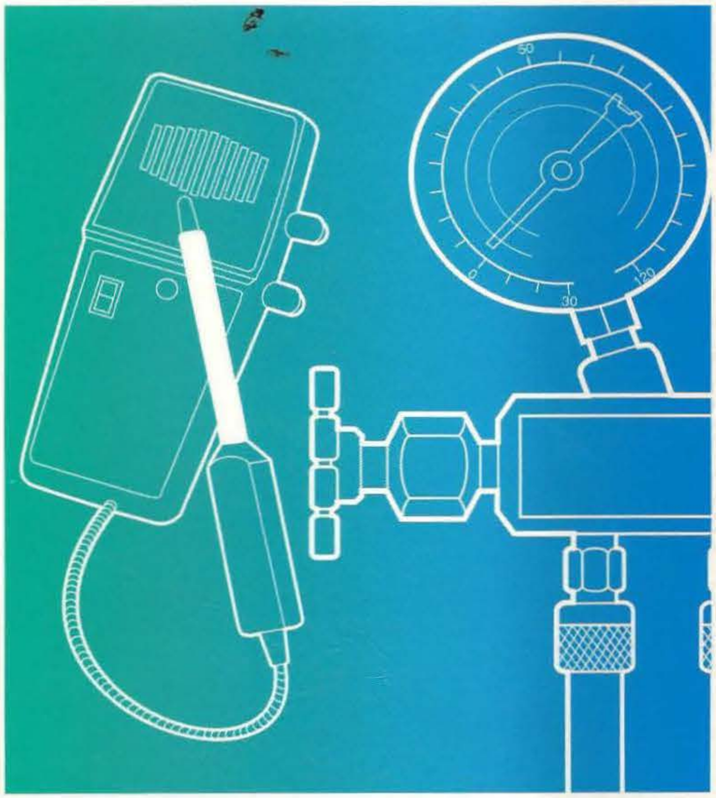
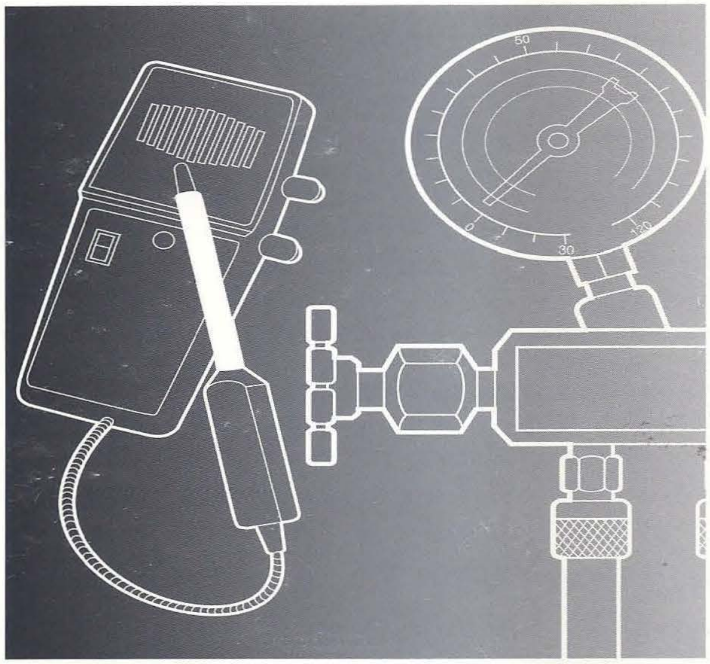
HVAC SERVICING PROCEDURES



- Instruments and Devices
- Safety
- General Service Considerations
- Service Procedures

Steve Hall

THIS COMPLETE SERVICING REFERENCE IS . . .



. . . FOR PROFESSIONAL HVAC SERVICE TECHNICIANS

PREFACE

The focus of this manual is placed on the field servicing of residential and light commercial HVAC equipment. Emphasis is placed on the "hands-on" use of the service instruments and how to perform the service procedures, rather than on related theory or scientific principles. The field-proven servicing procedures described provide an invaluable resource for both the entry-level and experienced service technician. This is especially true when looking for alternative or up-to-date methods for performing a particular service task. Unlike many other manuals written about servicing HVAC equipment, this manual encompasses all areas of service, including the mechanical refrigeration system, electrical system, and air distribution system. All the material in this manual reflects the current EPA requirements of Section 608 of the Clean Air Act.

This manual has been designed as a field companion to be carried with you in your truck and on the job. Some of its features include:

- Spiral binding to allow both hands free when following procedures.
- The binder and pages are sturdy enough to withstand the rigors of field use, and printed on wipe-clean paper that resists grease and dirt.
- All safety and other important information is highlighted in red.
- All sections of the manual are separated by dividers for quick cross-referencing.
- Each section divider contains an alphabetical index of section contents.
- The first page of each section contains a complete Table of Contents for the section.
- All sections of the manual are liberally illustrated for easy use on the job.
- Service procedures are presented in an easy-to-use tabular format that is keyed to supporting illustrations, with all the tables and illustrations on facing pages for easy reference.
- The service procedures provide references to the detailed descriptions contained in Section 1 for each instrument or device used in the procedure.
- Glossary of Terms and Pressure/Temperature Charts are included in the back of the manual.

ACKNOWLEDGMENTS

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SECTION 1
INSTRUMENTS AND DEVICES

INTRODUCTION

This section contains brief descriptions of the instruments and devices commonly used in servicing residential and light commercial air conditioning systems. Its purpose is to familiarize the entry-level service technician with these instruments and their uses. The experienced service technician will find this information useful when considering alternative service procedures, or when purchasing new service instruments.

When particular features of instruments are discussed, it is intended as guideline information only and is not an endorsement or recommendation of any manufacturer. The instruments covered in this section are readily available for purchase and are commonly used in the field.

To help you reference between sections, each instrument has been assigned an item number. For example, if you are using a procedure in Section 4 and need more information about one of the test instruments referenced there, the item number will help you to quickly find the information in this section.

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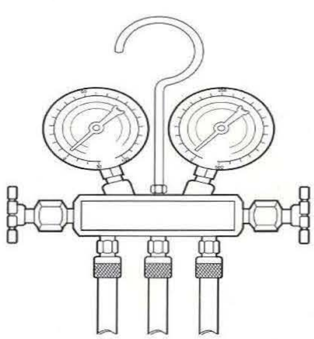
Figure 1-1.
Standard Two-Valve Gauge Manifold Set



REFRIGERATION SYSTEM SERVICE INSTRUMENTS AND DEVICES

Gauge Manifold Set (Item 1)

The gauge manifold set (Figure 1-1) is one of the most common items of service equipment. It is used to monitor the low-side and high-side pressures in an operating system in order to evaluate system performance. When installing new systems or servicing existing systems, the gauge manifold set is regularly used to route and control the flow of refrigerant, refrigerant oil, or other acceptable fluids or gases to and from the system. Typically, this is required for tasks such as leak testing, evacuation and dehydration, adding or removing refrigerant, and other service operations.

The standard two-valve gauge manifold set consists of two pressure gauges mounted on a manifold assembly.

A compound gauge mounted at the left side of the manifold is used to measure system low-side (suction) pressures, including lower-than-atmospheric pressures. The compound gauge is normally calibrated to measure system pressures in the range of 0 to 120 psig and vacuums from 0 to 30 inches of mercury (in. Hg) vacuum. A high-pressure gauge at the right side of the manifold is used to measure system high-side (discharge) pressures. It is typically calibrated to measure system pressures in the range of 0 to 500 psig. Most pressure gauges supplied on gauge manifold sets are marked with scales calibrated according to the evaporating temperature of common refrigerants. This feature gives the technician a choice from referring to pressure-temperature tables and curves to determine the correct temperature relationships for the various refrigerants. Figure 1-2 shows a two-valve gauge manifold set connected to measure system pressures.

Two-valve gauge manifold sets have two hand valves and three hose ports. The hand valves route the flow of refrigerant to and from the system during servicing.

The hose ports are connected to the system being serviced and/or other service instruments through a set of environmentally safe high-pressure service hoses. To comply with clean air non-venting requirements, it is desirable that these hoses be equipped with self-sealing fittings that immediately trap refrigerant when disconnected.

Most gauge manifold sets and service hoses are color coded. Blue identifies the low-pressure compound gauge, hand valve, and related hose port. A blue service hose is normally connected between the manifold low-pressure hose port and the equipment suction service valve. Red marks the high-pressure gauge, hand valve, and hose port. A red service hose is normally connected between the manifold high-pressure hose port and the equipment discharge service valve or liquid line. The center hose port is the utility port. This port is normally connected through a yellow service hose to other service instruments or devices.

Gauge manifold sets are also available with four hand valves and related hose ports (Figure 1-3). This type of manifold can reduce service time by eliminating the need to switch the utility hose between service devices. Four-valve manifolds and related service hoses are color coded as follows: blue (low pressure), red (high pressure), yellow (charging) and black (vacuum).

High-capacity evacuation gauge manifold sets with larger ports and shorter, larger-diameter service hoses to speed up the evacuation process are also available. In addition, there are also gauge manifolds designed specifically for use with heat pumps. These have two high-pressure gauges instead of one, eliminating the need to switch hoses between the liquid and vapor tube service ports when changing between the cooling and heating modes. Digital (electronic) gauge manifold sets are also available. They use liquid crystal display (LCD) indicators instead of analog gauges to display the system pressure readouts (Figure 1-4).

The gauge manifold set is a precise measuring instrument and its accuracy is critical to correct servicing. The technician must insure that the gauge manifold set is always handled with care. The "O" rings in the hoses and the calibration of the gauge manifold set should be checked regularly.

Thermometer (Item 2)

Thermometers are used to measure temperatures for a variety of HVAC service tasks. The thermometer is frequently used to determine the suction line or liquid line temperatures when charging cooling systems. These measurements are important because the proper calculation and adjustment of the superheat or subcooling temperature is critical to determining the correct system charge. Another common use for the thermometer is to measure return air and supply air temperatures to determine the temperature difference for the purpose of determining the airflow rate in a system.

Figure 1-2.
Two-Valve Gauge Manifold Set Used to Take Pressure Readings

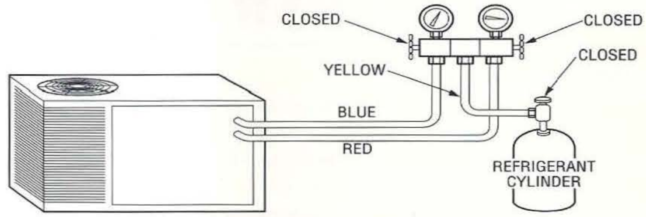


Figure 1-3.
Four-Valve Gauge Manifold Set

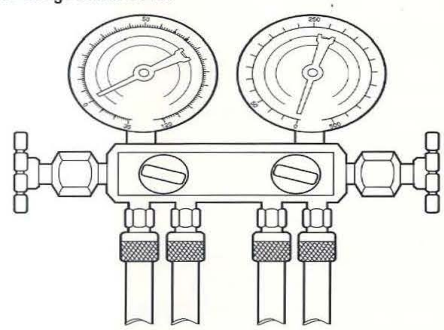
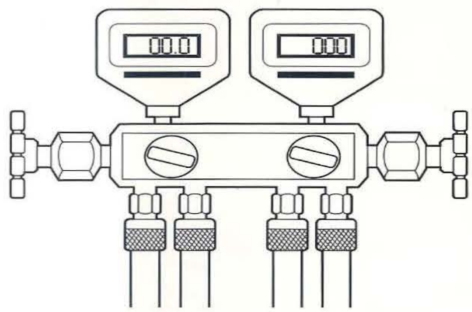
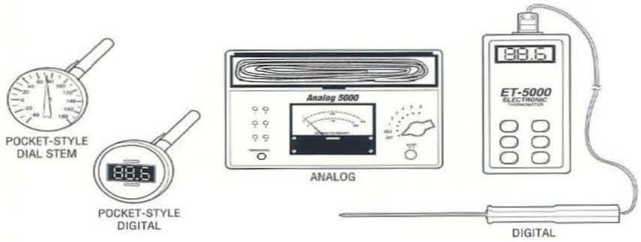


Figure 1-4.
Gauge Manifold Set with Digital Readout



▼ Figure 1-5.
Common Thermometers Used to Service HVAC Equipment



Shown in Figure 1-5 are the various types of thermometers commonly in use. Included are simple pocket-style bimetal dial-indicator and digital thermometers and two versions of electronic thermometers. In addition to the examples shown, many other special-purpose thermometers are also available. Thermometers come in a variety of temperature ranges based on their intended use. For heating and air conditioning work, thermometers covering the temperature range of -40° F to 180° F or 0° F to 220° F are commonly used. Because pocket-style bimetal thermometers can be inaccurate and difficult to read, the use of electronic thermometers is advised for obtaining the most accurate temperature readings.

Electronic thermometers may have several different sensor probes to cover different temperature ranges. Sensor probes used with electronic thermometers are normally thermocouple, thermistor, or resistance temperature detector (RTD) probes. Thermocouple probes convert heat into low-level DC voltages that produce the temperature reading on the electronic thermometer. Thermocouple probes tend to be rugged and inexpensive.

Thermistor and RTD probes have sensing elements in which the resistance varies depending on the applied heat. The thermometer circuit translates the resistance into a temperature value, which is displayed on the meter. Thermistor probes tend to respond more quickly and produce higher outputs than RTD probes. On the other hand, RTD probes usually provide more stable, accurate, and linear readings than either the thermocouple or thermistor probes.

Digital multimeters (Item 11, page 11) equipped with thermocouple and/or thermistor probe accessories can also be used to make temperature measurements. Infrared temperature sensor accessories that can be used with digital multimeters are also available. These sensors can read the surface temperature or refrigerant line temperature just by pointing the sensor at the surface or line.

QUICK NOTE

When selecting sensor probes for electronic thermometers, keep the following in mind:

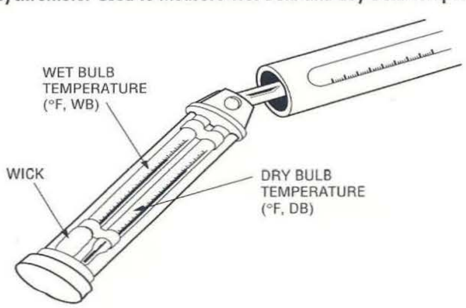
- *Thermocouple probes tend to be rugged and inexpensive.*
- *Thermistor probes are faster-acting and produce higher outputs than RTD probes.*
- *Of the three types of probes, RTD probes usually provide the most stable, accurate, and linear readings.*

Psychrometer (Item 3)

Psychrometers contain two identical thermometers, one to measure the dry bulb temperature and one to measure the wet bulb temperature. The sensing bulb of the wet bulb thermometer is covered with a wick, which is saturated with distilled water before taking a reading. Evaporation occurs at the wick of the wet bulb thermometer, giving it a lower temperature reading. The wet and dry bulb temperatures can be used to find the relative humidity of the measured air using either a built-in chart on the psychrometer or a separate psychrometric chart.

Sling psychrometers (Figure 1-6) are often used when servicing air conditioning equipment. One use is to measure the wet bulb temperature of the indoor air entering the indoor coil (evaporator). Wet bulb temperatures take into account the latent heat load in the indoor air and give a better indication of the load on the indoor coil. To get an accurate wet bulb temperature measurement, the sling psychrometer must be spun rapidly in the air being tested.

▼ Figure 1-6.
Sling Psychrometer Used to Measure Wet Bulb and Dry Bulb Temperatures



Another use of the sling psychrometer is to measure dry and wet bulb temperatures in order to determine the room temperature and percent relative humidity (RH). Relative humidity is measured to determine the level of environmental comfort in the various rooms of a house or other conditioned space. Proper control of RH is also critical to many commercial and manufacturing processes. Most people feel comfortable when the indoor temperature and humidity conditions fall within certain ranges called *comfort zones*. For winter, temperatures between 67° F and 76° F and an RH of about 30% are considered comfortable. For summer, the comfort zone is between 72° F and 81° F with an RH of about 40%. Properly-controlled temperature and humidity conditions are important to insure comfort and health in all seasons. Proper control of these conditions also helps to reduce the load on cooling and heating equipment.

Squeeze-bulb and battery-operated aspirating psychrometers (Figure 1-7) are used in confined spaces where a sling psychrometer would be difficult to operate. The squeeze-bulb aspirating psychrometer works by rapidly squeezing the bulb to draw air over the thermometers. In the battery-operated version, a fan draws air over the thermometers.

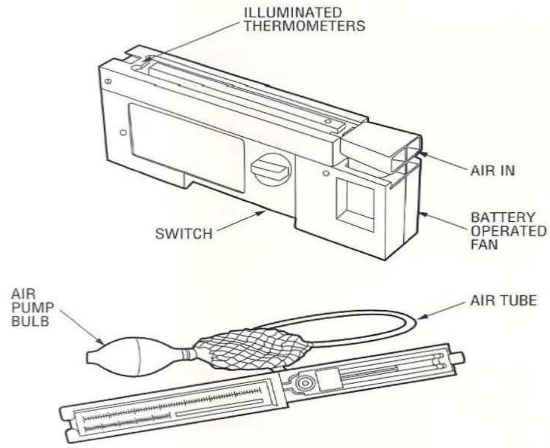
Refrigerant Recovery and Recovery/Recycle Units (Item 4)

Use of recovery/recycle units (Figures 1-8 and 1-9) is required by U.S. Environmental Protection Agency (EPA) regulations. Technicians who service and dispose of air conditioning and refrigeration equipment must recover the refrigerant instead of venting it to the atmosphere. With the exception of extremely small releases of refrigerant such as occurs when disconnecting service hoses, a technician who knowingly releases or vents refrigerant to the atmosphere is in violation of this EPA regulation. Before opening any system for service or repair, the refrigerant must be collected using an approved recovery device or the charge must be isolated in another part of the system. To insure compliance, EPA regulations require that contractors who perform on-site recovery or recycling of refrigerant certify that they own and are properly using certified recovery or recycling equipment.

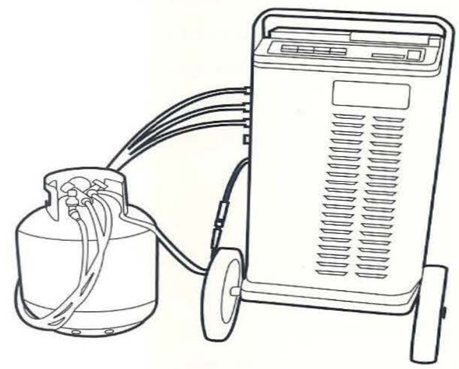
The descriptions given in the following paragraphs emphasize the recovery and recycle units used mainly to service residential and small commercial air conditioning and refrigeration equipment. When servicing larger commercial systems such as centrifugal chillers, different recovery and containment devices are used because of the larger volumes of refrigerant. Service training materials on recovery/recycle devices for large systems are readily available.

Recovery and recycle units are available in various sizes, types, and prices. They can be stand alone recovery or recycle units or combined into one unit that accomplishes both functions.

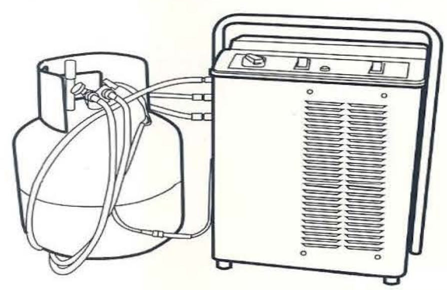
▼ Figure 1-7.
Aspirating Psychrometers



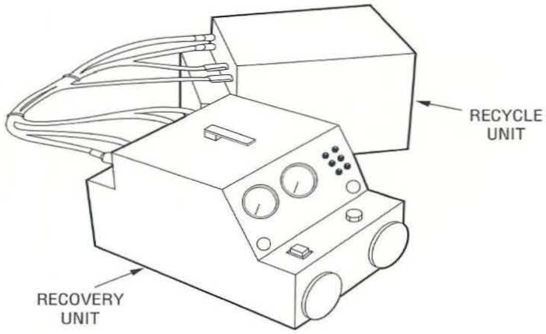
▼ Figure 1-8.
Recovery/Recycle Unit and Cylinder



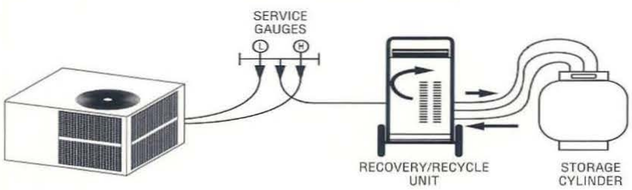
▼ Figure 1-9.
Recovery Unit and Cylinder



▼ **Figure 1-10.**
Separate Recovery and Recycle Units Connected as Recovery/Recycle Unit



▼ **Figure 1-11.**
Recovery/Recycle Unit Connected for Recycle Operation



As shown in Figure 1-10, many stand alone recovery and recycle units are designed so they can be connected together to form an integrated recovery/recycle unit.

Recovery units by themselves do not provide for any cleaning or filtration of the refrigerant. They are used at the job site to remove (recover) refrigerant from a system and store it in an approved external container. The normal procedure is to test the recovered refrigerant for moisture and/or acid to determine if it can be reused in the same system as is, or if it needs to be processed through a recycling unit to remove contaminants before reuse.

Recycling is typically performed using single or multiple passes through filter core driers or similar devices that remove moisture, acid, and particles. Figure 1-11 shows a recovery/recycle unit connected for recycle operation. After the refrigerant is recycled, it may be returned to the same system or to another system belonging to the same owner. Combined recovery/recycle units perform all the processes described for both recovery and recycle units.

When selecting a recovery or recovery/recycle unit, make sure it can perform the functions needed for your particular service application. Once recovery/recycle equipment is obtained, maintain it according to the manufacturer's instructions, especially with regard to changing filter devices and draining oil. If the equipment is used to recover different types of refrigerants, it must be properly serviced to avoid refrigerant mixing.

Some of the standard features of recovery/recycle units used in residential and light commercial applications are:

- The ability to process R-12, R-22, R-500, R-502, and/or R-134a refrigerant as a liquid or a vapor.
- The ability to test refrigerant for moisture and acid contamination.
- Processing time (rate of recovery) of 1.5 to 3 lbs. of vapor/minute or 3 to 5 lbs. of liquid/minute.
- Refrigerant recovery efficiency range of 80 to 96 percent. The maximum recovery efficiency is the percentage of refrigerant that the equipment is capable of recovering from a unit. It is directly related to the depth of vacuum that the unit can achieve. Units that can evacuate a system to a negative pressure as low as 20 inches of mercury (in. Hg) are common.
- Reusable refrigerant cylinder capacity of at least 50 lbs. and automatic shutoff when the cylinder is 80 percent full.
- Hermetic, reciprocating, or rotary compressor.
- Power input of 110 to 120 VAC. Easy operation in manual mode. Many are available with automatic microprocessor-controlled operation.
- Handles/lifting bars and wheels that make the unit easy to transport in and out of service trucks and work sites. Most recovery/recycle units typically weigh between 75 and 160 lbs. Individual recovery or recycle units weigh about 50 lbs.

Leak Detector (Item 5)

One of the most common problems encountered when servicing air conditioning or heat pump equipment is refrigerant loss due to leaks. Leaks usually result from poor installation practices, physical damage, or factory defects. Often these leaks are very tiny, allowing minuscule quantities of refrigerant to continuously escape to the atmosphere without giving any sound or visual sign to aid in detection. Leaks result in steadily deteriorating system performance and may eventually cause the need for a costly repair. In addition to poor system performance, damage to the environment will be caused by the release of CFC and HCFC refrigerants into the atmosphere.

Leak detectors like the one shown in Figure 1-12 are used to:

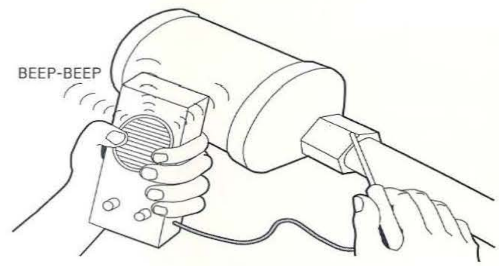
- Check for small leaks after making a major repair to a system.
- Check for leaks before evacuating a system because moisture can enter the system through the leak during evacuation or pumpdown.
- Check for leaks when the required vacuum level cannot be achieved while evacuating a system.

Many types of leak detectors are available, including simple bubble solutions and detection instruments such as halide torch detectors, electronic leak detectors, ultrasonic leak detectors, and ultraviolet lamp and fluorescent-additive detectors. Because leak detection is so important and refrigerant leaks in a system can be very tiny, sensitive leak detection instruments are usually required. Leak detectors are available for systems using CFC, HCFC, or HFC refrigerants. (See Section 3 for specific information about CFC, HCFC, and HFC refrigerants.) For many reasons, including price, accuracy, and ease of use, the electronic leak detector is used by most technicians who service residential and light commercial systems. Figure 1-13 shows typical electronic leak detectors.

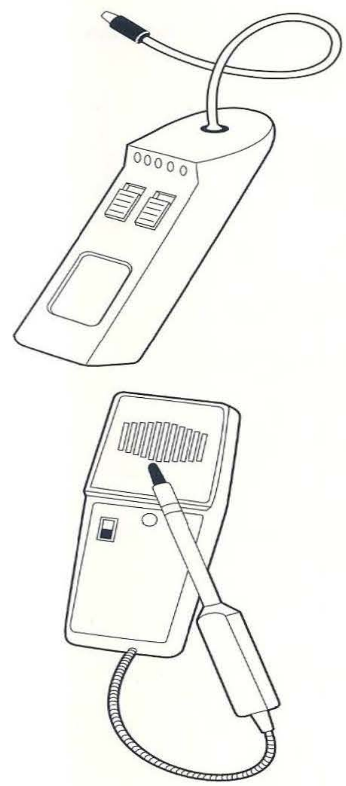
Electronic leak detectors generally consist of a probe connected to a control unit. They have an air pump that draws sample air through the detector tip and over the sensing element. When leaking refrigerant is detected, the electronic detector sounds an audible alarm or generates a bright flashing light at the probe tip, or both. Features to look for in an electronic leak detector include:

- The ability to sense leaks in contaminated areas.
- Leak sensitivity that detects 1/2 oz. per year.
- Battery-operated; instant warm-up if 115 VAC powered.
- Audible and visible leak indicators.
- Sensor not contaminated by large doses of refrigerant or other gases such as nitrogen.
- Long flexible probe for hard-to-reach areas.
- The ability to detect a variety of refrigerants with little or no modification.

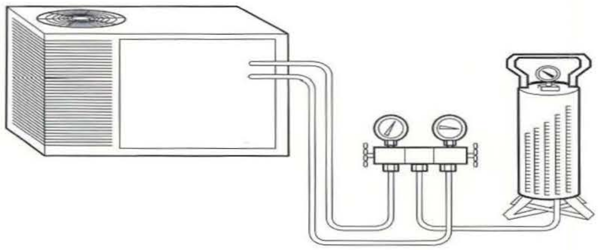
▼ Figure 1-12.
Electronic Leak Detector Used to Check for Leaking Refrigerant



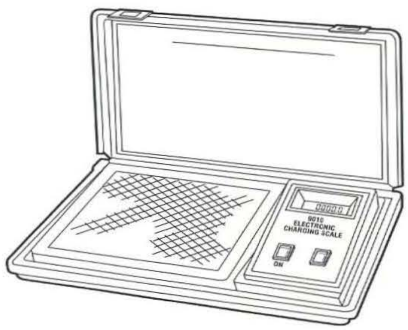
▼ Figure 1-13.
Electronic Leak Detectors



▼ Figure 1-14.
Charging Cylinder Used to Charge a System



▼ Figure 1-15.
Electronic Charging Scale



QUICK NOTE

Did you know that some state and/or local Bureaus of Weights and Measures require that the calibration of your charging scale be certified? Regardless of whether it's a law or not, it's just good practice to have an accurately calibrated scale.

Charging Cylinder/Charging Scale (Item 6)

Charging cylinders and scales are used to insure that the correct amount of refrigerant is measured into a system when it is being charged. Charging scales are often used when recovering refrigerant from a system in order to determine the exact amount that has been recovered. Use of a particular charging cylinder/scale is determined mainly by the type and size of the system being serviced. Since the operation and efficiency of the refrigeration system depends on having a proper charge, the most important feature to be considered when selecting a charging cylinder/scale is its accuracy.

Graduated charging cylinders (Figure 1-14) are used for charging refrigerant into smaller systems whose charge is stated in ounces or a few pounds and ounces. The charging cylinder has marked graduations and a visible column of liquid refrigerant so that the liquid level can be observed as it drops during charging. On top of the cylinder is a pressure gauge used to determine, by pressure-temperature relationships, the temperature of the refrigerant in the cylinder. Most cylinders have heaters in the bottom to keep the temperature and pressure of the refrigerant from dropping as refrigerant is being removed from the cylinder. To maintain the accuracy of a system charge, the charging cylinder selected should be large enough to hold the full charge of the system being worked on.

Electronic charging meters (scales) can be used to charge both small and large systems by weight. The scale used must be matched to the system size. For example, a scale used to charge residential and light commercial systems must be accurate to within an ounce. Also, be sure the scale weighing platform mechanism is strong enough to handle the maximum size refrigerant cylinders you intend to use.

Electronic scales (Figure 1-15) and programmable, fully automatic charging scales are available. Depending on the model and its intended use, charging scales are calibrated to weigh refrigerant in pounds, ounces, kilograms, and/or grams with an accuracy of about ±2 percent. Typically, they display the cylinder/refrigerant weight using a five-digit LCD display, sensitive to 1/2-ounce resolution. Programmable models control the flow of refrigerant. They can be set to automatically dispense a preset amount of refrigerant and turn off when the preset amount is reached. Most have a hold function that interrupts charging if the refrigerant cylinder empties before the full system charge is reached.

Vacuum Pump (Item 7)

CAUTION ➧

Never use a converted refrigerant compressor or the system compressor as a vacuum pump.

Air conditioning and heat pump systems are designed to operate with only refrigerant and oil circulating within them. New field-piped systems and systems that have been opened for repair may be exposed to moisture and other contaminants.

These systems must be evacuated and dehydrated before they are placed in operation (Figure 1-16). If dehydration is not performed properly, safe operation and the life expectancy of the system will be jeopardized.

The vacuum pump (Figure 1-17) is a motor-driven pump used to evacuate (remove) the air and other non-condensible gases from closed air conditioning and heat pump systems and refrigerant storage cylinders. Vacuum pumps remove air by pumping the system down to a pressure below atmospheric pressure (14.7 psi). If the vacuum pump is operated so that deep levels of vacuum are obtained in the system, water will also be removed (dehydrated) as a result of the water boiling and evaporating. A deep vacuum satisfactory for dehydrating a system is considered to be any absolute pressure of 500 microns or below. 500 microns is about equal to an absolute pressure of 0.02 inches of mercury (in. Hg) absolute, which is a vacuum reading of 29.90 in. Hg vacuum.

A quality vacuum pump is a must for the service technician. A good pump is capable of evacuating a system down to 29.90 in. Hg vacuum (0.02 in. Hg absolute or 500 microns). Most use a direct drive, two stage, rotary-type vane pump driven by a motor with thermal overload protection. They usually have an oil level sight gauge, easy-to-fill oil port, and an oil drain. Pumps should have a solenoid-operated inlet line shutoff valve that prevents loss of vacuum pump oil if the pump input power is disconnected when the system is under vacuum. A gas ballast between the pump's first and second stages is desirable to prevent some of the moisture from condensing in the vacuum pump crankcase.

Vacuum pumps need periodic maintenance. Since the oil in the vacuum pump becomes contaminated through normal use, it is a good practice to change the oil after every 10 hours of pump operation, and always immediately after pumping down a wet or contaminated refrigeration system.

Vacuum Gauge/Indicator (Item 8)

The vacuum gauge/indicator is used to measure lower-than-atmospheric pressures (vacuums). An accurate vacuum gauge is needed to measure the 500-micron deep vacuum levels that must be achieved to properly evacuate and dehydrate air conditioning and heat pump systems.

Even though the compound gauge on a gauge manifold set is capable of measuring a vacuum, it should not be used for this purpose because the scale calibration is not accurate enough to read the specific vacuum levels needed in the evacuation/dehydration process. U-tube manometers can be used, but they are more suitable for use in the laboratory than for field service. When servicing air conditioning and heat pump systems in the field, most technicians use electronic vacuum gauge/indicators.

Two common types of electronic vacuum gauge/indicators are shown in Figures 1-18 and 1-19. One displays the measured vacuum on a dial indicator.

Figure 1-16.
Vacuum Pump and Vacuum Gauge Connected to Evacuate and Dehydrate a System

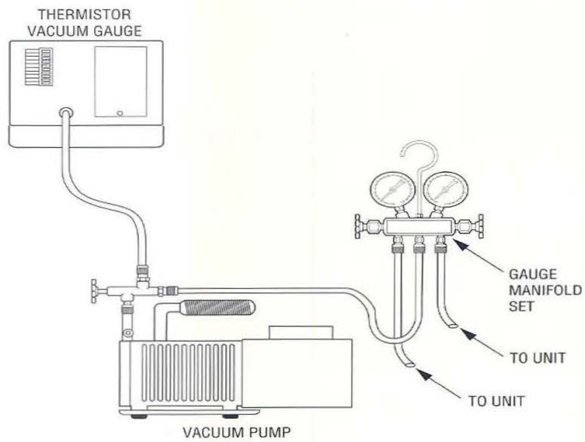


Figure 1-17.
Vacuum Pumps

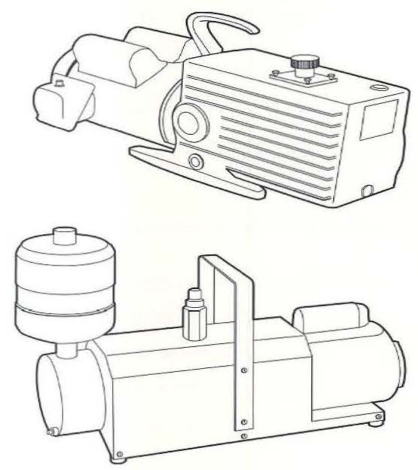


Figure 1-18.
Dial-Type Vacuum Gauge/Indicator

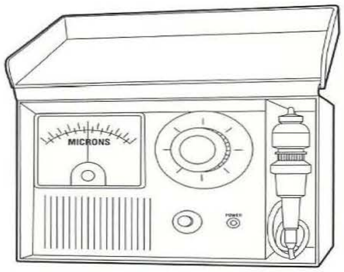


Figure 1-19.
LED-Type Vacuum Gauge/Indicator

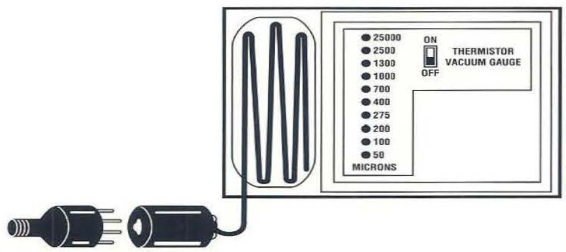
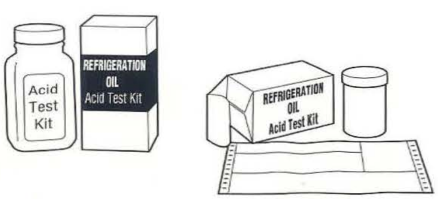


Figure 1-20.
Self-Contained Acid/Moisture Test Kit

Figure 1-21.
Refrigeration Oil Acid Test Kits



The other uses a display consisting of several light emitting diode (LED) indicators. The electronic vacuum gauge/indicator measures absolute pressure in microns. As the vacuum levels go deeper, the needle on the dial moves, indicating lower and lower micron readings. For the LED gauge, the LED indicators, each representing a specific vacuum level in microns, turn off sequentially from the highest micron level to the lowest as the system vacuum pressure goes deeper. For both types of indicators, the lower the measured vacuum reading in microns, the deeper the vacuum being measured.

Test Kit – Acid/Moisture (Item 9)

Acid/moisture kits are one of the methods used to test refrigeration or air conditioning systems for the presence of moisture and/or corrosive acid. Acid/moisture testing is normally performed as a preventive maintenance check or in conjunction with servicing procedures such as system evacuation/dehydration, refrigerant recovery, or refrigerant recycling.

Acid/moisture testing is important because many troubles in the system can be caused by the presence of moisture. Moisture, as it circulates through the system along with the refrigerant and compressor oil, may freeze at the metering device, causing it to become clogged or partly clogged. In conjunction with high temperatures like those encountered in the compressor and condensing units, moisture may cause the refrigerant to break down and form harmful acids, which can lead to compressor motor burnout. In a properly operating system, the compressor oil circulating through the system along with the refrigerant lubricates and cools the compressor. If this oil should become acidic, its ability to supply the needed lubrication and cooling is reduced, which can result in damage to the compressor.

Acid/moisture test kits can be self-contained, as shown in Figure 1-20. This device is attached to a system service port for about 10 minutes to obtain a sample of the refrigerant in the system. A disposable test tube located within the tester contains chemical crystals that change color in the presence of acid and moisture. The tube is removed from the tester after a 10-minute sample period and compared against a color chart to check the acid/moisture content of the sampled gas.

Refrigeration oil acid test kits and oil analysis test kits (Figure 1-21) can also be used to check the quality of refrigeration oil in a system with a semi-hermetic compressor. This method is not commonly used on residential equipment because it is difficult to remove oil from hermetic compressors. Use of these kits normally requires that a sample of the oil be extracted from the system, mixed with the chemicals in the kit, and the oil judged to be good or acidic based on the color of the oil-chemical mixture. Some refrigeration analysis kits require that the oil sample be returned to the kit manufacturer for complete oil analysis.

ELECTRICAL SYSTEM SERVICE INSTRUMENTS AND DEVICES

AC Clamp-On Ammeter (Item 10)

The alternating current (AC) clamp-on ammeter is used to measure the total AC current being drawn by a system or by the individual loads in a system, such as the compressor, fan motors, or heaters. In three-phase systems, it is used to measure the current drawn by each phase to determine the percent of current imbalance.

The main advantage of the clamp-on ammeter is that it allows current measurements to be made without disconnecting any of the circuit wiring. Figure 1-22 shows a clamp-on ammeter connected to measure current. Clamp-on ammeters have a movable set of jaws that can be opened and placed around each of the wires to be measured, one wire at a time. The clamp-on ammeter works like a transformer. The wire being measured acts like the primary of the transformer and the jaws of the ammeter as the secondary. Current flowing through the wire creates a magnetic field that induces a current in the jaws of the clamp-on ammeter. This induced current passes through the meter movement, providing an indication of how much current is passing through the wire. Even though most clamp-on ammeters can also measure voltage and low-level values of resistance, their primary use is for current measurement.

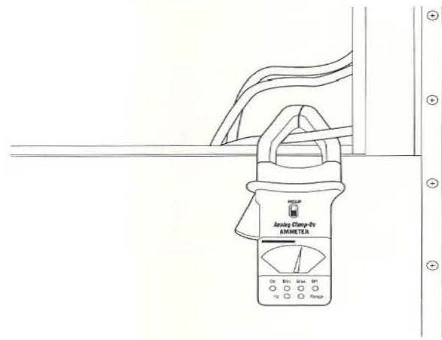
Both analog and digital clamp-on ammeters are available, and are usually capable of measuring up to 300 amperes. Digital meters (Figure 1-23) are popular because of their accuracy and ease of use. Generally, the accuracy of the ammeter increases if it has a number of selectable current ranges. When servicing three-phase equipment where the current imbalance must not exceed 10 percent, the accuracy of the ammeter is extremely important. Analog meters with a full-scale accuracy of ±3% and digital meters with an accuracy of ±2% are typical. Other useful features include rugged construction, the ability to capture and hold surge currents, and protection against meter damage caused by over-ranging.

Volt-Ohm-Milliammeter (Item 11)

The volt-ohm-milliammeter (VOM) is also called a *multimeter*. The multimeter is used for all phases of service work including installation, preventive maintenance, and troubleshooting.

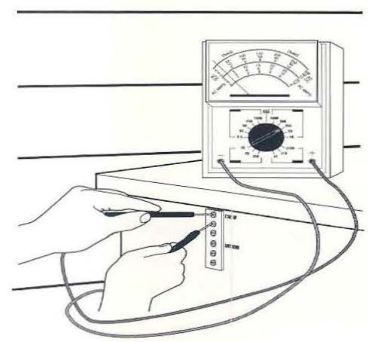
The multimeter is used to measure high-level AC voltages in power and load circuits and low-level AC voltages in control circuits (Figure 1-24). In units containing direct current (DC) operated control circuit devices, it is used to measure low-level DC voltages and currents. In troubleshooting, the multimeter is frequently used to measure voltage and make continuity checks on system and component wiring. It is typically used to check motor windings, relay coils, and motor starter/contactor coils for resistance values and for short, open, or grounded circuits. Another common use of the multimeter is to check the start and run capacitors of motors for a shorted or open condition.

▼ Figure 1-22.
Analog Clamp-On Ammeter Measuring Current

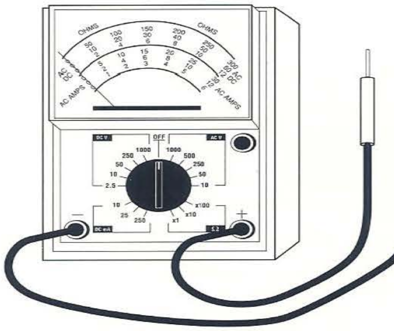


▼ Figure 1-23.
Digital Clamp-On Ammeter

▼ Figure 1-24.
Analog Multimeter Measuring Voltage



▼ Figure 1-25.
Analog Multimeter (VOM)



▼ Figure 1-26.
Digital Multimeter (DMM)

QUICK NOTE

The clamp-on ammeter is the most common tool used for making AC current measurements, but digital multimeters can also be used to measure low-level AC and DC currents in the microampere range. This feature of the digital multimeter is useful for servicing the flame sensing system on heating equipment.

Both pocket-size and hand-held analog multimeters (VOMs) or digital multimeters (DMMs) are used for field service work. Analog multimeters (Figure 1-25) are best for observing changes, instantaneous response, and peak or dip indications when making adjustments. However, the technician must identify the proper scale to use when making measurements and must interpret the pointer location to obtain the reading. Scale divisions may limit resolution. The accuracy of an analog meter is based on percent of full scale reading and is typically in the range of ±1.0 to ±5.0 percent. While electrical protection is normally provided, analog meters can be damaged by measuring in the wrong mode or range.

Digital multimeters (Figure 1-26) have direct-reading, high resolution displays that give accurate readings without the need for scale interpretation. Accuracy is generally in the range of ±0.1 to ±0.5 percent. DMMs normally have fuses for current protection and input limiting on volts and ohms. Because they have no moving parts, digital multimeters are less likely to fail or lose their calibration than analog multimeters.

The multimeter feature most needed for field servicing HVAC equipment is the capability to accurately measure AC voltage over several scales, ranging from 0 volts to 1,000 volts. Generally the multimeter should also measure DC voltages over several ranges, but the 0 to 50-volt DC range is the most important for servicing low-voltage DC control circuits. The full scale accuracy for the readings should be about ±0.5 to ±2 percent.

The multimeter should be capable of measuring resistance over several scales, ranging from 0 ohms to 30 million (meg) ohms. The ability of the multimeter to accurately measure resistance is very important because of the need to make critical motor and relay/solenoid winding resistance measurements as well as checks for shorted, open, or grounded circuits.

Since the clamp-on ammeter is the most frequently used instrument for making AC current measurements, the current-measuring function of the multimeter is not as important as its ability to measure voltage and resistance. However, most of the multimeters that meet the voltage and resistance measurement requirements for HVAC servicing can also measure AC and DC currents over several scales ranging from 0 to 10 amperes. Digital multimeters can normally measure low-level AC and DC currents in the microampere range. This feature is useful for servicing the flame sensing system on heating equipment.

Many special-purpose accessories are available for use with digital multimeters. Thermocouple and thermistor temperature probe accessories and non-contact infrared surface temperature probes enable the digital multimeter to measure temperature. Non-contact probes measure the surface temperature or temperature in a refrigerant line by simply pointing the probe at the surface or line to be measured. Clamp-on ammeter accessories are also available that enable the digital multimeter to be used to measure high-level AC currents up to about 400 amperes.

In addition, there are accessories that enable the digital multimeter to measure pressures up to about 350 psig.

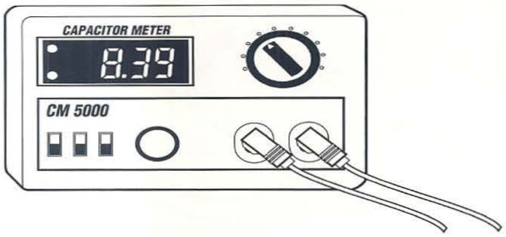
Capacitor Tester (Item 12)

The capacitor tester (Figure 1-27) is used to test capacitors to determine their specific capacitance value and to find out if they are good, open, or shorted. For field service work, most technicians usually test capacitors using the resistance (ohmmeter) function of the VOM.

There are times, however, when it is necessary to determine the actual value of capacitance in microfarads (MFD) for a particular capacitor or group of capacitors. This task cannot be done with most VOMs. The need to determine the actual capacitance value may occur because the value stamped on the capacitor is unreadable. It is also done when it is necessary to wire two or more capacitors in parallel or series to make a substitute capacitor for one that is not readily available. Also, if motor problems persist even though previous tests using a VOM showed the capacitor to be good, you should use the capacitor tester to verify the capacitor's value.

A capacitor tester must be able to quickly and accurately check for leaky, open, or shorted capacitors. It should be capable of measuring the capacitance of capacitors ranging from 0.01 MFD to 10,000 MFD.

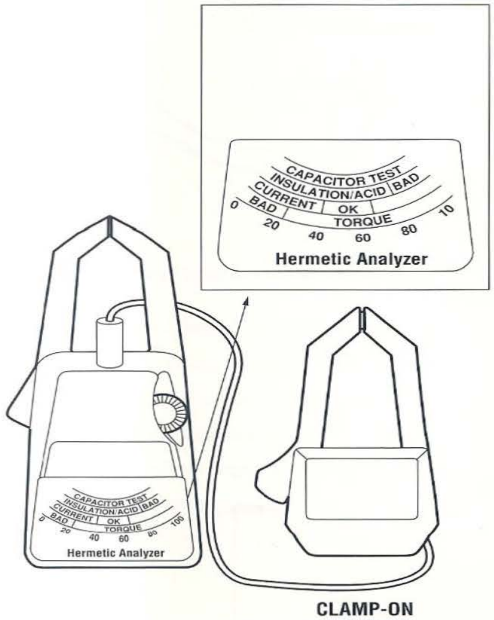
▼ Figure 1-27.
Capacitor Tester



Hermetic Compressor Analyzer (Item 13)

The hermetic compressor analyzer (Figure 1-28) is a single test instrument used to make multiple tests on hermetic compressors. This device eliminates the need for using a combination of other test instruments such as the capacitor tester and volt-ohm-milliammeter. Similar to a clamp-on ammeter, the hermetic compressor analyzer uses clamp-on sensors that allow testing of the compressor without disconnecting the wires. The hermetic compressor analyzer uses computer electronic circuitry to diagnose the problem and guide the service technician directly to the cause. A typical hermetic compressor analyzer can test hermetic compressors in the 200 to 20,000-watt (20 kW) class with current draws ranging from 3 to 200 amperes. It can test a compressor for starting torque, insulation breakdown, mechanically frozen condition, open or shorted capacitors, value of capacitance in MFD, open start or run windings, and open relays.

▼ Figure 1-28.
Hermetic Compressor Analyzer



AIR SYSTEM SERVICE INSTRUMENTS AND DEVICES

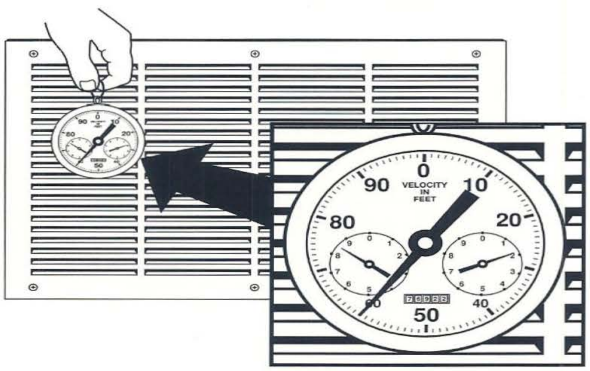
Anemometer (Item 14)

Anemometers are used to measure the velocity of airflow. Measurement of air velocity must be performed when evaluating the total operation of an air distribution system. It must also be done when adjusting an air distribution system to balance the volume of air in cubic feet per minute (CFM).

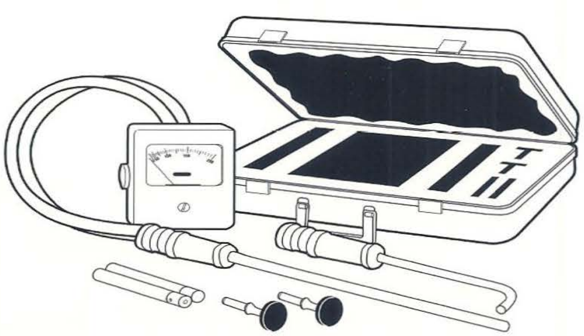
QUICK NOTE

Rotating-vane anemometers require a stop watch and conversions to measure air velocity in FPM, while swinging-vane and hot-wire anemometers measure the air velocity directly.

▼ **Figure 1-29.**
Rotating-Vane Anemometer Used to Measure Supply Grille Output Air Velocity



▼ **Figure 1-30.**
Direct Reading Swinging-Vane Anemometer



When evaluating and/or balancing an air distribution system, the anemometer is used primarily to measure the airflow being delivered to the supply grilles and at the input to the return air grilles. Refer to the discussion on air velocity meters (velometers) in this section for other instruments that are commonly used to measure airflow velocity in air distribution systems.

Rotating-vane, swinging-vane, and hot-wire anemometers are three types in common use. Rotating-vane anemometers require that a stop watch be used to time the air measurement and that calculations and/or corrections be made in order to convert the measured rate of airflow into air velocity in feet per minute (FPM). Swinging-vane and hot-wire anemometers give direct readings of air velocity in FPM. For this reason, they are often called *velometers*.

The *rotating-vane anemometer* (Figure 1-29) has three calibrated velocity dials that are mechanically driven by a nearly frictionless propeller (vane) that rotates on impact with the airstream being measured. In addition to the calibrated dials, the rotating-vane anemometer has a zero reset lever to return all dial readings to zero prior to the start of each measurement. It also has a brake lever to turn the velocity dial mechanism on and off at the start and finish of each timed measurement. Accompanying the instrument should be a calibration chart used to correct the readings.

As shown, the outer scale of the rotating-vane anemometer reads directly from 0 to 100 feet in 1-foot increments; a 100-foot scale on the left reads from 0 to 1,000 feet in 100-foot increments; and a 1,000-foot scale on the right reads from 0 to 10,000 feet in 1,000-foot increments. To measure air velocity in FPM, each measurement made with the anemometer is timed for one minute with a stop watch. The anemometer shown in Figure 1-29 is recording a velocity of 1,860 FPM, which is read from the dials as follows: the 1,000's dial on the right reads more than 1,000 but less than 2,000 = 1,000 feet; the 100's dial on the left reads more than 800 but less than 900 = 800 feet; and the direct dial reads 60 feet. After each measurement or series of measurements, calculations and/or corrections are usually required to convert the measured value of airflow into the real value for airflow velocity in FPM. It is best to make several measurements and then average the results to achieve greater accuracy. To maintain its accuracy, the rotating-vane anemometer must be calibrated periodically against known velocities.

The *swinging-vane anemometer* (Figure 1-30) gives direct readings of velocity. When positioned to make a measurement, the airstream being measured passes through the anemometer sensor probe, causing a precision-balanced vane to tilt at different angles based on the air velocity. The position of the vane determines the velocity reading of the air displayed on the meter scale in FPM. Various attachments such as static pressure tips or pitot tubes are used with the anemometer when measuring supply and return airstreams. Swinging-vane anemometers are available in several velocity ranges from 0 to 2,500 FPM.

A *hot-wire anemometer* (Figure 1-31) provides direct readings of air velocity in FPM. This instrument uses a sensing probe containing a small resistance heater element. When the probe is held perpendicular to the airstream, the temperature of the heater element changes due to variations in the airflow. This causes its resistance to change, which alters the amount of current flow applied to the meter circuitry, where it automatically calculates the air velocity for display on the meter scale or a digital readout.

Velometer (Item 15)

Velometers (Figure 1-32) are used to measure the velocity of airflow. Like the anemometers described previously, velometers are used when evaluating the operation and/or balancing the airflow in air distribution systems. Velometers provide instantaneous, direct readings of air velocity in FPM without the need for timing or calculations. Some can also provide direct readings in CFM.

Several analog and electronic types of velometers are in common use. Sensing probes used with the velometers have a sensitively-balanced vane or a small resistance heater element that when placed in the airstream produces a measurement of airflow for application to the velometer meter scale. Depending on the sensing probe or attachment used, velometers are available to measure air velocities in several ranges within the overall range of 0 to 10,000 FPM. Certain electronic velometers use a microprocessor that can automatically average up to 250 individual readings taken across an area to provide the average air velocity and temperature. Some can also drive an optional micro-printer to record the readings.

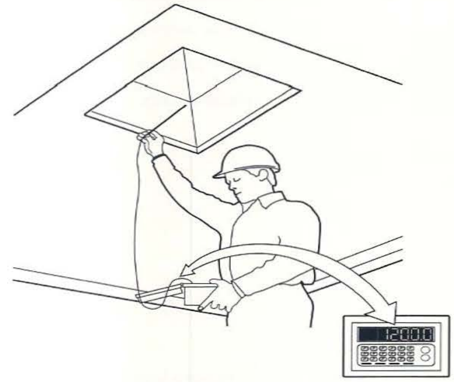
Velometers like the one shown in Figure 1-33 are often called *air volume balancers*. When balancing air distribution systems, this type of velometer is held against the grille to get a direct reading of air velocity in either FPM or CFM.

Another type of velometer, called a *balometer* or *flow hood* (Figure 1-34), is frequently used to get direct velocity readings in CFM when measuring air output or when balancing commercial air distribution systems with large air diffusers.

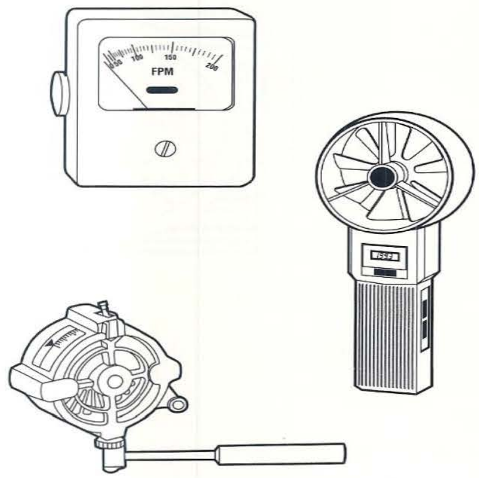
Psychrometric Chart (Item 16)

Psychrometrics is the study of air and its properties, including temperature, pressure, moisture, and other characteristics. Control of these properties is essential for human comfort, optimum equipment operation, and to prevent damage to home furnishings. Psychrometric charts show the relationships of these air properties graphically. A brief description of the psychrometric chart and a discussion of some of its more common uses in servicing HVAC systems will be provided here. For a review of psychrometric theory and instructions for using the psychrometric chart, refer to the many HVAC-related textbooks and other materials that are readily available.

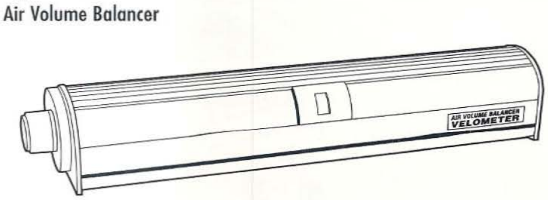
▼ Figure 1-31.
Hot-Wire Anemometer Used to Measure Exhaust Duct Output Air Velocity



▼ Figure 1-32.
Velometers



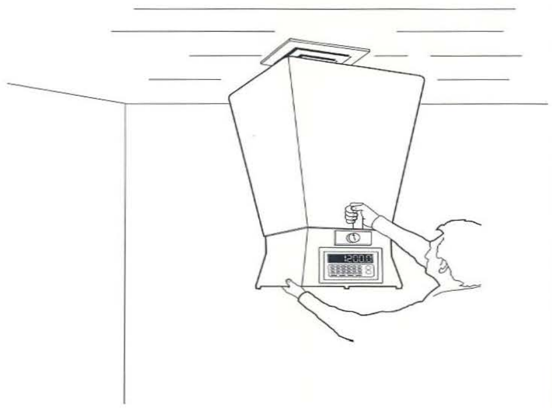
▼ Figure 1-33.
Air Volume Balancer



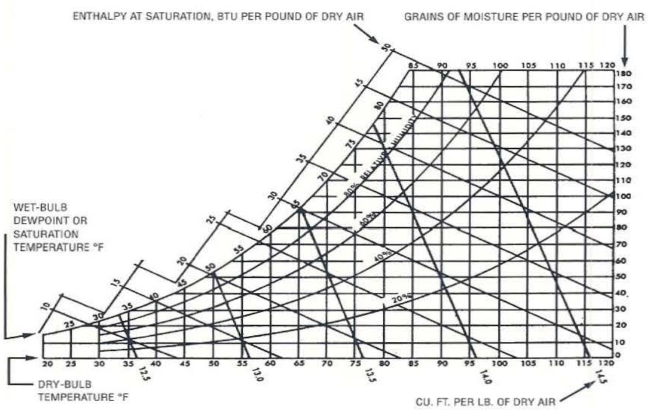
DID YOU KNOW...

... that the psychrometric chart is based on formulas produced by Dr. Willis Carrier in 1911?

▼ **Figure 1-34.**
Flow Hood/Balometer Used to Take CFM Measurements at Ceiling Diffuser



▼ **Figure 1-35.**
Psychrometric Chart



The psychrometric chart (Figure 1-35) is used to determine how each of the following air properties varies as the amount of moisture in the air changes:

- Dry bulb temperature
- Wet bulb temperature
- Enthalpy at saturation
- Relative humidity
- Grains of moisture
- Specific volume
- Dewpoint temperature

Charts are available that graph the air properties at low temperatures (-20 to 50° F), normal temperatures (20 to 110° F), and high temperatures (60 to 250° F) at sea level and at various elevations to correct for changes in barometric pressure. They are also available in metric (SI) form.

Using the easily-measured values of dry bulb and wet bulb temperatures taken with a psychrometer, the psychrometric chart can be used to find the value for one or more of the remaining properties of a given sample of conditioned air. For field service, these temperatures are frequently used to find the relative humidity (RH) of a conditioned space. RH is the ratio of the amount of moisture present in the air to the amount it can hold at saturation. It is expressed as a percentage, and helps to determine the level of indoor comfort that exists in the various rooms of a house or other conditioned space. High relative humidities create moist environments. Potential problems that can occur include loss of personal comfort, development of bacteria, viruses, fungi, and mites, and the warping of wood. On the other hand, low humidity levels may cause respiratory ailments, static electricity, and damage to electronic devices such as computers.

Another common use of the psychrometric chart is to check the capacity of air conditioning equipment. Using the wet bulb temperatures of the airstream entering and leaving the heat exchanger, the enthalpy function of the psychrometric chart is used to find the total heat difference (change in enthalpy) between the two readings in Btu/lb. of air. This value of change in enthalpy, along with the value for the airstream velocity in cubic feet per minute, is used to calculate the equipment capacity in Btu/hr. using the total heat formula shown below.

Btu/Hr. = 4.5* x CFM x Change in Enthalpy (Btu/lb.)

**4.5 is a factor derived when the specific density for standard air is substituted for the specific density of the leaving air.*

One major advantage of the psychrometric chart over other instruments such as a hygrometer (discussed below) is that the chart can be used as an estimating tool to determine the impact of planned modifications.

Hygrometer (Item 17)

Hygrometers (Figure 1-36) are used to measure the relative humidity in a controlled space. Hygrometers are also commonly called *relative humidity meters*. See Item 16 for a description of relative humidity.

Many types of hygrometers are available. The dial-type hygrometer uses a synthetic hair that expands and contracts as the humidity changes. Many humidifiers also work on the same principle. For field service work, the electronic hygrometer is the most common type. Electronic hygrometers have temperature-humidity sensing probes to measure the conditioned air. The measured RH and/or temperature readings are usually displayed on an LCD. Some hygrometers are capable of reading dewpoint. Others, using two or more temperature probes, can calculate the differential temperature between probes.

Some types of hygrometers can display temperature and RH readings simultaneously. Common electronic hygrometers can measure RH in the range of 0 to 98 percent with an accuracy of ±2 percent. They typically measure temperatures in the range from -20° F to 160° F.

Manometers and Pitot Tubes/Static Pressure Tips (Item 18)

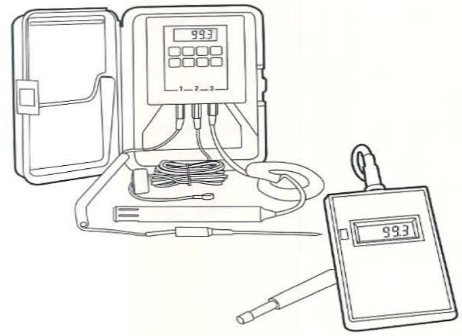
Manometers (Figures 1-37 and 1-38) are used to measure velocity and static air pressures and gas pressures. Pitot tubes and static pressure tips are probes used with manometers to take measurements inside the ductwork of an air distribution system (Figures 1-39 and 1-40).

Most manometers used for HVAC servicing are calibrated in inches of water column (in. w.c.). Manometers with pitot tubes or static pressure tips are used to measure static pressure, velocity pressure, and total pressure in the supply, return, and branch ductwork of air distribution systems. These measurements are used to determine the air quantities supplied to each branch. The measured quantities can be compared to the design specifications to evaluate the overall system performance and to make air supply adjustments as needed. When troubleshooting systems, manometers are often used to measure the pressure drop across the individual components in the system to detect airflow restrictions.

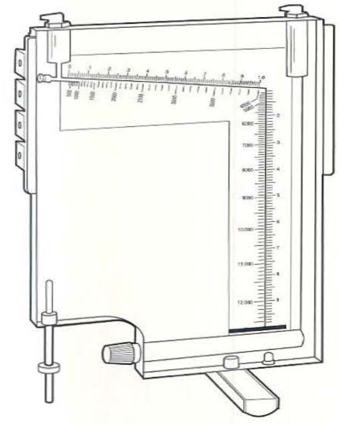
Non-electronic manometers work on the principle that air pressure is indicated by the liquid-level difference between two columns of liquid, one on each side of the manometer. If there is a pressure difference, the column of liquid will move until the liquid level in the low-pressure side is high enough so that its weight and the low air pressure being measured will equal the higher pressure in the other tube. Manometers typically use water or oil as the measuring fluid.

Most manometers used for HVAC servicing are calibrated in inches of water column (in. w.c.) and use an oil with a specific gravity of 0.826 as the measuring fluid. The manufacturer of the gauge specifies the type of oil to be used; therefore, substitution for the specified oil is not recommended. Manometers

▼ Figure 1-36.
Electronic Hygrometers (Relative Humidity Meters)

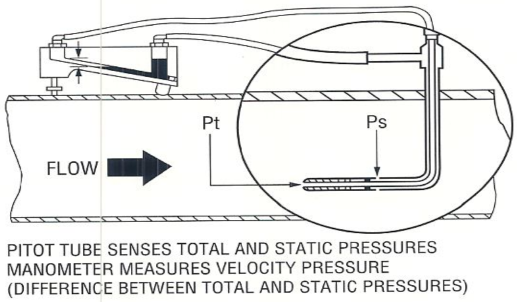


▼ Figure 1-37.
Inclined-Vertical Manometer (Air Velocity Meter)

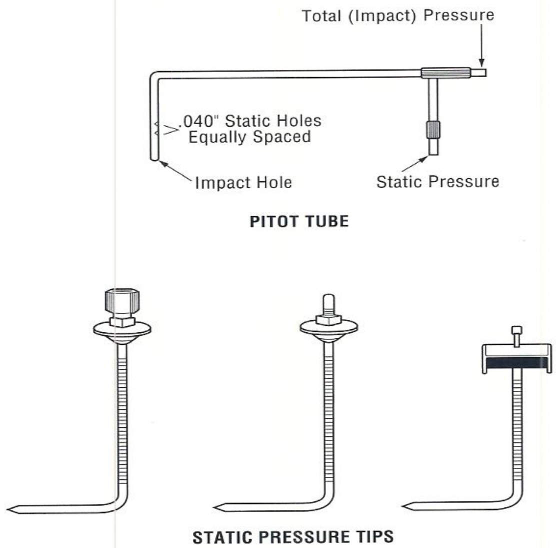


▼ Figure 1-38.
Electronic Manometers

▼ Figure 1-39.
Inclined Manometer and Pitot Tube Connected to Measure Velocity Pressure



▼ Figure 1-40.
Pitot Tube and Static Pressure Tips



QUICK NOTE

For ducts 8 inches in diameter and larger, use a standard pitot tube.

For ducts smaller than 8 inches, use a pocket-size pitot tube.

come in many types, including U-tube, inclined, and combined U-inclined. Electronic manometers are also widely used.

Individual U-tube and inclined manometers are available in many pressure ranges. Inclined manometers are usually calibrated in the lower pressure ranges and are more sensitive than U-tube manometers. U-inclined manometers combine the sensitivity of the inclined manometer with the high-range capability of the U-tube manometer in one instrument. Inclined-vertical manometers, often called *air velocity meters*, also combine an inclined section for high accuracy and a vertical manometer section for extended range. They have an additional scale that indicates air velocity in feet per minute (FPM).

Electronic manometers typically measure differential pressures of -1 to 10 in. w.c. Many can give direct air velocity readings in the range of 300 to 9,990 FPM, eliminating the need for calculations.

The standard pitot tube used for making measurements in ducts 8 inches in diameter and larger has a 5/16-inch outer tube with eight equally-spaced 0.04-inch diameter holes used to sense static pressure. For measurements in ducts smaller than eight inches, use of pocket-size pitot tubes with a 1/8-inch outer tube and four equally-spaced 0.04-inch diameter holes is recommended.

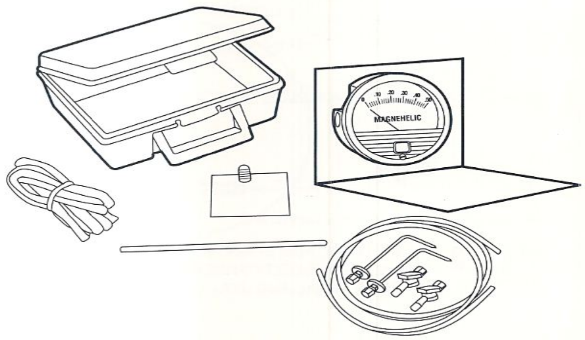
The pitot tube consists of an impact tube which receives the total pressure input. It is fastened concentrically inside a second tube of slightly larger diameter, which receives static pressure input from the radial sensing holes around the tip. The air space between the inner and outer tubes permits transfer of pressure from the sensing holes to the static pressure connection at the opposite end of the pitot tube, and then through the connecting tubing to the low or negative pressure side of the manometer. When the total pressure tube is connected to the high side of the manometer, velocity pressure is indicated directly. To insure accurate velocity pressure readings, the pitot tube tip must be pointed directly into the duct airstream. Pitot tubes come in various lengths ranging from 6 to 60 inches with graduation marks at every inch to show the depth of insertion in the duct.

