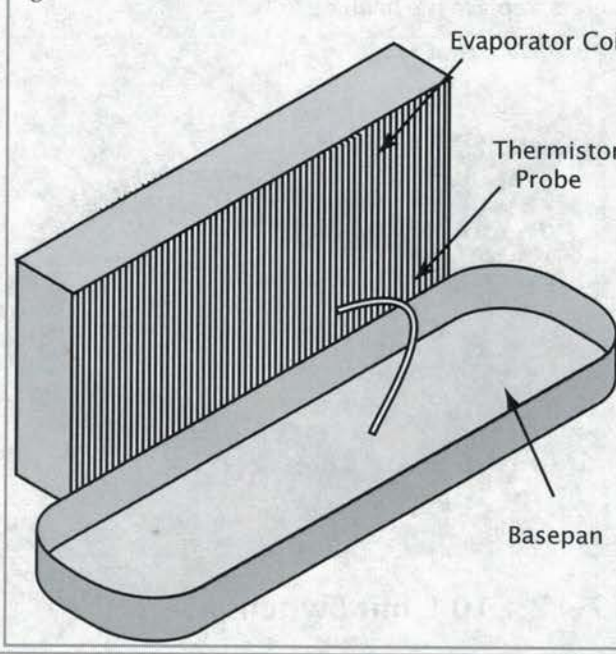
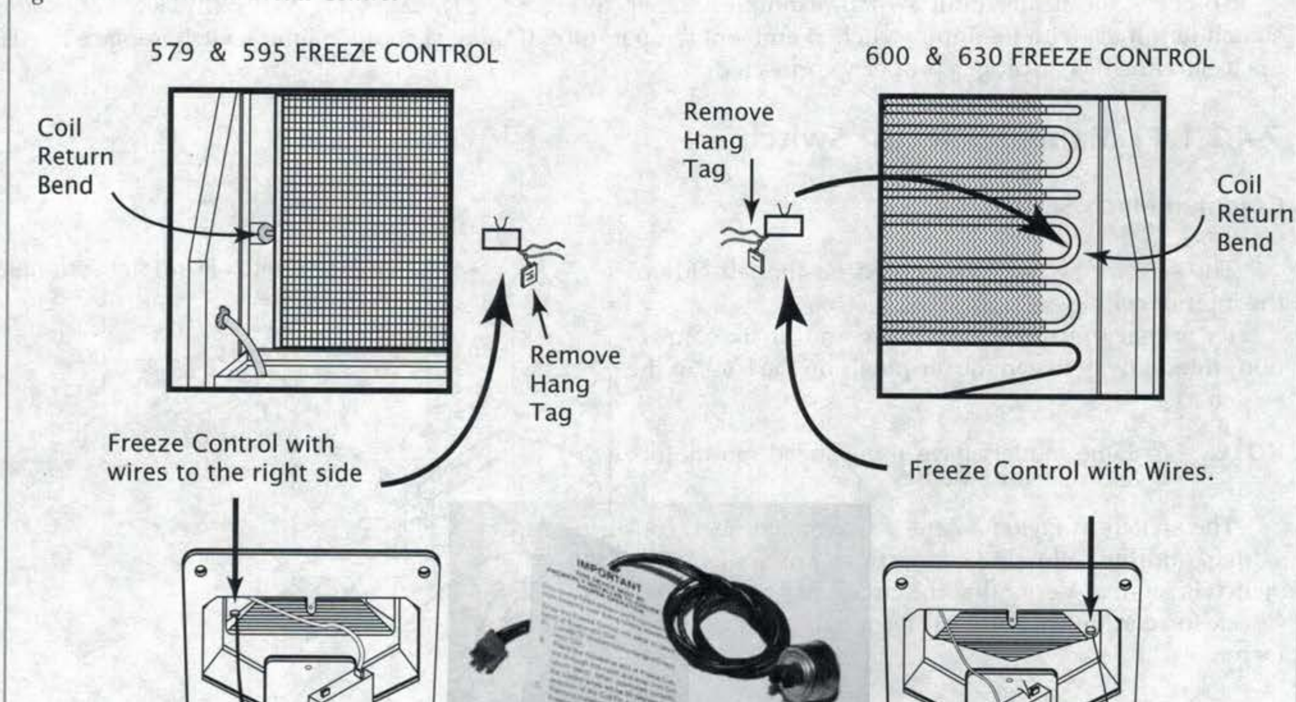


Figure 7-19 Duotherm Freeze Control



7-4.2.1.9 Heat Strip

The heater, as shown in *Figure 7-20*, is an optional component on many models. To diagnose the heat strip, turn the air conditioner circuit breaker OFF. Unplug the heater and take an ohm reading across the two wiring terminals. There should be an ohm reading of 9.5¾ ± 10 percent. If the ohm reading is outside of these parameters, replace the heater.

Figure 7-20 Heat Strip

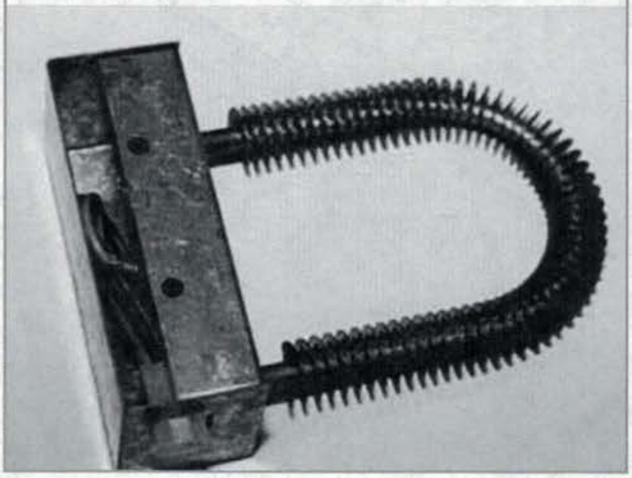
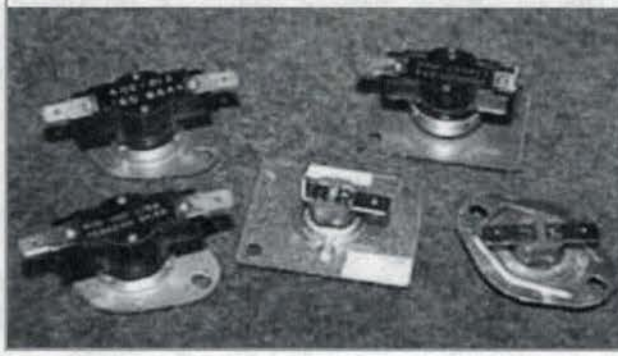


Figure 7-21 Limit Switches



7-4.2.1.10 Limit Switch

To check the heater limit switch (examples shown in *Figure 7-21*), check for continuity across the limit switch terminals with the limit switch at ambient temperature. If there is an open limit switch, replace it. Also make sure the heater plug is properly connected.

7-4.2.1.11 Manual Selector Switch

Coleman Mach Series

The selector switch is mounted on the left side of the interior ceiling assembly.

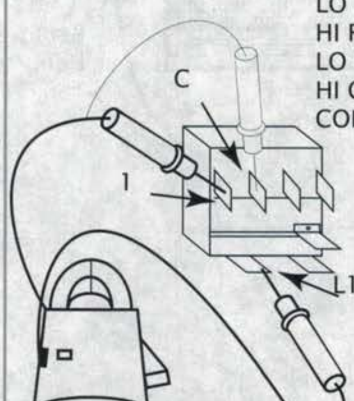
Its primary purpose is to make and break connections internally between the terminals on the back of the switch.

NOTE: Some models have three-speed fan motors and selector switches.

The switch in *Figure 7-22* is a two-speed heat/cool switch, and the following connections are made as the switch is rotated. Verify that the circuit has no 120 VAC. Check for continuity between terminals with an ohmmeter.

Figure 7-22 Coleman Selector Switch

Switch Position	Continuity
HEAT	L-1-3
LO FAN	L-1
HI FAN	L-2
LO COOL	L-1-4
HI COOL	
COLEMAN	L-2-4



Dometic Selector Switch

For proper operation of the air conditioner, AC voltage must stay between 103.5 VAC and 126.5 VAC. Operation of the unit outside of this voltage range can result in component damage. To determine if power is reaching the air conditioner, the switch, shown in *Figure 7-23*, can be checked by using a voltmeter with power turned on or by using an ohmmeter with power turned off. For safety reasons, use the ohmmeter and proceed as follows:

The air box should still be off. The electrical box needs to be dropped from the template and switch cover removed. Disconnect the wiring from the switch (be sure to note wire location for proper replacement) and remove it from the electrical box.

There are three different selector switches used in the manufacture of the air conditioner. They are the ten-position, eight-position and five-position switches. A quick check of the air box decal will indicate which switch is in the air conditioner.

The switch should be checked with an ohmmeter to determine if continuity exists. *Table 7-2* shows the correct terminals to check. Example: switch is in high cool position and the ohmmeter shows continuity between L1, C, and 1.

Figure 7-23 Dometic® Selector Switch

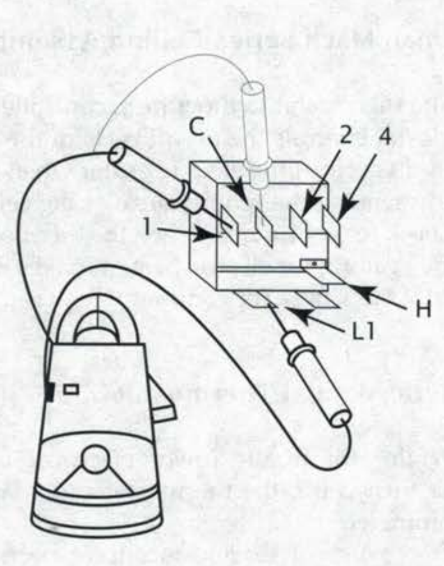


Table 7-2 Dometic® Selector Switch Continuity Test

Switch Setting	10-Position***	8-Position	5-Position
High cool	L1, C, 1	L1, C, 1	L1, C, 1
Med. cool	L1, C, 2	L1, C, 2	L1, C, 2
Low cool	L1, C, 4	L1, C, 4	L1, C, 4
High heat	L1, H, 1	NONE*	NONE*
Med. heat	L1, H, 2	NONE*	NONE*
Low heat	L1, H, 4	L1, H, 4	L1, H, 4
High fan	L1, 1	L1, 1	NONE
Med. fan	L1, 2	L1, 2	NONE
Low fan	L1, 4	L1, 4	L1, H, 4**

* Note: selector switch does not have high or medium heat positions.

** Note: selector switch has no fan settings. If heat strip is not installed, low heat is same as low fan.

*** Note: also used for heat pump.

NOTE: Terminal locations on back of switch will vary with the manufacturer of the switch. Use white numbers stamped on the body of switch for the terminal number

If there is no continuity through the switch as shown in *Table 7-2*, the switch is defective and should be replaced.

7-4.2.1.12 Thermostat (Manual Rotary)

Coleman Mach Series Ceiling Assembly

The thermostat (temperature controller) is mounted on the right side of the interior ceiling assembly. The thermostat controls the on-off cycle of the compressor when the selector switch is in the cooling position and the on-off cycle of the electric heater when the selector switch is in the heating position. The thermostat is actuated by sensing the temperature of the ceiling assembly return air. Rotate the thermostat from warm to cool and check for continuity. When the thermostat calls for cooling, it makes a connection between terminals 2 and 3. When calling for electric heat, it makes the connection between terminals 2 and 1. Verify that the circuit has no 120 VAC. Check for continuity between terminals with an ohmmeter. Temperature range is 65 to 90°F (18 to 32°C).

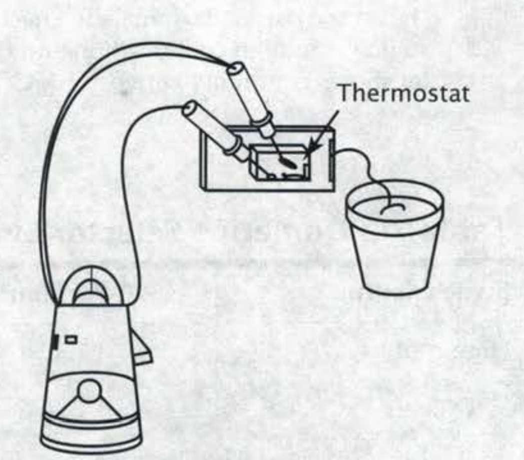
Dometic Manual Thermostat

While still in the lower electrical box with the power turned off, the thermostat can be checked with an ohmmeter.

Two types of thermostats have been used in the manufacture of our air conditioner: cooling-only and heat/cool.

The cooling-only thermostat is adjusted so the air conditioner will not start the compressor below 65°F (18°C). In some situations, it may be necessary to warm the sensing bulb with your hand or place it in warm water [95 to 100°F (35 to 38°C)]. (See *Figure 7-24*.)

Figure 7-24 Ohmmeter Checking Thermostat



When the contact points make connection, continuity should show across the terminals. Failure to show continuity indicates that the thermostat is defective.

The thermostat will not cycle off if the temperature is above 90°F (32°C). Immersing the sensing bulb in ice water should cause the points to open. Failure to open or break continuity indicates that it is defective and should be replaced.

The heat/cool thermostat is very similar to the cooling-only thermostat except it contains two sets of contacts. When the cooling contacts make connection, the heating contacts break connection. For example, in 90°F (32°C) temperature, the cooling contacts will be closed (terminals 1 and 2), and the heating contacts (terminals 2 and 3) will be open. Below 65°F (18°C), the heating contacts (terminals 2 and 3) will be closed, and the cooling contacts (terminals 1 and 2) will be open. Failure to properly make and break the circuit indicates a defective thermostat.

NOTE: Some models are cool-only and have only two electrical terminals.

7-4.3 Requirements for Proper Operation

7-4.3.1 Electrical Power Requirements

7-4.3.1.1 AC Voltage

The air conditioner is a 120 VAC, 60 Hz appliance. The proper operation range is between ±10 percent (103.5 and 132 VAC). The voltage reading should be taken at the unit power supply leads. One test, static voltage, should be performed when the unit is turned OFF, but another, running voltage, with it under a load. If the voltage is not within the manufacturer's proper operating range, it must be corrected before operating the air conditioner. Check for proper AC volts at the connections at the unit's electronic control box on roof-mounted units and at the connections at the electric box on basement units.

NOTE: Improper voltage could be caused by a problem with the voltage supply (i.e., generators, inverters, or shore power source).

7-4.3.1.2 DC Volt Requirements

On certain models of air conditioners, a DC voltage supply is wired to the control board or wall thermostat. The operating range is 9 to 16 volts (check the manufacturer's specifications). If voltage is below manufacturer's specifications at the control board, improper operation of the components within the main board may occur.

7-4.3.1.3 Breaker

The air conditioner circuit is to be protected by a time-delay fuse or a special breaker rated specifically for heating, air conditioning, and refrigeration (HACR). The HACR designation will be printed on the label on the breaker. By taking an amp reading at the unit AC voltage supply line, it can be determined if the breaker is tripping prematurely. Place a clamp-on type ammeter around the black wire from the breaker going to the unit. Turn on the unit and record amp draw. If the supply voltage is in the proper range and the breaker trips before the rated amperage, replace the breaker.

NOTE: Air conditioner amperage may spike at start-up. This should not be confused with running amperage.

7-4.3.1.4 Wiring

With the line circuit breaker turned OFF, check to see if the unit is wired correctly. Each unit is supplied with a wiring diagram. Check all wires for proper location and tight connections.

The size wire for the air conditioner is determined by its installation requirements (See *Chapter 7-7*). Some smaller air conditioners (less than 7,000 Btu/hr) are permitted on a 15 A circuit with 14 ga wire. Most rooftop air conditioners require a 20 A circuit and 12 ga wire. In some cases where a run of wire in excess of 25 ft is used, the installation instructions will require a 10 ga wire or larger to be used.

7-4 Review

1. What are the four selector switches used in the manufacture of RV air conditioners?

   A. Eight-, seven-, six-, and five-position

   B. Eight-, six-, four-, and two-position

   C. Ten-, eight-, six-, and five-position

   D. Ten-, eight-, six-, and four-position

2. The two types of thermostats used in air conditioners are ________________ and ________________.

3. Since the start and run windings are connected to the common terminal of the compressor, a simple test with an ________________ will determine the electrical condition of the compressor.

4. The start relay contacts stay closed as long as the compressor is running.

   True False

5. All air conditioners have a compressor start relay.

   True False

6. A circuit breaker is designed to open a circuit automatically on a predetermined ________________ of current.

7. The first check to be made on the PTCR device is

   A. Polarity

   B. Continuity

   C. Amperage

   D. Voltage

8. When checking the compressor and the outside or inside ambient temperature rises, the load conditions change and amperage ________________.

   A. Increases

   B. Decreases

   C. Remains the same

   D. Is shut off

9. The start capacitor can be checked by either a ________________ or an ________________.

10. The start capacitor and the run capacitor are one device that serves both functions.

    True False

11. The RV air conditioner is a ________________ appliance.

    A. 12 VDC, 60 Hz

    B. 120 VAC, 60 Hz

    C. 12 VDC, 50 Hz

    D. 120 VAC, 50 Hz

12. HACR is the abbreviation for:

    A. Hot and cold reader

    B. Home and car refrigerant

    C. High alternating current requirement

    D. Heating, air conditioning, and refrigeration

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Chapter
7-5 12 VDC Remote Control Circuits

- Measure operations of air conditioner circuits.
- Determine proper air conditioning 12 VDC system operation.
- Determine proper air conditioning 12 VDC system operation.
- Test the air conditioning 12 VDC system function.
- Inspect evaporator.
- Explain the operation of a wall thermostat.
- Describe the operation of a relay or printed circuit board.

7-5.1 RV Products (Coleman) 12 VDC Circuits

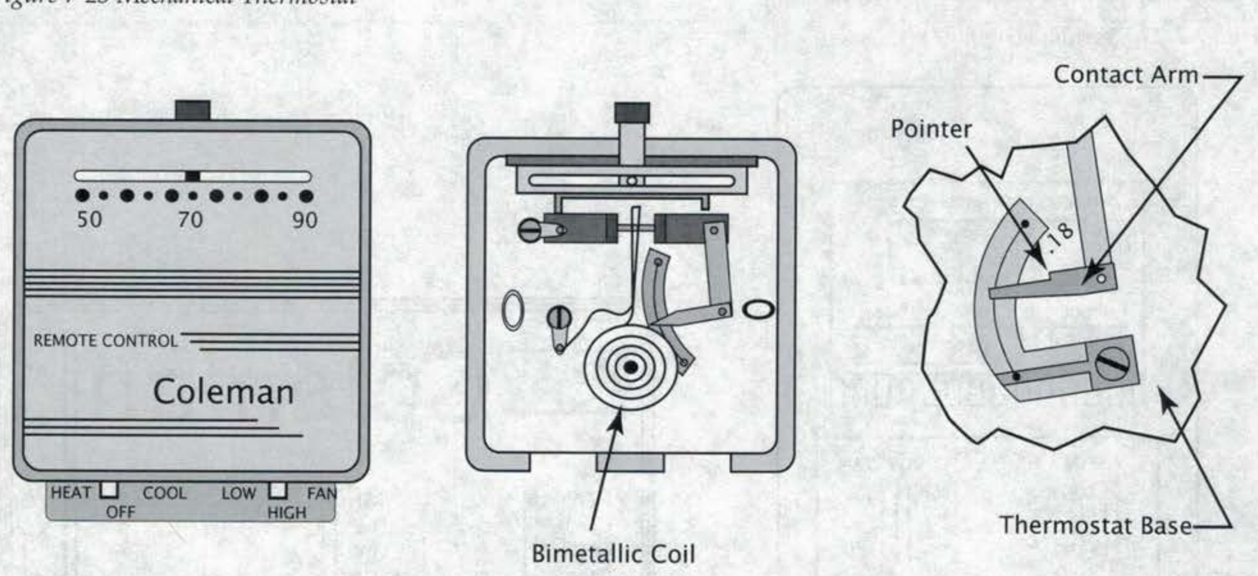
7-5.1.1 Introduction to Wall Thermostats

All of the air conditioning functions are controlled by the wall-mounted thermostat. These thermostats utilize a 12 VDC electrical circuit, which is supplied by the vehicle manufacturer or the installer of the air conditioner unit. Most of the thermostats provided by Recreation Vehicle Products (RVP) are combination (heat/cool) thermostats. These thermostats are capable of operating both the rooftop air conditioner and any furnace with a 12 VDC control circuit. There are three basic types of wall thermostats that have been commonly used with RVP air conditioners.

7-5.1.1.1 Mechanical Thermostats

Mechanical thermostats, as shown in *Figure 7-25*, incorporate a bimetallic coil that expands and contracts with a changing temperature. This expansion and contraction will make or break a mechanical set of points to control the heating and cooling functions. In the cool mode, the fan runs continuously, and the compressor cycles on and off at the temperature set point. These thermostats are equipped with an adjustable heat anticipator located on the thermostat base. The anticipator should be set according to the furnace manufacturer's requirements.

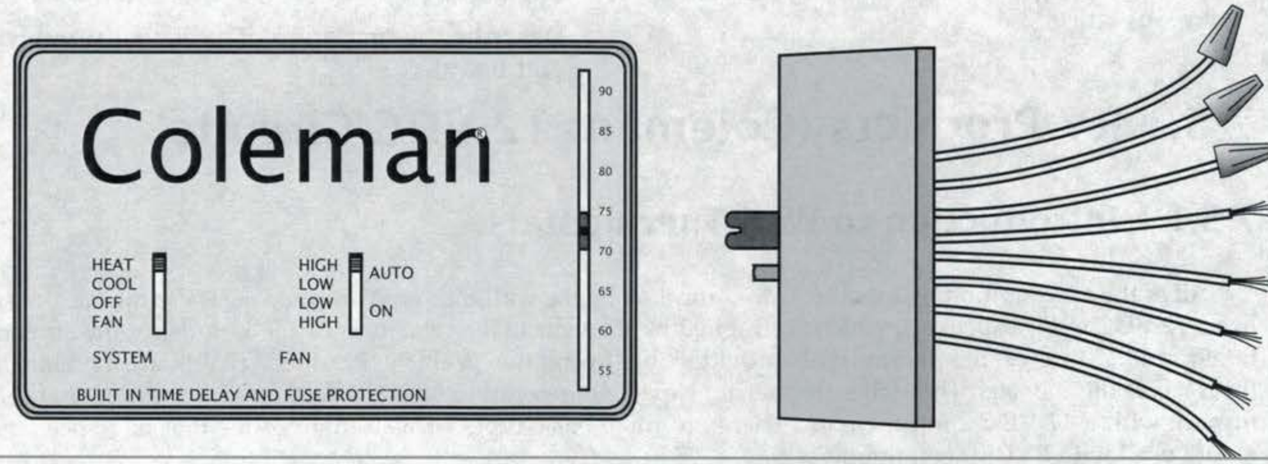
Figure 7-25 Mechanical Thermostat



7-5.1.1.2 Electronic Thermostats

Electronic thermostats, as shown in *Figure 7-26*, typically are more accurate and maintain a much closer tolerance in room temperature. The thermostat uses a thermistor to monitor this temperature. These thermostats are protected by a 2 A fuse located on the back of the thermostat body. All of RVP electronic thermostats give the retail customer the option of choosing continuous or automatic fan operation.

Figure 7-26 Electronic Thermostat

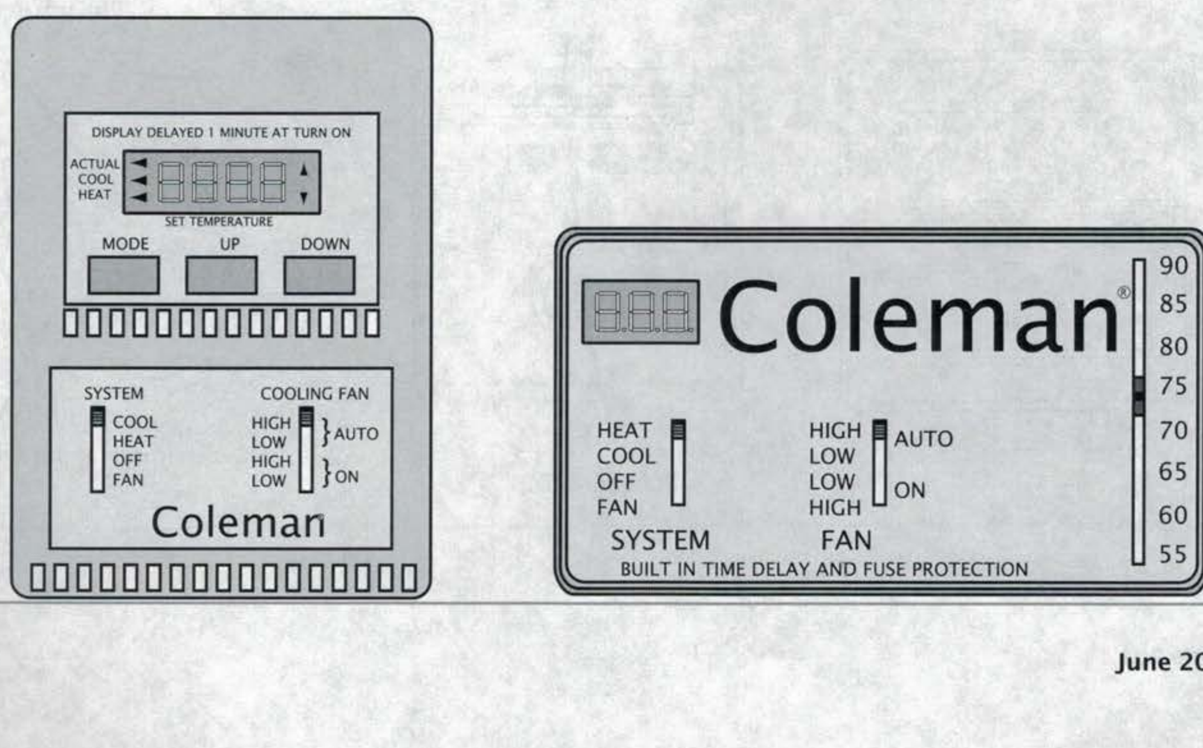


NOTE: Electronic thermostats have a three-minute time delay for compressor protection.

7-5.1.1.3 Electronic Digital Thermostats

The digital thermostats shown in *Figure 7-27* were designed to operate the Recreation Vehicle Products' two-ton package units. These are two-stage thermostats, with one degree temperature differential between stages. When (if) these thermostats are installed with rooftop air conditioners, only the first stage will be connected. The thermostat's operation would be identical to the electronic one mentioned in *"Electronic Thermostats" on page 7-48*. If either of these digital thermostats is used on rooftop units, the freeze switch circuit (terminals F and F) must be connected.

Figure 7-27 Electronic Digital Thermostat



All RV Products' wall-mounted thermostats basically make the same internal electrical connections. All thermostats are really nothing more than temperature-controlled switches. When the thermostat demands the need for cooling or heating, it closes a set of contacts internally and sends 12 VDC to relays or a PC board, which in turn energizes the air conditioner or furnace. So, in theory, the thermostat is maintaining the desired room temperature by simply opening and closing a set of contacts. *Table 7-3* indicates that 12 VDC (+) is supplied to thermostat "R" terminal at all times. *Table 7-3* also shows the electrical connections the thermostat makes internally while in operation.

Table 7-3 Thermostat Connections

Thermostat Operations	Internal 12 VDC Connections Made
Cool Mode Selected on Low Fan	Red "R" to Yellow "Y" and Gray "GL"
Cool Mode Selected on High Fan	Red "R" to Yellow "Y" and Green "GH"
Heat Mode Selected on Any Fan Speed (Note: furnace blower operates independently from sequencer or time delay in furnace)	Red "R" to White "W"
Fan Only Selected (Hi-Fan Only)	Red "R" to Green "GH"

NOTE: When the auto cool mode is selected on the thermostat, the fan cycles "on" and "off" with the compressor as needed. When the on-cool mode has been selected, the fan runs continuously, and the compressor cycles "on" and "off" as needed.

7-5.1.2 Thermostat Location

Thermostats are very sensitive instruments. For accurate temperature control and comfort, the following considerations for thermostat locations should be taken.

1. Locate the thermostat on an inside wall about five feet above the floor. Pick a dry area where air circulation is good. The thermostat should be mounted within a reasonable distance from the appliance the thermostat will control. This will ensure a more accurate temperature relationship between the thermostat and the appliance the thermostat will control.
2. Do not install the thermostat where there are unusual heating conditions—such as direct sunlight or heat-producing appliances (television, radio, wall lamp, and so forth)—or a furnace or air conditioner supply register.
3. When installing or servicing these thermostats, the technician should take all necessary precautions not to short any positive wire to ground. Permanent damage to the thermostat may occur. Make sure all connections are good and tight. Loose connections may cause relay chattering, which leads to welded relay contacts on air conditioner printed circuit boards.

NOTE: The 12 VDC (+) and (-) wires to the thermostat are supplied by the vehicle manufacturer or installer and must be connected to the (R) red and (B) blue wires. The ground wire must be a zero "0" resistance ground.

Table 7-4, *Figure 7-28*, and *Figure 7-29* indicate the thermostat wiring and their destinations.

Figure 7-28 7000 Series Wiring

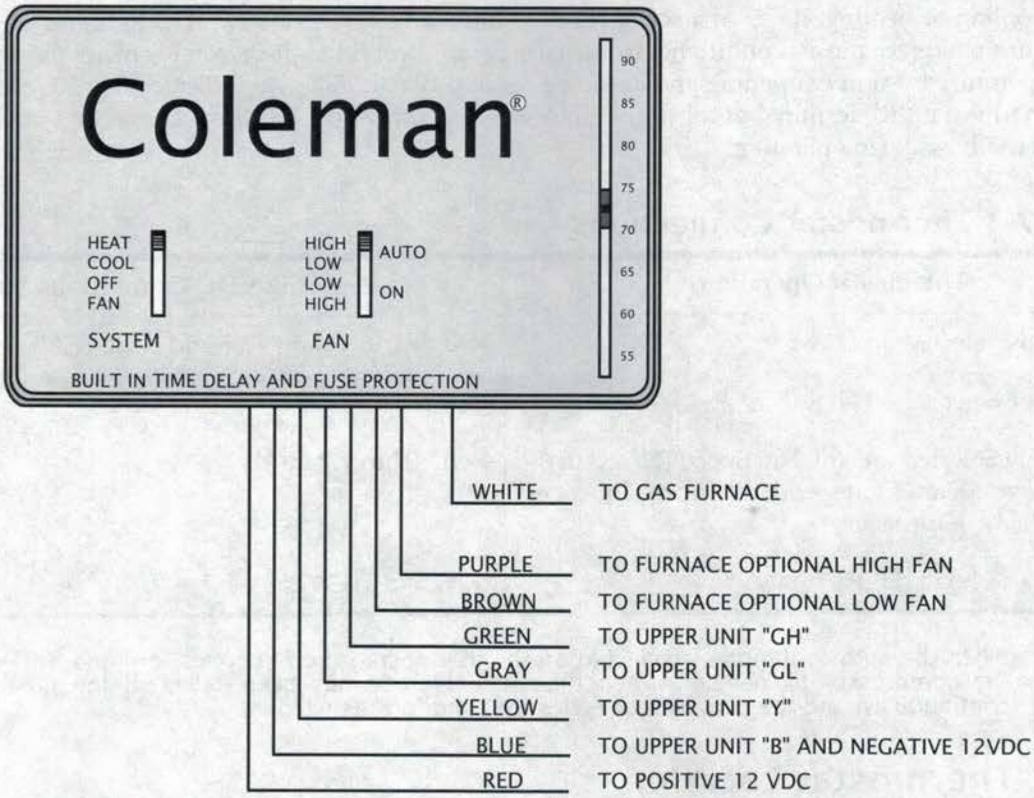
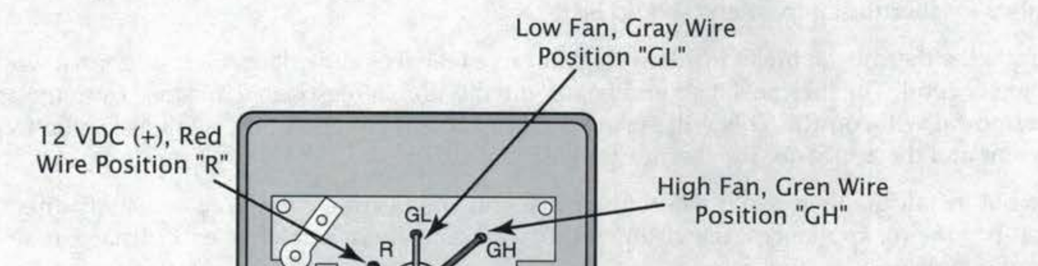


Figure 7-29 6799 Series Wiring



NOTE: Some thermostats will be provided with wire leads instead of terminal designations.