Like the pitot tube, static pressure tips are used with manometers and differential pressure gauges to measure static pressure in a duct system. They are typically L-shaped with four radially-drilled 0.04-inch sensing holes.

Magnehelic® (Differential Pressure) Gauge (Item 19)

Magnehelic® differential pressure gauges provide a direct reading of pressure and/or air velocity. These gauges are used to measure filter resistance, air velocity, and furnace draft. Magnehelic® gauges capable of measuring just pressure or both pressure and air velocity are available. Single-scale pressure models, calibrated either in inches water column (in. w.c.) or psi, are common. Dual-scale gauges are normally calibrated for pressure in in. w.c. and for air velocity in feet per minute (FPM). Several models with dual-scale gauges are available. They cover pressures from 0.0 to 10 in. w.c. and air velocity ranges from 300 to 12,500 FPM. Generally, Magnehelic® gauges are permanently installed in the equipment, but portable models like the one shown in Figure 1-41 are also available. Like manometers, pitot tubes and/or static pressure tips are accessories frequently used with portable Magnehelic® gauges to make air pressure and velocity measurements in air distribution system ductwork.

▼ Figure 1-41.
Portable Magnehelic® Pressure/Air Velocity Gauge



SECTION TWO
SAFETY

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SECTION 2
SAFETY

INTRODUCTION

This section summarizes general safety information for persons involved with the installation, operation, and maintenance of Heating, Ventilating, and Air Conditioning (HVAC) equipment. Be careful! Working on HVAC systems means that you will encounter many potentially dangerous situations involving:

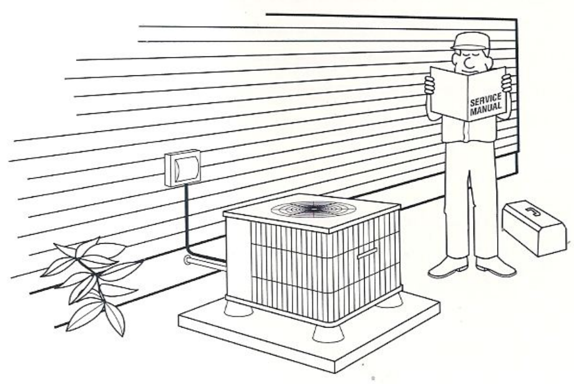
- Equipment containing liquids and gases under pressure.
- Energized electrical equipment.
- Contact with extremely hot and cold equipment surfaces.
- Rotating machinery.
- Contact with chemicals and hazardous materials.
- Installation and repair work involving movement of heavy objects.

Only trained and qualified service personnel should install or service HVAC equipment (Figure 2-1). Untrained personnel may perform basic maintenance tasks such as cleaning and replacing filters with little supervision. However, unfamiliar servicing tasks must be performed by (or under the supervision of) an experienced service technician.

The final responsibility for on-the-job safety rests with you. Job and construction sites can be hazardous places to work, but an awareness of the information provided in this section will help you avoid injuring yourself or damaging equipment. The safety instructions given in this section and the remainder of this manual are general in nature and are not to be used as a substitute for the manufacturer's instructions. No attempt should be made by anyone to install, operate, adjust, repair, or dismantle any equipment until the manufacturer's specific instructions have been read and are thoroughly understood (Figure 2-2).

Figure 2-1.
Always Learn New Skills Under the Supervision of a Qualified Service Technician

Figure 2-2.
Read and Follow Specific Instructions in Manufacturer's Service Literature



PERSONAL SAFETY

Personal Safety Equipment

Many on-the-job injuries occur because workers do not use personal protective equipment (Figure 2-3). The exact type of personal safety equipment depends on the potential hazards involved and on the local and/or Occupational Safety and Health Administration (OSHA) rules that apply to the job site. The most common items of personal safety equipment you will use as an HVAC technician are:

- Hard Hat – Protects head from hard blows and falling objects.
- Safety Glasses or Goggles – Protect eyes from flying objects or chemical splashes.
- Gloves – Protect hands from cuts, scrapes, burns, and chemical or refrigerant spills.
- Safety Shoes – Protect feet from falling objects and prevent sharp objects from puncturing the foot.
- Ear Plugs/Muffs – Protect ears from exposure to high noise levels.
- Respirator – Protects against breathing hazards or suffocation that might occur in the presence of certain refrigerants or other gases.
- Safety Harness/Lanyard – Prevents falls when working more than six feet above the ground or near deep holes.

To ensure that safety and protective equipment provides the intended protection, it should:

- Be inspected regularly.
- Be cared for properly as directed by the manufacturer's instructions.
- Be used properly, when needed, as directed by the manufacturer's instructions.
- Never be altered or modified in any way.

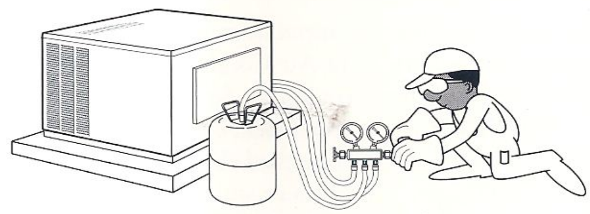
Loose-Fitting Clothing and Jewelry Hazards

Rings or other jewelry, neckties, cloth gloves, or loose-fitting clothing must not be worn when working around equipment with rotating or moving components. Motors that drive fans, compressors, and pumps are an example. If jewelry or clothing becomes caught in a motor drive pulley or coupling, severe injury could occur. Rings or watches must not be worn when working around energized electrical equipment (Figure 2-4). Contact between the jewelry and an energized circuit may result in electric shock, injury, or death.

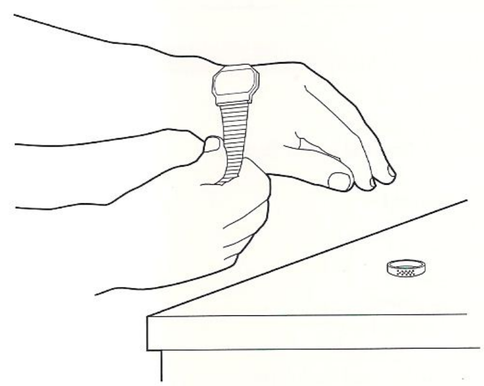
Lifting

Lifting or moving heavy objects causes many injuries. Lift with your legs rather than your back, because your leg muscles are stronger. When lifting heavy objects, wear a back support belt or similar device for added protection from injury. Use the following procedure to lift heavy objects (Figure 2-5).

▼ Figure 2-3.
HVAC Technician Wearing Safety Glasses and Gloves



▼ Figure 2-4.
Remove Watches and Other Jewelry Before Servicing Equipment



▼ Figure 2-5.
How to Lift Safely

QUICK NOTE

If the object is too heavy to lift comfortably, ask for assistance or use a hoist or other lifting device. Remember, it is a lot easier to ask for help than it is to nurse an injured back!

- Move close to the object to be lifted.
- Squat down. Keep your back straight and chin tucked in. Position one foot behind the other with the forward foot at the side of the object.
- Grip the object from underneath using whole hands (not just fingertips), wrap your arms around it, or use lifting handles when provided.
- Draw the object close to your body.
- Lift the object by slowly straightening your legs. Keep the weight centered over your legs as much as possible. If possible, pick the object up in the direction of travel to avoid twisting your back or knees.

ELECTRICAL EQUIPMENT

When working on electrical equipment, always observe the precautions in the service literature, on tags, and on labels attached to or shipped with the unit. Perform all work to meet the local and national electrical codes. For additional guidance, refer to the current issue of the National Electrical Code (NEC).

Electricity can be dangerous, but if you develop the proper safety attitude about working with it, you should have no problems. Working on HVAC equipment involves working near exposed electrical components and/or conductors. This can expose you to the potential hazards of electric shocks and burns.

Electric Shock

Electric shock happens when electrical current flows through your body. It can damage your heart by causing it to beat erratically or it might even cause it to stop, resulting in death. High voltage levels, such as 120 volts AC or 240 volts AC, are always dangerous. However, even low voltages can be lethal (Figure 2-6).

Many technicians think of DC voltages as low and relatively safe. In most cases, this is true. However, you can encounter high DC voltage in HVAC equipment that can be quite dangerous. Exercise caution in these situations.

Usually, the high resistance presented by the human body will prevent harm from low voltage. However, when skin is moist, or damaged as from a cut, the resistance of your body is greatly reduced. Under such conditions, even 40 volts or less can present a hazard. To prevent shocks, bodily contact between live (hot) circuits or a live circuit and ground must be avoided.

Circuit breakers with built-in Ground Fault Circuit Interrupters (GFCI) may be used to protect HVAC equipment. These circuit breakers protect the equipment from current overload. They also help to protect individuals against shock. The GFCI device in the circuit breaker can detect a small current leak to ground, causing the circuit breaker to trip and open the circuit. Such a leak may not be detected by a conventional circuit breaker.

Figure 2-6.
Both High and Low Voltages can be Dangerous

BE CAREFUL!

- **HIGH VOLTAGE IS ALWAYS DANGEROUS.**
- **EVEN 40 VOLTS CAN BE LETHAL IF SKIN IS WET OR DAMAGED.**

Portable, plug-in GFCI devices like the one shown in Figure 2-7 are available that turn a standard utility outlet receptacle into a GFCI-protected circuit. GFCI-protected extension cords are also available. Use them for added protection against potential shock from an electrically-shorted power tool.

Electrical shock can result from using defective and/or improperly grounded power tools or from connecting power tools to improperly grounded utility circuits. Use only approved tools, equipment, and safety devices. Before use, always make sure that the tools, equipment, and safety devices are working properly and are in good condition.

When using tools or extension cords that have three-prong plugs, never remove or alter the grounding prong on the three-prone plug in order to insert it into a two-prong electrical utility outlet. If you must connect equipment to a two-prong outlet, always do so using an approved adapter with a green grounding lug. Make sure you connect the adapter grounding lug to a known ground such as a properly grounded outlet box. Since many outlet boxes are not properly grounded, always use a multimeter to verify that a good ground connection exists.

Electrical Burns

Electrical energy can pass for short distances through air. When it does, the arc and flash can cause burns, fires, and even explosions. Burns resulting from electrical arcs, such as in a short circuit to ground, can be extensive and deep. More serious ones can even result in amputation of the affected limb.

Lock Out/Tagout

Whenever possible, shut off electrical power at the disconnect or service entrance panel before working on HVAC equipment. As shown in Figure 2-8, the disconnect or panel should be locked in the off position with a padlock and tagged (lock out/tagout) to make others aware that service is in progress. Never assume that the equipment is "dead." Use a meter to verify it.

If you must perform a test with power applied, do not wear rings, watches, or other metal jewelry. Follow the safety guidelines listed below when you must work on equipment with the power on:

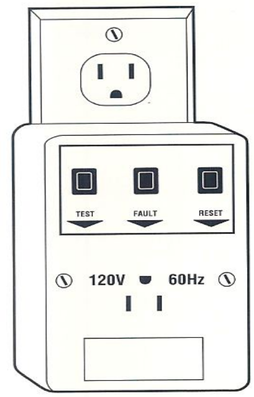
- Have only one hand in the unit.
- Avoid working in wet or damp conditions.
- Avoid working in poor light or when tired.
- Unless required by the manufacturer's service procedure, do not bypass safety devices such as door interlock switches.
- Make sure all grounds are connected properly.

MECHANICAL EQUIPMENT

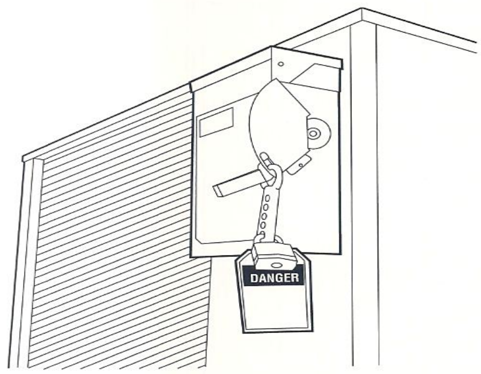
Rotating and Moving Parts

Equipment should not be operated without the coupling or belt guards installed, even if for only a short interval such as when checking motor rotation.

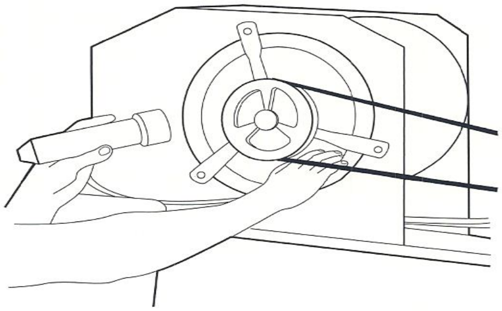
▼ Figure 2-7.
Portable Ground Fault Circuit Interrupter (GFCI) Module



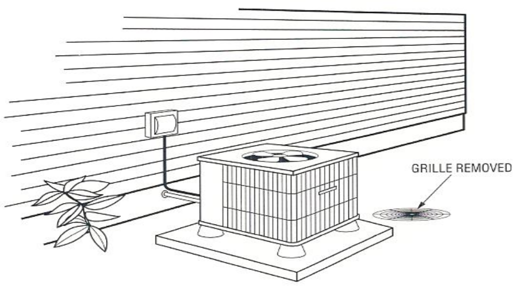
▼ Figure 2-8.
Lock Out/Tagout Equipment Disconnect Switch



▼ Figure 2-9.
Deenergize, Lock Out, and Tag Equipment Before Removing Guards to Service Rotating Components



▼ Figure 2-10.
Never Attempt Service Until All Rotating and Moving Parts have Stopped



QUICK NOTE

Even equipment that appears familiar may have special model differences from year to year. NEVER ASSUME ANYTHING! Always review and follow the manufacturer's instructions when deenergizing and servicing any equipment.

When servicing equipment, guards should not be removed from the equipment until it is deenergized, locked out, and tagged (Figure 2-9). After removing electrical power from a unit, never attempt to service it until all rotating and moving parts have come to a complete stop (Figure 2-10). Never try to stop a coasting motor or fan blade. If you grip the motor shaft, belt drive, pulley, or blades, the momentum can dismember or cut your hand severely or pull your hand into the rotating mechanism.

Loose hardware thrown from a rotating component can be deadly. All set screws and other attaching hardware must be tightened to specifications before starting a motor or other moving part. It is a good practice to tighten all coupling bolts twice to be sure that none have been overlooked.

Sharp Objects

Contact with sharp metal edges and other objects can cause injury. Be careful to avoid such contact when removing or replacing parts.

Hot and Cold Surfaces and Work Areas

Contact with hot surfaces can burn your skin and leave permanent scars. These surfaces include: furnace burners, heat exchangers, flues, electric heating elements, compressors, motors, and refrigerant lines.

Take care when soldering or brazing. High heat is present in the torch flame and the area surrounding the parts being soldered or brazed. When soldering or brazing, keep a fire extinguisher close by and know how to use it. Also, avoid wearing clothing made from man-made materials such as polyester because these materials can turn into molten plastic should a flame accidentally come in contact with the clothing.

Cold surfaces can be as harmful as hot ones. Contact with extremely cold metal surfaces can result in frostbite or other injury. Frostbite can also result from prolonged exposure to cold when working outdoors or inside a freezer or cold storage room.

REFRIGERANT AND OTHER PRESSURIZED GASES

Exposure to Refrigerants

Gloves and safety glasses must be worn when working with refrigerants. Avoid getting refrigerant on the skin or into your eyes. When accidentally released to the atmosphere, refrigerant can cause frostbite or burn the skin.

All refrigerants can cause suffocation if the concentration and time of exposure are great enough. Always provide adequate ventilation when working with refrigerants. Refrigerant vapor is invisible, usually has little or no odor, and is heavier than air. Therefore, be especially careful of low places where it might accumulate.

Equipment rooms or other areas with large machines holding large amounts of refrigerant must have alarm systems which detect small amounts of leakage and sound an alarm. Refrigerants increase dramatically in toxicity when exposed to an open flame or a hot surface. Self-contained breathing apparatus must be available outside the equipment room or other area containing large equipment in case leakage occurs and entry into the contaminated area becomes necessary. Some equipment rooms have a mechanical ventilation system to clear contaminated air from the room.

Refrigerant Containers

See Figure 2-11. Low-pressure refrigerants CFC-11, CFC-113, and HCFC-123 come in standard steel drums or cylinders. Their boiling point is close to, or slightly above, ambient temperature. The pressure they exert on the container is much less than that of medium and high-pressure refrigerants such as CFC-12, HCFC-22, HFC-134a, CFC-500, and CFC-502. These refrigerants are liquefied compressed gases. If improperly handled, the pressurized containers that hold these refrigerants can burst or leak, causing damage, injury, or even death.

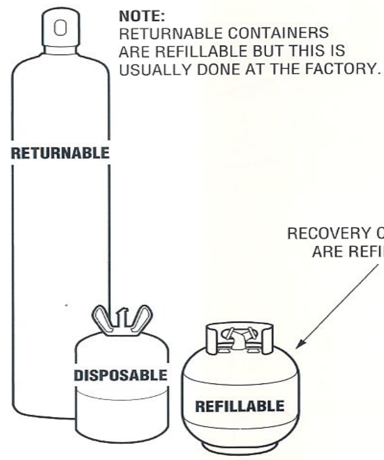
Medium and high-pressure refrigerants come in either returnable or disposable metal containers which vary in shape and size. They range in capacity from about one pound of refrigerant to 1,000 pounds or more. ***Do not reuse disposable (nonreturnable) containers nor attempt to refill them.*** Disposable containers are made from common steel, which can rust. Rust weakens the container walls and seams so that they can no longer hold pressure and contain gases. Disposable cylinders should be stored in dry locations to prevent rusting, and transported carefully to prevent abrasion of their painted surfaces. Keep disposable containers in their original cartons as an added measure of protection.

Refillable refrigerant containers must not be filled with more than 80% liquid. Never exceed their rated capacity in pounds as expressed by the net weight on the cylinder label. Be sure to take into account the container weight ("tare lbs.") when estimating the net weight of refrigerant in a cylinder. Excess liquid in a cylinder causes hydrostatic pressure that can result in an explosion. Hydrostatic pressure increases rapidly with even small changes in temperature.

NEVER HEAT A CYLINDER WITH AN OPEN FLAME OR PLACE AN ELECTRIC RESISTANCE HEATER IN DIRECT CONTACT WITH IT. If it is necessary to warm a cylinder, do it gradually and evenly with warm water (Figure 2-12). Do not exceed 125° F on any part of the cylinder.

Always double check to be sure you are using the proper refrigerant. The containers are color-coded and are also labeled to identify their contents. Container labels also include product, safety, and warning information.

Figure 2-11.
Refrigerant Containers



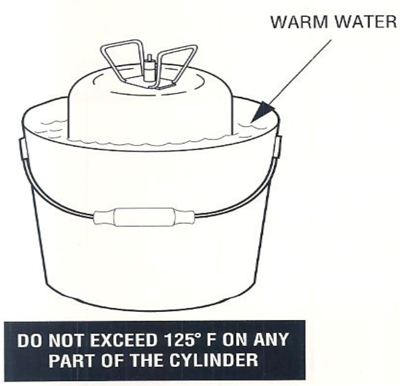
Color Codes

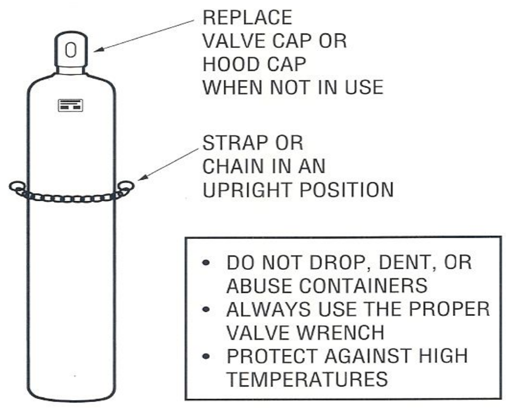
HCFC-22 Green	CFC-11 Orange
CFC-12 White	CFC-113 Dark Purple
CFC-500 Yellow	HFC-134a Light Blue
CFC-502 Purple	HCFC-123 Grey

CAUTION

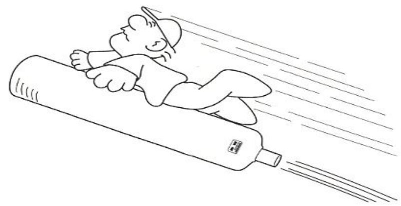
Figure 2-12.
Warming Cylinder with Warm Water

WARNING

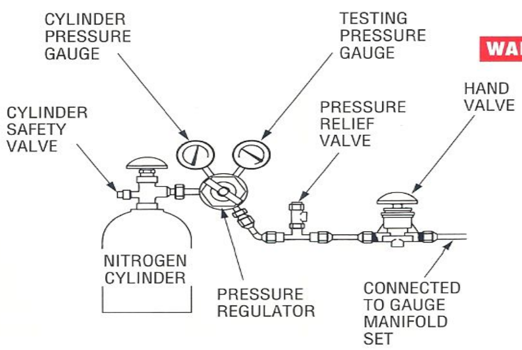




▼ **Figure 2-13.**
Refrigerant Container Safety



▼ **Figure 2-14.**
Compressed Gas Cylinder Becomes a Dangerous Projectile if Valve is Broken Off



▼ **Figure 2-15.**
Gauge-Equipped Pressure Regulator Used with Nitrogen

Technical bulletins and Material Safety Data Sheets (MSDS) available from the manufacturers provide information important to your health and safety. They describe the flammability, toxicity, reactance, and health problems that could be caused by a particular refrigerant if spilled or incorrectly used.

In addition to the precautions described above, follow these rules when handling and using refrigerant containers (Figure 2-13):

- Do not drop, dent, or abuse refrigerant containers. Do not tamper with safety devices.
- Always use a proper valve wrench to open and close the valve.
- Replace the valve cap and hood cap to protect the cylinder valve when not in use or empty.
- Secure containers in place to prevent them from becoming damaged from moving around, especially in a van or truck. Strap or chain cylinders in an upright position.
- Do not store containers where the temperature can exceed the cylinder relief valve settings.

Other Pressurized Gas Hazards

Nitrogen, oxygen, acetylene, and LP gases are commonly used when servicing HVAC equipment. These gases are compressed and shipped under medium to high pressures in cylinders. Because their use is so common, technicians often get careless about handling them.

Nitrogen – Nitrogen is supplied in cylinders at pressures of about 2,000 psi. These cylinders must not be moved unless the protective caps are in place. Dropping a cylinder without the cap installed may result in breaking the valve off the cylinder. This allows the pressure inside to escape, causing the cylinder to propel like a rocket (Figure 2-14). Store nitrogen cylinders in an upright position and away from all flammable and combustible materials.

Because of the high pressure, a gauge-equipped pressure regulator must be used on the nitrogen tank (Figure 2-15). In addition, a relief valve must be installed in the pressure feed line to limit the pressure to a safe level for use in the equipment being serviced.

WARNING

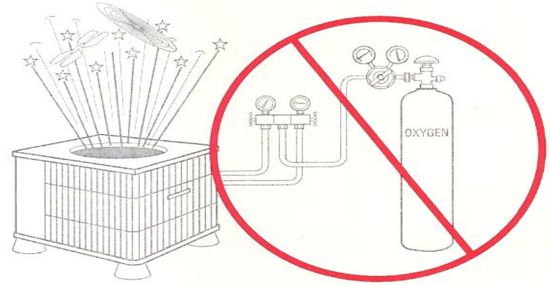
NEVER CONNECT BOTH A REFRIGERANT CYLINDER AND A REGULATOR-EQUIPPED NITROGEN CYLINDER TO THE EQUIPMENT AT THE SAME TIME BECAUSE THE HIGHER PRESSURE NITROGEN CAN CAUSE THE REFRIGERANT CYLINDER TO EXPLODE.

Oxygen – Like nitrogen, oxygen is supplied in cylinders at pressures of about 2,000 psi. When handling oxygen cylinders, follow the same precautions for handling nitrogen cylinders.

Oxygen can cause ignition even when no flame or spark is present, especially when it comes into contact with oil or grease (Figure 2-16). ***OXYGEN MUST NEVER BE USED TO PRESSURIZE A SYSTEM SINCE AN EXPLOSION HAZARD EXISTS WHEN OIL AND OXYGEN ARE MIXED.*** Never handle oxygen cylinders with oily hands or gloves. Keep oil and grease away from the cylinders and cylinder attachments or valves. Store oxygen in an upright position and away from all flammable and combustible materials, including gases like acetylene. There should be a minimum of 20 feet separating oxygen cylinders from fuel cylinders in storage, or a 1/2 hour minimum fire-rated wall 5 feet high separating them. Never use an oxygen regulator for any other gas and never use a regulator for oxygen that has been used for other service.

WARNING

▼ Figure 2-16.
Oxygen Mixed with Oil can Cause an Explosion



Acetylene – Acetylene cylinders are pressurized at about 250 psi. Even with its much lower pressure, acetylene should be handled with the same precautions as nitrogen and oxygen because acetylene is flammable. A pressure-reducing regulator must be used and set at a pressure of not more than 15 psig. Acetylene becomes unstable and volatile above 15 psig. The valve wrench should be left in position on open acetylene valves. This enables quick closing in an emergency. It is a good practice to open the acetylene valve as little as possible, but never more than 1-1/4 turns. Also, be sure not to use a torch tip that will exceed the flow capacity of the cylinder type (MC or B) being used. Use of too large a tip can result in excess flow from the cylinder, causing the tank absorbent (acetone) to be drawn from the cylinder and flow into the regulator, hose, and torch. This can occur when small multiple-flame (rose bud) tips are used with an "MC" cylinder or large rose bud tips are used with a "B" cylinder.

Liquid Petroleum (LP) – LP gases such as propane and butane are usually pressurized at less than 300 psi and should be handled with the same precautions as nitrogen and oxygen. LP gas is heavier than air and explosive. It is normally used as a fuel gas in furnaces. As with the other gases discussed, a pressure-reducing regulator must be used. Gloves and safety glasses must be worn when working with LP gas. When accidentally released to the atmosphere, LP gas can cause frostbite or burn the skin. Do not use pure LP gas in a furnace set up for natural gas because an unsafe condition will be created. If using LP gas for soldering, be sure not to turn the cylinder upside down. This allows liquid fuel to flow into the torch and may cause an explosion.

Figure 2-17 summarizes the cylinder pressures of common gases.

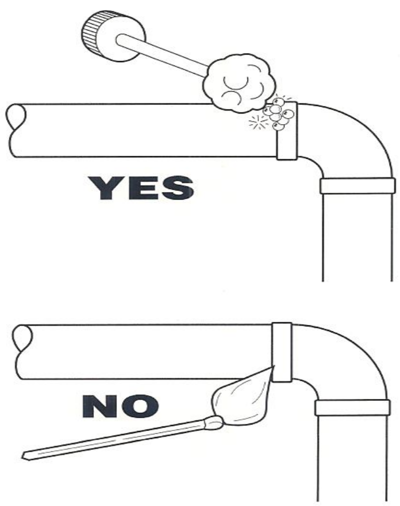
▼ Figure 2-17.
Cylinder Pressures of Common Gases

GAS	PRESSURE
NITROGEN	2,000 psi
OXYGEN	2,000 psi
ACETYLENE	250 psi
LIQUID PETROLEUM	<300 psi

GAS AND OIL HEATING EQUIPMENT

When working on heating equipment, always observe the precautions in the service literature, on tags, and on labels attached to or shipped with the unit. Perform all work to meet the local and national gas or oil codes. For additional guidance, refer to the current issues of the National Fuel Gas Code (NFPA No. 54/ANSI Z223.1) and/or the National Fire Protection Association Code.

▼ Figure 2-18.
Never Use an Open Flame to Check for Leaks



Gas Leaks

Heating equipment can be hazardous due to the combustible fuels involved. Natural gas can be dangerous because it can displace oxygen in the air and, if it accumulates, can be explosive. LP gases are heavier than air and can collect in low places to form pockets of highly explosive gas. All fuel gases have odorants added to make leak detection easier. If a leak occurs that causes gas to collect inside a building, the following immediate actions should be taken:

- Clear the area of all occupants. Do not re-enter until safe.
- Notify the local gas utility.
- Shut off the supply of gas.
- Use every reasonable means to eliminate sources of ignition. Do not operate electric switches. If lights are already turned on, do not turn them off. If turned off, leave them off.
- Ventilate the area by opening windows and doors.
- Never use matches, candles, a flame, or other sources of ignition to check for gas leaks. Use a soap and water solution (Figure 2-18).
- Use only a battery-operated flashlight or approved safety lamp when searching for the leak.

Oil Leaks

Fuel oil on the floor or an accumulation in the furnace combustion chamber are usually signs of a leak. Leaking fuel oil in the presence of air and an ignition source can result in a fire. As a precaution to prevent leaks, compression fittings should not be used to pipe an oil-burning system. Absorb and clean any oil spilled on the floor with rags, absorbant, a suction pump, shop vacuum, etc. (Figure 2-19).

▼ Figure 2-19.
Always Clean Up Oil Leaks Immediately

Care should be taken not to start a furnace if any oil has accumulated in the combustion chamber. If oil has accumulated, shut off the oil valves and vent the chamber. Turn off the electrical power. Remove the oil with a suction pump until all danger is gone.

If the puddle of accumulated oil is ignited, it will burn intensely. You may not be able to extinguish the fire: it will have to burn itself out. If this happens:

- Notify the fire department.
- Shut off the burner motor but allow the furnace fan to run to help dissipate the heat.

- Shut off the air shutter to reduce the air to the burner.
- Let the fire burn itself out with reduced air.

Standing Leak Test and Purging

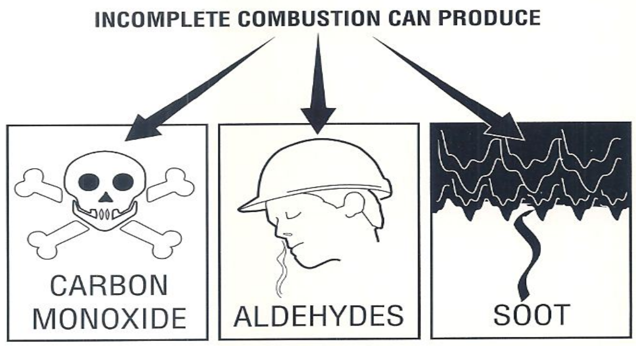
OXYGEN MUST NEVER BE USED TO LEAK TEST OR PURGE A GAS OR OIL FURNACE PIPING SYSTEM SINCE AN EXPLOSION HAZARD EXISTS WHEN OIL AND OXYGEN ARE MIXED.

After the leak test of a gas furnace is completed, the gas trapped in the system should be purged in a well-ventilated area to rid the system of air or other gases. When doing so, be careful not to purge the gas where it will collect in the furnace combustion chamber. After purging, but before operating the unit, it is a good practice to wait at least 5 minutes to allow any accumulated gas to dissipate. When lighting the furnace pilot, never stand in front of or look into the combustion chamber.

Incomplete Combustion

Only experienced technicians should make furnace combustion adjustments and then only as directed by the manufacturer's instructions. Fuel and combustion air must be mixed safely. Incorrect gas or oil pressure, wrong orifice type or size, or improper burner position or adjustment can result in incomplete combustion. This causes the furnace to produce aldehydes, soot, and carbon monoxide gas (CO) (Figure 2-20). Carbon monoxide gas is deadly. Prolonged breathing of carbon monoxide can result in sickness or death. An inadequate supply of primary or secondary air to the burners caused by some restriction to airflow can cause flame rollout, possibly starting a fire.

Figure 2-20.
Incomplete Combustion



Other Gas and Oil Heating Precautions

In addition to the safety precautions discussed above, the following guidelines should be observed when servicing gas and oil heating equipment:

- Gas, oil, and electricity should be turned on only when it is necessary to check the operation of a component or the furnace. At all other times during equipment maintenance, they should be turned off.
- Gas and oil furnaces should not be installed where flammable vapors or combustible materials exist.
- Never operate a furnace with a corroded, pitted, or cracked heat exchanger. Leaking combustion gases may cause sickness or death.
- Do not jumper limit switches or other safety devices. These devices protect the furnace, building, and occupants from fire or damage caused by malfunctions that result in overheating.

- Gas and oil furnaces must be properly vented to avoid leaking carbon monoxide in the heated area should the furnace combustion be incomplete. Also, any vent gases that leak into the heated area will reduce the oxygen level.
- Be extremely cautious when working around energized pilot lights, electronic spark igniters, and oil furnace ignition circuits. The control transformer secondary voltage and electrodes of some ignition devices operate in the range of about 10,000 to 20,000 volts.

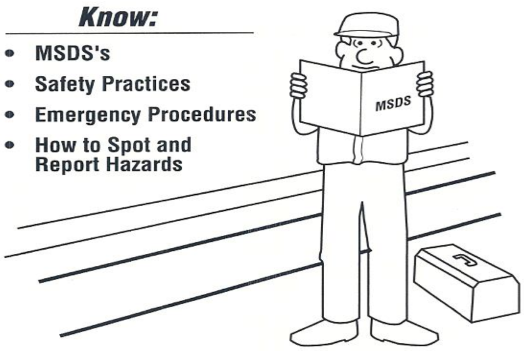
GENERAL SAFETY AWARENESS

Hazard Communication Standard

The work place contains many hazards that need to be recognized and respected (Figure 2-21). The OSHA Hazard Communication Standard (HazCom), commonly called the "Right To Know" requirement, affects every worker. It addresses the worker's right to know the specifics about any major environmental, chemical, biological, physical, or radiation hazards that may exist at the job site. It requires that a Material Safety Data Sheet (MSDS) accompany every shipment of a hazardous chemical or substance and be available to you on the job site. It is your responsibility to:

- Read the Material Safety Data Sheets that pertain to your work and work location to identify any physical and health hazards.
- Know and practice the actions necessary to protect yourself and others from any hazards. Know the actions to take in an emergency.
- Spot and report potential hazards on the job.

▼ Figure 2-21.
Safety Depends on Your Awareness



Confined Spaces

Installation and service work is not always done outside or in open areas. Much of it takes place in confined spaces. A confined space is any area that cannot be easily ventilated, such as a basement equipment room. Confined spaces can contain hazardous gases and/or fluids when the equipment is operating. Work you are doing, such as soldering and brazing, may introduce hazardous fumes into the space. To ensure safety, special precautions are needed before entering, and while working in, a confined space. You should:

- Have one person inside and one outside the confined space. Voice or visual contact should be maintained to identify the need for aid in case of an emergency.
- Keep rescue equipment ready for an emergency.
- Use respiratory protection equipment when required (Figure 2-22). If in doubt, have air sample readings taken to check for low levels of oxygen and/or explosive gases.
- Use only approved electrical tools, extension cords, etc.

▼ Figure 2-22.
Use Respiratory Equipment when Required

Hazardous Waste Management

Waste such as used oil or refrigerant, used chlorinated solvents, chemical treatment solutions, acids, etc. may contain toxic components that require special handling and proper disposal at an EPA-approved waste management facility. When working with hazardous waste, you should:

- Be knowledgeable about the use of chemicals from the Material Safety Data Sheets and follow the manufacturer's instructions.
- Wear the proper protective equipment, safety goggles, rubber gloves, and aprons when handling or containing hazardous waste.
- Use only EPA/DOT-approved containers for storage, transport, and disposal of hazardous wastes. Make sure the content of the container is identified by the proper EPA/DOT label containing all the required information.

SUMMARY OF DANGERS, WARNINGS, CAUTIONS, AND SAFETY INSTRUCTIONS

The terms *DANGER*, *WARNING*, and *CAUTION* have specific meanings that identify the degree of hazard. The definitions shown in Figure 2-23 are typical of those used in the HVAC industry to prioritize safety hazards.

Figures 2-24 through 2-31 contain the safety precautions you will encounter when performing the procedures in Section 4. These precautions are fairly typical of safety precautions you will see in manufacturer's literature and on equipment warning labels.

To avoid hazards and servicing mistakes, it is a good practice to always review a procedure before doing it. This review makes you aware of, and able to handle, all of the important safety and servicing conditions before you start.

Figure 2-23.
Typical Terms Used to Prioritize Safety Hazards

DANGER

There is an *immediate hazard* which WILL result in *severe* personal injury or death.

WARNING

Hazards or unsafe practices which COULD result in *severe* personal injury or death.

CAUTION

Potential hazards or unsafe practices which COULD result in *minor* personal injury or equipment damage.

▼ Figure 2-24.
Electrical Equipment Precautions

DANGER

DO NOT attempt to check voltage supplies until you know the proper procedures and have the proper equipment. SEVERE PERSONAL INJURY CAN RESULT. Consult your power company for specific instructions and obtain their services when necessary.

DO NOT attempt to take measurements on high-voltage systems (600 volts or over) with hand-held instruments. Always use current and potential transformers to take high-voltage measurements.

DO NOT take measurements or make continuity checks on a compressor until you are sure that ALL POWER IS TURNED OFF TO THE UNIT OR SYSTEM, INCLUDING THE CRANKCASE HEATERS. When taking voltage, current, or continuity measurements on a hermetic or semi-hermetic compressor in a pressurized system, always take measurements at terminal boards and test points away from the compressor, rather than at the compressor. If the compressor terminals are damaged and the system is pressurized, disturbing them to take measurements could cause them to blow out, causing injury. Once a system has been evacuated and is no longer under pressure, measurements can be taken at the compressor. Check the lockout and tagout of both electrical components and the compression system.

WARNING

DO NOT work on high-voltage equipment unless you are an experienced HVAC technician qualified to maintain electrical equipment or a qualified electrician.

GROUND all electrical equipment.

USE a ground fault circuit interrupter with power hand tools.

DO NOT work on electrical components, including control panels, switches, starters, or heaters until you are sure that ALL POWER IS OFF and *no residual voltage* can leak from capacitors or solid-state components.

LOCKOUT AND TAGOUT electrical circuits before working on them. IF WORK IS INTERRUPTED, confirm that the circuits are deenergized before resuming work.

DO NOT remove terminal box covers while machine or compressor is running.

DO NOT tighten any connection on a terminal board until the main disconnect switch is in the OFF position and locked out.

DO NOT attempt to stop a machine by opening an isolating knife switch. High intensity arcing can occur and cause serious injury.

NEVER USE an ohmmeter in any energized circuit. Destruction of the meter could result in personal injury.

NEVER apply voltage to or operate a compressor when there is a vacuum in the system. This can cause the compressor terminals to fail due to internal arcing which, in turn, can result in severe personal injury.

NEVER energize a compressor until the discharge service valve is open to the system. Failure to do so can result in excessive pressure buildup.

DO NOT exceed the manufacturer's torque specifications when making electrical connections. Terminal bolts could snap and propel from the terminal block.

CAUTION

BE AWARE that certain automatic start arrangements *can engage the starter*. Open the disconnect and lock it out *ahead of* the starter in addition to shutting off the machine or pump.

DO NOT bypass, block interlocks, or remove a lockout/tagout that is in place unless it is yours.

MINOR SHOCKS can surprise you. While the shock itself would probably not be injurious, a resulting fall could be.

DO NOT check a circuit until you are sure that the power is off in any adjacent circuit.

Figure 2-25.
Gas and Oil Heating Equipment Precautions

WARNING

Improper installation, adjustment, alteration, service, maintenance, or use can cause carbon monoxide poisoning, explosion, fire, electrical shock, or other conditions which may cause personal injury or property damage. Consult a qualified installer, service agency, local gas supplier, or your distributor or branch for information or assistance. The qualified installer or agency must use only factory-authorized and listed kits or accessories when modifying products. Failure to follow this warning could result in electric shock, fire, personal injury, or death.

When a furnace is installed in a residential garage, it must be installed so that burners and ignition sources are located a minimum of 18 in. above the floor. The furnace must be located or protected to avoid physical damage by vehicles. When a furnace is installed in a public garage, airplane hangar, or other building having a hazardous atmosphere, the unit must be installed in accordance with the requirements of the National Fire Protection Association Inc.

NEVER USE OXYGEN OR COMPRESSED AIR to leak test or purge gas or oil furnace piping systems since an EXPLOSION HAZARD exists when oil and oxygen are mixed. Follow the manufacturer's recommendations for leak testing or purging.

NEVER use matches, candles, flame, or other sources of ignition for the purpose of leak detection. Use a battery-operated flashlight or approved safety lamp when searching for the source of the leak. For gas leaks, use a soap-and-water solution to check for leakage. Failure to follow this warning could result in fire, explosion, personal injury, or death.

NEVER purge a gas line into a combustion chamber. Failure to follow this warning could result in fire, explosion, personal injury, or death.

Use the proper length of pipe to avoid stress on the gas control manifold. Failure to follow this warning could result in a gas leak resulting in fire, explosion, personal injury, or death.

▼ Figure 2-26.
Leak Testing and Pressure Testing Precautions

⚠ DANGER

NEVER USE OXYGEN to leak test, purge lines, or pressure test a machine. Nitrogen is recommended for these purposes. Always use a gauge-equipped regulator on the nitrogen cylinder and verify that the gauge has been recently checked and calibrated.

> *The full pressure of a nitrogen cylinder can cause a refrigerant cylinder to rupture violently*. Therefore, when using nitrogen and a refrigerant trace for leak testing, *always put the refrigerant in first*. Then valve off and remove the refrigerant cylinder before connecting and adding the regulated nitrogen.

NEVER EXCEED the specified field leak test pressures. Verify the allowable *field test* pressure by checking the instruction literature.

> *Do not allow the full cylinder pressure to enter a pressurizing line*. Valve off and *disconnect* the nitrogen cylinder when the recommended test pressure is attained. Do not rely on the shutoff valve or pressure regulator.
>
> *Do not pressure test any vessel at its design pressure (found on the equipment nameplate)*. Testing at these pressures must be done in a special enclosure or by using a hydraulic fluid under the direction of the manufacturer.
>
> *Do not confuse water (brine) side test pressures with refrigerant side test pressures*.

HEAVY CONCENTRATIONS of nitrogen within a confined space or area can displace enough oxygen in the work area air to cause suffocation.

DO NOT enter any vessel or confined space immediately after the use of significant amounts of nitrogen without the protection of SCBA or have tested the oxygen level. Utilization of respiratory protection should not be needed if adequate ventilation of the space is allowed to occur prior to entry and the oxygen level has been tested and is above 19.5 percent.

▼ Figure 2-27.
Mechanical Equipment Precautions

DANGER

DO NOT remove coupling (or belt) guards to work on a machine until all rotating parts have come to a complete halt.

MACHINES MUST BE locked out and tagged out regardless of the type of energy powering the equipment.

NEVER ENTER an enclosed fan cabinet or reach into a unit while the fan is running.

NEVER use a torch to remove a compressor or component from the refrigerant circuit. The oil could ignite and cause a fire. Use a pipe cutter and follow correct procedures when cutting refrigerant lines.

WARNING

NEVER OPERATE an open-drive machine, pumpout unit, or other equipment without coupling (or belt) guards in place. This warning applies even to short runs such as a motor rotation check. Serious injury can result from contact with moving parts.

NEVER loosen any head or cover bolts when the compressor is open to the system or when it is under pressure. Make sure the internal pressure is at 0 to 2 psig *before* any bolts are loosened to prevent propulsion of compressor parts.

DO NOT attempt to remove fittings and covers or break lines while the machine is under pressure or while it is running.

USE CARE when working near or in line with a compressed spring. Sudden release of the spring can cause it and objects in its path to act as projectiles.

DO NOT syphon refrigerants or other chemicals by mouth. Check the manufacturer's instructions for correct syphoning procedures.

CAUTION

DOUBLE CHECK that coupling nut wrenches, dial indicators, or other items have been removed before rotating any shaft. Remember to wear safety glasses.

PERIODICALLY INSPECT coupling for proper lubrication and alignment to minimize the possibility of failure and resultant flying particles.

TIGHTEN all coupling bolts *twice* to be sure that none have been overlooked.

CHECK coupling locknuts for tightness and for insertion of setscrews.

DO NOT weld or flamecut any vessel or line until all refrigerant has been removed.

DO NOT loosen a packing gland nut before making sure that it has a positive thread engagement.

PERIODICALLY INSPECT all valves, fittings, and piping for corrosion, rust, leaks, or damage.

VALVE OFF AND TAG steam, water, and refrigerant lines before opening them.

DO NOT step on refrigerant lines. Broken lines can whip about and cause severe personal injury.

USE only repair or replacement parts that meet the code requirements of the original equipment.

Figure 2-28.
Oxy-Acetylene Welding and Cutting Precautions

DANGER

DO NOT use oxygen as a substitute for compressed air, or for any purpose other than welding or flamecutting.

WARNING

DO NOT store oxygen cylinders near combustible material, especially oil and grease, nor handle oxygen cylinders or apparatus with oily hands or gloves.

Oxygen supports and accelerates combustion and will cause oil, grease, and plastic materials to burn with great intensity.

DO NOT weld or flamecut near combustible materials, nor in an atmosphere containing refrigerant, nor until pressure vessels and piping have been completely evacuated.

DO NOT weld or flamecut in a confined area unless the area is adequately ventilated. Where it is impossible to provide adequate ventilation, wear SCBA and have another person on standby immediately outside the confined area.

DO NOT carry a plastic liquid-fuel cigarette lighter or other flammable materials while welding, soldering, or brazing. Welding sparks, molten metal, and heat from a torch can ignite the contents of the lighter and cause it to explode.

CAUTION

DO NOT store oxygen and fuel gas cylinders near any heat source nor adjacent to each other.

STORE oxygen and fuel gas cylinders in an upright position and strap securely in place.

WEAR flame-retardant protective clothing and equipment when welding and flamecutting, and when in the vicinity of such operations.

DO NOT block passageways, ladders, and stairways with welding equipment.

Use effective safeguards when working on platforms, scaffolds, or runways including safety belts and safety lines when necessary.

SAFETY INSTRUCTIONS

Observe the color coding of pipelines, cylinder, and hoses. Double check the code by reading all labels.

Do not use defective hoses.

Do not tape more than 4 inches out of every 12 inches when taping parallel sections of fuel and oxygen hose.

Do not use connectors other than those made especially for acetylene welding and cutting equipment. Make sure all connections are tight.

Do not fail to crack the cylinder valve before attaching the regulator.

Release the regulator adjusting screw before opening a cylinder valve.

Stand to one side when opening a regulating valve.

Before each use, inspect torches for leaking shutoff valves and tip connection.

Do not use a defective torch.

Ignite torches by friction lighters only.

Customer requirements and construction work sites may or could specifically require utilization of safety equipment such as hard hats, gloves, goggles, safety glasses, safety shoes, respirators, etc. Be prepared by having these items safely stored in a clean and secure compartment of the service vehicle, readily available for use when necessary.

Figure 2-29.
Personal Protection Precautions

⚠ WARNING

WEAR a hard hat wherever there is potential danger from falling or flying objects.

DO NOT touch electrical equipment if your hands are wet or if you are standing on a wet surface.

DO NOT look at arcs or other welding processes, regardless of distance, without appropriate eye protection.

DO NOT carry or use a plastic liquid-fuel cigarette lighter or other flammable materials when in the vicinity of welding operations. Sparks from a welding torch can ignite the lighter and cause it to explode.

Safety shoes, hard hats, and safety glasses are required at construction job sites.

⚠ CAUTION

DO NOT WEAR:
- Rings or other jewelry, long ties, gloves, or loose clothing when working around moving machinery.
- Rings or watches when working around electrical equipment.

WEAR:
- Safety glasses with side shields and safety shoes before entering construction sites or manufacturing areas.
- Goggles and gloves when handling chemicals; welding helmets when welding, cutting, brazing, or grinding; and when in the vicinity of these operations.
- Gloves before touching any part of a mchine that is operating or one that has recently been shut down. Assume that the metal is hot!
  Wear gloves when handling machinery components after a major failure; e.g., after a motor burnout: not only the refrigerant but also the oil will be acidic.
- Gloves and coveralls when working with or around sheet metal.
- Hearing protection in areas where sound levels exceed 90 dBA.
- Safety shoes, or specially treated shoes when necessary to protect against corrosive chemicals.
- Flame-retardant protective clothing suitable for the type of welding being done.

Figure 2-30.
Rigging Precautions

DANGER

DO NOT use cranes under power lines.

Obtain assistance from a utility company as necessary.

Damaged or defective equipment or equipment that does not have load capacity information shall be taken out of service.

Alloy 80 chain is the only type recommended for maintenance and servicing operations.

WARNING

CHECK the manufacturer's drawings and service instructions for assembly or component weights to be sure they can be handled safely by the rigging equipment.

CHECK the centers of gravity and note any specific rigging instructions.

DO NOT use other than OSHA-approved rigging equipment and methods.

INSPECT all rigging equipment *prior* to use to be sure it is in good condition and has load limit ratings on it.

DO NOT use eyebolt holes to rig an entire assembly, nor use eyebolts to rig a compressor.

DO NOT move a loaded crane, hoist, or chain fall until you are sure there is no obstruction or personnel in its path and have determined that the unit will remain stable and upright.

Safety shoes are recommended when working with rigging, gantries, and hoists.

CAUTION

USE MECHANICAL EQUIPMENT (chain fall, hoist, etc.) to lift or move the inspection covers or other heavy components. Even if the components are light, use such equipment when there is a risk of slipping, losing your balance, or injuring your back.

DO NOT climb over a machine or fan cabinet; use platforms, catwalks, or staging.

LOOK for objects on the floor or slippery areas that could cause falls.

SAFETY INSTRUCTIONS

FOLLOW safe practices when using OSHA-approved ladders.

Use lifting lugs, where provided, in accordance with each rigging instruction.

Be aware of the location of your fellow workers at all times.

▼ Figure 2-31.
Refrigerant Precautions

⚠ WARNING

NEVER APPLY an open flame or live steam to a refrigerant cylinder. When it is necessary to heat the refrigerant, use warm (110° F/43° C) water.

DO NOT STORE refrigerant cylinders where the surrounding temperature can exceed the relief valve setting. When this is not possible, use a water shower or similar type cooling.

SLOWLY OPEN charging and regulating valves to prevent overpressurizing.

ALWAYS USE the proper valve wrench to open and close valves. Loosen the packing nut before turning on the valve; retighten the nut after closing the valve.

NEVER FORCE connections.

DO NOT REUSE disposable (nonreturnable) cylinders nor attempt to refill them. IT IS DANGEROUS; it is also illegal. When a cylinder is emptied, bleed off the remaining gas pressure, loosen the collar, and unscrew and discard the valve stem. DO NOT INCINERATE.

ALWAYS leave room for expansion when filling a refrigerant cylinder. Hydrostatic pressure increases rapidly with even a small change in temperature.

DO NOT tamper with safety devices.

Use appropriate equipment to move refrigerant cylinders, such as hand trucks, dollies, etc.

⚠ CAUTION

ALWAYS REPLACE the valve and hood caps when a cylinder is not in use or is empty.

DO NOT alter cylinders.

DO NOT dent, drop, or abuse refrigerant cylinders.

SECURE all refrigerant cylinders, whether full or empty, in an upright position with a strap or chain.

AVOID pressure surges when transferring refrigerant. Use a pressure regulating valve to make gradual adjustments. The pressure relief valve device on a cylinder cannot protect against an instantaneous pressure surge.

NEVER charge a refrigerant cylinder beyond the weight marked on the cylinder.

DO NOT depend on the color of a cylinder for identification of the refrigerant; *read the label*.

INSPECT hoses, manifolds, and fittings regularly and keep them in good condition.

DO NOT USE damaged or defective equipment.

Figure 2-31.
Refrigerant Precautions (Cont.)

WARNING

DO NOT enter and perform work inside any vessel without proper respiratory protection and a second person on standby outside the vessel (the buddy system).

DO NOT enter any equipment room or space containing air conditioning or refrigeration machinery *after a known refrigerant spill* until you are using a self-contained breathing apparatus (SCBA) and are using the buddy system.

AVOID spilling liquid refrigerant on the skin or getting it into your eyes. USE SAFETY GOGGLES. Wash any spills from the skin with soap and water. If any refrigerant enters the eyes, IMMEDIATELY FLUSH EYES with water and consult a physician.

CAUTION

DO NOT weld or flamecut in an atmosphere containing refrigerant vapor until the area has been well ventilated.

DO NOT weld or flamecut any vessel or refrigerant line until the refrigerant has been removed.

AVOID breathing refrigerant fumes.

DO NOT smoke in an atmosphere containing refrigerant vapor.

Refrigerants are heavier than air and water and will settle in all low places.

RESPIRATORY PROTECTION such as a SCBA may be necessary for entry into and work within areas where spillage has occurred.

NOTES:

SECTION THREE
GENERAL SERVICE CONSIDERATIONS

SECTION 3
GENERAL SERVICE CONSIDERATIONS

INTRODUCTION

This section describes the servicing and environmental factors mandated by the passage of the Clean Air Act Amendments in 1990. The terms recover, recycle, and reclaim are defined. Also included are instructions for the use and proper handling of refrigerants, refrigerant cylinders, and used refrigerant and oil.

Basic instructions are given in this section in the use of the gauge manifold set, ammeter, and multimeter. Refrigerant service valves used on HVAC systems are also discussed, including how they control the flow of refrigerant and how to use them to gain access to the refrigeration system.

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QUICK NOTE

Ozone can be both helpful and harmful, depending on its location in the atmosphere:

- *Tropospheric ozone (closer to the Earth) contributes to smog and has an unpleasant odor.*
- *Stratospheric ozone (farther from the Earth) is necessary to protect all living things from ultraviolet radiation.*

ENVIRONMENTAL CONSIDERATIONS

Ozone Depletion

Ozone is found both in the Earth's troposphere, which extends from ground level to 7 miles up, and in the stratosphere, which is 7 to 30 miles above the Earth's surface. Ozone is chemically identified as O_3, which is an oxygen molecule (O_2) with an additional oxygen atom attached.

Tropospheric ozone is undesirable because it contributes to smog and has a strong odor.

Ozone within the Earth's stratosphere is beneficial because it protects the Earth and its inhabitants from exposure to excessive amounts of ultraviolet radiation. In sufficient quantities, ultraviolet radiation can cause an increase in skin cancer and other health problems for humans and animals. It can also have an adverse effect on crops and other plant growth.

For millions of years, nature has created and destroyed ozone in the stratosphere in an environmentally-balanced process. With the introduction of man-made chemicals containing chlorine into the stratosphere, the process has become unbalanced. The result is that the ozone is being depleted faster than it is being generated. This allows too much harmful ultraviolet radiation to reach the Earth.

Chlorofluorocarbon (CFC) refrigerants are considered the most damaging to the Earth's ozone layer because they are chemically stable and can survive the long trip to the stratosphere. CFC refrigerants contain chlorine, fluorine, and carbon atoms. It is the chlorine that reacts with the sun's ultraviolet radiation to alter the ozone molecules present in the stratosphere.

Figure 3-1 shows an example of the ozone depletion process. Simply speaking, it involves the transfer of an oxygen atom from ozone to another molecule.

The process starts when ultraviolet radiation from the sun strikes a CFC-12 molecule, causing one of its chlorine (Cl) atoms to break off. This free chlorine atom then bonds with one of the three oxygen atoms in an ozone molecule and forms a molecule of harmful chlorine monoxide (ClO). Also, because the third oxygen atom is removed, the ozone molecule (O_3) is converted into an oxygen molecule (O_2). Thus an ozone molecule has been removed or depleted. The process continues when the oxygen atom in the chlorine monoxide molecule reacts with a free oxygen atom. The two oxygen atoms bond to form an oxygen molecule. This sets the remaining chlorine atom free again, allowing it to repeat the cycle by attacking and breaking down another ozone molecule.

HCFC refrigerants are not as harmful to the ozone layer as CFC refrigerants, but they still contribute to ozone depletion. HCFC refrigerants contain chlorine as well as hydrogen, fluorine, and carbon. It is the hydrogen in HCFCs that causes them to be less stable. This instability allows HCFC refrigerants to decompose in the troposphere. The result is that very few HCFC molecules reach the stratosphere intact to react with the ozone. HFC refrigerant molecules do not contain chlorine atoms; therefore, they do not contribute to ozone depletion.

A measure of the ability of a refrigerant to attack and deplete the ozone layer is called its *Ozone Depletion Potential* (ODP). The ODP values of all refrigerants are compared to CFC-11, which is the most harmful and thus is given an ODP of 1. The lower the ODP number, the less harmful the refrigerant is to the environment. Some common ODP values for refrigerants are:

OZONE DEPLETION POTENTIAL (ODP)	
CFC-11	1.0
CFC-12	0.93
HCFC-22	0.05
HCFC-123	0.016
HFC-134a	0.0
AC9000	0.0

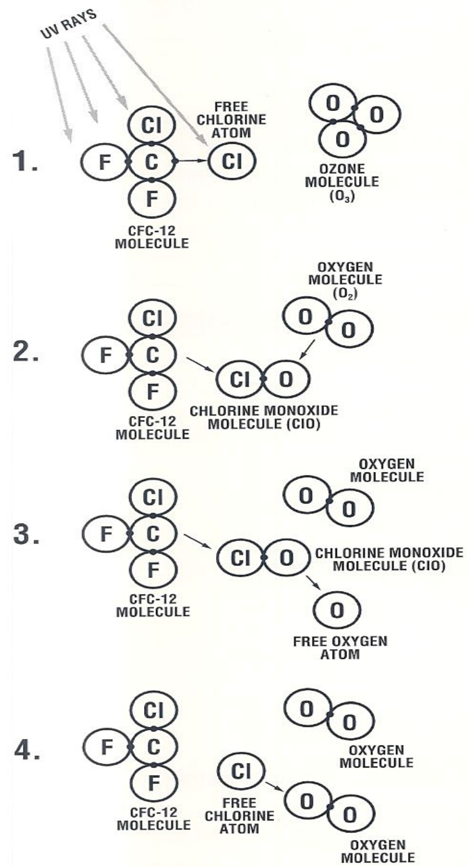
Global Warming

Global warming, also referred to as the *greenhouse effect*, is another major environmental concern (Figure 3-2). Do not confuse ozone depletion with global warming. These are two entirely different environmental problems. When compared to ozone depletion, the use of refrigerants contributes very little to the overall global warming problem.

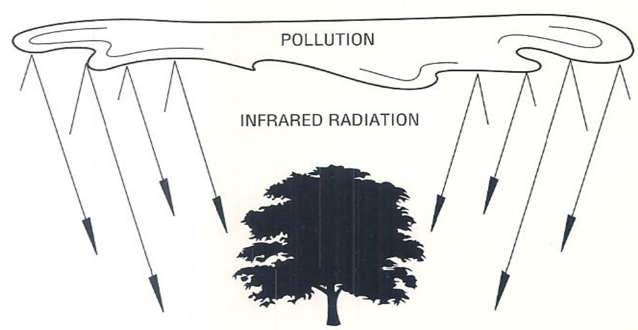
Global warming occurs as a result of the pollutants present within the Earth's troposphere. Included among the pollutants are elements of refrigerants, tropospheric ozone or smog, fog, carbon dioxide, carbon monoxide, and sulphur oxide. Refrigerants have little direct effect on the global warming process. It is carbon dioxide which is considered to be the most harmful element contributing to global warming. Sulphur oxide and carbon monoxide are also major contributors.

Global warming occurs because the pollutants in the troposphere absorb heat and act as reflectors. Infrared radiation emitted from the Earth is reflected back to the Earth instead

▼ Figure 3-1.
Ozone Depletion Process



▼ Figure 3-2.
Global Warming



of passing through the troposphere and stratosphere, then into outer space. The result is a gradual increase in the average temperature levels on Earth. As the levels of pollution in the troposphere increase, global warming also increases.

Scientists are concerned that increased global warming will cause the polar ice caps and glaciers to melt, substantially increasing water levels on the Earth. Global warming can also result in decreased crop yields, added smog levels, and changes in climatic patterns.

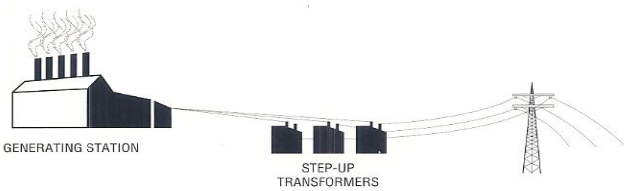
A measure of the ability of a refrigerant to directly contribute to global warming is called its *Global Warming Potential* (GWP). The GWP values of all refrigerants are compared to CFC-11, which has a GWP of 1. Again, the lower the number, the less harmful the refrigerant is to the environment. Some common GWP values for refrigerants are:

GLOBAL WARMING POTENTIAL (GWP)	
CFC-12	3.10
CFC-11	1.00
HCFC-22	0.34
AC9000	0.28
HFC-134a	0.27
HCFC-123	0.02

Some newer alternate and replacement refrigerants can contribute indirectly to global warming. Typically, these refrigerants are less efficient than the older, environmentally-harmful refrigerants. This means the equipment that uses the newer refrigerants consumes more electrical power in order to provide the same amount of cooling capacity.

The increased demand for electricity caused by the equipment's inefficiency means that more fossil fuels are burned by the utility companies in order to generate the electricity (Figure 3-3). More carbon dioxide is being generated and released into the troposphere as a by-product of the combustion process. This further increases the pollution in the troposphere, thereby causing an increase in global warming. In HVAC applications, it is this indirect pollution resulting from equipment inefficiency that has the greatest effect on global warming.

▼ Figure 3-3.
Increased Demand for Electricity Increases Global Warming



The Clean Air Act

As a result of worldwide concerns about ozone depletion and global warming, refrigerants and the people who work with them have come under increasing regulation by government agencies. In 1990, the U.S. Congress passed the Clean Air Act, which calls for early phase-out of the most harmful refrigerants, eventual elimination of all CFCs and HCFCs, and strict refrigerant control and labeling requirements. The United States Environmental Protection Agency (EPA) is responsible for implementing and enforcing this law. The Clean Air Act has a significant impact on the Air Conditioning and Refrigeration industry for the decade of the 1990's and beyond. Here are some of the more important aspects:

- No voluntary or involuntary release of refrigerant can occur in any way that allows the refrigerant to enter our atmosphere, except for *de-minimus* (minimal) releases. Allowable minimal releases of refrigerant are those that typically occur when connecting and disconnecting gauge manifold sets and refrigerant recovery service equipment. Anyone who knowingly releases refrigerant is subject to a stiff fine and possibly a prison term.
- Substantial leaks that occur in industrial processes, commercial refrigeration, comfort cooling chillers, and any other equipment that contains more than 50 pounds of refrigerant must be repaired.
- Anyone handling refrigerants must have EPA-sanctioned certification. Without it, you cannot even buy refrigerants.
- Records must be kept on all transactions involving refrigerants. This includes purchase, use, reprocessing, and disposal.

Technician Certification

Since November 1994, the EPA has required the certification of all technicians who service air conditioning and refrigeration equipment. This includes anyone who performs installation, maintenance, or repair, including owners of equipment who perform service on their own equipment.

Technicians must be certified in all equipment categories that they intend to service or install. Certification is achieved by passing the test for each category, as given by an EPA-approved certifying agency. The technician receives a Certificate of Completion (Figure 3-4) that records the successful completion of the test(s). The EPA has established four categories or types of certification. They are:

- Type I – Technicians can work on any small appliance. Small appliances are defined as those that have five pounds or less of refrigerant, such as residential refrigerators and window-type air conditioners.
- Type II – Technicians can work on any appliance that uses a high-pressure refrigerant like HCFC-22, CFC-500, or CFC-502). These are typically used in residential and commercial air conditioners and heat pumps and commercial refrigeration. This category does not include small appliances.
- Type III – Technicians can work on any appliance that uses a low-pressure refrigerant like CFC-11, CFC-113, or HCFC-123). These are typically used in centrifugal or absorption chillers.
- Type IV (Universal) – Technicians can work on all equipment covered by category types I, II, and III.

QUICK NOTE

Accidental leaks caused by inadvertently punching or drilling a hole into system tubing are considered to be de-minimus leaks. However, any such occurrence should be documented on an Accidental or Unintentional Venting Report, including what action(s) were taken to avoid a reoccurrence, for internal company record-keeping purposes.

Figure 3-4.
Typical Certificate of Completion

Refrigerant Transition and Recovery Certification Program
CERTIFICATE OF COMPLETION

JOHN DOE
has been certified as a
Universal
technician as required by
40 CFR Part 82, Subpart F

CERTIFICATION NUMBER: 000-00-0

CERTIFICATION TYPES

TYPE I	- Small Appliances
TYPE II	- High-Pressure and Very High-Pressure Appliances
TYPE III	- Low-Pressure Appliances
UNIVERSAL	- Type I, II, and III

QUICK NOTE

RECOVERY

Remove refrigerant and store it in an external container without necessarily testing or processing it.

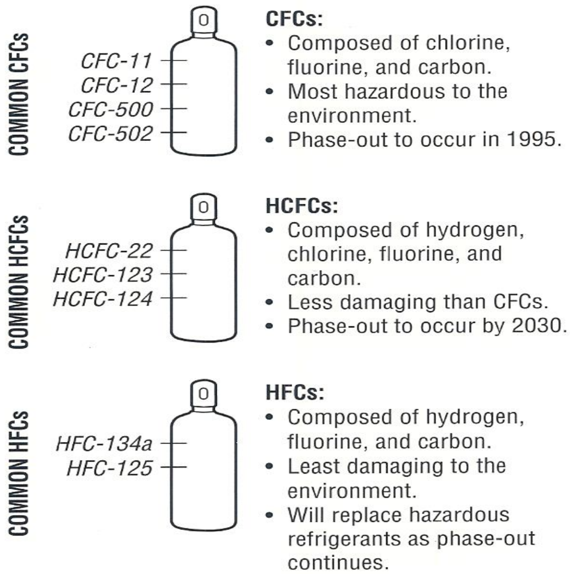
RECYCLE

Clean refrigerant for reuse by removing moisture, acid, and other contaminants.

RECLAMATION

Process refrigerant to meet new refrigerant specifications.

▼ Figure 3-5.
Refrigerant Classifications



Recovery, Recycling, and Reclamation

One of the requirements mandated by the EPA is that refrigerant removed from existing systems must be captured, and when possible, reused. This requirement has created new terminology that needs to be defined and clarified before we go any further.

Recovery means to capture refrigerant in a sealed container as it is removed from the system. Recovery does not imply anything about the quality or reuse potential of the refrigerant.

Recycle means to process refrigerant through a cleaning and decontamination process so that it is suitable for reuse in the same system or another system with the same owner. This does not imply that it meets the cleanliness specifications for new refrigerants.

Reclamation means a refrigerant is "reclaimed" so it meets the new refrigerant specifications for purity. Reclamation is generally considered as being a *factory process*, rather than a field process. Recovery and recycling are considered field activities.

Refrigerants

Servicing a mechanical refrigeration system often involves recovering the refrigerant charge, making repairs, and evacuating and recharging the system. Therefore, a service technician must know what refrigerant is in a system before servicing it.

Refrigerants are divided into three classifications (Figure 3-5). The first group is the chlorofluorocarbons, called CFCs. This group of refrigerants is made up of **C**hlorine, **F**luorine, and **C**arbon atoms. It includes CFC-11, CFC-12, CFC-500, and CFC-502. CFCs are the most hazardous to the environment. For this reason, they are under the strictest regulation and are being phased out of production. Production of CFCs will cease in the United States on December 31, 1995.

The second group is the hydrogenated chlorofluorocarbons, called HCFCs. This group of refrigerants is made up of **H**ydrogen, **C**hlorine, **F**luorine, and **C**arbon atoms. HCFC refrigerants are considered as short-term alternates to replace CFC refrigerants when applicable. HCFCs are considered far less damaging to the environment than CFCs. Their ozone depletion capability ranges from 25% to 1% of that for the CFCs. Some HCFC refrigerants in use are HCFC-22, HCFC-123 and HCFC-124. As of 1996, HCFC refrigerant production is frozen to historic usage levels with eventual phase-out scheduled for the year 2030.

The third group is the hydrogenated fluorocarbons, called HFCs. They are made up of **H**ydrogen, **F**luorine, and **C**arbon. These refrigerants are considered to be least damaging to the environment. HFC refrigerants HFC-134a and HFC-125 are being used mainly to replace refrigerants CFC-12 and CFC-502, respectively. HFC-134a is used primarily in commercial and residential medium-temperature refrigeration and residential and transportation air conditioning equipment. HFC-125 is used for low-temperature supermarket refrigeration and commercial food transportation.

A refrigerant will be either a single chemical compound (pure refrigerant) or a blend of two or three refrigerants. CFC-12 is an example of a pure refrigerant. Blends are classified as either *azeotropes* or *zeotropes*.

An azeotropic refrigerant blend behaves like a compound when evaporating or condensing. It has a constant volume and saturation temperature as it evaporates or condenses at a constant pressure. The boiling point of the mixture is different from either of the base refrigerants. Azeotropic blends typically have identifiers in the 500 series. CFC-500 (Freon 500™ and Gentron 500™) and CFC-502 (Freon 502™ and Gentron 502™) are examples of azeotropic blends in common use. Since these are CFC refrigerants, they are being phased out of production and use.

Pure refrigerants and azeotropic refrigerants have only one temperature at which they evaporate or condense associated with one given pressure. Most zeotropic blends are *ternary blends*; i.e., a blend of three refrigerants. Zeotropic blends, unlike azeotropic blends, never mix chemically; therefore, they have a *temperature glide* when they evaporate or condense. Temperature glide is a range of temperatures within which evaporating or condensing takes place at a given pressure. The exact amount of glide is determined by the system design and chemical makeup of the refrigerant blend. Because of temperature glide, the methods used to calculate subcooling and superheat for zeotropes are somewhat different than those used with pure refrigerants or azeotropes. The methods used for calculating subcooling and superheat are described in Section IV of this manual.

Another property of zeotropic blends is *fractionation*. Fractionation means that one or more refrigerants of the same blend leak at a faster rate than the other refrigerants in the same blend.

This different leakage rate is caused by the influence a given pressure has on each of the individual refrigerants contained in the blend. From a service point of view, fractionation means that some precautions must be taken to make sure that the composition of the blend remains unchanged while being charged into a system. Typically this is done by removing the refrigerant blend from the charging cylinder as liquid only, applying it through a metering valve or other expansion device to ensure that the liquid is converted into vapor, then charging the vapor into the low side of the system. To avoid damage to the compressor, care must be taken to make sure that all the liquid refrigerant is converted to vapor prior to entering the system. Another effect of fractionation is that a leaking system cannot just be topped-off after the leak is repaired. The system charge must be removed and the system recharged.

Zeotropic blends typically have identifiers in the 400 series. Refrigerant blends R-401A (SUVA™ and Gentron™ MP-39) and R-402A (SUVA™ MP-80) and R-404A (SUVA™ MP-62) are examples of some zeotropic blends in use.

QUICK NOTE

Facts About Zeotropes:

- *They are usually composed of three refrigerants.*
- *They have a temperature glide (that is, a range of temperatures at which they evaporate or condense).*
- *They may be affected by fractionation (different parts of the blend may leak at different rates).*
- *They may require special instruments/tools for servicing. Example: R-410A requires a special gauge manifold and hoses that are rated for the higher pressures of that refrigerant.*

QUICK NOTE

Always identify the refrigerant used in a system before servicing it.

DO NOT substitute refrigerants in a system without the equipment manufacturer's approval.

New, environmentally-safe alternative refrigerants are continuously being developed to either replace the harmful CFC and HCFC refrigerants in existing equipment or for use in new equipment. SUVA™ refrigerant MP-39 and Gentron™ AZ-50 are examples of replacement refrigerants. MP-39 is a zeotropic blend made to replace CFC-12; AZ-50 is an azeotropic blend made to replace CFC-502. SUVA™ blend MP-33 is a refrigerant being made for use in new refrigeration equipment. SUVA™ AC9000 is an HFC-based alternative refrigerant ternary blend developed to replace R-22 in new air conditioning equipment.

CAUTION

It is important to remember that most replacement refrigerants are not direct replacements for the CFC-type refrigerants. System modifications are usually necessary for the replacement refrigerant to be compatible with existing equipment. ***Never substitute a refrigerant in a system without first getting the manufacturer's approval.*** Even though "replacement" refrigerants claim to be an equal substitute for various refrigerants, none is identical to the refrigerant it replaces.

The kind of refrigerant used in a system can be identified using one or more of the following methods:

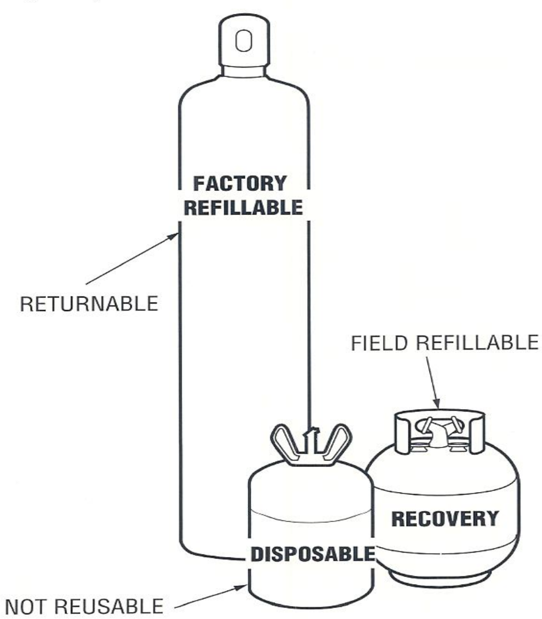
- Check the equipment nameplate.
- On equipment that uses a thermostatic expansion valve, the refrigerant type is usually marked on the valve.
- When no printed data can be found, take a pressure and saturation temperature reading for the refrigerant when the machine is off and ambient temperatures have been reached. Compare the saturation temperature/pressure relationship with refrigerant cards or charts to identify the refrigerant.

Use and Handling of Refrigerant Cylinders

There are specific regulations about the handling of refrigerants and their containers as a result of the Clean Air Act. These regulations require that specific types of cylinders be used for the recovery, storage, and/or transportation of refrigerants.

Refrigerant Cylinders – Refrigerant cylinders (Figure 3-6) are considered pressure vessels and must comply with all state and federal laws governing their use and construction. Medium-pressure and high-pressure refrigerants come in metal cylinders that vary in shape and size. Medium-pressure and high-pressure refrigerants such as CFC-12, HCFC-22, HFC-134a, CFC-500, and CFC-502 come in either returnable or disposable metal cylinders that range in capacity from about one pound of refrigerant to 1,000 pounds or more. The labels on the cylinders are marked and the cylinders are color-coded to avoid confusion. Refrigerant cylinder labels also include important safety and health information.

▼ Figure 3-6.
Refrigerant Cylinders



COMMON MEDIUM-TEMPERATURE REFRIGERANT CYLINDER COLOR CODES

CFC-12	WHITE	HCFC-22	GREEN
CFC-500	YELLOW	CFC-502	PURPLE
HFC-134a	LIGHT BLUE		

REFRIGERANT RECOVERY CYLINDER – GREY WITH YELLOW TOP SHOULDER

Disposable Cylinders – Disposable cylinders are one-way cylinders. That is, once emptied, their use is over. They are made from steel; therefore, they can rust. Rust can weaken the container so that it can no longer hold pressure. To prevent rust, protect the painted surfaces of disposable cylinders by keeping them in the original carton during use and transportation, and always store them in dry locations. Never allow nearly-full disposable cylinders to lay around unused for extended periods of time. Over time, rough handling or excessive heat could cause them to explode, especially if weakened by rust or corrosion.

WARNING

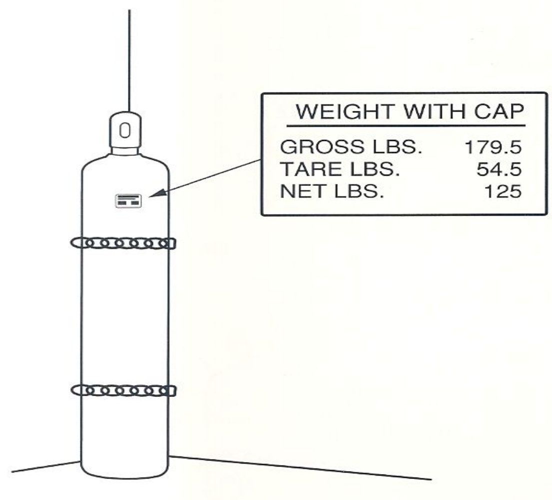
DISPOSABLE CYLINDERS MUST NEVER BE REFILLED. NOT ONLY IS IT DANGEROUS, IT IS ALSO AGAINST THE LAW. Violators can be fined up to $25,000 and can face up to five years in jail.

Once empty, disposable cylinders are recycled as scrap metal. Be sure that the cylinder pressure is released to zero pounds pressure, then render the cylinder useless by puncturing the rupture disk or breaking off the shutoff valve.

Returnable/Reusable Cylinders – Returnable/reusable cylinders are made to be returned to the refrigerant distributor or manufacturer for refilling. They are well constructed, enabling them to withstand constant handling. Returnable/reusable cylinders have shutoff and relief valves and a protective cap that should always be screwed over the valve when moving the cylinder and during shipment. **Never** use a returnable/reusable cylinder as a recovery cylinder.

Usually, returnable/reusable cylinders are labeled to indicate three values of cylinder weight (Figure 3-7). These values are important because they can be used by the service technician to find the amount of refrigerant remaining in a cylinder. They are more important to the manufacturers and/or distributors of refrigerant because they use these weights to prevent overfilling a cylinder, which might cause an explosion.

Figure 3-7.
Returnable/Reusable Cylinder Weight Label



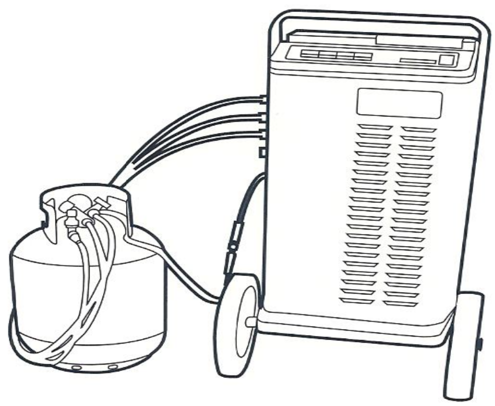
The first weight value you should be aware of is *tare weight*. Tare weight is the empty weight of the cylinder.

The next value is *gross weight*. Gross weight is the combined weight of the cylinder (tare weight) plus the weight of the refrigerant when the cylinder is full. Be aware that the term full cylinder actually means a cylinder that is filled to 80% of liquid capacity, based on the highest expected ambient temperature, which is generally accepted to be 130° F. The remaining 20% of the volume must be available to allow room for expansion.

QUICK NOTE

Make sure the recovery cylinder is rated to handle the refrigerant being recovered. Example: R-410A, an HFC alternative to R-22, has higher pressures than R-22.

▼ Figure 3-8.
Refillable Recovery Cylinder and Recovery/Recycle Unit



CAUTION ➧

QUICK NOTE

The maximum gross weight marked on the returnable cylinder means:

Gross Weight	=	Tare Weight	+	Net Weight

Where:

Tare Weight = Weight of the empty cylinder.

Net Weight = Maximum weight of the refrigerant that the cylinder can safely contain. Value allows 20% of the cylinder volume to remain for vapor head due to expansion.

The last weight value of importance is *net weight*. Net weight is the weight of the contents in the cylinder. For example, when ordering 30 pounds of refrigerant from a supplier, we are actually talking about the net weight. Manufacturers design cylinders so that when the full net weight is reached, 20% of the cylinder volume is remaining for expansion.

Refillable Recovery Cylinders – The refillable recovery cylinder is normally supplied with recovery or recovery/recycle units such as the one shown in Figure 3-8. Refillable recovery cylinders in the capacity range of 15 to 50 pounds are commonly used. The one shown is a 50-pound (22.7 kg) cylinder. Refillable recovery cylinders can be recognized by their color and valve arrangement. They are yellow on top with a special valve that allows liquid or vapor refrigerant to be added or removed from the cylinder.

Recovery cylinders must always be used when recovering or recycling and/or charging used refrigerants. According to government regulations, the cylinders must be labeled to properly identify the type of refrigerant.

Never use a disposable or reusable cylinder for recovery. You should have a separate recovery cylinder for each type of refrigerant you intend to recover. Always read the cylinder label to make sure that the cylinder is intended for use with the type of refrigerant you want to recover. If you are recovering different refrigerants, **DO NOT MIX THEM.** If refrigerants get mixed, they must go through an expensive processing procedure, or may require incineration.

Be careful not to overfill the cylinder. ***Never exceed the cylinder's maximum gross weight.*** The maximum capacity of any cylinder is 80 percent by maximum net weight, based on the highest expected ambient temperature, which is generally accepted to be 130° F. Most refillable recovery cylinders have a built-in float switch that provides overfill protection to turn off the associated recovery/recycle unit if the cylinder is full. The use of recovery/recycle equipment and recovery cylinders equipped with this feature is strongly recommended.

Handling Cylinders – The precautions and procedures for handling cylinders are discussed in detail in Section 2 of this manual. The main precautions are repeated here:

- Do not drop, dent, or abuse refrigerant cylinders.
- Keep disposable cylinders in original cartons as an added measure of protection.
- Always secure cylinders in place to prevent them from tipping over or being damaged when moving around.
- Replace the protective cap, if available, to protect the cylinder valve.
- Always use a proper valve wrench to open and close the valve.
- Never heat a cylinder with an open flame or place an electric resistance heater in direct contact with it. If it is

necessary to warm a cylinder, do it by placing the cylinder in a pan of warm water. Do not exceed 125° F on any part of the cylinder.

Hazardous Waste Disposal

If refrigerants are recycled or reclaimed, they are not considered hazardous under federal law. In addition, used oils contaminated with CFCs are not hazardous on the condition that:

- They are not mixed with other waste.
- They are subjected to CFC recycling or reclamation.
- They are not mixed with other used oils from other sources.

Used oil is a hazardous waste if tests show that it contains compounds such as mercury, cadmium, or lead, or if it exhibits the characteristics of ignitibility or corrosiveness. Hazardous oil must be stored properly and sent to a licensed hazardous waste disposal facility for proper disposal. Because regulations pertaining to hazardous waste are under constant revision, individuals with questions regarding the proper handling of hazardous waste materials should contact the applicable EPA office for assistance.

QUICK NOTE

Returnable/reusable cylinders must be retested every five years. The date when the cylinder was manufactured or last tested should be stamped on the shoulder or collar of the cylinder.

REFRIGERATION SYSTEM SERVICE VALVES

Some service valves are used to control the flow of refrigerant in a unit or system. Others just provide access to the unit or system for servicing. Still others allow both functions. The type of service valve used depends on the equipment type, size, make, and even its age. Common service valves include the following:

- Piercing Valve
- Forward-Seat-Only Valve
- Schrader Valve
- In-Line Valve
- Process Valve

Refer to Figures 3-9 through 3-13 for descriptions of these valves. Since there are many types of service valves, always refer to the manufacturer's service literature for specific information about the valves used on the equipment you are servicing.

QUICK NOTE

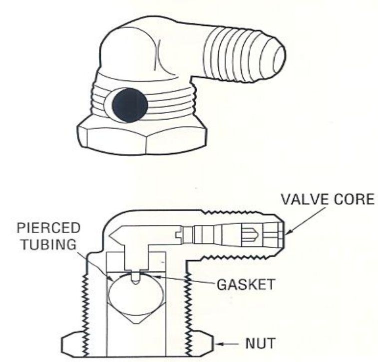
Don't be overwhelmed by the variety of service valves and their different positions. Remember, the best way to avoid mistakes is through preparation: ALWAYS review the manufacturer's service literature.

▼ Figure 3-9.
Piercing Valve

PIERCING VALVE

- Typically used for penetrating refrigerant lines in equipment with hermetically-sealed compressors that have no service valves. This valve is normally bolted onto the line. A sharp needle in the valve penetrates the tubing when the nut is tightened. The operation is similar to that of a process valve.

- Also used as a temporary service access port installed on a pinch-off tube or suction line. A piercing valve is normally used to remove a refrigerant charge. When the task is finished, the piercing valve should be replaced with a permanent valve.



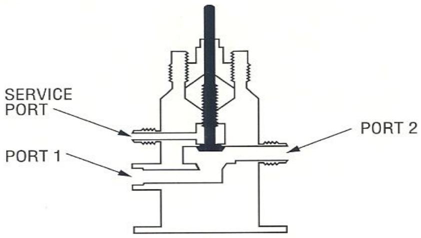
▼ Figure 3-10.
In-Line Service Valve

IN-LINE VALVE

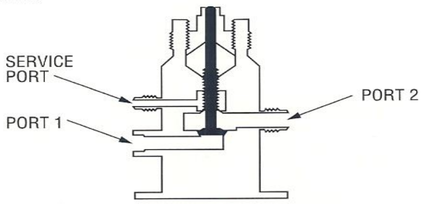
The valve positions used in this description are defined as follows:

Back-Seated – Valve stem turned all the way out (fully counterclockwise).
Front-Seated – Valve stem turned all the way in (fully clockwise).
Mid-Seated – Valve stem turned halfway between back-seated and front-seated position.
Cracked – Valve stem turned about one turn clockwise from the back-seated position.
NOTE: The port numbers shown have been arbitrarily assigned for the purpose of this description.

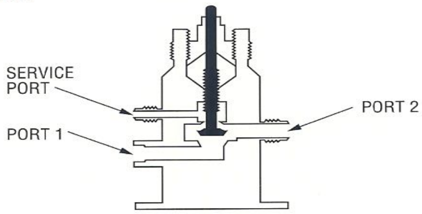
BACK-SEATED



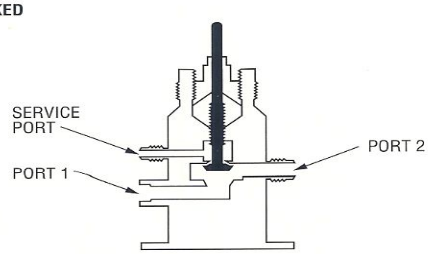
FRONT-SEATED



MID-SEATED



CRACKED



BACK-SEATED

- Used for normal (non-service) system operation. Flow of the system refrigerant is through the valve via ports 1 and 2. The direction of refrigerant flow depends on valve placement (low side or high side) in a system. The service port is completely closed off.

FRONT-SEATED

- Path between port 1 and port 2 is closed, resulting in no refrigerant flow through the valve.
- System components on the port 1 side of the valve are isolated from those on the port 2 side.
- Provides access to the system via the service port and port 2. This allows the measurement of the system pressure that exists on the port 2 side of the valve. It also makes the system components on the port 2 side of the valve accessible for the purpose of evacuation and refrigerant recovery or charging.

MID-SEATED

- Flow of refrigerant is through the valve via ports 1 and 2.
- Provides access to the system through the service port and ports 1 and 2. This allows measurement of the system. It also allows access to the system components on both sides of the valve for the purpose of evacuation, recovery, and charging.

CRACKED

- When cracked, the service port is opened to the system. This position is used only if a pressure reading is required. One clockwise turn from the back-seated position is enough to crack the valve for this purpose.

▼ Figure 3-11.
Forward-Seat-Only Valve

FORWARD-SEAT-ONLY VALVE

The valve positions used in this description are defined as follows:

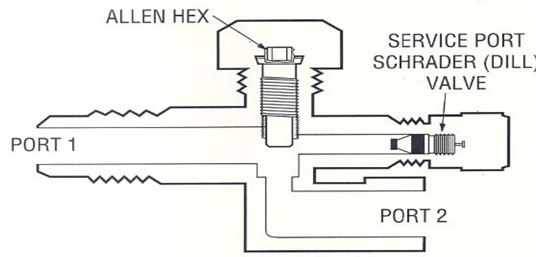
Back-Seated – Valve stem turned all the way out (fully counterclockwise).
Front-Seated – Valve stem turned all the way in (fully clockwise).
NOTE: The port numbers shown have been arbitrarily assigned for the purpose of this description.

BACK-SEATED

- Used for normal system operation. Valve is fully opened. Flow of the system refrigerant is unrestricted through the valve via ports 1 and 2. The direction of flow through the valve depends on its placement (low side or high side) in a system. A Schrader valve (Figure 3-13, page 54) service port is at the prevailing system pressure, but is closed off.

- Access to the system is provided through the Schrader valve. This allows measurement of the system pressure that exists at the valve. It also allows access to the system components on both sides of the valve for the purpose of evacuation, recovery, and charging.

BACK-SEATED

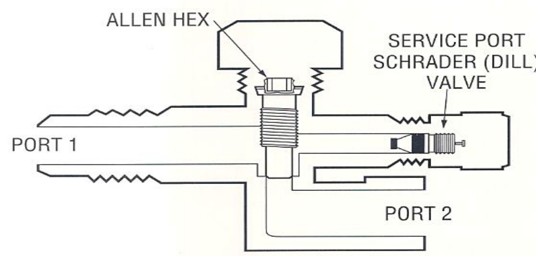


FRONT-SEATED

- Path between ports 1 and 2 is closed, resulting in no refrigerant flow through the valve.

- System components on the port 1 side of the valve are isolated from those on the port 2 side. However, the enlarged area around the valve plug enables the refrigerant at port 1 to be applied at the Schrader valve. This allows the measurement of the system pressure that exists on the port 1 side of the valve. It also makes the system components on the port 1 side of the valve accessible for the purpose of evacuation and refrigerant recovery or charging.

FRONT-SEATED



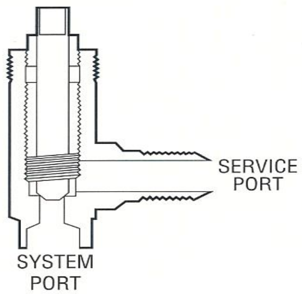
▼ Figure 3-12.
Process Valve

PROCESS VALVE

Used solely to provide access to the closed refrigerant system. It is not installed in the normal path of refrigerant flow through the system. The valve positions used in this description are defined as follows:

Front-Seated – Valve stem turned all the way in (fully clockwise).
Back-Seated – Valve stem turned all the way out (fully counterclockwise).
Cracked – Valve stem turned about one turn counterclockwise from the front-seated position.

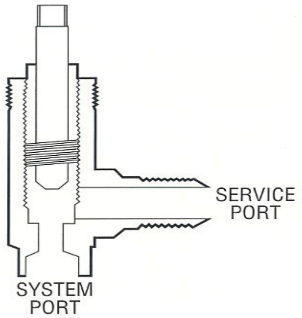
FRONT-SEATED



FRONT-SEATED

- In this position, the service port is isolated from the system. This position is used for normal (non-service) operation.
- This position is used when attaching the gauge manifold set or other service equipment to the valve.

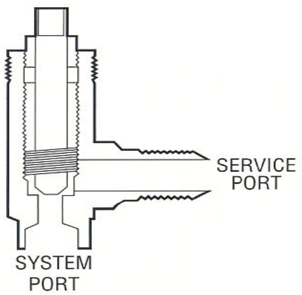
BACK-SEATED



BACK-SEATED

- Used when evacuating, recovering refrigerant, or charging the system. This position presents the least resistance to refrigerant flow.

CRACKED



CRACKED

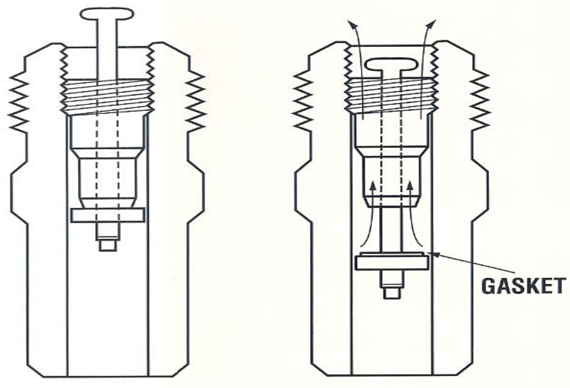
- When cracked, the service port is opened to the system. This position is used only if a pressure reading is required. One counterclockwise turn is enough to crack the valve for this purpose.

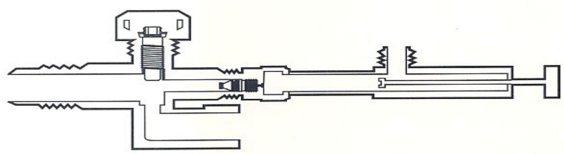
Figure 3-13.
Schrader Valve

SCHRADER VALVE

The Schrader valve uses the same type of valve core as used on automobile tires. It has a spring-loaded, gasketed core which closes when released and opens when depressed.

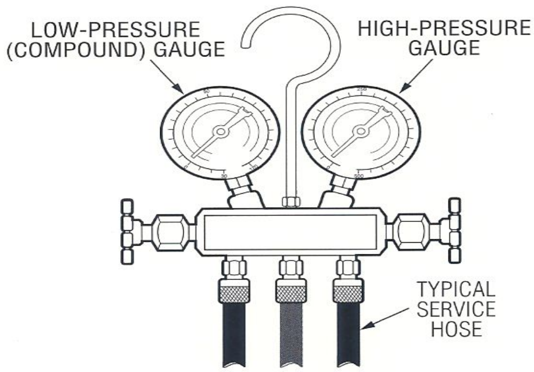
- Often used on systems not equipped with service shut-off valves. In such cases, the Schrader access ports may be used any time because they are self-sealing. The valve cap should be in place during normal system operation.
- When evacuating or recovering refrigerant or recharging a system with Schrader valves, a valve core remover/replacer tool is often used. This tool removes the valve core and holds it back out of the way inside the tool to eliminate restriction and provide full refrigerant flow or faster evacuation. Use of the tool roughly doubles the speed of the charging, recovery, or evacuation procedure.
- When the core remover is used, it is screwed to the Schrader valve. The manifold hose is connected to the remover rather than to the valve. Without the core remover, the manifold hoses must have built-in Schrader valve core depressors or an accessory core depressor must be fastened between each valve and the manifold hose.



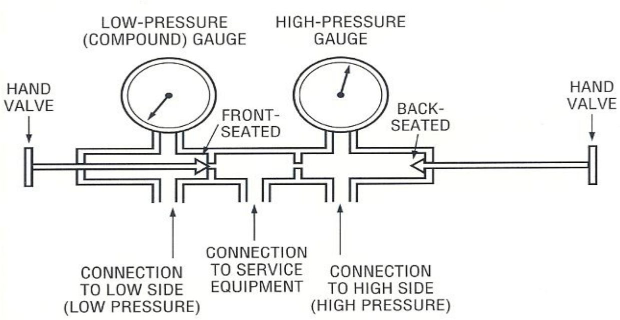


ACCESS VALVE CORE
REMOVER/REPLACER TOOL

▼ Figure 3-14.
Typical Two-Valve Gauge Manifold Set



▼ Figure 3-15.
Control of Refrigerant Flow



GAUGE MANIFOLD SET BASICS

This section describes the basic procedures you will need to correctly operate the gauge manifold set. The gauge manifold set is one of the most frequently used items of service equipment. It is used to determine system operation, add a charge, recover a charge, and equalize or evacuate a system.

The typical two-valve gauge manifold set (Figure 3-14) has a compound gauge, high-pressure gauge, two hand valves, and three hose ports. The hand valves are adjusted to monitor system pressures on the compound gauge and high-pressure gauge and to route the flow of refrigerant to and from the system during servicing activities.

The gauge manifold set hose ports are connected to the system being serviced and other service instruments through a set of high-vacuum/high-pressure service hoses. It is recommended that these hoses be equipped with fast self-sealing fittings that immediately trap refrigerant in the hose when disconnected. Their use helps meet the non-venting regulations and also greatly reduces the amount of air that can enter the hose once disconnected.

CAUTION ➧

When using self-sealing fittings, it is important to always check the gauge pressure readings before removing or changing any service hose. ***With the use of self-sealing fittings, high-pressure refrigerant can be trapped and remain in the service hoses after they have been disconnected from the equipment, causing possible injury or burns.*** To prevent injury from any refrigerant trapped in the service hoses or to remove the refrigerant trapped in the hoses, always follow the procedures for connecting and disconnecting the gauge manifold set given later in this section.

Generally, the gauge manifold set and service hoses are color-coded. Blue identifies the low-pressure compound gauge, hand valve, and related hose port. A blue service hose is normally connected between the manifold low-pressure hose port and the equipment suction service valve. Red marks the high-pressure gauge, hand valve, and hose port. A red service hose is normally connected between the manifold high-pressure hose port and the equipment discharge service valve or liquid line. The center hose port is the utility port. This port normally is connected through a yellow service hose to other service instruments or devices such as a recovery/recycle unit, vacuum pump, refrigerant cylinder, etc.

Adjusting the Gauge Manifold

Figure 3-15 shows how the flow of refrigerant through the gauge manifold set is controlled. The hand valve on the left controls the flow to or from the low side of the system. The one on the right controls the flow to or from the high side of the system. When either valve is turned all the way in (clockwise), we say it is *front-seated*.

In Figure 3-15, the low-pressure valve is shown front-seated. In this position, both the hose and gauge above it are connected to the system so that pressure readings can be taken. However, there is no flow through the valve either into or out of the system, because the gauge manifold acts as a dead end in the hose.

When either valve is turned all the way out (counterclockwise) we say it is *back-seated*. Refrigerant is free to flow from the manifold into the hose or from the hose into the manifold. The direction of flow is determined by the pressure difference. Flow is from a higher pressure area to a lower pressure area.

When the valves are opened part way, they are said to be in the *cracked* position. The rate of flow can be regulated by adjusting the amount of valve opening. Maximum flow is achieved at the fully back-seated position.

CAUTION

Do not over-tighten the valves on the gauge manifold set when closing (front-seating) the valves. Over-tightening the valves may damage the manifold.

Some of the most common service gauge settings used to accomplish various tasks are shown in Figure 3-16.

Connecting the Gauge Manifold

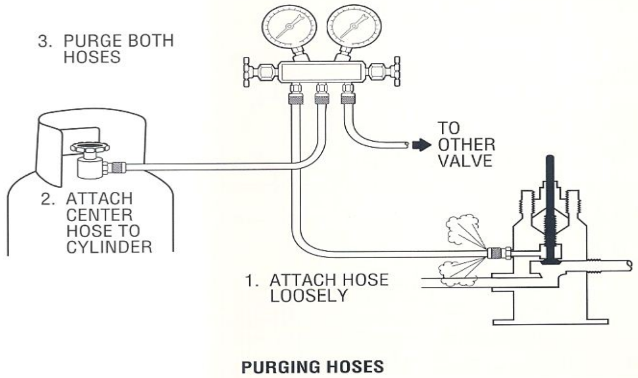
For years, refrigerant has been used to purge air from the service hoses prior to making the final connection to the unit. Obviously this causes refrigerant to be released to the atmosphere. To comply with the no-venting requirements, certain precautions must be followed when connecting or disconnecting the gauge manifold set.

When connecting the gauge manifold hoses to a system for the purpose of charging, any air trapped in the hoses must be removed. If this is not done, the air will contaminate the system. The need to purge the hoses can, for all practical purposes, be eliminated if the hoses are equipped with fast-sealing fittings. Such fittings greatly reduce the chance of air entering the hoses. They also prevent the hoses from becoming contaminated when not in use.

Should you need to purge the service hoses, follow steps 1 through 6 below.

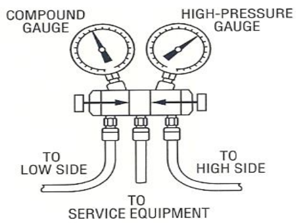
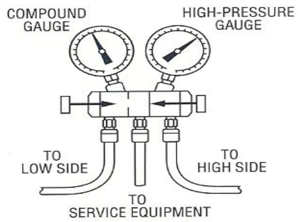
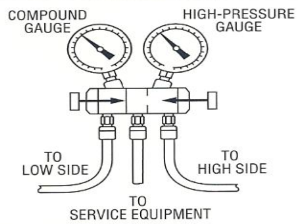
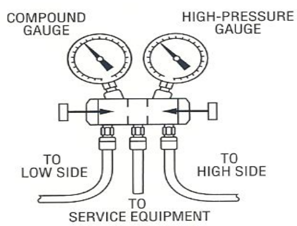
1. Connect the low-side and high-side hoses loosely to their matching service ports on the unit (Figure 3-17). Make sure both gauge manifold set valves are front-seated.
2. Attach the utility hose to the refrigerant cylinder. Crack the valve on the refrigerant cylinder.
3. On the gauge manifold set, crack the low-pressure valve for no more than two seconds, then close it. This allows the refrigerant to displace most of the air from the manifold and hoses while allowing only a minimal amount of refrigerant to escape.
4. Tighten the hose connection at the service valve or low-pressure service port.
5. Repeat the procedure for the high-pressure hose.
6. Close the valve on the refrigerant cylinder.

Figure 3-17.
Two-Second Purge of Service Hoses



▼ Figure 3-16.
Common Service Gauge Settings

GAUGE MANIFOLD VALVE SETTINGS

LOW-PRESSURE VALVE	HIGH-PRESSURE VALVE	GAUGE MANIFOLD SET VIEW	FLOW AND GAUGE READINGS
Front-Seated	Front-Seated		Used when connecting the gauge manifold set to the equipment and for reading gauge pressures. Compound gauge reads system low-side pressure. High-pressure gauge shows system high-side pressure. The utility port is isolated from the refrigeration system. This allows service equipment such as a recovery/recycle unit, vacuum pump, refrigerant cylinder, etc., to be connected to or disconnected from the gauge manifold set while the system is operating.
Back-Seated	Front-Seated		The compound gauge reads the system low-side pressure, or the pressure of a refrigerant cylinder connected to the utility port, whichever is higher. The high-pressure gauge reads the system high-side pressure. The low side of the refrigeration system is connected through the gauge manifold set to any service equipment connected at the utility port.
Front-Seated	Back-Seated		The compound gauge reads the system low-side pressure. The high-pressure gauge reads the system high-side pressure, or the pressure of a refrigerant cylinder connected to the utility port, whichever is higher. The high side of the refrigeration system is connected through the gauge manifold set to any service equipment connected at the utility port.
Back-Seated	Back-Seated		Both gauges show the prevailing system pressure (compressor off). If the utility port is capped, the high-side pressure travels into the low side. If the utility port is used, both the low side and high side of the refrigeration system are connected through the gauge manifold set to any service equipment connected at the utility port. Evacuation, recovery, or charging is through both the high side and low side of the system.

Disconnecting the Gauge Manifold

The procedure used for disconnecting the gauge manifold set varies, depending on the type of service valves installed in the unit.

If the unit being serviced contains back-seating service valves, the charge remaining in the hoses can be drawn back into the operating system using the following procedure:

1. On the gauge manifold set, close (front-seat) both valves. Make sure you close the valve on the refrigerant cylinder (if used).
2. Start and run the system to check temperatures and pressures. If they are correct, back-seat the system high-side service valve. This traps refrigerant in the high-side hose and the utility hose.
3. Open both valves on the gauge manifold set to allow any refrigerant trapped in the high side and utility hoses to be drawn into the system through the low-side service valve.
4. Once both manifold gauge pressures have equalized at the low-side pressure, back-seat the low-side service valve. This allows only a minimal amount of refrigerant to escape to the atmosphere when all hoses are disconnected.

If the system is equipped with Schrader valves instead of back-seating service valves, service hoses equipped with fast self-sealing fittings **must** be used with the gauge manifold set for this procedure to work. To remove the gauge manifold hoses from a system with Schrader valves, use the following procedure:

1. Turn off the equipment or system.
2. Close (front-seat) both gauge manifold set valves. If applicable, make sure you close the valve on the refrigerant cylinder. Remove the high-side hose from the service valve or service port. Leave the low-side hose attached to the service valve or service port. This traps refrigerant in the high-side hose at the high-side pressure. It also traps the refrigerant in the utility hose (if used) at the cylinder pressure.
3. Start the equipment or system, then open (crack) both gauge manifold valves. This allows the refrigerant trapped in the high side and utility hoses to be brought down to a lower and safer low-side (suction) pressure by drawing it into the operating system.
4. Remove the low-side hose. This traps the remaining refrigerant in the low-side hose at suction pressure.

Care of the Gauge Manifold

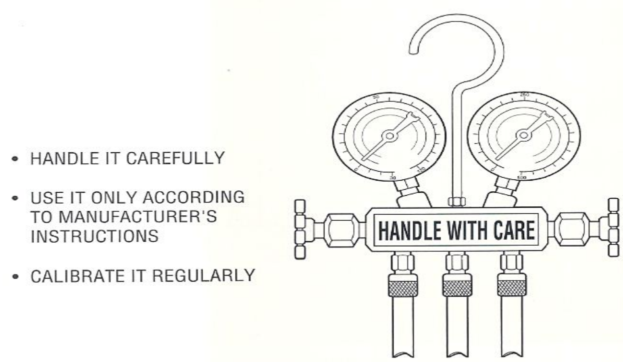
The gauge manifold set is a precision instrument and must be handled and maintained as such (Figure 3-18).

- Never drop or abuse the gauge manifold. Cap the ports or charging lines when not in use.
- Never use the gauge manifold with any fluid other than refrigerant, nitrogen, and clean oil.
- Have gauges calibrated regularly.

QUICK NOTE

Whenever possible, always try to draw any refrigerant remaining in the service hoses back into the operating system through the low-side service fitting.

▼ Figure 3-18.
Maintaining the Gauge Manifold Set

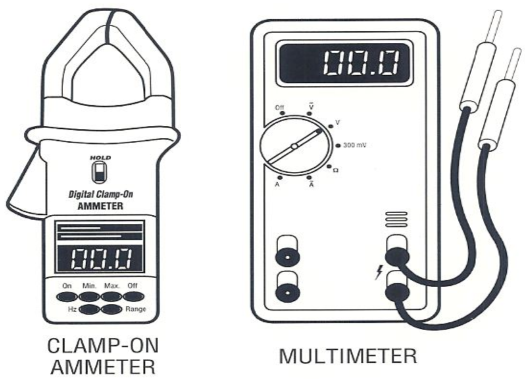


- Never subject gauges to pressures higher than the scale face maximum. Also, it is a good practice not to subject the high-pressure gauge to a vacuum for an extended period of time.
- Replace service hoses that are leaking, crushed, chafed, or stretched. Be sure they meet high-pressure requirements.

AMMETER AND MULTIMETER (VOM/DMM) BASICS

Installing and servicing HVAC equipment involves the use of electrical test instruments. The two most common instruments are the clamp-on ammeter (Figure 3-19) and the multimeter, also called a VOM (analog multimeter) or a DMM (digital multimeter). These are used to measure voltage, current, and resistance in support of many service tasks. Detailed descriptions for both analog and digital versions of these instruments are given in Section 1. The paragraphs that follow describe the use of these instruments to make basic electrical measurements.

Figure 3-19.
Digital Multimeter and Clamp-On Ammeter

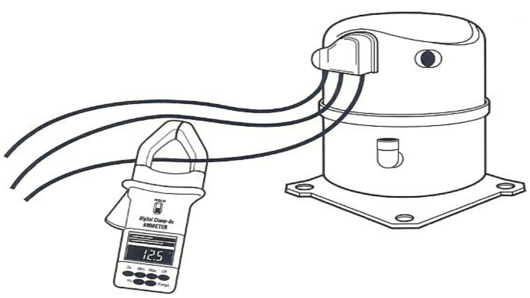


Ammeters

Ammeters measure current flow through a circuit. Depending on the level of the current being measured, the ammeter reads in amperes, milliamperes (one thousandth of an ampere) or microamperes (one millionth of an ampere). Current must flow directly through the ammeter meter movement for it to record. For this reason, standard (in-line) ammeters such as those incorporated in multimeters, must always be connected in series with the load. This requires disconnecting or opening the normal circuit to insert the ammeter. Because of this inconvenience, as well as for safety reasons, the AC clamp-on ammeter is used almost exclusively for HVAC field service.

The clamp-on ammeter is most often used to measure the total AC current being drawn by a system or by individual loads like the compressor, fan motors, or heaters (Figure 3-20). For servicing three-phase systems, it is used to measure the current drawn by each phase to determine the percent of current imbalance, if any.

Figure 3-20.
Clamp-On Ammeter Connected to System for Current Measurement



Clamp-on ammeters have a movable set of jaws that can be opened and placed (clamped) around each of the wires to be measured, one wire at a time. The clamp-on ammeter works like a transformer. The wire being measured acts like the primary of a transformer and the "jaws" of the ammeter as the secondary. Current flowing through the wire creates lines of force that induce a current in the jaws. The induced current passes through the meter movement, providing an indication of how much current is passing through the wire. A clamp-on ammeter is easy to use, but a review of a few basic techniques will help you to obtain maximum performance.

- The jaws must be clean and properly aligned, or an error in the reading can result.
- Always start to measure within the highest possible measurement range and work toward the lower range to prevent damage to the meter.

- Do not turn a motor off and then on with the meter clamped around the motor lead. This precaution prevents damage to the meter from current surges.
- Do not clamp the jaws of the meter around two different wires at the same time. This will cause the meter to read an incorrect value of current.

Sometimes, the current being measured will be so low that it is difficult to get an accurate measurement, even on the lowest scale of the meter. One way to overcome this problem is to coil the wire through the jaws of the meter (Figure 3-21).

Winding one loop of the wire (two passes) around the jaws doubles the strength of the magnetic field, resulting in a meter reading that is twice the amount of current than is actually flowing in the circuit. If one loop is passed through the jaws, you must divide the meter reading by two (because of two passes) to determine the actual current. If two loops are passed through the jaws, you divide by three (three passes), and so on.

The adjustment of a room thermostat heat anticipator is a practical example of a procedure where this method is commonly used. The thermostat heat anticipator must be set to match the current draw of the components (heat control, gas valve, etc.) connected in the R-W circuit. As shown in Figure 3-22, an insulated wire is looped nine times around the jaws (ten passes through the jaws) of a clamp-on ammeter, then connected to the R and W terminals of the thermostat. For the purpose of this example, assume that the ammeter reads 5 amperes. Based on this measurement, you would adjust the heat anticipator to 0.5 amps (5 amps ÷ 10 passes = 0.5 amps).

Multimeters (VOM/DMM)

Analog (VOM) and digital (DMM) multimeters are used to measure voltage (volts), resistance (ohms), and current (amperes). Some can be used to make other measurements such as temperature or high current; these usually involve the use of one or more special probes or accessories that are readily available. Figure 3-23 shows an analog multimeter.

The multimeter is used mainly to measure:

- High-level AC voltages in power and load circuits.
- Low-level AC and DC voltages and DC currents in control and electronic module circuits.
- Resistance and continuity on system and component wiring, including motor windings, relay coils, and motor starter/contactor coils.
- Run and start capacitors for a shorted or open condition.

Measuring Voltage – Voltage measurements are usually made to determine source voltage, voltage drop, and/or voltage imbalance. Be sure to always connect the multimeter across (in parallel with) the circuit being measured. Know the capabilities and limitations of your multimeter before attempting any measurements. Read and follow the manufacturer's instructions.

Figure 3-21.
Increasing Measurable Current Using a Clamp-On Ammeter

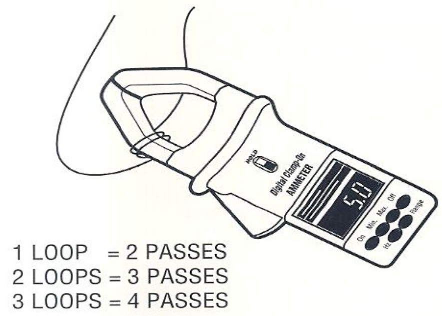


Figure 3-22.
Clamp-On Ammeter Connected for Room Thermostat Heat Anticipator Adjustment

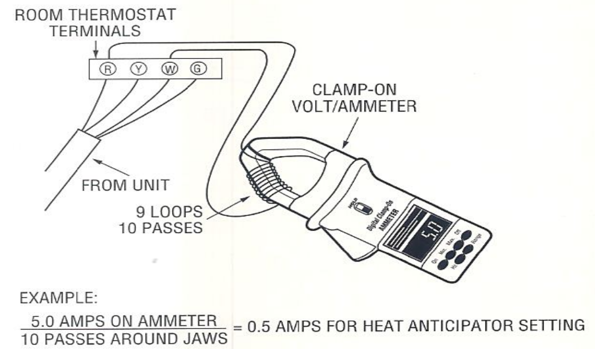
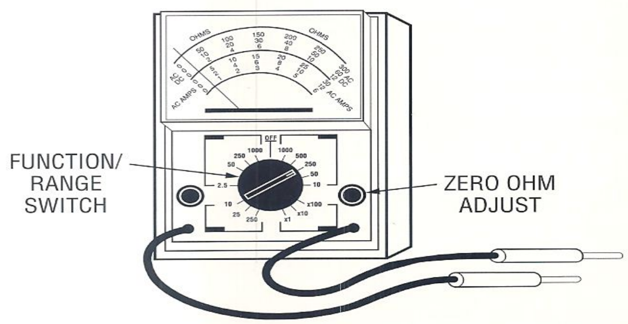
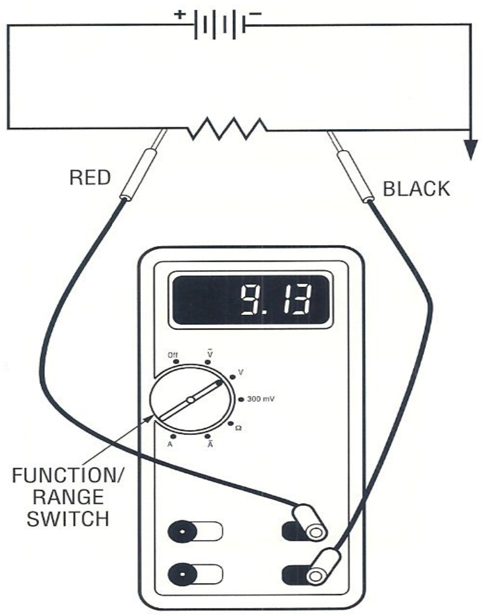


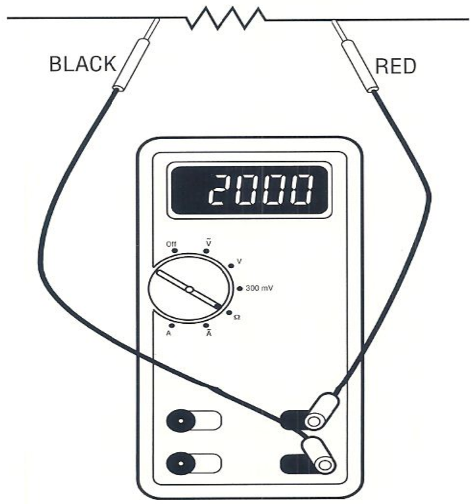
Figure 3-23.
Analog Multimeter (VOM)



▼ Figure 3-24.
Digital Multimeter Connected for Voltage Measurements



▼ Figure 3-25.
Digital Multimeter Connected for Resistance Measurements



See Figure 3-24. Make voltage measurements as follows:

1. Use the function/range switch to select AC or DC volts.
   If using an analog meter, always select a range higher than the highest anticipated reading. For example, if you expect to measure 24 volts AC, select the 300-volt AC range on the meter. Once a reading is obtained, switch to a lower range when making the measurement. For accuracy, select a range where the meter pointer reads in the mid to upper half of the selected range scale.
2. Plug the test probes into the meter jacks. Usually the black probe is connected to the common (COM) or minus (–) jack and the red probe to the plus (+) or V-Ohm jack.
3. Connect the test probe tips to the circuit in parallel with the load or power source. Measurement is easier and safer if an alligator clip is used on one of the leads. Be sure to shut off power to the equipment before attaching the alligator leads.
   If using an analog meter to measure DC voltage, you must observe correct polarity (+/–). Connect the red test probe to the positive side of the circuit and the black test probe to the negative side or circuit ground. If you reverse the connections, the meter movement will go off the scale in the opposite direction and damage to the meter may result. If using a digital meter with auto polarity, the reading will display a minus sign to indicate negative polarity.
4. View the reading on the digital meter readout. Be sure to note the unit of measurement indicated. If using an analog meter, read the voltage value indicated by the pointer on the AC or DC voltage scale. Make sure to use the scale that matches the selector switch voltage setting.

Measuring Resistance – Multimeters can measure the resistance in ohms (Ω) of all or any part of the circuit. Resistance values of HVAC components can vary greatly from a few ohms to several million ohms. Most multimeters can measure below one ohm; some measure as high as 300 million (meg) ohms. Multimeters contain their own battery power for use when making resistance measurements. Resistance measurements must be made with the equipment power off and all capacitors in the circuit discharged, otherwise damage to the meter can result. Some multimeters have high voltage protection (500 volts or more) in the resistance mode in case of accidental contact with voltages. This level of protection varies greatly between models.

Resistance measurements are usually made to determine the resistance of a load; e.g., relay, contactor or starter coils; motor windings; and electronic components such as diodes and resistors.

Make resistance measurements as follows (Figure 3-25).

1. Turn off power to the equipment or circuit.
2. Select resistance (ohms or Ω) using the function/range switch.

If using an analog meter, select the lowest resistance range that will accurately read the value. If unknown, start at the highest, then work your way down to a lower range when making the measurement. For accuracy, select the range where the pointer reads in the mid to upper half of the scale.

3. Plug the test probes into the meter jacks. Usually the black probe is connected to the common (COM) or minus (–) jack and the red probe to the plus (+) or V-Ohm jack.
   If using an analog meter, always zero the meter before the first measurement and whenever you change range scales. To zero the meter, touch the tips of the test probes together, then use the zero adjustment knob (Figure 3-23) to set the pointer to zero.
4. Before measuring resistance, make sure to electrically isolate the component being measured by disconnecting at least one lead of the component from the circuit. This is important in order to get an accurate resistance reading. Otherwise, the meter will read the combined resistance of all components that are connected in parallel with the component to be measured.
5. Connect the test probe tips across the component or portion of the circuit you want to measure.
6. View the reading on the digital readout or analog scale.

If using a digital meter, be sure to note the unit of measurement: ohms (Ω), kilohms (kΩ), or megohms (MΩ) shown for the reading.

If using an analog meter, determine the resistance value by multiplying the scale reading by the number (R x 1, R x 10, etc.) next to the function/range switch.

As shown on Figure 3-26, the reading "5" is multiplied by the selector setting R x 1, yielding a resistance of 5 ohms. At the R x 100 setting, the same reading would be 500 ohms, and at the R x 10,000 setting, it would be 50,000 ohms.

A *continuity check* is a go/no-go resistance test used to test for open and closed circuits. Examples are shown in Figure 3-27.

A good fuse offers no resistance. If using an analog meter for the measurement as shown, the pointer moves all the way to the right, displaying continuity (zero ohms). If using a digital meter, it may beep to indicate that continuity was detected and the digital readout will also show zero ohms. The level of resistance required to trigger the digital beeper varies from model to model. This beep feature is helpful because it allows continuity checks to be made without having to look at the meter reading.

If the fuse is bad, it has no path for current flow. The analog meter has no deflection and the pointer remains at the far left as shown, displaying infinite resistance or infinity (∞). This indicates an open circuit. If using a digital meter, it would indicate infinite resistance by reading "OL", flashing digits, or a similar message on the display indicating that the resistance is greater than the digital meter can measure.

Figure 3-26.
Interpreting Analog Meter Resistance Ranges

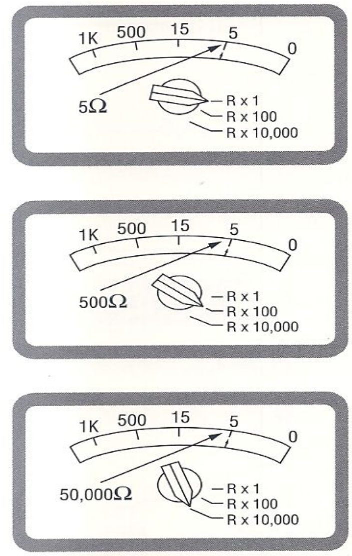
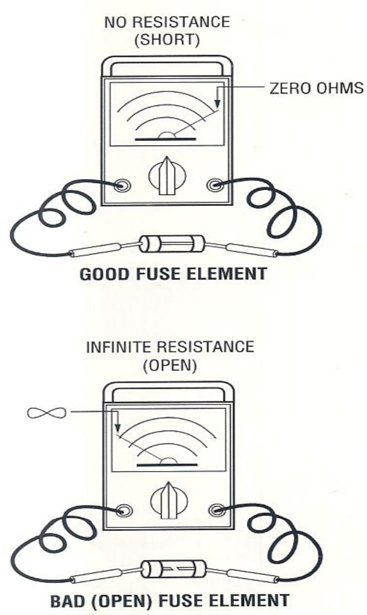


Figure 3-27.
Analog Meter Used to Measure Continuity



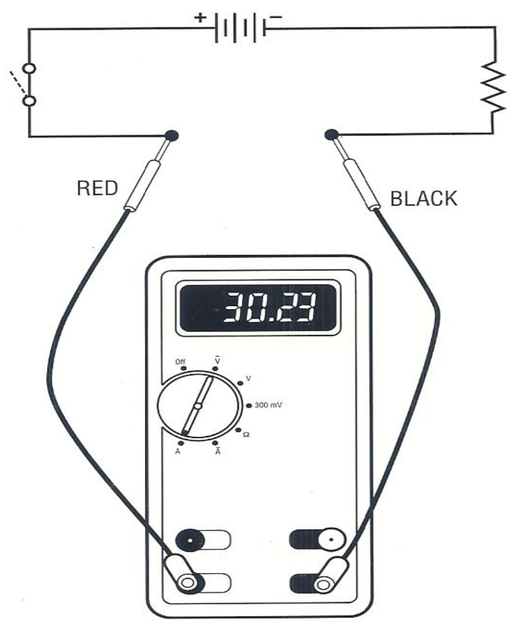
Unless specified by the manufacturer, the VOM/DMM should not be used to make resistance measurements on an electronic device. This is because when set up to measure resistance, the test voltage supplied by the internal battery of the VOM/DMM may exceed the safe voltage level for the electronic device under test, resulting in damage to the device.

Measuring Current – Making current measurements with a multimeter is different than making other measurements with a multimeter. Current measurements are made in series, unlike voltage or resistance measurements, which are made in parallel. The entire current being measured flows through the meter. As previously discussed, the clamp-on ammeter is used to make most of the higher AC current measurements needed for HVAC servicing. The multimeter is used mainly to make low-level DC current measurements in electronic control circuit modules.

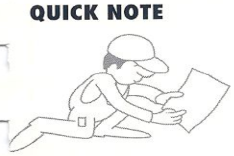
Make current measurements as follows (Figure 3-28):

1. Turn off power to the equipment or circuit. Disconnect a component or circuit to make a place where the multimeter probes can be inserted in series with the circuit to be measured.
2. Use the function/range switch to select DC amps. Select AC amps if AC is being measured.
   If using an analog meter, always select the highest range. If necessary, switch to a lower range when making the measurement. For accuracy, select the range where the indicator reads in the upper half of the scale face.
3. Plug the test probes into the meter jacks. Usually the black probe is connected to the common (COM) or minus (–) jack. Connect the red probe to the input jack marked for the DC range of the expected reading, the plus (+) jack, or other jack as applicable.
4. Connect the test probe tips in series with the circuit so that all current flows through the meter. Measurement is easier if alligator clips are used to connect the meter leads to the circuit. Be sure to turn the circuit power off before connecting the alligator clips.
   If using an analog meter to measure DC current, you must observe correct polarity (+/–). Connect the red test probe to the positive side of the circuit and the black test probe to the negative side or circuit ground. If you reverse the connections, the meter movement goes off the scale in the opposite direction and damage to the meter can result. If using a digital meter with auto polarity, the reading will display a minus sign to indicate negative polarity.
5. Turn the circuit power on. View the reading on the digital meter readout. Be sure to note the unit of measurement indicated. If using an analog meter, read the voltage value indicated by the pointer on the DC current scale. Make sure to use the scale that matches the selector switch current setting.

▼ **Figure 3-28.**
Digital Multimeter Connected for Current Measurements



QUICK NOTE



Inaccurate or intermittent readings may occur when using a digital multimeter to take measurements in the vicinity of high-voltage sparks, such as generated by a furnace pilot ignitor.

Care of Electronic Test Instruments

Electronic test instruments are precision instruments and must be handled and maintained as such. Most are battery operated. Aging of the battery(s) will affect the accuracy of the meter. If so equipped, the digital meter internal battery test should be performed to check the condition of the battery. Otherwise, the battery should be replaced periodically. If an analog meter cannot be zeroed, it is a good indication that the battery is weak and needs to be replaced. Operate and care for the meter as directed by the manufacturer, and always follow the manufacturer's recommended calibration and maintenance schedules.

QUICK NOTE

ALWAYS zero a meter before each use, and make a habit of using the digital meter internal battery test (if so equipped). An inaccurate meter can cause costly and embarrassing mistakes.

SECTION FOUR
SERVICE PROCEDURES

SECTION 4
SERVICE PROCEDURES

INTRODUCTION

This section contains procedures used most often for the field service of residential and light commercial HVAC equipment. The procedures provide the entry-level service technician with a reference set of field-proven, recommended methods for performing the most frequently needed servicing tasks. The experienced technician will find the information useful when considering alternative service procedures. The service procedures contained in this section are divided into three categories:

• **Refrigeration System** (SP-1 through SP-6) • **Electrical System** (SP-7 through SP-12) • **Air System** (SP-13 through SP-18)

Service Procedures

The format used for the service procedures in this section (Figure 4-1) is essentially the same for all procedures. Each service procedure consist of two parts. In the first part, introductory text briefly explains the purpose for performing the procedure, and why and when the procedure is normally performed. Background information needed by the technician to understand what the procedure is to accomplish is also given. If applicable, variations or options are described. The important pre-test conditions, precautions, and/or safety information pertaining to a procedure are also emphasized.

The second part of each procedure identifies the specific instruments and devices needed to perform the procedure, followed by the detailed step-by-step instructions for performing the task covered by the procedure. The instructions are presented in an easy-to-use tabular format that is keyed to the supporting illustrations.

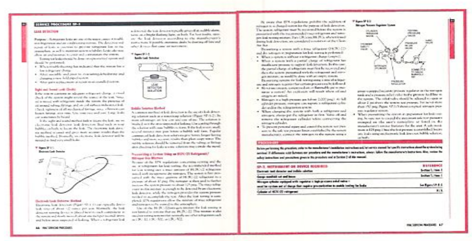
Service Procedure Precautions

Before attempting the service procedures contained in this section, always follow the precautions listed below.

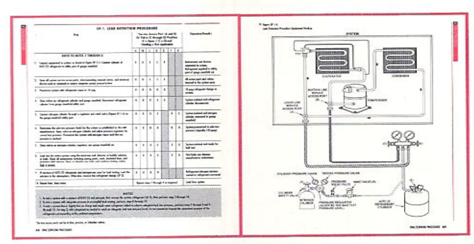
- Read the safety instructions and precautions given in Section 2 of this manual.
- To avoid hazards and servicing mistakes, always review a procedure before doing it. This review makes you aware of, and able to handle, all of the important safety and servicing conditions before you start.
- Before proceeding with a particular procedure, always refer to the manufacturer's installation instructions and/or service manual for specific instructions about the system being serviced. If differences exist between our procedure and the manufacturer's instructions, always follow the manufacturer's instructions.

CONTENTS **PAGE**

Figure 4-1.
Service Procedure Format



INTRODUCTORY TEXT



DETAILED PROCEDURE

SERVICE PROCEDURE SP-1

LEAK DETECTION

Purpose – Refrigerant leaks are one of the major causes of trouble in refrigeration and air conditioning systems. The detection and repair of leaks is essential to prevent refrigerant loss to the atmosphere, as well to maintain system reliability. Leaks also may allow air and moisture to enter and contaminate the system. Testing for leaks should be done on a pressurized system and should be performed:

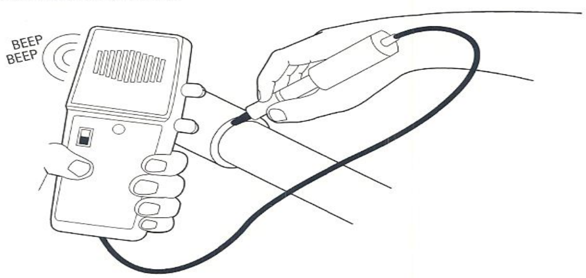
- When troubleshooting has indicated that the system has a low refrigerant charge.
- After assembly and prior to evacuating/dehydrating and charging a new field-piped system.
- After parts replacement or repair in an installed system.

Sight and Sound Leak Checks

If the system contains an adequate refrigerant charge, a visual check of the system might reveal the source of the leak. Since oil is mixed with refrigerant inside the system, the presence of oil around tubing, fittings, and on coil surfaces indicates a leak. Check tightness of all mechanical fittings, since vibration can loosen fittings over time. Use your eyes and ears. Large leaks can sometimes be heard.

If the sight and sound method fails to locate the leak, use an electronic leak detector, leak detection fluid such as soap bubbles, or both, to locate the leak. The electronic leak detector method is easier and gives more accurate results than the bubble method. Normally, an electronic leak detector will be needed to find very small leaks. Make sure your leak detector can sense the refrigerant.

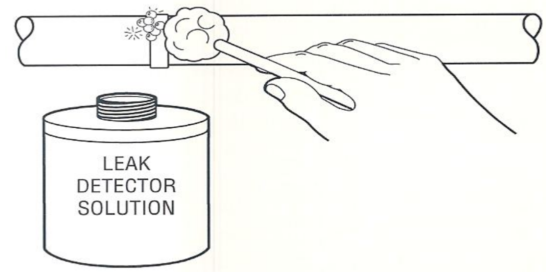
▼ Figure SP-1-1.
Electronic Leak Detector



Electronic Leak Detector Method

Electronic leak detectors (Figure SP-1-1) can typically detect leak rates of about 1/2 ounce per year. Normally, the leak detector sensing device is placed next to each component in the system and slowly moved (about one inch per second) above and below areas suspected of leaking. When a refrigerant leak is detected, the leak detector typically gives off an audible alarm, turns on a bright flashing light, or both. For best results, operate the leak detector according to the manufacturer's instructions. If possible, minimize drafts by shutting off fans and other devices that cause air movement.

▼ Figure SP-1-2.
Bubble Leak Detection



Bubble Solution Method

A common method of leak detection is the use of a leak detecting solution such as a water/soap solution (Figure SP-1-2). Its main advantages are low cost and ease of use. The solution is brushed over the area suspected of leaking. Gas coming through the solution will cause bubbles to form. If the leak is very small, several minutes may pass before a bubble will form. Popular commercial leak detection solutions give better, longer-lasting bubbles and more accurate results than plain soapy water. The bubble solution should be removed from the tubing or fittings after checking for leaks as some solutions may corrode the metal.

Pressurizing a System Using an HCFC-22 Refrigerant/ Nitrogen Gas Mixture

Because of the EPA regulations concerning venting and the use of refrigerants for leak testing, the recommended method for leak testing uses a trace amount of HCFC-22 refrigerant mixed with inexpensive dry nitrogen. The system is first pressurized with the trace quantity of HCFC-22 refrigerant to a pressure of about 10 psig. Dry nitrogen is then used to further increase the system pressure to about 125 psig. The trace refrigerant in this mixture is enough to be detected by an electronic leak detector, while the nitrogen provides the system pressure needed to accomplish the test. After the leak testing is completed, EPA regulations allow the mixture of trace refrigerant and nitrogen to be vented to the atmosphere.

Use of the HCFC-22/nitrogen mixture for leak testing is not limited to systems that use HCFC-22. This mixture is also used for testing systems that normally use other refrigerants such as CFC-12, CFC-500, or CFC-502.

Be aware that EPA regulations prohibit the addition of nitrogen to a charged system for the purpose of leak detection. The system refrigerant must be recovered before the system is pressurized with the recommended trace refrigerant and nitrogen leak-testing mixture. Pure CFCs and HCFCs, when released during leak detection, are considered a violation of the Clean Air Act.

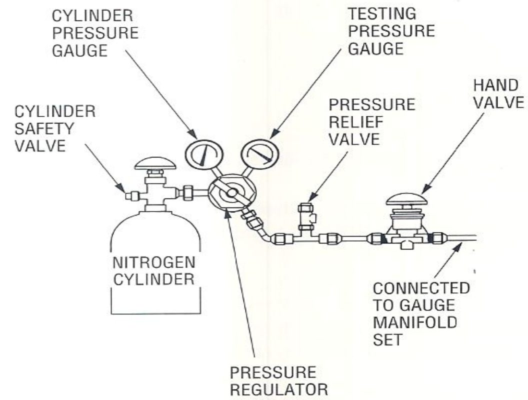
Pressurizing a system with a trace refrigerant (HCFC-22) and dry nitrogen in preparation for leak testing is performed:

- When a system is without a refrigerant charge (empty).
- When a system with a partial charge of refrigerant has insufficient pressure to support leak detection. In this case, the partial charge of refrigerant must first be recovered and then the system pressurized with the refrigerant and nitrogen mixture, as would be done with an empty system.

Pressurizing systems for leak testing using a mix of refrigerant and nitrogen requires that certain precautions be followed:

- Never use oxygen, compressed air, or flammable gas to pressurize a system! An explosion will result when oil and oxygen are mixed.
- Nitrogen is a high-pressure gas (about 2,000 psig). At full cylinder pressure, nitrogen can rupture a refrigerant cylinder and/or the refrigeration system.
- When charging the system with both a refrigerant and nitrogen, always put the refrigerant in first. Valve off and remove the refrigerant cylinder before connecting the nitrogen cylinder.
- To prevent personal injury and control the system test pressure to the safe test pressure limits established by the system manufacturer, connect the nitrogen to the system using a gauge-equipped accurate pressure regulator on the nitrogen tank and a pressure relief valve in the pressure feed line to the system. The relief valve should be adjusted to open at about 2 psi above the system test pressure, but never more than 150 psig. Figure SP-1-3 shows a typical nitrogen pressure regulator system.
- When pressurizing the system in preparation for leak testing, be sure not to exceed the maximum safe test pressures stamped on the unit's nameplate or listed in the manufacturer's service literature for the unit. A safe maximum is 125 psig. Once the test pressure is established, locate any leaks using an electronic leak detector, bubble solution, or both.