NOTE: Never jump any terminal to "B," 12 VDC (-) negative. All other terminals are positive 12 VDC (+).

Table 7-4 7330-3351 Wall Thermostat Wiring

(Note: the purple and brown wires are used only if the furnace is equipped with a two-speed fan motor.)

	Mate With		
	Thermostat Terminal	**Control and Supply Wiring**	**Ceiling Assembly Terminal**
	R or Red	One Red, +12 VDC Supply Wire to Thermostat	N/A
	B or Blue	Two Blue, One –12 VDC Supply Wire to Thermostat and One Blue Control Wire to Ceiling Assembly/Plenum	B
	Y or Yellow	One Yellow, Compressor Control Wire to Ceiling Assembly/Plenum	Y
	GH or Green	One Green, Hi Fan Control Wire to Ceiling Assembly/Plenum	GH
	GL or Gray	One Gray, Lo Fan Control Wire to Ceiling Assembly/Plenum	GL
N/A on Cool-Only Models	W or White	One White, Engages RV Furnace (from thermostat)	Furnace
700 Series Thermostat Only	HH or Purple	One Purple Wire for Gas Furnace Motor High Speed	Furnace Blower High
	HL or Brown	One Brown Wire for Gas Furnace Motor Low Speed	Furnace Blower Low

7-5.1.3 Relays and Printed Circuit Boards

In the section *"Introduction to Wall Thermostats" on page 7-47*, we learned that he wall thermostat makes the necessary connections that provides low-voltage power to initiate all of the air conditioning or heating functions. There is one question left unanswered. How is 12 VDC power used to operate a 120 VAC appliance? Relays or printed circuit boards with relays located on them are used. So what is a relay? A relay is defined as an electromagnetic mechanism moved by a small electrical current in a control circuit (12 VDC in this case). How does this relay work? As this mechanism moves back and forth in the relay, it will open or close a set of contracts capable of carrying high voltage (VAC in this case). All of RV Products' control circuit relays are normally open, and the contacts close as power from the thermostat is applied.

As shown in *Figure 7-30*, the VAC power to the compressor is interrupted by a set of normally open contacts on the relay. In order for these contacts to close, 12 VDC must be applied by the wall thermostat to the relay coil. When the thermostat switch is placed in the cool position, 12 VDC (+) travels from the thermostat yellow (Y) wire to the relay coil. When the coil is activated, an electromagnet inside the relay will pull the contacts closed. The VAC will now operate the compressor until the thermostat opens or the system switch is turned to the off position.

Figure 7-30 shows a very simplified control circuit for compressor operation. The whole control circuit for the entire air conditioner/heating system would include the rest of the thermostat functions and possibly two or three more relays. A relay for **Low Fan**, one for **High Fan**, and possibly one for **Heat**, would be needed if an electric heating element is used.

NOTE: If the heating system includes a gas-fired furnace, the thermostat will energize the furnace control circuit (usually a time-delay relay located at the furnace).

Recreation Vehicle Products has built two basic types of ceiling assembly packages, which incorporate individual relays for the different system functions. They are the 6799-730 Series Ducted Ceiling Plenums (*Figure 7-31*) and the -720 and -726 Free Deliver Ceiling Plenums (*Figure 7-32*).

Figure 7-30 Control Circuit

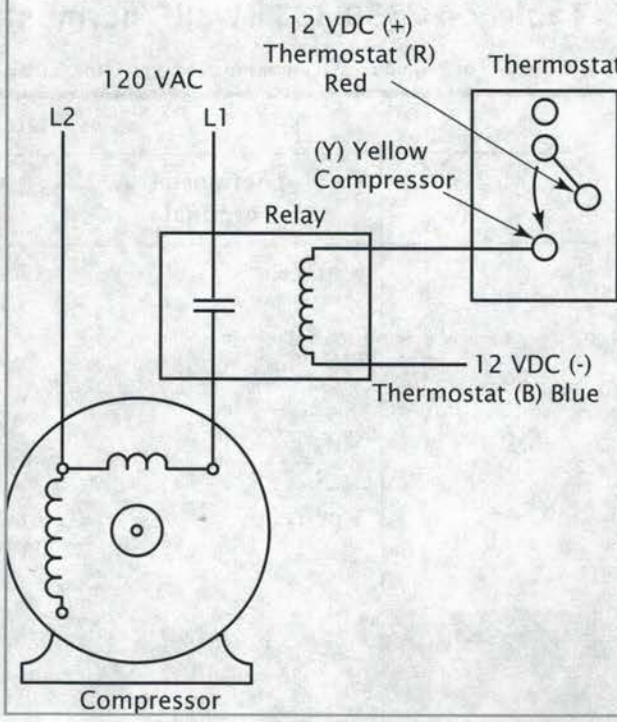


Figure 7-31 6799 - 730 Series Ducted Ceiling Plenums

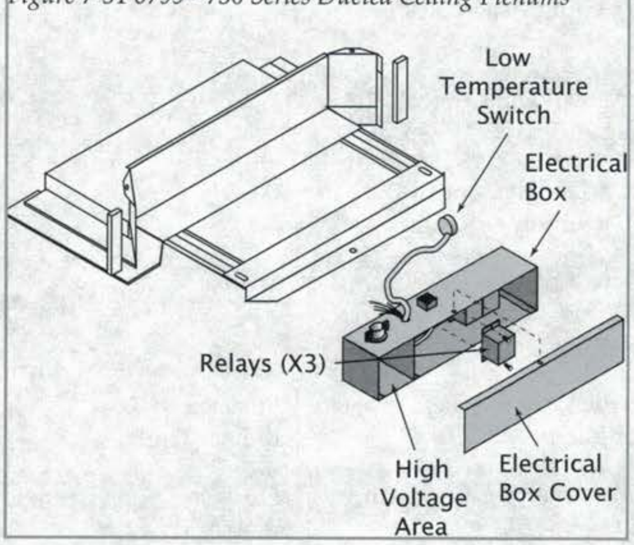
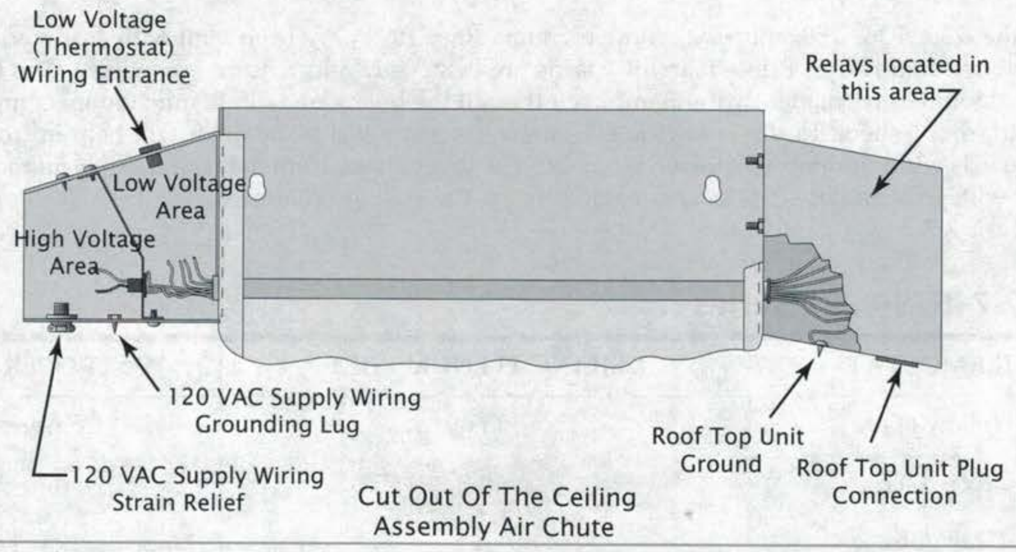


Figure 7-32 -720 and -726 Free Deliver Ceiling Plenums



The low-voltage connections for these ceiling packages would be hard wired by the manufacturer or installer of the unit. They connect to the wall thermostat as shown in *Table 7-5* and *Table 7-6*.

Table 7-5 -720 and -726 Series

THERMOSTAT	CEILING PLENUM WIRE	UNIT OPERATION
Yellow (Y)	Yellow	Compressor
Green (GH)	Green	High Fan
Gray (GL)	Gray	Low Fan
Blue (B) (12 VDC–)	Blue	N/A
White (W)	White	N/A

Table 7-6 -6799-730 Series

THERMOSTAT	CEILING PLENUM WIRE	UNIT OPERATION
Yellow (Y)	Black	Compressor
Green (GH)	Green	High Fan
Gray (GL)	Gray	Low Fan
Blue (B) (12 VDC–)	Blue	N/A

NOTE: Never short any other thermostat wire to the blue wire or to ground; permanent damage may occur.

NOTE: The -730 series ceiling plenums all have a low-temperature switch that opens the compressor circuit if the evaporator coil starts freezing.

7-5.1.4 Printed Circuit Boards

All of the -730, -736, -750, and -752 ceiling plenums since 1992 have been built with a printed circuit board instead of individual relays. Printed circuit boards are less costly and require less wiring. The PC boards all have relays mounted permanently on them. Even though the boards may look much more complicated, they are easier to troubleshoot. In the following text, there are some visual aids that will help in troubleshooting these PC boards without removing the wire box lid. The low voltage from the wall thermostat may be checked at the low-voltage terminal strip located externally on the ceiling plenum wiring box. The connections are shown in *Table 7-7*.

Table 7-7 -6799-730 Series

THERMOSTAT	CEILING PLENUM WIRE	UNIT OPERATION
Yellow (Y)	(Y)	Compressor
Green (GH)	(GH)	High Fan
Gray (GL)	(GL)	Low Fan
Blue (B) (12 VDC-)	(B)	N/A

If the thermostat makes a call for high fan, 12 VDC should be readable between terminals GH and B at the low-voltage terminal strip. For low fan, 12 VDC should be readable between GL and B. For compressor operation, 12 VDC should be readable between Y and B. If there is no voltage reading at these locations, the problem is in the thermostat or the low-voltage wiring.

Let's say the thermostat makes a call for any one of the air conditioner unit functions and that function does not work. To locate the problem, **first verify the VAC power source** to the unit. If the air conditioner unit is still not functioning after verifying these two steps, the problem is either in the PC board or the unit itself. The operation of the PC board may be checked without removing the electric box lid. Whenever the thermostat connections in*Table 7-8* are made, the relays on the PC board should make the VAC connections at the nine-pin high-voltage connector (*Figure 7-33*).

Table 7-8 Thermostat Connections

THERMOSTAT CONNECTIONS AT THE LOW-VOLTAGE TERMINAL STRIP (*Figure 7-35*)	120 VAC CONNECTIONS MADE BETWEEN TERMINALS AT THE NINE-PIN CONNECTOR
12 VDC at Y and B	Terminals #1 and #3
12 VDC at GH and B	Terminals #5 and #9
12 VDC at GL and B	Terminals #6 and #9

If the VAC connections are not made at the nine-pin connector plug after the thermostat power has been confirmed, the problem is in the PC board—with one exception. The low-temperature thermistor probe could open the compressor relay if the evaporator starts to freeze. This switch opens at 32°F (0°C) and closes at 55°F (13°C), and it should be found pushed into the evaporator coil as shown in *Figure 7-34*. If the thermistor is open on the PC board, this would keep the compressor from running, as it breaks the electrical circuit.

Figure 7-33 VAC Plug

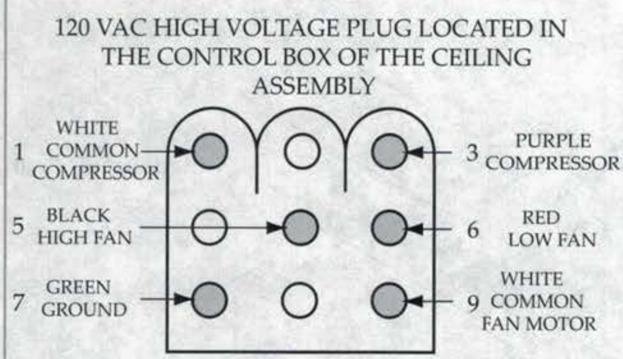


Figure 7-34 Thermistor Probe

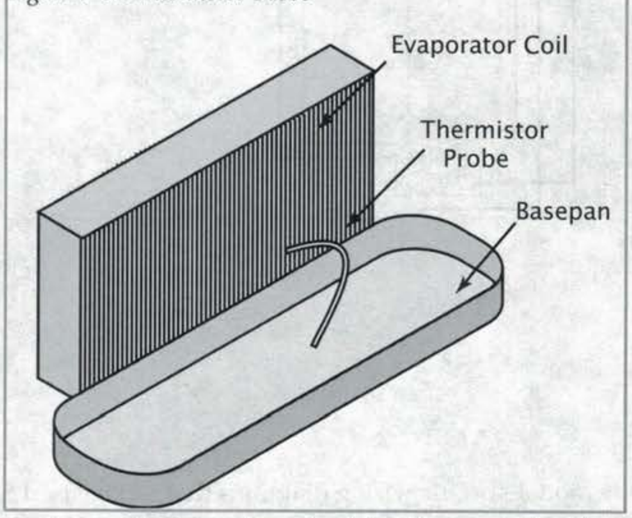
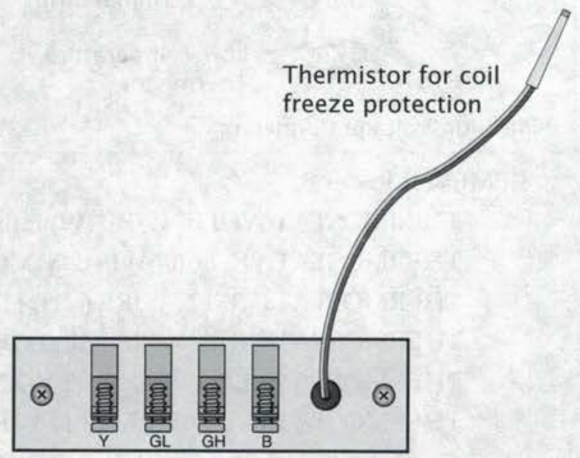


Figure 7-35 Low-Voltage Strip



In conclusion, when checking for operational problems, look and listen for what is and isn't running. For instance, if any one of the functions is running, this immediately indicates that there is VAC present to the air conditioner unit and 12 VDC present to the wall thermostat. Without both of these, nothing would run. These steps may be passed up in doing further troubleshooting.

A lot of time can be saved by always going immediately to the ducted control box assembly for troubleshooting (see *Figure 7-36* and *Figure 7-37*). There, in a matter of minutes, it can be determined if the problem is in the thermostat, the PC board, or the upper unit.

Figure 7-36 Control Box Assembly Ducted Ceiling Plenums

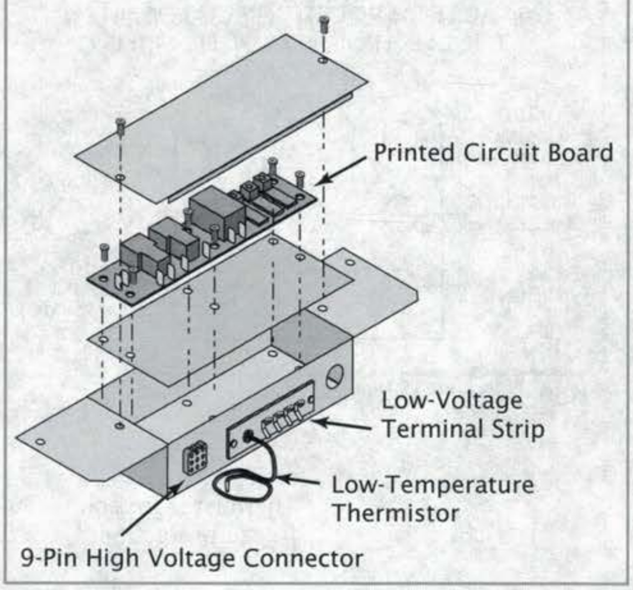
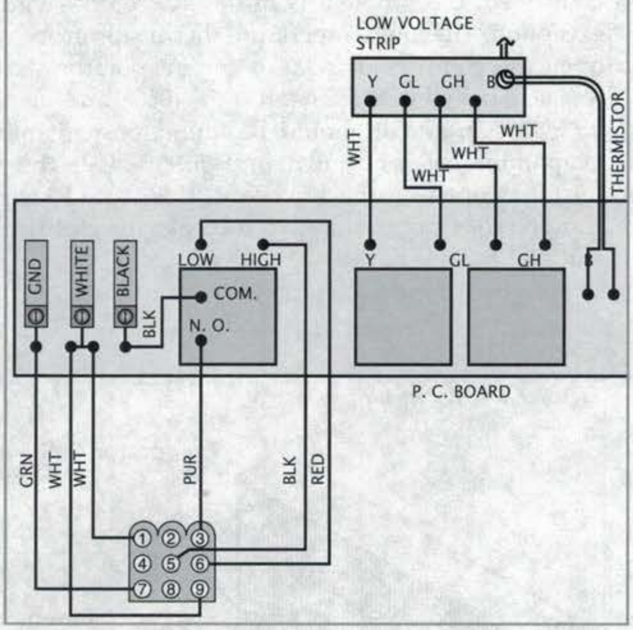


Figure 7-37 Control Box Assembly Ducted Ceiling Plenum Wiring Diagram



REMEMBER:

THERMOSTAT WHITE WIRE (W) HEATING
THERMOSTAT YELLOW WIRE (Y) COOLING
THERMOSTAT GREEN WIRE (GH) HIGH FAN
THERMOSTAT GRAY WIRE (GL) LOW FAN
THERMOSTAT RED WIRE (R) 12 VDC (+)
THERMOSTAT BLUE WIRE (B) 12 VDC (–)

The following *Figure 7-38* through *Figure 7-44* provide model-specific wiring diagrams that can be used for troubleshooting.

Figure 7-38 Wiring Diagram for 6798-370 and 6799-730 Only Flush-Mount Ceiling Plenums

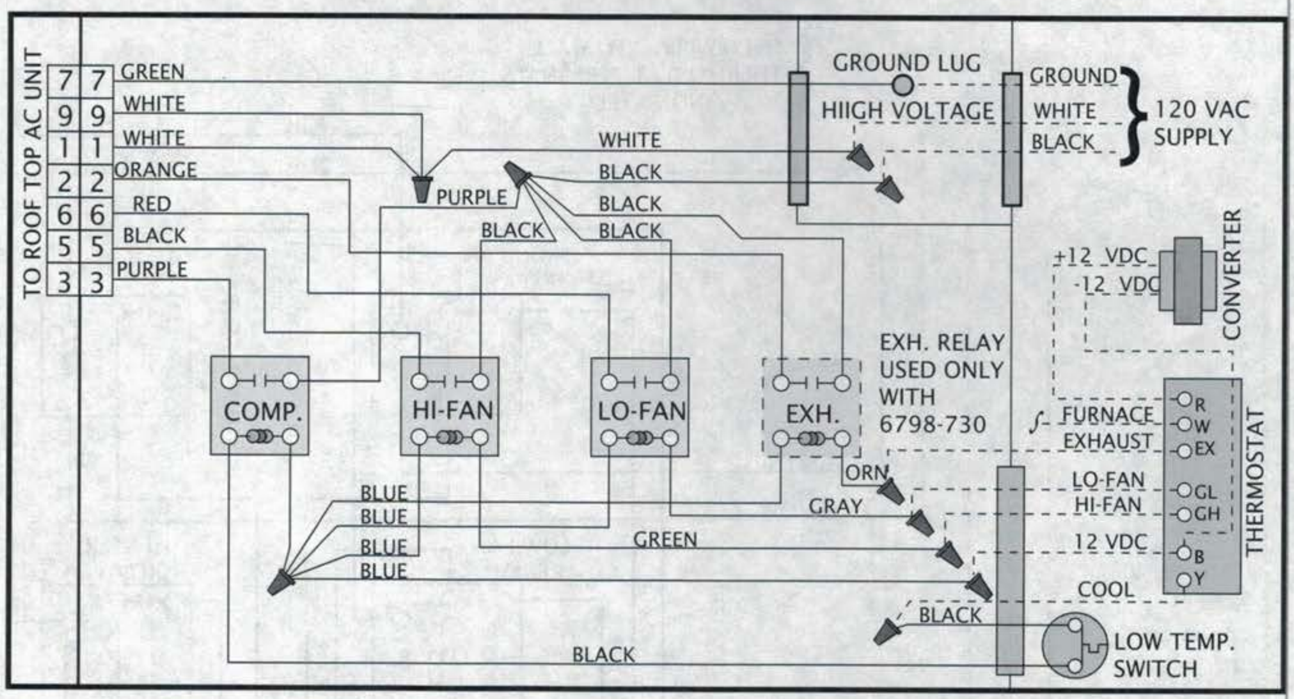


Figure 7-39 Wiring Diagram for 6799-720 Cool-Only Remote Ceiling Assembly

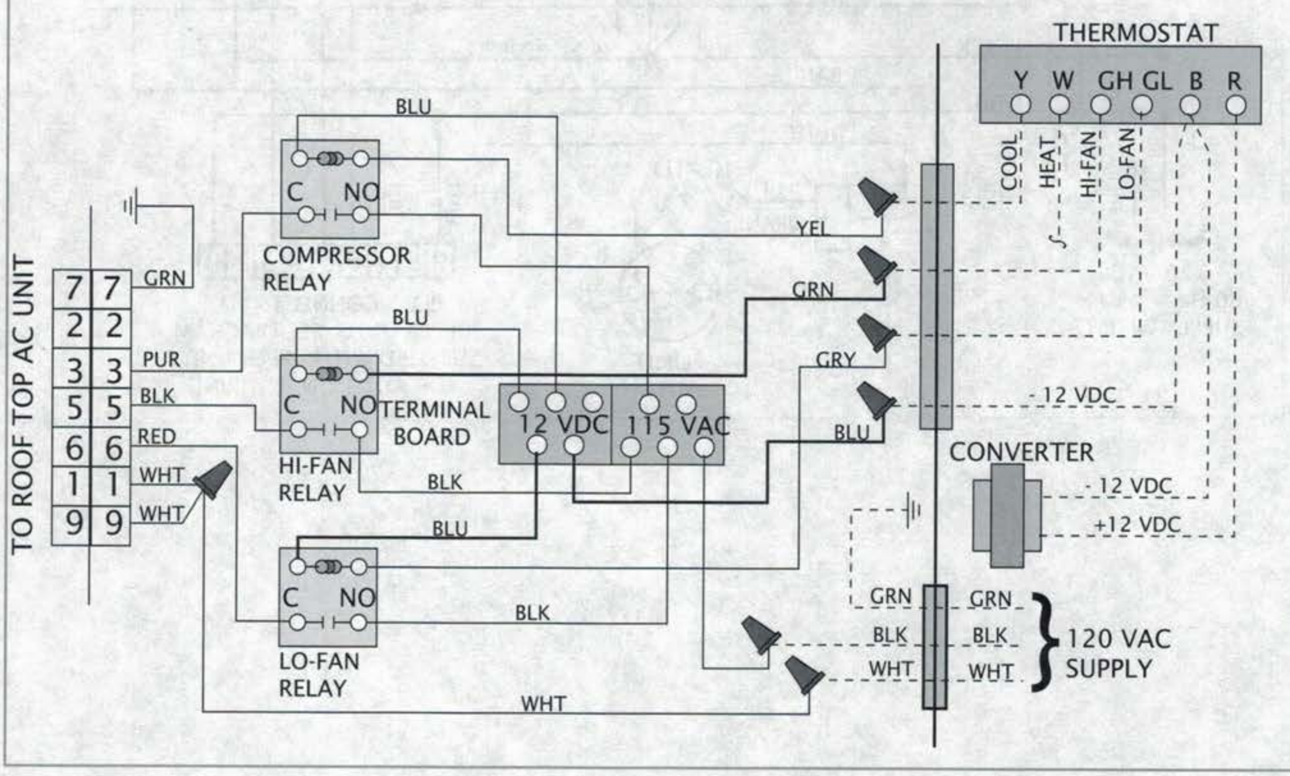


Figure 7-40 Wiring Diagram for 6799-726-Heat/Cool Remote Ceiling Assembly

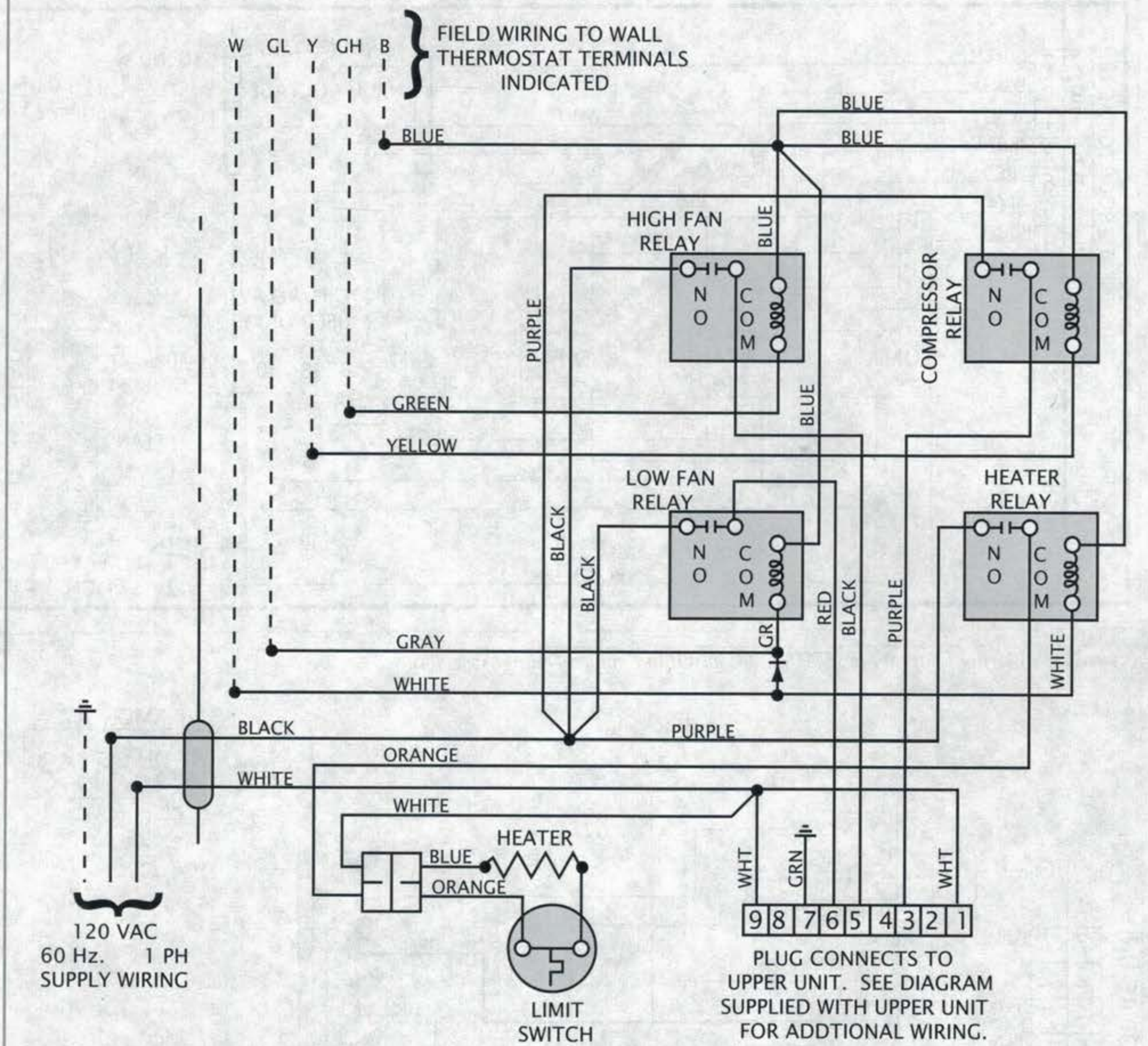


Figure 7-41 Wiring Diagram for 7330-720 AND 8330-723 Cool-Only Remote Free Delivery Ceiling Assemblies

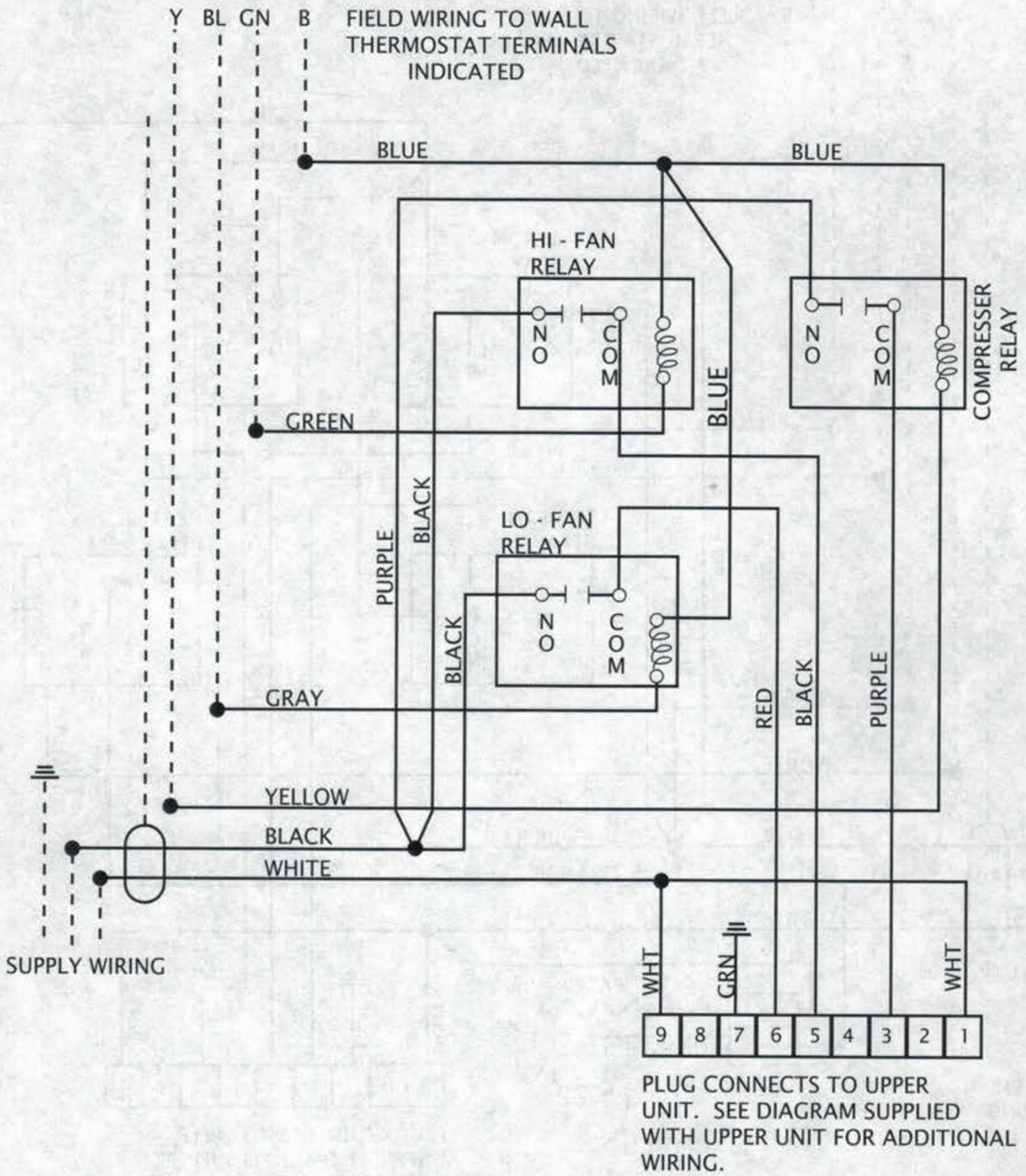


Figure 7-42 Wiring Diagram for 7330A726 and 8330-725 Heat/Cool Remote Free Delivery Ceiling Assemblies