▼ Figure SP-1-3.
Nitrogen Pressure Regulator System



PROCEDURE

Before performing this procedure, refer to the manufacturer's installation instructions and/or service manual for specific instructions about the system being serviced. If differences exist between our procedure and the manufacturer's instructions, always follow the manufacturer's instructions. Also, review the safety instructions and precautions given in this procedure and in Section 2 of this manual.

SP-1. INSTRUMENT OR DEVICE REQUIRED	REFERENCE
Electronic leak detector and bubble solution	Section 1, Item 5
Gauge manifold set and hoses	Section 1, Item 1
Nitrogen cylinder equipped with regulator & high-pressure relief valve – used for system out of charge that requires pressurization to enable testing for leaks	See Figure SP-1-3
Cylinder of HCFC-22 refrigerant	N/A

SP-1. LEAK DETECTION PROCEDURE

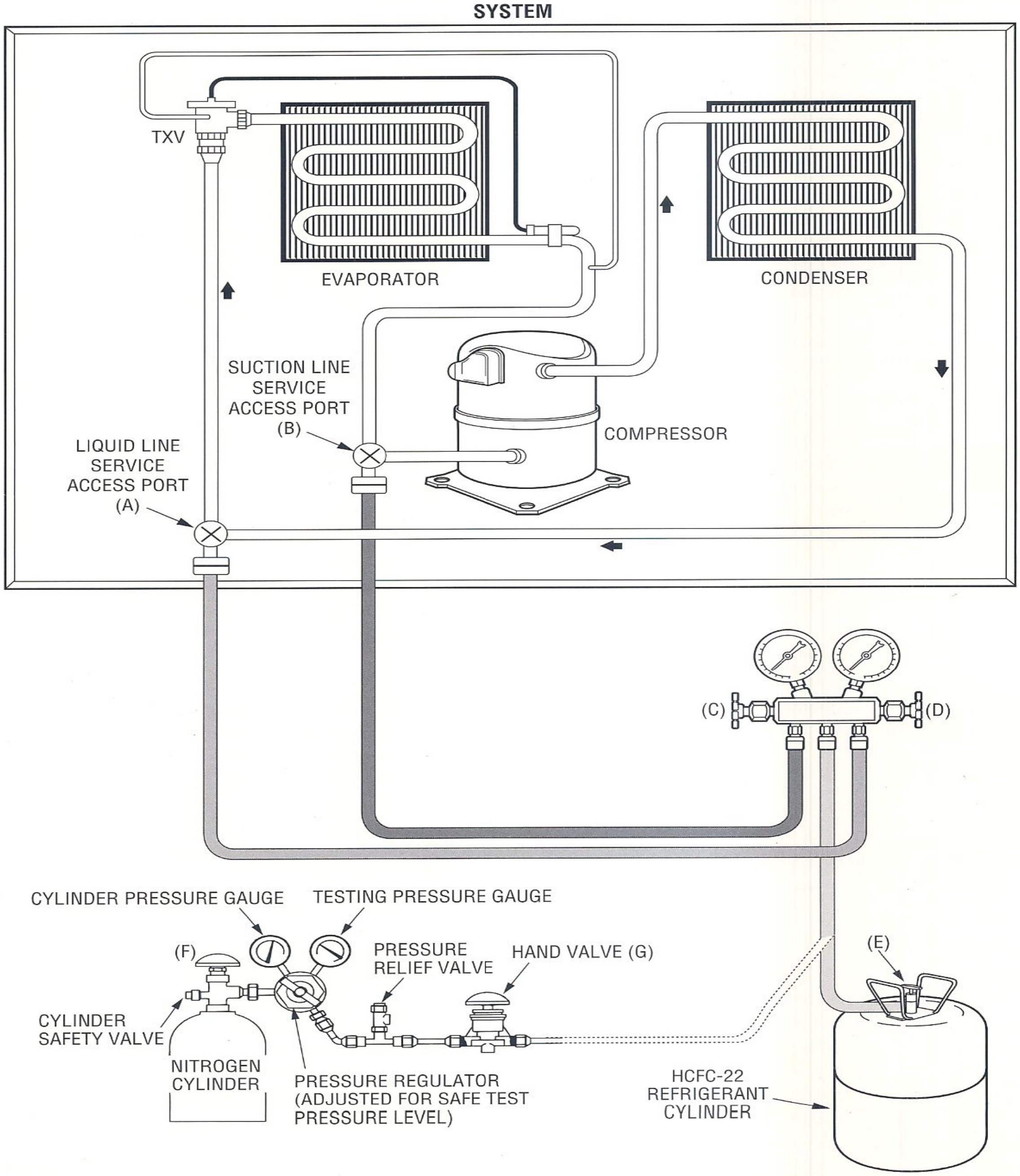
Step	*Service Access Port (A and B) Or Valve (C through G) Position O = Open / X = Closed Shading = Not Applicable							Expected Results
	*A	*B	C	D	E	F	G	
REFER TO NOTES 1 THROUGH 3								
1. Connect equipment to system as shown in Figure SP-1-4. Connect cylinder of HCFC-22 refrigerant to utility port of gauge manifold.	X	X	X	X	X			Instruments and devices connected to system. Refrigerant supplied to utility port of gauge manifold set.
2. Open all system service access ports, interconnecting manual valves, and electrical devices such as solenoids to ensure complete system pressurization.	O	O	X	X	X			All access ports and valves internal to the system open.
3. Pressurize system with refrigerant vapor to 10 psig.	O	O	O	O	O			10 psig refrigerant charge in system.
4. Close valves on refrigerant cylinder and gauge manifold. Disconnect refrigerant cylinder from gauge manifold utility port.	O	O	X	X	X			System isolated and refrigerant cylinder disconnected.
5. Connect nitrogen cylinder through a regulator and relief valve (Figure SP-1-4) to the gauge manifold utility port.	O	O	X	X		X	X	System isolated and nitrogen cylinder connected to gauge manifold.
6. Determine the safe test pressure limits for the system as established by the unit manufacturer. Open valve on nitrogen cylinder and adjust pressure regulator for correct test pressure. Pressurize the system with nitrogen vapor until the test pressure is reached.	O	O	O	O		O	O	System pressurized to safe test pressure (typically 125 psig).
7. Close valves on nitrogen cylinder, regulator, and gauge manifold set.	O	O	X	X		X	X	System isolated and ready for leak test.
8. Leak test the entire system using the electronic leak detector or bubble solution, or both. Check all components including piping, joints, seals, insulated lines, and pressure relief devices. Mark or identify any leaks and continue testing, unless leak is severe.	O	O	X	X		X	X	Find leaks per detector manufacturer instructions.
9. If mixture of HCFC-22 refrigerant and nitrogen was used for leak testing, vent the mixture to the atmosphere. Otherwise, recover the refrigerant charge (SP-2).	O	O	O	O				Refrigerant/nitrogen mixture vented or refrigerant recovered.
10. Repair leak, then retest.	Repeat steps 1 through 9 as required.							Leak-free system.

NOTES

1. To test a system with a mixture of HCFC-22 and nitrogen, first recover the system refrigerant (SP-2), then perform steps 1 through 10.
2. To test a system with adequate pressure to accomplish leak testing, perform steps 8 through 10.
3. To test a system that is slightly low on charge and needs some refrigerant added to achieve adequate leak test pressure, perform steps 1 through 3 and 8 through 10. For step 3, add refrigerant as needed to reach an adequate leak test pressure level. Do not pressurize beyond the saturation pressure of the refrigerant corresponding to the ambient temperature.

*Service access ports can be in-line, process, or Schrader valves.

▼ Figure SP-1-4.
Leak Detection Procedure Equipment Hookup



REFRIGERANT RECOVERY, RECYCLING, AND RECLAMATION

Purpose – Venting of refrigerant is against the law and violators are subject to fines and loss of certification. EPA regulations require that all CFC and HCFC refrigerants be recovered before any system can be opened for service.

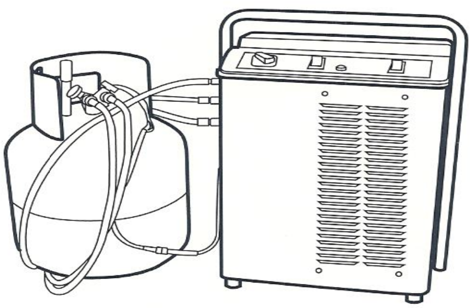
Recovery

The recovery of refrigerant removes refrigerant in any condition of purity from a system or container for storage in an approved external container (recovery cylinder). No processing is necessarily done on the recovered refrigerant. Currently, recovered refrigerant is only reusable if it does not change ownership from the owner of the equipment being serviced.

Recovery of refrigerant from a system is done using a certified recovery unit (Figure SP-2-1) or a combined recovery/recycle unit (Figure SP-2-2). Recovery must be performed:

- Before a refrigeration system can be opened to make repairs.
- Before pressurizing a system for leak testing with a mixture of HCFC-22 refrigerant and nitrogen.
- Before disposing of any system or component containing CFC or HCFC refrigerants.
- When it is necessary to remove excess charge from an overcharged system.

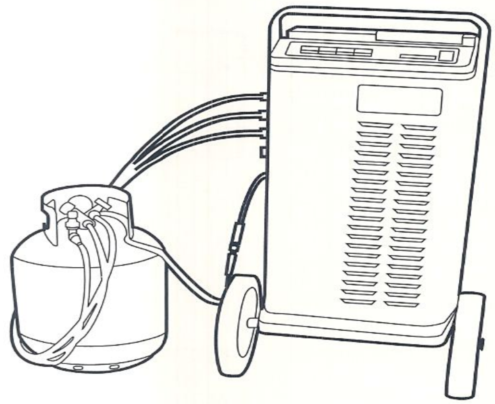
▼ Figure SP-2-1.
Recovery Unit



Recycling

Recycling means to process refrigerant recovered from a system through a cleaning and decontamination process so that it is suitable for reuse. This does not imply that its purity meets the cleanliness specifications for new refrigerants. Recycling is usually performed at the job site or service shop using a recycling unit or a combined recovery/recycle unit (Figure SP-2-2). Recycled refrigerant is only reusable by the owner of the equipment being serviced.

▼ Figure SP-2-2.
Combined Recovery/Recycle Unit



Reclamation

Reclaiming refrigerant is a distillation process that returns recovered refrigerant to the purity of factory-fresh refrigerant. In order for refrigerant to be classified as "reclaimed," it must be tested to meet ARI Standard 700. Refrigerant cleaned to meet this standard can be used in any application. Reclamation is a complicated process and is done only at reprocessing or manufacturing facilities. Because of this, reclamation is not a field service procedure.

Recovery/Recycle Unit Method

As part of the no-venting regulations, the EPA requires that all refrigerant be recovered from a system before the system can be opened for servicing. Recovery of all refrigerant actually means recovery to levels considered acceptable by the EPA. The acceptable levels of recovery are defined by a set of required levels of evacuation (Figure SP-2-3) that must be achieved when recovering refrigerant from a system, or component of a system, for the various categories of equipment.

When opening any system, except for small appliances, you must evacuate the system to the vacuum level set forth by the EPA. The EPA defines small appliances as those in which the refrigerant is sealed within the unit at the factory and the amount of charge is five pounds or less. An example of a small appliance is a room air conditioner. For small appliances, the system is considered completely recovered when either 90% of the refrigerant is removed if the unit has a running compressor, or 80% of the refrigerant is removed if the unit has a non-operating compressor. Since it is difficult to know when the 80% to 90% levels are reached, for practical purposes, small appliances can

▼ **Figure SP-2-3.**
Required Levels of Evacuation

Type of Appliance	Inches of mercury vacuum at standard atmospheric pressure of 29.92 inches of mercury using recovery equipment manufactured:	
	Before Nov. 15, 1993	On or After Nov. 15, 1993
HCFC-22 appliance with less than 200 lbs. of charge	0	0
Other high-pressure appliance with less than 200 lbs. charge	4	10
Small appliance (factory installed and sealed charge of 5 lbs. or less)	0	0

be considered recovered to an acceptable level when evacuated to 0 psig (0 inches of mercury).

There are some exceptions to these EPA recovery evacuation levels. If evacuation to the specified levels is not achievable because of leaks in the system, or if recovery to these levels would contaminate the refrigerant being recovered, you must:

- When possible, isolate the leaking components from the rest of the system.
- Evacuate non-leaking components to the required levels, if they are to be opened.
- Evacuate leaking components to the lowest level attainable without substantially contaminating the refrigerant. This level cannot exceed 0 psig.

Recovery of refrigerant from a system to the evacuation levels specified by the EPA requires the use of a certified refrigerant recovery unit or recovery/recycle unit. Generally speaking, the greater the vacuum pulled by the recovery unit, the higher the probability that a high percentage of the refrigerant is recovered. Most recovery units are capable of recovering refrigerant from a system in either the vapor or liquid state. Many automatically adjust to liquid or vapor recovery so refrigerant is pulled from the system as efficiently as possible. Because there is a wide difference in the capabilities of recovery or recovery/recycle units made by the various manufacturers, you must always follow the manufacturer's safety and operating instructions for the recovery unit being used to achieve the best results.

When the refrigerant to be recovered is highly contaminated, such as after a compressor burnout, or when liquid refrigerant is being recovered, it is a good practice to install an external filter-drier in the common center hose of the gauge manifold set connected to the recovery unit. Be sure to orient the filter-drier for correct flow direction.

Keep in mind that recovery units are not vacuum pumps and do not provide that function. If the dehydration/evacuation of a system is required, a vacuum pump must be used. Refer to Service Procedure SP-3 for instructions on the dehydration/evacuation of a system.

A recycle unit is used to dehydrate and purify the refrigerant so that it can be returned to the system in a purer condition than when recovered. Always make sure that the unit used is capable of processing the refrigerant you plan to handle. The dehydrating and purifying capability of recycle units varies from one model and manufacturer to another. Most recycle units circulate the refrigerant through a distillation, filtration, and drying process to achieve the desired refrigerant quality.

When recycling is completed, the refrigerant is cleaned, but not necessarily to the manufacturer's original specifications. Acid/moisture testing of recycled refrigerant should be performed to verify the quality of recycled refrigerant before placing it back into the system. For instructions on how to perform an acid/moisture test, refer to Service Procedure SP-5. Recycled refrigerant can only be reused in the same system from which it was recovered, or another system owned by the same customer.

Before using a recovery unit or recycling unit to process a different refrigerant than was last processed, the recovery or recycle unit compressor oil must be drained and replaced with new oil. All filter-driers must be replaced and the recovery or recycle unit must be evacuated. Always make sure to use a recovery cylinder designated for use with the type of refrigerant to be recovered or recycled.

PROCEDURE

Before performing this procedure, refer to the manufacturer's installation instructions and/or service manual for specific instructions about the system being serviced. If differences exist between our procedure and the manufacturer's instructions, always follow the manufacturer's instructions. Also, review the safety instructions and precautions given in this procedure and in Section 2 of this manual.

Refer to the unit nameplate or manufacturer's literature to find out how much refrigerant the unit holds when fully charged. When in doubt, the rule of thumb is to estimate the system charge at about 2 pounds per ton of design capacity. Knowing the amount of charge is necessary so that you can have enough clean, dry, empty refrigerant cylinders to hold the entire system charge. To avoid contamination of the recovered refrigerant, be sure to evacuate any empty recovery cylinders you intend to use and do not mix refrigerants in the recovery cylinder. Use caution before opening any piping connections; refrigerants under pressure are present in the system being serviced and in the recovery or recovery/recycle unit.

SP-2. INSTRUMENT OR DEVICE REQUIRED

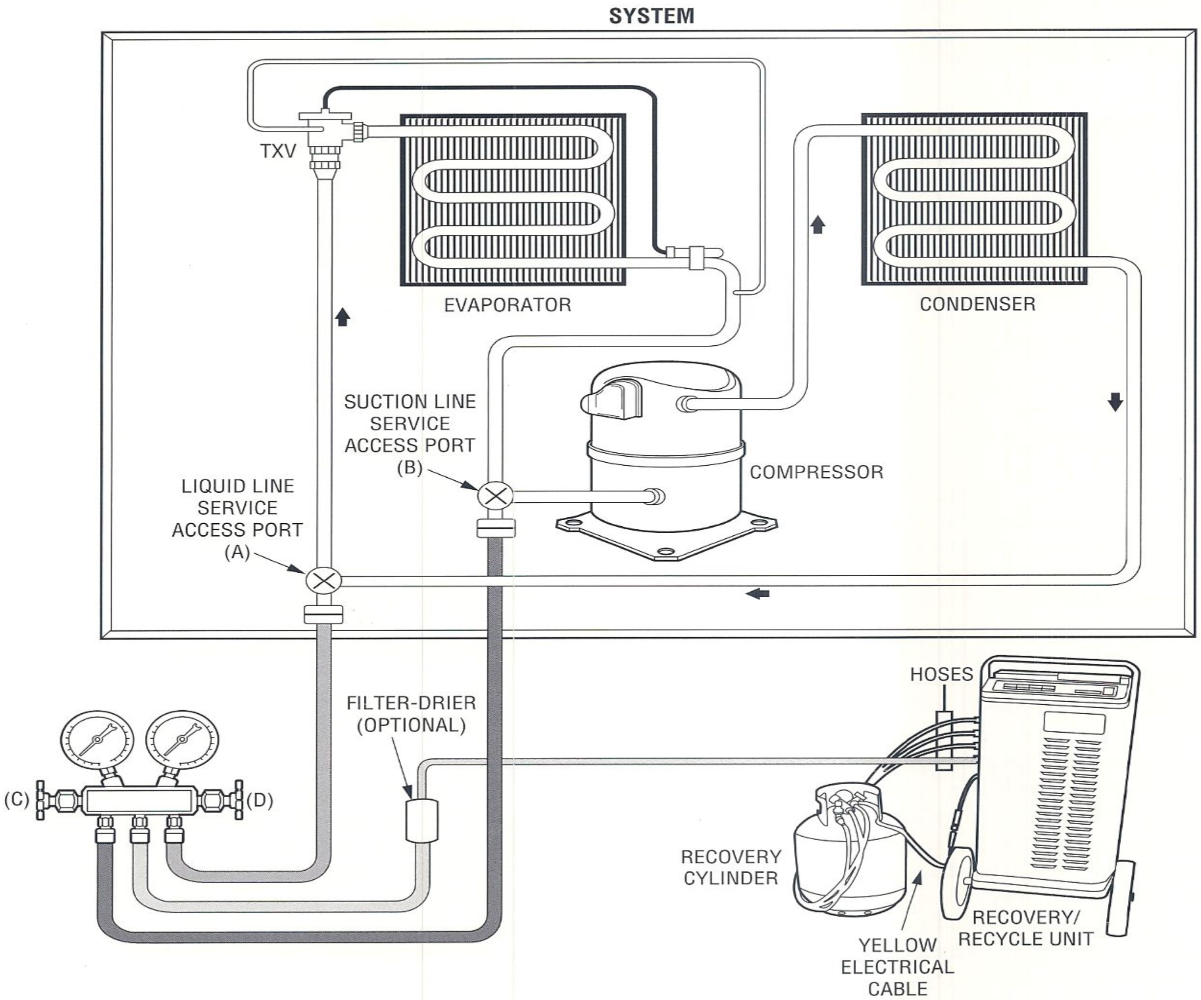
Instrument or Device	REFERENCE
Gauge manifold set and hoses	Section 1, Item 1
Recovery unit, recycle unit, or an integrated recovery/recycle unit	Section 1, Item 4
Empty and evacuated recovery cylinder(s) to hold refrigerant recovered from the equipment being serviced (Recovery cylinders should have a built-in 80% shutoff sensor designed to work with the recovery or recovery/recycle unit being used)	Section 3
Filter-drier – used when recovering liquid refrigerant or refrigerant that is highly contaminated, such as after a compressor burnout, or when liquid refrigerant is being recovered	N/A

SP-2. REFRIGERANT RECOVERY/RECYCLE PROCEDURE

Step	*Service Access Port (A and B) Or Valve (C and D) Position O = Open / X = Closed Shading = Not Applicable				Expected Results
	*A	*B	C	D	
1. Connect equipment to system as shown in Figure SP-2-4. Follow the manufacturer's instructions for connecting the recovery cylinder to the recovery or recovery/recycle unit.	X	X	X	X	Instruments and devices connected to system.
2. Recover system refrigerant. Follow the manufacturer's instructions for operating the recovery or recovery/recycle unit. Be sure to obtain the level of evacuation required by EPA regulations.	O	O	O	O	Refrigerant is recovered from system in accordance with EPA required levels of evacuation and stored in the recovery cylinder. It can then be recycled or recharged into the original system.
3. Isolate the system from the recovery or recovery/recycle unit. Disconnect instruments and devices as applicable.	X	X	X	X	System ready for repair or other service procedure.
4. If desired, recycle the recovered refrigerant. Follow the manufacturer's instructions for operating the unit.					Recovered refrigerant is recycled to remove contaminants. It can then be recharged into the original system, or another system owned by the same customer.

*Service access ports can be in-line, process, or Schrader valves.

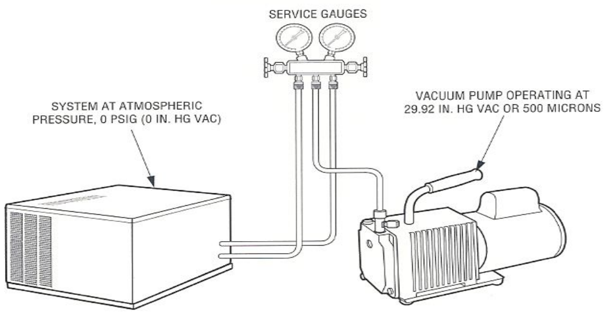
▼ Figure SP-2-4.
Refrigerant Recovery/Recycle Procedure Equipment Hookup



EVACUATION AND DEHYDRATION

Purpose – Evacuation removes air and moisture trapped in a refrigeration system by the use of a vacuum pump. Air occupies space in the refrigeration system, reduces heat transfer, and causes erratic operation. Moisture creates problems of freeze-up that can result in blocked refrigerant flow. Moisture also combines with oil and refrigerant to form corrosive acid and sludge. All of these conditions can cause system damage or failure.

▼ Figure SP-3-1.
Higher System Pressure Moves to Lower Vacuum Pump Pressure



The vacuum pump creates a pressure differential between the system and the pump. This causes air and moisture vapor trapped in the system at a higher pressure to move into a lower pressure (vacuum) area created in the vacuum pump. When the vacuum pump lowers the pressure (vacuum) in the system enough, as determined by the ambient temperature of the system, liquid moisture trapped in the system will boil and change into vapor. Water will boil at room temperature if it is in a deep enough vacuum. Like free air, this water vapor is then pulled out of the system, processed through the vacuum pump, and exhausted to the atmosphere.

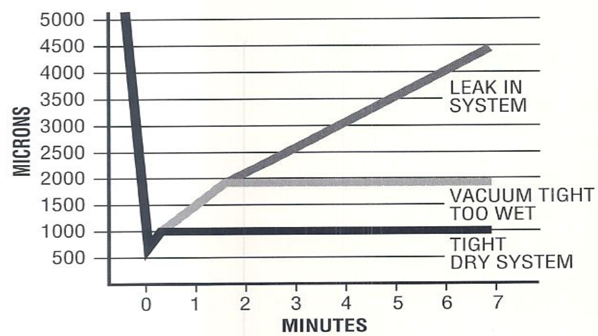
The *deep vacuum method* and *triple evacuation method* of system evacuation and dehydration are both used frequently. The deep vacuum method is typically used after a repair was made that required the system charge to be recovered and the system opened. Use of the triple evacuation method is recommended when a system has been especially wet. This can be determined by performing an acid/moisture test on the system refrigerant (SP-5) before or during recovery of the refrigerant. Generally, evacuation and dehydration of a system is performed in the following circumstances:

- After assembly and prior to charging a new field-piped split system, evacuate/dehydrate the low-pressure side and piping. When complete, open the service valves and add refrigerant charge to the system as needed.
- After assembly of a field-piped system, evacuate/dehydrate the entire system before charging.
- After an installed system is opened to the atmosphere as a result of parts replacement or leak repair.
- When an acid/moisture test (SP-5) shows moisture or non-condensible gas in the system.

Deep Vacuum Method

The deep vacuum method of dehydration relies on evacuation alone to remove moisture from the system. A deep vacuum is any vacuum of 500 microns or less; that is, 29.92 in. Hg vac. or greater. When a deep vacuum is established in a closed system, non-condensibles are reduced to a negligible level. As the pressure is reduced, the boiling point of water is also reduced. As long as the ambient temperature surrounding the system is higher than the boiling point of the internal moisture, it will boil off and be expelled. For example, at a vacuum of about 29.72 in. Hg vac. or 5,000 microns, liquid water will boil anywhere in a system where the temperature is 35° F or higher.

▼ Figure SP-3-2.
System Check After Deep Vacuum



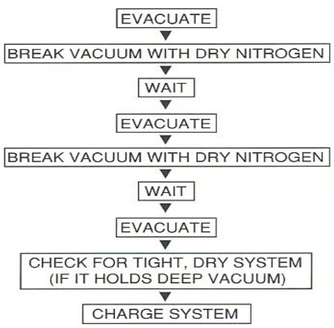
In order to know the system has been adequately evacuated, the final equilibrium pressure of the entire system must be found after the system is pumped down and before it is charged. See Figure SP-3-2. First, the system is reduced to a pressure of about 500 microns or below, then it is isolated from the vacuum pump. The reading on the vacuum gauge/indicator is then monitored to note any change in the level of vacuum in the system. If the indicator shows a pressure rise and the pressure continues to rise without leveling off, a leak exists in the system or the connecting tubing. Locate the leak (SP-1) and repair it.

If the indicator shows a pressure rise but levels off between 1,000 and 2,000 microns, this indicates that the system is leak-tight, but still too wet. A constant reading on the indicator of between 500 and 1,000 microns indicates a leak-tight, dry system.

Triple Evacuation Method

The triple evacuation method is a multiple evacuation procedure based on diluting the non-condensibles and water in the system with dry nitrogen. The nitrogen is then vented from the system, carrying with it some of the contaminants. As the procedure is repeated, the remaining contaminants are reduced until a contaminant-free system is available. This method relies on the moisture-absorbing ability of nitrogen to absorb (blot up) moisture in the system during the time period between each evacuation. When the nitrogen is removed, the moisture absorbed is "swept" out of the system. Field experience has shown that three repeats of this procedure will usually assure a contaminant-free system, hence the name triple evacuation method. The triple evacuation method is also called the *triple sweep method*, the *dilution method*, and the *blotter method*. Figure SP-3-3 shows the sequence of the triple evacuation process.

Figure SP-3-3.
Triple Evacuation Process



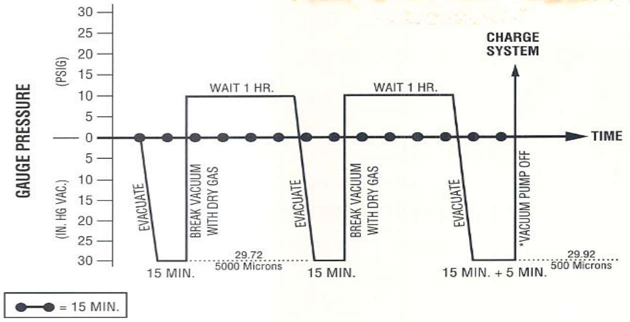
As shown in Figure SP-3-4, the triple evacuation process takes about three hours when performed as recommended. This time can vary depending on how deep a vacuum is drawn in each step, how large the system is, and how great a capacity the vacuum pump has. As shown, the system is evacuated to 29.72 inches of mercury (in. Hg) vacuum, or about 5,000 microns during the first two evacuations. The vacuum pump continues to run at this level or lower for at least 15 minutes.

Between the evacuations, the system is pressurized with dry nitrogen to about 10 psig and allowed to sit for about an hour so that the nitrogen can absorb the moisture. Be aware that using a pressure higher than 10 psig only wastes nitrogen. A pressure of 10 psig provides enough nitrogen to adequately absorb moisture in the system. At this time, it is a good practice to install a filter-drier in the system to prevent future moisture problems.

For the third and last evacuation, a deep vacuum of 29.92 in. Hg or 500 microns is drawn and the system is leak tested in the manner previously described for the deep vacuum method.

One benefit of using the triple evacuation method is that the majority of moisture is swept out rather quickly in the first two evacuations. The third and deeper evacuation takes care of the liquid water that the shallow evacuations do not remove. Another benefit is that the dry nitrogen used between evacuations absorbs moisture well and is readily available and inexpensive. Also, it can be vented from the system to the atmosphere after each of the waiting periods.

Figure SP-3-4.
Triple Evacuation Cycles and Pressures



Using nitrogen to pressurize systems for triple evacuation requires that certain precautions be followed:

- Never use oxygen, compressed air, or flammable gas to pressurize a system! An explosion will result when oil and oxygen are mixed.
- Nitrogen is a high-pressure gas (about 2,000 psig). At full cylinder pressure, nitrogen can rupture a refrigerant cylinder and/or the refrigeration system.
- To prevent personal injury and to control the system test pressure to the safe test pressure limits established by the system manufacturer, connect the nitrogen to the system using a gauge-equipped accurate pressure regulator on the nitrogen tank and a pressure relief valve in the pressure feed line to the system. The relief valve should be adjusted to open at about 2 psig above the system test pressure, but never more than 150 psig.

Vacuum Pump Maintenance

The oil used in the vacuum pump can become contaminated. It should be changed after every 10 hours of operation or immediately after evacuating a wet or contaminated system.

Moist vapor passing through a vacuum pump condenses into a liquid and mixes with the vacuum pump oil unless the pump is equipped with a gas ballast. All quality vacuum pumps have a gas ballast that should be opened during the early stages of a pumpdown. This valve introduces air into the second stage of the pump. This air mixes with the vapor being evacuated from the system and minimizes pump oil contamination. The ballast valve can be opened or closed at any time when the pump is running, but should be closed each time the pump is started. Oil may be discharged during the first revolution if it is left open.

PROCEDURE

Before performing this procedure, refer to the manufacturer's installation instructions and/or service manual for specific instructions about the system being serviced. If differences exist between our procedure and the manufacturer's instructions, always follow the manufacturer's instructions. Also, review the safety instructions and precautions given in this procedure and in Section 2 of this manual.

Prerequisites for this procedure are: the system refrigerant has been recovered (SP-2), it has been tested for leaks (SP-1), and all system pressures are at 0 psig.

SP-3. INSTRUMENT OR DEVICE REQUIRED	REFERENCE
Gauge manifold set and services hoses	Section 1, Item 1
Vacuum gauge/indicator	Section 1, Item 8
Vacuum pump	Section 1, Item 7
Additional service hose, tee and adapters – used to provide connection for vacuum gauge/indicator	See Figure SP-3-5
Nitrogen cylinder equipped with regulator & high-pressure relief valve – used for triple evacuation method	See Figure SP-3-5

SP-3. EVACUATION/DEHYDRATION PROCEDURE (STEPS 1 THROUGH 8)

Step	*Service Access Port (A and B) Or Valve (C through F) Position O = Open / X = Closed Shading = Not Applicable						Vacuum Pump	Vacuum Indicator	Expected Results
	*A	*B	C	D	E	F			
REFER TO NOTES 1 AND 2									
1. Connect vacuum pump and vacuum gauge/indicator to system as shown in Figure SP-3-5.	X	X	X	X			Off	Off	Instruments and devices connected to system.
2. Check service hookup for leaks.	X	X	O	O			On	On	Vacuum gauge/indicator reads 500 to 300 microns.
3. Evacuate system to 5,000 microns (29.72 in. Hg vac.) or lower, continue to evacuate for 15 minutes.	O	O	O	O			On	On	Vacuum gauge/indicator reads 5,000 microns.
4. Close valves C and D on gauge manifold set. Shut off vacuum pump and disconnect from gauge manifold set utility hose. Connect nitrogen cylinder through a regulator and relief valve to the vacuum pump as shown in Figure SP-3-5.	O	O	X	X	X	X	Off	Off	Nitrogen cylinder connected to system.
5. Open nitrogen cylinder valve E and adjust the pressure regulator for a 10 psig pressure, then open valve F to pressurize system. Charge system to 10 psig with nitrogen.	O	O	O	O	O	O			Gauge manifold set gauges read 10 psig.
6. Allow nitrogen to remain in system for one hour to absorb moisture.	O	O	X	X	X	X			Gauge manifold set gauges read 10 psig.
7. Disconnect nitrogen cylinder from gauge manifold set utility hose. Open gauge manifold set valves C and D to vent nitrogen through utility hose to the atmosphere.	O	O	O	O	X	X			Gauge manifold set gauges read 0 psig.
8. Complete second evacuation, nitrogen charge, wait, and vent cycle.	Repeat steps 1 through 7.								Gauge manifold set gauges read 0 psig.

SP-3. EVACUATION/DEHYDRATION PROCEDURE (STEPS 9 THROUGH 11)

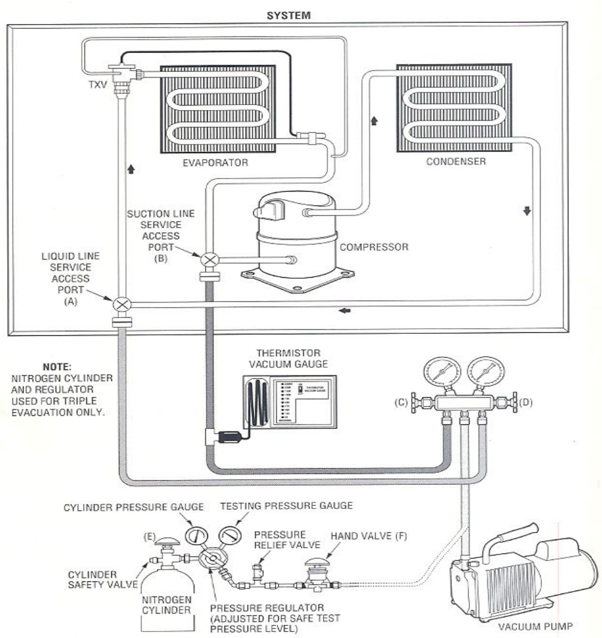
Step	*Service Access Port (A and B) Or Valve (C through F) Position 0 = Open / X = Closed Shading = Not Applicable						Vacuum Pump	Vacuum Indicator	Expected Results
	*A	*B	C	D	E	F			
9. Repeat steps 1 and 2. Evacuate system to obtain a deep vacuum of 500 microns (29.92 in. Hg vac.) or lower.	0	0	0	0			On	On	Vacuum gauge-indicator reads 500 micron or lower.
10. Close valves C and D on gauge manifold set. Shut off vacuum pump. Allow system pressure to equalize while observing vacuum indicator. If pressure stabilizes at 1,000 to 1,500 microns, system is most likely leak-free, but wet. If pressure continues to rise, a leak exists in the system.	0	0	X	X			Off	On	Reading rises slightly, then holds at 500 microns or below for at least 5 minutes.
11. Close service access ports A and B on system and valves C and D on gauge manifold set. Shut off vacuum gauge/indicator. Disconnect vacuum pump and vacuum gauge/indicator from gauge manifold set.									System ready for refrigerant charging (SP-4).

NOTES

1. For deep vacuum, perform steps 1,2, and 9 through 11.
2. For triple evacuation, perform steps 1 through 11.

*Service access ports can be in-line, process, or Schrader valves.

▼ Figure SP-3-5.
Evacuation/Dehydration Procedure Equipment Hookup



REFRIGERANT CHARGING

Purpose – Every mechanical refrigeration system that is opened for servicing must be charged before it is returned to service. Also, some models come factory charged, but may need charge adjustment in the field before being placed into service. Regardless of system size, accurate refrigerant charge is critical for many reasons. Figure SP-4-1 summarizes the conditions that result from undercharging, proper charging, and overcharging a system.

▼ Figure SP-4-1.
System Undercharge, Proper Charge, and Overcharge Conditions

CHARGE ACCURATELY

Undercharge	Proper Charge	Overcharge
• LOW LOW-SIDE PRESSURE	• LONG LIFE	• HIGH HIGH-SIDE PRESSURE
• HIGH SUPERHEAT	• SAFE OPERATION	• HIGH DISCHARGE TEMPERATURE
• OVERHEATED COMPRESSOR AND MOTOR	• DESIGN CAPACITY	• FLOODBACK
• LOW SYSTEM CAPACITY	• PEAK EFFICIENCY	• LOW SYSTEM CAPACITY
• POOR EFFICIENCY		• POOR EFFICIENCY
• SLUDGE/ CARBONIZATION		• SLUDGE/ CARBONIZATION

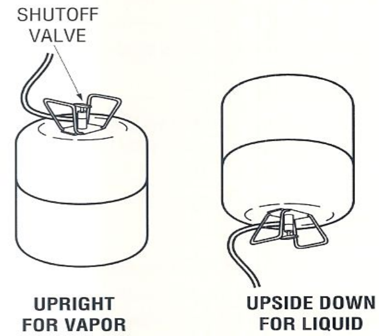
Charging methods vary with equipment types and manufacturer. The method used also depends on the operating condition of the system and the availability of charging points in the high-pressure and low-pressure sides of the system. *It is important to remember that recovered and/or recycled refrigerant can only be recharged into the system from which it was initially recovered, or another one owned by the same customer.* The methods described in this procedure are those commonly used to service residential and light commercial equipment. They include:

- Liquid Charging by Weight
- Vapor Charging for Proper Superheat
- Vapor Charging for Proper Subcooling
- Charging with a Recovery/Recycle Unit
- Charging Using Charging Charts

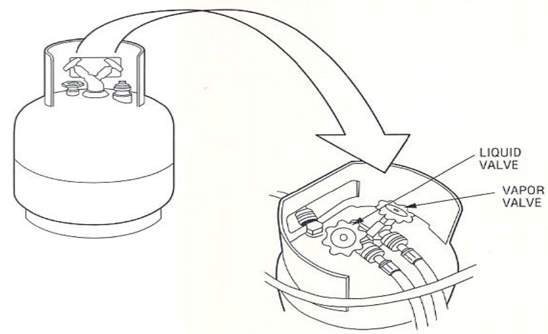
Liquid and Vapor States of Refrigerants

Refrigerant may be added to a system in either a vapor (gas) or liquid state. Both saturated vapor and liquid refrigerant exist in a refrigerant cylinder. Vaporized refrigerant is at the top of the cylinder and liquid refrigerant is at the bottom. The method used to charge refrigerant depends on the type of cylinder being used. If using a disposable cylinder, the cylinder must be set in the upright position in order to charge with vapor (Figure SP-4-2). To charge liquid refrigerant into the system, the cylinder must be turned upside down.

▼ Figure SP-4-2.
Removing Vapor or Liquid Refrigerant from a Disposable Cylinder



▼ Figure SP-4-3.
Removing Vapor or Liquid Refrigerant from a Recovery (Refillable) Cylinder



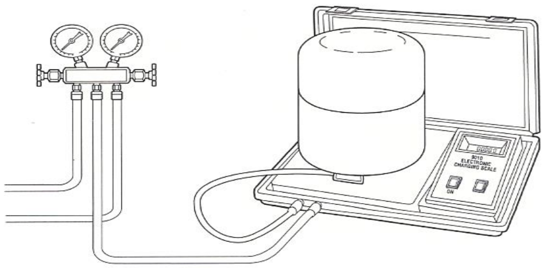
Cylinders normally used with recovery or recycle units remain in the upright position when charging. They have valves that are used to select either vapor or liquid refrigerant for charging (Figure SP-4-3).

Measuring Refrigerant Charge by Weight

Both liquid and vapor refrigerant can be charged into a system by weight using an accurate charging scale. The amount of refrigerant being weighed into the system may be controlled manually if using a basic scale, or automatically if using an electronic scale. A scale used to charge residential and light commercial systems must be accurate to ±1 ounce. Also, make sure the scale weighing platform mechanism is strong enough to handle the heaviest refrigerant cylinders you intend to use.

Typically, an electronic scale displays the cylinder and/or refrigerant charge weight using a digital readout (Figure SP-4-4).

▼ **Figure SP-4-4.**
Use Accurate Charging Scale to Charge by Weight



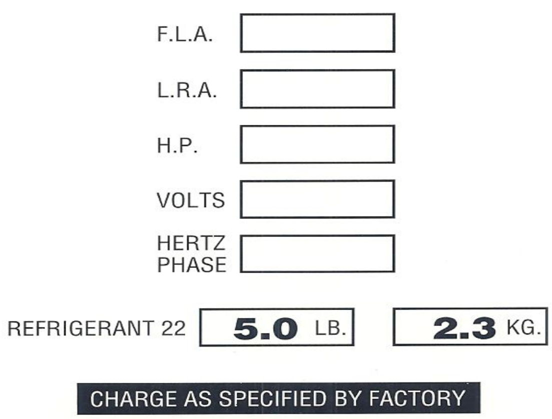
Programmable models control the flow of refrigerant and can be set to automatically dispense a preset amount of refrigerant and stop flow when the preset amount is reached. Most have a hold function that interrupts charging if the refrigerant cylinder empties before a full system charge is reached. For proper weighing of the charge, always follow the manufacturer's operating instructions for the charging scale you use.

Another accurate charging device commonly used to weigh the refrigerant charge into a system is a charging cylinder. Never use bathroom scales or produce scales to weigh a refrigerant charge. They are not accurate enough.

Determining the Correct System Charge Weight

Charging by weight is used if a complete charge is to be added to the system and the weight of the charge is known. To find the needed charge weight and type of refrigerant, check the equipment nameplate (SP-4-5), or the manufacturer's service literature.

▼ **Figure SP-4-5.**
Typical Unit Nameplate Charge Information



Nameplates on residential split systems normally give the charge weight for the system based on the use of a standard refrigerant line length. Always be sure to consult the manufacturer's service literature to find out what the specific standard line length is. If the system being serviced uses a line length that exceeds the standard line length, consult the manufacturer's instructions to find the amount of additional refrigerant charge that must be added to compensate for this increased length.

For example, assume the nameplate charge weight for a residential split system is marked "5 pounds" based on a standard line length of 15 feet. Also, assume that the system is using a line length of 35 feet. Further, suppose that the manufacturer's instructions require .58 ounce of additional refrigerant for each foot of 3/8-inch liquid line in excess of 15 feet. Based on this information, you would charge the system to 5 pounds and 11.6 ounces (5 pounds nameplate weight + 20 feet excess length x .58 ounce per foot).

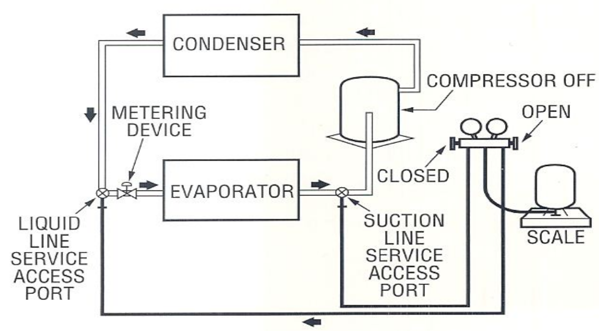
If adding a filter-drier or other accessory, also be sure to compensate for its volume by adding the amount of charge as stated in the manufacturer's instructions.

Charging by Weight

Charging by weight is used if a complete charge is to be added to the system and the weight of the charge is known. Liquid charging an empty system (Figure SP-4-6) is much faster than charging with vapor refrigerant because the density of liquid refrigerant is much greater than that of vapor refrigerant. The result is that the same charging hoses deliver much more liquid refrigerant than vapor to the system over a fixed period of time. Because the liquid charging method is faster and more economical, it is sometimes used to recharge a small system (5 pounds of charge or less) that contains a partial charge. In this case, all the remaining charge in the system is recovered, then the system is recharged with the total amount.

Charging by weight is the only method that can be used to charge heat pump units operating in the heating mode.

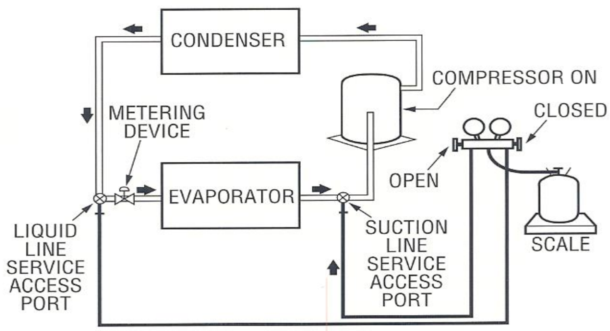
▼ **Figure SP-4-6.**
Liquid Charging by Weight



Liquid charging is performed with the compressor off and the proper charge weighed in to the high side of the system using an accurate charging scale (Figure SP-4-6). Liquid refrigerant is charged through the opened liquid line service valve. The suction line service valve is closed. *Never charge liquid refrigerant into the low side of the system. Compressor failure can result from the compressor trying to compress liquid refrigerant that may have entered the compressor.*

Under most conditions, the entire charge will flow into the system in the liquid state. At other times, the flow of liquid refrigerant may slow down to a trickle or stop before the entire charge can be weighed in. Should this happen, stop liquid charging and close the high-side service valve. Then, turn on the compressor and vapor-charge the remainder of the required charge into the low side of the system using the weigh-in method (Figure SP-4-7).

▼ **Figure SP-4-7.**
Vapor Charging by Weight

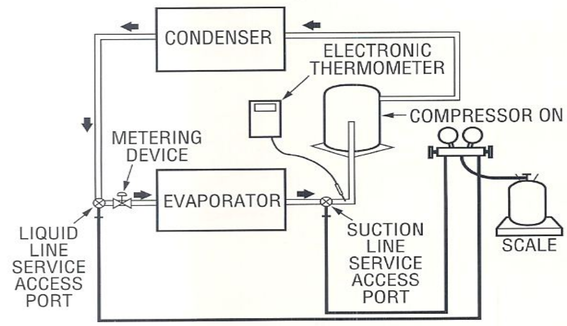


Vapor Charging for Proper Superheat

Superheat is the heat added to refrigerant after all the refrigerant has changed to a vapor. By knowing the amount of superheat in the system suction line, you can tell if the system is properly charged. Also, maintaining superheat is critical because it ensures that no liquid refrigerant returns to the compressor, where it can cause damage and possible failure.

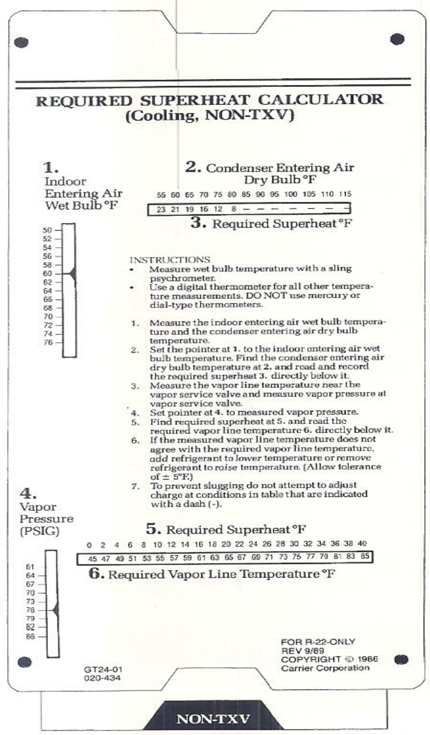
The superheat method can be used to check and adjust the charge in an operating system. It is only used for systems with a fixed-orifice metering device such as a capillary tube or metering piston. This method takes into consideration the operating conditions of the system and establishes a required superheat. The required superheat is then reached by adjusting the refrigerant charge in the system to obtain the correct superheat temperature in the system suction (vapor) line (Figure SP-4-8).

▼ **Figure SP-4-8.**
Vapor Charging for Proper Superheat



Required Superheat/Subcooling Calculators can be used when charging HCFC-22 systems (Figure SP-4-9). When used in conjunction with the temperatures and pressures measured in an operating system, this calculator is used to find the values for the system's required superheat and the required vapor line temperatures. Complete instructions for charging by superheat are printed on the calculator.

▼ **Figure SP-4-9.**
Required Superheat/Subcooling Calculator – Required Superheat Side



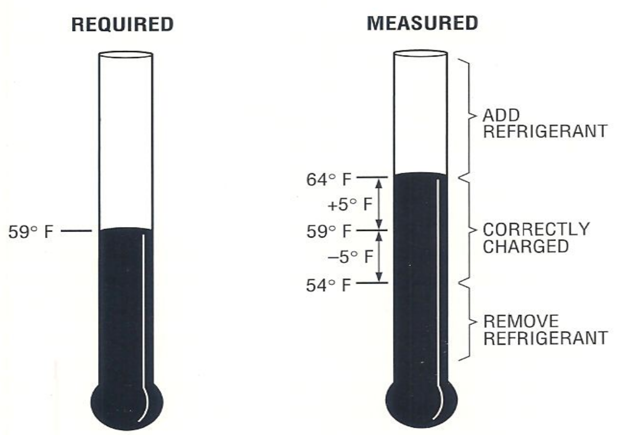
A detailed procedure and illustrated examples for charging by superheat using the Superheat Calculator are provided later in this section. A brief overview of the procedure and the use of the calculator follows.

After the system has run for at least 15 minutes and operation has stabilized, the following measurements are taken:

- Indoor wet bulb temperature of the air entering the evaporator coil.
- Outdoor dry bulb temperature of the air entering the condenser coil.
- System suction (vapor) line pressure.
- System suction (vapor) line temperature.

The measured temperatures for the indoor and outdoor air entering the evaporator and condenser, respectively, are used with the calculator to find the required level of superheat (°F). Following this, the value for the required superheat and the measured system vapor line pressure are used with the calculator to find the required vapor line temperature (°F). Then, the actual vapor line temperature is compared to the required vapor line temperature to determine if an adjustment in the system refrigerant charge is needed. A tolerance of ±5° F is allowed before any adjustment is required (Figure SP-4-10).

▼ **Figure SP-4-10.**
Superheat Temperature Tolerance



If the measured vapor line temperature is too high, vapor refrigerant must be added to lower the temperature of the vapor line. If the measured vapor line temperature is too low, remove (recover) refrigerant to raise the temperature of the vapor line. This procedure must be repeated each time refrigerant is either added or removed, because the system pressures and temperatures will change, but the required superheat remains the same.

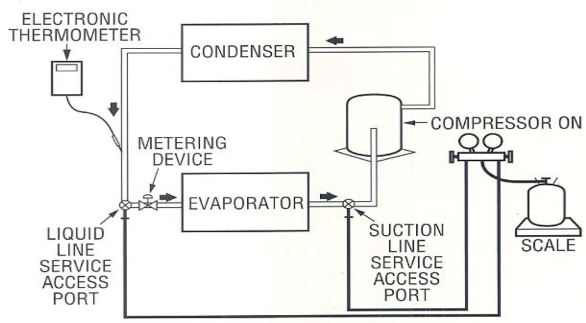
If a calculator is not available, or you are working on a system that uses a refrigerant other than HCFC-22, the charging by superheat method can still be used. Superheat and suction line temperature tables are attached to the unit or given in the manufacturer's instructions. Use them to find the required vapor line temperature for a correctly charged system.

Vapor Charging for Proper Subcooling

The thermostatic expansion valve (TXV) maintains a constant superheat over a wide range of load conditions. Because of this, charging using the superheat method cannot be done with systems that contain TXVs or similar devices. Instead, subcooling is used to check the charge. Subcooling is the temperature removed from a refrigerant after all the refrigerant has condensed into a liquid.

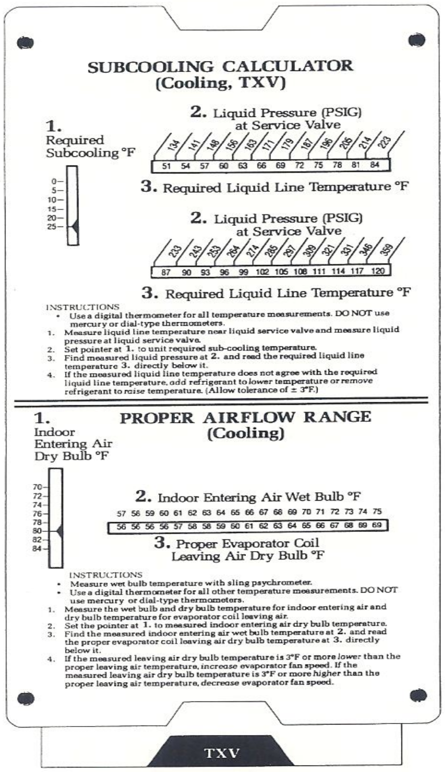
The subcooling method (Figure SP-4-11) can be used to check and adjust the charge in an operating system. This method measures the temperature of the refrigerant in the liquid line to determine if the proper quality of liquid refrigerant is being applied to the TXV metering device. If the liquid line temperature is incorrect, it can be changed by adjusting the amount of refrigerant in the system.

▼ **Figure SP-4-11.**
Vapor Charging for Proper Subcooling



The same Required Superheat/Subcooling Calculator shown in the previous example can be used when charging with the subcooling method. The subcooling calculator is on the reverse side (Figure SP-4-12). When used in conjunction with the liquid line temperature and pressure measured in an operating system, this calculator is used to find the required liquid line temperature. Complete instructions for charging by subcooling are printed on the calculator.

▼ Figure SP-4-12.
Required Superheat/Subcooling Calculator – Subcooling Side

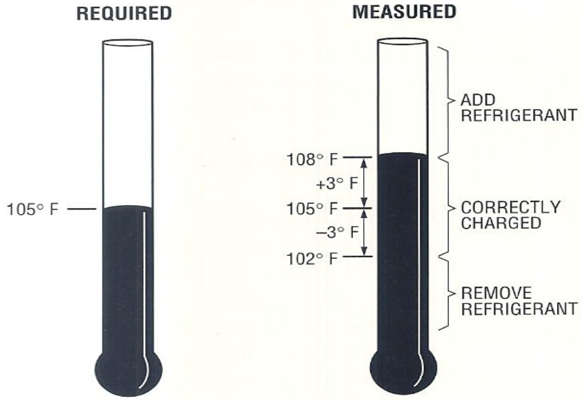


A detailed procedure and illustrated examples for charging by subcooling using the Subcooling Calculator are provided later in this section. A brief overview of the procedure and the use of the calculator follows.

After the system has run at least 15 minutes and operation has stabilized, measure the liquid line temperature and pressure. Also, refer to the unit nameplate or the service manual for the unit to find the subcooling temperature required for the system.

The required value of subcooling obtained from the unit nameplate and the liquid line pressure measured on the system are used with the calculator to find the required liquid line temperature (°F). To determine if an adjustment in the system refrigerant charge is needed, the actual liquid line temperature is compared to the required liquid line temperature found with the calculator. A tolerance of ±3° F is allowed before any adjustment is required (Figure SP-4-13).

▼ Figure SP-4-13.
Subcooling Temperature Tolerance



If the measured liquid line temperature is too high, add refrigerant vapor to lower the temperature in the liquid line. If the measured subcooling temperature is too low, remove (recover) excess refrigerant to raise the temperature in the liquid line. If it is necessary to add or remove refrigerant, the procedure must be repeated each time because the system pressures and temperatures will change, but the required subcooling remains the same.

If a Subcooling Calculator is not available, or you are working on a system that uses a refrigerant other than HCFC-22, the subcooling method of charging can still be used. In these cases, the measured liquid line temperature and pressure can be used along with a standard pressure-temperature chart to find the system subcooling. Using the pressure-temperature chart and the measured liquid line pressure, the saturated temperature of the refrigerant in the liquid line can be found. Then, the subcooling in the liquid line can be calculated by subtracting the measured liquid line temperature from the saturated temperature found with the chart. The calculated value for system subcooling is compared with the required value of subcooling specified on the unit nameplate or service literature to determine if an adjustment of the refrigerant charge is necessary. A tolerance of ±3° F is allowed before any adjustment is required.

For example, assume the following:

- The nameplate for an HCFC-22 system shows the required subcooling is 10° F.
- The measured liquid line temperature is 105° F.
- The measured liquid line pressure is 243 psig.

For this example, the pressure-temperature chart shows that the saturated temperature corresponding to the liquid line pressure of 243 psig for HCFC-22 refrigerant is 115° F.

By subtracting the actual liquid line temperature (105° F) from the saturated temperature found with the pressure-temperature chart (115° F), the amount of subcooling in the system liquid line is calculated to be 10° F (115° F – 105° F = 10° F).

Since the calculated value of 10° F subcooling is within ±3° F of the required nameplate value (also 10° F), no adjustment is needed.

Charging with a Recovery/Recycle Unit

Many certified recovery/recycle units have the capability to recharge recovered refrigerant, in the liquid or vapor state, into a system. When charging with such a recovery/recycle unit, the manufacturer's instructions must always be followed.

Charging Using Charging Charts

Charging charts are sometimes used to charge the system. These charts are usually attached to the unit or included in the manufacturer's service instructions. Use the charts as directed by the manufacturer to charge the unit. Also, be sure that the indoor airflow CFM is the same as that specified on the charts.

If charging a heat pump using a chart, it must be charged in the cooling mode. Be sure that the chart you use for charging is a cooling charging chart. Never use the heating cycle check chart to add or remove a refrigerant charge.

Charging Systems that Use Zeotropic Refrigerant Blends

Most refrigerants such as HCFC-22 are made from a single pure chemical compound. Others are made by mixing (blending) two or more different refrigerants. Refrigerant blends can be HCFC based, HFC based, or a combination of both. *Azeotropic blends* are made when two different liquid refrigerants are mixed to form a new refrigerant with its own properties. Azeotropic blends act like a compound. At a constant pressure, they do not change volumetric composition or saturation temperature as they evaporate or condense. The boiling temperature of the blend is independent of the boiling temperatures of the individual refrigerants used in the blend. An example of an azeotropic blend refrigerant is AZ-50™, which is a mixture of HFC-125 and HFC-143a. CFC-500 and CFC-507 are some other examples of azeotropic blend refrigerants.

Zeotropic blends are made when two or more different liquid refrigerants are mixed to form a new refrigerant that retains the individual properties of its constituent refrigerants. Unlike pure compounds or azeotropic blends, zeotropic blends change volumetric and saturation temperatures as they evaporate or condense. For a given system pressure, the zeotropic refrigerant blend will have one temperature at which it evaporates and a different one at which it condenses. This characteristic is called *temperature glide*. The exact amount of glide is determined by the system design and the refrigerants used in the blend.

Zeotropic blend refrigerants are commonly called *ternary blends* because most zeotropes are made from a blend of three refrigerants. An example of a zeotrope refrigerant is MP-39 (R-401A) made from a blend of HCFC-22, HFC-152a, and HCFC-124. Zeotropic blend refrigerants are usually identified by 400-series R-numbers: e.g., R-407C.

The methods used to charge a system with a zeotrope refrigerant are somewhat different than those used with pure compounds or azeotropes. This is because each zeotropic refrigerant has a different temperature glide. For this reason, always follow the manufacturer's instructions when charging a system that uses a zeotropic blend refrigerant.

Some important points to remember when charging a system that uses a zeotropic refrigerant are:

- If the refrigerant is in good condition (clean, dry, and no evidence of leakage prior to servicing), it can be charged back into the unit from which it was removed.
- *If recharging a system after the repair of a leak, always recharge with new refrigerant.* This is necessary because the leak can cause fractionation to occur in the zeotrope refrigerant remaining in the system. When there is a vapor leak, the refrigerant component of the blend that has the highest pressure will leak out of the system at a faster rate than the lower pressure refrigerant components. This changes the chemical composition of the refrigerant remaining in the system. Operation of the system using this altered refrigerant can cause poor system performance and possible system damage. Some zeotropic refrigerants such as R-410A have such a small glide that they can effectively be treated as a pure refrigerant, with no regard for glide. If in doubt, always follow the manufacturer's charging recommendations.
- Zeotropic refrigerants must be "liquid charged" into the high side of the system, so the components in the blend do not separate. Charging by weight is the preferred method for admitting the correct charge.
- *If it is necessary to charge refrigerant into the low side of an operating system, always make sure that all the liquid refrigerant taken from the liquid port of the cylinder is passed through a throttling (metering) valve so that the refrigerant enters the low side of the system in vapor form. This is necessary to avoid compressor damage.*

QUICK NOTE

Always check the refrigerant cylinder before charging. Zeotropic refrigerant cylinders may be configured to dispense liquid in the upright position instead of the traditional inverted position.

PROCEDURE

Before performing this procedure, refer to the manufacturer's installation instructions and/or service manual for specific instructions about the system being serviced. If differences exist between our procedure and the manufacturer's instructions, always follow the manufacturer's instructions. Also, review the safety instructions and precautions given in this procedure and in Section 2 of this manual. Use caution before opening any service valves or connections; refrigerants under pressure are present in the system being serviced and the recovery or recovery/recycle units.

If charging by weight, be sure that any existing system refrigerant charge has been recovered (SP-2). If vapor charging for proper superheat or subcooling, make sure the system has an adequate existing charge so that it can be operated without danger of damaging the compressor.

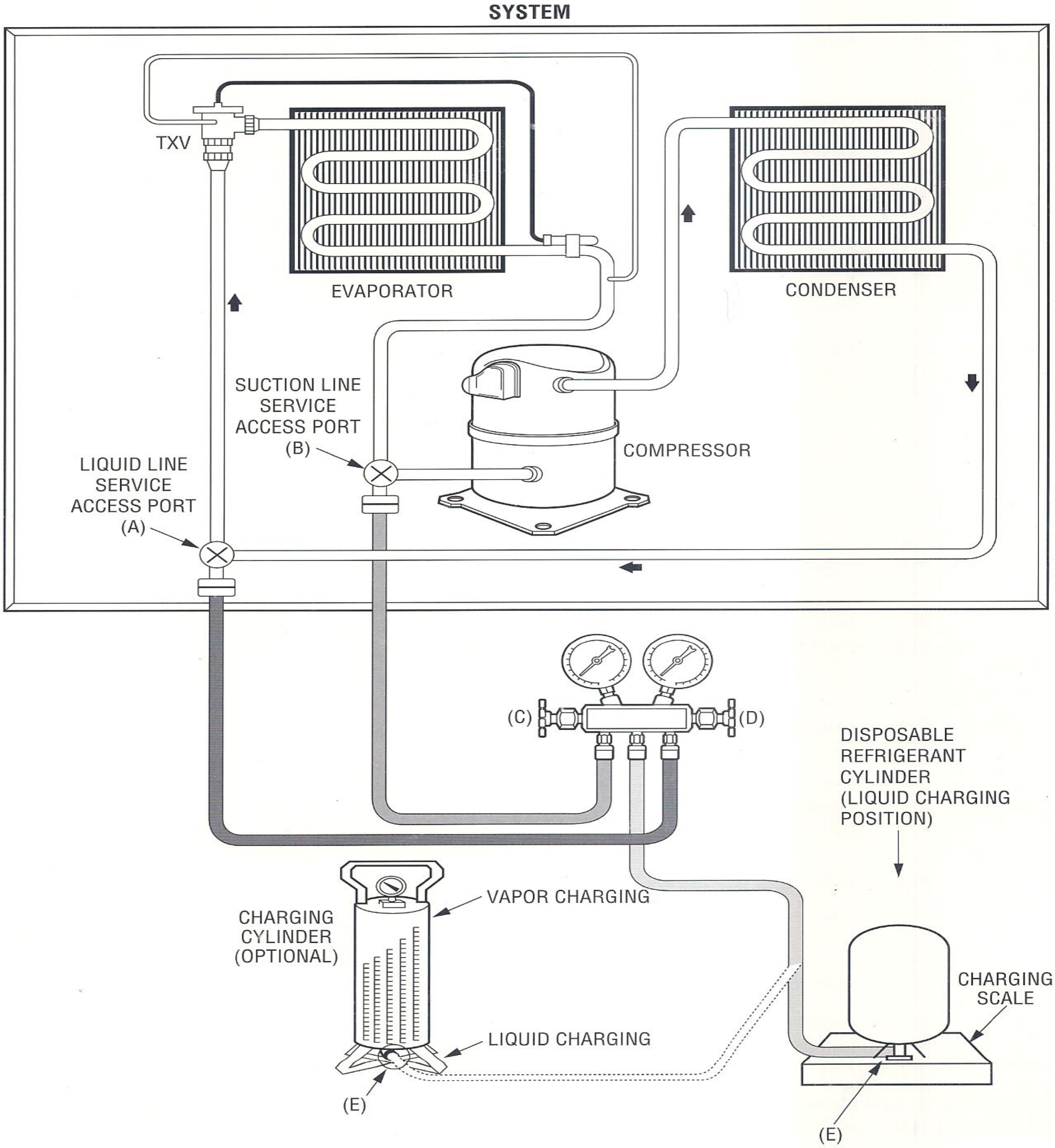
SP-4. INSTRUMENT OR DEVICE REQUIRED	REFERENCE
Gauge manifold set and hoses	Section 1, Item 1
Electronic charging scale or charging cylinder	Section 1, Item 6
Refrigerant cylinder(s) of refrigerant type used for equipment being serviced	N/A
Electronic thermometer – used to measure dry bulb temperatures for superheat and subcooling charging methods	Section 1, Item 2
Sling psychrometer – used to measure wet bulb temperatures for superheat charging method	Section 1, Item 3
Required superheat/subcooling calculator – used for vapor charging by the superheat or subcooling method	N/A

SP-4. REFRIGERANT CHARGING PROCEDURE – CHARGING BY WEIGHT METHOD

Step	*Service Access Port (A and B) Or Valve (C through E) Position O = Open / X = Closed					Expected Results
	*A	*B	C	D	E	
1. Connect the charging equipment to the system as shown in Figure SP-4-14. Turn the refrigerant cylinder upside down to select liquid refrigerant for charging.	X	X	X	X	X	Instruments and devices connected to system.
2. Check the unit nameplate or manufacturer's service literature for the correct charge weight. Make sure to consider any adjustments to the charge amount needed to account for nonstandard line set length or the use of a filter-drier.	X	X	X	X	X	Correct charge amount known.
3. Zero the scale, then weigh the refrigerant cylinder, making sure that the connection hoses do not cause a false weight indication. Write down the container weight or set the scale. Subtract the system charge weight and record the value.	X	X	X	X	X	Charging scale zeroed and adjusted to dispense correct charge.
4. With the system compressor turned off, charge the system with liquid refrigerant. Monitor the flow of refrigerant into the system by watching the scale or charging cylinder.	O	X	X	O	O	System is being charged through the high-pressure side (liquid) service access port.
5. When the charging scale or cylinder shows that the total charge has been introduced into the system, close the service access port A and valves D and E. If the flow of liquid refrigerant slows down or stops before the total charge can be weighed in, close service access port A and valve D, then proceed to step 6.	X	X	X	X	X	Charging system with liquid refrigerant is complete.
6. Turn the refrigerant cylinder upright to select vapor refrigerant for charging. Assuming that more than 50% of the required charge is in the system, turn the system compressor on. Open service access port B and valves C and E, then finish charging the system by weight using refrigerant vapor.	X	O	O	X	O	Charging system with refrigerant vapor.
7. When the charging scale or cylinder shows that the total charge has been introduced into the system, close service access port B and valves C and E.	X	X	X	X	X	System is ready for normal operation.

*Service access ports can be in-line, process, or Schrader valves.

Figure SP-4-14.
Refrigerant Charging Procedure Equipment Hookup — Charging by Weight Method



SP-4. REFRIGERANT CHARGING PROCEDURE – VAPOR CHARGING FOR PROPER SUPERHEAT METHOD (STEPS 1 THROUGH 10)

Step	*Service Access Port (A and B) Or Valve (C through E) Position O = Open / X = Closed					Expected Results
	*A	*B	C	D	E	
SEE NOTES AT END OF TABLE						
1. Connect equipment to system as shown in Figure SP-4-15. Make sure service access ports A and B and valves C through E are closed.	X	X	X	X	X	Instruments and devices connected to system.
2. Use the electronic thermometer to measure and record the outdoor air dry bulb temperature entering the condenser (outdoor coil).	X	X	X	X	X	Outdoor dry bulb air temperature measured and recorded. *For our example, assume outdoor air temperature is 95° F.*
3. Attach and insulate the same electronic thermometer to the vapor (suction) line near service access port B. Run the system for a minimum of 15 minutes to allow the system pressures and temperatures to stabilize, then measure and record the vapor line temperature.	X	X	X	X	X	Vapor line temperature measured and recorded. *For our example, assume vapor line temperature is 59° F.*
4. Monitor the vapor line pressure using the gauge manifold set.	X	O	X	X	X	Vapor line pressure (psig) measured and recorded. *For our example, assume pressure is 70 psig.*
5. Using a sling psychrometer, measure and record the indoor wet bulb temperature at the location specified by the manufacturer. Typically, this measurement is taken in the conditioned space.	X	O	X	X	X	Indoor wet bulb air temperature measured and recorded. *For our example, assume indoor air wet bulb temperature is 70° F.*
6. Using the Superheat Calculator, set the pointer to the indoor entering wet bulb temperature measured in step 5.	X	O	X	X	X	*For our example, the pointer is at 70° F as shown in Figure SP-4-16A.*
7. On the calculator, find the condenser entering air dry bulb in °F, then read the required superheat temperature directly below it.	X	O	X	X	X	*For our example, 95° F shows a required superheat of 18° F, as shown in Figure SP-4-16B.*
8. On the calculator, set the vapor pressure pointer to the vapor line pressure monitored in step 4.	X	O	X	X	X	*For our example, the pointer is at 70 psig, as shown in Figure SP-4-16C.*
9. On the calculator, find the required superheat value from step 7, then read the required vapor line temperature directly below it.	X	O	X	X	X	*For our example, 18° F shows a required vapor line temperature of 59° F, as shown in Figure SP-4-16D.*
10. Compare the vapor line temperature measured in step 3 with the required vapor line temperature found in step 9. • If the measured vapor line temperature and the required vapor line temperature are within ±5° F, the system is correctly charged. Close service access port B. • If the measured vapor line temperature is higher than the required vapor line temperature by more than 5° F, perform steps 11 and 13. • If the measured vapor line temperature is lower than the required vapor line temperature by more than 5° F, perform steps 12 and 13.	X	X	X	X	X	*For our example, the measured and required suction line temperatures are the same (59° F). Therefore, the system is correctly charged.*

SP-4. REFRIGERANT CHARGING PROCEDURE – VAPOR CHARGING FOR PROPER SUPERHEAT METHOD (STEPS 11 THROUGH 13)

Step	*Service Access Port (A and B) Or Valve (C through E) Position O = Open / X = Closed					Expected Results
	*A	*B	C	D	E	
11. If the measured vapor line temperature is higher than the required vapor line temperature by more than 5° F, open service access port B and valves C and E to add refrigerant vapor to the system as needed to lower the vapor line temperature to the correct level.	X	O	O	X	O	Refrigerant vapor is added to the system to lower the vapor line temperature to the correct level.
12. If the measured vapor line temperature is lower than the required vapor line temperature by more than 5° F, remove (recover) refrigerant per Service Procedure SP-2 as needed to raise the vapor line temperature to the correct level.	Recover excess refrigerant charge per Service Procedure SP-2.					Excess refrigerant charge is recovered from the system to raise the vapor line temperature to the correct level.
13. If the pressure at the suction line changes, repeat the procedure and charge to the new vapor line temperature shown on the calculator.	X	X	X	X	X	System is correctly charged.

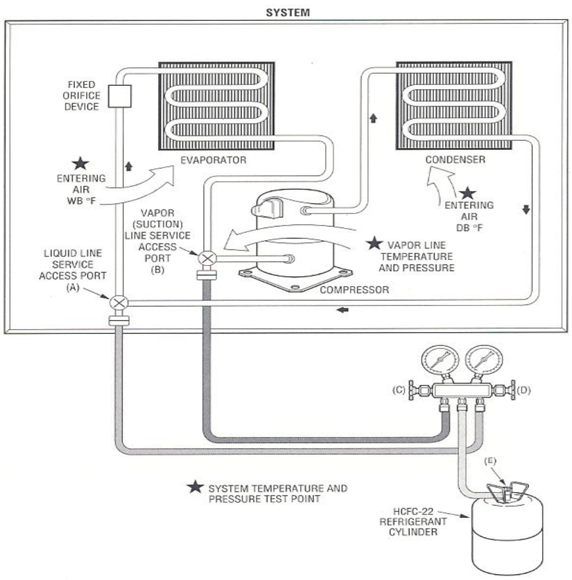
NOTES

This procedure, and the Superheat Calculator used in it, assumes that the system being serviced uses HCFC-22 refrigerant. If servicing a system that uses a refrigerant other than HCFC-22, refer to the manufacturer's instructions.

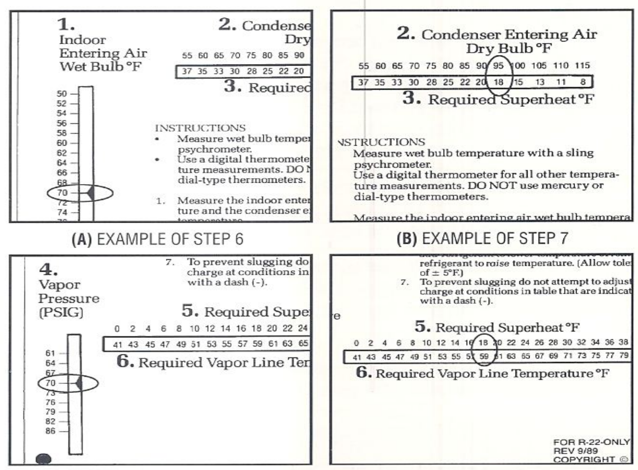
For split systems, this procedure assumes that the indoor and outdoor units are matched, that the correct size metering device piston is installed, and that sufficient air (400 - 450 CFM per ton) is flowing across the indoor coil.

*Service access ports can be in-line, process, or Schrader valves.

▼ Figure SP-4-15.
Refrigerant Charging Procedure Equipment Hookup – Vapor Charging for Proper Superheat Method



▼ Figure SP-4-16.
Use of Superheat Calculator



(A) EXAMPLE OF STEP 6
(B) EXAMPLE OF STEP 7
(C) EXAMPLE OF STEP 8
(D) EXAMPLE OF STEP 9

SP-4. REFRIGERANT CHARGING PROCEDURE – VAPOR CHARGING FOR PROPER SUBCOOLING METHOD

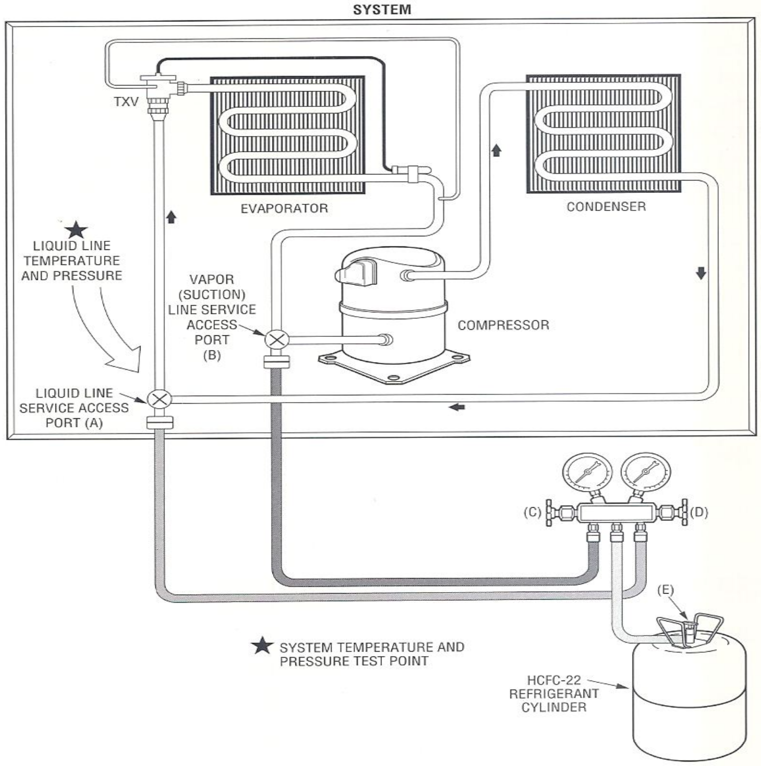
Step	*Service Access Port (A and B) Or Valve (C through E) Position 0 = Open / X = Closed					Expected Results
	*A	*B	C	D	E	
SEE NOTE AT END OF TABLE						
1. Connect equipment to system as shown in Figure SP-4-17. Make sure service access ports A and B and valves C through E are closed.	X	X	X	X	X	Instruments and devices connected to system.
2. Attach and insulate an electronic thermometer to the liquid line near service access port A. Run system for a minimum of 15 minutes to allow the system pressures and temperatures to stabilize, then measure and record the liquid line temperature.	X	X	X	X	X	Liquid line temperature measured and recorded. *For our example, assume liquid line temperature is 105° F.*
3. Monitor the liquid line pressure using the gauge manifold set.	0	X	X	X	X	Liquid line pressure (psig) measured and recorded. *For our example, assume pressure is 243 psig.*
4. From the unit nameplate or service manual find the required subcooling value in °F for the unit.	0	X	X	X	X	Required subcooling value for unit specified by manufacturer is known. *For our example, assume required subcooling is 10° F.*
5. Using the Subcooling Calculator, set the pointer to the required subcooling value as found in the previous step.	0	X	X	X	X	*For our example, the pointer is at 10° F, as shown in Figure SP-4-18A.*
6. On the calculator, find the closest value for the liquid line pressure that was measured in step 3 of this procedure. Then, read the required liquid line temperature directly below it.	0	X	X	X	X	*For our example, the liquid line pressure of 243 psig on the calculator shows a required liquid line temperature of 105° F, as shown in Figure SP-4-18B.*
7. Compare the liquid line temperature measured in step 2 with the required liquid line temperature found in step 6. • If the measured liquid line temperature and the required liquid line temperature are within ± 3° F, the system is correctly charged. Close service access port A. • If the measured liquid line temperature is higher than the required liquid line temperature by more than 3° F, perform steps 8 and 10. • If the measured liquid line temperature is lower than the required liquid line temperature by more than 3° F, perform steps 9 and 10.	X	X	X	X	X	*For our example, the measured liquid line temperature and the required liquid line temperature are the same (105° F). Therefore, the system is correctly charged.*
8. If the measured liquid line temperature is higher than the required liquid line temperature by more than 3° F, open service access port B and valves C and E to add refrigerant vapor to the system as needed to lower the liquid line temperature to the correct level.	X	0	0	X	0	Refrigerant vapor is added to the system to lower the liquid line temperature to the correct level.
9. If the measured liquid line temperature is lower than the required liquid line temperature by more than 3° F, remove (recover) refrigerant per Service Procedure SP-2 as needed to raise the liquid line temperature to the correct level.	Recover excess refrigerant charge per service procedure SP-2.					Excess refrigerant charge is recovered from the system to raise the liquid line temperature to the correct level.
10. If any charge has been added or removed, repeat the procedure using the changed temperatures and pressures measured in the system.	X	X	X	X	X	System is correctly charged.

NOTE

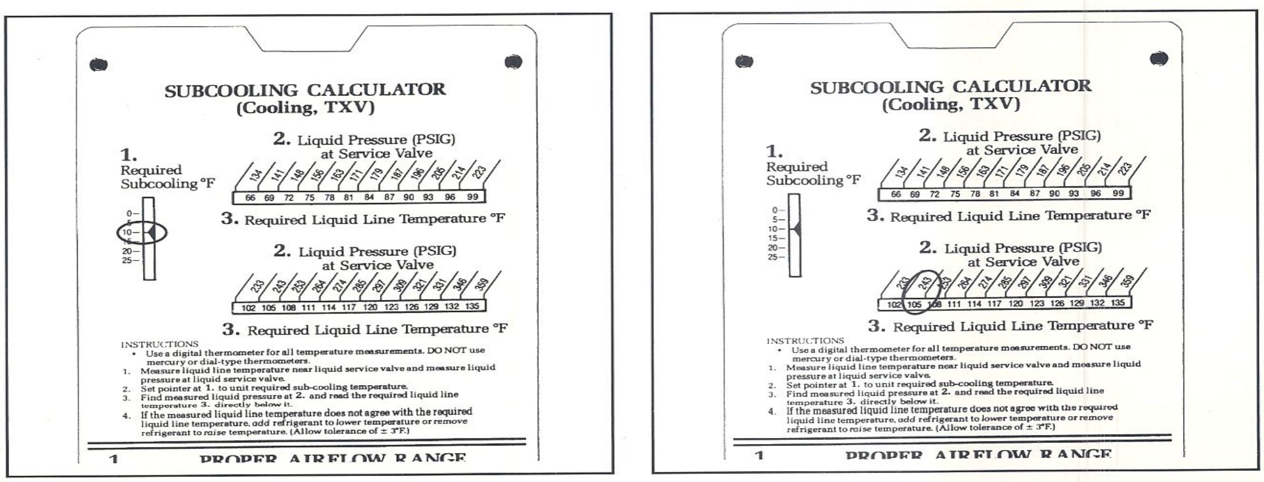
This procedure, and the Subcooling Calculator used in it, assumes that the system being serviced uses HCFC-22 refrigerant. If servicing a system that uses a refrigerant other than HCFC-22, refer to the manufacturer's instructions.

*Service access ports can be in-line, process, or Schrader valves.

▼ Figure SP-4-17.
Refrigerant Charging Procedure Equipment Hookup – Vapor Charging for Proper Subcooling



▼ Figure SP-4-18.
Use of Subcooling Calculator



(A) EXAMPLE OF STEP 5 **(B)** EXAMPLE OF STEP 6

SERVICE PROCEDURE SP-5

ACID/MOISTURE TESTING

Purpose – Refrigeration systems are intended to contain only refrigerant and oil. Anything else in the closed system is considered a contaminant. Contaminants such as air, moisture, acid, and dirt are major causes of system and compressor failures. They can be introduced into a system in two ways:

- Air, moisture, and dirt usually enter the system during installation or servicing.
- Acid can be created in the system as a result of a compressor motor burnout or as a result of moisture contamination.

The presence of acid and/or moisture in a system can be detected by testing the refrigerant with an acid/moisture test kit, or by testing the oil with an acid test kit. Acid and moisture testing is usually performed:

- Any time the refrigeration system requires service or maintenance.
- When recovering or recycling the system's refrigerant.
- After a compressor motor burnout to gauge the severity of the burnout (mild or severe) in order to determine the amount of system cleanup that is needed.

Acid and Moisture Contamination

Air entering a system contains moisture. Moisture in the refrigerant can create oil sludge, which reduces the lubrication properties of the oil and plugs oil passages and screens in the compressor. Moisture can also freeze at the expansion device.

Acid is not introduced into a system; it is formed inside an operating system by the reaction of moisture with the refrigerant. Under the heat of compression, moisture will react with the refrigerant to form hydrochloric and hydrofluoric acid. These acids erode machined surfaces and can cause copper from the system to be deposited on the heated bearing surfaces in the compressor, resulting in compressor failure. Acid also creates sludge and varnish, which act to plug compressor oil passages and restrict the strainers in the lubrication system. These contaminants can cause the insulation on the motor windings to break down. Acid is produced in greater quantities in a system that runs hotter than normal.

PROCEDURE

Before performing this troubleshooting procedure, refer to the manufacturer's installation instructions and/or service manual for specific instructions about the system being serviced. If differences exist between our procedure and the manufacturer's instructions, always follow the manufacturer's instructions. Review the safety instructions and precautions given in this procedure and in Section 2 of this manual.

When working on a system suspected of containing acid, such as after a compressor burnout, wear rubber gloves and eye protection to prevent possible injury.

Two methods commonly used to check for acid and/or moisture contamination are:

- With an acid/moisture test kit that checks refrigerant.
- With an acid test kit that checks oil.

SP-5. INSTRUMENT OR DEVICE REQUIRED	REFERENCE
Acid/moisture test kit	Section 1, Item 9
Oil acid test kit	Section 1

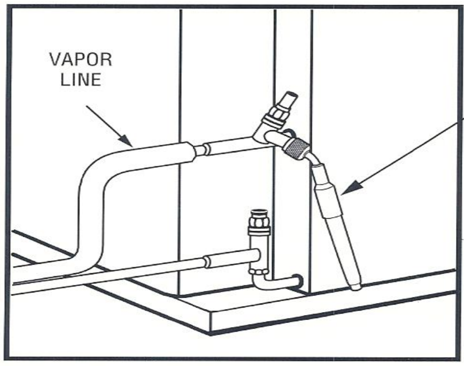
SP-5. ACID/MOISTURE TESTING

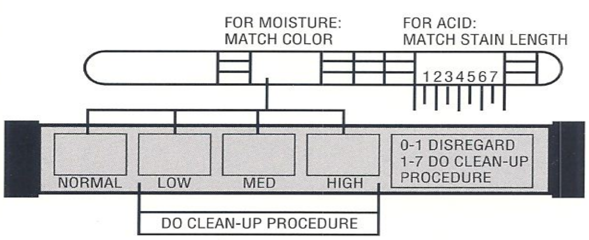
ACID/MOISTURE TEST KIT METHOD

Some sealed-tube test kits like TOTALTEST® can measure the acid/moisture content in refrigerant vapor without the need for an oil sample. The TOTALTEST® procedure is performed as follows:

1. Insert a disposable test tube supplied with the kit in the test instrument.
2. Connect the instrument to the system service port as shown in Figure SP-5-1.
3. Open the service port to allow refrigerant to enter the tube.
4. Allow about ten minutes for the chemical crystals to react with any acid or moisture in the refrigerant.
5. Close the service valve and detach the instrument from the system.
6. Remove the disposable test tube and compare it to the chart on the test kit package to determine the condition of the system (Figure SP-5-1).

▼ Figure SP-5-1.
Instrument Attached to the System





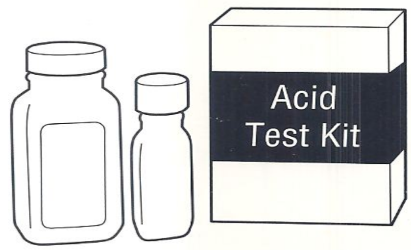
OIL ACID TEST KIT METHOD

Oil acid test kits (Figure SP-5-2) require that an oil sample be taken from the system. The test is performed following the specific instructions supplied with the test kit. Typically, this involves mixing the oil sample with acid test solutions in containers supplied in the kit. Finally, the condition of the oil is determined by comparing the color of the liquid with the various colors shown on a comparison chart.

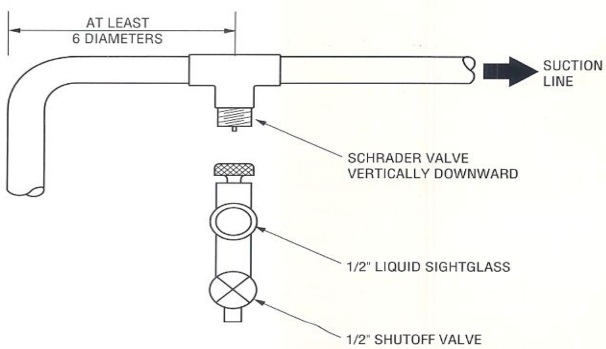
Use of an oil acid test kit is normally limited to testing systems with a serviceable semi-hermetic compressor, where the oil sample can easily be obtained at a drain plug or oil fill hole. For systems that use welded hermetic compressors, testing of the refrigerant with an acid/moisture test kit is the best method.

If repeated testing is desired on an operating system, an oil trap with a Schrader valve can be installed in the suction line. The small amount of oil that collects in the trap can be drained out for testing using the device shown in Figure SP-5-3. After the oil sample is taken, the sampler is removed and the Schrader valve is capped.

▼ Figure SP-5-2.
Typical Acid Test Kit



▼ Figure SP-5-3.
Suction Line Oil Sample Trap



OIL CHARGING AND REMOVAL

Purpose – It is important to maintain the proper oil level in the compressor to ensure proper lubrication. This is necessary to avoid possible mechanical problems that can shorten compressor life. Maintaining the proper oil level also prevents excessive amounts of oil from being circulated through the system.

Oil charging is done to replace oil lost in a compressor as a result of a leak. It is also done whenever all the oil must be replaced in a compressor, such as when performing the cleanup of a system that is contaminated as a result of a severe electrical burnout. Oil is removed from a compressor when it has been overcharged with oil, or when all the oil must be drained from the compressor to accomplish a service task.

Refrigerant oil usually comes in one-gallon or five-gallon containers. It is free of moisture, but readily absorbs moisture if exposed to air. Therefore, refrigerant oil should be bought in containers no larger than needed for the job. *Do not use oil from a container that has been open for any significant length of time or that contains used oil. Never buy oil in bulk or in unsealed containers. Polyolester (POE) oil quickly absorbs moisture from the air which can contaminate the oil. Follow the manufacturer's instructions when handling POE oil.*

▼ Figure SP-6-1.
Refrigerant Oil Guidelines

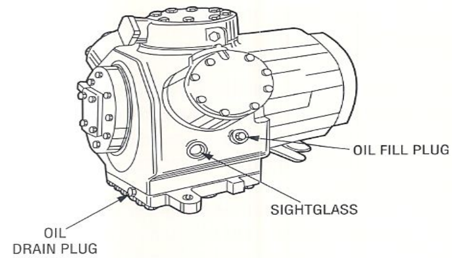
- Buy Correct Size
- Don't Use Old Oil
- Don't Buy in Bulk or in Unsealed Containers

Before charging oil into a compressor, always refer to the manufacturer's instructions for the equipment being serviced. Make sure to use the correct type of oil and the amount specified by the manufacturer.

Typically, welded hermetic compressors have no method of determining the oil level. Since these compressors are usually factory installed in assembled equipment, they are shipped with a full oil charge that is adequate for normal operation. The same is true for welded hermetic replacement compressors. Normally, there are no problems with the oil level in welded hermetic compressors, except in the case of an oil leak. In this case, the compressor is usually removed and the remaining oil drained from the compressor's suction stub or process tube. The correct amount of new oil is then charged into the compressor.

Semi-hermetic compressors, found in some commercial equipment, normally have an oil fill plug and oil level sightglass (Figure SP-6-2). This allows the oil level to be monitored.

▼ Figure SP-6-2.
Typical Semi-Hermetic Compressor



An oil level should always be observed in the oil sightglass, regardless of whether the unit is running or idle. When the compressor is running, the oil level is typically between 1/8 and 3/8 up from the bottom of the sightglass. Most semi-hermetic compressors also have an oil drain plug.

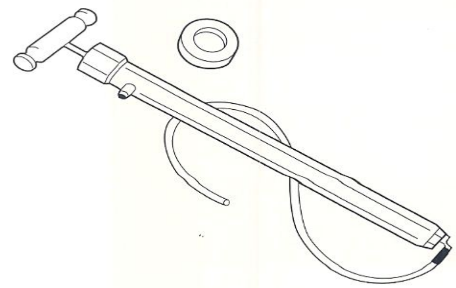
There are many ways to charge oil into a semi-hermetic compressor. The procedure in this section describes the use of a refrigeration oil pump to charge a semi-hermetic compressor using a closed system method.

Refrigeration Oil Pump

When adding oil to a compressor, there is a danger of introducing contaminants into the refrigeration system. This can be prevented by adding oil to the compressor with an oil pump like the one shown in Figure SP-6-3.

This pump can operate against system pressures up to 250 psig, eliminating the need to remove the charge from the system. The pump mounts on a one-gallon oil container with a sealed cap. Because of this, the pump does not need to be removed until the container is empty. The pump is connected to the system by a refrigerant charging hose or with copper tubing. A siphon kit can be used with the oil pump when it is necessary to remove oil from the compressor.

▼ Figure SP-6-3.
Refrigeration Oil Pump



PROCEDURE

Before performing this troubleshooting procedure, refer to the manufacturer's installation instructions and/or service manual for specific instructions about the system being serviced. If differences exist between our procedure and the manufacturer's instructions, always follow the manufacturer's instructions. Review the safety instructions and precautions given in this procedure and in Section 2 of this manual.

SP-6. OIL CHARGING AND REMOVAL

CLOSED SYSTEM METHOD FOR CHARGING OIL (SEMI-HERMETIC COMPRESSOR)

The closed system method uses the refrigeration oil pump to charge oil into the compressor crankcase. The closed system method is performed on an operating compressor using the following general guidelines:

1. Run the compressor fully loaded, then close the suction service valve and reduce the crankcase pressure to 0 psig. Note that the low pressure switch may have to be bypassed.
2. Stop the compressor and isolate it from the system by closing the discharge service valve.
3. Remove the oil fill plug and install an angle service valve in the oil fill plug hole.
4. Connect the refrigeration oil pump with attached container of refrigerant oil to the angle service valve.
5. Open the service valve. While watching the oil level in the sightglass, pump oil into the compressor crankcase from the container of oil as needed.
6. Close the service valve and disconnect the pump.
7. To remove any moisture that may have entered the compressor, evacuate the compressor to 500 microns (29.92 inches of mercury) as described in SP-3.
8. Open the suction and discharge service valves, then restart the compressor.
9. Run the system for about 20 minutes fully loaded, then recheck the oil level at the sightglass.

REMOVING OIL

When removing oil, be sure to wear rubber gloves and eye protection to prevent injury. Contaminated refrigerant oil may contain heavy concentrations of acid. Do not allow contact with the skin or eyes as severe burns may result.

Removing Oil from a Compressor with a Drain Plug

Removing oil from a compressor with a drain plug is performed using the following general guidelines:

1. If possible, run the compressor fully loaded. Then close the suction service valve and reduce the crankcase pressure to 0 psig. Note that the low pressure switch may have to be bypassed.
2. Stop the compressor and isolate it from the system by closing the discharge service valve.
3. If removing only some of the oil through the compressor drain plug, do not completely remove the plug, because the full oil charge may be lost. Just loosen the plug until the oil seeps around the plug threads. Drain the oil in this manner until the oil is lowered to the correct level in the compressor. Tighten the plug. If removing all the oil from the compressor, remove the drain plug and drain all the oil. After the oil has been completely drained, replace the plug.

NOTE: If all the oil was removed from the compressor, make sure to refill the compressor with new oil. Use the closed system method previously described in this section.

4. Open the suction and discharge service valves. Restart the compressor.
5. Run the system for about 20 minutes fully loaded and then recheck the oil level at the sightglass.

Removing Oil from a Compressor with an Oil Fill Plug Hole Only

Removing oil from a compressor with only an oil fill plug is performed using the following general guidelines:

1. If possible, run the compressor fully loaded. Then, close the suction service valve and reduce the crankcase pressure to 0 psig. Note that the low pressure switch may have to be bypassed.
2. Stop the compressor and isolate it from the system by closing the discharge service valve.
3. Remove the oil fill plug. Use the refrigeration oil pump with the siphon kit to remove the oil from the compressor. Continue to remove the oil in this manner until the oil is lowered to the proper level in the compressor, or if applicable, all the oil is removed. Replace the plug.

NOTE: If all the oil was removed from the compressor, make sure to refill the compressor with new oil. Use the closed system method for charging oil previously described in this section.

4. To remove any moisture that may have entered the compressor, evacuate the compressor to 500 microns (29.92 inches of mercury) as described in SP-3.
5. Open the suction and discharge service valves. Restart the compressor.
6. Run the system for about 20 minutes fully loaded and then recheck the oil level at the sightglass.

WASTE OIL DISPOSAL

Used oils contaminated with CFCs are not hazardous to the environment on the condition that:

- They are not mixed with other waste.
- They are subjected to CFC recycling or reclamation.
- They are not mixed with other used oils from other sources.

Used oil is considered a hazardous waste if tests show that it contains compounds such as mercury, cadmium, or lead, or if it exhibits the characteristics of ignitibility or corrosiveness. Hazardous oil must be stored properly and sent to a licensed hazardous waste disposal facility for proper disposal. Because regulations pertaining to hazardous waste are under constant revision, individuals with questions regarding the proper handling of hazardous waste materials should contact the applicable EPA office for assistance.

SERVICE PROCEDURE SP-7

INPUT VOLTAGE MEASUREMENTS AND FAULT ISOLATION CHECKS

Purpose – This procedure describes the input voltage measurements commonly made when installing and/or servicing single-phase and three-phase powered HVAC equipment. Measurement of the input voltage is necessary to make sure that the voltage is within the correct range specified by the manufacturer.

This procedure also provides a set of measurements and checks that can be used to troubleshoot electrical problems that commonly occur in HVAC systems. The scope of the troubleshooting in this procedure is limited to those measurements and/or checks needed to isolate an electrical fault to a functional circuit. Service Procedure SP-8 provides instructions for isolating the fault to a defective component.

Keep in mind that some problems that appear to be electrical may actually be the result of refrigerant-side or air-side problems that cause electrical devices to trip. For example, excessive refrigerant charge can cause the high pressure switch to trip and open the compressor contactor circuit, shutting down the compressor.

Equipment Input Power, Load, and Control Circuits

Troubleshooting electrical problems in HVAC equipment may appear complex. However, electrical troubleshooting can be simplified if the unit's electrical components are divided into functional groupings based on the operation they perform. Most air conditioning equipment can be divided into the three functional circuit areas shown in Figure SP-7-1. The functional areas are:

- Input power distribution circuits
- Load circuits
- Control circuits

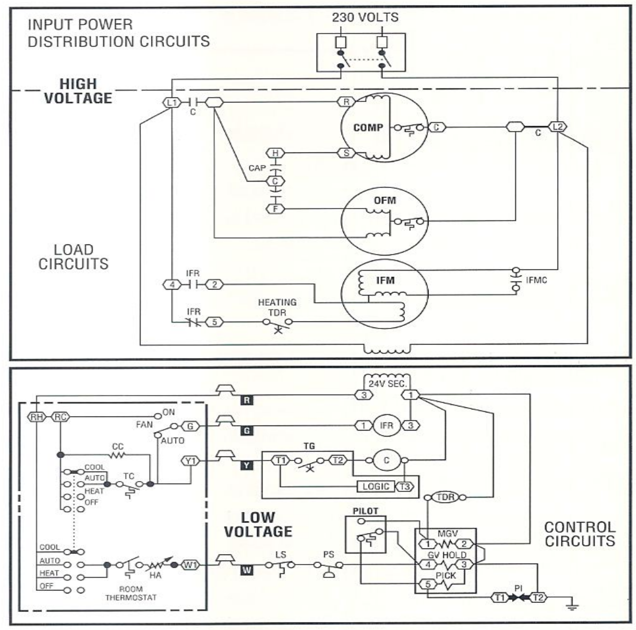
Input Power Distribution Circuits

Input power distribution circuits serve as the power source for the entire unit. They operate at either single-phase or three-phase line voltage and distribute the input power to the various loads in the unit. Power circuits usually consist of the field-installed power wiring from the main electrical service to a disconnect switch located near the unit, and from the disconnect switch to the unit. The input power and distribution circuits include protective devices such as fuses and/or circuit breakers.

Load Circuits

Loads are devices that convert electrical energy to another form of energy such as heat or mechanical motion. In the process, loads consume power. Compressor motors, fan motors, heater elements, and the primary winding of transformers are all loads normally found in cooling and heating units. Because the input

▼ Figure SP-7-1.
Equipment Functional Circuits



power distribution circuits and the load circuits are both energized and operate at the input voltage level, they are often called the *high-voltage circuits*.

Control Circuits

Control circuits provide a link between the loads and the input power. Control circuits start, stop, or otherwise control the operation of a load. They usually contain one or more control devices, such as relays, switches, and thermostats that work to apply or remove power from the loads. The more complex the system, the more control devices it will have. When a load such as a compressor motor is not working, you have to determine whether the problem is in the load itself or in the circuits controlling the load.

Control circuits or low-voltage circuits generally operate at 24 volts. This low voltage is obtained by using a control transformer to step down the line voltage. Use of a low voltage to power the control circuits has the following advantages:

- Low-voltage control circuits are safer to operate and to work on.
- Low-voltage control circuits draw less power.
- Low-voltage control circuit components and their related wiring are smaller and lighter.

- Low-voltage control circuit components, such as those in a room thermostat, provide more accurate temperature control.

In some larger systems using three-phase line voltages of 230 volts and higher, a control voltage of 115 volts or higher may be used for some of the control devices. You should refer to the manufacturer's literature and/or the unit schematic to determine what specific voltage is used for the unit's control circuits. Also, it is a good practice to always measure the control circuit voltage. *Never assume the control circuit voltage is a low voltage.*

Voltage Systems

For residential and light commercial users, an electric utility company supplies single-phase or three-phase power to users at voltages from 115 volts to 460 volts. Voltage systems vary from one locality to another. If in doubt about the correct input voltage, contact the local utility company. Typical AC input voltage systems that will be encountered when servicing HVAC equipment include the following:

- 115 volt, single-phase
- 120/240 volt, single-phase, 60 Hz
- 208/230 volt, single-phase, 60 Hz
- 208/230 volt, three-phase, 60 Hz
- 460 volt, three-phase, 60 Hz

Input Voltage Measurements

Input voltage measurements are made to determine if the proper source voltage is being supplied to a unit in order for it to operate efficiently and economically. Input voltage checks are usually the first test made when troubleshooting electrical problems.

Effects of High and Low Input Voltage

Too high or too low an operating voltage can cause overheating and possible failure of a motor. Operating voltages applied to motors and other electrical components must be maintained within minimum-maximum limits from the voltage value given on the component's nameplate. If the operating voltage falls outside these limits, the system should be turned off and the problem corrected before restarting the system. The problem may be with the building distribution system or the power supplied to the building. Voltage tolerances used for motors are:

- Single-Voltage Rated Motors – The input supply voltage should be within ±10% of the motor's nameplate voltage. For example, a motor with a nameplate voltage rating of 230 volts should have an input voltage that ranges between 207 volts and 253 volts (±10% of 230 volts).
- Dual-Voltage Rated Motors – The input supply voltage should be within ±10% of the motor's nameplate voltage. For example, a motor with a nameplate dual voltage rating of 208/230 volts should have an input voltage that ranges between 187 volts (–10% of 208 volts) and 253 volts (+10% of 230 volts).

QUICK NOTE

When the unit contactor is closed, applying power to the compressor and outdoor (condenser) fan motor circuits, the voltage level may drop about 3% from the measured open circuit voltage (contactor open). This is acceptable if the voltage does not drop below the manufacturer's stated minimum voltage level. A 10% drop can indicate loose connections, undersized wire, etc.

Voltage and Current Phase Imbalance in Three-Phase Systems

The voltage imbalance between any two legs of the supply voltage applied to a three-phase motor may not exceed 2%. A small imbalance in the input voltage results in a considerable amount of heat being generated in the motor windings. With only a 5% imbalance, the winding temperature can increase as much as 50% over the safe level. An example of how to calculate the voltage imbalance in a three-phase system is provided in the detailed procedure given later in this section. *Any voltage imbalance of more than 2% must be corrected.*

Current imbalance between any two legs of a three-phase system should not exceed 10%. Voltage imbalance will always produce current imbalance, but a current imbalance may occur without a voltage imbalance. This can occur when an electrical terminal, contact, etc. becomes loose or corroded, causing a high resistance in the leg. Since current follows the path of least resistance, the current in the other two legs will increase, causing more heat to be generated in those two windings. Refer to Service Procedure SP-9 for the procedure used to check current imbalance.

Isolating Faults to Functional Circuit Areas

We cannot overemphasize the importance of knowing how a piece of equipment operates before attempting to troubleshoot it. If you are unfamiliar with the operation of a particular piece of equipment, always refer to the manufacturer's installation and/or service manual. Most manufacturer's service literature describes in detail the electrical operation and sequence of events. Also, most manufacturers provide troubleshooting aids, such as a wiring diagram, fault isolation diagram, and/or troubleshooting tree attached to the equipment or contained in the service manual. Some equipment has built-in diagnostic circuits that can run a complete checkout of all system functions, then report back the results by means of a display device.

Isolation to the faulty functional circuit (input power distribution circuit, load circuit, or control circuit) is relatively easy to accomplish by analyzing the equipment operation. Talking to the customer prior to working on the equipment is always recommended because it can provide valuable clues that can aid in the troubleshooting process.

For example, on an extremely hot summer day, you answer a service call on a packaged heating/cooling unit. The customer mentions that the air conditioning seems to operate most of the time, but on the extremely hot days, when it is needed most, it always seems to fail. During the conversation, the customer mentions that on those days when it fails, they notice that the outdoor fan does not run.

Your observation confirms that indeed the outdoor fan is not running. You also confirm that both the compressor and indoor fan *are* running. Based on your observations and an analysis of the unit's wiring diagram (Figure SP-7-2), it is obvious that most of the circuits can be eliminated as the source of the problem, except for the outdoor fan motor circuit. Because the symptoms allowed you to easily identify the defective circuit, you would continue to troubleshoot the outdoor fan motor circuit to find the faulty component using the hopscotch method of troubleshooting as described in Service Procedure SP-8.

For our example, assume the internal overload in the fan was open, stopping it from running. You observe that overgrown bushes surrounding the outdoor unit are restricting the airflow through the coil. On extremely hot days, when the fan runs most of the time, this airflow restriction is enough to cause the motor to overheat and open its internal overload, stopping the motor. On cooler days, when the motor did not run as often, motor operation remained normal. Clearing the bushes away from the coil would solve this problem.

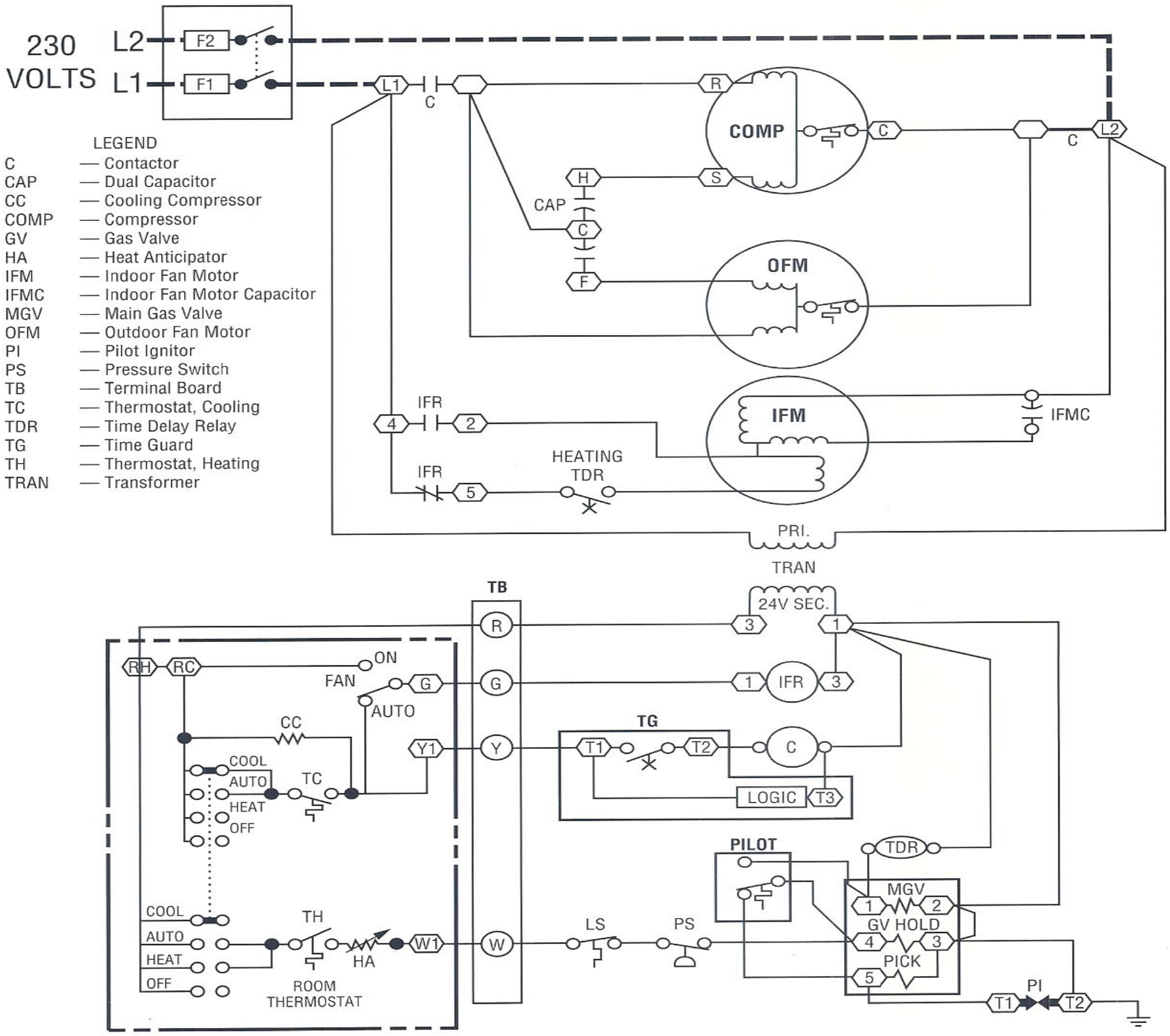
The schematic diagram for the heating/cooling unit shown in Figure SP-7-2 is typical of those you will encounter in the field. Figure SP-7-3 shows a simple tree diagram for troubleshooting heating/cooling units. The troubleshooting guidelines given in the tree diagram are keyed to the detailed procedures given at the end of this section. Both the tree and the troubleshooting procedures can be used to troubleshoot most heating/cooling equipment. You would use them when the symptoms of an electrical problem do not allow you to easily find the faulty circuit, such as in the previous example.

Safety Precautions

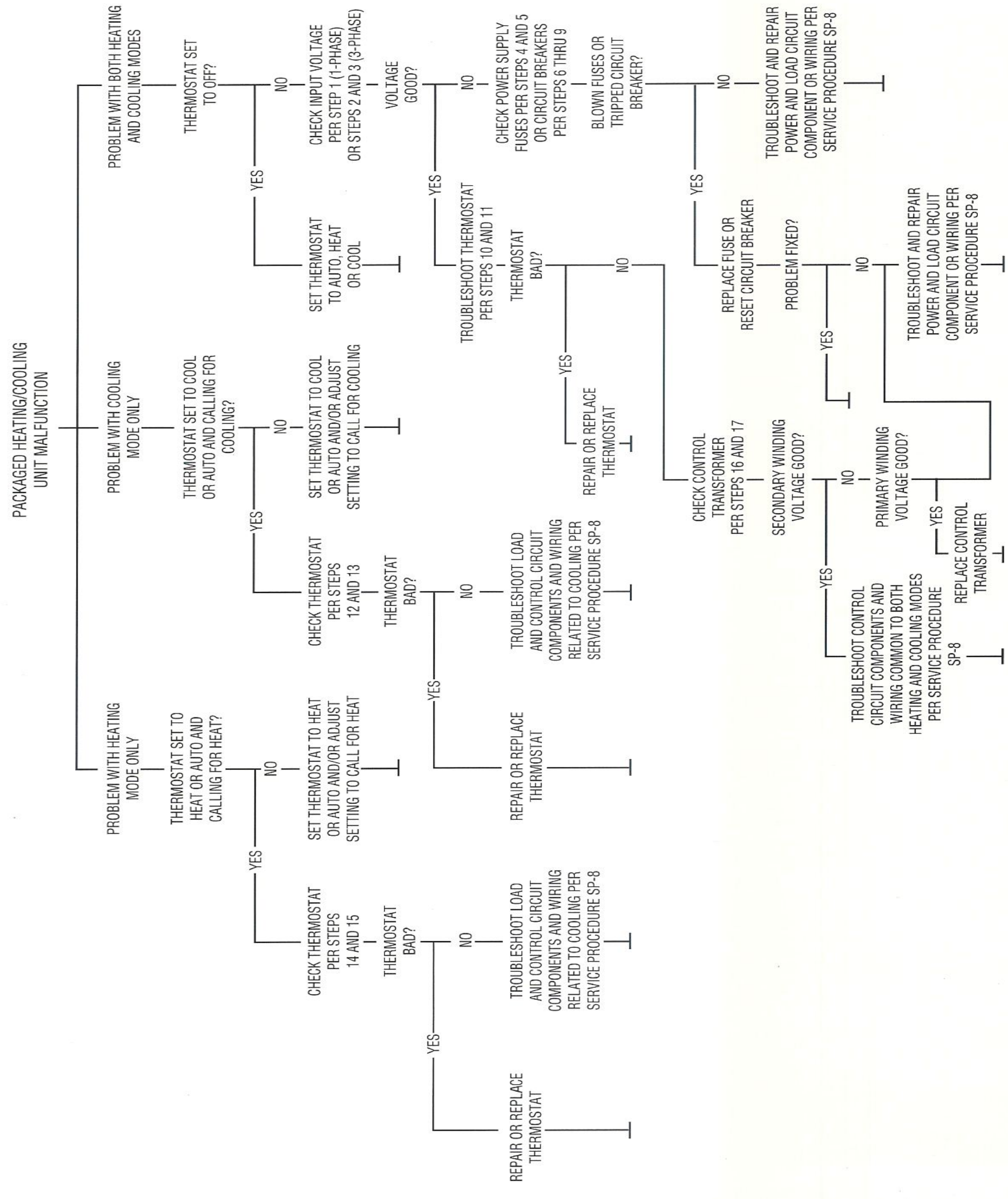
When making electrical measurements and/or repairs on equipment, always follow the precautions listed below.

- Read and follow all safety instructions given in the manufacturer's installation instructions and/or service manual for the specific system being serviced.
- Always turn off the main power to a system before making any repairs. There may be more than one disconnect switch. If applicable, turn off the accessory power. Tag and lock out all disconnect switches.
- Always remove rings, watches, and other jewelry to lessen the chance of electrical shock.
- When making voltage, current, or continuity measurements on a hermetic or semi-hermetic compressor in a pressurized system, do not take the measurement directly on the compressor terminals. If the compressor terminals are damaged and the system is pressurized, disturbing them to take measurements could cause them to blow out, causing injury. Once the charge has been removed and the system is no longer under pressure, measurements can be made at the compressor terminals.
- Do not override or bypass safety controls such as electrical interlocks, unless directed by the manufacturer's service literature.
- Never replace a blown fuse without correcting the cause of the original failure. If thermally-operated circuit breakers or overloads are tripping, make sure the trip is not due to excessively high ambient temperatures or loose connections. Also, make sure that HACR-rated circuit breakers are being used.

Figure SP-7-2.
Schematic Diagram for Typical Packaged Heating/Cooling Unit



▼ Figure SP-7-3.
Fault Isolation Tree for Typical Heating/Cooling Unit



PROCEDURE

Before performing this troubleshooting procedure, refer to the manufacturer's installation instructions and/or service manual for specific instructions about the system being serviced. If differences exist between our procedure and the manufacturer's instructions, always follow the manufacturer's instructions. Review the safety instructions and precautions given in this procedure and in Section 2 of this manual.

The measurements covered in this procedure are listed below. These measurements can be performed independent of one another, or in the sequence directed by the typical heating/cooling fault isolation tree shown in Figure SP-7-3.

- Step 1 – Input voltage measurement for single-phase systems.
- Step 2 – Input voltage measurement for three-phase systems.
- Step 3 – Percent of voltage imbalance for three-phase systems.
- Steps 4 and 5 – Fuse continuity measurement.
- Steps 6 through 8 – Circuit breaker voltage measurement.
- Step 9 – Circuit breaker current measurement.
- Steps 10 through 15 – Thermostat checks.
- Steps 16 and 17 – Control transformer checks.

QUICK NOTE

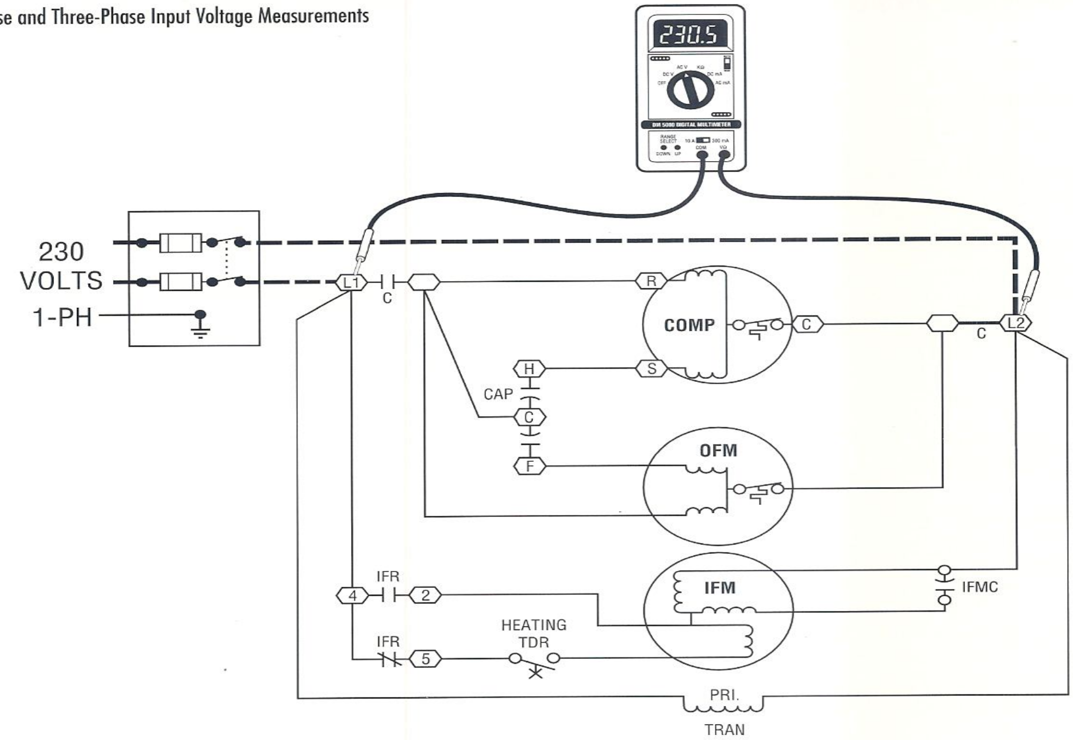
Remember, most cooling equipment has a compressor short-cycle protection device to prevent the compressor from starting when adverse conditions exist. When troubleshooting, power to the equipment is often repeatedly turned off, then on. Under these conditions, the short-cycle device will activate and must time out (30 seconds to 5 minutes, depending on the equipment) before the system compressor can run.

SP-7. INSTRUMENT OR DEVICE REQUIRED	REFERENCE
Clamp-on ammeter	Section 1, Item 10
Volt-ohm-milliammeter (VOM/DMM) and test leads with alligator clips so the leads can be attached to the test points without the need for the technician to hold them in place	Section 1, Item 11

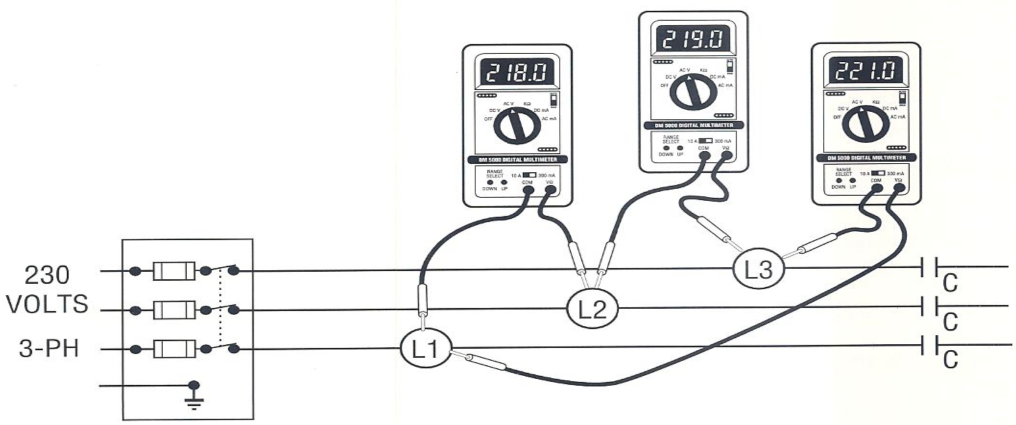
SP-7. INPUT VOLTAGE AND CURRENT MEASUREMENT PROCEDURES (STEPS 1 THROUGH 3)

Step	Expected Result/Action
1. Measure input voltage on a single-phase system as follows: Turn power off. Set up the VOM/DMM to measure AC voltage on a range that is higher than the highest voltage expected. (Refer to the unit nameplate.) Connect the VOM/DMM between test points L1 and L2 as shown in Figure SP-7-4, View A. Turn power on, then measure and record the input voltage level. Turn power off and disconnect VOM/DMM.	Measured voltage should be between the "permissible max. and min." values given on the unit nameplate. If none are given, allow a tolerance of ±10% from the power supply volts value marked on the unit nameplate. For example, a unit with a nameplate single voltage rating of 230 volts should have an input voltage that ranges between 207 volts and 253 volts (±10% of 230 volts). Operating a unit continuously at either voltage extreme (+10% or -10%) is poor practice and shorter component life is to be expected. If voltage is excessively high or low, check for excessive wire length, poor contact, etc. If all potential local problems are ruled out, contact the electric utility.
2. Measure input voltage on a three-phase system as follows: Turn power off. Set up the VOM/DMM to measure AC voltage on a range that is higher than the highest voltage expected. (Refer to the unit nameplate.) Connect VOM/DMM between test points L1 and L2, as shown on Figure SP-7-4, View B. Turn power on, then measure and record the input voltage. Repeat the input voltage measurement for the remaining two phases by measuring between test points L2 and L3, and L3 and L1, as shown in Figure SP-7-4, View B. Turn power off and disconnect VOM/DMM.	Measured voltage should be between the "permissible max. and min." values given on the unit nameplate. If none are given, allow a tolerance of ±10% from the power supply volts value given on the unit nameplate. Note that operating a unit continuously at either voltage extreme (+10% or -10%) is poor practice and shorter component life is to be expected. If voltage is excessively high or low, check for excessive wire length, poor contact, etc. If all potential local problems are ruled out, contact the electric utility.
3. Calculate percent of voltage imbalance for a three-phase system using the formula below. % Voltage Imbalance = Maximum Voltage Deviation ÷ Average Voltage x 100	The percent voltage imbalance should be 2% or below. (See the example calculation below.) If the voltage imbalance exceeds 2%, contact the electric utility. **Example of % voltage imbalance calculation** *Voltage measured L1-L2* *218 volts* *Voltage measured L2-L3* *219 volts* *Voltage measured L3-L1* *221 volts* *Average voltage* *658 volts ÷ 3 = 219.3* *Difference between the average voltage and the measured voltage:* *L1-L2 = 219.3V - 218.0V = 1.3V* *L2-L3 = 219.3V - 219.0V = 0.3V* *L3-L1 = 221.0V - 219.3V = 1.7V* *% Imbalance = Maximum Voltage Deviation ÷ Average Voltage x 100* *% Imbalance = 1.7 ÷ 219.3 x 100 = 0.8%* *Since imbalance is less than 2%, the input voltage balance between phases is good.*

▼ Figure SP-7-4.
Single-Phase and Three-Phase Input Voltage Measurements



A. SINGLE-PHASE INPUT VOLTAGE MEASUREMENT

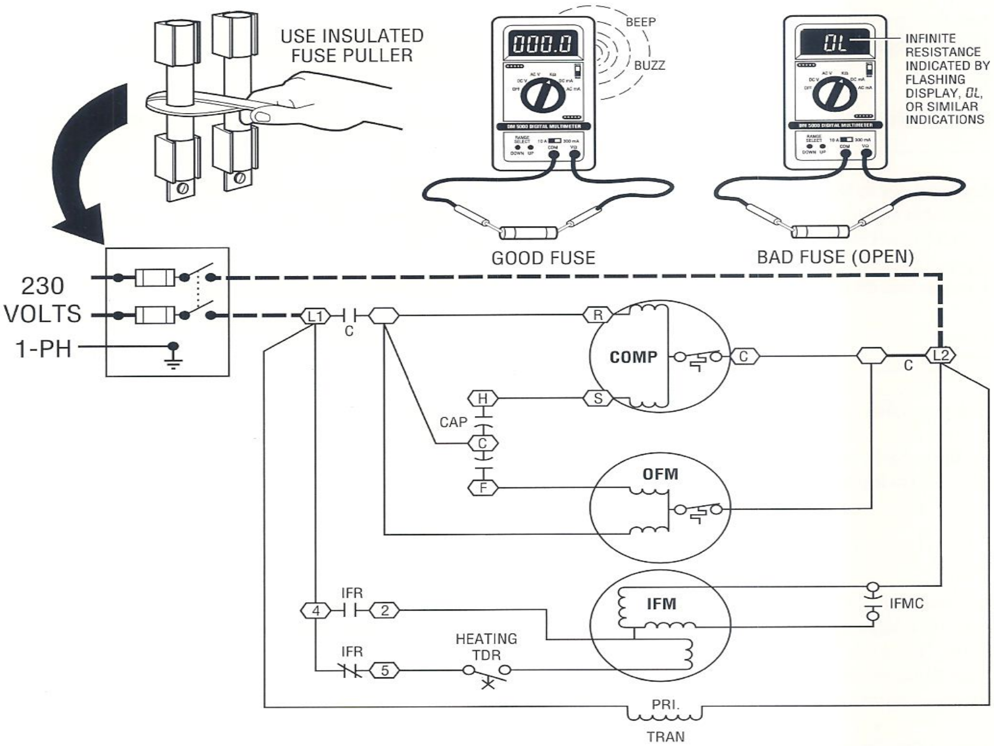


B. THREE-PHASE INPUT VOLTAGE MEASUREMENT

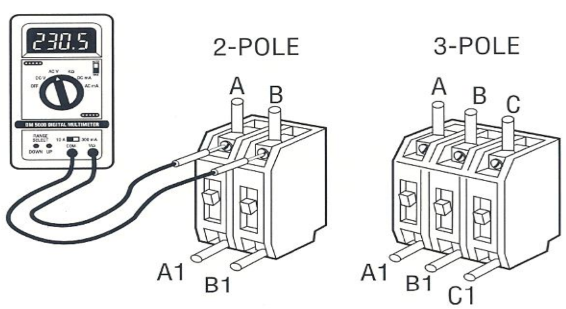
SP-7. FUSE AND CIRCUIT BREAKER MEASUREMENT PROCEDURES (STEPS 4 THROUGH 9)

Step	Expected Result/Action
NOTE: Steps 4 and 5 check the condition (good or open) of the disconnect box fuse(s). 4. Set disconnect switch to off. Using an insulated fuse puller, remove fuse(s) from the disconnect switch.	Fuse(s) removed from disconnect switch in preparation for measurement.
5. Set up the VOM/DMM to measure continuity. If using a VOM, select the R x 1 range. Measure the resistance across the fuse as shown in Figure SP-7-5, View A.	Fuse is good if VOM/DMM reads zero ohms. The DMM may also beep or buzz. Fuse is bad if VOM/DMM reads an open or a measurable resistance. *Fuses can fail because of poor contact in the disconnect switch. Check disconnect switch for loose connections, discolored or hot clips, blades, etc.*
NOTE: Steps 6 through 9 check the condition (good or bad) of the input power or distribution panel circuit breaker(s). 6. At the power distribution panel, set the circuit breaker to off. If required, remove the panel that covers the circuit breaker to expose the body of the breaker and the wires connected to its terminals.	Circuit breaker is turned off.
7. Set up the VOM/DMM to measure AC voltage on a range that is higher than the highest voltage expected. (Refer to the unit nameplate.) As shown in Figure SP-7-5, View B, measure the voltage applied to the circuit breaker input terminals: A to neutral or ground (single-pole breaker), A to B (2-pole breaker), or A to B, B to C, and C to A (3-pole breaker).	Voltage is applied to the input of the circuit breakers, and it is within $\pm$10% of the power supply volts required for the unit as marked on the unit nameplate. For example, our typical heating/cooling unit should have an input voltage that ranges between 207 volts and 253 volts ($\pm$10% of 230 volts), measured across the circuit breaker input terminals A and B.
8. Make sure that the breaker is closed by first setting it to the off position, then to on. Measure the voltage at the circuit breaker output terminals A1 to neutral or ground (single-pole breaker), A1 to B1 (2-pole breaker), or A1 to B1, B1 to C1, and C1 to A1 (3-pole breaker).	Voltage is measured at the output of the circuit breakers. If the voltage is significantly lower than that measured at the input to the circuit breakers in step 7, visually inspect breakers for loose wires and terminals or signs of overheating. If none are found, replace the circuit breaker. If breaker shows signs of overheating or trips when voltage is applied to the equipment, reset it, then check the current flow through the breaker per step 9.
9. Measure the current flow through the input power circuit breaker(s) as follows: Set up the AC clamp-on ammeter to measure AC current on a range that is higher than the highest current expected. Check the ampere rating of the breaker. It is usually stamped on the breaker lever or body. Refer to Figure SP-7-5, View C. One wire at a time, measure the current flow in the wires connected to the circuit breaker output terminals: A1 (single-pole breaker), A1, B1 (2-pole breaker), or A1, B1, and C1 (3-pole breaker).	Compare the measured current with the breaker ampere rating. If the measured current through the breaker is higher than the rating, an overload condition exists in the breaker load circuit. If the breaker is tripping at a current below its rating or not tripping at a higher current, replace it. Be sure the breaker is not being tripped due to excessively high ambient temperature, such as might exist if the box is in direct sunlight, in hot desert areas, or on roof tops. Make sure HACR-rated circuit breakers are being used to power HVAC equipment.

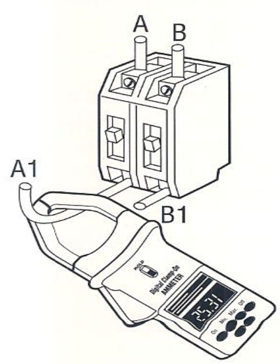
Figure SP-7-5.
Fuse and Circuit Breaker Measurements



A. FUSE CONTINUITY CHECK



B. CIRCUIT BREAKER VOLTAGE CHECK

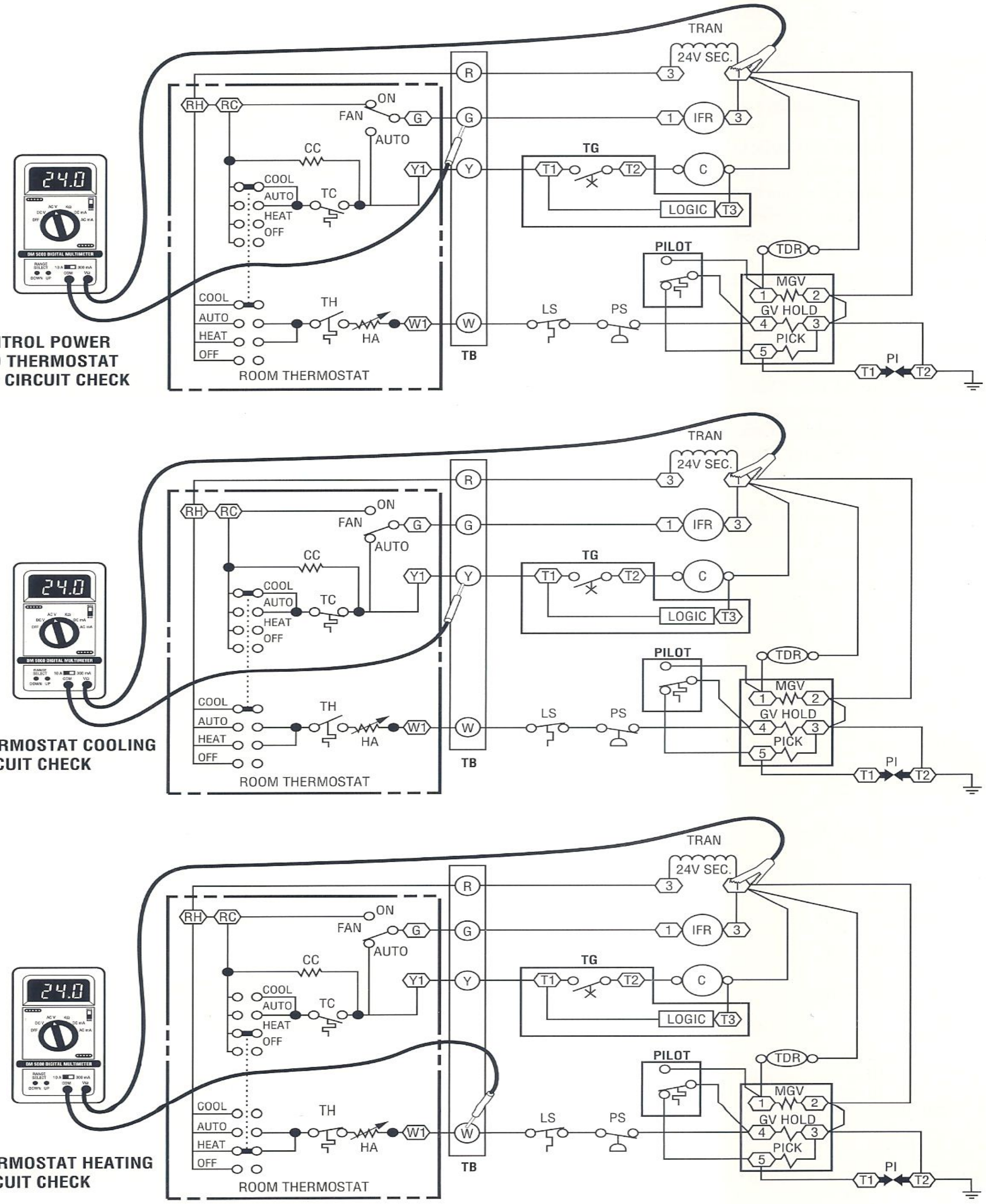


C. CIRCUIT BREAKER CURRENT CHECK

SP-7. THERMOSTAT CHECKS AND MEASUREMENT PROCEDURE (STEPS 10 THROUGH 15)

Step	Expected Result/Action
NOTE: Steps 10 and 11 check the input voltage and fan circuit section of the thermostat. 10. At the thermostat, set the FAN switch to the ON position.	If the indoor fan motor runs, the control transformer is operating and the fan switch section of the thermostat is good. Troubleshoot the related load and control circuits per SP-8. If the indoor fan motor does not start, proceed to step 11.
11. Turn off power to the equipment. Set up the VOM/DMM to measure AC control voltage on a range that is higher than the highest voltage expected. (Refer to the unit schematic.) Connect the VOM/DMM between test point 1 (C) and terminal G as shown in Figure SP-7-4, View A. Turn power on, then observe the VOM/DMM voltage indication. Turn power off and disconnect VOM/DMM.	If the VOM/DMM indicates control voltage (24 volts), the fan switch section of the thermostat is good. Troubleshoot the related indoor fan motor control and load circuits per SP-8. If the VOM/DMM indicates zero volts, check voltage at the control transformer secondary winding per step 16. If voltage is good, replace the thermostat or repair the associated open wiring.
NOTE: Steps 12 and 13 check the cooling circuit section of the thermostat. 12. At the thermostat, set the FAN switch to the AUTO position and the function switch to the COOL position. Set the thermostat to call for cooling.	If the compressor, outdoor fan, and/or indoor fan motor start, the cooling switch section of the thermostat is operating. Troubleshoot the related load and control circuits per SP-8. If the compressor, outdoor fan, and/or indoor fan motor do not start, proceed to step 13.
13. Turn off power to the equipment. Set up the VOM/DMM to measure AC control voltage on a range that is higher than the highest voltage expected. (Refer to the unit schematic.) Connect the VOM/DMM between test point 1 (C) and terminal Y as shown in Figure SP-7-4, View B. Turn power on, then observe the VOM/DMM voltage indication. Turn power off and disconnect VOM/DMM.	If the VOM/DMM indicates control voltage (24 volts), the cooling switch section of the thermostat is good. Troubleshoot the related cooling control and load circuits per SP-8. If the VOM/DMM indicates zero volts, replace the thermostat or repair the associated open cooling control circuit wiring.
NOTE: Steps 14 and 15 check the heating circuit section of the thermostat. 14. At the thermostat, set the function switch to the HEAT position. Set the thermostat to call for heat.	If the pilot ignites, the heating switch section of the thermostat is working. Troubleshoot the related load and control circuits per SP-8. If the pilot does not ignite, proceed to step 15.
15. Turn off power to the equipment. Set up the VOM/DMM to measure AC control voltage on a range that is higher than the highest voltage expected. (Refer to the unit schematic.) Connect the VOM/DMM between test point 1 (C) and terminal W as shown in Figure SP-7-4, View C. Turn power on, then observe the VOM/DMM voltage indication. Turn power off and disconnect VOM/DMM.	If the VOM/DMM indicates control voltage (24 volts), the heating switch section of the thermostat is good. Troubleshoot the related heating control and load circuits per SP-8. If the VOM/DMM indicates zero volts, replace the thermostat or repair the associated open heating control circuit wiring.