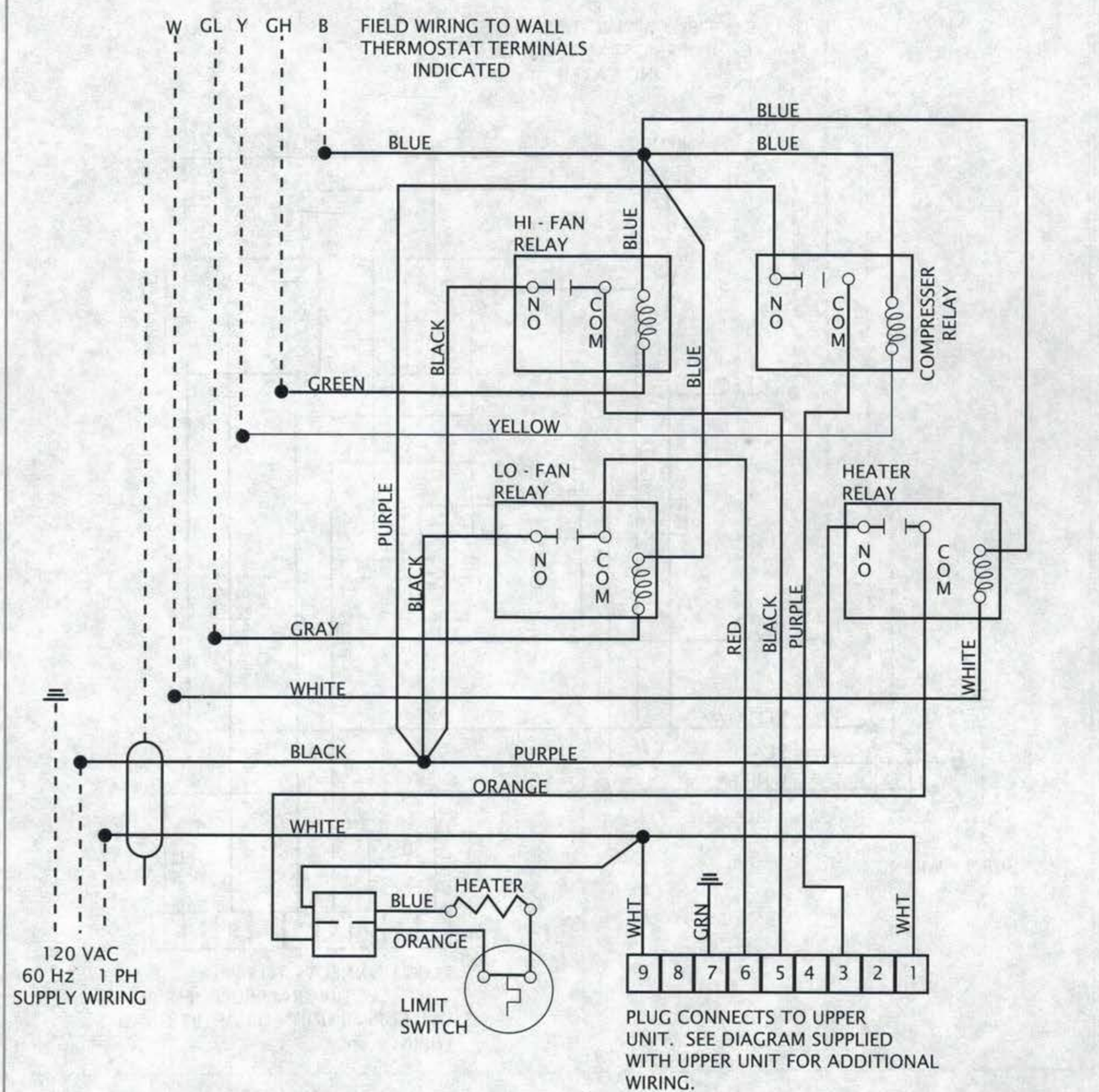


Figure 7-43 Wiring Diagram for 7330-730 and 8330-733 Cool-Only Flush-Mount Ceiling Plenums

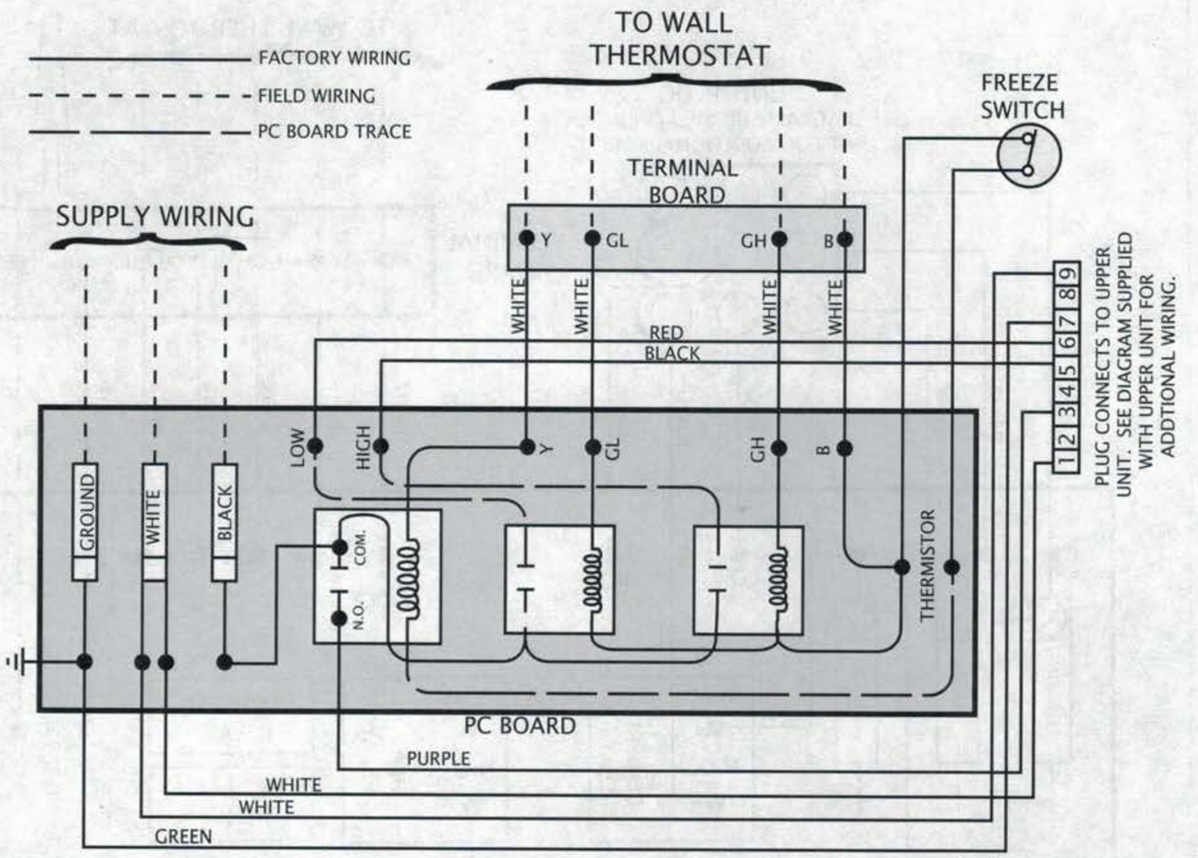
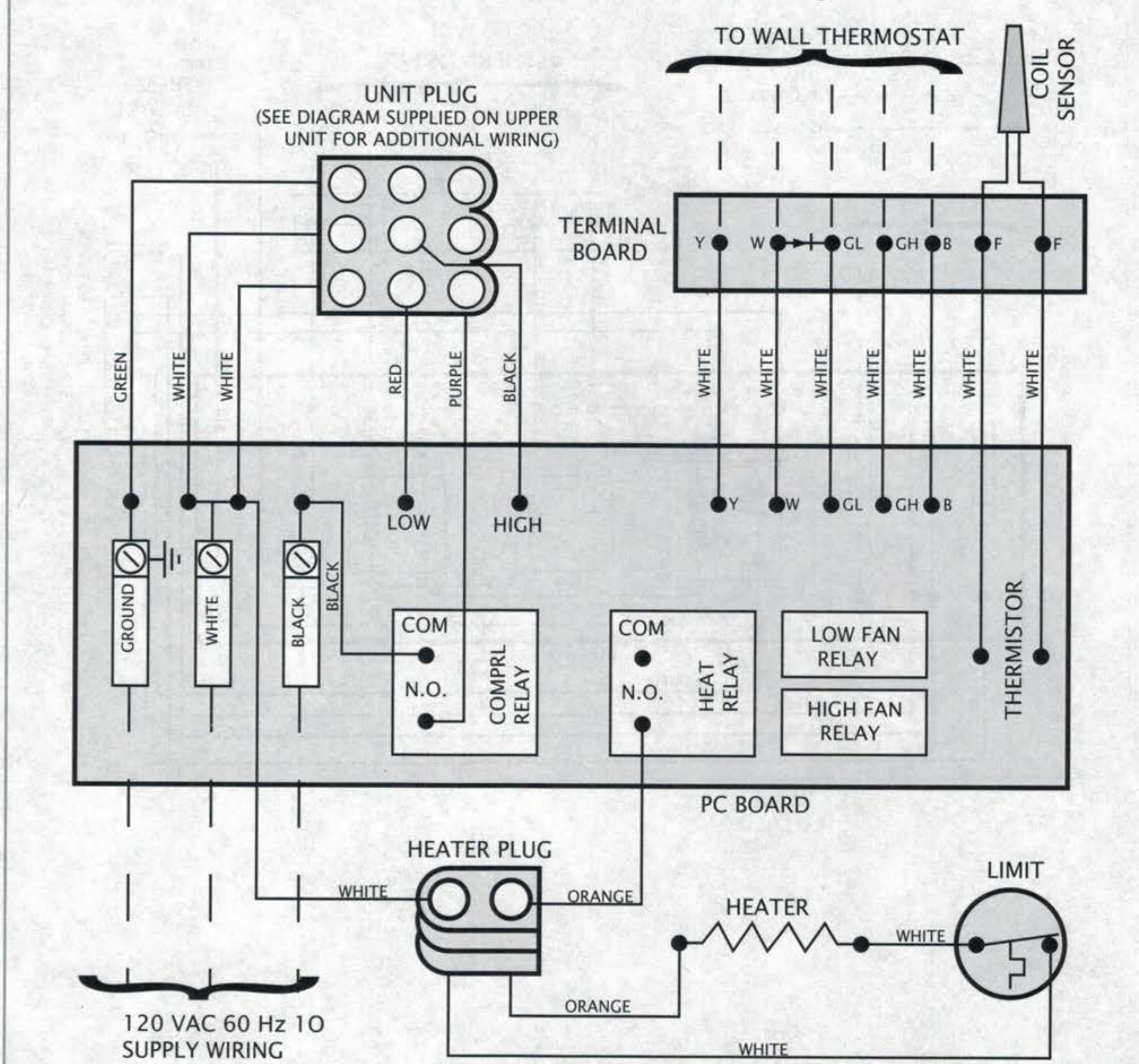


Figure 7-44 Wiring Diagram for 7330-736 and 8330-735 Cool-Only Flush-Mount Ceiling Plenums

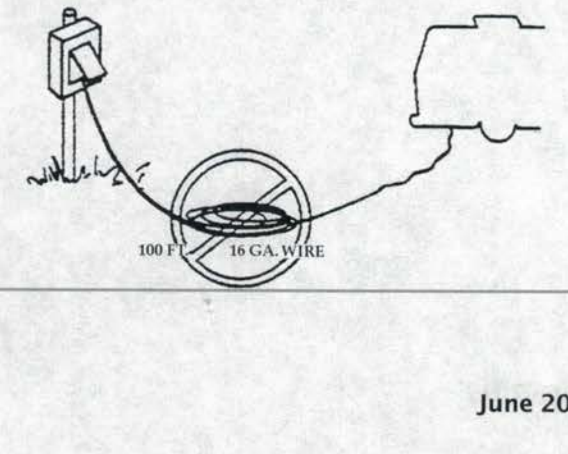


7-5.2 Dometic Analog Control System AC Power Source

If the compressor or fan fails to operate, it is probably not receiving power. Be sure the power cord is plugged in and no fuses or breakers are tripped.

NOTE: Many customers use extremely long power cords that are undersized, as shown in *Figure 7-45*. If possible, ask the owner to hook up the RV just like it was when the problem occurred.

Figure 7-45 Example of Extremely Long Undersized Power Cord



NOTE: If an air conditioner draws 15 A, a minimum of an 8 ga wire is needed for a 100 ft power cord.

NOTE: For normal operation of the unit, AC voltage must stay between 103.5 VAC and 126.5 VAC. Operation of the unit outside of this voltage range can result in component damage.

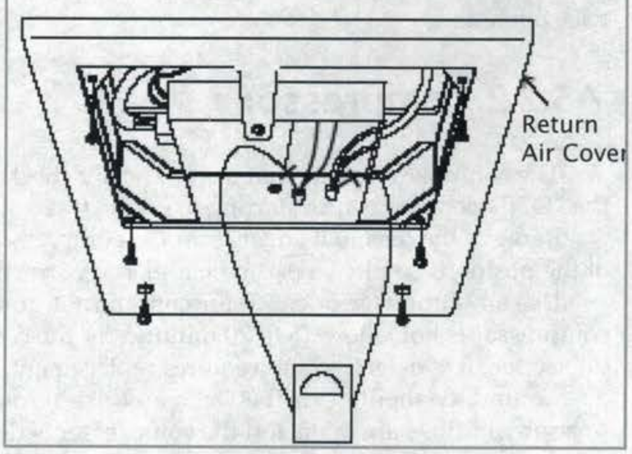
Make note of the wire size and length of wire. Compare it to *Table 7-9* for wire sizing. To determine if power is reaching the unit, the inside plastic air diffuser box must be removed. The junction box will now be exposed. Remove the cover from the junction box to gain access to the connection between the RV and the unit wires, as shown *Figure 7-46*. Check with a voltmeter for voltage at the connections of the unit to RV wires. USE CAUTION, as 120 VAC may be present. If no voltage is present, the problem is in the coach wiring or breaker/fuse box.

Table 7-9 Wire Size

Current in Amps	16	14	12	10	8	6
			Length in Feet			
5	47	76	121	192	216	486
10		38	60	96	153	243
15		25	40	64	102	162
20			30	48	76	121

7-5.2.1 DC Voltage

Figure 7-46 Junction Box Access



A DC volt supply is required for operation of the analog control system. The operating range is 9 to 16 VDC. If DC voltages are outside of the operating range, erratic operation may result.

Use a DC voltmeter to check for the incoming DC voltage between the red positive (+) and the black negative (–) at the connections of the analog control box. If no DC voltage is found, check the supply breaker or fuses.

Check the output DC voltage from the analog control box with the thermostat wires disconnected. This can be done at the analog control box wires listed in *"Current-Model Color Coding" on page 7-63* and *"Early-Model Color Coding" on page 7-64*.

7-5.2.1.1 Current-Model Color Coding

Check for voltage between the **GREEN (GND)** wire and:

1. **Tan** wire for voltage ranging from 8.38 to 17.31 VDC. Fan terminal on thermostat.
2. **Blue** wire for voltage ranging from 8.38 to 17.31 VDC. High fan terminal on thermostat.
3. **White** wire for voltage ranging from 8.38 to 17.31 VDC. Furnace terminal on thermostat.

4. **Yellow** wire for voltage ranging from 6.73 to 7.53 VDC. Cool terminal on thermostat.
5. **Red/White** wire (labeled "TO T-STAT +7.5 SCREW") for voltage ranging from 6.74 to 7.5 VDC. +7.5 terminal on thermostat.
6. **Orange** wire (present only on heat strip or heat pump models) for voltage ranging from 8.38 to 17.31 VDC. HS/HP terminal on thermostat.

If a furnace is to be operated by the analog control system, the furnace thermostat leads are connected to the blue/white striped wires out of the analog control box. The furnace wires can be connected to either wire, as polarity is not important. DC voltage is required by the analog control board on one of the two wires for furnace operation.

7-5.2.1.2 Early-Model Color Coding

Check for voltage between the **BLACK (GND terminal on thermostat)** (unlabeled) wire and:

1. **Orange** wire for voltage ranging from 8.38 to 17.31 VDC. Fan terminal on thermostat.
2. **Blue** wire for voltage ranging from 8.38 to 17.31 VDC. High fan terminal on thermostat.
3. **White** wire for voltage ranging from 8.38 to 17.31 VDC. Furnace terminal on thermostat.
4. **Yellow** wire for voltage ranging from 6.73 to 7.53 VDC. Cool terminal on thermostat.
5. **Red** wire (labeled "TO T-STAT +12 SCREW") for voltage ranging from 6.74 to 7.5 VDC. +12 terminal on thermostat.
6. **Violet** wire (present only on heat strip or heat pump models) for voltage ranging from 8.38 to 17.31 VDC. HS/HP terminal on thermostat.

If a furnace is to be operated by the analog control system, the furnace thermostat leads are connected to the blue/white striped wires out of the analog control box. The furnace wires can be connected to either wire, as polarity is not important. DC voltage is required by the analog control board on one of the two wires for furnace operation.

7-5.2.2 Compressor

The compressor motor can be electrically checked. Be sure to disconnect all power and turn all switches to the "OFF" position before starting to do the tests.

Remove the terminal cover from the compressor to the three leads connected to the terminals. Make note of the positions so the wires can be replaced correctly.

Use an ohmmeter to check for continuity through the overload device. If no continuity is found and the compressor is hot, allow 15 to 20 minutes for the compressor to cool. If a repeat of the test shows the overload to be open, it is defective and requires replacement.

Continuity should exist between all three terminals of the compressor. If there is no continuity, the compressor windings are open and the compressor is defective.

Scrape the compressor casing to bare metal and check continuity from each terminal to the casing. If continuity is found to the casing on any of the terminals, the compressor is shorted and is defective.

7-5.2.3 Capacitors

Duo-Therm® air conditioners and heat pumps use three different capacitors: (1) a compressor run capacitor (2) a compressor start capacitor, and (3) a fan/blower capacitor. On some units, the compressor run and fan/blower capacitor are in the same case.

The compressor run and fan/blower capacitors are housed in a steel or aluminum case. The start capacitor is in a Bakelite shell. Some have a 15,000-3/4 bleeder resistor across the terminals.

The power must be turned "OFF," and capacitors must be discharged before testing. Use an AC voltmeter (set to the highest scale) or a 15,000-3/4, 2 W resistor to bleed away any charge left in the capacitor.

Remove the wires from the terminals and inspect the casing. If it is bulged, cracked, or split, the capacitor is defective.

Use an analog voltmeter (dial or hand-reading indicator) to test the capacitor after it has been discharged. Set the ohmmeter to mid-range and check for resistance to the case. Any resistance to the case from the terminals indicates that it is defective and needs to be replaced.

Set the ohmmeter to the highest scale and read across the terminals on the capacitor. The ohmmeter should swing toward zero and slowly move back toward infinity. Reverse the leads and repeat the test. If the ohmmeter stays on infinity, it is open and needs to be replaced. If very little meter movement is noticed, switch the meter to a lower scale and repeat the test.

The capacitors with the 15,000-3/4 resistor should be checked on the 1,000-3/4 scale. The ohmmeter should swing below 15,000-3/4 and return. Reverse leads and repeat the test. If the capacitor does not act as described, it is defective and needs to be replaced.

7-5.2.4 Motors

To determine if a motor is good, test the windings with an ohmmeter. Disconnect the power supply, and turn all the switches to the "OFF" position. Disconnect the motor leads (on some models, disconnect the six-pin plug from the electrical box). The motor should show continuity between all leads and the white wire. Infinity or no continuity indicates that the winding is open and the motor is defective.

Check for continuity between the motor frame and each lead. If a continuity reading is present to any lead, the motor is shorted and defective.

The motor can be tested with an ammeter to determine if the operation is within the rating (±10 percent) listed on the model plate. Many times, the motor windings will check good, but bad bearings or a bad capacitor may be found in an ampere test.

7-5.2.5 Wiring

Miswiring or loose wires can cause electrical short or component failure. Use the wiring diagram to verify and correct wiring. Loose terminals should be tightened or replaced.

7-5.2.6 Reversing Valve

The reversing valve is the heart of a heat pump. It changes the direction of the refrigerant flow through the coils and changes the system from cooling to heating.

The reversing valve's solenoid can be energized in either the heat or cool mode of operation. Duo-Therm rooftop heat pumps have the solenoid energized in the cool mode.

One method of checking the reversing valve is to feel the refrigerant line at the top of the inside coil. In the COOL mode, this line will be cool to the touch. In the heat mode, the line will be warm or hot to the touch. If a cold line cannot be felt in the cooling mode, the direction of flow is not correct.

Check the solenoid coil for ohms resistance. The correct reading is approximately 465-3/4 ± 10 percent.

7-5.2.7 PTCR Device

The positive temperature coefficient resistor (PTCR) has replaced the compressor start relay and, in some cases, the start capacitor. It should be checked in two different ways:

1. Check continuity. Turn "OFF" the AC power at the main breaker and analog control system switch. Disconnect the PTCR from the circuit. Using an ohmmeter, check for continuity through the PTCR. If there is no continuity, the PTCR is open and needs to be replaced.

NOTE: This is an energized circuit. Shock can occur if not tested properly. Testing is to be done by a qualified service technician.

2. The second check is an amp reading. Clamp an ammeter around the wire from the start capacitor. Turn on the AC power and set the analog control system to the cooling mode. When the compressor starts, the ammeter should show a reading for approximately one second. If there is no amperage reading or a prolonged reading, the PTCR is faulty and must be replaced.

7-5.2.8 Heat Strip

Check the heat strip for continuity across the outside terminals at the heat strip plug. If the circuit is open (no continuity) the fuse link, limit, or heater element may be defective.

7-5.2.9 Cold Control

The cold (freeze) control is a low-temperature protection device used on rooftop air conditioners only. If used with rooftop heat pumps, it can cause premature shutoff of the compressor.

The cold control is normally open (no continuity), and closed when the temperature is below 41 to 49°F (5 to 7°C). The switch will return to the open position at 52 to 62°F (11 to 16.6°C).

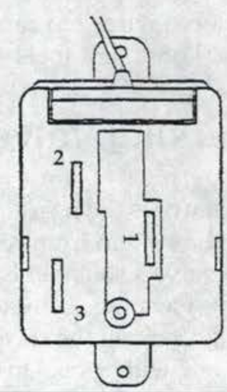
Check continuity through the switch. In temperatures over 62°F (16.6°C), it should be open (no continuity). In temperatures below 41°F (5°C), it will be closed. Any variation requires the switch to be replaced.

7-5.2.10 Outdoor Thermostat

The outdoor thermostat allows the operation of the heat pump until the ambient (outside) temperature drops below 40°F (±2°F) [4.4°C (±1.1°C)]. The heat pump operation will resume after the ambient temperature rises above 45°F (±2°F) [7.2°C (±1.1°C)].

The outdoor thermostat, as illustrated in *Figure 7-47*, can be checked with an ohmmeter for continuity between terminals 2 and 3 in temperatures above 45°F (7.2°C). In temperatures below 40°F (4.4°C), continuity should be present between terminals 1 and 2.

Figure 7-47 Outdoor Thermostat



7-5.2.11 Thermostat Cable

The thermostat cable connects the analog thermostat to the analog control box. The HEAT/COOL-only application requires only six conductors. The COOL/FURNACE/HEAT STRIP and the COOL/FURNACE/HEAT PUMP models require seven conductors. It is common for most manufactures to install an eight-conductor thermostat cable.

The cable is easily checked by an ohmmeter. Disconnect the thermostat cable from the analog control box and the analog thermostat. No continuity should exist between any of the conductors. Continuity indicates a problem (e.g., a staple) in the cable.

7-5.2.12 Analog Thermostat

There are three different analog thermostats being used to control Duo-Therm air conditioners, air conditioners with heat strips, and heat pumps. The type of thermostat used depends on the unit and accessories used with it.

It is very important for the proper location of the analog thermostat to ensure that it will provide a comfortable RV temperature. Observe the following rules when selecting a location:

A. Locate the analog thermostat 54 in. (137 cm) above the floor.

B. Install the analog thermostat on a partition, not on an outside wall.

C. Never expose it to direct heat from lamps, sun, or other heat-producing items.

D. Avoid locations close to doors that lead outside, windows, and adjoining outside walls.

E. Avoid locations close to supply registers and the air flowing from them.

The analog thermostat is mounted on the wall of the RV and is connected to the analog control box with six or seven wires, depending on the unit and accessories being used.

If nothing operates on the unit, turn the **System Switch** to "OFF," FAN **Auto/On Switch** to "AUTO," and **FAN HIGH/LOW Switch** to "LO." Remove the analog thermostat cover and verify the following voltage readings:

A. Current-model terminal identification is illustrated in *Figure 7-48*. Check for voltage between the GND (green wire on control box) terminal and:

1. **FAN** terminal for voltage ranging from 8.38 to 17.31 VDC. Tan wire on control box.

2. **HI FAN** terminal for voltage ranging from 8.38 to 17.31 VDC. Blue wire on control box.

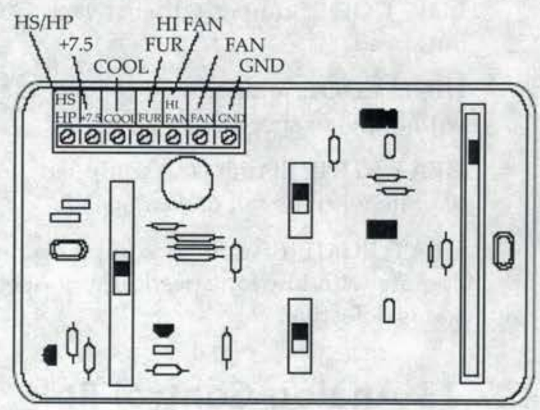
3. **FUR** terminal for voltage ranging from 8.38 to 17.31 VDC. White wire on control box.

4. **COOL** terminal for voltage ranging from 6.73 to 7.53 VDC. Yellow wire on control box.

5. **+7.5** terminal for voltage ranging from 6.74 to 7.5 VDC. Red with white striped wire on control box.

6. **HS/HP** terminal (present only on heat strip or heat pump models) for voltage ranging from 8.38 to 17.31 VDC. Orange wire on control box.

Figure 7-48 Current-Model Terminal Identification



B. Early-model terminal identification is illustrated in *Figure 7-49*. Check for voltage between the **GND** (black wire on control box) terminal and:

1. **FAN** terminal for voltage ranging from 8.38 to 17.31 VDC. Orange wire on control box.

2. **HI FAN** terminal for voltage ranging from 8.38 to 17.31 VDC. Blue wire on control box.

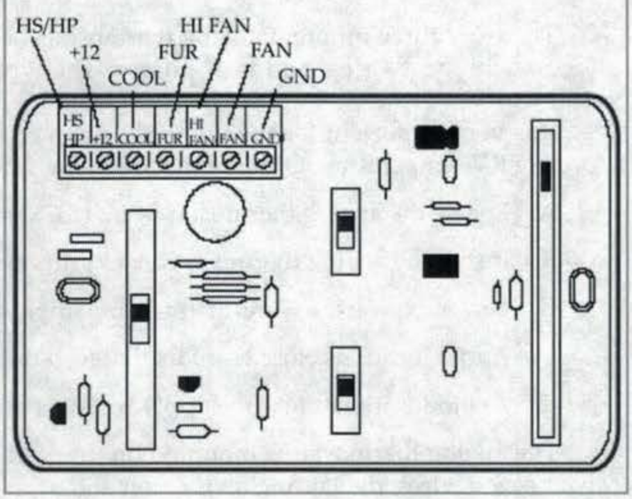
3. **FUR** terminal for voltage ranging from 8.38 to 17.31 VDC. White wire on control box.

4. **COOL** terminal for voltage ranging from 6.73 to 7.53 VDC. Yellow wire on control box.

5. **+12** terminal for voltage ranging from 6.74 to 7.5 VDC. Red wire on control box.

6. **HS/ HP** terminal (present only on heat strip or heat pump models) for voltage ranging from 8.38 to 17.31 VDC. Violet wire on control box.

Figure 7-49 Early Model Terminal Identification



If any one of the volt readings is missing, check thermostat cable (B12) or analog control box (B14).

If the voltages shown above are present, use a jumper wire to test unit operation as follows:

LOW FAN, jumper wire between GND and FAN. The unit should operate on low fan speed.

HIGH FAN, jumper wire between GND, FAN, and HI FAN. The unit should operate on high fan speed.

FURNACE (if furnace connected to the blue/white wires on the analog control box), jumper wire between GND and FUR. The furnace should operate.

LOW COOL, jumper wire between GND, FAN, and Cool. The compressor should operate with low fan speed.

HIGH COOL, jumper wire between GND, FAN, HI FAN, and COOL. The compressor should operate with high fan speed.

HEAT STRIP (if unit is so equipped), jumper between GND, FAN, and HS/HP. The heat strip should operate with the fan on low speed.

HEAT PUMP (if unit so equipped), jumper between GND, FAN, HS/HP. The heat pump should operate with low fan speed. If unit operates properly when terminals are jumped, the analog thermostat is defective.

7-5.2.13 Analog Control Box

The analog control box comes in three different configurations, which are not interchangeable. The analog control board consists of several relays, plug receptacles, and other components. If any one of these is defective, the entire analog control box should be replaced.

The analog control box works with the analog thermostat to change or switch AC circuits that control the operation of the Duo-Therm unit.

7-5.2.13.1 Air Conditioners

To verify that circuits are being completed by the analog control box, first disconnect the six-pin plug connector from the analog control box.

Using a 120 VAC incandescent bulb, check from terminal 5 (white-common) to the other terminals to determine if a particular circuit is completed through the analog control box. If the circuit is completed, the light will illuminate.

Terminal 1 is a blue wire and the compressor circuit.
Terminal 2 is a black wire and the high fan circuit.

Terminal 3 is a yellow wire and not used.
Terminal 4 is a red wire and the low fan circuit.
Terminal 5 is a white wire and the common AC connection.
Terminal 6 is green/yellow wire and chassis ground.

NOTE: DO NOT use a voltmeter to do these checks, as it will give erroneous readings.

If the circuit is completed and a component is not operating, the problem is in the rooftop unit.

7-5.2.13.2 Air Conditioners with Heat Strip

To verify that circuits are being completed by the analog control box, first disconnect the six-pin plug connector from the analog control box.

Using a 120 VAC incandescent bulb, check from terminal 5 (white-common) to the other terminals to determine if a particular circuit is completed through the analog control box. If the circuit is completed, the bulb will illuminate.

Terminal 1 is a blue wire and the compressor circuit.
Terminal 2 is a black wire and the high fan circuit.
Terminal 3 is a yellow wire and not used.
Terminal 4 is a red wire and the low fan circuit.
Terminal 5 is a white wire and the common AC connection.
Terminal 6 is green/yellow wire and chassis ground.

To verify heat strip operation, disconnect the three-pin plug and, using a 120 VAC bulb, check from terminal 1 to terminal 3. If the circuit is completed, the bulb will illuminate. To check heat strip, see *"Heat Strip" on page 7-66*.

NOTE: DO NOT use a voltmeter to do these checks, as it will give erroneous readings.

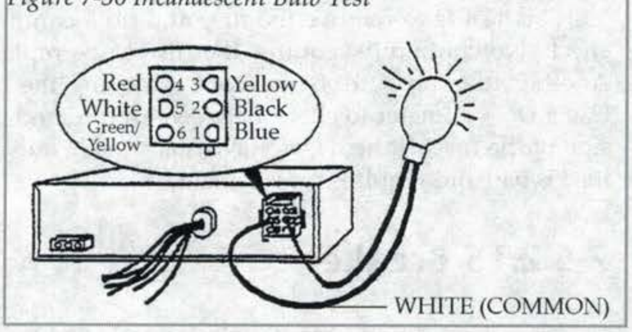
If the circuit is completed and a component is not operating, the problem is in the rooftop unit.

7-5.2.13.3 Rooftop Heat Pump

To verify that circuits are being completed by the analog control box, first disconnect the six-pin plug connector from the analog control box.

Using a 120 VAC incandescent bulb, check from terminal 5 (white-common) to the other terminals to determine if a particular circuit is completed through the analog control box. If the circuit is completed, the light will illuminate as depicted in *Figure 7-50*.

Figure 7-50 Incandescent Bulb Test



Terminal 1 is a blue wire and the compressor circuit.
Terminal 2 is a black wire and the high fan circuit.
Terminal 3 is a yellow wire and reversing valve circuit.
This circuit is energized in the cooling mode and not energized in the heat pump mode.
Terminal 4 is a red wire and the low fan circuit.
Terminal 5 is a white wire and the common AC connection.
Terminal 6 is green/yellow wire and chassis ground.

NOTE: DO NOT use a voltmeter to do these checks, as it will give erroneous readings.

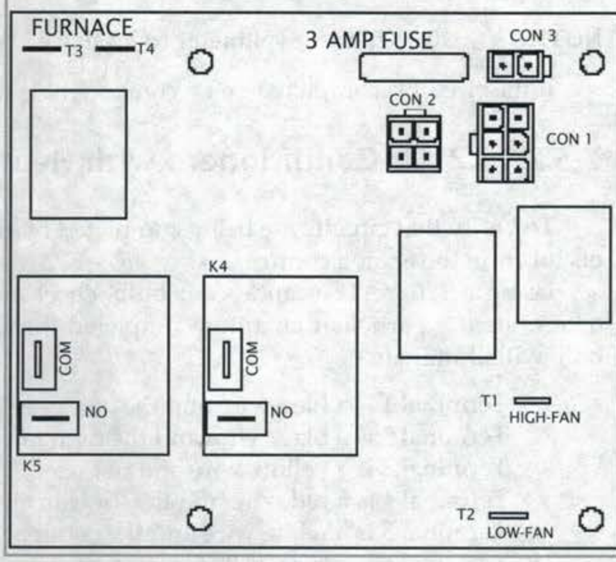
If the circuit is completed and a component is not operating, the problem is in the rooftop unit.

7-5.2.13.4 Basement Heat Pump

To verify that circuits are being completed by the analog control board, shown in *Figure 7-51*, the cover of the unit electrical box must be removed.

Using a 120 VAC incandescent bulb, check from terminal "C" (white wire) on the fan/run capacitor to the terminals on the analog control board. If the circuit is completed, the light will illuminate.

Figure 7-51 Analog Control Board



"COM" terminal (black)	on K4 relay 120 VAC supply
"NO" terminal (blue)	on K4 relay compressor
Terminal T1 (black)	on control board high fan
Terminal T2 (red)	on control board low fan
Terminal "NO" (black)	on K5 relay reversing valve

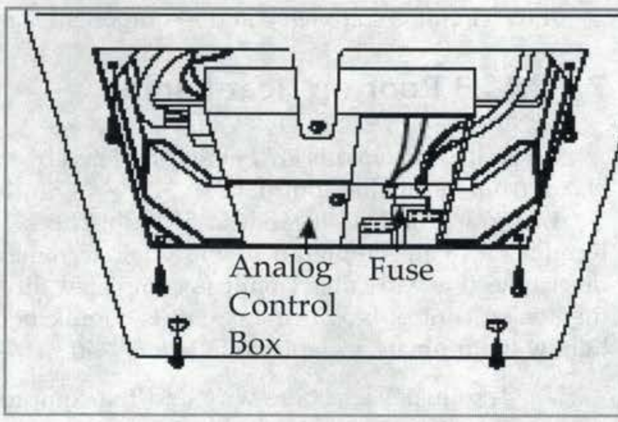
NOTE: Do not use a voltmeter to do these checks, as it will give erroneous readings.

If the circuit is completed and a component is not operating, the problem is in the component of the basement unit.

7-5.2.14 Fuse

A 3 A fuse is installed in the analog control box to protect the system from shorts or overload created by disconnecting or reconnecting components, when DC power is still connected to the system, as shown in *Figure 7-52*.

One test is to remove the fuse and do a continuity check. No continuity requires the fuse to be replaced. Another test can be done without removing the fuse. Use a DC voltmeter to check between ground and each side of the fuse. If there is voltage on one side only, the fuse is bad and requires replacement.



7-5.2.15 Breaker

The air conditioner circuit is to be protected by a time-delay fuse or a heating, air conditioning, and refrigeration (HACR) breaker. The first step is to measure the amperage draw at the unit's AC connection. If the breaker is tripping at a reading lower than its rated load, it may be defective and in need of replacement. If the breaker proves good, also measure for low voltage and check the air conditioner for proper cycling. Low voltage and short cycling can also trip the circuit breaker.

7-5.3 Dometic Comfort Control Center (CCC) Controls

7-5.3.1 Power Source

If the compressor or fan fails to operate, it is probably not receiving power. Be sure the power cord is plugged in and no fuses or breakers are tripped.

NOTE: Many customers use extremely long power cords that are undersized, as shown in *Figure 7-53*. If possible, ask the owner to hook up the RV just like it was when the problem occurred.

Make note of the wire size and length of wire. Compare it to *Table 7-10* for wire sizing.

Figure 7-53 Example of Extremely Long Undersized Power Cord

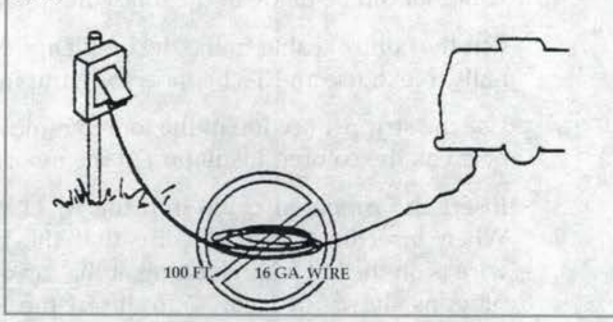


Table 7-10 Wire Size

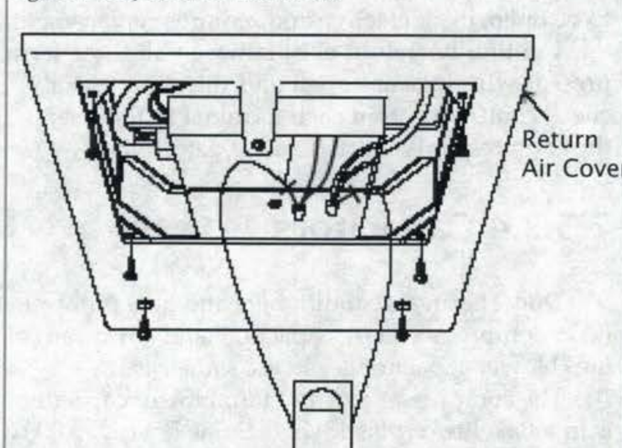
Current in Amps	16	14	12	10	8	6
			Length in Feet			
5	47	76	121	192	216	486
10		38	60	96	153	243
15		25	40	64	102	162
20			30	48	76	121

NOTE: For normal operation of the unit, AC voltage must stay between 103.5 and 126.5 VAC. Operation of the unit outside of this voltage range can result in component damage.

To determine if power is reaching the air conditioner, the inside plastic air diffuser box must be removed. The junction box will now be exposed. Remove the cover from the junction box to gain access to the connection between the RV and the unit wire, as shown in *Figure 7-54*. Check with a voltmeter for voltage at the connections of the unit to RV wires. USE CAUTION, as 120 VAC may be present.

If no voltage is present, the problem is in the coach wiring or breaker/fuse box.

Figure 7-54 Junction Box Access



7-5.3.2 Cable Assembly

A flat control cable, as shown in *Figure 7-55*, must be routed from the unit to the comfort control center. It must be 26 ga stranded copper wire, four (4) conductor (yellow, green, red, and black). The cable must be terminated with a four (4) position telephone RJ-11 connector.

Figure 7-55 Flat Control Cable

NOTE: Do not use a premade telephone extension cable. The order of the connectors is reversed and will cause failure of the system.

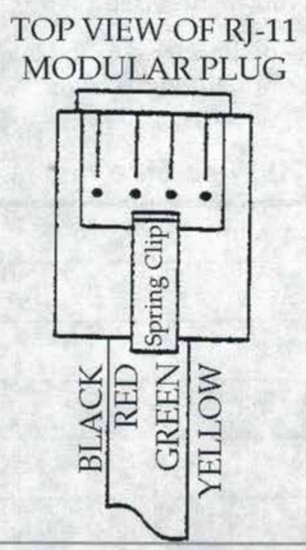
The cable should be made in the following manner:

Cut the control cable to the desired length. When cutting, make sure ends are cut straight, not diagonally. Next, use an RJ-11 connector crimping tool.

Use the stripper section of the tool to remove the outer insulation of the cable. Be careful not to remove or break the colored insulation of the inner conductors. Repeat on the opposite end.

Insert the prepared cable into the RJ-11 plug. When inserting cable, be sure that the black wire is on the left when looking at the top of the plug, as shown in *Figure 7-56*. Insert the RJ-11 plug into the tool and squeeze to the stop. Repeat the procedure for the other end.

Figure 7-56 RJ-11 Modular Plug



The finished cable can be tested with a 3107127.007 comfort control cable tester. See *"System Reset" on page 7-80* for more information on the testing of the cable.

7-5.3.3 Compressor

The compressor motor can be electrically checked. Be sure to disconnect all power and turn all switches to the "OFF" position before starting to do the tests.

NOTE: Remove the terminal cover from the compressor and disconnect the three leads connected to the terminals. Make note of the positions so the wires can be replaced correctly.

Use an ohmmeter to check for continuity through the overload device. If no continuity is found and the compressor is hot, allow 15 to 20 minutes for the compressor to cool. If a repeat of the test shows the overload to be open, it is defective and requires replacement.

Continuity should exist between all three terminals of the compressor. If there is no continuity, the compressor windings are open and the compressor is defective. Scrape the compressor casing to bare metal and check continuity from each terminal to the casing. If continuity is found to the casing on any of the terminals, the compressor is shorted and is defective.

7-5.3.4 Capacitors

Duo-Therm air conditioners and heat pumps use three different capacitors: (1) a compressor run capacitor, (2) a compressor start capacitor, and (3) a fan/blower capacitor. On some units, the compressor run and fan/blower capacitor are in the same case.

The compressor run and fan/blower capacitors are housed in a steel or aluminum case. The start capacitor is in a Bakelite or plastic shell. Some have a 15,000-3/4 bleeder resistor across the terminals.

The power must be turned "OFF," and capacitors must be discharged before making the test. Use an AC voltmeter (set to the highest scale) or a 15,000-3/4, 2 W resistor to bleed away any charge left in the capacitor.

Remove the wires from the terminals and inspect the casing. If it is bulged, cracked, or split, the capacitor is defective.

Use an analog voltmeter (dial or hand-reading indicator) to test the capacitor after it has been discharged. Set the ohmmeter to mid-range and check for resistance to the case. Any resistance to the case from the terminals indicates it is defective and needs to be replaced.

Set the ohmmeter to the highest scale and read across the terminals on the capacitor. The ohmmeter should swing towards zero and slowly move back toward infinity. Reverse the leads and repeat the test. If the ohmmeter stays on infinity, it is open and needs to be replaced. If very little meter movement is noticed, switch the meter to a lower scale and repeat test.

The capacitors with the 15,000-3/4 resistor should be checked on the 1,000-3/4 scale. The ohmmeter should swing below 15,000-3/4 and return. Reverse leads and repeat the test. If the capacitor does not act as described, it is defective and needs to be replaced.

7-5.3.5 Motors

To determine if a motor is good, test the windings with an ohmmeter. Disconnect the power supply, and turn all the switches to the "OFF" position. Disconnect the motor leads (on some models disconnect the six-pin plug from the electrical box). The motor should show continuity between all leads and the white wire. Infinity or no continuity indicates that the winding is open and the motor is defective.

Check for continuity between the motor frame and each lead. If a continuity reading is present to any lead, the motor is shorted and defective.

The motor can be tested with an ammeter to determine if the operation is within the rating (±10 percent) listed on the model plate. Many times, the motor windings will check good, but bad bearings or a bad capacitor may be found in an ampere test.

7-5.3.6 Remote Sensor

The remote sensor is the temperature sensor that allows the unit for a zone to cycle "ON" and "OFF" by temperature. A remote sensor is used for each unit or zone. A remote sensor is usually optional for zone 1, but in some applications the comfort control center is located for convenience of access and the remote sensor is placed for temperature control.

The proper location of the remote sensor is very important to maintain a comfortable temperature in the RV. The following rules should be observed when selecting a location:

A. Locate the remote sensor 54 in. (137 cm) above the floor.

B. Install the remote sensor on a partition, never on an outside wall.

C. Avoid locations that are close to doors that lead outside, windows, or outside adjoining walls.

D. Keep them away from discharge from supply registers.

E. Place them in areas that have good air movement. Avoid corners and under cupboards.

Unplug the remote sensor and test its cable with an ohmmeter (see *Figure 7-57*). The ohm reading should be as shown in *Table 7-11*.

Figure 7-57 Remote Sensor Locations

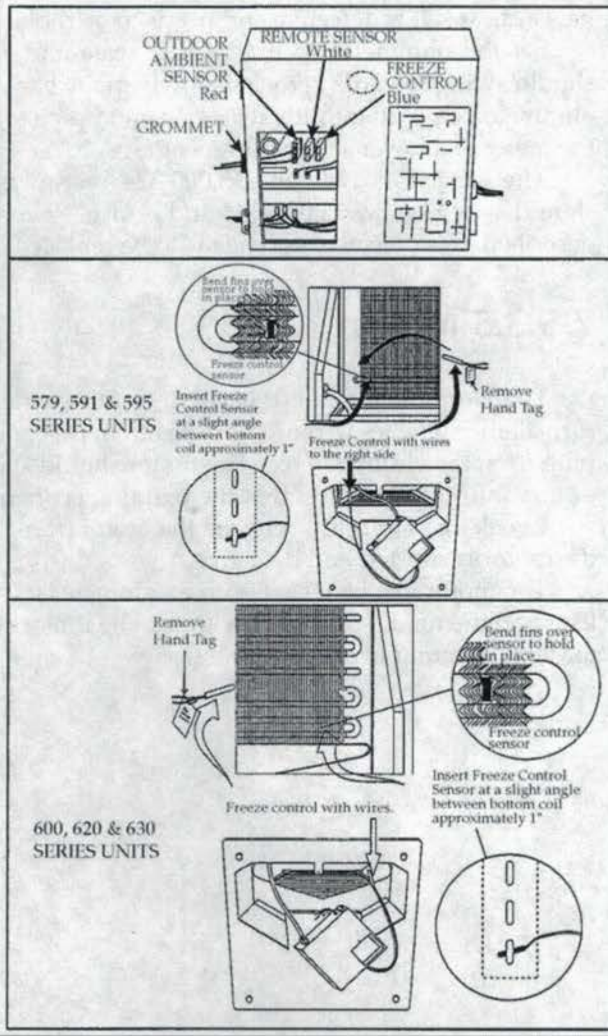


Table 7-11 Ohm Readings

Temperature	Ohm Readings
55°F (12.7°C)	11,667
60°F (15.5°C)	10,212
65°F (18°C)	8,959
70°F (21°C)	7,876
75°F (24°C)	6,939
80°F (26.6°C)	6,126
85°F (29.4°C)	5,418
90°F (32°C)	4,802
95°F (35°C)	4,264
100°F (37.7°C)	3,793

NOTE: Any ohm reading has a tolerance of ±10 percent.

7-5.3.7 Wiring

Miswiring or loose wires can cause electrical shorts or component failure. Use the wiring diagram to verify and correct wiring. Loose terminals should be tightened or replaced.

7-5.3.8 AC Power Module

The AC power module board consists of a relay, dual in-line (DIP) switches, plug receptacles, and other electrical components. If an one of these is defective, the **complete AC control box** (some models, only the AC power module) must be replaced. The 3 A fuse is the only replaceable part on the module board.

The board receives messages from the comfort control center and completes AC circuits to operate the unit. Before diagnosing the AC power module, make sure the configuration, DC and AC voltages, and operation are correct.

7-5.3.8.1 Rooftop Air Conditioners

The operation of the AC control box can be checked at the six-pin plug connection. Disconnect the unit and use a 120 VAC light bulb to check from terminal 5 (the white or common wire) to:

Terminal 1 (blue) is the compressor.
Terminal 2 (black) is high-speed fan.
Terminal 3 (yellow) is medium-speed fan.
Terminal 4 (red) is low-speed fan.
Terminal 6 (green/yellow) chassis ground.

If the circuit is completed, the light bulb will illuminate.

NOTE: Do not use a voltmeter to do the above tests, as it will give erroneous readings.

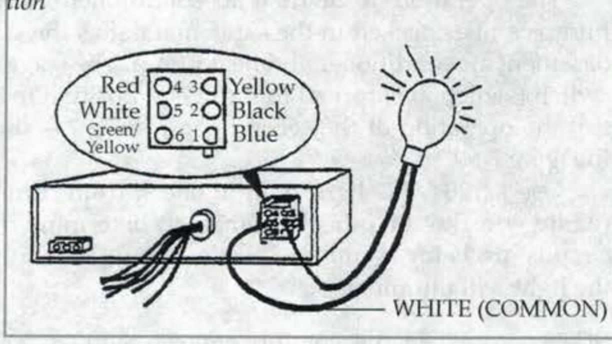
If the circuit is competed to a particular component and that component will not operate, the problem is in the rooftop unit.

7-5.3.8.2 Rooftop Heat Pump

The operation of the AC control box can be checked at the six-pin plug connection. See *Figure 7-58*. When the comfort control center is set to operate the heat pump, the fan will operate in the low speed only in the auto fan mode. Disconnect the unit and use a 120 VAC light bulb to check from terminal 5 (the white or common wire) to:

Terminal 1 (blue) is the compressor.
Terminal 2 (black) is high-speed fan.
Terminal 3 (yellow) reversing valve—this wire is energized in cooling mode only.
Terminal 4 (red) is low-speed fan.
Terminal 6 (green/yellow) chassis ground.

Figure 7-58 Incandescent Bulb Test at Six-Pin Plug Connection

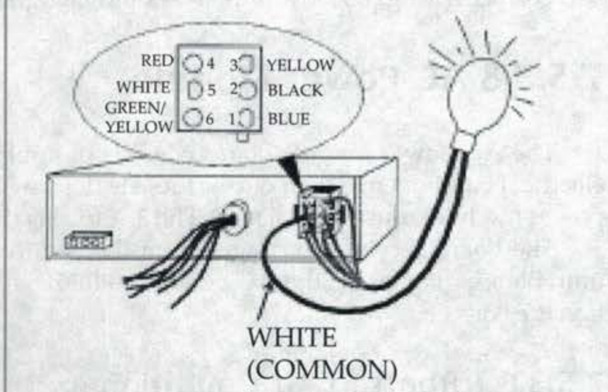


If the circuit is completed, the light bulb will illuminate.

NOTE: Do not use a voltmeter to do the above tests, as it will give erroneous readings.

If the circuit is completed to a particular component and that component will not operate, the problem is in the rooftop unit. **NEVER MIX four-button circuit boards and comfort control centers with the five-button circuit boards and comfort control center.**

Figure 7-59 Incandescent Bulb Test Directly on Board



7-5.3.8.3 Single Basement Air Conditioners and Heat Pumps

The single air conditioner/heat pump requires check and replacement of the AC power module board only. The diagnosis of the board would be similar to the complete control box except the tests are done directly on the board, as shown in *Figure 7-59*.

Use an AC light bulb to test if the relays on the board are completing a circuit. Check from the common (white wire) to:

"NO" is a black or blue wire on the compressor relay.
Terminal T1 is a black wire for high fan speed.
Terminal T2 is the reversing valve on heat pumps. If the violet wire is connected to T4 (violet), it will operate in reverse of the mode selected.
Terminal T3 is a red wire for low fan speed.

NOTE: Do not use a voltmeter to do these checks, as it will give erroneous readings.When the comfort control center is set to operate the heat pump, the fan will operate in the low-speed only auto fan mode.

If the circuit is completed and that component is not operating, the problem is in the wiring to the component.

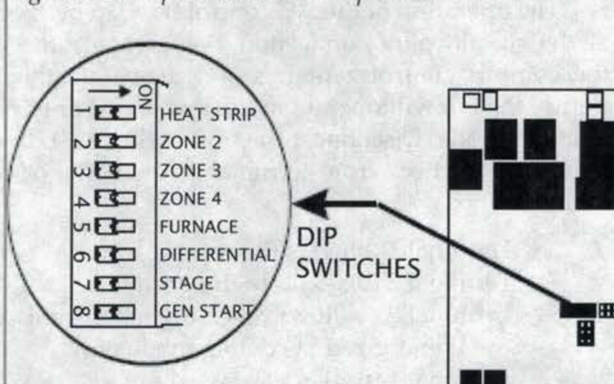
7-5.3.8.4 Dual Basement Air Conditioners and Heat Pumps

The operation of the dual air conditioner and heat pump can be checked in the same manner as the single basement air conditioner and heat pump. The stage DIP switch (switch 7) is turned to the "ON" position to control the operation of the second compressor, as shown in *Figure 7-60*.

Use a 120 VAC light bulb to check from common (white wire) to the other terminals to determine if the circuits are being completed. If the circuit is complete, the light will illuminate.

NOTE: When the comfort control center is set to operate the heat pump, the fan will operate in the low-speed only auto fan mode.

Figure 7-60 Dip Switch in "ON" position



7-5.3.9 Reversing Valve

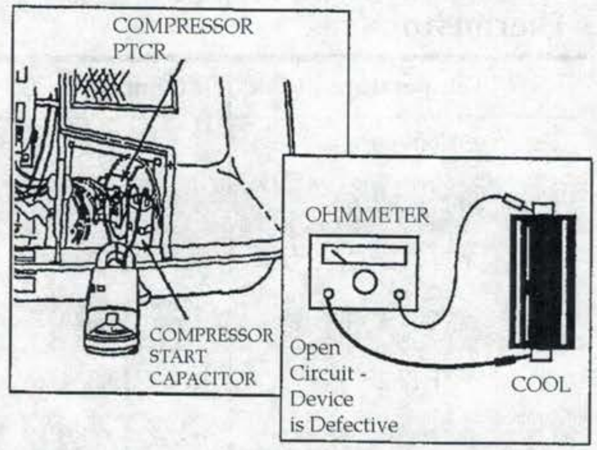
The reversing valve is the heart of a heat pump. It changes the direction of the refrigerant flow through the coils and changes the system from cooling to heating.

The reversing valve's solenoid can be energized in either the heat or cool mode of operation. Duo-Therm rooftop heat pumps have the solenoid energized in the cool mode.

One method of checking the reversing valve is to feel the refrigerant line at the top of the inside coil. In the COOL mode, this line will be cool to the touch. In the heat mode, the line will be warm or hot to the touch. If a cold line cannot be felt in the cooling mode, the direction of flow is not correct.

Check the solenoid coil for ohms continuity. An open circuit (no continuity) shows that the solenoid is defective and must be replaced.

Figure 7-61 Checking PTCR Device



7-5.3.10 PTCR Device

The positive temperature coefficient resistor/PTCR has replaced the compressor start relay and, in some cases, the start capacitor. It should be checked in two different ways:

1. Check continuity. Turn "OFF" the AC power at the main breaker and comfort control center system switch. Disconnect the PTCR from the circuit. Using an ohmmeter, check for continuity through the PTCR. If there is no continuity, the PTCR is open and needs to be replaced.

NOTE: This is an energized circuit. Shock can occur if not tested properly. Testing is to be done by a qualified service technician.

2. The second check is an amp reading. Clamp an ammeter around the wire from the start capacitor, as shown in *Figure 7-61*. Turn on the AC power and set the comfort control center to the cooling mode. When the compressor starts, the ammeter should show a reading for approximately one second. If there is no amperage reading or a prolonged reading, the PTCR is faulty and must be replaced.

7-5.3.11 Heat Strip

Check the heat strip for continuity across the outside terminals at the heat strip plug. If the circuit is open (no continuity), the fuse link limit or heater element may be defective. When the comfort control center is set to operate the heat strip, the fan will operate in the low-speed only the auto fan mode.

7-5.3.12 Cold Control

The cold (freeze) control is a low-temperature protection device used on both air conditioners and heat pumps. When the temperature of the coil reaches the freezing point, the compressor will stop operation and the fan will automatically go to high speed.

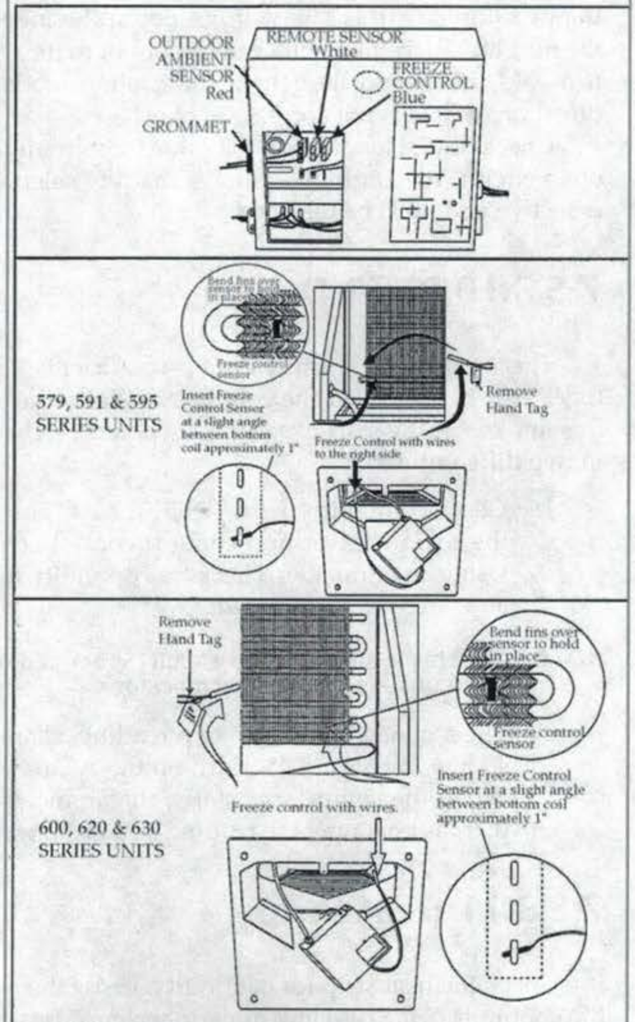
The cold control is a thermistor that senses the coil temperature. Check continuity through the sensor and compare it to *Table 7-12*. Any variation requires the sensor to be replaced. Sensor location is depicted in *Figure 7-62*.

Table 7-12 Continuity Ratings for Thermistor

Temperature	Ohm Readings
25°F (-3.9°C)	27,271
30°F (-1.1°C)	23,528
35°F (1.7°C)	20,348
40°F (4.4°C)	17,642
45°F (7.2°C)	15,334
50°F (10°C)	13,360
55°F (12.8°C)	11,667

NOTE: Any ohms reading has a tolerance of ±10 percent to indicate a good component. A very precise and accurate ohmmeter must be used before replacing the cold control. Never use a cold control designed to operate with a different control system.

Figure 7-62 Remote Sensor Locations



7-5.3.13 Ambient Sensor

The ambient sensor is the outside air temperature sensor and is used on heat pumps only. This device allows the heat pump to operate down to 30°F (-1.1°C).

To check the ambient sensor, first measure the outside temperature near the sensor. Unplug the sensor (red plug) from the AC power module board. Using an ohmmeter, check the ohms through the ambient sensor on the wire side of the plug. See *Figure 7-63*.

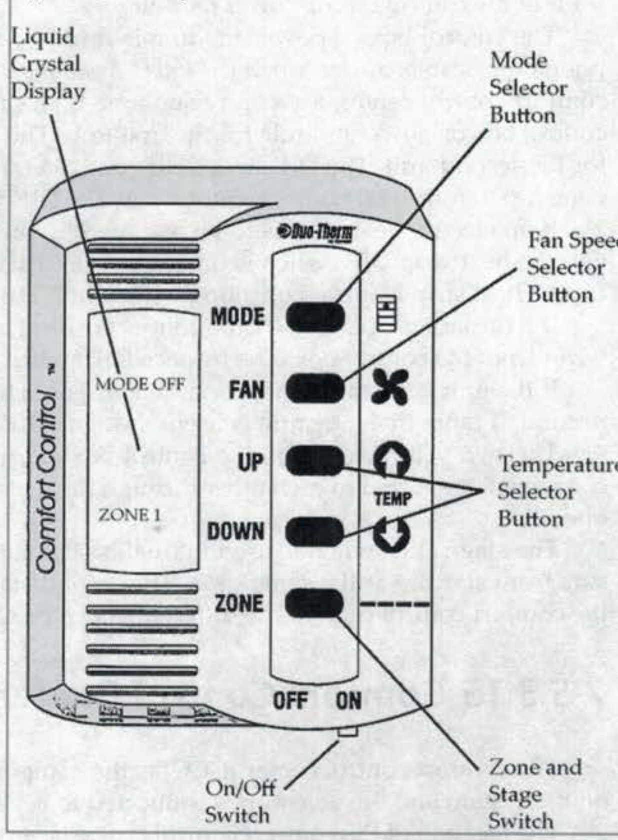
The temperature reading taken near the ambient sensor should correspond to the readings in *Table 7-13*.