Figure SP-7-6.
Thermostat Checks



A. CONTROL POWER AND THERMOSTAT FAN CIRCUIT CHECK

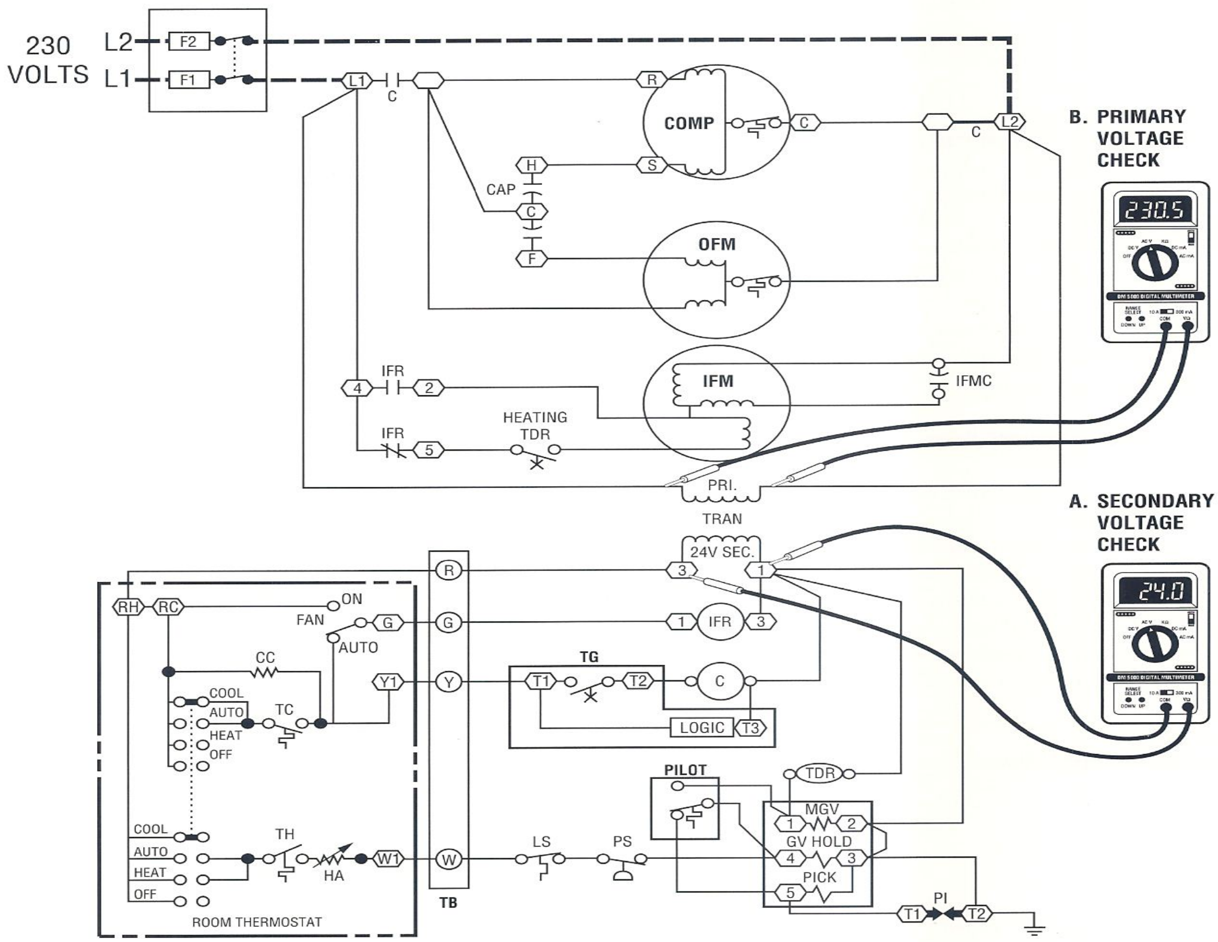
B. THERMOSTAT COOLING CIRCUIT CHECK

C. THERMOSTAT HEATING CIRCUIT CHECK

SP-7. CONTROL TRANSFORMER MEASUREMENT PROCEDURE (STEPS 16 AND 17)

Step	Expected Result/Action
NOTE: Steps 16 and 17 check control transformer operation. 16. Measure the voltage at the secondary windings of the control transformer. Turn power off. Set up the VOM/DMM to measure AC control voltage on a range that is higher than the highest voltage expected. (Refer to the unit schematic or manufacturer's service literature.) Connect VOM/DMM across control transformer secondary winding, as shown in Figure SP-7-7, View A. Turn power on, then measure the control transformer secondary voltage. Turn power off and disconnect VOM/DMM.	If measured voltage across secondary winding is within ±10% of the voltage indicated by the schematic or manufacturer's service literature, the control transformer is good. Troubleshoot control circuit components and wiring common to both the heating and cooling modes of operation. If secondary voltage is low, it can affect the operation of relays and other control circuit components. Check for low primary voltage per step 17. If primary voltage is good, replace transformer. If there is no voltage at the secondary winding, perform step 17.
17. Measure the voltage at the primary winding of the control transformer. Turn power off. Set up the VOM/DMM to measure AC voltage on a range that is higher than the highest voltage expected. (Refer to the unit schematic or manufacturer's service literature.) Connect VOM/DMM across the control transformer primary winding, as shown in Figure SP-7-7, View B. Turn power on, then measure the control transformer primary voltage. Turn power off and disconnect VOM/DMM.	If no voltage, or low voltage, is measured at the primary winding, measure the equipment input voltage per step 1 (single-phase system) or step 2 (three-phase system). If the input voltage is good, troubleshoot the load circuit wiring between the power supply and the control transformer primary winding.

▼ **Figure SP-7-7.**
Control Transformer Voltage Measurements



COMPONENT FAULT ISOLATION CHECKS AND RESISTIVE/ INDUCTIVE LOAD AND SWITCHING DEVICE MEASUREMENTS

Purpose – This procedure describes checks and measurements used when troubleshooting an electrical problem located in the load or control circuits of HVAC equipment. It also describes the measurements needed to confirm whether a component is open, shorted, or good. Confirmation that a component is defective is necessary because faulty wiring connected to the component can also be the cause of a problem.

The procedures in this section assume that the source of an electrical problem has already been isolated to the malfunctioning circuit either by performing Service Procedure SP-7, or through analysis of the system operating conditions. The troubleshooting in this procedure covers the types of components listed below.

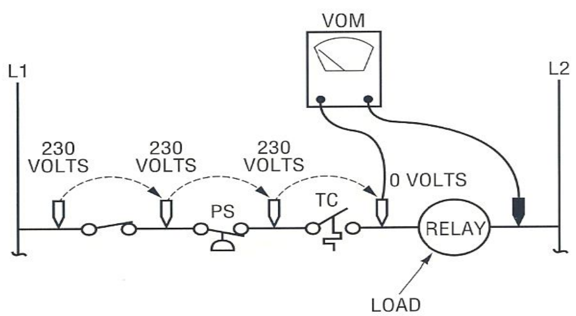
- Resistive loads, such as crankcase heaters and heater elements.
- Inductive loads, such as relay/solenoid coils, transformer windings, etc.
- Switches and contactor/relay-actuated switched contacts.

The troubleshooting and measurement of capacitors are covered in Service Procedures SP-9 and SP-10.

Finding a Faulty Component Using the Hopscotch Troubleshooting Method

Once the source of an electrical problem has been isolated to a malfunctioning load or control circuit (Service Procedure SP-7), the next step in the troubleshooting procedure is to find the faulty component in the circuit. This can be done by observing what load devices are working and not working in the equipment, then troubleshooting the circuit containing the load device that is not working. It is done by using a troubleshooting technique called *hopscotching*.

▼ Figure SP-8-1.
Example of the Hopscotch Method of Troubleshooting

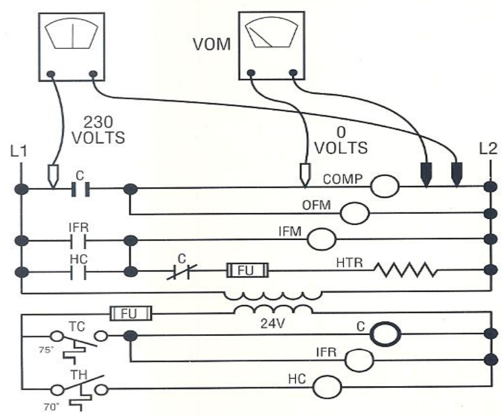


As shown in Figure SP-8-1, hopscotching involves making a series of voltage measurements across each component in the malfunctioning circuit. The measurements start from the line or control voltage side of the circuit and move toward the load device, such as a motor or a relay coil. Measurements are made until either no voltage is observed, or until the voltage has been measured across all the components in the circuit. As a result of making the voltage measurements, one of the conditions described below should be observed.

Open Component – At some point within the circuit being tested, no voltage is indicated on the VOM/DMM. This pinpoints an open component or set of switch contacts between the last measurement point and the previous measurement point. Figure SP-8-1 shows an example of this situation, where the thermally-activated TC contacts are open, preventing the relay coil from energizing.

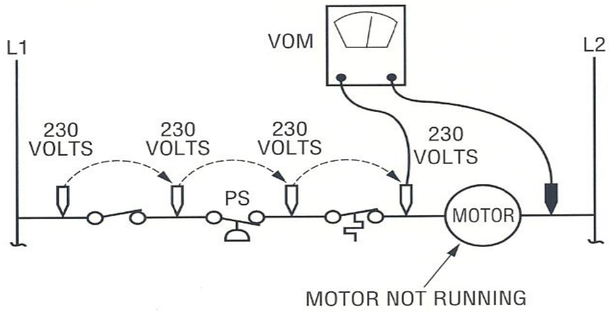
If the open is caused by a set of contactor or relay contacts, you must find out if the problem is because the related contactor or relay coil is not being energized or is bad. Figure SP-8-2 shows an example of this situation. The contacts (C) in the load circuit are open, preventing the compressor (COMP) and outdoor fan motor (OFM) from running. These contacts close when the contactor coil (C) in the control circuit is energized. Before assuming that the problem is caused by the open contacts, you must use the hopscotch method to troubleshoot the control circuit containing the related contactor coil to find out if the coil is energized or bad. For example, if the thermostat cooling contacts (TC) are open as shown in Figure SP-8-2, the contactor coil (C) will not energize.

▼ Figure SP-8-2.
Example of Hopscotch Troubleshooting in Circuit with Open Contactor Contacts



Load Device is Defective – If voltage is observed at the contactor coil, motor, or other load device, and the device is not working, the load device is most likely bad. You should turn off the power to the unit, then disconnect the load from the circuit and test its resistance to confirm that it is bad. For example, in Figure SP-8-3, there is power to the motor but it is not running. The motor is probably bad in this case.

▼ Figure SP-8-3.
Example of Hopscotch Troubleshooting in Circuit with Faulty Load Device



Resistive Loads

Electric crankcase heaters and electric heater elements (Figure SP-8-4, Views A and B) are typical examples of resistive loads encountered in HVAC equipment.

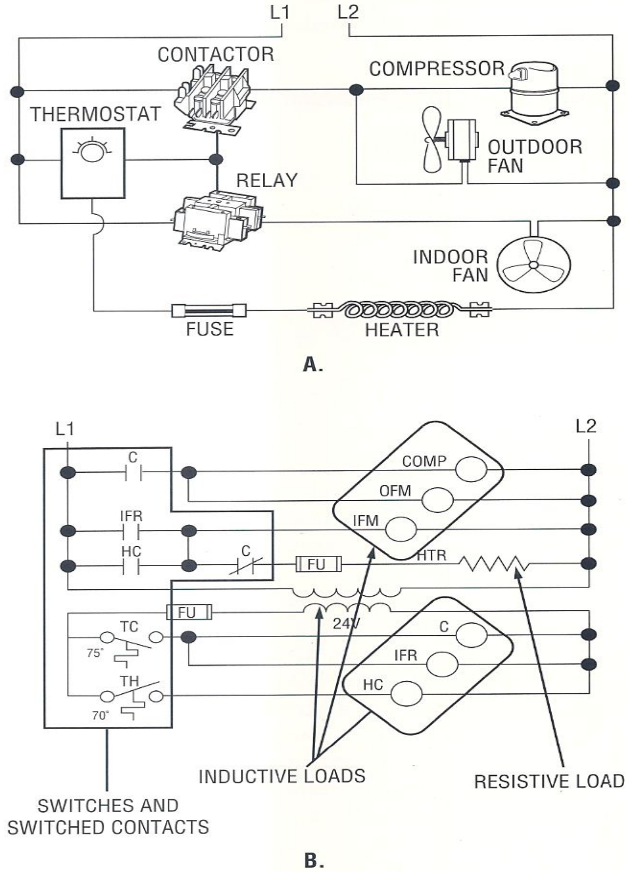
Once a *resistive load* has been identified as the probable cause of an electrical problem by using hopscotch troubleshooting, it should be tested to confirm its electrical condition (good or bad). The recommended way to test the resistive load is by measuring its resistance. Measuring the voltage across a resistive load is not a dependable way to determine its electrical condition. When a voltmeter is placed across a load, it will read the applied voltage regardless of whether the load is good or bad.

Before measuring resistance, make sure to electrically isolate the component being measured by disconnecting at least one lead of the component from the circuit. This is important in order to get an accurate resistance reading. Otherwise, the meter will read the resistance of other components that are connected to the component to be measured. For general instructions on how to use a VOM/DMM to make resistance measurements, refer to Section 3 of this manual.

Inductive Loads

Inductive loads include relay and contactor coils, compressor motors, and fan motors (Figure SP-8-4). They also include control transformers, solenoid valves, and some gas valves. This section covers the methods used to electrically test relay coils, solenoids, gas valves, and transformers. Detailed instructions for testing compressors and other motors are given in Service Procedures SP-9 and SP-10.

▼ Figure SP-8-4.
Resistive Loads, Inductive Loads, and Contactor/Relay Switched Contacts



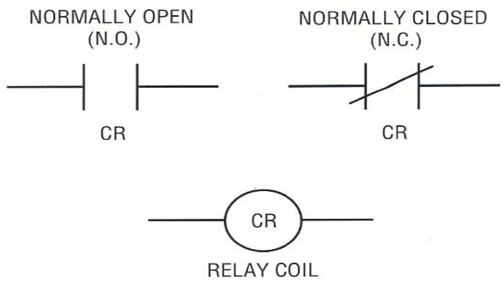
Once an *inductive load* has been identified as the probable cause of an electrical problem by using hopscotch troubleshooting, it should be tested to confirm its electrical condition (good or bad). The recommended way for checking an inductive load is to measure its resistance. Measuring the voltage across an inductive load is not a dependable way to determine the electrical condition of the inductive load. When a voltmeter is placed across a load, it will read the applied voltage regardless of whether the load is good or bad.

Switches and Contactor/Relay Switched Contacts

Once a switch or set of contactor/relay switched contacts (Figure SP-8-4) have been identified as the probable cause of an electrical problem by using hopscotch troubleshooting, the contacts should be tested to confirm their position (open or closed). Switches and contactor/relay switched contacts can be tested with continuity measurements.

A continuity measurement can be used to determine whether a switch or contact is open or closed. If the switch is open, the VOM/DMM should indicate an infinite reading. If the switch is closed, the VOM/DMM should indicate a short (zero ohms).

Figure SP-8-5.
Schematic and Wiring Diagram Contactor/Relay Switched Contact Symbols



Keep in mind that power must be off to perform the continuity check. As such, the check can only confirm the status of normally open and closed switch contacts. It may have no bearing on the status of the contacts when the system is powered up. When working with contactor or relay contacts (Figure SP-8-5), remember the following:

- Contacts that open when the contactor/relay is energized are called *normally closed (N.C.) contacts*.
- Contacts that close when the contactor/relay is energized are called *normally open (N.O.) contacts*.
- Note that the contacts of a contactor/relay may or may not be marked N.O. or N.C. on the schematic or wiring diagram. However, a schematic or wiring diagram always shows the contacts as they are positioned in the deenergized condition of the contactor/relay. Therefore, a contact that is shown closed would be considered a normally closed contact and a contact that is shown open would be considered normally open.

Safety Precautions

When making electrical measurements and/or repairs on equipment, always follow the precautions listed below.

- Read and follow all safety instructions given in the manufacturer's installation instructions and/or service manual for the specific system being serviced.
- Always turn off the main power to a system before making any repairs. There may be more than one disconnect switch. If applicable, turn off the accessory power. Tag and lock out all disconnect switches.
- Always remove rings, watches, and other jewelry to lessen the chance of electrical shock.
- When making voltage, current, or continuity measurements on a hermetic or semi-hermetic compressor in a pressurized system, do not make the measurement directly on the compressor terminals. If the compressor terminals are damaged and the system is pressurized, disturbing them to take measurements could cause them to blow out, causing injury. Once the charge has been removed and the system is no longer under pressure, measurements can be made at the compressor terminals.
- Do not override or bypass safety controls such as electrical interlocks, unless directed by the manufacturer's service literature.
- Never replace a blown fuse without correcting the cause of the original failure. If thermally-operated circuit breakers or overloads are tripping, make sure the trip is not due to excessively high ambient temperatures or loose connections. Also, make sure that HACR-rated circuit breakers are being used.

4 SERVICE PROCEDURES

PROCEDURE

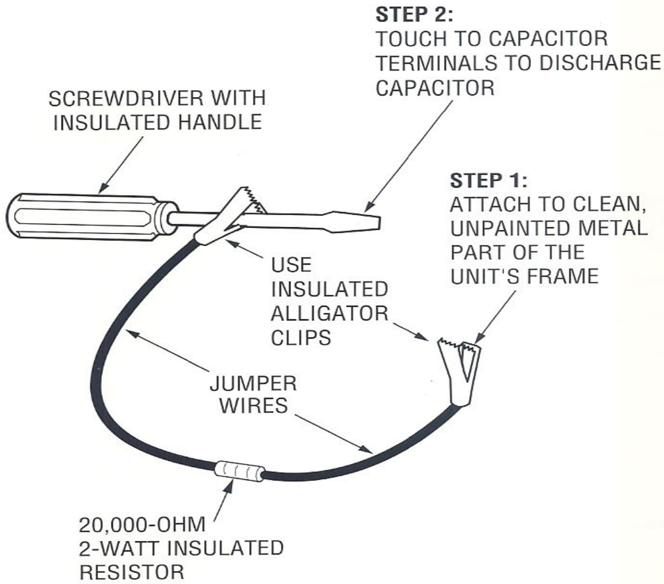
Before performing the following troubleshooting procedure, refer to the manufacturer's installation instructions and/or service manual for specific instructions about the system being serviced. If differences exist between our procedure and the manufacturer's instructions, always follow the manufacturer's instructions. Review the safety instructions and precautions given in this procedure and in Section 2 of this manual.

The measurements given in this procedure are used to confirm the condition, good or bad, of resistive and inductive loads. Also, the procedure confirms the position (open or closed) of switches and contactor/relay switched contacts. The procedures assume that the resistive and inductive loads, switches, and/or contactor/relay switched contacts have been isolated as the probable cause of an electrical problem by troubleshooting using the hopscotch method. The measurements covered in this procedure are listed below. These measurements can be performed independent of one another.

- Steps 1 and 2 – Resistive load resistance measurements.
- Steps 3 and 4 – Inductive load resistance measurements.
- Steps 5 and 6 – Switch and contactor/relay switched contacts resistance (continuity) measurements.

SP-8. INSTRUMENT OR DEVICE REQUIRED	REFERENCE
Volt-ohm-milliammeter (VOM/DMM) and test leads with alligator clips so the leads can be attached to the test points without the need for the technician to hold them in place	**Section 1, Item 11**
Capacitor discharge tool made from: two jumper wires with alligator clips; one 20,000-ohm, 2-watt resistor; and a screwdriver with an insulated handle	**Refer to Figure SP-8-6**

▼ Figure SP-8-6.
Capacitor Discharging Tool



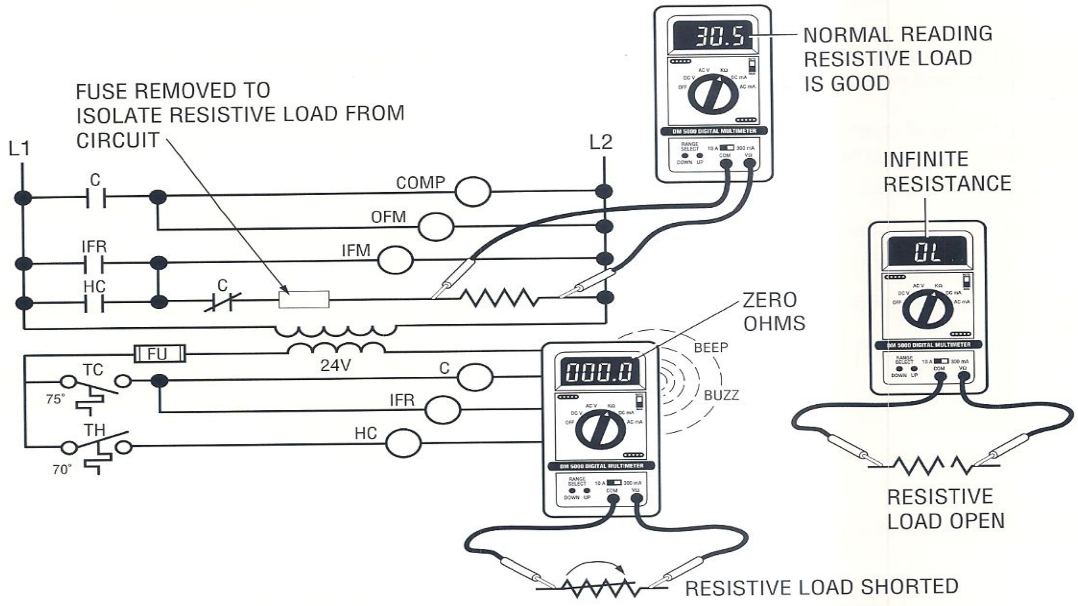
SP-8. RESISTIVE AND INDUCTIVE LOAD MEASUREMENT PROCEDURES (STEPS 1 THROUGH 4)

Step	Expected Result/Action
NOTE: Steps 1 and 2 test resistive loads. Resistive loads include resistors, electric crankcase heaters, electric heater elements, and similar devices. 1. Turn power off, then discharge all capacitors in the circuit. Disconnect at least one lead of the resistive load from the circuit.	Power is off and the resistive load is isolated from the circuit in preparation for the resistance measurement.
2. Set up the VOM/DMM to measure resistance. Select a resistance range that is higher than the resistance expected. If unknown, start at the highest range then work your way down to a lower range when making the measurement. Connect the VOM/DMM across the resistive load as shown in Figure SP-8-7, View A. Measure the resistance.	If the VOM/DMM shows a normal resistance reading, as specified by the manufacturer, the resistive load is good. If the VOM/DMM shows an infinite resistance reading, the resistive load is open; if it shows a zero reading, the resistive load is shorted. In either case, the resistive load is bad and should be replaced.
NOTE: Steps 3 and 4 test inductive loads. Inductive loads include relay and contactor coils, control transformer windings, solenoids, and gas valve coils. Tests for compressor motors and other motors, which are also inductive loads, are covered in Service Procedure SP-9 (compressor motors) and SP-10 (other motors). 3. Turn power off, then discharge all capacitors in the circuit. Disconnect at least one lead of the inductive load from the circuit.	Power is off and the inductive load is isolated from the circuit in preparation for the resistance measurement.
4. Set up the VOM/DMM to measure resistance. Select a resistance range that is higher than the resistance expected. If unknown, start at the highest range then work your way down to a lower range when making the measurement. Connect the VOM/DMM across the inductive load as shown in Figure SP-8-7, View B. Measure the resistance.	If the VOM/DMM indicates the normal resistance reading, as specified by the manufacturer, the inductive load is good. If the VOM/DMM indicates an infinite resistance reading, the inductive load is open; if it indicates a zero resistance reading, the inductive load is shorted. In either case, the inductive load is bad and should be replaced.

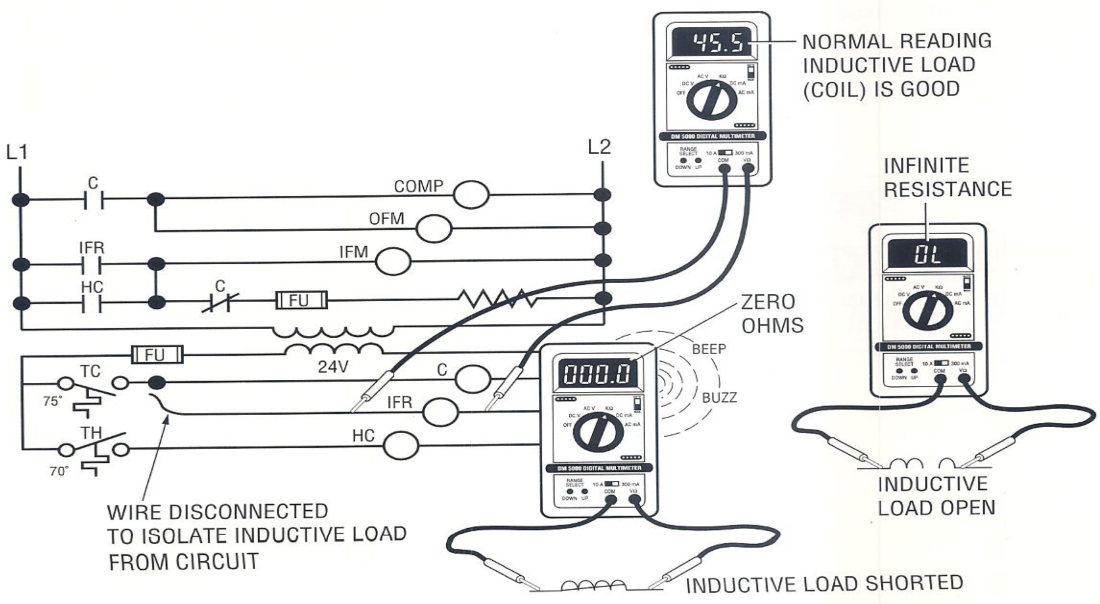
QUICK NOTE

Having a "feel" for the normal resistance of a component comes mainly by experience. All functional loads have resistance. Typically, the larger the load, the lower the resistance. Other ways to determine the normal resistance of a component are to consult the manufacturer's specification sheet or make a comparison of the resistance with a like component that is known to be good.

▼ Figure SP-8-7.
Resistive Load and Inductive Load Resistance Measurements



A. RESISTIVE LOAD MEASUREMENT

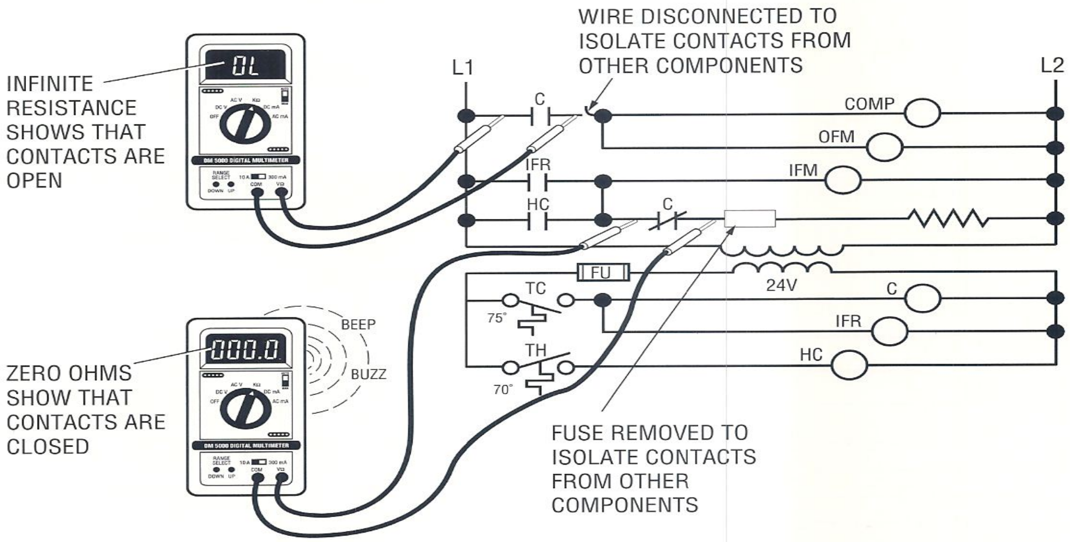


B. INDUCTIVE LOAD MEASUREMENT

SP-8. SWITCH/SWITCHED CONTACTS RESISTANCE MEASUREMENT PROCEDURES (STEPS 5 AND 6)

Step	Expected Result/Action
NOTE: Steps 5 and 6 test switches and contactor/relay contacts using the resistance (continuity) check method. 5. Turn power off, then discharge all capacitors in the circuit. Disconnect at least one lead of the switch or contacts from the circuit.	Power is off in preparation for the resistance measurement.
6. Set up the VOM/DMM to measure resistance. If using a VOM, select the R x 1 range. Connect the VOM/DMM across the switch or contacts as shown in Figure SP-8-8. Measure the resistance.	If the VOM/DMM shows an infinite resistance reading, the switch/switched contacts are open. If the VOM/DMM shows a short (zero resistance) reading, the switch/switched contacts are closed. If the VOM/DMM shows a measurable resistance, the switch contacts are neither fully open or closed or some other problem exists. This condition is not permitted and the device should be replaced.

Figure SP-8-8.
Switch and Contactor/Relay Switched Contacts Resistance Measurements



COMPRESSOR CHECKS AND ELECTRICAL MEASUREMENTS

Purpose – The compressor is the heart of the cooling system. It creates the pressure difference that causes the refrigerant flow around the system. Compressor motors are one of the primary electrical loads used in cooling systems. Compressor checks and measurements are made mainly when troubleshooting the unit. Since compressors are expensive and their replacement can be time consuming, you want to be absolutely sure that a compressor is bad before replacing it. Compressor testing is also needed in order to isolate the fault to the compressor, compressor motor, or to a related component, such as a start or run capacitor, starting relay, etc.

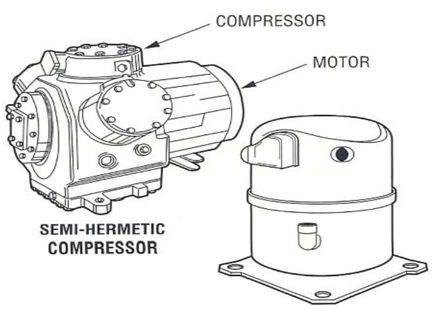
Compressor Types

The most common types of compressors encountered when servicing residential and light commercial equipment are the reciprocating, rotary, and scroll-type hermetic compressors. In a hermetic compressor (Figure SP-9-1) the motor is connected directly to the compressor crankshaft. Both components are sealed in a welded steel enclosure or shell. Because it is sealed, the entire unit must be replaced when it fails.

The semi-hermetic compressor (Figure SP-9-1), also called a *serviceable hermetic compressor*, is used in commercial equipment. In the semi-hermetic compressor, the compressor motor is connected directly to the compressor crankshaft. If failure occurs, access to the compressor or motor for some repairs is possible by removal of the cylinder heads and/or bottom and end plates.

Because the majority of compressors used in residential and light commercial equipment are hermetic compressors, the remainder of this section will emphasize procedures used to service these compressors. Most of these same procedures can also be used when servicing semi-hermetic compressors.

▼ SP-9-1.
Hermetic and Semi-Hermetic Compressors



Causes of Compressor Failures

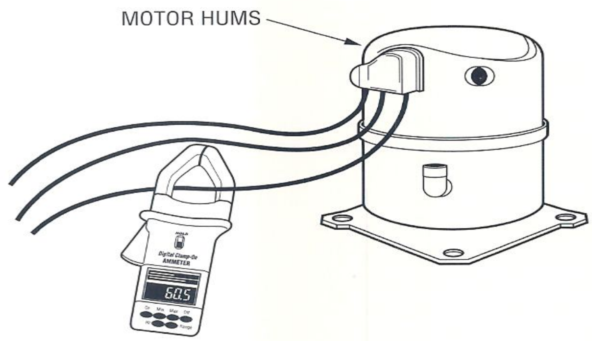
If not corrected, many refrigeration system problems will result in compressor failure. If the compressor fails and the cause has not been found and eliminated, the replacement compressor will probably fail. Problems that can cause compressor failure can be divided into two groups: mechanical failures and electrical failures.

Mechanical Failures – The most common causes of mechanical failures in hermetic compressors are:

- Seized compressor
- Low capacity (runs but does not pump)
- Leaks
- Noise

Seized Compressor – A compressor is generally considered to be seized if it hums but will not start, and draws locked rotor current for several seconds as measured with a clamp-on ammeter (Figure SP-9-2). This can be caused by a mechanical or electrical problem within the compressor or by an external electrical problem. Normally, locked rotor current lasts for a fraction of a second when the motor first starts. The locked rotor current can be four to six times the normal running current.

▼ Figure SP-9-2.
Seized Compressor



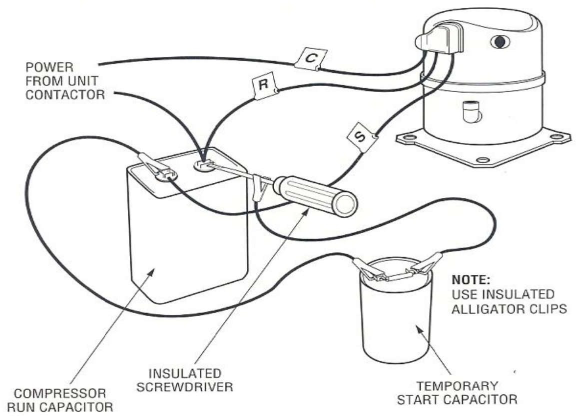
Many compressors are replaced unnecessarily because they are incorrectly judged to be seized. Before condemning the compressor, be sure that the mechanical refrigeration system or electrical system conditions listed below have been considered.

- Unequalized system pressures, especially in units using permanent split capacitor (PSC) compressor motors.
- Low supply voltage. If the supply voltage is within ±10% of the motor's nameplate rating, but a single-phase PSC motor fails to start, the installation of a start capacitor and start relay may be required to increase the motor starting torque to correct the problem.

- Compressor contactor not making good contact on all poles.
- Defective (open) start relay.
- Start or run capacitor open or weak.

If a single-phase PSC compressor motor will not start, it may be a result of low voltage, improper pressure equalization, or a weak run capacitor. Also, the compressor motor may have open, shorted, or grounded windings. After you have determined that none of the above conditions are the cause for the motor not starting, you should attempt to start the motor with a temporary capacitance boost (Figure SP-9-3). The procedure for capacitance boosting a PSC compressor motor is provided in the detailed procedure given at the end of this section, and is briefly described here.

Figure SP-9-3.
Capacitance-Boosting PSC Compressor Motor



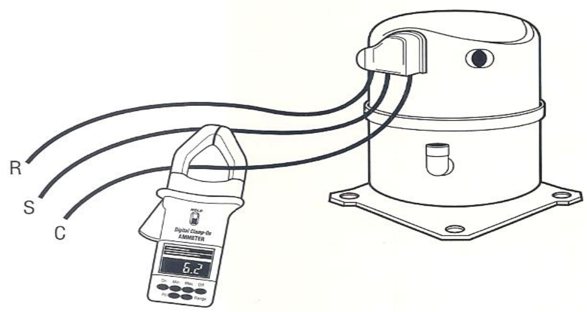
Capacitance boosting involves *momentarily* connecting a start capacitor approved by the compressor manufacturer (at least 88 to 108 MFD, 440-volt) across the unit's existing run capacitor when power to the compressor is turned on. Since the start capacitor is in parallel with the run capacitor, the values of the capacitors combine, providing increased capacitance and increased torque to start the PSC motor. The compressor motor should continue running at full speed with the start capacitor removed from the circuit. Once started, allow the compressor to run for about ten minutes, then turn off the power to the unit.

Allow the system pressures to equalize, then try starting the compressor again without the temporary start capacitor. If the motor does not start after several attempts, a start kit should be installed. Start kits designed for use with most compressors are available from HVAC distributors.

Start kits include all the components and hardware needed to complete an installation, including a start capacitor and a start relay. Start kits that use a resistive device called a *thermistor,* instead of a start capacitor and start relay, are also available. The operation of both the start relay/start capacitor circuit and the start thermistor circuit are discussed in more detail later in this section.

Three-phase motors can sometimes be started or unstuck by *temporarily* reversing or interchanging any two of the leads. *After the motor has started, always turn off the power, then reconnect the compressor leads as shown on the unit wiring diagram. Failure to wire the compressor per the wiring diagram will result in the compressor crankshaft rotating in the opposite direction. This may cause improper compressor operation and may result in damage to the compressor.*

Figure SP-9-4.
Low Capacity Check

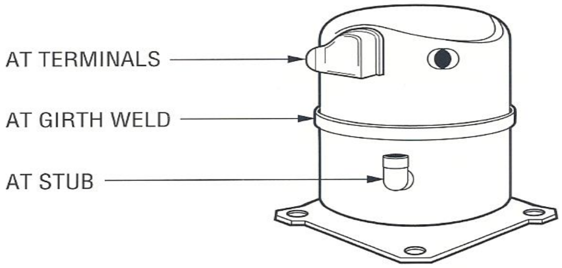


RUNNING CURRENT IS CONSIDERABLY LOWER THAN NORMAL AT A LOADED CONDITION, ACCOMPANIED BY ABNORMAL SUCTION AND/OR DISCHARGE PRESSURE READINGS.

Low or No Capacity (Runs But Does Not Pump) – Compressors depend upon their valves and rings to provide a seal between the high-pressure and low-pressure sides of the system and the compressor. If either is damaged, correct operating pressures can never be developed. This condition can be checked using the gauge manifold set. If the system is properly charged, but the suction pressure is excessively high and/or the discharge pressure is excessively low, the compressor most likely has an internal problem that allows pressure to leak between the high and low sides of the system. This means that the compressor should be replaced. An ammeter can also be used to confirm that the compressor has low capacity (Figure SP-9-4). If the running current measured with an ammeter is considerably lower than normal at a loaded condition, and the pressures are abnormal, the compressor needs replacement.

Leaks – If a leak exists at the electrical terminals of a hermetic compressor (Figure SP-9-5), it cannot be repaired and the compressor must be replaced. If a leak exists at the girth weld or at the stubs, recover all refrigerant and repair the leak with silver brazing alloy. If the leak cannot be repaired, replace the compressor.

▼ Figure SP-9-5.
Hermetic Compressor Leaks



Noise – Internal or external factors may cause a compressor to be noisy. If the noise can be reduced by enclosing the compressor with a sound shield or by the installation of a muffler in the discharge line, replacement is usually not necessary. If the noise level is still objectionable, replace the compressor.

Other System Problems that can Result in Compressor Failures – In addition to the failure modes previously described, there are several other system-related problems that, if not corrected, can result in the mechanical failure of a compressor. The major ones are listed here for consideration when troubleshooting compressors. Detailed coverage about the cause and effect of each of these system problems is beyond the scope of this manual. Detailed information related to these problems can be found in other Carrier Corporation compressor-related documents available through the catalog referenced at the front of this manual.

- Slugging of liquid refrigerant and/or oil in the compressor.
- Flooding of liquid refrigerant into the compressor crankcase.
- Flooded starts where the oil in the crankcase is diluted with liquid refrigerant when it migrates back to the compressor during shutdown.
- Loss of lubrication caused by loss of oil or by refrigerant diluting the oil.
- Contamination of the refrigeration system with air, moisture, and dirt.
- Overheating of the compressor or the motor windings.
- Incorrect installation of any system component, piping, or accessories.
- Electrical problems often caused by mechanical problems.

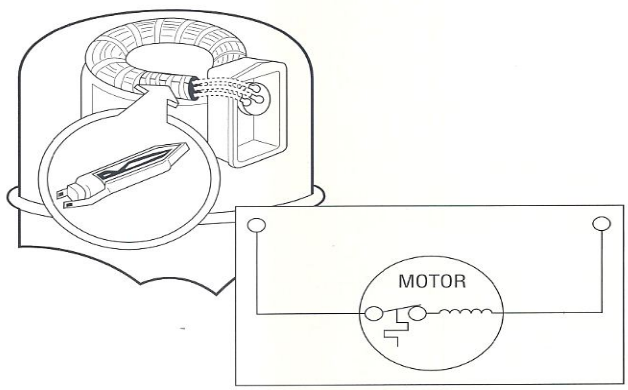
Electrical Problems – The most likely causes of electrical failures in compressors include:

- A grounded, open, or shorted motor
- An open internal overload

Grounded, Open, or Shorted Motor – Hermetic motors are rugged and reliable but they can fail in several ways. A broken wire in a motor winding can prevent the motor from running. It can also fail due to an internal short circuit where one or more motor winding conductors short together or short to ground. Any one of these problems justifies the replacement of a hermetic compressor. The electrical tests used to determine if a motor is open, shorted, or grounded are given in the detailed procedure at the end of this section.

Open Internal Overloads – Most hermetic and semi-hermetic compressors have some type of internal overload. Single-phase compressors have internal overloads called *line breaks* (Figure SP-9-6) that sense both motor current and winding temperature. If the overload opens, it breaks the current path and shuts down the motor. Some single-phase and three-phase hermetic compressors have an internal thermostat that senses winding temperature only. This thermostat is wired in series with other components in the low-voltage control circuit and will open if temperature limits are exceeded. This in turn opens the control circuit, deenergizing the compressor contactor.

▼ Figure SP-9-6.
Internal Line Break Overload



Should a line break overload or internal thermostat fail in the open position, compressor replacement is required. *Before replacing a compressor because of an open winding or internal overload, always make sure that the compressor has cooled down enough to allow any internal overload device to reset. It may require more than an hour for the overload to reset.* Generally, the motor must be below 115° F before checking the continuity of the motor windings through an internal overload device.

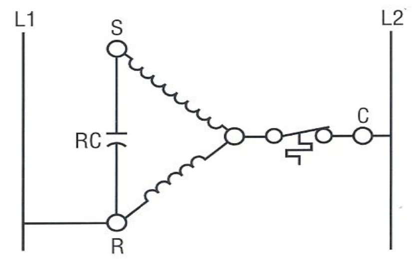
One way to ensure that sufficient cool-down time has elapsed is to advise the customer to turn the indoor thermostat switch to OFF immediately. The time between the customer's call and the service call visit is usually long enough for the motor to cool down.

Electrical Motor Types

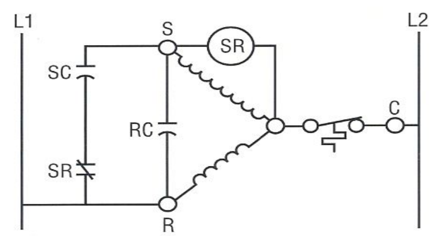
Both single-phase and three-phase motors are used in residential and light commercial system compressors. Permanent split capacitor (PSC) and capacitor start-capacitor run (CSR) motors are commonly used in single-phase hermetic compressors because of their good running characteristics and high efficiency.

As shown in Figures SP-9-7 and SP-9-8, both the PSC and CSR motors have at least three external terminals leading to two internal windings. The main or run winding (R) contains relatively few turns of heavy wire. The start winding (S) contains a greater number of turns of lighter wire. The point where the two windings meet internally is called common (C). As shown, the arrangement of the motor windings used in both the PSC and CSR motors is the same.

▼ Figure SP-9-7.
Permanent Split Capacitor (PSC) Motor Schematic



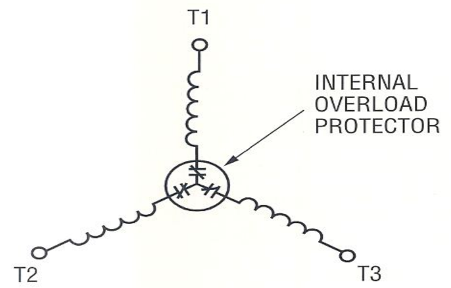
▼ Figure SP-9-8.
Capacitor Start-Capacitor Run Motor Schematic



The designation of a motor as a PSC or CSR motor is determined by the run and/or start circuit components used with the motor. As shown in Figure SP-9-7, the PSC motor has a run capacitor (RC) permanently connected across the run and start windings. Since the run capacitor remains in the circuit during operation, it helps improve the efficiency of the motor. The PSC motor will sometimes use an extra capacitor to aid in starting. When this is done, the motor is designated as a CSR motor. As shown in Figure SP-9-8, the CSR motor has a start capacitor (SC) and the contacts of a start relay (SR) connected in parallel with the run capacitor. When the motor is turned on and reaches about 75% of full speed, these contacts open and remove the start capacitor from the circuit. The operation of the start relay circuit is discussed in detail later in this section.

Three-phase motors are generally used when high starting torque is needed or when the motor requirements are greater than 7 HP. All have at least three internal windings, with each winding having an equal resistance and the same number of wire turns. Three-phase motors have good starting and running characteristics and high efficiency. As shown in Figure SP-9-9, three-phase motors require no external starting relays or capacitors.

▼ Figure SP-9-9.
Three-Phase Motor



Electrical Considerations

Always be sure that the electric power source matches the motor power requirements. Check operating voltage, frequency, and phase. External field wiring to a motor should be done in accordance with the latest edition of the National Electrical Code (NEC) and local code requirements.

Operating voltages applied to compressor motors must be maintained within ±10% of the voltage value given on the compressor/compressor motor nameplate. If the operating voltage falls outside these limits, the system should be turned off until the problem is corrected. Voltage tolerances used for single-phase and three-phase compressor motors are:

- Single-Voltage Rated Motors – The input supply voltage should be within ±10% of the motor's nameplate voltage. For example, a motor with a nameplate single voltage rating of 230 volts should have an input voltage that ranges between 207 volts and 253 volts (±10% of 230 volts).
- Dual-Voltage Rated Motors – The input supply voltage should be within ±10% of the motor's nameplate voltage. For example, a motor with a nameplate dual voltage rating of 208/230 volts should have an input voltage that ranges between 187 volts (–10% of 208 volts) and 253 volts (+10% of 230 volts).
- Three-Phase Motors – These motors should never be used where a voltage imbalance greater than 2% exists. Failure to meet these basic considerations will damage motor windings.

A voltage imbalance of more than 2% between any two legs of the supply voltage applied to a three-phase compressor motor must be corrected. A small imbalance in the input voltage results in a considerable amount of heat being generated in the motor windings. With only a 5% imbalance, the winding temperature can increase as much as 50% over the safe level. The procedure for the measurement of three-phase input voltage and the calculation of the voltage imbalance in a three-phase system is provided in Service Procedure SP-7.

QUICK NOTE

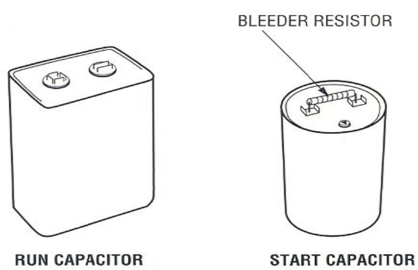
When the unit contactor is closed, applying power to the compressor and outdoor (condenser) fan motor circuits, the voltage level may drop about 3% from the measured open circuit voltage (contactor open). This is acceptable if the voltage does not drop below the manufacturer's stated minimum voltage level. A 10% drop can indicate loose connections, undersized wire, etc.

Current imbalance between any two legs of a three-phase system may not exceed 10%. Voltage imbalance will always produce current imbalance, but a current imbalance may occur without a voltage imbalance. This can happen when an electrical terminal, contact, etc. becomes loose or corroded, causing a high resistance in the leg. Since current follows the path of least resistance, the current in the other two legs will increase, causing more heat to be generated in those two windings. The procedure used to check current imbalance is included in the detailed procedure at the end of this section.

Motor Run/Start Capacitor Checks and Replacement

Run and start circuits on single-phase compressor motors use capacitors which affect the wattage, amperage draw, torque, speed, and efficiency of the motor. Figure SP-9-10 shows typical run and start capacitors.

▼ **Figure SP-9-10.**
Typical Run and Start Capacitors



Run capacitors are connected in the motor circuit at all times and are therefore referred to as *continuous-duty capacitors*. Older run capacitors are usually larger in physical size but have lower capacitance ratings than start capacitors. Newer ones may be smaller in physical size and encased in hard plastic shells. Because run capacitors are in the circuit at all times, they typically are filled with a dielectric fluid that dissipates heat.

A shorted capacitor may give a visual indication of its failure. For example, the pop-out hole at the top of a start capacitor can bulge or blow out. A run capacitor may bulge or leak. If a capacitor is found to be defective, it should always be replaced with one specified by the manufacturer.

Testing of capacitors to determine if they are good or bad is commonly done by making resistance checks using a VOM/DMM. This method is described in the detailed procedure given at the end of this section. A capacitor analyzer should be used when accuracy is required in checking the electrical condition of the capacitor, especially when it is necessary to measure the actual capacitance (MFD) value of a capacitor. Note that some DMMs also have a capability to measure the MFD value of capacitors.

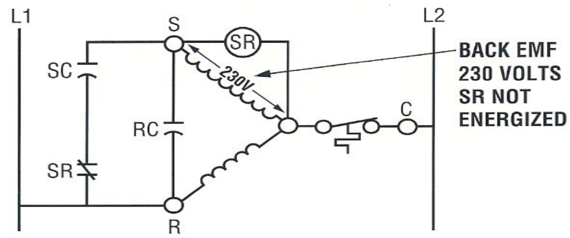
Motor Start Relay

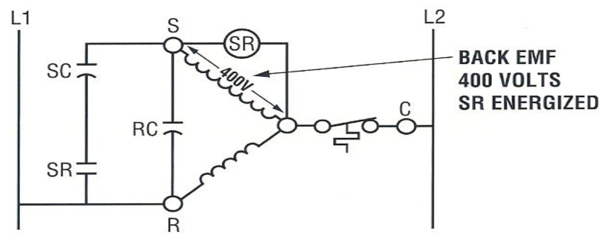
The motor start relay is used to remove the starting capacitor from the motor starting circuit when the motor reaches about 75 to 80 percent of its operating speed. Start relays are made that can be actuated by either current or voltage. The start relays used with HVAC equipment motors are normally voltage-actuated relays (potential relays); therefore, the remainder of this discussion will cover the operation of the voltage-actuated start relay.

Because all electric motors are inductive loads, they have some electrical voltage-generating capacity. The voltage generated is called *back EMF* (electromotive force). One important difference between back EMF and the line voltage applied to the motor is that the back EMF can be a much higher voltage. For example, a motor powered by 230 volts can generate back EMF voltages greater than 400 volts. It is this back EMF voltage that is used to energize the starting relay coil. The start relay is selected so that it will not energize at line voltage, but will energize at some higher voltage. When it is necessary to replace a motor start relay, an *identical* replacement must be used. Substitution of a relay with a different pickup voltage can cause damage to the start capacitor or compressor motor start winding. Also, the replacement relay must be positioned and wired exactly as the original. *When troubleshooting a start relay circuit, it is important to remember that the back EMF can be a much higher voltage than the line voltage applied to the motor.*

Figure SP-9-11 shows a CSR compressor motor with a voltage-actuated start relay. At the instant the motor is turned on, line voltage is applied across the motor start and run windings and the coil of the start relay. However, the back EMF voltage built up across the start winding is not high enough to cause the start relay coil to energize. Because the relay is deenergized, its closed contacts connect the start capacitor into the start winding circuit.

▼ Figure SP-9-11.
CSR Motor with Voltage-Actuated Start Relay





As the motor speeds up and reaches about 75 to 80 percent of its maximum speed, the back EMF reaches the voltage level that causes the start relay coil to energize. When the start relay coil energizes, its contacts open and remove the start capacitor from the motor circuit. The motor start capacitor will remain disconnected until the motor is turned off and the start relay is once again deenergized.

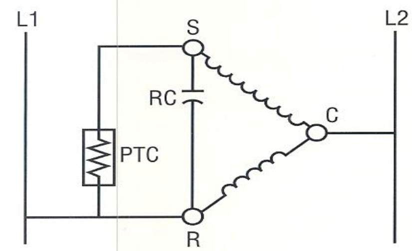
The procedure for testing the start relay is provided in the detailed procedure given at the end of this section. Motor start relays tend to fail with the contacts closed. When this happens, the start capacitor remains in the compressor start circuit, causing the start winding to overheat and fail. When the contacts are stuck closed, it may also result in the failure of the start capacitor.

Start Thermistors

Start thermistors are used to provide additional starting torque for PSC compressors. The start thermistor is a temperature-sensitive device whose electrical resistance changes as a result of a change in temperature. Positive temperature coefficient (PTC) thermistors increase their resistance with an increase in temperature. PTC thermistors are commonly used in the start circuit of PSC compressor motors.

Figure SP-9-12 shows a PSC compressor motor with a PTC start thermistor. As shown, the PTC thermistor is placed across the run capacitor. At room temperature, the PTC thermistor resistance is very low, about 25 to 50 ohms. When the compressor is turned on, the application of voltage provides an initial surge of high current through the start winding because the low resistance of the PTC thermistor is effectively bypassing (shorting) the run capacitor. This surge results in increased motor starting torque due to increased current flow in the start winding. The temperature increase created by the high current causes the PTC thermistor resistance to increase very rapidly to several thousand ohms, blocking current flow and effectively removing the thermistor from across the run capacitor. However, a small leakage current through the thermistor is enough to keep the thermistor heated and its resistance high. The compressor then runs as a normal PSC compressor. Circuit operation remains this way until the compressor is turned off. When turned off and after a cool-down period, the thermistor's resistance will once again be the low value needed to start the compressor.

▼ Figure SP-9-12.
PSC Compressor Motor with PTC Start Thermistor



Testing the status of a thermistor (good or bad) is done by taking a resistance measurement of the thermistor. The cold resistance of any PTC thermistor should be about 100 to 180 percent of the thermistor ohm rating. For example, a thermistor rated at 25 ohms should have a cold resistance of 25 to 45 ohms. If the PTC thermistor resistance is much lower or more than 200% higher than its rating, the thermistor should be replaced. The procedure for testing a start thermistor is provided in the detailed procedure at the end of this section.

Identifying Unmarked Terminals of a PSC/CSR Motor

Sometimes the terminals on a single-phase compressor are not marked or are hard to identify. The terminals can be identified using a VOM/DMM to measure the resistance of the motor windings. The procedure is provided in the detailed procedure at the end of this section and briefly described below.

First, use the VOM/DMM to find the two terminals across which the highest resistance is measured. These are the run (R) and start (S) terminals. The remaining terminal is the common (C) terminal. Next, put one lead of the VOM/DMM on the common (C) terminal, then put the other lead on one of the other two remaining terminals to find the highest resistance. This is the start winding (S) terminal. The remaining terminal is the run winding (R) terminal.

Safety Precautions

When making electrical measurements and/or repairs on equipment, always follow the precautions listed below.

- Read and follow all safety instructions given in the manufacturer's installation instructions and/or service manual for the specific system being serviced.
- Always turn off the main power to a system before making any repairs. There may be more than one disconnect switch. If applicable, turn off the accessory power. Tag and lock out all disconnect switches.
- Always remove rings, watches, and other jewelry to lessen the chance of electrical shock.
- When making voltage, current, or continuity measurements on a hermetic or semi-hermetic compressor in a pressurized system, do not place the meter probes directly on the compressor terminals. If the compressor terminals are damaged and the system is pressurized, disturbing them to take measurements could cause them to blow out, causing injury. Once the charge has been removed and the system is no longer under pressure, measurements can be made at the compressor terminals.
- Do not override or bypass safety controls such as electrical interlocks, unless directed by the manufacturer's service literature.
- When troubleshooting a start relay circuit, remember that the back EMF generated by a motor can be much higher than the line voltage applied to the motor. For example, a motor powered by 230 volts can generate back EMF voltages greater than 400 volts.
- Never replace a blown fuse without correcting the cause of the original failure. If thermally-operated circuit breakers or overloads are tripping, make sure the trip is not due to excessively high ambient temperatures or loose connections. Also, make sure that HACR-rated circuit breakers are being used.
- Do not allow fluid from a ruptured run capacitor to contact your skin or clothing. Older capacitors may contain PCBs (polychlorinated biphenyls). These capacitors must be treated as hazardous waste and be disposed of in accordance with applicable local or national codes.

PROCEDURE

Before performing the following troubleshooting procedure, refer to the manufacturer's installation instructions and/or service manual for specific instructions about the system being serviced. If differences exist between our procedure and the manufacturer's instructions, always follow the manufacturer's instructions. Review the safety instructions and precautions given in this procedure and in Section 2 of this manual.

The measurements given in this procedure are used to confirm the condition, good or bad, of a compressor or related start/run circuit component. The procedures assume that the compressor has been isolated as the probable cause of an electrical problem by troubleshooting using the hopscotch method described in Service Procedure SP-8. The measurements covered in this procedure are listed below. These measurements can be performed in sequence or independently.

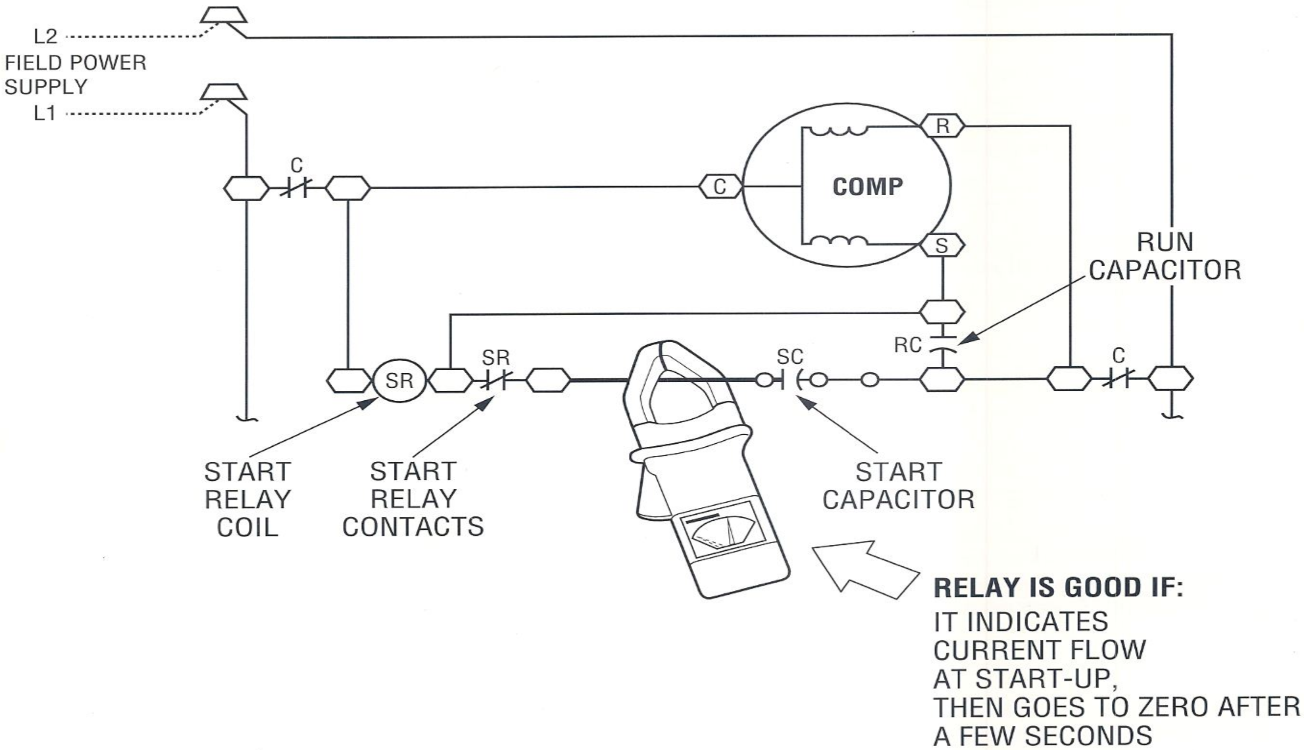
- **Steps 1 through 3 – Start relay measurements.**
- **Steps 4 through 8 – Start, run, and other capacitor measurements.**
- **Steps 9 through 12 – Compressor motor open, shorted, or grounded winding measurements.**
- **Steps 13 and 14 – Compressor motor winding-to-winding resistance measurements.**
- **Steps 15 through 18 – Identification of unmarked single-phase motor terminals.**
- **Steps 19 and 20 – Three-phase compressor current imbalance measurements.**
- **Steps 21 through 24 – Starting a "stuck" PSC compressor.**
- **Steps 25 through 28 – Starting a "stuck" three-phase compressor.**
- **Steps 29 through 32 – PTC start thermistor resistance measurements.**

SP-9. INSTRUMENT OR DEVICE REQUIRED	REFERENCE
Volt-ohm-milliammeter (VOM/DMM) and test leads with alligator clips so the leads can be attached to the test points without the need for the technician to hold them in place	Section 1, Item 11
Clamp-on ammeter – analog type or digital type with min./max. current capability needed	Section 1, Item 10
Capacitor tester – optional item used to determine the actual capacitance value of capacitors (If used, follow the tester manufacturer's instructions to test capacitors)	Section 1, Item 12
Hermetic compressor analyzer – optional equipment used to troubleshoot compressors (If used, follow the analyzer manufacturer's instructions to test compressors)	Section 1, Item 13
Capacitor discharge tool made from: two jumper wires with alligator clips; one 20,000-ohm, 2-watt resistor; and a screwdriver with an insulated handle	Refer to Figure SP-8-6
Start capacitor (at least 88 to 108 MFD, 440-volt), two jumper wires with alligator clips, and a screwdriver with an insulated handle (These items are used to start a "stuck" PSC compressor)	N/A

SP-9. START RELAY CHECKS AND MEASUREMENTS (STEPS 1 THROUGH 3)

Step	Expected Result/Action
NOTE: Steps 1 through 3 check the operation of a motor start relay. 1. Check the compressor and/or motor nameplate for full load amps (FLA).	Compressor full load amps are known.
2. Set up a clamp-on ammeter to measure AC current on the highest range scale (higher than motor FLA). If using a digital clamp-on ammeter, use the min./max. capability. Place the clamp-on ammeter around the wire that connects the compressor start capacitor to the start relay contacts as shown in Figure SP-9-13.	Equipment and test instruments prepared for measurement.
3. While watching the clamp-on ammeter, turn on the power. Observe the current flow in the start capacitor circuit as the compressor motor starts. Turn the power off after the observation is made.	At start-up, the clamp-on ammeter should momentarily indicate current flow, then fall back to zero as the compressor comes up to speed. This shows that the start relay is good because its contacts have opened, indicating that the relay coil has energized. This happens very fast. If the clamp-on ammeter continues to show current after the compressor comes up to speed, the relay contacts have not opened, indicating the relay is bad and should be replaced. If no current is shown on the clamp-on ammeter, the relay contacts can be stuck open, the related start capacitor has failed open, or the related wiring is open. The condition of the start capacitor can be tested by performing steps 4 through 8 of this procedure.