Table 7-13 Ohm Readings

Temperature	Ohm Readings
55°F (12.7°C)	11,667
60°F (15.5°C)	10,212
65°F (18°C)	8,959
70°F (21°C)	7,876
75°F (24°C)	6,939
80°F (26.6°C)	6,126
85°F (29.4°C)	5,418
90°F (32°C)	4,802
95°F (35°C)	4,264
100°F (37.7°C)	3,793

NOTE: Any ohms reading has a tolerance of ±10 percent to indicate a good component. A very precise and accurate ohmmeter must be used before replacing the ambient sensor.

Figure 7-63 Comfort Control



7-5.3.14 Configuration

The comfort control center configuration relates to setting the DIP switches and particular components (remote sensor, cold control, furnace, ambient sensor, and load management system) that can be connected to the AC power module board. The comfort control systems can operate up to four units for one comfort control center (thermostat) provided the configuration is correct.

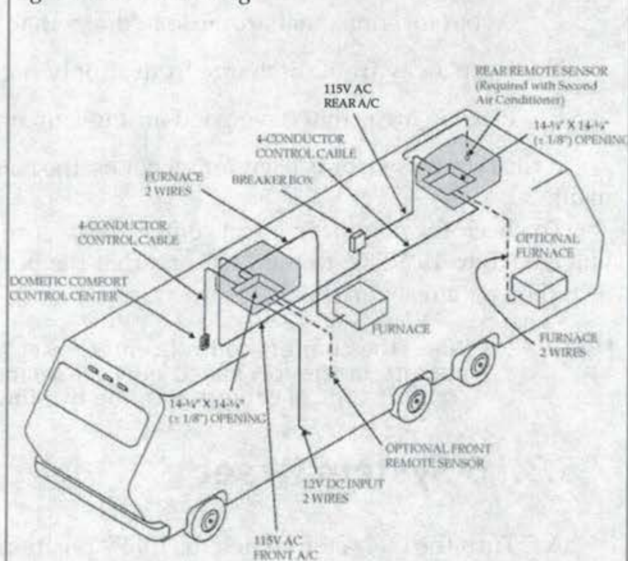
NOTE: If the configuration of the DIP switches and other components is not correct, the unit could operate erratically or not at all.

NOTE: Improper configuration may cause damage to components of the system.

Configuration is done on the AC power module board, usually at the time of installation of the unit. Locate the control box or electric box that contains the AC power module board.

The configuration for zone 1 is all DIP switches "OFF." All units require the cold control to be plugged into the blue P5 connector on the board, and the sensor is inserted in the evaporator coil. If a remote sensor is used, it will be plugged into the white P4 connector. See *Figures 7-63* and *7-64*.

Figure 7-64 RV Wiring



The comfort control center requires DC voltage to be supplied to the red (positive, +) and black (negative, -) leads of the control box or power module.

The control box or power module is connected to the comfort control center (wall thermostat) by a telephone type cable, as described in *"Cable Assembly" on page 7-71*. If more than one unit is to be operated off the comfort control center, a second telephone-type cable is needed. Both telephone cables are plugged into the control box or power module for the first unit. The second cable is routed to the control box or power module for the second unit. The DIP switch for zone 2, as shown in *Figure 7-60*, needs to be turned on. Each additional zone (up to four total zones) requires only the DIP switch for its zone number to be turned on.

If an electric heat strip is to be operated by the comfort control center, it is plugged into the control box, and the heat strip DIP switch is turned to "ON." If a second unit is equipped with a heat strip, the DIP switch for the heat strip is turned on along with zone 2 DIP switch.

If a furnace is operated by the comfort control center, the thermostat wires are attached to the two (2) blue wires from the control box. The furnace DIP switch for that zone (control box or power module) is turned on.

If the unit is a heat pump, the ambient sensor for the outdoor temperature is plugged into the red P3 connection. If more than one unit is used, the zone DIP switch must be turned on.

The two yellow leads on the control box are for use with the load management system. If the wires are connected or shorted to each other through the metal of the mounting or electrical box, the compressor will not operate.

The stage DIP switch is used in dual basement heat pumps or air conditioners. It prevents both compressors from starting at the same time. The second stage is controlled by a temperature differential that is set in the comfort control center. The differential can be set from 0 to 10°F (–17.8 to –12.2°C).

7-5.3.15 Comfort Control Center

The comfort control center (CCC) is the component that makes all the decisions for operation, depending on the system and the accessories connected to it.

The location of the comfort control center is very important if it is being used without a remote sensor. Use the following guidelines for the location:

A. Locate the remote sensor 54 in. (137 cm) above the floor.

B. Install the remote sensor on a partition, never on an outside wall.

C. Avoid locations that are close to doors that lead outside, windows, or outside adjoining walls.

D. Keep away from discharge from supply registers.

E. Place in areas that have good air movement. Avoid corners and under cupboards.

If the remote sensor is used for all zones, the comfort control center can be located anywhere that is convenient.

To check the comfort control center, make sure the ON/OFF switch is in the ON position. Check for DC voltage (10 to 16 VDC) to the CCC and that the polarity is correct. If the previously mentioned items are correct, then do a reset on the CCC.

NOTE: When the comfort control center is set to operate the heat strip or heat pump, the fan will operate in the low-speed only auto fan mode. NEVER MIX four-button circuit boards and comfort control centers with the five-button circuit boards and comfort control center.

7-5.3.16 System Reset

A. Turn the ON/OFF switch to "OFF" position.

B. Simultaneously depress and hold the MODE and ZONE push buttons while turning the ON/OFF switch to "ON." FF should appear in the LCD display until the MODE and ZONE push buttons are released.

C. When a DIP switch is turned on or off after initial configuration, a system reset will need to be done before the comfort control center will recognize the updated selection. See *Figure 7-63*.

7-5.3.17 DC Voltage

A DC volt supply is required for operation of the comfort control center. The operating range is 10 to 16 VDC. If DC voltages are outside of the operating range, erratic operation may result.

Use a DC voltmeter to check for the incoming DC voltage between the red (positive, +) and the black (negative, –) at the connections of the electronic control box. If no DC voltage is found, check the supply breaker or fuses.

Check the output voltage by using the telephone wall jack. One end of the cable is plugged into the A/C power module RJ-11 jack. The comfort control center end is plugged into the telephone wall jack. Use a DC voltmeter to test for DC power between the red and black terminals. See *Figure 7-65* and *Figure 7-66*. If there is no voltage present, check the control cable, as described in *"Cable Assembly" on page 7-71*.

Figure 7-65 CCC Wiring Example 1 (Pre-2002)

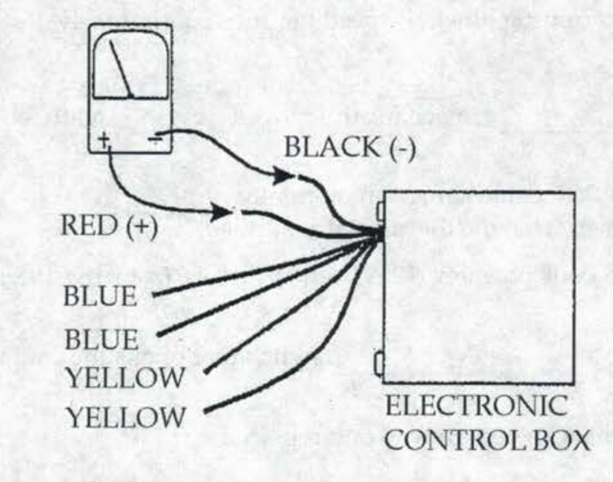
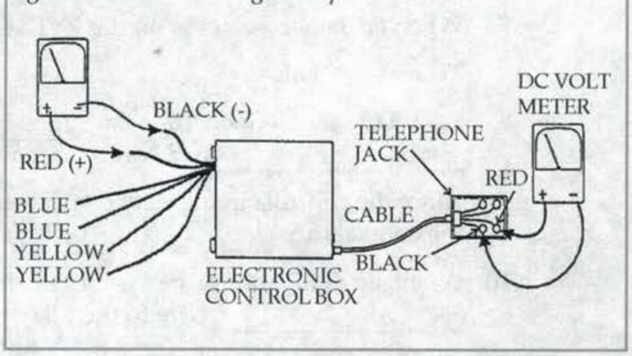


Figure 7-66 CCC Wiring Example 2



7-5 Review

1. The heat anticipator on an RVP mechanical thermostat should be set according to the ________________ requirements.
2. RVP electronic thermostats use a ________________ to monitor room temperature.
3. RVP electronic thermostats are protected by a ________________ fuse.
4. When installing or servicing RVP wall thermostats, the technician should take precautions not to short any positive wires to ________________, or permanent damage to the thermostat may occur.
5. When the on-cool mode is selected on the RVP thermostat, the fan runs continuously even when the compressor cycles off.

   True False
6. When locating an RVP thermostat, it should be installed on an inside wall about 5 ft (0.75 m) from the floor.

   True False
7. When *fan only* is selected on the RVP wall thermostat, the low-speed fan runs continuously.

   True False
8. A relay is defined as an ________________ mechanism moved by a small electrical ________________ in a control circuit.
9. All of the control circuit relay contacts on RVP air conditioners are normally ________________, and the contacts are ________________, as power from the thermostat is applied.
10. When an RVP thermostat is placed in the cool position, 12 VDC (+) travels from the thermostat ________________ wire to the relay coil.
11. All RVP -730 series ceiling plenums all have a ________________ switch that opens the compressor circuit if the evaporator coil starts to freeze.
12. Printed circuit boards have relays on them that can be removed and replaced.

    True False
13. If the RVP thermostat makes a call for high fan, 12 VDC should be read between terminals GH and B at the low voltage terminal strip.

    True False
14. The RVP low-temperature thermistor probe could open the compressor relay if the evaporator starts to freeze up.

    True False
15. The RVP low-temperature thermistor probe opens the compressor relay at 32°F (0°C) and closes at 90°F (32.2°C).

    True False
16. Never short any other RVP thermostat wire to the blue wire or to ground—permanent damage will occur.

    True False
17. If a thermistor is open on a printed circuit board, this will not keep the compressor from running.

    True False

18. A Dometic air conditioner draws 5A. What gauge power cable is required for a 100 ft (30.5 m) power cord?

    A. 14

    B. 12

    C. 10

    D. 8

19. The 12 VDC operating range for a Dometic air conditioner is:

    A. 10 to 12

    B. 10 to 14

    C. 9 to 14

    D. 9 to 16

20. Which color wire is GROUND on current Dometic air conditioner thermostats?

    A. Red

    B. Black

    C. Green

    D. Blue

21. Which color wire is HIGH FAN on current Dometic air conditioner thermostats?

    A. Blue

    B. Orange

    C. White

    D. Yellow

22. Capacitors must be turned OFF and the wires disconnected from the terminal before testing them.

    True False

23. An ammeter can be used to test an air conditioner motor to see if it is within the rating (±10 percent) listed on the model plate.

    True False

24. The heart of a heat pump is the

    A. Heat strip

    B. PTCR device

    C. Reversing valve

    D. Solenoid valve

25. Dometic recommends that the analog thermostat be mounted ____________ inches above the floor.

    A. 36

    B. 48

    C. 54

    D. 60

26. On current-model Dometic air conditioners, the terminal marked HS/HP stands for:

    A. HIGH SPEED/HIGH POWER

    B. HIGH SPEED/HIGH PUMP

    C. HEAT STRIP/HEAT PUMP

    D. HEAT STRIP/HIGH POWER

27. For Dometic air conditioner normal operation, AC voltage needs to stay within a range of:

    A. 100.5 to 124

    B. 103.5 to 126.5

    C. 110 to 130.5

    D. 115 to 126.5

28. The flat control cable that is routed from the air conditioner unit to the comfort control center must be ________________ gauge, stranded copper wire, four conductor (yellow, green, red, and black).

    A. 14

    B. 18

    C. 22

    D. 26

Chapter 7-6 Sealed System

- Identify tools and their use (compressor analyzer, recovery equipment).
- Measure airflow temperature [Delta T (ΔT)].
- Recovery and recycling of refrigerant.
- Braze lines and components into an air conditioner unit.
- Determine when a system requires evacuation.
- Evacuate a refrigeration system.
- Maintain a vacuum pump.
- Recharge a refrigeration system.
- Identify safe handling and environmental concerns of refrigerant.
- Test the system's function.

7-6.1 Determining When a System Needs Evacuation

7-6.1.1 Tests with Refrigerant Pressures

Our goal is to prevent service technicians from invading or tapping the refrigeration sealed system if possible. It should be seen as a last resort. **CHARGE IS VERY RARELY THE PROBLEM.** The refrigerant charge in a recreation vehicle air conditioner is very critical; the charge is usually ±1/4 oz. **If specific training has not been received, do not attempt to add or subtract charge or do any type of sealed system repairs (See *Chapter* 7-2).** Should sealed system repairs become necessary, the refrigerant charge must be weighed in when repairs are done.

NOTE: Never attempt to check the charge by pressures.

7-6.1.2 Tests with Amperages

Approximate compressor amperage may be determined by:

1. Read full-load amps (FLA) or rated-load amps (RLA) from the air conditioner rating plate.
2. This information is correct under design conditions: 95°F (35°C) outside temperature, 80°F(26.7°C) indoor temperature, and 50 percent humidity.
3. Adjust the compressor amps from rated conditions. Adjust up or down approximately 1 A for every 5°F (2.8°C) in change in outdoor temperature.

   Example:

   95°F (35°C) outdoor = FLA
   100°F (37.8°C) outdoor = FLA + 1 A
   105°F (40.6°C) outdoor = FLA + 2 A
   85°F (29.4°C) outdoor = FLA – 2 A

7-6.1.3 Tests with Temperature Differentials

7-6.1.3.1 Procedure for Checking Air Temperature Drop (ΔT) across Evaporator Coil

Check the air temperature drop across the evaporator coil as follows. Note that before this can be done effectively, the air temperatures inside and outside of the coach should be above 75°F (24°C). [Operating temperatures cooler than 75°F (24°C) could promote coil freeze-up problems.]

1. Completely open all supply (discharge) air registers.
2. Start the air conditioning unit and allow it to run for at least 1/2 hour on its high setting. The objective is to saturate the evaporator coil before running a temperature test.
3. With a standard dial-type or digital thermometer, measure the temperature of the air immediately entering the return air grill of the air conditioner unit (return air temperature).
4. With a standard dial-type or digital thermometer, measure the temperature of the air immediately leaving the supply (discharge) louvres (supply air temperature).
5. Subtract the supply air temperature from the return air temperature (if it is a ducted air conditioner unit, use the closest discharge register and make sure the temperature sensing device is measuring supply air temperature only).
6. A properly running air conditioner unit should have a nominal temperature difference of 20°F (11.1°C) [18 to 22°F (10 to 12.2°C)].

NOTE: Slightly lower temperature differences are possible under extremely humid conditions. (The unit may have to run longer to remove moisture.)

7. Temperature differences greater than 22°F (12.2°C) are possible in warm, dry weather. Restricted airflow over the evaporator coil or low fan speed may also cause greater than 22°F (12.2°C) temperature differences.

NOTE: When using two thermometers, one for intake and one for discharge, be certain they are calibrated to each other.

7-6.1.4 Leak Detection Methods

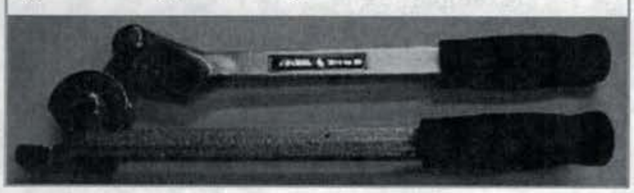
Leaks may be detected visually by applying leak detector solution or by using an electronic leak detector. Leaks may also be detected by submersing the system in a tank and looking for bubbles, or by performing a dye test. The dye test introduces a dye into the refrigeration system, making the leak easier to detect visually, as the dye will leave a stain on adjacent surfaces.

7-6.1.5 Copper Tubing

7-6.1.5.1 Characteristics

Copper tubing is rather soft and pliable to absorb vibration and shock. Use copper tubing during the repair process.

Figure 7-67 Copper-Bending Tool



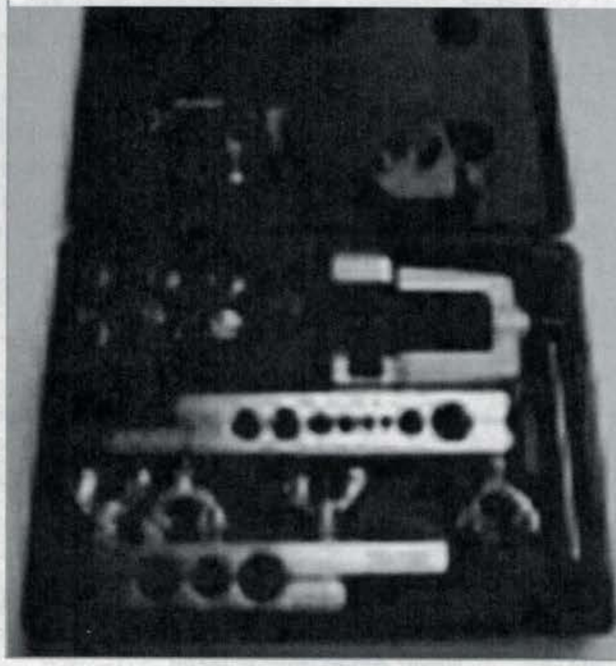
7-6.1.5.2 Bending Copper

Use suitable copper-bending tools, available at local appliance supply houses and so forth, as shown in *Figure 7-67*.

7-6.1.5.3 Swaging Copper Tubing

Swaging copper tubing should be done by using suitable swaging tools, available at local heating and air conditioning supply houses, as shown in *Figure 7-68*.

Figure 7-68 Swaging Copper Tubing



7-6.1.5.4 Cleaning Copper Tubing

Refrigeration copper tubing must be clean to ensure a good braze joint. The tubing may be cleaned with emery cloth or special tube-cleaning brushes available at local supply houses. Remove all residue before brazing (see *"Brazing Methods" on page 7-87*).

7-6.1.6 Access Valves and Installation

7-6.1.6.1 Temporary Saddle Valves

These valves are a tool used for recovery of refrigerants only. These should never be left on the air conditioner during regular operation.

7-6.1.6.2 Permanent Valves

Permanent access valves include sweat-on saddle valves, schraeder valves, and process stubs. Process stubs and pinch-off methods are factory recommended.

7-6.2 Brazing Methods

7-6.2.1 Silver Alloy Solder

The role that silver plays in brazing metals varies, depending on the alloy system, but one area of considerable importance to the air conditioning and refrigeration field is the use of silver in phosphorus-copper brazing filler metals. Silver is useful in that it broadens the melting range of the filler metal, giving it more body to fill poorly fitted joints.

7-6.2.2 Temperature Ranges of Brazing

Both silver and phosphorus have an effect on the melting range and other physical properties of the filler metal. Of the two, phosphorus is far more effective in lowering the melting range. Just 1 percent phosphorus content will lower the liquid's temperature by about 100°F (55.6°C); it would take about 6 percent silver to accomplish the same effect.

7-6.2.3 Capillary Action or "Sweating"

To join two metal parts into a permanent bond by brazing them, the parts are fluxed, assembled, and heated to brazing temperature. The brazing rod is touched to the joint area. The rod melts at the tip, and the molten brazing alloy is drawn instantly through the joint area. The force that draws the molten brazing alloy through the entire joint area is capillary action—the molecular attraction between the surfaces of a liquid and a solid. If the clearance between the two metal parts had been too great, capillary action would not have been able to work; the molecules of molten alloy would have been attracted to each other more than to the molecules of the solid. Based on laboratory tests of butt joints, the strongest joint is obtained when the clearance is a close one, about 0.0015 in. (0.038 mm).

7-6.2.4 Reaction of Copper to Brazing

Copper melts within the range of 1800 to 1900°F (982.2 to 1038°C). Do not put the alloy into the torch flame; the flame will burn off phosphorus and other elements that are present for a brazing agent. Once overheated, the copper can oxidize so much that it makes it impossible to repair the joint. Heat control is important and is developed with practice.

7-6.2.5 Reaction of Refrigerant to Brazing

NOTE: Never braze into a closed system.

If refrigerants contact glowing metal or open flame [approximately 1300°F (704.4°C)], the refrigerant will chemically break down into acids. The acids, if not removed, will in time destroy the compressor motor windings and contaminate the entire refrigeration circuit.

7-6.3 Evacuation, Dehydration, and Charging

7-6.3.1 Refrigerant Safety

The following are general safety considerations concerning fluorocarbon refrigerants. Before using or handling any refrigerant, personnel should be familiar with safety concerns for the specific product. Specific product safety information is available from the manufacturer.

7-6.3.1.1 Health Hazards

Although the toxicity of fluorocarbon refrigerants is low, the possibility of injury or death exists in unusual situations and if they are deliberately misused. The vapors are several times heavier than air. Good ventilation must be provided in areas where high concentrations of the heavy vapors might accumulate and exclude oxygen.

Inhalation of concentrated refrigerant vapor is dangerous and can be fatal. Exposure to levels of fluorocarbons above the recommended exposure levels can result in loss of concentration and drowsiness. There have been reported cases of fatal cardiac arrhythmia (change in regular heartbeat—*see glossary*). The heart may seem to skip a beat, beat irregularly, or beat very fast or very slow in humans accidentally exposed to high levels.

Skin or eye contact with liquid refrigerant can result in irritation and frostbite.

Note that exposure levels for some of the new replacement refrigerants are much lower.

7-6.3.1.2 First Aid

If refrigerant vapor has been inhaled, remove the victim to fresh air. If the victim is not breathing, give artificial respiration. If the victim experiences difficultly breathing, give oxygen. Avoid stimulants. Do not give adrenaline (epinephrine), as this can complicate possible effects on the heart. Call a physician.

In the case of eye contact, flush eyes promptly with plenty of water for at least 15 minutes. Call a physician. Flush exposed skin with water (not hot) or use other means to warm the skin slowly.

7-6.3.1.3 Other Hazards

Most halogenated compounds will decompose at high temperatures such as those associated with gas flames or electric heaters. The chemicals that result under these circumstances always include hydrofluoric acid. If the compound contains chlorine, hydrochloric acid will also be formed and, if a source of water (or oxygen) is present, a smaller amount of phosgene. Fortunately, the halogen acids have a very sharp, stinging effect on the nose and can be detected by odor at concentrations below their toxic level. These acids serve as warning agents that decomposition has occurred. If they are detected, the area should be evacuated until the air has been cleared of decomposition products.

Removing Refrigerant to Proper Levels

Federal regulations require small appliances with less than 200 lb (91 kg) of charge to be recovered and evacuated to 0 psig before opening the system or disposing of the appliance.

7-6.3.2 Equipment for Evacuation, Dehydration, and Charging

NOTE: All the following tools are necessary to evacuate and recharge an air conditioner unit.

7-6.3.2.1 Access Valves

Temporary Saddle Valves

These valves are a tool used for recovery of refrigerants only. These should never be left on the air conditioner during regular operation.

Permanent

Permanent access valves include sweat-on saddle valves, schraeder valves, and process stubs. Process stubs and pinch-off methods are the best to use.

Process Stub Valve Adapter Kits

These allow access at process stubs. They are provided by some manufacturers and commercially available.

7-6.3.2.2 Pinch-Off Tools

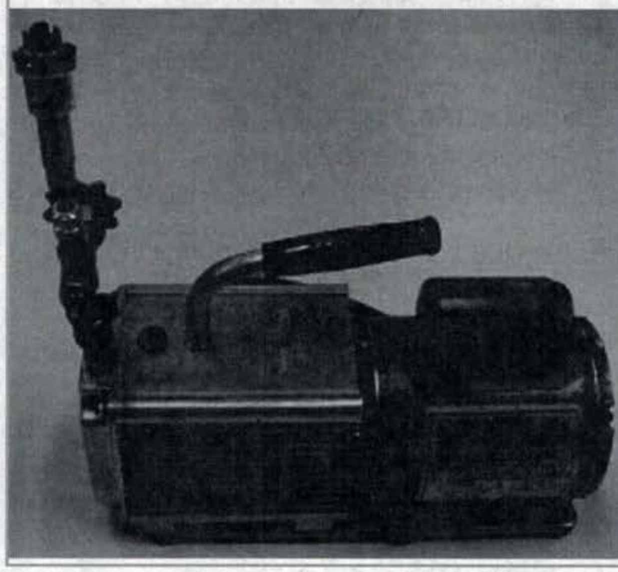
These tools pinch off the process stub to allow the system to be resealed.

7-6.3.2.3 Manifold Gauges

A typical gauge manifold consists of a low-pressure (compound) gauge used on the low side of the system and a high-pressure gauge for the system's high side. The low-pressure gauge is often color-coded blue. It measures pressure in pounds per square inch, gauge (psig) and vacuum as inches of mercury (in. Hg). The high-pressure gauge is usually color-coded red and reads pressure from 0 to 500 psi. By correctly positioning the valves of the manifold, the low-pressure gauge, connected by its hose to the low side, will read low-side pressure or vacuum. The high-side gauge connects by its hose to the high side of the system for reading pressure. The two center hoses (usually a black hose for recovery and evacuation and a yellow hose for charging) are used for refrigerant recovery, evacuation, and charging.

7-6.3.2.4 Two-Stage Vacuum Pump

Figure 7-69 Two-Stage Vacuum Pump



The vacuum pump works on the principle that as pressures are reduced, so are the boiling temperatures of liquids. By lowering the pressures in an air conditioner, we can actually "boil" all the moisture out of the system. Remember, a vacuum pump will not remove solids. Single-stage vacuum pumps are available that are capable of pulling a very high vacuum but, in general, they are vulnerable to oil contamination. If the exhaust is vent to protect the oil, the pump's efficiency is reduced. Although single-stage pumps may be quite satisfactory for small systems, for best high-vacuum performance in refrigeration usage, a two-stage vacuum pump, as shown in *Figure 7-69*, with gas ballast on the second stage is recommended. In order to prevent condensation, some vacuum pumps have a vented exhaust or gas ballast feature. Basically, this involves allowing a small bleed of atmospheric air to enter the second stage of a two-stage pump, or the discharge chamber of a single-stage pump prior to the discharge stroke to prevent condensation of water during compression.

Care of Pump

The vacuum pump requires at least minimal care. "Minimal care" means changing the oil after each use, or possibly several times during the evacuation process, when a system is badly contaminated.

7-6.3.2.5 Vacuum Analyzer

Figure 7-70 Vacuum Gauge

The refrigeration serviceman's gauge reads pressure only in relation to absolute pressure, and a given gauge reading may cover a wide range of actual pressures. For this reason, and also because the ordinary Bourdon tube gauge is not designed for the extreme accuracy required in evacuation work, a special vacuum gauge, as shown in *Figure 7-70*, is required for high vacuum readings. A thermocouple vacuum gauge is recommended. This type of gauge (reads in microns) is relatively inexpensive, easy to operate, and rugged enough for field use, and it requires little or no maintenance.

Vacuum is measured in inches of mercury. A perfect vacuum = 29.921 in. Hg. Vacuum analyzers read the vacuum in microns, which is a smaller unit of measure. 1 micron =1/25,000 of an inch.

7-6.3.2.6 Charging Devices

These devices are designed to measure the amount of refrigerant put back into the system.

Charging Station

Some manufacturers combine many of these devices into one piece of equipment with evacuation and recharging equipment both present. These setups (often called *charging stations*), are not usually set up with hoses long enough to service an RV rooftop air conditioner.

7-6.3.2.7 Refrigerant R22 Bottle

Refrigerants are usually packaged in disposable containers for use by air conditioning and refrigeration service personnel. Disposables are manufactured in three sizes: 15, 30, and 50 lb capacities. Refrigerant manufacturers and packagers voluntarily color code cylinders for their chlorofluorocarbon products.

7-6.3.2.8 Acetylene Torches (Turbo Torches)

These may not be hot enough with the wind blowing outside.

7-6.4 Checking for Leak After Soldering

7-6.4.1 Leak Testing

Checking for leaks while the system is pressurized is preferred, because it makes the leaks easier to detect.

When the equipment is uncharged, the typical procedure to test for leaks is to introduce nitrogen with a small quantity of refrigerant. Add a small charge of the refrigerant, then pressurize the system with nitrogen. Always use a pressure regulator on the nitrogen cylinder. [Adding a small amount (less than 2 oz) of R22 with the nitrogen will make the electronic detector more effective.]

The **soap bubble test** is inexpensive and good for finding large leaks.

The **ultrasonic leak detector** uses an ultrasonic detector to listen for leaking gas. This method requires some advance knowledge of the location and a fairly low background noise level.

An **ultrasonic leak detector** can also be used with a noise source of a specific frequency placed inside the equipment and the detector tuned to the frequency.

An **electronic halide detector** uses an ionization cell to detect the presence of halides. These detectors are effective at detecting small leaks but may be ineffective in the event of major leaks or background halides.

The final check for leaks is the **standing vacuum test** in which the system is evacuated and a deep vacuum is pulled on the system. An increase in pressure indicates a leak.

7-6.5 Procedure for Evacuation, Dehydration, and Charging

7-6.5.1 Theory of Dehydration

Dehydration is the process of removing water through the process of vaporization and the subsequent removal of the vapor by means of a deep vacuum. Dehydration will not occur unless a deep vacuum (500 microns or lower) is obtained.

7-6.5.2 Sealed System

If all other methods of checking the air conditioner's cooling system have failed to provide satisfactory results, it may become necessary to access the refrigeration sealed system.

NOTE: The technician must be EPA/HRAI certified to enter a sealed system.

7-6.5.2.1 Recharging

NOTE: The Clean Air Act of 1990 set guidelines in regard to the recapture or disposition of refrigerants. Check with local authorities for proper handling or evacuation of refrigerants.

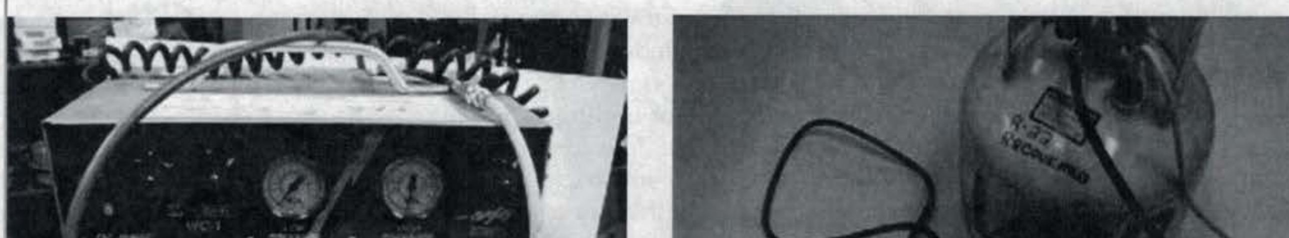
The equipment needed to properly evacuate and recharge a sealed system consists of a piercing-type clamp-on saddle valve, a braze-on processing valve, a core-removal tool, a process tube fitting, a set of gauges, a vacuum pump, equipment to weigh a precise amount of refrigerant, R22 refrigerant, gas welding equipment, an R22 refrigerant leak detector, and recovering or recycling equipment.

To drain the R22 refrigerant, attach a clamp-on saddle valve on the low-side process tube. If the air conditioner does not have a low-side process tube, attach a saddle valve at the point where the process tube will be added. Slowly drain the R22 refrigerant by using recovering or recycling equipment. **Do not leave the clamp-on saddle valve on the unit after recovery, as it will cause leaks.** If using the braze-on processing valve, once the refrigerant has been drained, use a tubing cutter and cut the tube near the end. Do this on both the low- and high-side processing tubes.

7-6.5.2.2 Recovery Machines

A machine, as shown in *Figure 7-71*, is necessary to remove refrigerant in any condition from a system and store it in an external container without necessarily testing or processing it in any way. A machine of this type is required by law for removing refrigerant from the RV air conditioner.

Figure 7-71 Recovery Machines



7-6.5.2.3 Recycling Machine

This machine, shown in *Figure 7-72*, is used to clean refrigerant for reuse by oil separation and single or multiple passes through devices (e.g., replaceable-core filter-driers) that reduce moisture, acidity, and particular matter. This term usually applies to procedures implemented at the field job site or at a local service shop.

The general rule is that it is acceptable to recycle refrigerant that is removed from a system and is to be returned to that same system. The foreword of ARI 700-88, Standard for Fluorocarbon Refrigerants, states:

> It is never acceptable to take refrigerant from one system and introduce it into another. Always use new or reclaimed refrigerant if the amount of recycled refrigerant is not enough for correct system operation. This will probably occur every time the system has had a leak. Nor is it acceptable to represent recycled refrigerant as new. No matter how clean the refrigerant or how sophisticated the machine, refrigerant that is used in a different system should have a certificate of purity issued by the reclaimer.

Figure 7-72 Recycling Machine

Since RV air conditioners use only a small quantity of refrigerant, it should be recovered and sent to a reclaimer and new or reclaimed refrigerant installed after the repair. Contact local air conditioner suppliers for reclaimer locations.

Reclaim

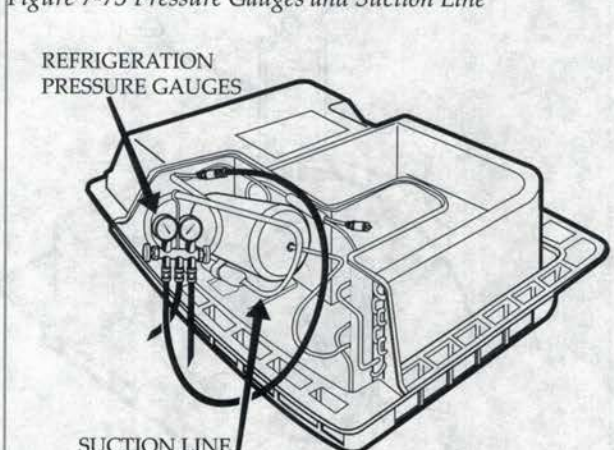
To *reclaim* means to reprocess refrigerant to new-product specifications by means that may include distillation. This requires a chemical analysis of the refrigerant to determine that appropriate product specifications are met. This term usually implies the use of processes or procedures available only at a reprocessing or manufacturing facility.

7-6.5.2.4 Recovery Cylinders

Federal and state guidelines have been established for the filling, storage, and return of recovery cylinders. Check with your local authorities.

NOTE: Recovery/recycling machines, vacuum pumps, and charging cylinders are all connected to the refrigeration system in a similar manner with a set of manifold gauges.

Figure 7-73 Pressure Gauges and Suction Line

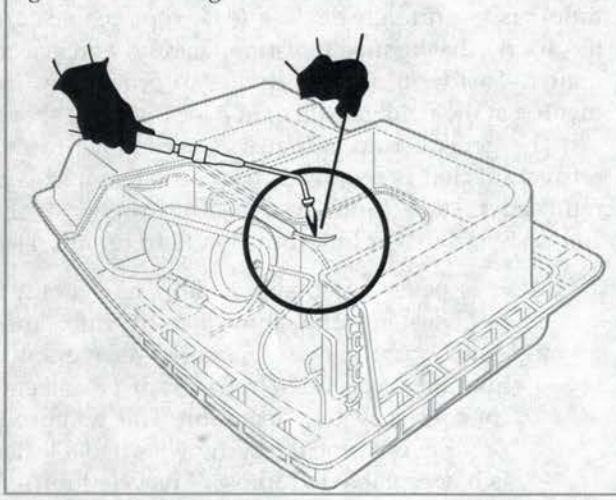


7-6.5.2.5 Oxygen/Acetylene Torches

This is the best choice. They operate at close to 5000°F (2760°C). See *"Acetylene Torches (Turbo Torches)" on page 7-91*.

Next, weld the process tube in place as shown in *Figure 7-74*. We recommend using a brazing material that melts between 950°F (510°C) and 1450°F (787.8°C) and contains a minimum of 2 percent silver and 5 to 10 percent phosphorous. This type of brazing material does not require the use of a flux to join copper to copper. If using the weld-on process valve, be sure the valve core is removed before any heat is applied. Connect the blue-colored low-pressure line of the gauges to the charging port on the low-side pressure tubing. Next, connect the red-colored high-pressure line of the gauges to the charging port on the high-side pressure tubing.

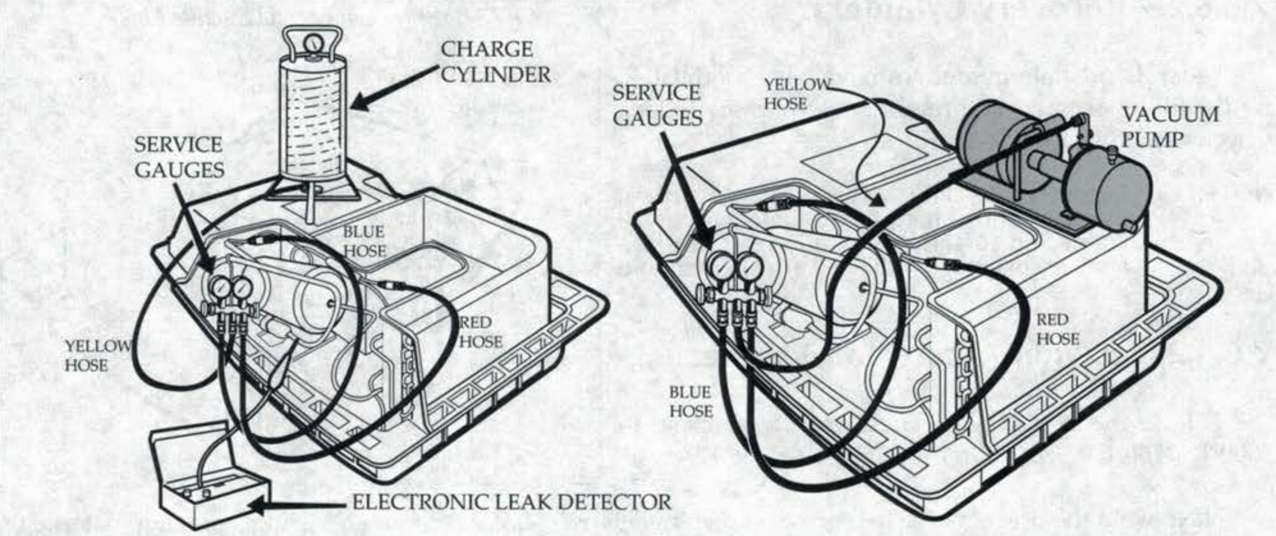
Figure 7-74 Welding Tube in Place



Next, connect the yellow-colored line of the gauges to the charging cylinder and add two or more ounces of R22 refrigerant, as shown in *Figure 7-75*, to the sealed system and check all weld joints for leaks. Allow the refrigerant to stay in the system for at least 10 minutes. If a leak is detected, drain the system and repair the leak before proceeding. Once the system is sealed, drain any refrigerant from the system and connect the yellow common line of the gauges to the recovery unit. Open the pressure relief valve on the vacuum pump. Once all refrigerant is removed, connect to the vacuum pump. Both the low- and high-side valves on the gauge set should be opened and the vacuum pump turned on. After 5 minutes, close the pressure relief valve on the vacuum pump. Check the blue gauge after running the vacuum pump for 10 minutes. A vacuum reading of zero to 10 in. would indicate a leak in the system or the hose connections. Check all hose connections for tightness. If the low-side gauge does not change, there is a leak in the sealed system. Locate the leak and correct it before proceeding. If the blue low-side gauge is well below 10 in.of vacuum, continue the evacuation for at least 40 to 45 minutes or until a dry system is obtained. We recommend using a micron gauge attached to your vacuum pump. (Follow instructions that come with the gauge.) Using a micron gauge is the only accurate way to ensure a proper evacuation.

At this time, there should be a good, deep evacuation, or dry atmosphere inside the sealed system. Close both the low- and high-side valves on the gauge set and turn off the vacuum pump. Monitoring the low-side gauge and seeing an increase or reduction in vacuum would indicate a leak in the system. Disconnect the yellow-colored hose at the vacuum pump and connect it to the bottom port or connection on the charging cylinder. Open the valve on the cylinder. For the correct amount of R22 refrigerant charge, check the data plate of the air conditioner being working on. To compensate for the red liquid line on the gauge set (approximately 30 to 36 in. (76 to 91.4 cm) long), add 1 oz to the data plate amount. A weighted charge can now be performed. The air conditioner charge is critical and must be exact for proper cooling.

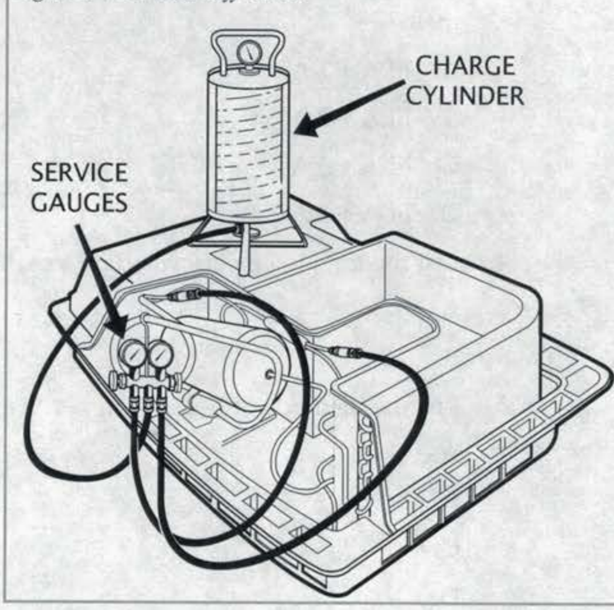
Figure 7-75 Charging Cylinder and Vacuum Pump



NOTE: Using a hand valve at the process tube attached directly to the air conditioner will eliminate the need to add 1 oz to the refrigerant charge. Fill the gauges with refrigerant all the way up to the valve, then zero the scale and weigh in the charge and close the valve.

Allow the refrigerant charge to equalize by waiting 10 minutes before starting the system. After 10 minutes, do a cooling performance test to determine whether the problem was in the amount of charge or within the components of the system. Now the blue low-side and the red high-side lines should be disconnected. **Make sure that the air conditioner connections are sealed before removing the lines.** The process tube can be pinched off in two places, as shown in *Figure 7-76*: the charging port cutoff and the end of the tube brazed for a hermetically sealed (air-tight) system.

Figure 7-76 Pinch-Off Tubes



7-6.5.3 Sealed System Problems

One mechanical problem one may encounter is refrigerant flow restriction. There are two types of restrictions, high-side and low-side. The basics to use to determine a restriction are amp draw and pressure. To determine the approximate high-side pressure, add 32 to your ambient temperature. Find that temperature on in *Table 7-1 on page 7-13*. The pressure listed to the right of the temperature should be your correct high-side pressure, ±7 psig. For the approximate low-side pressure, divide the high-side pressure by four. This will be the low-side pressure, ±3 psig.

High-side restriction will cause higher than normal amp draw and slightly higher than normal low-side pressures.

Low-side restriction will cause lower than normal amp draw—drastically lower than normal low-side pressures draw. A restriction that would not follow these basic conditions is a liquid line restriction, which is in the high side of the air conditioner. It will give the same results as a low-side air conditioner restriction. A total blockage in the refrigeration system will cause the suction pressure to pull into a deep vacuum and result in a very low amperage draw.

The most common restriction is the capillary tube or tubes and/or at the filter-drier. If there is a restriction in the liquid line, there will be a temperature drop from one side of the restriction to the other side.

In the case of a capillary tube restriction, one tube would be normal (warm to the touch), and the restricted tube would be cool or cold to the touch and could even sweat if operated long enough.

A restriction in the filter-drier would cause a temperature drop at the point of the restriction. A buildup of frost or sweat could be evident if operated long enough. Refrigerant leaks can occur from an improper weld, a broken line, or other damage. Compressor oil will often be noticeable at the location of major leaks.

Replace any parts that are found to be defective. Whenever a component is replaced in the sealed system, or the system has been opened to the atmosphere, a new filter-drier (if one exists) must be installed, and an evacuation is required.

NOTE: Refrigerant flow restrictions are very rare especially on new, never-serviced equipment.

7-6 Review

1. FLA means ________________.
2. RLA means ________________.
3. Outside temperature is 110°F (43.3°C) in Phoenix, AZ. What is the correct compressor amp adjustment?

   A. FLA + 1 A

   B. FLA + 2 A

   C. FLA + 3 A

   D. FLA + 4 A
4. List the tests to be performed on a sealed system air conditioner.

   A.

   B.
5. List the methods of leak testing.

   A.

   B.

   C.

   D.

   E.
6. Use copper tubing when performing refrigeration repair.

   True False
7. Exposing refrigerant to extreme heat will cause the refrigerant to give off poisonous gasses (phosgene gas), which may cause severe health problems or even death.

   True False
8. If refrigerants contact glowing metal or open flame, the refrigerant will chemically break down into acids.

   True False
9. Technicians must be EPA certified to enter the sealed system of an air conditioner.

   True False
10. Which of the following are safety considerations when using fluorocarbon refrigerants?

    A. Good ventilation must be provided in areas where high concentrations of the heavy vapors might accumulate and exclude oxygen.

    B. Exposure to levels of fluorocarbons above the recommended exposure levels can result in loss of concentration and cause drowsiness.

    C. Exposure to levels of fluorocarbons above the recommended exposure levels can result in fatal cardiac arrhythmia.

    D. Contact with the skin can cause frostbite.

    E. Contact with the eyes can cause irritation.

    F. Hydrochloric acid can be formed if high temperatures are present.

    G. Phosgene gas can be formed if refrigerant is exposed to extreme heat.

11. The process of removing water through vaporization and the subsequent removal of the vapor by means of deep vacuum is called:

    A. Brazing

    B. Condensation

    C. Dehydration

    D. Sweating

12. The use of a micron gauge is the only accurate way to ensure ________________

    A. Proper refrigerant evacuation

    B. Saddle valves are tight

    C. Refrigerant pressure is correct

    D. Identification of type of refrigerant

13. The two types of refrigerant flow restrictions are left-side and right-side.

    True False

14. If the capillary tube has refrigerant flow restriction, one tube would be normal, and the restricted tube would be ________________.

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Chapter
7-7 Air Conditioner Installation

· Mount and seal the unit per specifications.

7-7.1 Installation

The installation must be according to manufacturer's instructions for the specific model. Some generic items will be discussed in this chapter. The air conditioner must not be installed in a valley on the roof; water may pool around the drain holes and be drawn into the air conditioner. Make sure the air conditioner is tightened to the specifications (approximately half the thickness of the gasket). Overtightening can cause the unit to leak. Use caution not to damage the mounting gasket when placing the air conditioner over the opening, as this can allow water to leak into the coach. The air conditioner may be installed across a roof seam, but make sure this area is properly sealed to prevent leakage.

7-7.1.1 Roof Strength and Preparation

7-7.1.1.1 Checking Roof Strength

Before installing or replacing a rooftop air conditioner, ensure the roof structure is capable of supporting the weight of the air conditioner. If necessary, contact the recreation vehicle manufacturer for roof load capabilities. Be aware there are two load considerations: static load and load while vehicle is in motion.

Preparing Roof for Installation

The air conditioner should be installed in a relatively flat and level section measured with the RV parked on a level surface. Check for obstructions in the area where the air conditioner will be installed. Ensure that the surface where the gasket mates with the roof is free of debris and other extraneous materials.

7-7.1.2 Electrical Requirements

7-7.1.2.1 Proper Wire Sizes for Air Conditioner

The conductor used must be sized as required by the air conditioner installation instructions. Supply wiring must be of copper conductor only. AWG 12 is usually required. Consult the individual air conditioner installation instructions. Long wire runs could require 10 ga wire or larger.

7-7.1.2.2 Dedicated Circuit Breaker

The power supply must be on a separate time-delay fuse or a heating, air conditioning, and refrigeration (HACR) circuit breaker.

7-7.1.3 Airflow

7-7.1.3.1 Discharge Ducts

All discharge air ducts must be properly insulated to prevent condensation from forming on their surfaces or adjacent surfaces during operation of the air conditioner or heat pump. Ducts and their joints must be sealed to prevent condensation from forming on adjacent surfaces during the operation of the air conditioner. A sample air conditioner ducting system is shown in *Figure 7-77*.

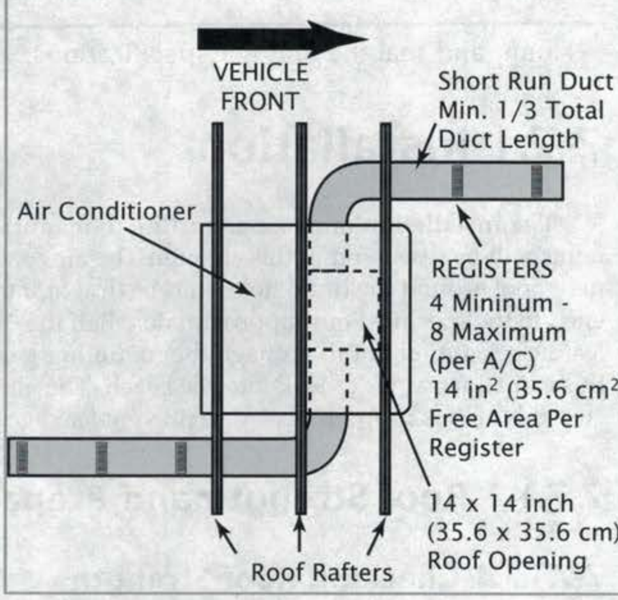


Figure 7-77 Sample Roof-Mounted Air Conditioner with Ducted Outlets

7-7.1.3.2 Separation of Return/Discharge Air

It is imperative to completely separate and seal the return and supply (discharge) air from each other, as shown in *Figure 7-78*. For specific details, refer to manufacturer's installation instructions. Recirculation of the supply (discharge) air can cause inefficiency and frost buildup (see *"Frost Buildup" on page 7-104*).

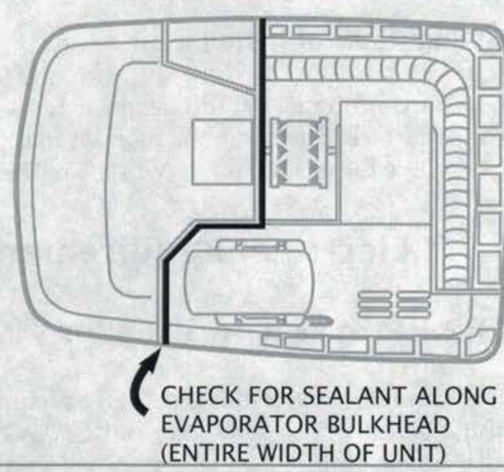


Figure 7-78 Separation of Return/Discharge Air

7-7.1.4 Heat Strips

7-7.1.4.1 Heating Element Installation

Many air conditioning units are equipped with heat strips: grids of electrical wiring connected to a thermostat temperature control system within the air conditioner. When the heat is turned on, the fan in the air conditioner circulates air, and the heat grids heat the incoming air before returning it to the RV interior.

7-7.1.4.2 Electrical Connections

Heat strips require 120 VAC power to operate.

7-7.1.5 Air Conditioner Maintenance

7-7.1.5.1 Return Air Filter Functions

Cleaning Requirements

Dirty intake filters will reduce airflow, so periodic cleaning or replacement of the filters is necessary, as shown in *Figure 7-79*. Dirty intake filters can also cause frost buildup. See *"Frost Buildup" on page 7-104*.

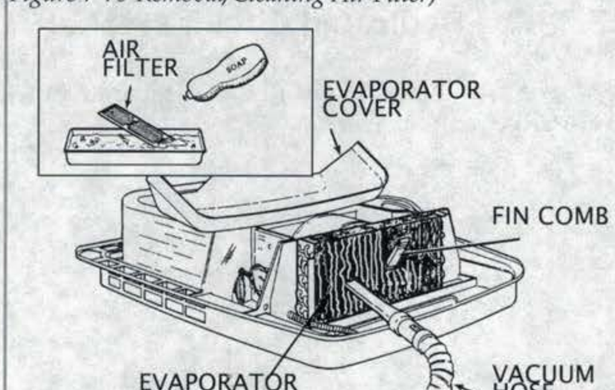


Figure 7-79 Removal/Cleaning Air Filter)

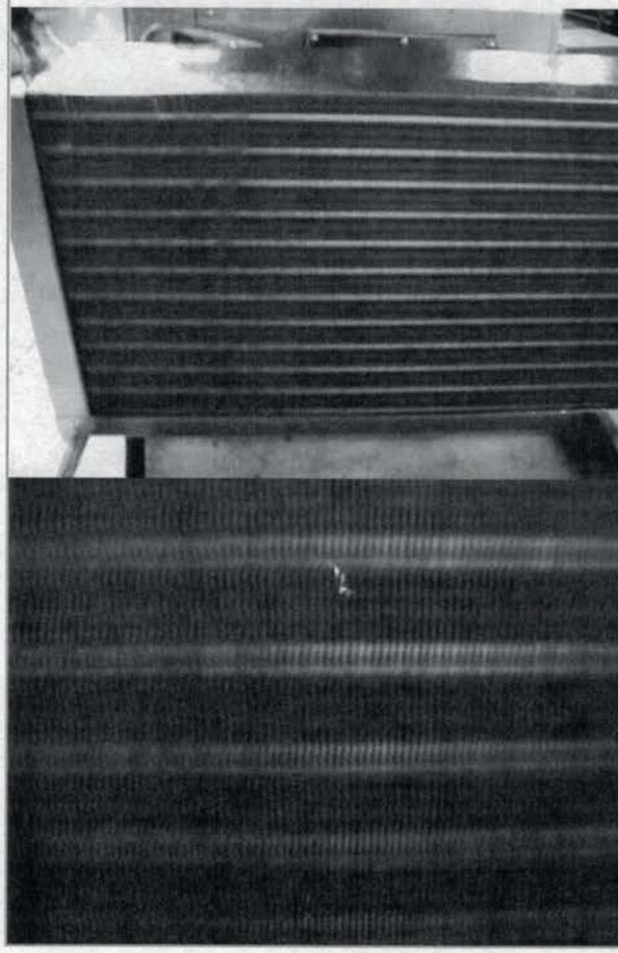
7-7.1.5.2 Inspection of Coils

Make sure the condenser and evaporator coils are clean and unclogged, as shown in *Figure 7-80*. If not, the unit cannot cool to its full potential, so it will try to run all the time to make up for the inefficiency. Remove the exterior cover shroud, then vacuum or blow out the coils to remove dirt.

7-7.1.5.3 Possible Fan Motor Maintenance

Many fan motors have a small oil cap on top of the motor. Remove the plastic plug from the cup and place three or four drops of an SAE 20-weight, nondetergent oil in the cup once a year. Do not overoil.

Figure 7-80 Straight Coil Fins



7-7 Review

1. The primary source of information on how to install an air conditioner is the ________________.

   A. Service manager

   B. Parts manager

   C. Manufacturer

   D. Distributor

2. The power supply for an air conditioner must be on a separate ________________ fuse or ________________ circuit breaker.

3. Consult individual air conditioner installation instructions for AWG size, but the conductor can only be ________________.

4. Without proper ________________, air ducts will form condensation on their surfaces or adjacent surfaces.

5. If an air conditioner runs constantly, it is usually a sign that the unit cannot ________________.

Chapter
7-8 Troubleshooting

- Measure operations of air conditioner circuits.
- Measure operations of air conditioner components.
- Diagnose air conditioner electrical systems.
- Repair air conditioner electrical connections and circuits.
- Replace faulty air conditioner components and wiring.
- Diagnose and repair a compression refrigeration system.
- Follow troubleshooting procedures.

7-8.1 Water Leaks

The following are possible causes of water leaks at or near the air conditioning unit:

- Gasket collapsed
- Mounting bolts worked loose
- Evaporator drain holes plugged
- Roof gasket not covering old vent mounting holes

Water dripping from around a ceiling register on a ducted system is an indication of a faulty seal between the air conditioner unit and roof.

7-8.2 Air Leaks

The following are possible causes of air leaks:

- Supply (discharge) ducts

  A problem often overlooked is inefficient cooling because outside air is being drawn into the evaporator housing due to poor installation. Check the roof and air-box seal, the return-air seal, and supply (discharge) seal. If necessary, reseal the unit completely, using high-quality metal tape, or strip caulking and metal tape. Never use duct tape; it will deteriorate over time and fail to hold, and is; therefore, a poor repair.

  Additional problems could also include improper installation of ducts and louvres, allowing airflow into the ceiling.

- Return/supply (discharge) ducts mixing
- Condenser air leaks
- Evaporator air leaks

7-8.3 Restricted Ducting

The following are possible types of restricted ducting:

- Collapsed ductwork
- Restricted duct entry
- Duct separation

- Improperly installed supply (discharge) louvres (extend too far into ducting)

7-8.4 Frost Buildup

The following are possible causes of frost buildup:

- Improperly installed cold control
- Low refrigerant
- Plugged or restricted capillary tube
- Defective cold control
- Defective relay board
- Improper airflow
- Return/supply (discharge) air mixing—not separated

7-8.5 Sample Troubleshooter Guide

NOTE: Some diagnostic testing may be done on energized circuits. Electrical shock can occur if not tested properly. Testing to be done by a qualified service technician only.

Table 7-14 Troubleshooting Mechanically Controlled Air Conditioners

Problem	Possible Cause	Troubleshooting Actions
Nothing runs.	The power supply could be off.	Check for open circuit breaker or fuse at service panel.
		Check for incoming 120 VAC at hot line (black) and neutral (white) at power entrance to the unit using a voltmeter.
	Low voltage.	Check incoming 120 VAC using a voltmeter.
	Selector switch could be open.	Turn off all power. Disconnect all wires. Rotate the selector switch and check for continuity between the appropriate terminals.
Compressor will not run.	Selector switch may be open to thermostat.	Turn off all power. Disconnect all wires. Check selector switch continuity with an ohmmeter.
	Thermostat may be open.	Turn off all power. Disconnect all wires. Check thermostat continuity with an ohmmeter.
	Overload switch may be open.	Turn off all power. Disconnect all wires. Check overload switch continuity with an ohmmeter.

Table 7-14 Troubleshooting Mechanically Controlled Air Conditioners

Problem	Possible Cause	Troubleshooting Actions
	Compressor winding may be open.	Turn off all power. Disconnect all wires. Check compressor winding continuity with an ohmmeter.
Compressor hums.	Voltage could be low.	Check voltage between #1 on the overload switch and the "R" terminal of the compressor while it is not humming.
		Check voltage from "C" to "R" of the compressor while it is humming.
		Check power cord for proper size.
	Capacitor could be shorted.	Turn off all power. Discharge the capacitor. Remove the capacitor and relay box. Check capacitor for continuity with an ohmmeter.
	Capacitor could be open.	Turn off all power. Discharge the capacitor. Remove the capacitor and relay box. Check capacitor for continuity with an ohmmeter.
	Capacitor could be weak.	The power must be turned OFF, and capacitors must be discharged before making the test. Use an AC voltmeter (set to the highest scale) or a 15,000-3/4, 2 W resistor to bleed away any charge left in the capacitor.
		Remove the wires from the terminals and inspect the casing. If it is bulged, cracked, or split, the capacitor is defective.
		Use an analog voltmeter (dial or hand-reading indicator) to test the capacitor after it has been discharged. Set the ohmmeter to mid-range and check for resistance to the case.
		Any resistance to the case from the terminals indicates it is defective and needs to be replaced.
		Set the ohmmeter to the highest scale and read across the terminals on the capacitor. The ohmmeter should swing toward zero and slowly move back toward infinity. Reverse the leads and repeat the test. If the ohmmeter stays on infinity, it is open and needs to be replaced. If very little meter movement is noticed, switch the meter to a lower scale and repeat test.

Table 7-14 Troubleshooting Mechanically Controlled Air Conditioners

Problem	Possible Cause	Troubleshooting Actions
	Start relay contacts could be open.	Turn off all power. Check for continuity between terminals 1 and 2 using an ohmmeter.
	Compressor start windings could be open.	Turn off all power. Disconnect all wires. Check compressor start winding continuity with an ohmmeter for infinity.
Compressor trips circuit breaker or thermal current overload.	Compressor start windings could be shorted.	Turn off all power. Disconnect all wires. Check compressor start winding continuity with an ohmmeter for 0-3/4.
	Compressor start windings could be grounded.	Turn off all power. Disconnect all wires. Check between any terminal and the compressor housing for any reading other than infinity.
	Compressor could be mechanically stuck.	Use hermetic analyzer according to manufacturer instructions.
	Burnt or broken wire shorted to the compressor case or ground	Fix or replace wire.
	Compressor winding is shorted.	Turn off all power. Disconnect all wires. Check between any terminal and the compressor housing for any reading other than infinity.
	Compressor winding is grounded.	Turn off all power. Disconnect all wires. Check between any terminal and the compressor housing for any reading other than infinity.
	Compressor run capacitor is grounded.	The power must be turned OFF, and capacitors must be discharged before making the test. Use an AC voltmeter (set to the highest scale) or a 15,000-3/4, 2 W resistor to bleed away any charge left in the capacitor.
		Remove the wires from the terminals and inspect the casing. If it is bulged, cracked, or split, the capacitor is defective.
		Use an analog voltmeter (dial or hand-reading indicator) to test the capacitor after it has been discharged. Set the ohmmeter to mid-range and check for resistance to the case.

Table 7-14 Troubleshooting Mechanically Controlled Air Conditioners

Problem	Possible Cause	Troubleshooting Actions
		Any resistance to the case from the terminals indicates that it is defective and needs to be replaced.
		Set the ohmmeter to the highest scale and read across the terminals on the capacitor. The ohmmeter should swing toward zero and slowly move back toward infinity. Reverse the leads and repeat the test. If the ohmmeter stays on infinity, it is open and needs to be replaced. If very little meter movement is noticed, switch the meter to a lower scale and repeat test.
	Circuit breaker or thermal current overload is weak.	Fix or replace.
Compressor makes loud growling noise.	Inadequate voltage to start relay.	Check voltage between "C" and "R" terminals of the compressor.
	Start relay contacts welded shut.	The positive temperature coefficient resistor, or PTCR, has replaced the compressor start relay and the start capacitor on some models. It should be checked in two different ways:
		First check continuity. Turn the air conditioner circuit breaker to OFF. Disconnect the PTCR from the circuit. Check for continuity. If there is no continuity, replace PTCR.
		The second check to take is an amperage reading. Clamp an ammeter around the wire from the PTCR to the capacitor. Turn the air conditioner circuit breaker to ON and start the air conditioner. When the compressor starts, there will be an amperage reading for approximately one second or less. If there is no reading, or if there is a prolonged reading, the PTCR or start relay is faulty and must be replaced.
	Start relay coil is open.	Check compressor windings.
Fan will not run.	Selector switch could be open.	Turn off all power. Disconnect all wires. Check selector switch continuity with an ohmmeter
	Fan motor circuit could be open.	Check for continuity on wires to the motor.