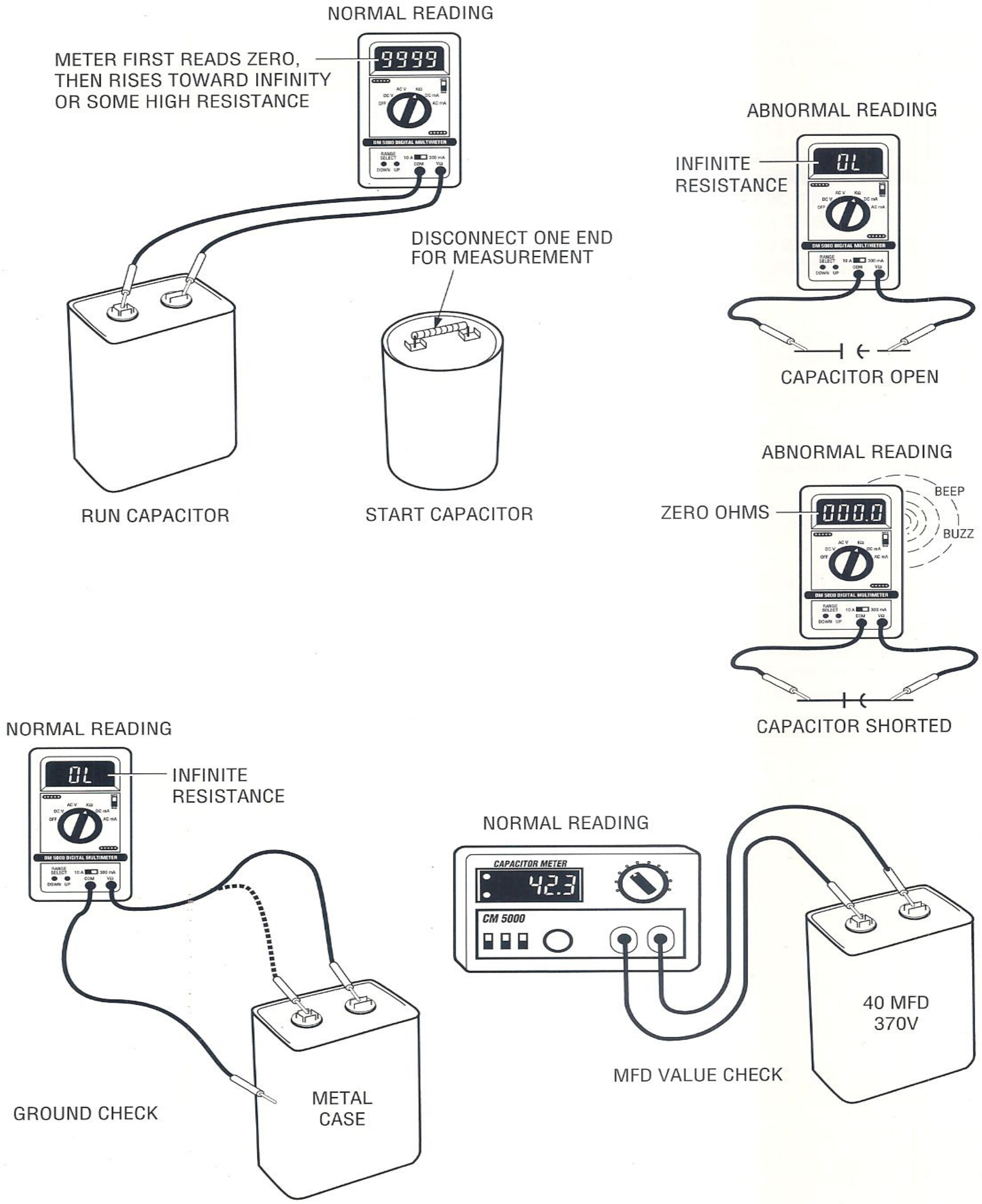
Figure SP-9-13.
Start Relay Checks and Measurements



SP-9. START/RUN CAPACITOR MEASUREMENT PROCEDURE (STEPS 4 THROUGH 8)

Step	Expected Result/Action
NOTE: Steps 4 through 8 are used to test the start and/or run capacitors associated with compressor motors. The same tests can also be used to check capacitors not used with motors. 4. Turn off all power to the unit. Use the capacitor discharge tool (Figure SP-8-6) to discharge the start and run capacitors and any other high-voltage circuit capacitors that may be used in the unit. (Note that most start capacitors have a bleeder resistor connected across their terminals. However, you should still bleed the charge off the capacitor with the discharge tool because the resistor may be open and may not bleed the charge.)	All high-voltage capacitors used in the equipment are discharged, including the run and start capacitors.
5. Locate and disconnect the wires from the start and/or run capacitor to isolate them from the remainder of the circuit. (Refer to the unit wiring diagram.) If testing a start capacitor, it is recommended that one end of the bleeder resistor also be disconnected. Inspect the capacitor for any visible signs of damage, such as bulging or leaking.	The start and/or run capacitor is isolated from the remainder of the circuit and prepared for measurement. If the visual inspection reveals a bulged or leaking capacitor, it should be replaced. Start capacitors usually have a relief plug or disc in their top that will be bulged or missing if the capacitor has overheated or failed.
6. Set up the VOM/DMM to measure resistance on the R x 1,000 or R x 10,000 ohm scale. Connect the VOM/DMM across the capacitor terminals and measure the resistance as shown in Figure SP-9-14.	VOM/DMM reading first indicates zero or a low resistance and then slowly rises toward infinity or some high value of measurable resistance. This indicates that the capacitor is most likely good. If it is necessary to find the capacitor's exact capacitance value, test it further using a capacitor tester per step 8. VOM/DMM reading goes to zero or a low resistance and stays there. This indicates that the capacitor is shorted. Replace the capacitor. VOM/DMM reading indicates infinity. This indicates that the capacitor is open. Replace the capacitor.
7. If testing a run capacitor enclosed in a metal case, check for a grounded capacitor. Set up the VOM/DMM to measure resistance on the R x 1,000 or R x 10,000 ohm scale. Connect the VOM/DMM between each one of the capacitor terminals and the metal case and measure the resistance.	VOM/DMM reading indicates infinity. This indicates that the capacitor is not grounded to its case. VOM/DMM reading indicates a measurable resistance. This indicates leakage to ground. Replace the capacitor.
8. To measure a capacitor's exact capacitance MFD value, test the capacitor using a capacitor tester. Follow the tester manufacturer's instructions to perform the test.	For a start capacitor, the measured MFD value should be -0% to +20% of the value shown on the capacitor. If the value is not within these limits, replace the capacitor. For a run capacitor, the measured value should be ±10% of the value shown on the capacitor. If the value is not within these limits, replace the capacitor.

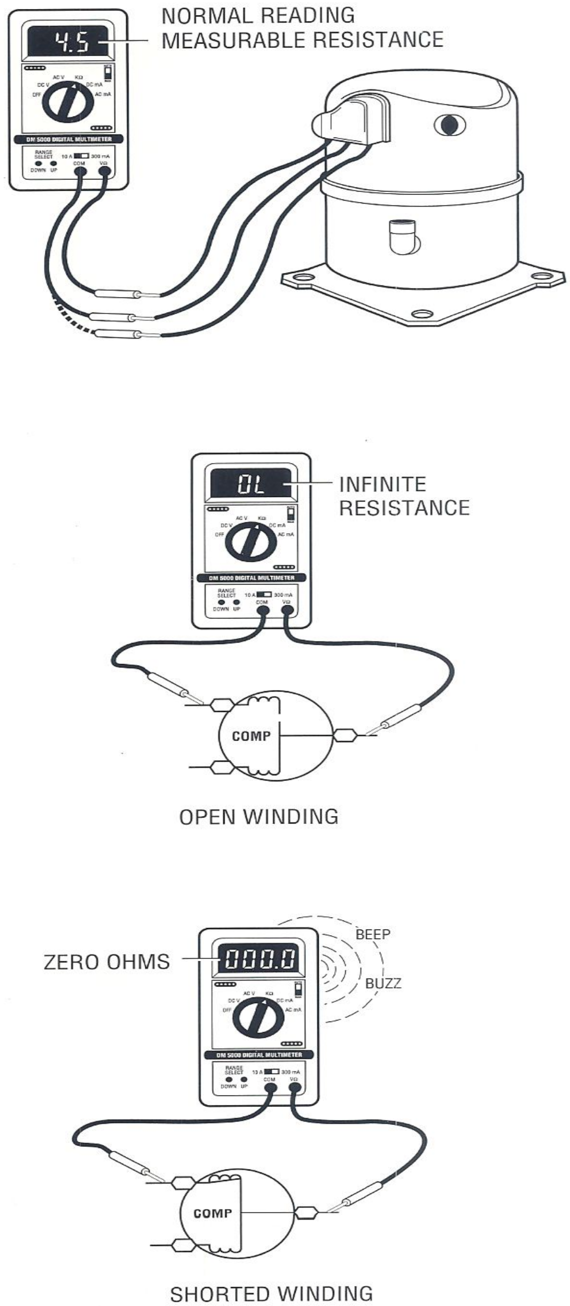
Figure SP-9-14.
Start and Run Capacitor Measurements



SP-9. COMPRESSOR MOTOR OPEN OR SHORTED WINDING MEASUREMENT PROCEDURE (STEPS 9 THROUGH 11)

Step	Expected Result/Action
NOTE: Steps 9 through 11 check single-phase/three-phase compressor motors for open or shorted motor windings. **WARNING ➧**  ***THE COMPRESSOR TERMINALS MUST NOT BE DISTURBED IF THE SYSTEM IS PRESSURIZED BECAUSE OF THE POSSIBILITY OF A DAMAGED TERMINAL BLOWING OUT AND CAUSING INJURY. DO NOT REMOVE OR CONNECT WIRING TERMINALS OR CONNECT MEASUREMENT INSTRUMENTS AT THE TERMINALS ON THE COMPRESSOR, UNLESS THE SYSTEM PRESSURE HAS BEEN REDUCED TO 0 PSIG.*** 9. Turn power off. Use the capacitor discharge tool (Figure SP-8-6) to discharge the start and run capacitors and any other capacitors that may be used in the unit. Locate the wiring connected to the compressor motor windings and start circuit. (Refer to the unit wiring diagram.)	The wiring related to the compressor motor and its starting circuit is identified. All high-voltage capacitors used in the equipment are discharged, including the run and start capacitors.
10. Isolate the compressor from the remainder of the circuit by disconnecting the compressor motor leads from all the related components, including the run and start capacitors and start relay.	Compressor motor leads are disconnected from other components to measure compressor motor resistance only.
11. Check the compressor motor for shorted or open windings as follows: Set up the VOM/DMM to measure resistance on the R x 1 ohm scale. If using a VOM, make sure that it is zeroed. Connect one lead of the VOM/DMM to one of the three motor leads as shown in Figure SP-9-15. Touch the other meter lead to the remaining motor leads, one lead at a time, and observe the meter indication.	VOM/DMM indicates a measurable resistance for both measurements. Check compressor motor for grounded winding per step 12. VOM/DMM indicates zero resistance for one or both measurements. This indicates a completely shorted winding. Replace the compressor. VOM/DMM indicates infinity for one or both measurements. This indicates that one or more motor windings are open. If checking a compressor with an internal motor protection device, make sure the compressor has had adequate time to cool off so that the protective device has reset. It may require an hour or more after the motor has been turned off before the internal protection device resets. Replace the compressor if the compressor is cool and the internal protection device has not reset.

Figure SP-9-15.
Compressor Motor Open or Shorted Winding Measurements



SP-9. COMPRESSOR MOTOR GROUNDED WINDING MEASUREMENT PROCEDURE (STEP 12)

Step

NOTE: Step 12 checks single-phase/three-phase compressor motors for grounded motor windings. This step assumes that the compressor motor has been checked for open or shorted windings as directed in steps 9 through 11.

As a result of performing steps 9 through 11, it is also assumed that power is still turned off, all the unit capacitors are discharged, and the wires connected to the compressor are disconnected to isolate the compressor from the remainder of the circuit.

WARNING ➧

THE COMPRESSOR TERMINALS MUST NOT BE DISTURBED IF THE SYSTEM IS PRESSURIZED BECAUSE OF THE POSSIBILITY OF A DAMAGED TERMINAL BLOWING OUT AND CAUSING INJURY. DO NOT REMOVE OR CONNECT WIRING TERMINALS OR CONNECT MEASUREMENT INSTRUMENTS AT THE TERMINALS ON THE COMPRESSOR, UNLESS THE SYSTEM PRESSURE HAS BEEN REDUCED TO 0 PSIG.

12. Check the compressor motor for grounded windings as follows:

Set up the VOM/DMM to measure resistance on the R x 10,000 ohm scale. Connect one lead of the VOM/DMM to a good ground connection, such as the compressor body or compressor discharge/suction line (Figure SP-9-16). Poor electrical contact because of a coat of paint, layer of dirt, or corrosion can cause an inaccurate measurement and hide a grounded winding. Touch the other meter lead to each of the motor leads, one lead at a time, and observe the meter indication.

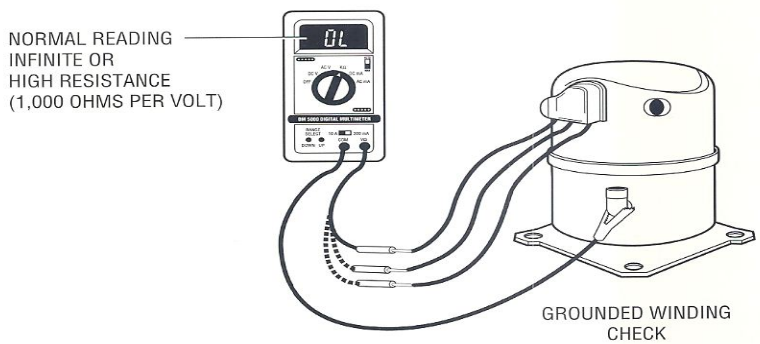
Expected Result/Action

VOM/DMM indicates infinity or high resistance. If a resistance reading is indicated, it should not be less than 1,000 ohms per volt. For example, on a 230-volt motor, the resistance should not be less than 230,000 ohms (230 volts x 1,000 ohms/volt = 230,000). A high resistance indicates that the motor windings are not grounded. Proceed to step 13 (single-phase PSC/CSR compressor) or step 14 (three-phase compressor) to check motor windings for partially shorted windings.

VOM/DMM indicates low or zero resistance, or a measurable resistance that is less than 1,000 ohms per volt. This may indicate that the motor windings are grounded. Before replacing the compressor, refer to the caution below.

NOTE: Steps 9 through 11 checked the compressor motor for open or completely shorted windings. Steps 13 and 14 check the resistance of the motor windings. These checks can find winding-to-winding shorts or partially shorted windings.

▼ Figure SP-9-16.
Compressor Motor Grounded Winding Measurements



CAUTION: ERRONEOUS READING TO GROUND CAN BE MEASURED IF LIQUID REFRIGERANT IS PRESENT IN THE COMPRESSOR SHELL. RECOVER THE REFRIGERANT FROM THE SYSTEM, THEN RETEST THE COMPRESSOR MOTOR FOR GROUNDED WINDINGS. IF VOM/DMM STILL INDICATES LOW OR ZERO RESISTANCE, OR A MEASURABLE RESISTANCE THAT IS LESS THAN 1,000 OHMS PER VOLT, REPLACE THE COMPRESSOR.

SP-9. SINGLE-PHASE COMPRESSOR MOTOR WINDING-TO-WINDING RESISTANCE MEASUREMENT PROCEDURE (STEP 13)

Step	Expected Result/Action
NOTE: Step 13 checks single-phase compressor motors for winding-to-winding shorts or partially shorted windings. This step assumes that the compressor motor has been checked for grounded, open, or shorted windings as directed in steps 9 through 12. As a result of performing steps 9 through 12, it is also assumed that power is still turned off, all the unit capacitors are discharged, and the wires connected to the compressor are disconnected to isolate the compressor from the remainder of the circuit. **WARNING ▶**  ***THE COMPRESSOR TERMINALS MUST NOT BE DISTURBED IF THE SYSTEM IS PRESSURIZED BECAUSE OF THE POSSIBILITY OF A DAMAGED TERMINAL BLOWING OUT AND CAUSING INJURY. DO NOT REMOVE OR CONNECT WIRING TERMINALS OR CONNECT MEASUREMENT INSTRUMENTS AT THE TERMINALS ON THE COMPRESSOR, UNLESS THE SYSTEM PRESSURE HAS BEEN REDUCED TO 0 PSIG.*** 13. Check a single-phase compressor motor for winding-to-winding shorts (partially shorted) windings as follows: Because of the extremely low resistance values being measured, an accurate VOM/DMM must be used to perform this step, otherwise a good compressor may be judged as bad. Set up the VOM/DMM to measure resistance on the R x 1 ohm scale. Make sure that the meter is zeroed. Connect the VOM/DMM across the leads connected to compressor terminals C and S, then measure and record the resistance of the start winding as shown in Figure SP-9-17. Connect the VOM/DMM across the leads connected to compressor terminals C and R, then measure and record the resistance of the run winding.	VOM/DMM indicates a measurable low resistance for both measurements. As a rule of thumb, the motor windings are usually judged to be good if the resistance measured across the start winding (C to S) is 3 to 6 times greater than the resistance measured across the run winding (C to R). **Example 1** *Assume that the resistance measured for the start winding is 3.0 ohms and the run winding is 0.5 ohm. In this example, the motor windings would be judged to be good because the start winding is 6 times the resistance of the run winding (3.0 ÷ 0.5 = 6).* **Example 2** *Assume that the resistance measured for the start winding is 1.25 ohms and the run winding is 0.5 ohm. In this example, the motor windings would be judged to be partially shorted because the start winding is only 2.5 times the resistance of the run winding (1.25 ÷ 0.5 = 2.5). (Start winding resistance in this example is less than 3 times greater than the run winding resistance.)* **Example 3** *Assume that the resistance measured for the start winding is 4.0 ohms and the run winding is about 0.33 ohm. In this example, the motor windings would be judged to be partially shorted because the start winding is about 12 times the resistance of the run winding (4.0 ÷ 0.33 = 12). (Start winding resistance in this example is more than 6 times greater than the run winding resistance.)*

▼ Figure SP-9-17.
Single-Phase Compressor Motor Winding-to-Winding Resistance Measurements

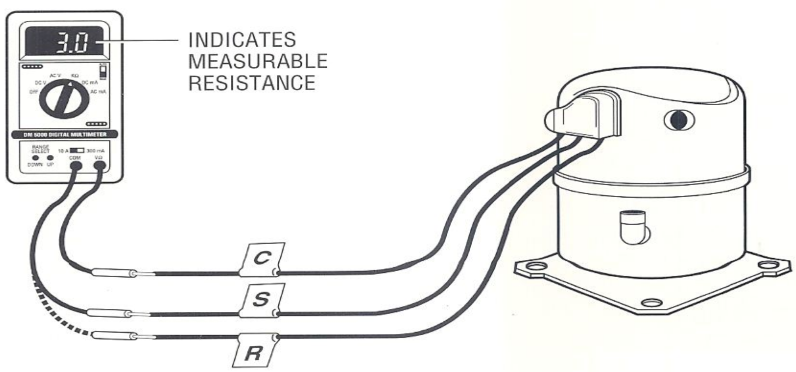
RULE OF THUMB:
RESISTANCE OF START WINDING (C TO S) EQUALS THREE TO SIX TIMES THE RESISTANCE OF RUN WINDING (C TO R).

EXAMPLE:

C —— 3.0Ω —— S

C —— 0.5Ω —— R

$\frac{3.0}{0.5} = 6$ = GOOD COMPRESSOR



SP-9. THREE-PHASE COMPRESSOR MOTOR WINDING-TO-WINDING RESISTANCE MEASUREMENT PROCEDURE (STEP 14)

Step

NOTE: Step 14 checks three-phase compressor motors for winding-to-winding shorts or partially shorted windings. This step assumes that the compressor motor has been checked for grounded, open, or shorted windings as directed in steps 9 through 12.

As a result of performing steps 9 through 12, it is also assumed that power is still turned off, all the unit capacitors are discharged, and the wires connected to the compressor are disconnected to isolate the compressor from the remainder of the circuit.

WARNING ➧

THE COMPRESSOR TERMINALS MUST NOT BE DISTURBED IF THE SYSTEM IS PRESSURIZED BECAUSE OF THE POSSIBILITY OF A DAMAGED TERMINAL BLOWING OUT AND CAUSING INJURY. DO NOT REMOVE OR CONNECT WIRING TERMINALS OR CONNECT MEASUREMENT INSTRUMENTS AT THE TERMINALS ON THE COMPRESSOR, UNLESS THE SYSTEM PRESSURE HAS BEEN REDUCED TO 0 PSIG.

14. Check a three-phase compressor motor for winding-to-winding shorts or partially shorted windings as follows:

    Because of the extremely low resistance values being measured, an accurate VOM/DMM must be used to perform this step, otherwise a good compressor may be judged as bad. Connect the VOM/DMM across the leads connected to the compressor terminals T1 and T2, then measure and record the resistance as shown in Figure SP-9-18.

    Repeat the resistance measurements between the leads connected to compressor terminals T2 to T3 and T3 to T1.

Expected Result/Action

VOM/DMM indicates a measurable resistance across each winding. As a rule of thumb, the motor windings are usually judged to be good if the resistance measured across each winding is nearly identical to that of the other two windings.

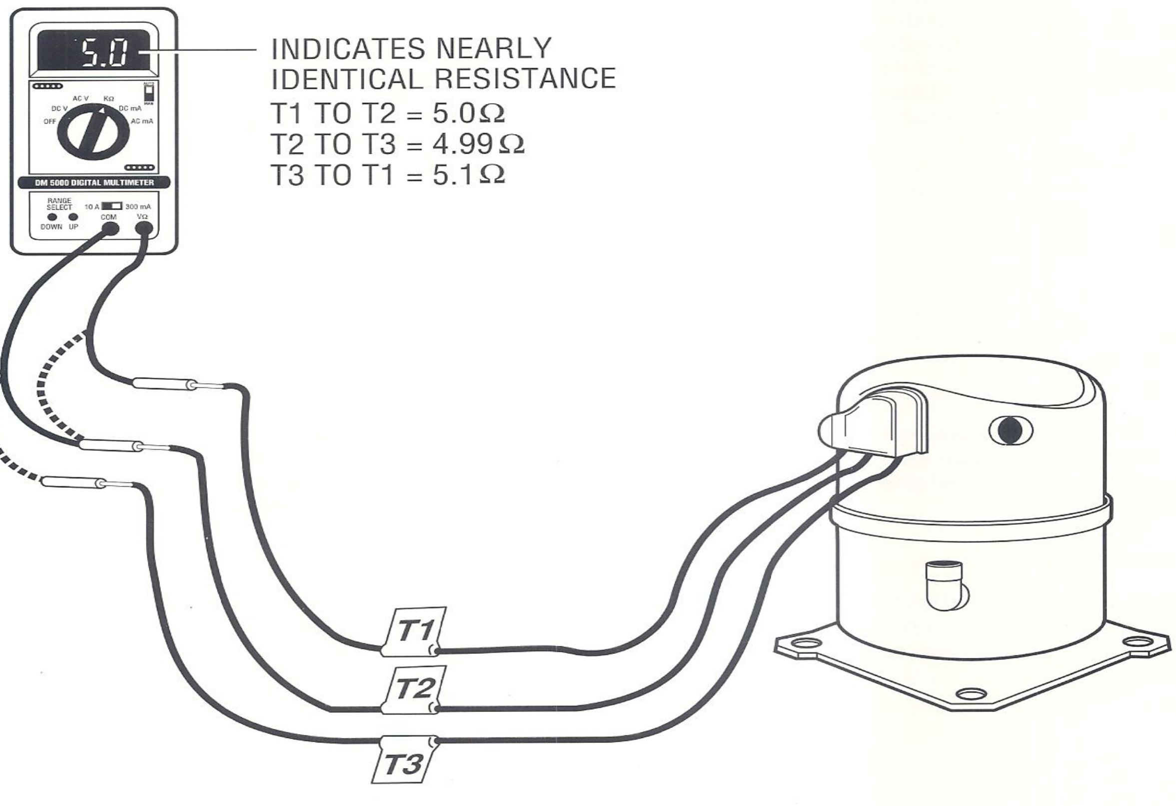
Example 1

Assume that the resistances measured across the three windings are 5 ohms, 4.99 ohms, and 5.1 ohms. In this example, the motor windings would be judged to be good because the three motor resistances are nearly identical.

Example 2

Assume that the resistance measured across the three windings are 5 ohms, 4.99 ohms, and 3.0 ohms. In this example, the motor windings would be judged to be partially shorted because one of the resistances (3.0 ohms) is significantly different than the other two.

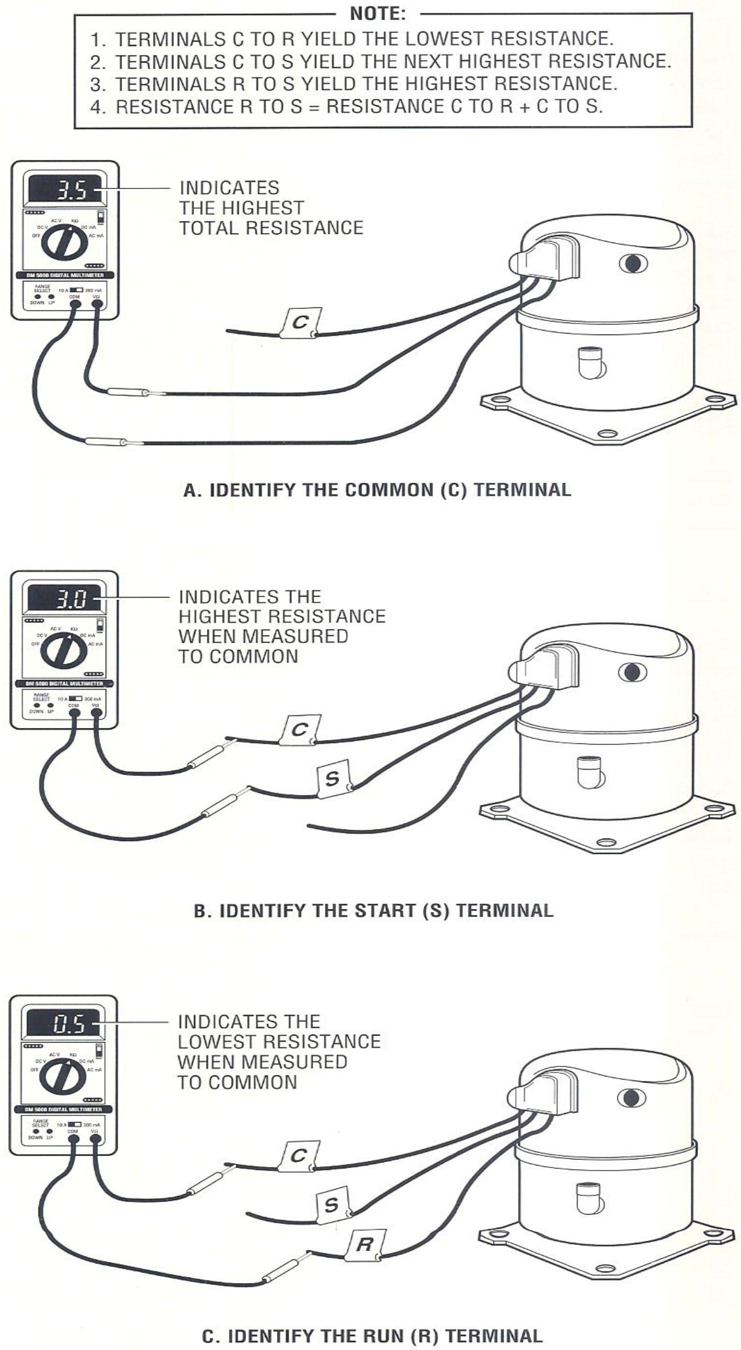
▼ Figure SP-9-18.
Three-Phase Compressor Motor Winding-to-Winding Resistance Measurements



SP-9. IDENTIFYING UNMARKED SINGLE-PHASE PSC AND CSR MOTOR TERMINALS MEASUREMENT PROCEDURE (STEPS 15 THROUGH 18)

Step	Expected Result/Action
NOTE: Steps 15 through 18 cover the procedure for identifying unmarked C (common), S (start), and R (run) terminals of single-phase PSC and CSR compressor motors. **WARNING ➨**  ***THE COMPRESSOR TERMINALS MUST NOT BE DISTURBED IF THE SYSTEM IS PRESSURIZED BECAUSE OF THE POSSIBILITY OF A DAMAGED TERMINAL BLOWING OUT AND CAUSING INJURY. DO NOT DISCONNECT OR CONNECT WIRING TERMINALS OR CONNECT MEASUREMENT INSTRUMENTS AT THE TERMINALS ON THE COMPRESSOR, UNLESS THE SYSTEM PRESSURE HAS BEEN REDUCED TO 0 PSIG.*** 15. Turn power off. Use the capacitor discharge tool (Figure SP-8-6) to discharge the start and run capacitors and any other capacitors in the unit. Locate the wiring connected to the compressor motor windings and start circuit. (Refer to the unit wiring diagram.)	The wiring related to the compressor motor and its starting circuit is identified. All high-voltage capacitors used in the equipment are discharged, including the run and start capacitors.
16. Isolate the compressor from the remainder of the circuit by disconnecting the compressor leads from all components, including the run and start capacitors and start relay.	Compressor leads disconnected from other unit wiring to measure compressor motor resistance only.
17. Set up the VOM/DMM to measure resistance on the R x 1 ohm scale. Make sure the meter is zeroed. Measure across the three motor leads to find the two motor terminals that give the highest resistance reading as shown in Figure SP-9-19, View A.	The two wires that produce the highest reading are the run and start windings. The VOM/DMM is reading the combined (series) resistance of the run and start winding. The remaining wire is connected to the motor C (common) terminal. Mark this wire as the C terminal. Proceed to step 18 to determine other terminals through the process of elimination.
18. Connect one lead of the VOM/DMM to the C terminal wire, identified in step 17. Touch the other meter lead to each of the remaining two compressor motor wires to find the highest resistance as shown in Figure SP-9-19, View B.	The highest resistance is the S (start) terminal of the compressor motor. The remaining terminal is the R (run) terminal.

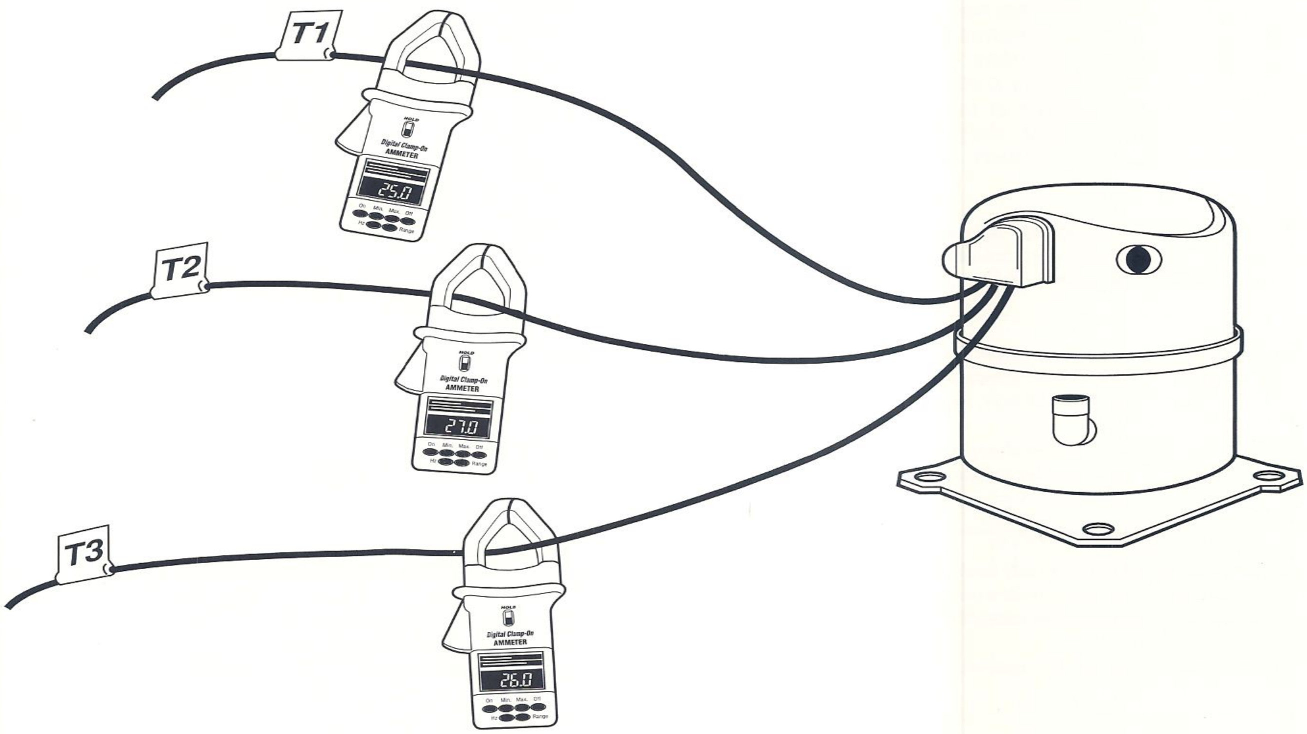
Figure SP-9-19.
Identifying Unmarked Single-Phase PSC and CSR Motor Terminals



SP-9. THREE-PHASE COMPRESSOR CURRENT IMBALANCE MEASUREMENT PROCEDURE (STEPS 19 AND 20)

Step	Expected Result/Action
NOTE: Steps 19 and 20 are used to determine if a current imbalance exists in a three-phase compressor motor. This measurement is usually performed if the compressor motor is shutting off on its overload. Before attempting this measurement, perform Service Procedure SP-7, steps 2 and 3, to make sure that the three-phase input voltage levels are good, and that any voltage imbalance between the legs is less than 2%. **WARNING**  ***THE COMPRESSOR TERMINALS MUST NOT BE DISTURBED IF THE SYSTEM IS PRESSURIZED BECAUSE OF THE POSSIBILITY OF A DAMAGED TERMINAL BLOWING OUT AND CAUSING INJURY. DO NOT DISCONNECT OR CONNECT WIRING TERMINALS OR CONNECT MEASUREMENT INSTRUMENTS AT THE TERMINALS ON THE COMPRESSOR, UNLESS THE SYSTEM PRESSURE HAS BEEN REDUCED TO 0 PSIG.*** 19. Turn power off. Use the capacitor discharge tool (Figure SP-8-6) to discharge any capacitors in the unit. Locate the wiring connected to the compressor motor windings. (Refer to the unit wiring diagram.)	The wiring related to the compressor motor is identified. All high-voltage capacitors used in the equipment are discharged.
20. Measure the three-phase current as follows: Check the compressor and/or motor nameplate for full load amps (FLA). Set up a clamp-on ammeter to measure AC current on the highest range scale (higher than motor FLA). Place the clamp-on ammeter around the wire connected to the T1 terminal of the compressor as shown in Figure SP-9-20. Turn power on, then measure and record the current drawn by the T1 leg. Repeat the current measurement for the remaining two phases. One at a time, measure the current flow through the wires connected to the T2 and T3 terminals of the compressor motor. Calculate percent of current imbalance for a three-phase system using the formula below. $\%\ \text{Imbalance} = \frac{\text{Maximum Current Deviation}}{\text{Average Current}} \times 100$	Current measured and recorded for the three legs. The percent current imbalance should be within 10%. (See the example calculation below.) If current imbalance exceeds 10%, look for an electrical terminal, contact, etc., that is loose or corroded and is causing a high resistance in the leg. **Example of % current imbalance calculation** *Current measured T1* — *25 amps* *Current measured T2* — *27 amps* *Current measured T3* — *26 amps* *Average current* — *78 amps ÷ 3 = 26 amps* *Difference between the average current and the measured current:* *T1 = 26 amps - 25 amps = 1 amp* *T2 = 27 amps - 26 amps = 1 amp* *T3 = 26 amps - 26 amps = 0 amp* $\%\ \text{Imbalance} = \frac{\text{Maximum Current Deviation}}{\text{Average Current}} \times 100$ $\%\ \text{Imbalance} = \frac{1}{26} \times 100 = 3.8\%$ *Since the imbalance is less than 10%, the current balance between phases is acceptable.*

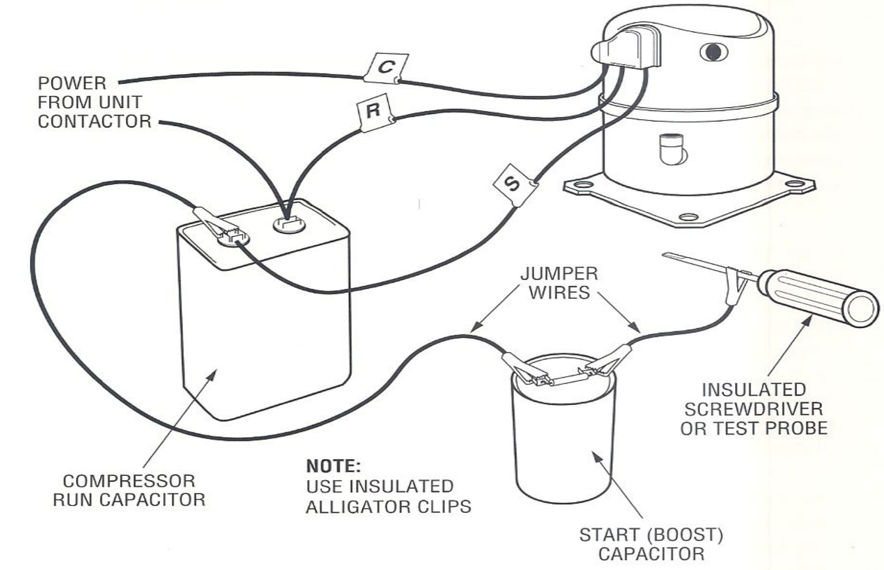
▼ Figure SP-9-20.
Three-Phase Compressor Current Imbalance Measurements



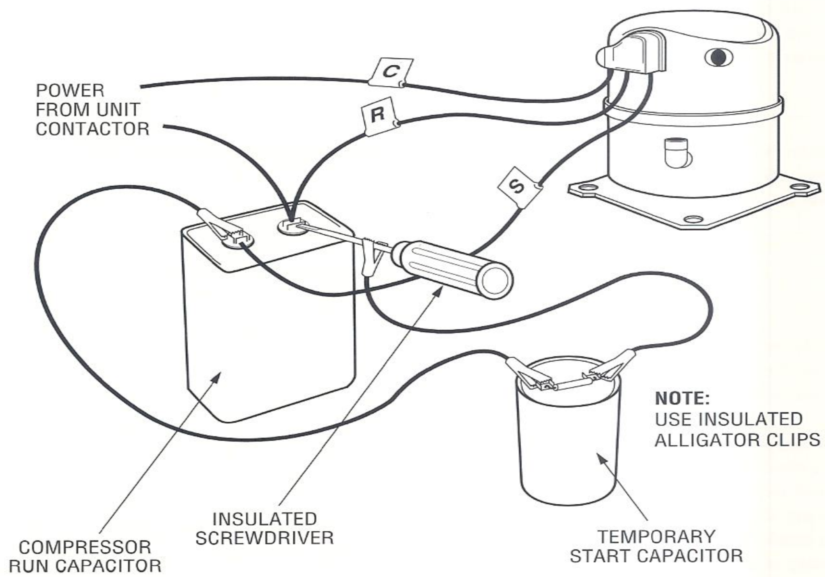
SP-9. RESTARTING A "STUCK" PSC COMPRESSOR PROCEDURE (STEPS 21 THROUGH 24)

Step	Expected Result/Action
NOTE: Steps 21 through 24 are used to restart a "stuck" PSC compressor. These steps assume that the compressor motor has been checked for grounded, open, or shorted windings as directed in steps 9 through 13. They also assume that the run capacitor is good (steps 4 through 8), and that no abnormal input voltage and/or improper pressure equalization conditions exist. Also, all wires and components should be connected for normal operation. **WARNING**  ***THE COMPRESSOR TERMINALS MUST NOT BE DISTURBED IF THE SYSTEM IS PRESSURIZED BECAUSE OF THE POSSIBILITY OF A DAMAGED TERMINAL BLOWING OUT AND CAUSING INJURY. DO NOT DISCONNECT OR CONNECT WIRING TERMINALS OR CONNECT MEASUREMENT INSTRUMENTS AT THE TERMINALS ON THE COMPRESSOR, UNLESS THE SYSTEM PRESSURE HAS BEEN REDUCED TO 0 PSIG.*** 21. Turn power off. Use the capacitor discharge tool (Figure SP-8-6) to discharge the run capacitor and any other capacitors in the unit. Locate the wiring connected to the run capacitor. (Refer to the unit wiring diagram.)	Compressor leads connected to the run capacitor terminal are identified.
22. Connect the temporary start capacitor, two jumper wires with insulated alligator clips, and an insulated screwdriver to one terminal of the run capacitor as shown in Figure SP-9-21, View A. **NOTE:** Always wear safety glasses when performing this procedure. For added protection against a possible rupture, shield the start capacitor in an enclosure.	Temporary start capacitor and other test equipment connected in preparation for starting the compressor.
23. Turn power on and simultaneously touch the screwdriver or probe to the other terminal of the run capacitor as shown in Figure SP-9-21, View B. Pull the screwdriver away from the terminal after a maximum of 3 seconds. Discharge the temporary start capacitor.	Compressor starts as a result of the capacitance boost. Run the compressor for about 10 minutes, then turn off power to the compressor. Let the compressor sit idle for about 5 minutes to allow time for the system pressures to equalize, then proceed to step 24.
24. Try restarting the compressor without the temporary start (boost) capacitor.	If the compressor will not start without a temporary boost, install a permanent start capacitor and start relay supplied in a manufacturer's recommended start kit.

▼ Figure SP-9-21.
Restarting a "Stuck" PSC Compressor



A. CAPACITOR BOOST EQUIPMENT SETUP

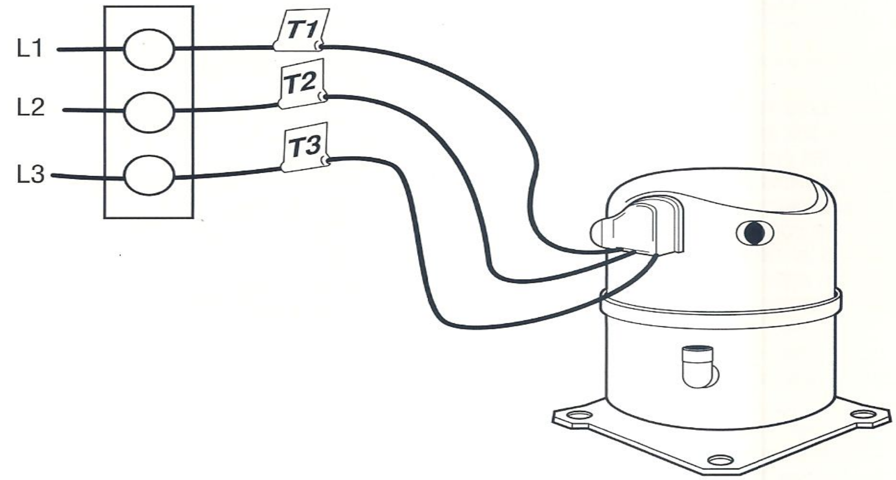


B. START CAPACITOR CONNECTED ACROSS RUN CAPACITOR FOR 3 SECONDS MAXIMUM

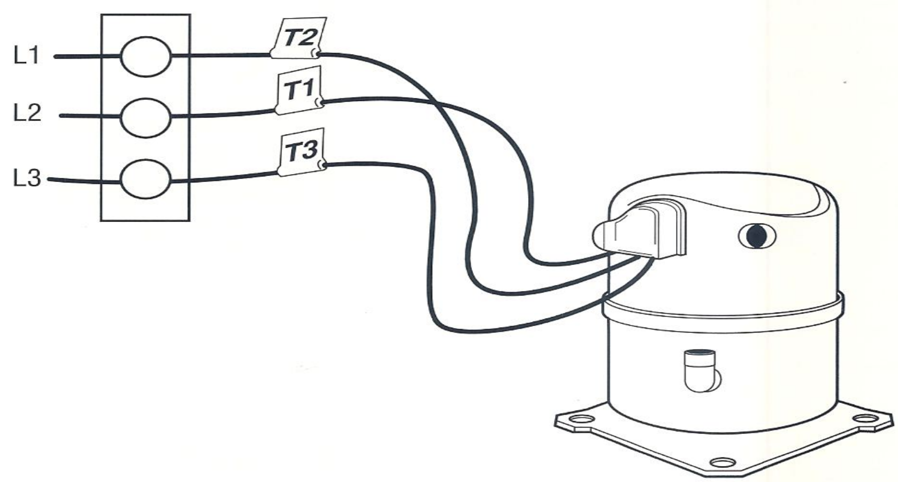
SP-9. RESTARTING A "STUCK" THREE-PHASE COMPRESSOR PROCEDURE (STEPS 25 THROUGH 28)

Step	Expected Result/Action
NOTE: Steps 25 through 28 are used to restart a "stuck" three-phase compressor. These steps assume that the compressor motor has been checked for grounded, open, or shorted windings as directed in steps 9 through 12 and 14. They also assume that no abnormal input voltage and/or improper pressure equalization conditions exist. Also, all wires and components should be connected for normal operation. **WARNING ➡** ***THE COMPRESSOR TERMINALS MUST NOT BE DISTURBED IF THE SYSTEM IS PRESSURIZED BECAUSE OF THE POSSIBILITY OF A DAMAGED TERMINAL BLOWING OUT AND CAUSING INJURY. DO NOT DISCONNECT OR CONNECT WIRING TERMINALS OR CONNECT MEASUREMENT INSTRUMENTS AT THE TERMINALS ON THE COMPRESSOR, UNLESS THE SYSTEM PRESSURE HAS BEEN REDUCED TO 0 PSIG.*** **CAUTION ➡** ***If working with a three-phase scroll compressor, consult the manufacturer's service instructions before performing this procedure. Reversing the direction of rotation of a scroll compressor will cause noisy operation, abnormal pressures, and damage to the compressor.*** 25. Turn power off. Use the capacitor discharge tool (Figure SP-8-6) to discharge any capacitors in the unit. Locate and tag the wires connected to the compressor motor terminals as shown in Figure SP-9-22, View A. (Refer to the unit wiring diagram.)	Leads connected to the compressor terminals are identified.
26. Disconnect the wiring connected to any two of the compressor terminals. Reconnect these two wires as shown in Figure SP-9-22, View B, so that two legs of the three-phase input power are reversed.	Wiring (leads) connected to any two compressor terminals are reversed.
27. Turn on the unit power.	Compressor starts as a result of the phase reversal. Proceed to step 28.
28. Turn power off. Use the capacitor discharge tool (Figure SP-8-6) to discharge any capacitors in the unit. Reconnect the two wires interchanged in step 26 to their original connection points (refer to the unit wiring diagram). **CAUTION ➡** ***After the motor has been restarted, always turn off the power, then reconnect the compressor leads as shown on the unit wiring diagram. Failure to wire the compressor per the wiring diagram will result in the compressor crankshaft rotating in the opposite direction. This may cause improper compressor operation and may result in damage to the compressor.***	Compressor is wired according to the unit wiring diagram.

Figure SP-9-22.
Restarting a "Stuck" Three-Phase Compressor



A. NORMAL THREE-PHASE COMPRESSOR CONNECTIONS

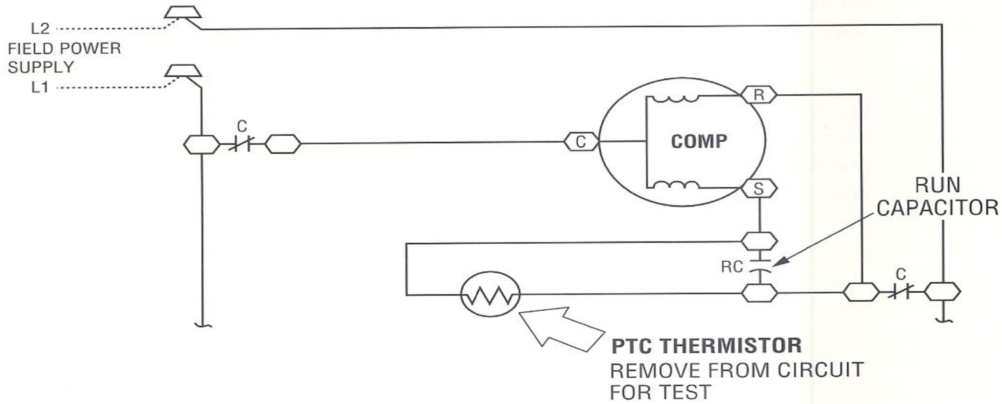


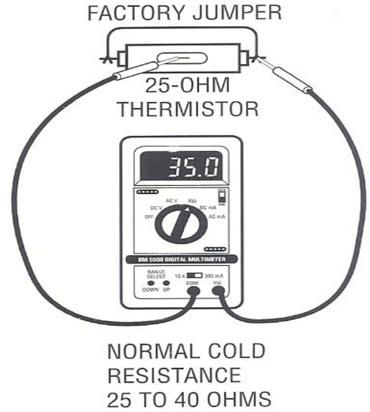
B. TWO COMPRESSOR LEADS TEMPORARILY REVERSED TO RESTART "STUCK" THREE-PHASE COMPRESSOR

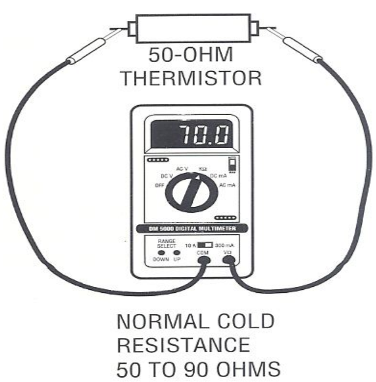
SP-9. PTC START THERMISTOR MEASUREMENT PROCEDURE (STEPS 29 THROUGH 32)

Step	Expected Result/Action
NOTE: Steps 29 through 32 are used to test a compressor PTC start thermistor. **WARNING ➧**  ***THE COMPRESSOR TERMINALS MUST NOT BE DISTURBED IF THE SYSTEM IS PRESSURIZED BECAUSE OF THE POSSIBILITY OF A DAMAGED TERMINAL BLOWING OUT AND CAUSING INJURY. DO NOT DISCONNECT OR CONNECT WIRING TERMINALS OR CONNECT MEASUREMENT INSTRUMENTS AT THE TERMINALS ON THE COMPRESSOR, UNLESS THE SYSTEM PRESSURE HAS BEEN REDUCED TO 0 PSIG.*** 29. Turn power off. Use the capacitor discharge tool (Figure SP-8-6) to discharge the run capacitor and any other capacitors in the unit.	Power is turned off and the unit capacitors are discharged.
30. Locate the wiring between the compressor start thermistor and the run capacitor, then disconnect and remove the start thermistor from the circuit. (Refer to the unit wiring diagram.)	The start thermistor is disconnected and removed from the unit in preparation for the resistance measurement.
31. Set up the VOM/DMM to measure resistance on the R x 100 ohm scale. **NOTE:** Before attempting to measure the resistance, wait at least 10 minutes to allow the PTC thermistor to cool to ambient temperature. If measuring a 25-ohm PTC thermistor, a factory-supplied jumper is across the two end terminals. Connect the VOM/DMM across the center tab and end tab as shown in Figure SP-9-23. Measure the resistance. If measuring a 50-ohm PTC thermistor, connect the VOM/DMM across the end tabs as shown in Figure SP-9-23. Measure the resistance.	The cold (ambient temperature) resistance of a good PTC thermistor should be about 100% to 180% of the stated resistance (25 ohms or 50 ohms). For example: A 25-ohm thermistor should measure between 25 and 45 ohms A 50-ohm thermistor should measure between 50 and 90 ohms If the resistance of the PTC thermistor is more than 180% higher than its rating, replace the thermistor. If the thermistor resistance is within the acceptable range and the compressor does not start, leave the thermistor disconnected from the circuit. Start the compressor by giving it a temporary capacitance boost as directed in steps 21 through 23. Run the compressor for about 10 minutes, then turn off the power to the compressor. Let the compressor sit idle for about 5 minutes to allow time for the system pressures to equalize. Use the capacitor discharge tool (Figure SP-8-6) to discharge the run and temporary start capacitors. Make sure the temporary start capacitor is disconnected from circuit and reconnect the start thermistor in the circuit. Proceed to step 32.
32. Turn on power to start the compressor.	Compressor starts. If the compressor does not start after two attempts, turn off the power to the unit. Use the capacitor discharge tool (Figure SP-8-6) to discharge the run and any other capacitors in the unit. Remove the start thermistor. Install a permanent start capacitor and start relay supplied in a manufacturer's recommended start kit.

Figure SP-9-23.
PTC Start Thermistor Measurement



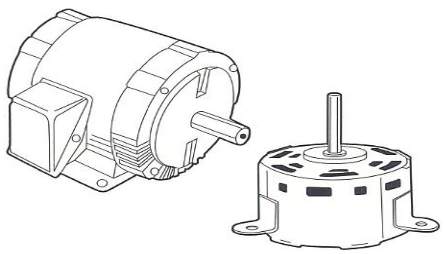




MOTOR CHECKS AND ELECTRICAL MEASUREMENTS (EXCLUDING COMPRESSOR MOTORS)

Purpose – Motors (Figure SP-10-1) are one of the primary electrical loads used in HVAC systems. Motor checks and measurements are made mainly when troubleshooting the unit. Since motors are expensive and their replacement can be time consuming, you want to be absolutely sure that a motor is bad before replacing it. Testing of a motor is also needed in order to isolate the fault to the motor or to a related component, such as a run capacitor. The information and procedures given in this section apply to motors used in most HVAC applications, except for compressor motors. Compressor motors are covered in detail in Service Procedure SP-9.

▼ Figure SP-10-1.
Typical HVAC Motors



System-Related Motor Problems

Motors can fail or appear to be faulty as a result of system-related mechanical and/or electrical problems. Many motors are replaced unnecessarily because they are incorrectly judged to have failed. Before condemning the motor, be sure that none of the system-related mechanical or electrical conditions listed below are causing the problem.

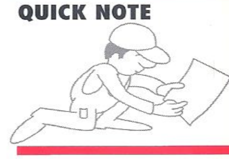
Electrical:

- Check for low supply voltage.
- Check for a motor contactor not making good contact on all poles.
- Check for an open or weak run capacitor.

Mechanical:

- Check for tight bearings due to lack of lubrication. If applicable, lubricate the bearings per the manufacturer's instructions. Note that motors with "lifetime" lubricated bronze bearings typically have a life of 5 to 7 years. After this, the bearings tend to become tight because they run out of oil.
- Check for tight belt tension or misaligned drive pulleys.
- Check for correct fan blade location, or for bent shroud or housing.

QUICK NOTE



Worn or seized bearings are the major cause of failures in fractional horsepower, direct-drive motors.

Motor Electrical Problems

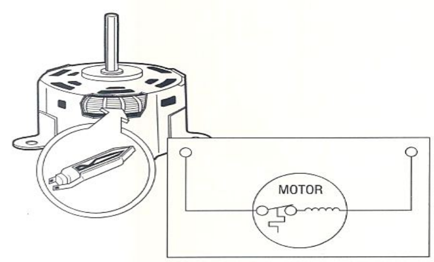
The most common causes of electrical failures in motors include:

- Grounded, open, or shorted windings
- Open internal overloads

Grounded, Open, or Shorted Windings – Motors are rugged and reliable, but can fail in several ways. The motor may fail when the wires in one or more of the motor windings break, thereby opening the motor circuit. It may fail grounded, where the wires touch the motor stator or housing. It can also fail due to an internal short circuit where one or more windings short together. Any one of these problems justifies the replacement of a motor. The electrical tests used to determine if a motor is open, shorted, or grounded are given in the detailed procedure at the end of this section.

Open Internal Overloads – Most motors have some type of internal overload. Single-phase motors usually have internal overloads (Figure SP-10-2) that sense both motor current and winding temperature. If the overload opens, it breaks the current path and shuts down the motor.

▼ Figure SP-10-2.
Internal Overload



Should an overload fail in the open position, motor replacement is required. *Before replacing a motor because of an open winding or internal overload, always make sure that the motor has cooled down enough to allow any internal overload device to reset. It may require more than an hour for the overload to reset.* Generally, the motor must be below 115° F before checking the continuity of the motor windings through an internal overload device.

One way to ensure that sufficient cool-down time has elapsed is to advise the customer to turn the thermostat switch to OFF immediately. The time between the customer's call and the service visit is usually long enough for the motor to cool down.

Electrical Motor Types

Both single-phase and three-phase motors are used in residential and light commercial systems. However, because of their good running characteristics and high efficiency, single-phase motors are used almost exclusively as indoor and outdoor fan motors and as blower motors. Single-speed and multi-speed permanent split capacitor (PSC) motors are typically used in these applications. Use of electronically-commutated motors (ECMs) is also on the increase in fan and blower motor applications. Because of their simplicity and efficiency, shaded-pole motors are also used in some low-torque applications, such as small direct-drive fan and blower motors.

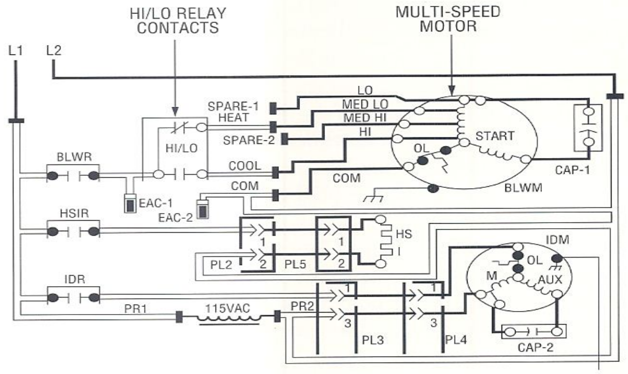
Single and Multi-Speed PSC Single-Phase Motors – The operation of basic PSC motors is described in Service Procedure SP-9. As previously described, PSC motors have at least three external terminals leading to two internal windings. The main or run winding (R) contains relatively few turns of heavy wire. The start winding (S) contains a greater number of turns of lighter wire. The point where the two windings meet internally is called common (C).

Multi-speed PSC motors capable of operating at two speeds (high and low) or three speeds (high, low, and medium) are commonly used to drive the fans and/or blowers in HVAC equipment. The motor's speed can be changed by switching the motor leads or terminal taps, or by using speed control switches or relays. In many heating/cooling units, the motor speed is selected automatically by the control circuits, as determined by the mode of operation. Normally, slower fan speeds are used with heating modes of operation and higher speeds for cooling operation.

There are many types of multi-speed motors. Figure SP-10-3 shows a schematic of a typical multi-speed blower motor (BLWM) used to run at high speed for cooling and at low speed for heating. As shown, the speed is changed by connecting the line voltage either to the low speed tap (LO), medium-low speed tap (MED LO), medium high-speed tap (MED HI) and/or high speed tap (HI) of the motor. The specific taps used are selected when installing the unit. For the example shown in Figure SP-10-3, the MED LO tap is used for heating operation and the HI tap is used for cooling operation. The HI/LO relay prevents both windings from being energized at the same time, a condition that would destroy the motor.

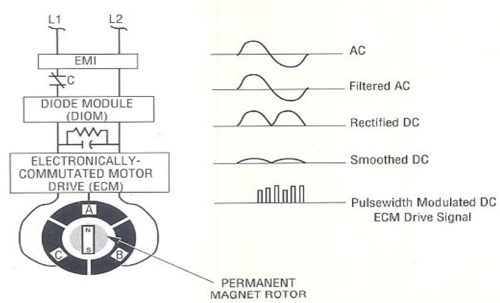
Multi-speed motors use tapped windings, series-connected winding sections, or other wiring configurations that enable operation at different speeds. They can fail so that the motor will not run in one or more speeds, but runs at other speeds. When troubleshooting multi-speed motors, it is important to eliminate the speed selection circuits external to the motor as the cause of a problem, before condemning the motor.

Figure SP-10-3.
Multi-Speed Motor Circuit



Electronically-Commutated Motors – Electronically-commutated motors (ECMs) are variable-speed, high-efficiency motors. These motors can vary their speed based on predetermined control instructions programmed into a built-in microprocessor. Typically, they are programmed to provide the speed needed to provide a constant airflow based on system requirements. The use of ECMs in HVAC equipment is rapidly increasing. They are typically used in the same applications where conventional shaded-pole and PSC motors are used, such as fan motors and draft inducer motors in high-efficiency furnaces. In the same application, ECMs tend to operate with a 60% to 75% energy savings over conventional motors. A brief description of ECM motor operation is given here.

Figure SP-10-4.
Electronically-Commutated Motor (ECM)



A functional diagram for an ECM is shown in Figure SP-10-4. As shown, single-phase AC power is used to power the ECM circuit. The AC power is first filtered in the electromagnetic interference (EMI) module. It is then rectified into pulsating DC by the diode module. After rectification, the power is smoothed by the capacitor placed across the line and fed to the motor drive. The smoothed DC voltage is fed sequentially to the three stator windings of the motor. The rotor is permanently magnetized.

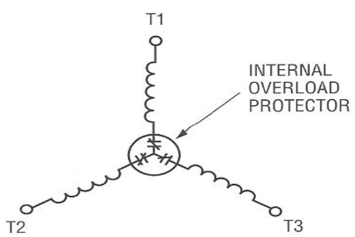
When the ECM drive signal is applied to the A-B windings, magnetic attraction causes the rotor to advance clockwise. The signal is then sequenced to the B-C windings, causing the rotor to advance further. Energizing the C-A windings completes one revolution. The frequency of the drive signal determines motor speed, while the current level determines the motor torque.

When troubleshooting ECMs, it is important to confirm that the input signals and voltages supplied to the motor are correct before condemning the motor.

When troubleshooting ECMs, you must treat the motor as a "black box" like you would when troubleshooting a circuit with an electronic control. As a first step, always check the equipment for any fault codes that may be indicated by the built-in diagnostic function (if equipped) and consult the troubleshooting guide. If the correct input voltages or signals are available and the motor does not run, the motor is probably defective. If the input voltages are present but are the wrong value, there is a good chance the problem is not in the motor but somewhere else. Unlike conventional motors, resistance checks cannot be used to check the motor windings of an ECM. Resistance readings taken across the leads of an ECM would make no sense. This is because of the built-in electronic components that are an integral part of the ECM.

Three-Phase Motors – Three-phase motors are generally used when the motor requirements are greater than 7 HP or higher starting torque is required. All three-phase motors have at least three internal windings of equal resistance and the same number of wire turns. Three-phase motors have good starting and running characteristics and higher running efficiency. Unlike single-phase motors, three-phase motors (Figure SP-10-5) require no external starting relays or capacitors. Multi-speed three-phase motors are seldom used in residential or light commercial equipment.

▼ Figure SP-10-5.
Three-Phase Motor



Electrical Considerations

Always be sure that the electric power source matches the motor power requirements. Check operating voltage, frequency, and phase. External field wiring to a motor should be done in accordance with the latest edition of the National Electrical Code (NEC) and local code requirements.

Operating voltages applied to motors must be maintained within 10% of the voltage value given on the motor nameplate. If the operating voltage falls outside these limits, the system should be turned off until the problem is corrected. Voltage tolerances used for single and three-phase motors are:

- Single-Voltage Rated Motors – The input supply voltage should be within 10% of the motor's nameplate voltage. For example, a motor with a nameplate voltage rating of 230 volts should have an input voltage that ranges between 207 volts and 253 volts (±10% of 230 volts).
- Dual-Voltage Rated Motors – The input supply voltage should be within 10% of the motor's nameplate voltage. For example, a motor with a nameplate voltage rating of 208/230 volts should have an input voltage that ranges between 187 volts (–10% of 208 volts) and 253 volts (+10% of 230 volts).
- Three-Phase Motors – These motors should never be used where a voltage phase imbalance greater than 2% exists. Failure to meet this basic requirement will damage motor windings.

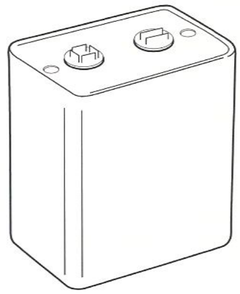
A voltage imbalance of more than 2% between legs of the supply voltage applied to a three-phase compressor motor must be corrected. A small imbalance in the input voltage results in a considerable amount of heat being generated in the motor windings. With only a 5% imbalance, the winding temperature can increase as much as 50% over the safe level. The procedure for measuring three-phase input voltage and the calculation of the voltage imbalance in a three-phase system is provided in Service Procedure SP-7.

Current imbalance between any two legs of a three-phase system should not exceed 10%. Voltage imbalance will always produce current imbalance, but a current imbalance may occur without a voltage imbalance. This can occur when an electrical terminal, contact, etc. becomes loose or corroded, causing a high resistance in the leg. Since current follows the path of least resistance, the current in the other two legs will increase, causing more heat to be generated in those two windings. The procedure for determining the current imbalance in a three-phase motor is the same as described for a three-phase compressor motor in Service Procedure SP-9.

Capacitor Checks and Replacement

Start and run circuits on single-phase motors use capacitors. Capacitors affect the wattage, amperage draw, torque, speed, efficiency, and power factor of a motor. Figure SP-10-6 shows a typical run capacitor used with a PSC motor.

▼ Figure SP-10-6.
Typical Run Capacitor



Run capacitors are connected in the PSC motor circuit at all times and are therefore referred to as *continuous-duty capacitors*. Older run capacitors are usually larger in physical size, but have lower capacitance ratings than start capacitors. Newer ones may be smaller in physical size and encased in hard plastic shells. Because run capacitors are in the circuit at all times, they are typically filled with a dielectric fluid that acts to dissipate heat. If a capacitor is found to be defective, it should always be replaced with one specified by the manufacturer.

A run capacitor may be bulged and/or leaking, giving a visual indication of its failure. Testing of capacitors to determine if they are good or bad is commonly done by making resistance checks using a VOM/DMM. This method is described in the detailed procedure given at the end of this section. A capacitor analyzer should be used when accuracy is required in checking the electrical condition of the capacitor, especially when it is necessary to measure the actual capacitance MFD value of a capacitor. Note that some DMMs also have a capability to measure the actual capacitance MFD value of capacitors.

Safety Precautions

When making electrical measurements and/or repairs on equipment, always observe the following precautions.

- Read and follow all safety instructions given in the manufacturer's installation instructions and/or service manual for the specific system being serviced.
- Always turn off the main power to a system before making any repairs. There may be more than one disconnect switch. If applicable, turn off the accessory power. Tag and lock out all disconnect switches.
- Always remove rings, watches, and other jewelry to lessen the chance of electrical shock.
- When making voltage, current, or continuity measurements on a hermetic or semi-hermetic compressor in a pressurized system, do not place the meter probes directly on the compressor terminals. If the compressor terminals are damaged and the system is pressurized, disturbing them to take measurements could cause them to blow out, causing injury. Once the charge has been removed and the system is no longer under pressure, measurements can be made at the compressor terminals.
- Do not override or bypass safety controls such as electrical interlocks, unless directed by the manufacturer's service literature.
- When troubleshooting a start relay circuit, remember that the back EMF generated by a motor can be much higher than the line voltage applied to the motor. For example, a motor powered by 230 volts can generate a back EMF voltage greater than 400 volts.
- Never replace a blown fuse without correcting the cause of the original failure. If thermally-operated circuit breakers or overloads are tripping, make sure the trip is not due to excessively high ambient temperatures or loose connections. Also, make sure that HACR-rated circuit breakers are being used.
- Do not allow fluid from a ruptured run capacitor to contact your skin or clothing. Older capacitors may contain PCBs (polychlorinated biphenyls). These capacitors must be treated as hazardous waste and be disposed of in accordance with applicable local or national codes.

PROCEDURE

Before performing the following troubleshooting procedure, refer to the manufacturer's installation instructions and/or service manual for specific instructions about the system being serviced. If differences exist between our procedure and the manufacturer's instructions, always follow the manufacturer's instructions. Review the safety instructions and precautions given in this procedure and in Section 2 of this manual.

The measurements given in this procedure are used to confirm the condition, good or bad, of a motor or related run circuit component. The procedures assume that the motor has been isolated as the probable cause of an electrical problem by troubleshooting using the hopscotch method described in Service Procedure SP-8. The measurements covered in this procedure are listed below. These measurements can be performed in sequence or independently.