Table 7-14 Troubleshooting Mechanically Controlled Air Conditioners

Problem	Possible Cause	Troubleshooting Actions
		Check that white wire is connected to "C" terminal.
		Check the connection between the red and black wire.
	Fan motor windings could be open.	To determine if a motor is good, test the windings with an ohmmeter. Disconnect the power supply and turn all the switches to the OFF position. Disconnect the motor leads (on some models disconnect the six- or nine-pin plug from the electrical box), depending on manufacturer of air conditioner.
		The motor should show continuity between all leads and the white wire. Infinity or no continuity indicates the winding is open and the motor is defective.
		Check for continuity between the motor frame and each lead. If a continuity reading is present to any lead, the motor is shorted and defective.
		The motor can be tested with an ammeter to determine if the operation is within the rating (±10 percent) listed on the model plate. Many times, the motor windings will check good, but bad bearings or a bad capacitor may be found in an ampere test.
	Fan capacitor may be shorted.	Turn off all power. Discharge the fan capacitor. Remove the capacitor and relay box. Check fan capacitor for continuity with an ohmmeter.
	Fan capacitor may be open.	Turn off all power. Discharge the fan capacitor. Remove the capacitor and relay box. Check fan capacitor for continuity with an ohmmeter.
	Fan capacitor may be weak.	The power must be turned OFF, and capacitors must be discharged before making the test. Use an AC voltmeter (set to the highest scale) or a 15,000-3/4, 2 W resistor to bleed away any charge left in the capacitor.
		Remove the wires from the terminals and inspect the casing. If it is bulged, cracked, or split, the capacitor is defective.

Table 7-14 Troubleshooting Mechanically Controlled Air Conditioners

Problem	Possible Cause	Troubleshooting Actions
		Use an analog voltmeter (dial or hand-reading indicator) to test the capacitor after it has been discharged. Set the ohmmeter to mid-range and check for resistance to the case.
		Any resistance to the case from the terminals indicates it is defective and needs to be replaced.
		Set the ohmmeter to the highest scale and read across the terminals on the capacitor. The ohmmeter should swing toward zero and slowly move back toward infinity. Reverse the leads and repeat the test. If the ohmmeter stays on infinity, it is open and needs to be replaced. If very little meter movement is noticed, switch the meter to a lower scale and repeat test.
No heat strip.	Limit switch could be open.	Check for continuity across the two terminals of the limit switch.
	Heating element could be open.	Turn off all power. Disconnect all wires. Check heating element continuity with an ohmmeter.
	Selector switch could be open.	Disconnect power from air conditioner. Remove wires from selector switch. Check for continuity between L1 and C terminal of the switch. Continuity should be read when in "cool" position.
	Thermostat could be open.	Turn off all power. Disconnect all wires. Check thermostat continuity with an ohmme-ter.
Compressor cycling on and off.	Compressor is cycling on the thermal current over-load.	Check for proper voltage between "C" and "R" terminals.
		Check to see if thermal current overload is open.
	Thermostat could be short cycling the compressor.	Check compressor calibration.
		Check to see if cold air is prematurely hitting the temperature probe.

Table 7-15 Troubleshooting Electronically Controlled Air Conditioners

Problem	Possible Cause	Troubleshooting Actions
Nothing runs.	12 VDC power is turned off.	**(Coleman)** Check 12 VDC. With switch on "Cooling–High Fan" check voltage between "Y" and "B" terminals and "GH" and "B" terminals on the PC board in the ceiling plenum.
		(Dometic – Analog and CCC) Check 12 VDC between red and black wire (12 VDC incoming) at the printed circuit board in the 14 × 14 opening.
	The 120 VAC power supply is turned off.	**(Coleman)** Check voltage between the hot line (black wire) and neutral (white wire) at the terminal lugs on the printed circuit board.
		Check voltage between #3 and #1 pin, and between #5 and #9 pin, on the high-voltage plug located on the PC board junction box.
		(Dometic – Analog and CCC) Check voltage between the hot line (black wire) and neutral (white wire) at the terminal lugs on the printed circuit board.
No cooling.	Thermostat could have an open.	**(Coleman)** Check for 12 VDC between "Y" and "B" at the terminal strip at the ceiling plenum.
		(Dometic – Analog) Use a jumper wire to test unit operation as follows:
		LOW FAN, jumper wire between GND and FAN. The unit should operate on low fan speed.
		HIGH FAN, jumper wire between GND, FAN, and HI FAN. The unit should operate on high fan speed.
		Furnace (if furnace connected to the blue/white wires on the analog control box), jumper wire between GND and FUR. The furnace should operate.
		LOW COOL, jumper wire between GND, FAN, and COOL. The compressor should operate with low fan speed.
		HIGH COOL, jumper wire between GND, FAN, HI FAN, and COOL. The compressor should operate with high fan speed.

Table 7-15 Troubleshooting Electronically Controlled Air Conditioners

Problem	Possible Cause	Troubleshooting Actions
		HEAT STRIP (if unit is so equipped), jumper between GND, FAN, and HS/HP. The heat strip should operate with the fan on low speed.
		HEAT PUMP (if unit so equipped), jumper between GND, FAN, HS/HP. The heat pump should operate on the low fan speed. If unit operates properly when terminals are jumped, the analog thermostat is defective.
		(Dometic—CCC) Perform a reset on the thermostat. Verify polarity and continuity of the four-strand RJ11 communication cable.
	The printed circuit board could have an open.	**(Coleman)** Check for 12 VDC between "Y" and "B" at the terminal strip in the ceiling plenum.
		Check for 120 VAC between the #3 and # 1 pins on the high-voltage plug located on the PC board junction box.
		Check for voltage by "jumping" across the two terminals for the thermistor on the printed circuit board.
		(Dometic—Analog and CCC) To verify circuits are being completed by the analog or CCC control box, first disconnect the six-pin plug connector from the analog or CCC control box.
		Using a 120 VAC incandescent bulb, check from terminal 5 (white-common) to the other terminals to determine if a particular circuit is completed through the analog control box. If the circuit is completed, the light will illuminate.
		Terminal 1 is a blue wire and the compressor circuit.
		Terminal 2 is a black wire and the high fan circuit.
		Terminal 3 is a yellow wire and not used.
		Terminal 4 is a red wire and the low fan circuit.

Table 7-15 Troubleshooting Electronically Controlled Air Conditioners

Problem	Possible Cause	Troubleshooting Actions
		Terminal 5 is a white wire and the common AC connection.
		Terminal 6 is green/yellow wire and chassis ground.
		Note: DO NOT use a voltmeter to do these checks, as it will give erroneous readings.
		If the circuit is completed and a component is not operating, the problem is in the rooftop unit.
	Malfunctioning compressor.	The compressor motor can be electrically checked. Be sure to disconnect all power and turn all switches to the OFF position before starting the tests.
		Remove the terminal cover from the compressor to the three leads connected to the terminals. Make note of the positions so the wires can be replaced correctly.
		Use an ohmmeter to check for continuity through the overload device. If no continuity is found and the compressor is hot, allow 15 to 20 minutes for the compressor to cool. If a repeat of the test shows the overload to be open, it is defective and requires replacement.
		Continuity should exist between all three terminals of the compressor.
		To determine if a motor is good, test the windings with an ohmmeter. Disconnect the power supply, and turn all the switches to the OFF position. Disconnect the motor leads (on some models disconnect the six-pin plug from the electrical box). The motor should show continuity between all leads and the white wire. Infinity or no continuity indicates the winding is open and the motor is defective.
		Check for continuity between the motor frame and each lead.
		If a continuity reading is present to any lead, the motor is shorted and defective.

Table 7-15 Troubleshooting Electronically Controlled Air Conditioners

Problem	Possible Cause	Troubleshooting Actions
		The motor can be tested with an ammeter to determine if the operation is within the rating (±10 percent) listed on the model plate. Many times, the motor windings will check good, but bad bearings or a bad capacitor may be found in an ampere test.
	Malfunctioning run capacitor.	The power must be turned OFF, and capacitors must be discharged before making the test. Use an AC voltmeter (set to the highest scale) or a 15,000-3/4, 2 W resistor to bleed away any charge left in the capacitor.
		Remove the wires from the terminals and inspect the casing. If it is bulged, cracked, or split, the capacitor is defective.
		Use an analog voltmeter (dial or hand-reading indicator) to test the capacitor after it has been discharged. Set the ohmmeter to mid-range and check for resistance to the case.
		Any resistance to the case from the terminals indicates it is defective and needs to be replaced.
		Set the ohmmeter to the highest scale and read across the terminals on the capacitor. The ohmmeter should swing toward zero and slowly move back toward infinity. Reverse the leads and repeat the test. If the ohmmeter stays on infinity, it is open and needs to be replaced. If very little meter movement is noticed, switch the meter to a lower scale and repeat test.
	Malfunctioning start relay.	The positive temperature coefficient resistor, or PTCR, has replaced the compressor start relay and the start capacitor on some models. It should be checked in two different ways:
		First check continuity. Turn the air conditioner circuit breaker to OFF. Disconnect the PTCR from the circuit. Check for continuity. If there is no continuity, replace PTCR.

Table 7-15 Troubleshooting Electronically Controlled Air Conditioners

Problem	Possible Cause	Troubleshooting Actions
		The second check to take is an amperage reading. Clamp an ammeter around the wire from the PTCR to the capacitor. Turn the air conditioner circuit breaker to ON and start the air conditioner. When the compressor starts, there will be an amperage reading for approximately one second or less. If there is no reading, or if there is a prolonged reading, the PTCR or start relay is faulty and must be replaced.
Compressor runs constantly with no fan operation.	Relay may be welded shut.	**(Coleman)** Disconnect the wire at the 'Y' terminal on the PC board junction box.
		(Dometic – Analog) Remove thermostat wires from the green ground and yellow compressor wires.
		(Dometic – CCC) Unplug four-strand RJ11 communication from CCC box.
		Check all wires and connections.
		Check for bad grounds.
		Check for low voltage to the PC board.
	Malfunctioning thermostat.	**(Coleman)** Disconnect the wire at the 'Y' terminal on the PC board junction box.
		(Dometic – Analog) LOW COOL, jumper wire between GND, FAN, and COOL. The compressor should operate and low fan speed.
		HIGH COOL, jumper wire between GND, FAN, HI FAN, and COOL. The compressor should operate and high fan speed.
		(Dometic – CCC) Perform a reset on the thermostat. Verify Polarity and continuity of the four-strand RJ11 communication cable.
No high speed fan operation.	Malfunctioning thermostat.	**(Coleman)** Select "High Fan" speed on the thermostat. Check for 12 VDC between the green and blue wires on the high-speed relay in the ceiling assembly.
		(Dometic – Analog) Use a jumper wire to test unit operation as follows:

Table 7-15 Troubleshooting Electronically Controlled Air Conditioners

Problem	Possible Cause	Troubleshooting Actions
		LOW FAN, jumper wire between GND and FAN. The unit should operate on low fan speed.
		HIGH FAN, jumper wire between GND, FAN, and HI FAN. The unit should operate on high fan speed.
		(Dometic—CCC) Perform a reset on the thermostat. Verify Polarity and continuity of the four-strand RJ11 communication cable.
	Malfunctioning relay.	**(Coleman)** Select "High Fan" speed on the thermostat. Check for 12 VDC between the green and blue wires on the high-speed relay in the ceiling assembly.
		Check for 120 VAC between pins #9 and #5 at the 120 VAC high-voltage plug located on the relay junction box.
		(Dometic—Analog and CCC) To verify circuits are being completed by the analog or CCC control box, first disconnect the six-pin plug connector from the analog or CCC control box.
		Using a 120 VAC incandescent bulb, check from terminal 5 (white-common) to the other terminals to determine if a particular circuit is completed through the analog control box. If the circuit is completed, the light will illuminate.
		Terminal 2 is a black wire and the high fan circuit.
		Terminal 3 is a yellow wire and not used.
		Terminal 4 is a red wire and the low fan circuit.
No cooling. Fan runs and then shuts off.	12 VDC to thermostat mis-wired.	**(Coleman)** Select "Auto/Cool/Low" fan position on the thermostat. Check for 12 VDC at the "GH" and "B" and "GL" and "B" terminals at the same time.
		(Dometic—Analog) Use a jumper wire to test unit operation as follows:

Table 7-15 Troubleshooting Electronically Controlled Air Conditioners

Problem	Possible Cause	Troubleshooting Actions
		LOW FAN, jumper wire between GND and FAN. The unit should operate on low fan speed.
		HIGH FAN, jumper wire between GND, FAN, and HI FAN. The unit should operate on high fan speed.
		LOW COOL, jumper wire between GND, FAN, and COOL. The compressor should operate and low fan speed.
		HIGH COOL, jumper wire between GND, FAN, HI FAN, and COOL. The compressor should operate and high fan speed.
		(Dometic – CCC) Perform a reset on the thermostat. Verify polarity and continuity of the four-strand RJ11 communication cable.
	120 VAC miswired to thermostat.	Check all wires and connections.
		Check for correct polarity using a multimeter or polarity checker.
Air conditioner is turned on but is not operating.	Lack of power.	Check incoming voltage to the air conditioner using a multimeter.
	Improper wiring.	Check all wires and connections.
		Check for proper polarity using a multimeter or polarity checker.
	Malfunctioning main board.	**(Coleman) 120 VAC Controlled** Disconnect all power to the air conditioner. Remove the fan speed wires and the compressor wire from the main board. Set the control board to "COOL" and "HIGH FAN" positions. Connect power to the air conditioner. Verify lights are on at the control board. If no lights are on, remove control board and attach directly into the main board ribbon cable. If lights do not come on, replace the main board.
		Verify functioning of all board settings using a multimeter or 120 VAC test light.

Table 7-15 Troubleshooting Electronically Controlled Air Conditioners

Problem	Possible Cause	Troubleshooting Actions
		12 VDC Controlled Check and ensure the "OFF/ON" switch on the control board is "ON." Measure the voltage at the outside terminals (#1 and #10) on the cable between the main board and the control board. The operating range is 10 to 16 VDC. If voltage is not within this range, correct the DC voltage supply.
		Verify functioning of all board settings using a multimeter or 12 VDC test light.
		(Dometic – Analog and CCC) To verify circuits are being completed by the analog or CCC control box, first disconnect the six-pin plug connector from the analog or CCC control box.
		Using a 120 VAC incandescent bulb, check from terminal 5 (white-common) to the other terminals to determine if a particular circuit is completed through the analog control box. If the circuit is completed, the light will illuminate.
		Terminal 1 is a blue wire and the compressor circuit.
		Terminal 2 is a black wire and the high fan circuit.
		Terminal 3 is a yellow wire and not used.
		Terminal 4 is a red wire and the low fan circuit.
		Terminal 5 is a white wire and the common AC connection.
		Terminal 6 is green/yellow wire and chassis ground.
		Note: DO NOT use a voltmeter to do these checks, as it will give erroneous readings.
		If the circuit is completed and a component is not operating, the problem is in the rooftop unit.
	Malfunctioning control board.	**(Coleman) 120 VAC Controlled** Turn power switch "ON." "FAN" and "MODE" LEDs should illuminate.

Table 7-15 Troubleshooting Electronically Controlled Air Conditioners

Problem	Possible Cause	Troubleshooting Actions
		Move the fan switch through all the positions. The LED lights should illuminate.
		Move "MODE" switch to all positions. The LED for each position should illuminate. If so, the control board is good.
		If LED does not illuminate at any position, check wire connections and correct condition as necessary.
		12 VDC Controlled Ensure the "MODE" switch is at the AIR CONDITIONER position. Air conditioner LEDs will not illuminate if switch is at the GAS HEAT position.
		Check polarity at the control board. Red wire attached to the positive and black wire attached to the negative.
		Check 12 VDC between the red and black wires using a multimeter. The 12 VDC range is 10 to 16 VDC.
		If voltage is within the acceptable range, check 12 VDC between #1 and #10 on the ribbon cable.
		Voltage should be the same at both locations. If no voltage is measured, replace the control board.
		If voltage is not within acceptable range, check wiring connections and correct as necessary.
		(Dometic—Analog) Use a jumper wire to test unit operation as follows:
		LOW FAN, jumper wire between GND and FAN. The unit should operate on low fan speed.
		HIGH FAN, jumper wire between GND, FAN, and HI FAN. The unit should operate on high fan speed.
		Furnace (if furnace connected to the blue/white wires on the analog control box), jumper wire between GND and FUR. The furnace should operate.

Table 7-15 Troubleshooting Electronically Controlled Air Conditioners

Problem	Possible Cause	Troubleshooting Actions
		LOW COOL, jumper wire between GND, FAN, and COOL. The compressor should operate and low fan speed.
		HIGH COOL, jumper wire between GND, FAN, HI FAN, and COOL. The compressor should operate and high fan speed.
		HEAT STRIP (if unit is so equipped), jumper between GND, FAN, and HS/HP. The heat strip should operate and the fan on low speed.
		HEAT PUMP (if unit so equipped), jumper between GND, FAN, HS/HP. The heat pump should operate on the low fan speed. If unit operates properly when terminals are jumped, the analog thermostat is defective.
		(Dometic – CCC) Perform a reset on the thermostat. Verify polarity and continuity of the four-strand RJ11 communication cable.
Air conditioner is turned on. Fan runs but compressor does not operate.	Improper wiring.	Refer to proper wiring diagram to verify unit is properly wired.
	Malfunctioning compressor.	The compressor motor can be electrically checked. Be sure to disconnect all power and turn all switches to the "OFF" position before starting the tests.
		Remove the terminal cover from the compressor to the three leads connected to the terminals. Make note of the positions so the wires can be replaced correctly.
		Use an ohmmeter to check for continuity through the overload device. If no continuity is found and the compressor is hot, allow 15 to 20 minutes for the compressor to cool. If a repeat of the test shows the overload to be open, it is defective and requires replacement.
		Continuity should exist between all three terminals of the compressor. To determine if a motor is good, test the windings with an ohmmeter. Disconnect the power supply and turn all the switches to the "OFF" position.

Table 7-15 Troubleshooting Electronically Controlled Air Conditioners

Problem	Possible Cause	Troubleshooting Actions
		Disconnect the motor leads (on some models disconnect the six-pin plug from the electrical box). The motor should show continuity between all leads and the white wire. Infinity or no continuity indicates the winding is open and the motor is defective.
		Check for continuity between the motor frame and each lead.
		If a continuity reading is present to any lead, the motor is shorted and defective.
		The motor can be tested with an ammeter to determine if the operation is within the rating (±10 percent) listed on the model plate. Many times, the motor windings will check good, but bad bearings or a bad capacitor may be found in an ampere test.
	Malfunctioning cold control.	Remove wires and check resistance.
	Malfunctioning main board.	**(Coleman) 120 VAC Controlled** Disconnect all power to the air conditioner. Remove the fan speed wires and the compressor wire from the main board. Set the control board to "COOL" and "HIGH FAN" positions. Connect power to the air conditioner. Verify lights are on at the control board. If no lights are on, remove control board and attach directly into the main board ribbon cable. If lights do not come on, replace the main board.
		Verify functioning of all board settings using a multimeter or 120 VAC test light.
		12 VDC Controlled Check and ensure the "OFF/ON" switch on the control board is "ON." Measure the voltage at the outside terminals (#1 and #10) on the cable between the main board and the control board. The operating range is 10 to 16 VDC. If voltage is not within this range, correct the DC voltage supply.
		Verify functioning of all board settings using a multimeter or 12 VDC test light.

Table 7-15 Troubleshooting Electronically Controlled Air Conditioners

Problem	Possible Cause	Troubleshooting Actions
		(Dometic – Analog and CCC) To verify circuits are being completed by the analog or CCC control box, first disconnect the six-pin plug connector from the analog or CCC control box.
		Using a 120 VAC incandescent bulb, check from terminal 5 (white-common) to the other terminals to determine if a particular circuit is completed through the analog control box. If the circuit is completed, the light will illuminate.
		Terminal 1 is a blue wire and the compressor circuit.
		Terminal 2 is a black wire and the high fan circuit.
		Terminal 3 is a yellow wire and not used.
		Terminal 4 is a red wire and the low fan circuit.
		Terminal 5 is a white wire and the common AC connection.
		Terminal 6 is green/yellow wire and chassis ground.
		Note: DO NOT use a voltmeter to do these checks, as it will give erroneous readings.
		If the circuit is completed and a component is not operating, the problem is in the rooftop unit.
	Malfunctioning control board.	**(Coleman) 120 VAC Controlled** Turn power switch "ON." "FAN" and "MODE" LEDs should illuminate.
		Move the fan switch through all the positions. The LED lights should illuminate.
		Move "MODE" switch to all positions. The LED for each position should illuminate. If so, the control board is good.
		If LED does not illuminate at any position check wire connections and correct condition as necessary.

Table 7-15 Troubleshooting Electronically Controlled Air Conditioners

Problem	Possible Cause	Troubleshooting Actions
		12 VDC Controlled Ensure the "MODE" switch is at the AIR CONDITIONER position. Air conditioner LEDs will not illuminate if switch is at the GAS HEAT position.
		Check polarity at the control board. Red wire attached to the positive and black wire attached to the negative.
		Check 12 VDC between the red and black wires using a multimeter. The 12 VDC range is 10 to 16 VDC.
		If voltage is within the acceptable range, check 12 VDC between #1 and # 10 on the ribbon cable.
		Voltage should be the same at both locations. If no voltage is measured, replace the control board.
		If voltage is not within acceptable range, check wiring connections and correct as necessary.
		(Dometic – Analog) Use a jumper wire to test unit operation as follows:
		LOW FAN, jumper wire between GND and FAN. The unit should operate on low fan speed.
		HIGH FAN, jumper wire between GND, FAN, and HI FAN. The unit should operate on high fan speed.
		Furnace (if furnace connected to the blue/white wires on the analog control box), jumper wire between GND and FUR. The furnace should operate.
		LOW COOL, jumper wire between GND, FAN, and COOL. The compressor should operate and low fan speed.
		HIGH COOL, jumper wire between GND, FAN, HI FAN, and COOL. The compressor should operate and high fan speed.

Table 7-15 Troubleshooting Electronically Controlled Air Conditioners

Problem	Possible Cause	Troubleshooting Actions
		HEAT STRIP (if unit is so equipped), jumper between GND, FAN, and HS/HP. The heat strip should operate and the fan on low speed.
		HEAT PUMP (if unit so equipped), jumper between GND, FAN, HS/HP. The heat pump should operate on the low fan speed. If unit operates properly when terminals are jumped, the analog thermostat is defective.
		(Dometic—CCC) Perform a reset on the thermostat. Verify polarity and continuity of the four-strand RJ11 communication cable.
Air conditioner is turned on. Compressor runs but no fan operation.	Improper wiring.	Check all wires and connections.
		Check for proper polarity using a multimeter or polarity checker.
	Malfunctioning run capacitor.	The power must be turned OFF, and capacitors must be discharged before making the test. Use an AC voltmeter (set to the highest scale) or a 15,000-3/4, 2 W resistor to bleed away any charge left in the capacitor.
		Remove the wires from the terminals and inspect the casing. If it is bulged, cracked, or split, the capacitor is defective.
		Use an analog voltmeter (dial or hand-reading indicator) to test the capacitor after it has been discharged. Set the ohmmeter to mid-range and check for resistance to the case.
		Any resistance to the case from the terminals indicates it is defective and needs to be replaced.
		Set the ohmmeter to the highest scale and read across the terminals on the capacitor. The ohmmeter should swing toward zero and slowly move back toward infinity. Reverse the leads and repeat the test. If the ohmmeter stays on infinity, it is open and needs to be replaced. If very little meter movement is noticed, switch the meter to a lower scale and repeat test.

Table 7-15 Troubleshooting Electronically Controlled Air Conditioners

Problem	Possible Cause	Troubleshooting Actions
	Malfunctioning motor.	To determine if a motor is good, test the windings with an ohmmeter. Disconnect the power supply and turn all the switches to the OFF position. Disconnect the motor leads (on some models disconnect the six- or nine-pin plug from the electrical box), depending on manufacturer of air conditioner.
		The motor should show continuity between all leads and the white wire. Infinity or no continuity indicates the winding is open and the motor is defective.
		Check for continuity between the motor frame and each lead.
		If a continuity reading is present to any lead, the motor is shorted and defective.
		The motor can be tested with an ammeter to determine if the operation is within the rating (±10 percent) listed on the model plate. Many times, the motor windings will check good, but bad bearings or a bad capacitor may be found in an ampere test.
	Malfunctioning main board.	**(Coleman) 120 VAC Controlled** Disconnect all power to the air conditioner. Remove the fan speed wires and the compressor wire from the main board. Set the control board to "COOL" and "HIGH FAN" positions. Connect power to the air conditioner. Verify lights are on at the control board. If no lights are on, remove control board and attach directly into the main board ribbon cable. If lights do not come on, replace the main board.
		Verify functioning of all board settings using a multimeter or 120 VAC test light.
		12 VDC Controlled Check and ensure the "OFF/ON" switch on the control board is "ON." Measure the voltage at the outside terminals (#1 and #10) on the cable between the main board and the control board. The operating range is 10 to 16 VDC. If voltage is not within this range, correct the DC voltage supply.

Table 7-15 Troubleshooting Electronically Controlled Air Conditioners

Problem	Possible Cause	Troubleshooting Actions
		Verify functioning of all board settings using a multimeter or 12 VDC test light.
		(Dometic – Analog and CCC) To verify circuits are being completed by the analog or CCC control box, first disconnect the six-pin plug connector from the analog or CCC control box.
		Using a 120 VAC incandescent bulb, check from terminal 5 (white-common) to the other terminals to determine if a particular circuit is completed through the analog control box. If the circuit is completed, the light will illuminate.
		Terminal 1 is a blue wire and the compressor circuit.
		Terminal 2 is a black wire and the high fan circuit.
		Terminal 3 is a yellow wire and not used.
		Terminal 4 is a red wire and the low fan circuit.
		Terminal 5 is a white wire and the common AC connection.
		Terminal 6 is green/yellow wire and chassis ground.
		Note: DO NOT use a voltmeter to do these checks, as it will give erroneous readings.
		If the circuit is completed and a component is not operating, the problem is in the rooftop unit.
	Malfunctioning control board.	**(Coleman) 120 VAC Controlled** Turn power switch "ON." "FAN" and "MODE" LEDs should illuminate.
		Move the fan switch through all the positions. The LED lights should illuminate.
		Move "MODE" switch to all positions. The LED for each position should illuminate. If so, the control board is good.

Table 7-15 Troubleshooting Electronically Controlled Air Conditioners

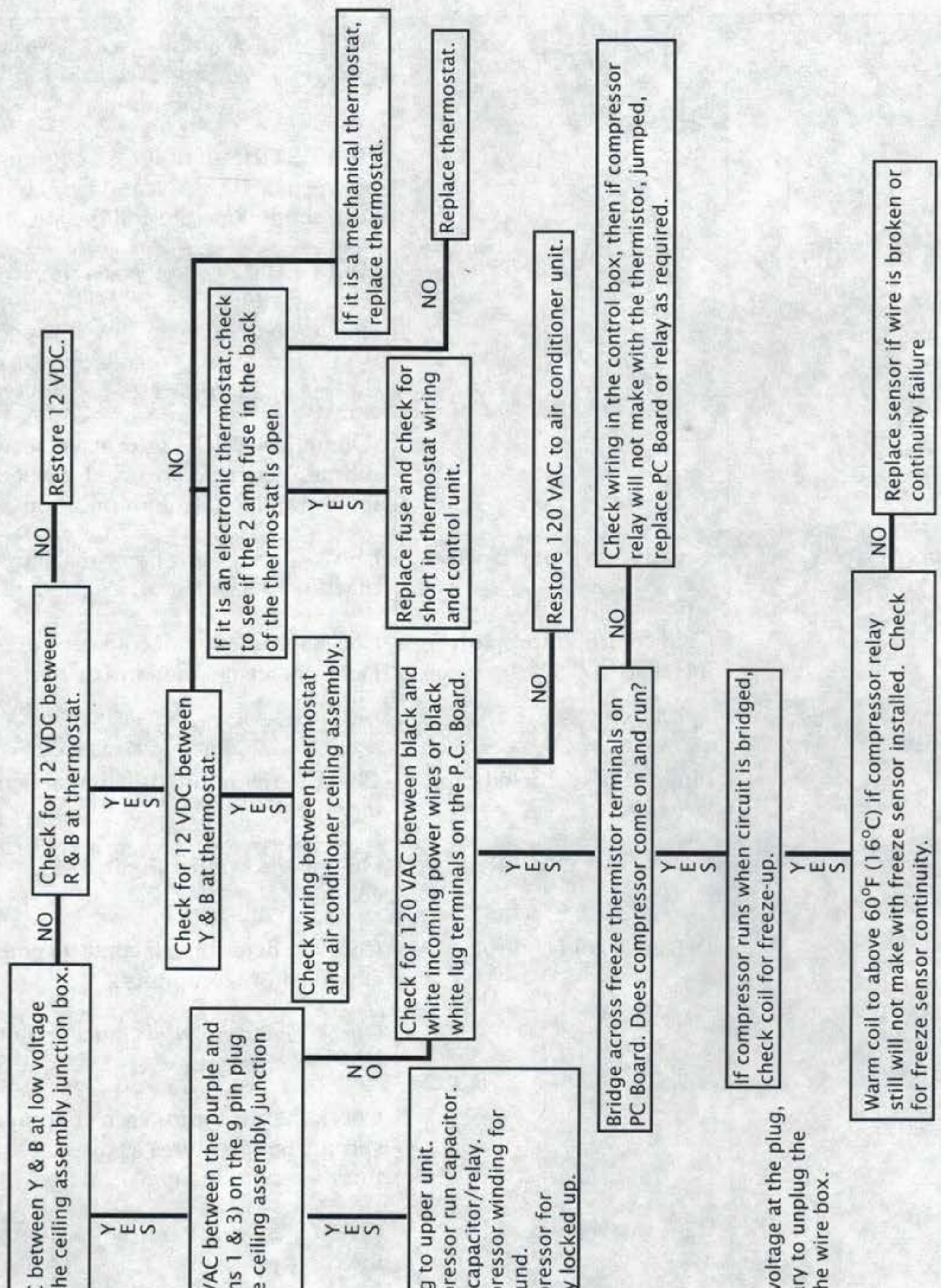
Problem	Possible Cause	Troubleshooting Actions
		If LED does not illuminate at any position, check wire connections and correct condition as necessary.
		12 VDC Controlled Ensure that the "MODE" switch is at the AIR CONDITIONER position. Air conditioner LEDs will not illuminate if switch is at the GAS HEAT position.
		Check polarity at the control board. Red wire attached to the positive and black wire attached to the negative.
		Check 12 VDC between the red and black wires using a multimeter. The 12 VDC range is 10 to 16 VDC.
		If voltage is within the acceptable range, check 12 VDC between #1 and # 10 on the ribbon cable.
		Voltage should be the same at both locations. If no voltage is measured, replace the control board.
		If voltage is not within acceptable range, check wiring connections and correct as necessary.
		(Dometic—Analog) Use a jumper wire to test unit operation as follows:
		LOW FAN, jumper wire between GND and FAN. The unit should operate on low fan speed.
		HIGH FAN, jumper wire between GND, FAN, and HI FAN. The unit should operate on high fan speed.
		Furnace (if furnace is connected to the blue/white wires on the analog control box), jumper wire between GND and FUR. The furnace should operate.
		LOW COOL, jumper wire between GND, FAN, and COOL. The compressor should operate and low fan speed.

Table 7-15 Troubleshooting Electronically Controlled Air Conditioners

Problem	Possible Cause	Troubleshooting Actions
		HIGH COOL, jumper wire between GND, FAN, HI FAN, and COOL. The compressor should operate and high fan speed.
		HEAT STRIP (if unit is so equipped), jumper between GND, FAN, and HS/HP. The heat strip should operate and the fan on low speed.
		HEAT PUMP (if unit so equipped), jumper between GND, FAN, HS/HP. The heat pump should operate on the low fan speed. If unit operates properly when terminals are jumped, the analog thermostat is defective.
		(Dometic – CCC) Perform a reset on the thermostat. Verify polarity and continuity of the four-strand RJ11 communication cable.
Air conditioner frosts up.	Unit installed improperly.	Check installation of air conditioner per manufacturer's installation instructions.
	Cold control improperly installed.	Check installation of cold control per manufacturer's installation instructions.
	Low refrigerant charge.	Check refrigerant charge.
	Plugged or restricted capillary tubes.	Check temperature differential between capillary tubes.
		On a single capillary unit, feel for cool versus cold.
	Defective cold control.	Check to determine if contacts points are closed (show continuity).
		Check to determine if contact points are open (show no continuity).
		Check thermistor for correct ohm readings at specific temperatures as directed in manufacturer's service manual.
	Defective relay board.	Check if the cold control has continuity while the compressor is on.
		With a thermistor-type cold sensor, check ohm readings versus temperature chart in the service manual.
	Improper airflow.	Check for proper air movement over and around the cold sensor.

7-8.6 Troubleshooting

Figure 7-81 No Compressor Operation TS Chart



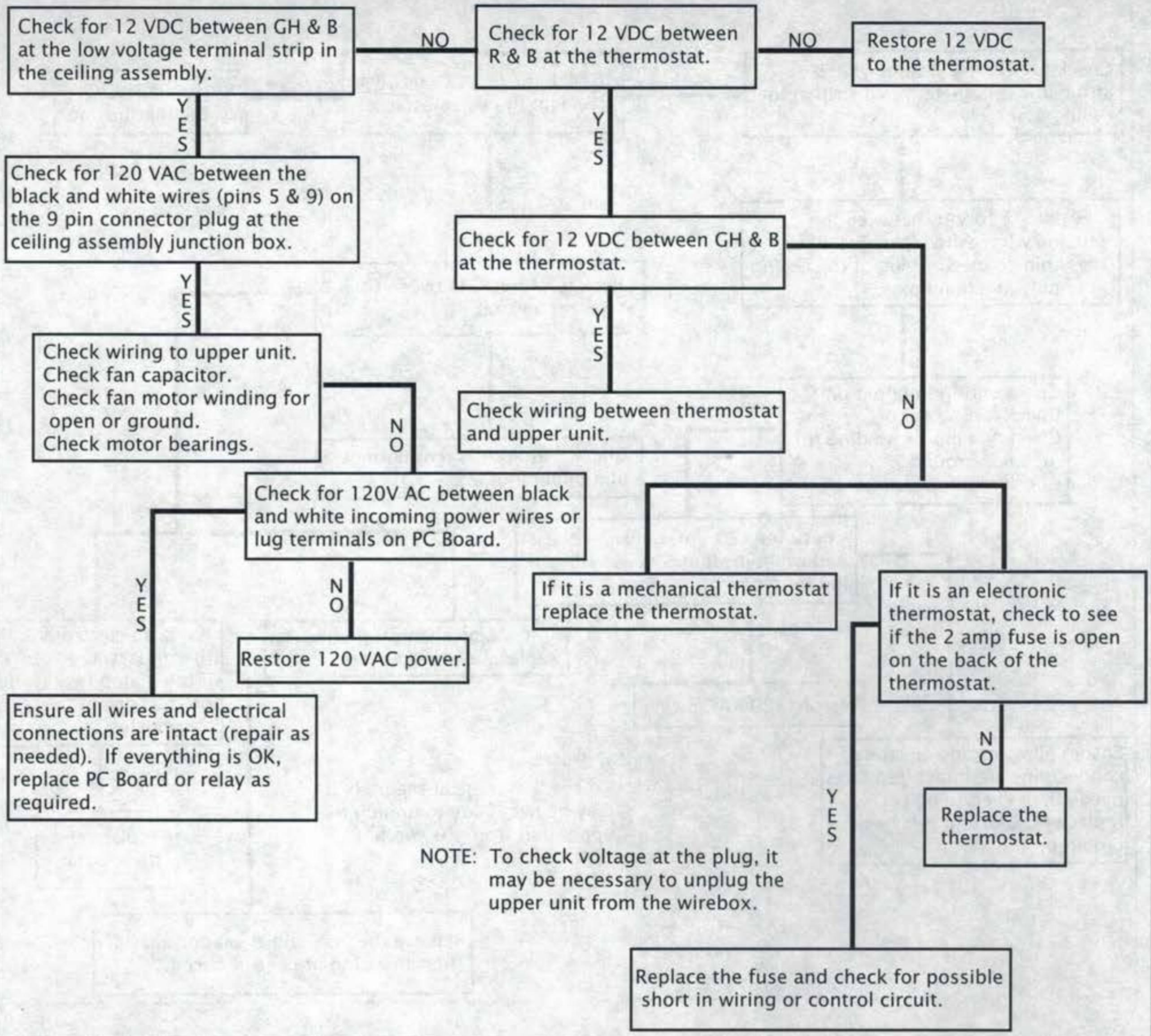


Figure 7-82 No High Fan Operation TS Chart

Figure 7-83 No Low-Fan Operation TS Chart

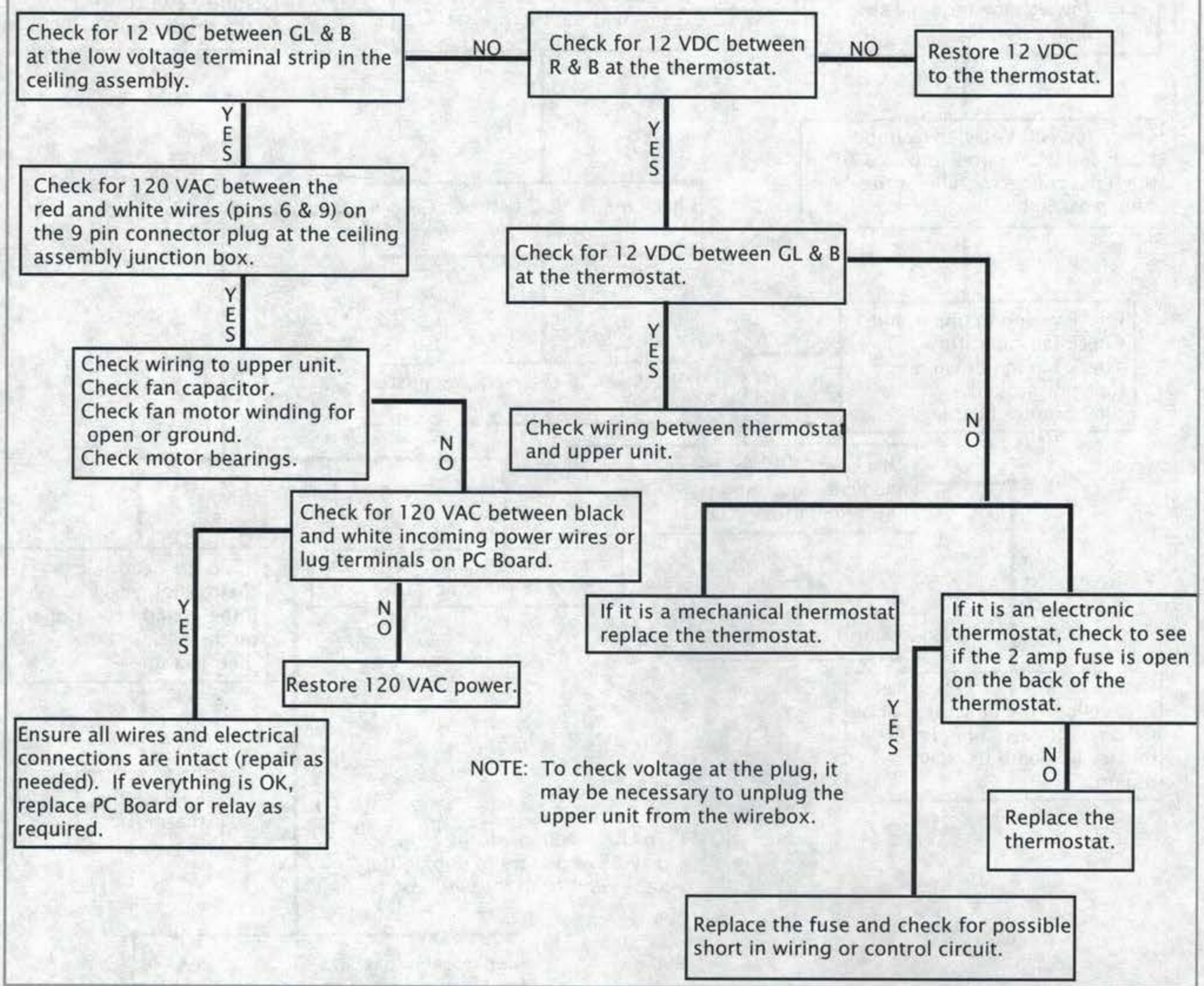
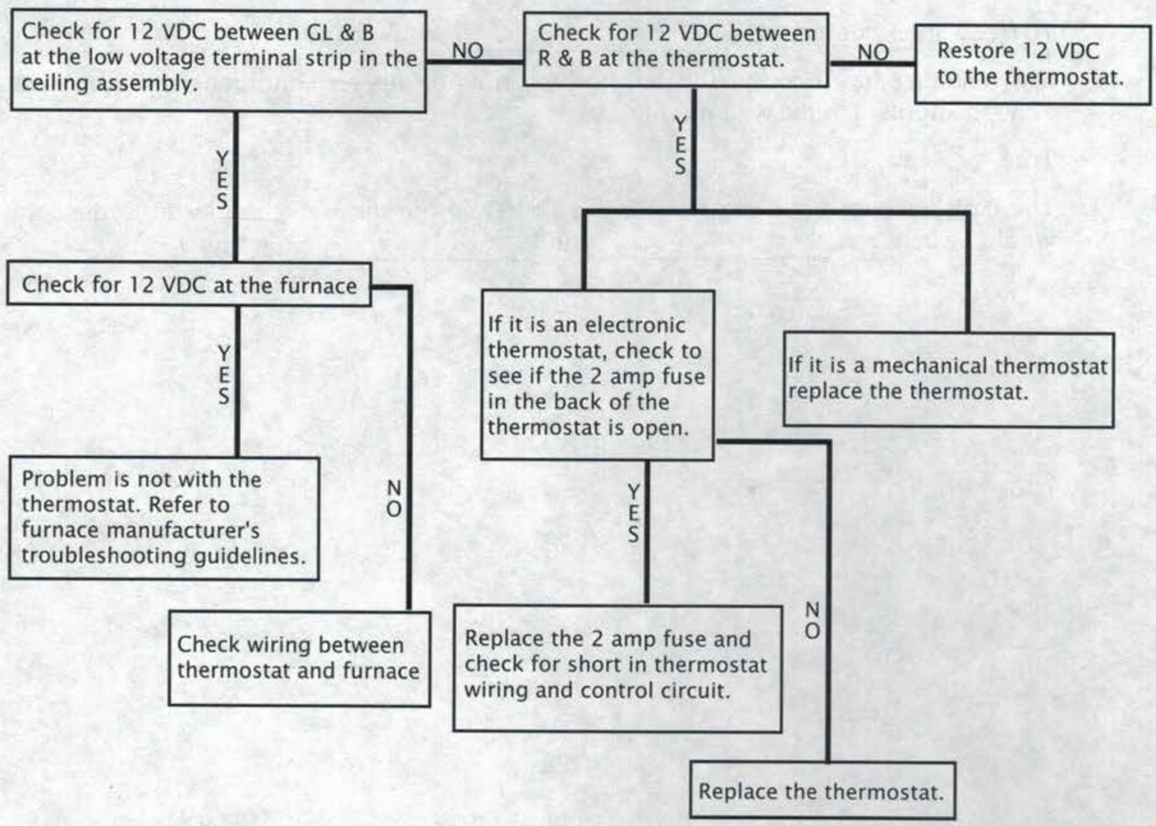


Figure 7-84 No Furnace Operation TS Chart



NOTE: Some furnace manufacturers use operation delays and special cycling features.

IMPORTANT NOTICE:
HEAT ANTICIPATORS (MECHANICAL THERMOSTATS)

1. The heat anticipator setting on the thermostat should match the furnace manufacturers load on the thermostat.

2. An anticipator setting of a greater number will result in longer furnace run times/fewer cycles per hour. Lower value settings will result in shorter furnace run times/more cycles per hour.

3. The heat anticipator setting is automatic and nonadjustable on all electronic thermostats.

7-8 Review

1. Duct tape is an excellent way to reseal an A/C roof unit.

   True False

2. To free a stuck compressor, a ________________ should be used.

3. If a customer has a complaint that nothing runs on his air conditioner, the problem could be no 12 VDC supplied to the wall thermostat.

   True False

4. The best place to see if one is receiving 12 VDC from the wall thermostat to the compressor relay would be between ________________ and ________________ terminals.

Chapter

7-9 Air Conditioner Codes and Standards

· Identify codes and standards.

7-9.1 Industry Codes and Standards

Industry codes and standards have been developed to ensure safety and to reduce liability. The major source of RV standards are the *NFPA 1192* and *CSA Z240*. These standards outline requirements for plumbing, heating (propane system), fire and life safety, and electrical.

The Recreation Vehicle Industry Association (RVIA) requires that member manufacturers agree to in-plant visits by the RVIA inspectors. If members refuse or fail to comply, they can be expelled and therefore lose the right to bear the association's seal of membership.

To help everyone better understand the requirements of the standard, an industry handbook is maintained by RVIA. Industry stakeholders work with RVIA to document the enforcement positions, which explains the standards in detail. Although standards are primarily designed for RV manufacturers, it is important from a liability standpoint that RV service technicians strive to follow these standards where possible when modifying, servicing, or installing RV systems or their components.

Agencies, state and private, involved with RV safety training use and follow the *NFPA* and *CSA Standards for Recreational Vehicles*. This NFPA standard is revised every three years, with dates being 2002, 2005, 2008, 2011, and so on. Industry always begins using the new edition of the NFPA requirements on or near May 1 of the revision year, and manufacturers must comply with requirements by September 1,of the new code edition year.

7-9.2 Code Summary

Table 7-16 is a summary of the current RV standard that pertains to the normal duties of the RV service technician. This summary is provided as a quick reference, NOT AS A SUBSTITUTE FOR THE ACTUAL STANDARD. Once the reference in these tables has been found, go to the referenced standard for the exact wording and use the handbook for the detailed explanation.

The *NFPA 1192 Standard for Recreational Vehicles*, RVIA's NFPA 1192 Handbook, *A Guide to NFPA 1192* and *ANSI/RVIA 12V Standard for Low Voltage Systems in Conversion and Recreational Vehicles* are available at www.rvia.org. The *National Electrical Code* is available from NFPA at www.nfpa.org/catalog/ or by calling 1-800-334-3555.

Information on CSA standards can be obtained by going to their website at www.shopcsa.ca.

Table 7-16 Appliances—Applicable to RV Service Technicians

Service Technicians Task	2008 CSA Z240	2011 1192	Summary of Requirement
Inspect/Repair/Replace Air Conditioner	5.1.1 Electric	551.40(B)	Any 120 VAC appliance must be listed and installed according to the installation instructions. The air conditioner shall be on its own circuit if required by the listing.

NOTE: There is no review for this chapter.

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7 Answer Keys

Chapter 7-1

1. True *(page 7-2)*
2. False *(page 7-1)*
3. False *(page 7-2)*
4. A. Thermoelectric refrigeration *(page 7-2)*
   B. Absorption refrigeration
   C. Air cycle refrigeration
   D. Compression cycle refrigeration
5. A. Rooftop *(page 7-2)*
   B. Split system
   C. Heat pumps
   D. Packaged basement
6. A *(page 7-2)*
7. D *(page 7-2)*
8. A. Radiant energy *(page 7-3)*
   B. Chemical energy
   C. Mechanical energy
   D. Electrical energy
   E. Nuclear energy
   F. Heat or thermal energy
9. A. Mechanical energy *(page 7-3)*
   B. Radiant energy *(page 7-3)*
   C. Heat or thermal energy *(page 7-3)*
   D. Electrical energy *(page 7-3)*
10. A. Sensible heat *(page 7-3)*
    B. Latent heat
11. B *(page 7-4)*
12. D *(page 7-5)*
13. British Thermal Unit *(page 7-5)*
14. A. Conduction *(page 7-6)*
    B. Radiation
    C. Convection
15. A. Radiation *(page 7-6)*
    B. Convection *(page 7-6)*
    C. Conduction *(page 7-6)*
16. A *(page 7-6)*
17. Saturated liquid *(page 7-7)*
18. Evaporation *(page 7-7)*
19. Saturated vapor *(page 7-8)*
20. Condensation *(page 7-8)*
21. A *(page 7-10)*
22. C *(page 7-9)*
23. B *(page 7-9)*
24. A *(page 7-11)*
25. Outside (outdoor), condenser *(page 7-11)*
26. Delta T (ΔT) *(page 7-11)*
27. A *(page 7-11)*
28. ALL (A-G) *(page 7-11)*

    Power voltage also. Power voltage is the form of a "brownout." It can affect air conditioner efficiency even though it is not listed as an example in the text.
29. B *(page 7-16)*
30. Reversing valve *(page 7-16)*

Chapter 7-2

1. Ozone layer depletion *(page 7-23)*
2. True *(page 7-24)*
3. True *(page 7-24)*
4. True *(page 7-24)*

Chapter 7-3

1. Volume, temperature, coils *(page 7-27)*
2. Electrical problems and improper airflow *(page 7-27)*
3. Evaporative and condensing temperatures *(page 7-27)*
4. Dry *(page 7-27)*
5. Evaporator coil, evaporator coil area *(page 7-28)*
6. A. Dirty return air filters *(page 7-28)*
   B. Dirty evaporator coil
   C. Supply air louvers closed
   D. Low ambient temperatures
   E. Restricted ductwork
7. A. Blow-through *(page 7-29)*

B. Suck-through

8. True *(page 7-30)*
9. False *(page 7-30)*
10. A. Check compressor voltage and amperage *(page 7-30)*.

    B. Check air temperature across the evaporator coil (ΔT).

Chapter 7-4

1. C *(page 7-33)*
2. Cool only, heat/cool *(page 7-33)*
3. Multimeter set to measure resistance in ohms *(page 7-33)*
4. False, only if the compressor is running above 75 percent of normal *(page 7-34)*
5. False, some have a PTCR instead *(page 7-34)*
6. overload *(page 7-35)*
7. B *(page 7-34)*
8. A *(page 7-36)*
9. Capacitor tester, analog VOM *(page 7-37)*
10. False, the capacitor-start/capacitor-run motor generally uses two capacitors *(page 7-34)*
11. B *(page 7-42)*
12. D *(page 7-43)*

Chapter 7-5

1. Furnace manufacturer's *(page 7-47)*
2. Thermistor *(page 7-48)*
3. 2 A *(page 7-48)*
4. Ground *(page 7-49)*
5. True *(page 7-49)*
6. True *(page 7-49)*
7. False, when fan only is selected, the HIGH fan speed runs continuously *(page 7-49)*
8. Electromagnetic, current *(page 7-51)*
9. Open, close *(page 7-51)*
10. Yellow *(page 7-51)*
11. Low-temperature thermistor probe *(page 7-55)*
12. False (they are permanently mounted) *(page 7-54)*
13. True *(page 7-54)*
14. True *(page 7-55)*
15. False (opens at 32°F (0°C) and closes at 55°F (13°C)) *(page 7-55)*
16. True *(page 7-53)*
17. False (a bad thermistor can keep the compressor from running since it "breaks" the electrical circuit) *(page 7-55)*
18. B *(page 7-63)*
19. D *(page 7-63)*
20. C *(page 7-63)*
21. A *(page 7-63)*
22. False—capacitors must be turned OFF and "discharged" before removing the wires.*(page 7-65)*

    Use an AC voltmeter set at its highest scale or a 15,000-3/4 resistor to discharge a capacitor.
23. True *(page 7-65)*
24. C *(page 7-65)*
25. C *(page 7-67)*
26. C *(page 7-67)*
27. B *(page 7-71)*
28. D *(page 7-71)*

Chapter 7-6

1. Full load amps *(page 7-85)*
2. Rated load amps *(page 7-85)*
3. C—FLA + 3 A *(page 7-85)*

   95°F + 15° = 95°F (FLA setting) + 15 (1 A for every 5°F over) = FLA + 3 A)
4. A. Tests with amperage *(page 7-85)*

   B. Tests with temperature differentials *(page 7-85)*
5. A. Visually *(page 7-86)*

   B. Leak detector solution

   C. Electronic leak detector

   D. Submersion

   E. Dye test
6. True *(page 7-86)*
7. True *(page 7-89)*

8. True *(page 7-88)*
9. True *(page 7-92)*
10. All—A-G *(page 7-88)*
11. C *(page 7-91)*
12. A *(page 7-94)*
13. False (high side and low side) *(page 7-95)*
14. Cool or cold *(page 7-95)*

Chapter 7-7

1. C *(page 7-99)*
2. Time-delay, HARC *(page 7-99)*
3. Copper *(page 7-99)*
4. Insulation *(page 7-100)*
5. Cool to its potential *(page 7-101)*

Chapter 7-8

1. False—never use duct tape; it will deteriorate over time and fail to hold *(page 7-103)*
2. Hermetic analyzer *(page 7-106)*
3. True *(page 7-110)*
4. Y and B, GH and B *(page 7-110)*

Chapter 7-9

There is no review for this chapter.

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7 Glossary of Air Conditioning Terms

Absorption Refrigeration Refrigeration in which cooling is effected by the expansion of liquid ammonia into vapor and then absorption of the vapor by water. This is commonly used in RV refrigerators.

Accumulator A chamber for storing low-side liquid refrigerant in a refrigeration system.

Air Conditioning The process of controlling temperature, humidity, ventilation, odor, and so on in a given space.

Air Cycle Refrigeration A refrigeration cycle characterized by the working fluid, air, remaining as a gas (vapor) throughout the cycle rather than being condensed into a liquid.

Ambient Temperature Surrounding temperature of any object.

AWG American wire gauge. A particular series of specified diameters and thicknesses established as a standard in the United States and used for nonferrous (no iron) sheets, rods, and wires. Also known as Brown and Sharp gauge.

Boiling Point The degree of heat at which a liquid is converted to a vapor by boiling. This point varies for different liquids and for the same liquid at different pressures.

Brazing The act of soldering metals by melting a nonferrous filler metal such as brass or brazing alloy (hard solder) with a melting point lower than that of the base metals at the point of contact.

British Thermal Unit (Btu) The amount of heat necessary to raise the temperature of one pound of water one degree Fahrenheit.

Capillary Action (Capillarity) The action by which the surface of a liquid, where it contacts a solid, is elevated or depressed because of the relative attraction of the molecules of the liquid for each other and for those of the solid. Also known as "sweating."

Capillary Tube A small-diameter tube or opening designed to meter refrigerant into the evaporator of a refrigeration device. It reduces refrigerant pressure and flow through friction determined by the size of the opening.

Cardiac Arrhythmia Change in regular heartbeat. The heart may seem to skip a beat, beat irregularly, or beat very fast or very slowly.

Chemical Energy Energy resulting from chemical change. Energy of a chemical compound which, by the law of conservation of energy, must undergo a change equal and opposite to the change of heat energy in a reaction; the rearrangement of the atoms in reacting compounds to produce new compounds causes a change in chemical energy.

Circuit Breaker An electrical safety overload protection device that is designed to open (shut off) an electrical circuit when a predetermined overload is achieved. As a manually operated device, it may also be used to close (complete) an electrical circuit.

Compression Cycle Refrigeration The cooling of a refrigerant by first compressing it to a liquid form (with resultant heat buildup), cooling the liquid by heat exchange, then releasing pressure to allow the liquid to vaporize (with resultant absorption of latent heat of vaporization and a refrigerative effect).

Compressor A device that uses compression to raise the pressure, temperature, and saturation point of refrigerant vapor.

Condenser A heat exchanger in which vapor is changed into a liquid through heat removal/transfer to another material.

Conduction of Heat Heat flow through a material by contact between particles. The flow can also be from one substance to another in direct contact.

Conductivity (K Factor) The rate of heat flow, in Btu/hr, through one square foot of material, one inch thick, with a temperature change of one degree Fahrenheit.

Continuity Continuous path for current. Reading of zero ohms with an ohmmeter.

Convection The transfer of heat by the circulation of fluids due to differences in temperature and density.

Dehydration The process of removing water through the process of vaporization and the subsequent removal of the vapor by means of a deep vacuum.

Delta-Temperature Relationship (ΔT) The difference in the temperature measured at one location and the temperature measured at another location.

Discharge Line The section of the line connecting the compressor to the condenser that carries high-pressure, high-temperature refrigerant vapor from the compressor into the condenser.

Electrical Energy A form of energy generated by friction, induction, or chemical change and having magnetic, chemical, and radiant effects. Energy of electric charges by virtue of their position in an electric field. Energy of electric currents by virtue of their position in a magnetic field.

EPA United States Environmental Protection Agency.

Evaporator A heat exchanger in which liquid is changed into a vapor through the process of heat absorption.

Expansion Valve A device to control the flow of refrigerant to the evaporator. The valve automatically adjusts the flow rate by the temperature of the suction line.

Fixed Orifice See *Capillary Tube*.

Flux In soldering, welding, and brazing, a material applied to the pieces to be united to reduce melting point of solders and filler metals and to prevent the formation of oxides.

Freeze Control A device used to protect against freezing of an air conditioner through the use of a temperature-sensing device or thermistor.

HACR Abbreviation for heating, air conditioning, and refrigeration. The name given to a time-delay-circuit breaker installed in RVs to handle appliances.

Heat Energy See *Thermal Energy*.

Heat Strip A heating element and a bimetal limit switch designed to open a circuit in the event of an overheating situation.

Hermetic To make airtight by sealing, as a container.

HRAI Canadian Heating, Refrigeration and Air Conditioning Institute.

Latent Heat Heat that causes a change in state without a change in temperature.

Latent Heat of Condensation The process caused when vapor changes to a liquid through condensation when the latent heat of the vapor is extracted.

Latent Heat of Freezing The process of extracting latent heat to change a liquid (water) to a solid (ice). The amount of latent heat that must be extracted is 144 Btu/hr per pound.

Latent Heat of Fusion The process of changing a solid to a liquid such as ice to water by adding heat; melting. The heat that is added is hidden or latent such as the heat in the air that is higher than the heat in the solid.

Latent Heat of Sublimation The process of changing a solid to a vapor without first changing into a liquid. Dry ice is a typical example of the process of latent heat of sublimation.

Latent Heat of Vaporization The process of changing a liquid into a vapor. Water boils and vaporizes at 212°F (100°C). If more heat is added, the vaporization process becomes quicker. All added heat above this threshold is latent heat.

Laws of Thermodynamics First law of thermodynamics: energy cannot be created or destroyed.
Second law of thermodynamics: heat always moves from hot to cold; it never moves from cold to hot.

Limit Switch A switch that prevents operation or movement of a machine, motor, or device beyond predetermined ranges or limits.

Liquid Line The section of piping connecting the condenser to a metering device that carries high-pressure, high-temperature refrigerant liquid from the condenser to the evaporator coil.

Mechanical Energy Energy that causes matter to move.

Metering Device A device designed to control the flow of refrigerant to the evaporator. Metering (control) can be accomplished by the use of a capillary tube, fixed orifice, or expansion valve.

Montreal Protocol An international agreement that controls the production and consumption of substances that can cause ozone depletion. The full name is the Montreal Protocol on Substances that Deplete the Ozone Layer. U.S. implementation of the provisions of the protocol is The Clean Air Act of 1990.

Nuclear Energy Energy released by nuclear fission (the division of an atomic nucleus into parts of comparable mass) or nuclear fusion (combination of two light nuclei to form a heavier nucleus with release of some binding energy).

Overload Protector (Overload Switch) A component that will open (shut off) the AC voltage circuit to the compressor if the compressor overheats due to an electrical problem.

PSIG Pounds per square inch gauge. The gauge pressure, measured as the number of pounds-force exerted in an area of one square inch.

Process Stub A copper tube used for charging or recovery of refrigerant in a sealed system. The system must be opened for installation or removal/replacement. Once used, the stub is crimped for sealing.

PTCR Positive temperature coefficient resistor. A device that may replace the compressor start relay on some air conditioner models. A resistor that controls the condition wherein the resistance, length, or some other characteristic of a substance increases when temperature increases.

Radiant Energy (Radiation) The energy transmitted by waves through space or some medium. Heat flow without contact between the hot (sun) and cold (earth) materials. Also, heat flow by electron flow, even across a vacuum.

Reclaim To reprocess refrigerant to new product specifications by means that may include distillation.

Recover To remove refrigerant in any condition from a system and store it in an external container without necessarily testing or processing it in any way.

Refrigeration The method of moving heat from one place to another.

Reversing Valve The main component of a heat pump that allows the unit to either heat or cool.

Run Capacitor A device that gives a motor starting torque and maintains high power factor during operation.

Saddle Valve A reusable clamp-on or soldered valve (preferred method) installed onto the refrigerant line and used for charging and recovery of refrigerant in a sealed system. The sealed system does not have to be opened for installation. Entry into the system is accomplished by piercing the sealed line with a twist-down probe after installation.

Saturated Liquid The condition of a liquid at its boiling point. A liquid at a given temperature and pressure that the addition of any heat will cause some of the liquid to change to vapor.

Saturated Vapor The condition of a vapor at its condensation point. A vapor at a given temperature and pressure such that the removal of any heat will cause some of the vapor to condense to liquid.

Schraeder Valve A brand name for a type valve used for charging and recovery of refrigerant on a sealed system. The system must be opened for installation of a schraeder valve.

Sensible Heat Heat whose effect on matter creates a change in temperature without causing a change in state.

Short Cycle A less than complete cycle within the refrigeration process of an air conditioner.

Start Capacitor A device that is used to provide a power surge to produce a high torque for starting a motor. The capacitor is disengaged when the motor achieves a predetermined percentage of its rated speed.

Start Relay A normally closed relay switch that connects the start capacitor in parallel to the run capacitor for increased motor starting torque.

Swage To taper or expand a tube so that one tube fits inside another to be sealed.

Subcooled Liquid Liquid refrigerant at a temperature below the saturation temperature corresponding to its pressure.

Suction Line A section of refrigeration piping that connects the evaporator to the compressor. The line carries low-pressure, low-temperature refrigerant vapor from the evaporator to the condenser.

Superheated Vapor A vapor that is at a temperature above its saturation temperature corresponding to its pressure.

Thermal (Heat) Energy Energy that produces molecular motion.

Thermistor A resistive circuit component having a high negative temperature coefficient of resistance so that its resistance decreases as the temperature increases.

Thermodynamics The study of the effects of heat and other forms of energy causing matter to move or be active.

Thermoelectric Refrigeration (Thermoelectric Cooling) Cooling of a chamber based on the Peltier effect; an electric current is sent through a thermocouple whose cold junction is thermally coupled to the cooled chamber while the hot junction dissipates heat to the surroundings.

Thermostat An instrument that measures changes in temperature and directly or indirectly controls sources of heating and cooling to maintain a desired temperature.

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