- **Steps 1 through 5 — Run capacitor measurements.**
- **Steps 6 through 9 — Motor open, shorted, or grounded winding measurements.**

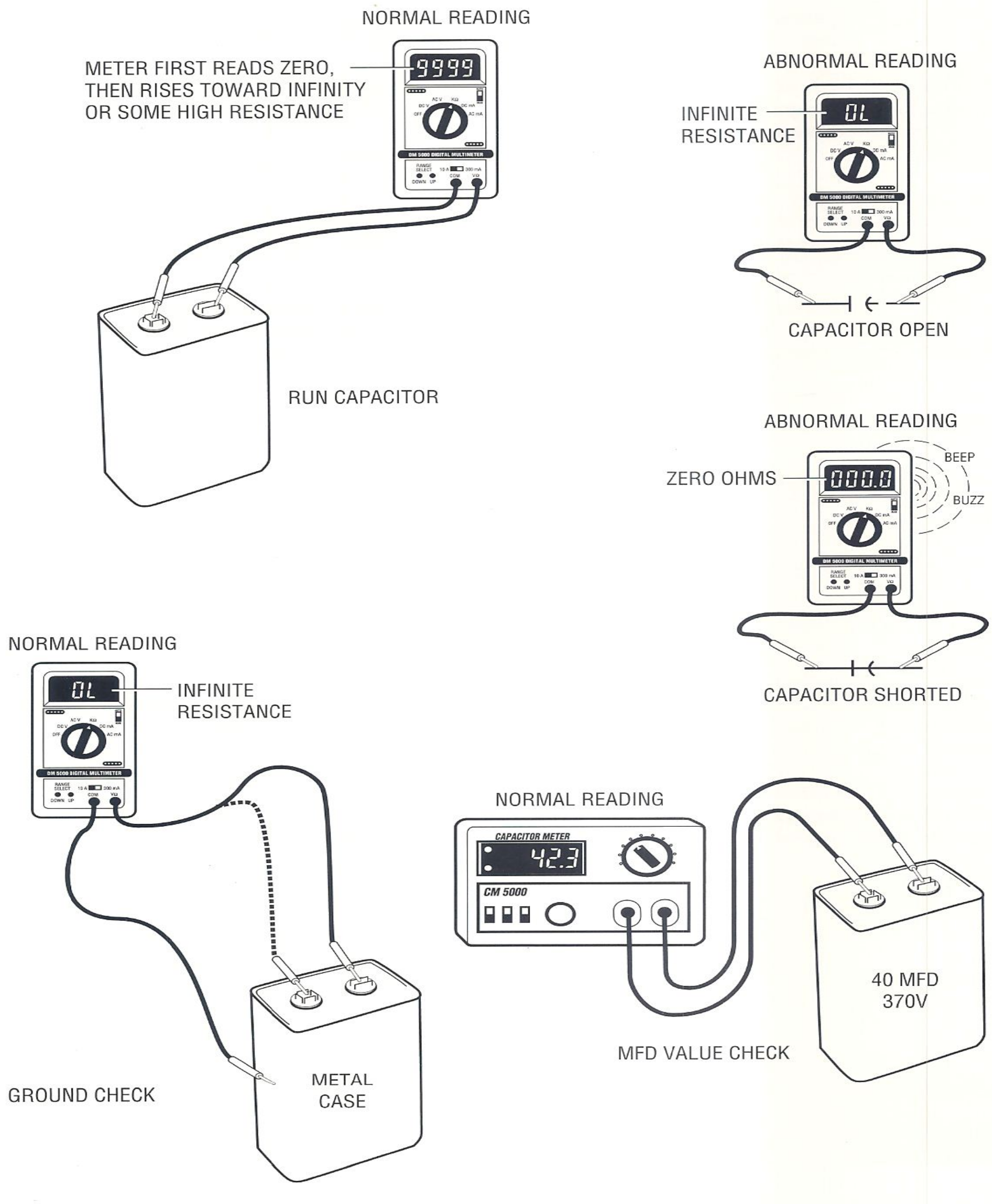
SP-10. INSTRUMENT OR DEVICE REQUIRED

Instrument or Device	REFERENCE
Volt-ohm-milliammeter (VOM/DMM) and test leads with alligator clips so the leads can be attached to the test points without the need for the technician to hold them in place	**Section 1, Item 11**
Capacitor tester – optional item used to determine the actual capacitance value of capacitors (If used, follow the tester manufacturer's instructions to test capacitors)	**Section 1, Item 12**
Capacitor discharge tool made from: two jumper wires with alligator clips; one 20,000-ohm, 2-watt resistor; and a screwdriver with an insulated handle	**Refer to Figure SP-8-6**

SP-10. RUN CAPACITOR MEASUREMENT PROCEDURE (STEPS 1 THROUGH 5)

Step	Expected Result/Action
NOTE: Steps 1 through 5 are used to test the run capacitor associated with motors. The same tests can also be used to check capacitors not used with motors. 1. Turn off all power to unit. Use the capacitor discharge tool (Figure SP-8-6) to discharge the run capacitor and any other high-voltage circuit capacitors that may be used in the unit.	All high-voltage capacitors used in the equipment are discharged, including the run capacitor(s).
2. Locate and disconnect the wires from the run capacitor to isolate it from the remainder of the circuit. (Refer to the unit wiring diagram.) Inspect the capacitor for any visible signs of damage, such as bulging or leaking.	The run capacitor is isolated from the remainder of the circuit and prepared for measurement. If the visual inspection reveals a bulged or leaking capacitor, it should be considered bad and must be replaced.
3. Set up the VOM/DMM to measure resistance on the R x 1,000 or R x 10,000 ohm scale. Connect the VOM/DMM across the capacitor terminals and measure the resistance as shown in Figure SP-10-7.	VOM/DMM reading first indicates zero or a low resistance, then slowly rises toward infinity or some high value of measurable resistance. This indicates that the capacitor is most likely good. If it is necessary to find out the capacitor's exact capacitance value, it must be tested further using a capacitor tester per step 5. VOM/DMM reading goes to zero or a low resistance and stays there. This indicates that the capacitor is shorted. Replace the capacitor. VOM/DMM reading indicates infinity. This indicates that the capacitor is open. Replace the capacitor.
4. If testing a run capacitor enclosed in a metal case, check for a grounded capacitor. Set up the VOM/DMM to measure resistance on the R x 1,000 or R x 10,000 ohm scale. Connect the VOM/DMM between each one of the capacitor terminals and the metal case and measure the resistance.	VOM/DMM reading indicates infinity. This indicates that the capacitor is not grounded to the case. VOM/DMM reading indicates a measurable resistance. This indicates that the capacitor is grounded to the case. Replace the capacitor.
5. To measure a capacitor's exact capacitance MFD value, test the capacitor using a capacitor tester. Follow the tester manufacturer's instructions to perform the test.	The measured value for a run capacitor should be ±10% of the value shown on the capacitor. If the value is not within these limits, replace the capacitor.

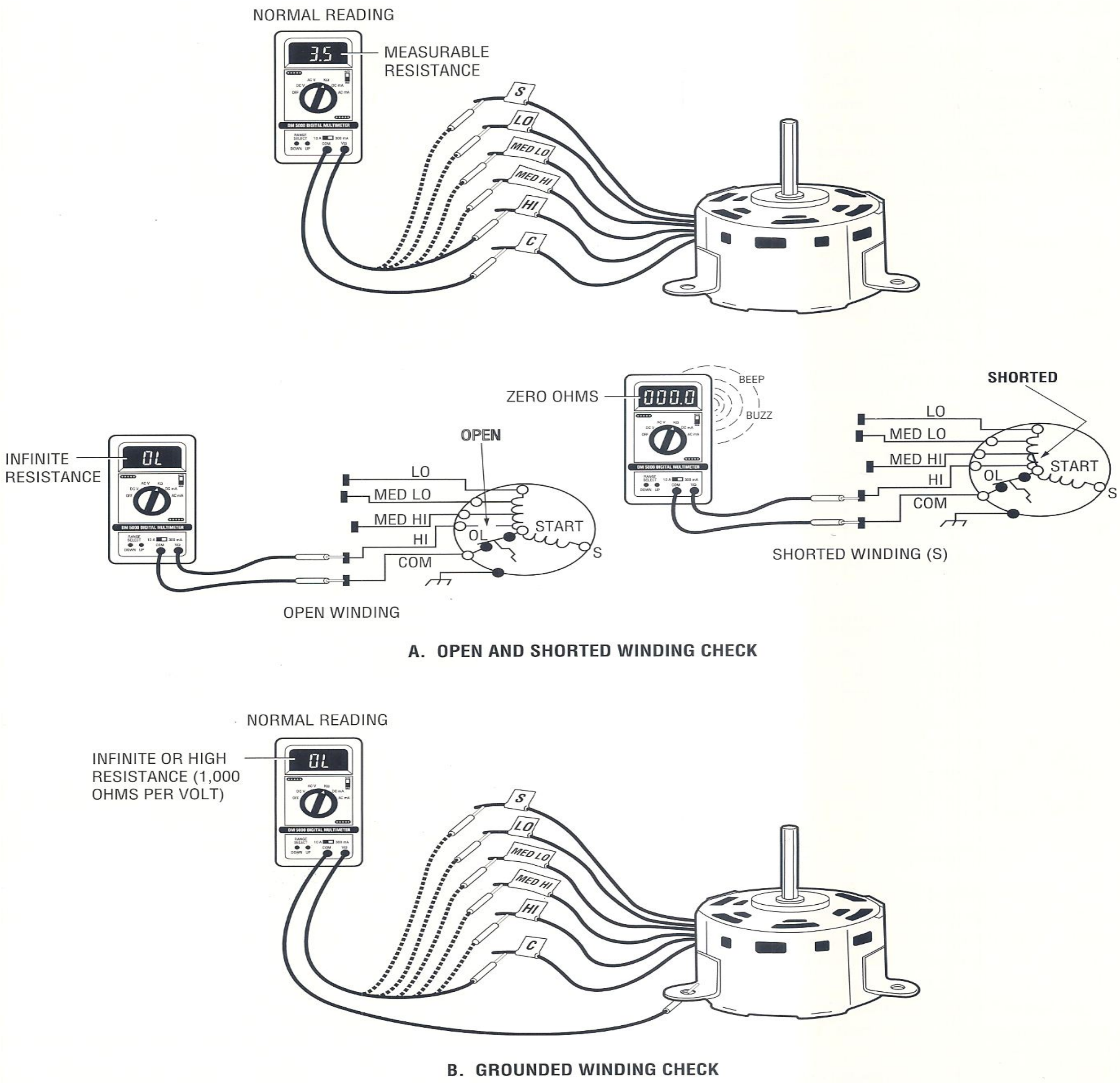
▼ Figure SP-10-7.
Run Capacitor Measurements



SP-10. MOTOR OPEN, SHORTED, OR GROUNDED CIRCUIT MEASUREMENT PROCEDURE (STEPS 6 THROUGH 9)

Step	Expected Result/Action
NOTE: Steps 6 through 9 check single-phase/three-phase motors for grounded, open, or shorted motor windings. 6. Turn power off. Use the capacitor discharge tool (Figure SP-8-6) to discharge the run capacitor and any other capacitors that may be used in the unit. Locate the wiring connected to the motor windings. (Refer to the unit wiring diagram.)	The wiring related to the motor is identified. All high-voltage capacitors used in the equipment are discharged, including the run capacitor.
7. Isolate the motor from the remainder of the circuit by disconnecting the motor leads from all the related components, including the run capacitor.	The motor leads are disconnected from other components to measure motor resistance only.
8. Check the motor for shorted or open windings as follows: Set up the VOM/DMM to measure resistance on the R x 1 ohm scale. If using a VOM, make sure that it is zeroed. Connect one lead of the VOM/DMM to the motor winding common lead as shown in Figure SP-10-8, View A. Touch the other meter lead to the remaining motor leads, one lead at a time, and observe the meter indication.	VOM/DMM indicates a measurable resistance for all measurements. When measuring the motor run winding leads, the highest resistance is normally measured between the common lead and the low (LO) speed run winding lead. The lowest resistance is measured between the common lead and the high (HI) speed run winding lead. VOM/DMM indicates zero resistance for one or more measurements. This indicates a completely shorted winding. Replace the motor. VOM/DMM indicates infinity for one or more measurements. This indicates that one or more motor windings are open. If checking a motor with an internal motor protection device, make sure the motor has had adequate time to cool off so that the protective device has reset. It may require an hour or more after the motor has been turned off before the internal protection device resets. Replace the motor if the motor is cool and the internal protection device has not reset.
9. Check the motor for grounded windings as follows: Set up the VOM/DMM to measure resistance on the R x 10,000 ohm scale. Connect one lead of the VOM/DMM to a good ground connection, such as the motor frame shown in Figure SP-10-8, View B. Poor electrical contact because of a coat of paint, layer of dirt, or corrosion can cause an inaccurate measurement and hide a grounded winding. Touch the other meter lead to all of the motor leads, one lead at a time, and observe the meter indication.	VOM/DMM indicates infinity or high resistance. If a resistance reading is indicated, it should not be less than 1,000 ohms per volt. For example, on a 230-volt motor, the resistance should not be less than 230,000 ohms (230 volts x 1,000 ohms/volt = 230,000). This indicates that the motor windings are not grounded. VOM/DMM indicates low or zero resistance, or a measurable resistance that is less than 1,000 ohms per volt. This indicates that the motor windings are grounded. Replace the motor.

▼ Figure SP-10-8.
Motor Open, Shorted, or Grounded Winding Measurements



FURNACE THERMOCOUPLE AND FLAME RECTIFICATION SENSOR MEASUREMENT

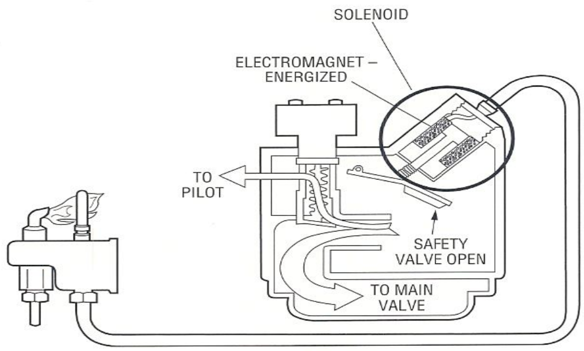
Purpose – The thermocouple and flame rectification sensor are safety devices used in furnaces to prove the furnace pilot flame and/or main burner flame are present. Thermocouples are tested when troubleshooting furnaces where the pilot will not stay lit. Flame rectification sensors are usually tested if the main burners shut off after initial ignition. Both the thermocouple and flame rectification sensor are described below.

Thermocouple

Thermocouples are used on residential gas furnaces equipped with standing pilots. A standing pilot is one which burns continuously, whether the main burner is on or off. A thermocouple standing pilot is only used with a 100% shutoff main gas valve. This type of gas valve shuts off gas to the pilot and will not open its main valve if there is insufficient pilot flame to ignite the main burners or if the thermocouple is defective.

The thermocouple (Figure SP-11-1) is a safety control device that senses the presence of the pilot flame by generating a small DC voltage (about 30 millivolts) when subjected to the heat of the pilot flame.

▼ Figure SP-11-1.
Thermocouple Standing Pilot



When the pilot is lit, the thermocouple develops the electrical signal that causes a small current to flow through the solenoid in the gas valve, energizing the solenoid. The energized solenoid holds the safety gas valve open, allowing gas to flow through the main gas valve to the pilot.

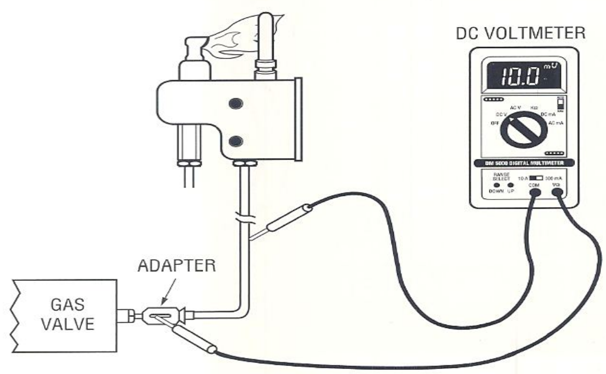
If the pilot flame goes out, the thermocouple cools and the voltage generated drops to zero. The current stops flowing in the solenoid, causing the safety valve to close, shutting off gas flow to the pilot and main gas valve. If the problem is suspected to be the thermocouple, visually check the pilot flame and the thermocouple for the conditions listed below before testing or replacing the thermocouple. Check for:

- Yellow pilot flame
- Pilot flame too small
- Pilot flame misdirected
- Pilot flame too low
- Pilot flame flickering
- Pilot flame floating
- Pilot flame lifting
- Thermocouple bent
- Thermocouple lead kinked
- Thermocouple insulator damaged
- Thermocouple end contact dirty

The thermocouple can be tested either under load or no-load conditions using a VOM/DMM. The procedure for both methods is provided in the detailed procedure given at the end of this section and is briefly described here.

To test the thermocouple under loaded conditions requires the use of a test adapter that allows voltage readings to be made while the thermocouple is connected to the gas valve. First, disconnect the thermocouple from the gas valve. Screw the thermocouple test adapter into the gas valve, then screw the thermocouple into the adapter (Figure SP-11-2). Connect a VOM/DMM set up on the lowest DC millivolt range to the adapter and thermocouple. Connect one meter lead to the adapter and the other lead to the thermocouple copper sheathing tube. Light the pilot by manually depressing and holding down the valve knob or reset button to keep gas flowing to the pilot during the test. After the pilot has been lit for five or more minutes, the reading on the VOM/DMM should be 9 millivolts or higher. This indicates that the thermocouple is good. If the reading is less than 9 millivolts, the thermocouple is defective and must be replaced.

▼ Figure SP-11-2.
Thermocouple Testing



No adapter is required to perform the thermocouple no-load test. First, the thermocouple is disconnected from the gas valve. Then the VOM/DMM is connected to the thermocouple. One meter lead is connected to the extreme end of the thermocouple lead and the other meter lead to the copper sheathing tube. Light the pilot by manually depressing and holding down the valve knob or reset button to keep gas flowing to the pilot during the test. After the pilot has been lit for five minutes, the reading on the VOM/DMM should be 18 millivolts or higher. This indicates that the thermocouple is probably good. If a reading of 18 millivolts or higher is not obtained, the thermocouple is defective and must be replaced.

Flame Rectification Sensor

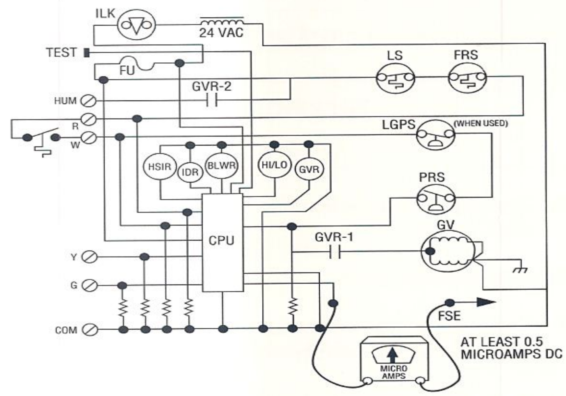
The flame rectification sensor is commonly used in high-efficiency furnaces that use direct burner ignition.

Direct Burner Ignition System Flame Rectification Circuit – Direct burner ignition systems light the burners using a hot surface ignition (HSI) or direct spark ignition method. In direct burner ignition systems, the flame sensing electrode (FSE), also called a *flame rod*, is used to detect that the main burner flame is established across the entire length of the burners. When the flame rod is encircled by the burner flame, the hot gas-ionized particles conduct electricity, thus completing a circuit through the flame rod to the furnace control or ignition module. Current flow through this circuit applies a flame-proving signal to the furnace control circuit microprocessor, signaling the microprocessor to keep the gas valve energized.

Flame sensing electrode operation (Figure SP-11-3) can be tested by measuring the flame-proving current signal applied to the microprocessor. This can be done by connecting an accurate ammeter capable of measuring microamps in series with the sensor input to the microprocessor. With this furnace, the ammeter should indicate a current of at least 0.5 microamps DC. Other furnaces may require a higher or lower flame sensing current. If the flame sensing current is low or nonexistent, check the following:

- Flame sensor rod position.
- The furnace is properly grounded per the manufacturer's instructions.
- The gas valve is grounded through the gas valve ground wire.
- There is good electrical contact at the sensor connection.
- There is no oxide film coating the flame sensing electrode. If there is a coating, clean it off by lightly rubbing with fine abrasive and wiping clean.

▼ Figure SP-11-3.
Testing Flame-Proving Signal



Safety Precautions

When making electrical measurements and/or repairs on equipment, always follow the precautions listed below.

- Read and follow all safety instructions given in the manufacturer's installation instructions and/or service manual for the specific system being serviced.
- Always turn off the main power to a system before making any repairs. There may be more than one disconnect switch. If applicable, turn off the accessory power. Tag and lock out all disconnect switches.
- Always remove rings, watches, and other jewelry to lessen the chance of electrical shock.
- Do not override or bypass safety controls such as electrical interlocks, unless directed by the manufacturer's service literature.
- Be extremely cautious when working around electronic spark ignition circuits. The transformer secondary voltage and electrodes of some ignition devices operate in the range of about 10,000 to 20,000 volts.

PROCEDURE

Before performing the following troubleshooting procedure, refer to the manufacturer's installation instructions and/or service manual for specific instructions about the system being serviced. If differences exist between our procedure and the manufacturer's instructions, always follow the manufacturer's instructions. Review the safety instructions and precautions given in this procedure and in Section 2 of this manual.

The measurements covered in this procedure are listed below. These measurements can be performed in sequence or independently.

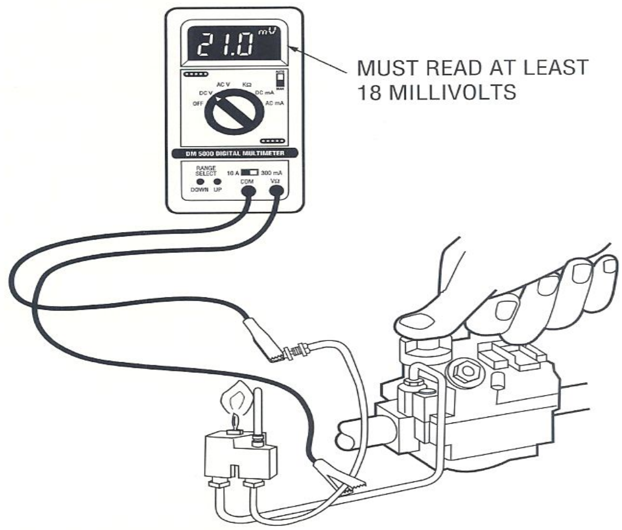
- **Steps 1 through 3 – Thermocouple measurement procedure.**
- **Steps 4 through 6 – Flame rectification circuit flame-proving signal measurement.**

SP-11. INSTRUMENT OR DEVICE REQUIRED	REFERENCE
Volt-ohm-milliammeter (VOM/DMM) and test leads with alligator clips so the leads can be attached to the test points without the need for the technician to hold them in place	Section 1, Item 11
Microammeter capable of measuring current in the 0.5 to 4.5 microamp DC range and test leads with alligator clips so that the microammeter can be connected in series with the unit wiring (Microammeter is used to measure the flame rectification circuit flame-proving low-level current signal)	N/A
Thermocouple test adapter – used for thermocouple test under load	N/A

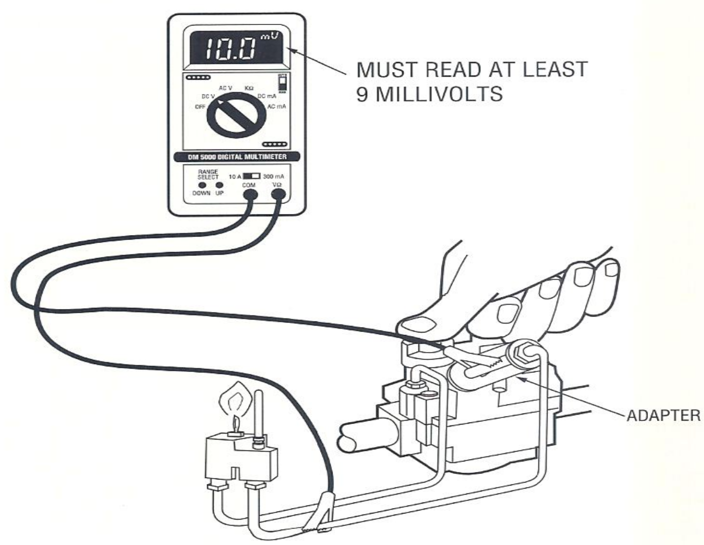
SP-11. THERMOCOUPLE VOLTAGE MEASUREMENT PROCEDURE (STEPS 1 THROUGH 3)

Step	Expected Result/Action
NOTE: Steps 1 through 3 are performed to test a thermocouple for its voltage output. 1. Shut off power and gas to unit. If testing the thermocouple under no-load conditions, disconnect the thermocouple from the gas valve by unscrewing the fitting. If testing the thermocouple under load conditions, disconnect the thermocouple from the gas valve by unscrewing the fitting. Screw the thermocouple test adapter into the gas valve, then screw the thermocouple into the adapter.	Power and gas to unit is turned off and thermocouple is disconnected from gas valve (no-load testing) or connected to the test adapter (loaded testing).
2. Set up the VOM/DMM to measure DC voltage on a millivolt range. Note that the voltage level expected can be 18 millivolts or higher. If testing the thermocouple under no-load conditions, connect the one VOM/DMM meter lead to the end contact (center) of the thermocouple and the other meter lead to the thermocouple copper tubing as shown in Figure SP-11-4, View A. If testing the thermocouple under load conditions, connect one VOM/DMM meter lead to the test adapter and the other meter lead to the thermocouple copper tubing as shown in Figure SP-11-4, View B.	Thermocouple and VOM/DMM prepared for measurement.
3. Turn on gas, then turn gas valve control to the pilot position. While holding down the gas valve knob/reset button, light the pilot. Continue to hold down the gas valve knob/reset button while observing the VOM/DMM reading. As the thermocouple is heated by the pilot flame, the VOM/DMM reading should begin increasing. Continue holding down the gas valve knob or reset button for 5 minutes.	After 5 minutes, if VOM/DMM reads at least 18 millivolts (no-load test) or 9 millivolts (loaded test), this indicates the thermocouple is probably good. If VOM/DMM reads less than 18 millivolts or 9 millivolts, check for one or more of the following conditions: • Yellow pilot flame • Pilot flame misdirected • Pilot flame floating • Thermocouple bent • Thermocouple insulator damaged • Pilot flame too small • Pilot flame flickering • Pilot flame lifting • Thermocouple lead kinked • Thermocouple end contact dirty If VOM/DMM reads less than 18 millivolts or 9 millivolts, correct the problem (listed above), or replace the thermocouple.

▼ Figure SP-11-4.
Thermocouple Voltage Measurements



A. THERMOCOUPLE TEST – NO LOAD

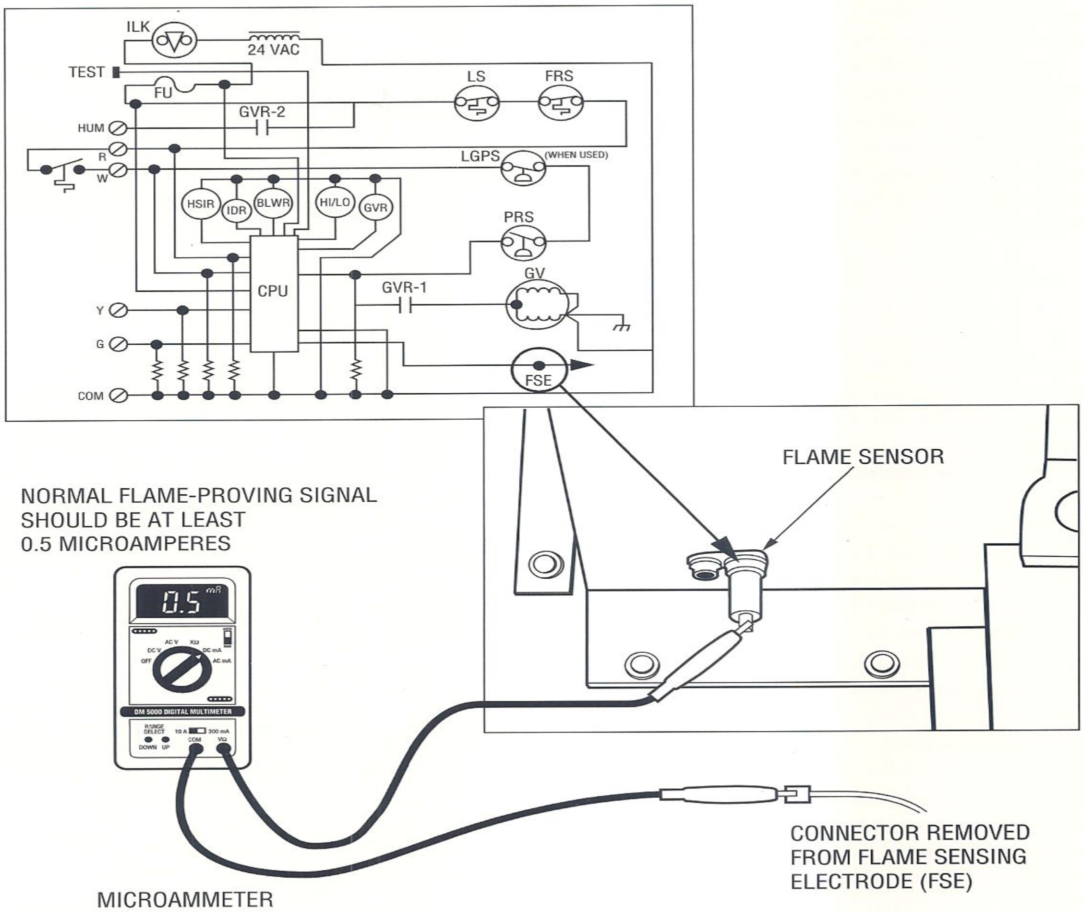


B. THERMOCOUPLE TEST – UNDER LOAD CONDITIONS

SP-11. FLAME RECTIFICATION CIRCUIT FLAME-PROVING SIGNAL MEASUREMENT PROCEDURE (STEPS 4 THROUGH 6)

Step	Expected Result/Action
NOTE: Steps 4 through 6 are performed to test a flame rectification flame-proving signal on furnaces that use hot surface ignition or direct spark ignition of the burners. 4. Shut off power to the unit. At the main burner enclosure, locate the wire connected to the flame sensor electrode (FSE). Refer to the unit wiring and parts location diagrams.	Power to unit is turned off and wire connected to the flame sensing electrode is located.
5. Set up a microammeter to measure DC current on the lowest microamp range. Note that the current level expected can be between 0.5 to 4.5 microamperes. Disconnect the lead from the flame sensor electrode, then connect the microammeter in series with the flame sensor electrode and the wire disconnected from the electrode as shown in Figure SP-11-5.	Microammeter connected in series with flame sensor electrode output and flame-proving circuit wire in preparation for measurement.
NOTE: If the microammeter indicator reads in the negative direction, reverse the microammeter test lead connections to obtain a positive meter reading. 6. Turn on power to the unit and adjust the thermostat to call for heat. After the unit has run for about 1 minute, observe the current indication on the microammeter and compare it to the manufacturer's specifications.	The microammeter indicates a minimum DC current of 0.5 microamperes or a value stated in the manufacturer's specifications. This indicates that a good flame-proving signal is being generated. If a flame-proving signal is low or not being generated, check for the following conditions: • Check flame sensor rod position. • Make sure the furnace is properly grounded per the manufacturer's instructions. • Make sure that the gas valve is grounded through the gas valve ground wire. • Make sure that a good electrical contact exists at the flame sensor electrode connection. • Check flame sensor electrode for an oxide film coating. Clean with fine abrasive. If a flame-proving signal is not being generated and none of the conditions listed above are the cause of the problem, refer to the manufacturer's instructions for information about the operating sequence of events in the furnace and related troubleshooting information.

▼ Figure SP-11-5.
Flame Rectification Circuit Flame-Proving Signal Measurement



FAULT ISOLATION METHODS USED WITH NON-REPAIRABLE ELECTRONIC CONTROLS

Purpose – This section describes the techniques used to troubleshoot an electrical problem in HVAC equipment that uses an electronic control. Electronic controls are expensive, so you want to be absolutely sure that the board is bad before replacing it. Checking the operation of a control is needed to make sure that the cause of a problem is in the control and not the result of a fault external to the control, such as a blower motor, compressor, gas valve, etc. Faulty wiring connected to the control can also be the cause of a problem.

Controls used in HVAC equipment are not designed to be field-repaired. If a control fails, it must be replaced. An electronic control should only be condemned as being bad when all the input signals to the control are known to be good, but the control fails to generate the proper output signals.

Approach to Troubleshooting

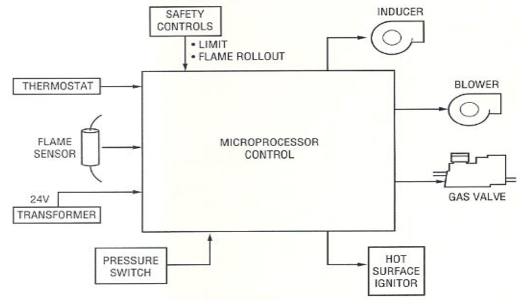
The approach to troubleshooting a unit with an electronic control is the same as that used for a unit without an electronic control. First, a diagnosis and/or measurements and checks are made to isolate an electrical fault to a functional circuit (power, control, or load) within the unit as described in Service Procedure SP-7. Once the defective functional circuit is known, the hopscotch method of troubleshooting (Service Procedure SP-8) is used to find the defective component.

In units that use a microprocessor control like the one shown in Figures SP-12-1 and SP-12-2, the microprocessor acts to control all sequences of operation for the unit. To determine the condition of the control (good or bad), it is necessary to check for the presence of the proper input signals to the control. It is also necessary to confirm that the control generates the proper output signal(s), in response to the input signal(s). Obviously, to troubleshoot the control correctly, you must understand the unit's sequence of operation.

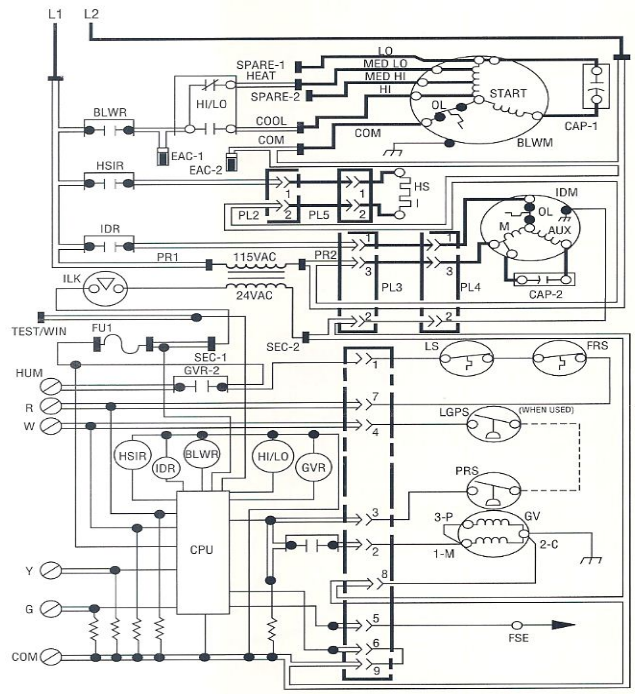
If you are not familiar with the unit being serviced, study the unit's electrical schematic and sequence of operation as described in the manufacturer's instructions.

Once you understand what the unit should be doing, you must find out what the unit is doing or what symptoms are present in the unit. To aid you in this analysis, many microprocessor-controlled units have built-in diagnostic circuits that can run a complete check of all system functions and report the status by means of a display device. When troubleshooting, always use the built-in diagnostic features (if available) and follow the related manufacturer's troubleshooting instructions.

▼ Figure SP-12-1.
Typical Microprocessor Furnace Control System



▼ Figure SP-12-2.
Schematic of Microprocessor-Controlled Furnace



FURNACE HEATING CYCLE SEQUENCE

- Ready to Start
- Thermostat Calls for Heat
- Inducer Runs
- Gas Valve Energized
- Flame Sensed
- Blower Operates – Heating
- Thermostat Satisfied
- Ready to Start

Sequence of Operation

Random testing of the input and output signals to any electronic control without regard to the unit's sequence of operation will most likely result in the needless replacement of a good control. Figure SP-12-2 shows a schematic and lists the sequence of operation for a typical microprocessor-controlled high-efficiency furnace. Figure SP-12-3 lists the unit's major signals and the voltages applied to and from the microprocessor control and how they vary according to the sequence. Knowing the sequence and the various inputs and outputs is critical to successful troubleshooting. The microprocessor control used in the example is typical of the controls encountered in the field. Controls used in other HVAC units may be simpler or more complex, but the methods used to troubleshoot them are the same.

▼ Figure SP-12-3.
Typical Microprocessor-Controlled Furnace Input and Output Signals and Voltages

INPUT VOLTAGES

LOCATION*	NORMAL READING	PURPOSE
L_1 & L_2	115 VAC	Main power supply input to furnace
PR1 & PR2	115 VAC	Powers transformer primary
SEC-1 & SEC-2	24 VAC	Power from transformer secondary, door switch closed
R & Com	24 VAC	Power from transformer secondary
W & Com	24 VAC	Call for heat signal from room thermostat
Y & Com	24 VAC	Call for cooling signal from room thermostat
G & Com	24 VAC	Call for continuous fan signal from room thermostat
PL1-7 & Com	24 VAC	Present if fuse, overtemperature switch, and limit switch closed
PL1-3 & Com	24 VAC	Present on call for heat and indicates closed pressure switch

OUTPUT VOLTAGES

LOCATION*	NORMAL READING	PURPOSE
HEAT & L_2	115 VAC	Power to blower motor in heating or continuous fan modes
COOL & L_2	115 VAC	Power to blower motor in cooling mode
EAC-1 & EAC-2	115 VAC	Power to electronic air cleaner whenever blower operates
PL2-1 & L_2	115 VAC	Power to HSI on call for heat
PL3-1 & L_2	115 VAC	Power to inducer motor on call for heat
PL1-2 & Com	24 VAC	Energizes gas valve
HUM & Com	24 VAC	Energizes humidifier when gas valve energizes

* Place meter probes at locations shown on wiring diagram. Digital meter gives best results

NOTE: ENTRIES SHOWN IN RED INDICATE KEY POINTS OF TEST WHERE MEASUREMENTS ARE MADE TO TROUBLESHOOT THE EXAMPLE FAILURE DESCRIBED IN THE DETAILED PROCEDURE AND SHOWN IN FIGURE SP-12-4.

PROCEDURE

Before performing the following troubleshooting procedure, refer to the manufacturer's installation instructions and/or service manual for specific instructions about the system being serviced. If differences exist between our procedure and the manufacturer's instructions, always follow the manufacturer's instructions. Review the safety instructions and precautions given in this procedure and in Section 2 of this manual.

SP-12. INSTRUMENT OR DEVICE REQUIRED	REFERENCE
Volt-ohm-milliammeter (VOM/DMM) and test leads with alligator clips so the leads can be attached to the test points without the need for the technician to hold them in place	**Section 1, Item 11**

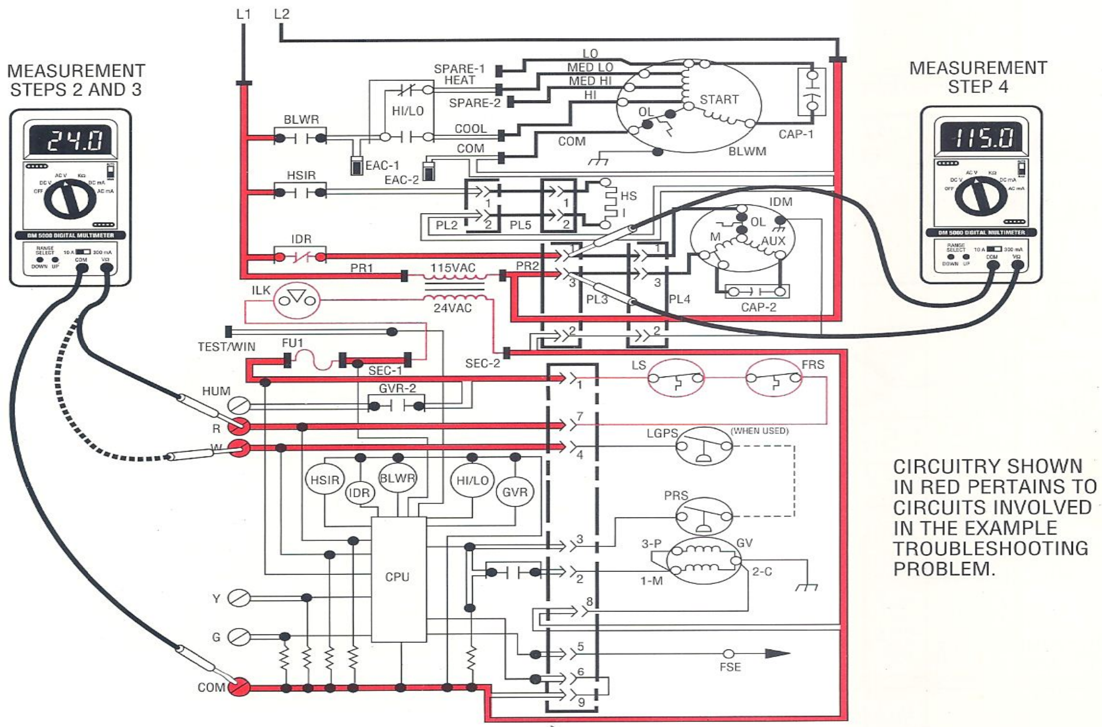
SP-12. FAULT ISOLATION OF NON-REPAIRABLE ELECTRONIC CONTROLS (STEPS 1 THROUGH 3)

Step	Expected Result/Action
NOTE: Electronic controls used in HVAC equipment are not designed to be field-repaired. If a control fails, it must be replaced. An electronic control should only be condemned as being bad when all the input signals applied to the control are known to be good, but the control fails to generate the proper output signals. This procedure gives an example of how to check the input and output voltages and signals applied to and from an electronic control in order to determine if the control, or a component external to the control, is defective. A typical microprocessor-controlled furnace is used in this example. Controls used in other HVAC units may be simpler or more complex, but the methods used to troubleshoot them are the same. This example assumes that the cause of the problem is a loose connection between the electronic control and the inducer motor. 1. With power applied to the furnace, use any built-in component test feature (if so equipped) to help isolate the cause of the problem. Refer to the manufacturer's service instructions.	Many units are equipped with some form of indicator on the electronic control that displays the unit's operating status and/or fault codes. Normally, a label is attached to the unit that defines the operating status or fault associated for each of the fault indication codes. Many units also are equipped with a built-in component test feature to aid the service technician in isolating problems. When the unit being serviced is so equipped, follow the manufacturer's instructions for the use of the built-in diagnostic features and for troubleshooting the unit. **For our example assume:** *You begin troubleshooting the unit based on your observation that the inducer motor failed to run during the component test.*
NOTE: Step 2 checks the 24 VAC control circuit power input to the electronic control. This step is optional if the presence of 24-volt power is obvious. In this example, the previous step of performing a component test indicates 24-volt power is available. 2. Set the VOM/DMM to measure AC voltage. Note that the voltage level expected is 24 volts. Connect the VOM/DMM meter leads across the thermostat connection R and COM terminals as shown in Figure SP-12-4.	If the VOM/DMM indicates 24 VAC, this indicates that the 24 VAC control voltage input to the electronic control is good. Proceed to step 3. If the VOM/DMM reads 0 VAC, use the hopscotch method to isolate any open or failed component or wiring. Check for the following: • Is power applied to the furnace? • Is the interlock (ILK) switch closed? • Is the fuse (FU1) on the control board good? • Is the flame rollout switch (FRS) or main limit switch (LS) open? **For our example assume:** *The VOM/DMM indicates 24 VAC.*
NOTE: Step 3 checks the 24 VAC "call-for-heat" input applied to the electronic control from the room thermostat. 3. Connect the VOM/DMM meter leads across the thermostat connection W and COM terminals as shown in Figure SP-12-4.	If the VOM/DMM reads 24 VAC, this indicates that the 24 VAC "call-for-heat" input to the electronic control is good. Proceed to step 4. If the VOM/DMM reads 0 VAC, use the hopscotch method to isolate any open or failed component or wiring. Check for the following: • Is the thermostat function switch set in the heating mode? • Is the thermostat temperature set high enough? • Is the thermostat defective? **For our example assume:** *The VOM/DMM indicates 24 VAC.*

SP-12. FAULT ISOLATION OF NON-REPAIRABLE ELECTRONIC CONTROLS (STEP 4)

Step	Expected Result/Action
NOTE: Step 4 checks the 115 VAC input applied to the inducer motor (IDM). 4. Set the VOM/DMM to measure 115 VAC. Connect the VOM/DMM meter leads across connector PL3 terminals 1 and 3 as shown in Figure SP-12-4.	The VOM/DMM reads 115 VAC but the inducer motor does not run. This indicates that the 115 VAC output from the electronic control is good; therefore, the control board is good. Use the hopscotch method to isolate any problem external to the electronic control. Check for the following: • Are the electrical connections tight? • Is the inducer motor capacitor defective? • Is there some mechanical defect such as a jammed inducer wheel preventing the motor from turning? • Is the motor hot, indicating the internal overload may be open? If the VOM/DMM reads 0 VAC, replace the control. **For our example assume:** *The VOM/DMM indicates 115 VAC, indicating that the electronic control is good. Further, assume the problem is found to be a loose connection between the electronic control and the inducer motor.*

▼ Figure SP-12-4.
Electronic Control Fault Isolation Measurements



INPUT VOLTAGE IS PRESENT – OUTPUT VOLTAGE IS PRESENT.
ELECTRONIC CONTROL IS GOOD – PROBLEM IS EXTERNAL TO THE CONTROL.

TEMPERATURE RISE MEASUREMENT IN A FOSSIL-FUEL FURNACE

Purpose – This procedure describes how to measure the temperature rise in fossil-fuel furnaces. Temperature rise is the difference between the return air temperature entering the furnace, and the supply air temperature leaving the furnace. The amount of temperature rise gives an indication of whether adequate air is flowing across the furnace heat exchangers. However, it cannot determine air quantity. Temperature rise measurements are normally made when a furnace is initially installed and when troubleshooting furnaces.

Temperature Rise

The correct temperature rise range for a particular furnace can be found on the furnace information plate (Figure SP-13-1). The correct amount of temperature rise is critical in high-efficiency furnaces. If too much air passes over the heat exchangers, condensing can take place in the heat exchangers or vent, causing corrosion and failure. If too little air passes over the heat exchangers, the resultant overheating may cause premature failure of the heat exchangers. If the temperature rise is too low or too high, the furnace's blower speed must be changed to bring the rise into the desired range. Before making temperature rise measurements, make sure that:

- The furnace is fired at its full rated input.
- The furnace air filter is clean.
- All supply and return registers are open and unrestricted.
- If equipped with a bypass humidifier, the damper in the bypass duct must be closed.

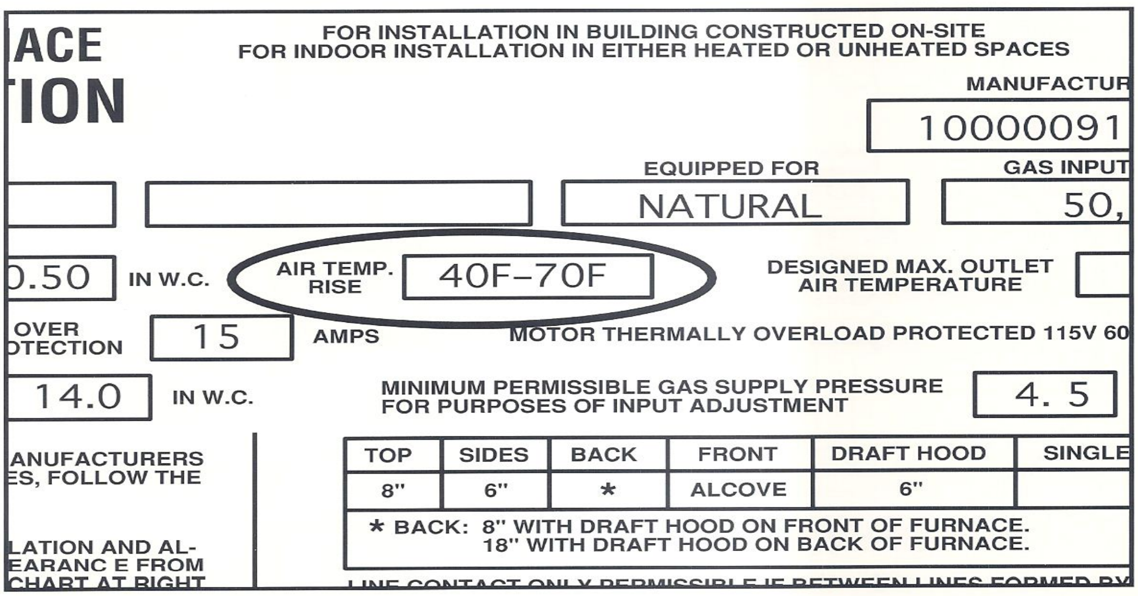
Temperature Rise Measurement

The method for measuring temperature rise is provided in the detailed procedure at the end of this section and briefly outlined here.

Temperature measurement holes are drilled in the return air duct near the furnace and in the supply air duct out of the line of sight of the heat exchangers (Figure SP-13-2). The furnace is turned on and operated for about ten minutes to allow the temperatures to stabilize.

The supply and return air temperatures are measured with an accurate thermometer, then the temperature rise is calculated by subtracting the return air temperature from the supply air temperature. Ideally, the temperature rise should be slightly

▼ Figure SP-13-1.
Temperature Rise Shown on Furnace Information Plate



above the midpoint of the range shown on the furnace information plate. If the temperature rise is too low, decrease the blower speed to reduce the airflow; if too high, increase the blower speed to increase the airflow.

Safety Precautions

When making measurements and/or repairs on equipment, always follow the precautions listed below.

- Read and follow all safety instructions given in the manufacturer's installation instructions and/or service manual for the specific system being serviced.
- Always turn off the main power before making any repairs. There may be more than one disconnect switch. If applicable, turn off the accessory power. Tag and lock out all disconnect switches.
- Always remove rings, watches, and other jewelry to lessen the chance of electrical shock.
- Do not override or bypass safety controls such as electrical interlocks, unless directed by the manufacturer's instructions.
- Be extremely cautious when working around electronic spark ignition circuits. The control transformer secondary voltage and electrodes of some ignition devices operate in the range of about 10,000 to 20,000 volts.

PROCEDURE

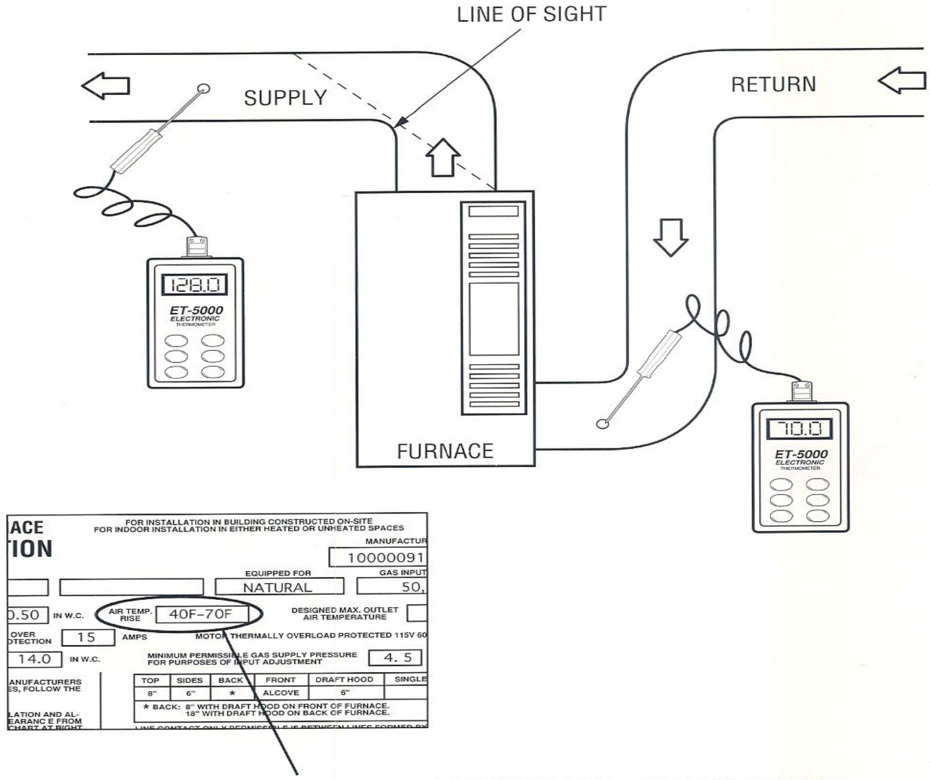
Before performing the following troubleshooting procedure, refer to the manufacturer's installation instructions and/or service manual for specific instructions about the system being serviced. If differences exist between our procedure and the manufacturer's instructions, always follow the manufacturer's instructions. Review the safety instructions and precautions given in this procedure and in Section 2 of this manual.

SP-13. INSTRUMENT OR DEVICE REQUIRED	REFERENCE
Electronic thermometer	Section 1, Item 2
Electric drill and bits – used to drill temperature measurement holes in the furnace supply and return air ducts	N/A
Plastic plugs or duct tape to seal holes drilled in duct	N/A

SP-13. TEMPERATURE RISE MEASUREMENT IN A FOSSIL-FUEL FURNACE

Step	Expected Result/Action
1. Drill a hole in the return air duct near the furnace as shown in Figure SP-13-2. Drill a second hole in the supply air duct out of the line of sight of the heat exchangers so that radiant heat does not affect the readings. This is especially important with straight duct runs.	Holes drilled in the supply and return air ducts in preparation for measurement.
2. Turn on the power and gas to the unit. Allow the furnace to run about ten minutes to stabilize the temperatures. Set the thermostat high enough to allow the furnace to run continuously during the measurement.	Furnace on and temperatures stabilized.
NOTE: Before making temperature rise measurements, make sure that: • The furnace is fired at its full rated input. • The furnace air filter is clean. • All supply and return registers are open and unrestricted. • If equipped with a bypass humidifier, the damper in the bypass duct must be closed. 3. Using the electronic thermometer, measure and record the return and supply air temperatures. Make sure the thermometer readings have stabilized for the measurement.	Supply and return air temperatures measured and recorded. **For our example assume:** *Supply temperature = 128° F* *Return temperature = 70° F*
4. Using the measured values of supply and return air temperatures, calculate the temperature rise using the formula: Supply Temperature - Return Temperature = Temperature Rise	Temperature rise is calculated. **For our example assume:** *128° F - 70° F = 58° F*
5. Compare the measured temperature rise to the temperature rise range on the furnace information plate.	If the temperature rise is within the range shown on the furnace information plate, no adjustment of airflow is required. Ideally, however, the rise should be slightly above the midpoint of the range. For example, with a temperature rise range of 40° F to 70° F, the midpoint is 55° F. **For our example assume:** *The temperature rise of 58° F falls slightly above the midpoint (55° F) of the range of 40° F to 70° F shown on the furnace information plate. This indicates that the airflow is adequate and no airflow adjustment is needed.* If the temperature rise is too low, decrease the blower speed to decrease the airflow. If the temperature rise is too high, increase the blower speed to increase the airflow. Follow the furnace manufacturer's instructions for increasing or decreasing the blower speed.

Figure SP-13-2.
Temperature Rise Measurement in a Fossil Fuel Furnace



SUPPLY TEMPERATURE – RETURN TEMPERATURE = TEMPERATURE RISE
128° F – 70° F = 58° F

THE TEMPERATURE RISE OF 58° F FALLS SLIGHTLY ABOVE THE MIDPOINT (55° F) OF THE RANGE OF 40° F TO 70° F SHOWN ON THE FURNACE INFORMATION PLATE. THIS INDICATES THAT THE AIRFLOW IS ADEQUATE AND NO AIRFLOW ADJUSTMENT IS NEEDED.

COOLING SYSTEM PROPER AIRFLOW RANGE

Purpose – This procedure describes how to determine if airflow across the evaporator in a cooling system is adequate. For proper operation of a cooling system, the blower should be moving from 400 to 450 CFM of air across the evaporator coil for each ton of cooling capacity. For example, on a 2-ton cooling unit, the volume of air should be at least 800 CFM. Too much or too little air can cause indoor comfort problems as well as equipment problems. The airflow is normally measured when a cooling system is initially installed, being charged with refrigerant, or when troubleshooting.

Airflow Problems

Too much air across the evaporator coil results in poor humidity control. If air moves too fast across the evaporator, moisture is not effectively removed. To correct the problem of too much air, decrease the blower speed.

While too much air can be a problem, the problem of too little air is more widely seen. The usual symptom is a frozen evaporator coil. Refrigerant flooding can result from low airflow and this in turn may cause compressor failures. To correct the problem of too little air, increase blower speed. However, before adjusting the blower speed, always make sure that:

- The system air filter is clean.
- The blower wheel is clean.
- The evaporator coil is clean.
- There are no loose or worn belts on belt-driven blowers.
- The blower is rotating in the right direction.
- The system has the correct refrigerant charge.

Airflow Measurement

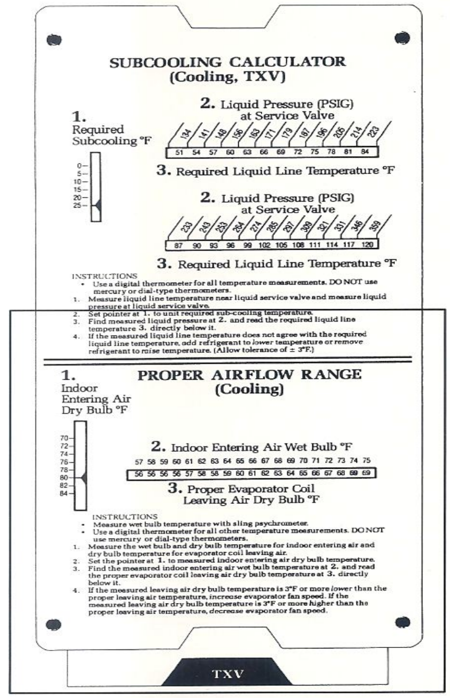
The procedure for measuring airflow given here uses the "Proper Airflow Range" section of the Required Superheat/Subcooling Calculator previously used in Service Procedure SP-4. This calculator is designed to provide a quick check to see if the airflow across the evaporator is adequate for proper cooling system operation. It cannot be used to find the actual air quantity in CFM. Methods for measuring actual CFM are shown in Service Procedures SP-15 through SP-17.

A detailed procedure and illustrated example for determining airflow using the Airflow Calculator is provided later in this section. A brief overview of the procedure and the use of the calculator follows.

After system operation has stabilized, the following temperatures are measured:

- Wet bulb and dry bulb of air entering the evaporator coil.
- Dry bulb of air leaving the evaporator coil.

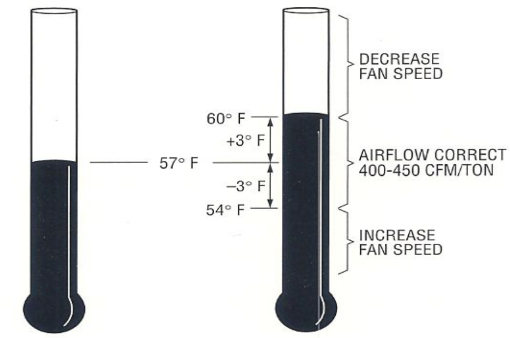
▼ Figure SP-14-1.
Required Superheat/Subcooling Calculator – Proper Airflow Range Side



The measured dry bulb and wet bulb temperatures for the air entering the evaporator are used with the calculator to find the proper evaporator coil leaving air dry bulb temperature. This step gives the correct leaving air temperature, assuming the system refrigerant charge is correct and the airflow across the coil is within the 400 to 450 CFM per ton range.

Following this, the actual dry bulb temperature of the air leaving the evaporator is compared with the value indicated by the calculator. Ideally, they should be the same. A tolerance of ±3° F is allowed before any adjustment is required (Figure SP-14-2). If the actual air temperature leaving the evaporator is more than 3° F lower than the proper airflow temperature, the evaporator blower speed should be increased. If the actual air temperature leaving the evaporator is more than 3° F higher than the proper air temperature, the evaporator blower speed should be decreased.

▼ Figure SP-14-2.
Evaporator Leaving Air Dry Bulb (°F)



Safety Precautions

When making measurements and/or repairs on equipment, always follow the precautions listed below.

- Read and follow all safety instructions in the manufacturer's installation instructions and/or service manual for the specific system being serviced.
- Always turn off the main power to a system before making any repairs. There may be more than one disconnect switch. If applicable, turn off the accessory power. Tag and lock out all disconnect switches.
- Always remove rings, watches, and other jewelry to lessen the chance of electrical shock.
- Do not override or bypass safety controls such as electrical interlocks, unless directed by the manufacturer's service literature.

PROCEDURE

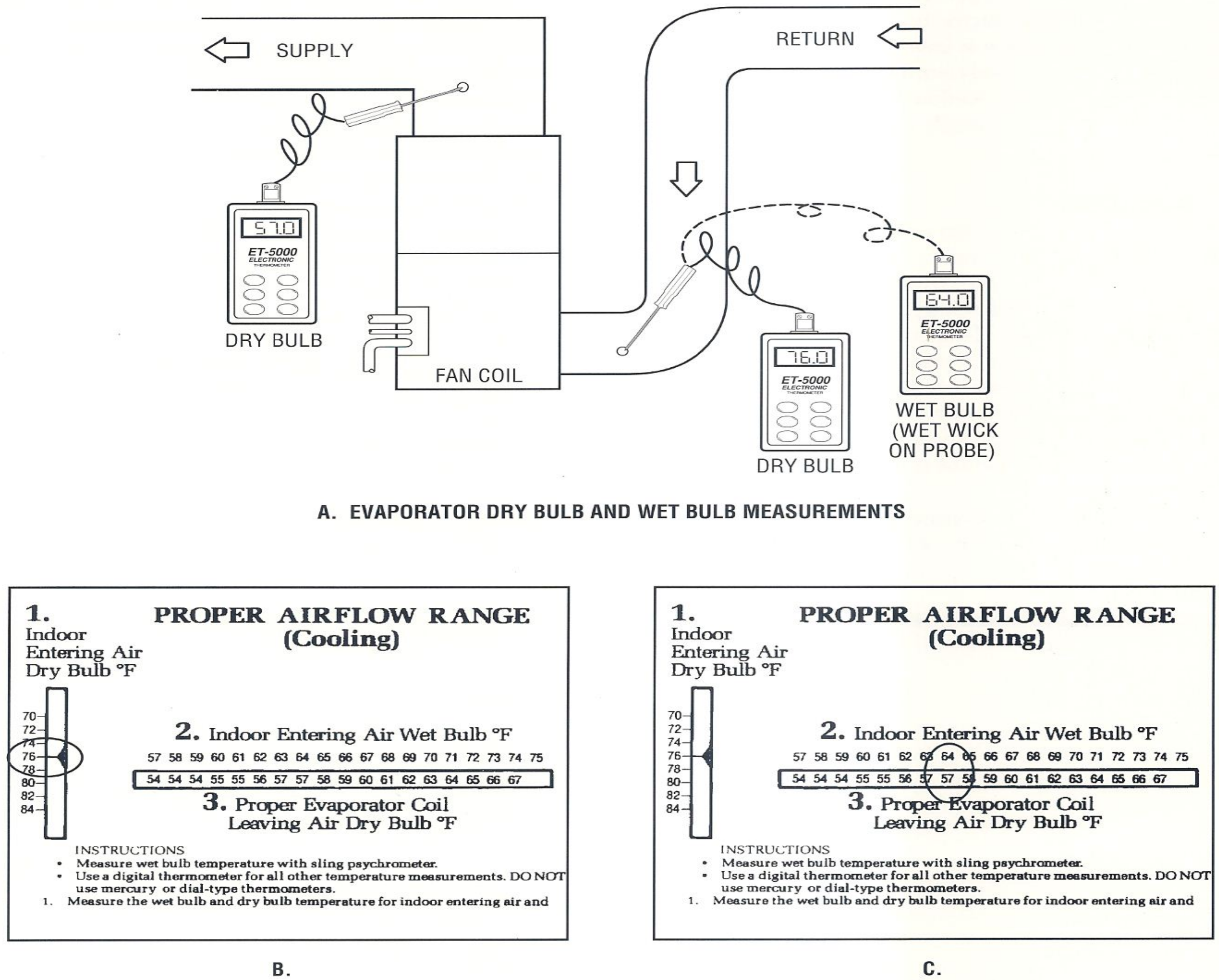
Before performing the following troubleshooting procedure, refer to the manufacturer's installation instructions and/or service manual for specific instructions about the system being serviced. If differences exist between our procedure and the manufacturer's instructions, always follow the manufacturer's instructions. Review the safety instructions and precautions given in this procedure and in Section 2 of this manual.

SP-14. INSTRUMENT OR DEVICE REQUIRED	REFERENCE
Electronic thermometer, including a wick and distilled water used with thermometer probe to make a wet bulb temperature measurement	Section 1, Item 2
Required Superheat/Subcooling Calculator	N/A
Electric drill and bits – used to drill temperature measurement holes in the supply and return air ducts	N/A
Plastic plugs or duct tape used to seal holes drilled in duct	N/A

SP-14. COOLING SYSTEM PROPER AIRFLOW RANGE

Step	Expected Result/Action
1. Drill a hole in the return air duct to measure the evaporator entering air temperature as shown in Figure SP-14-3, View A. Drill a second hole in the supply air duct to measure the evaporator leaving air temperature.	Holes drilled in the supply and return air ducts in preparation for measurement.
2. Turn on the power to the system. Make sure that all the supply and return registers are open. Allow the system to run for about ten minutes to stabilize the temperatures. Set the thermostat low enough so that the system runs continuously during the measurement.	System on and temperatures stabilized.
3. Using the electronic thermometer, measure and record the evaporator entering air wet bulb and dry bulb temperatures. Make sure the thermometer readings have stabilized for the measurement.	Evaporator entering air wet bulb and dry bulb temperatures measured and recorded. **For our example assume:** *Entering air wet bulb temperature = 64° F* *Entering air dry bulb temperature = 76° F*
4. Using the electronic thermometer, measure and record the evaporator leaving air dry bulb temperature. Make sure the thermometer reading has stabilized for the measurement.	Evaporator leaving air dry bulb temperature measured and recorded. **For our example assume:** *Leaving air dry bulb temperature = 57° F*
5. Using the proper airflow calculator, set the pointer to the indoor entering air dry bulb °F measured in step 3.	**For our example assume:** *The pointer is at 76° F as shown in Figure SP-14-3, View B.*
6. On the calculator, find the value for the indoor entering air wet bulb temperature measured in step 3, then read the proper evaporator leaving-air temperature directly below it.	**For our example assume:** *The evaporator (indoor) wet bulb temperature of 64° F is found on the calculator. Directly below it is the correct evaporator leaving air dry bulb temperature, as shown in Figure SP-14-3, View C.* *The proper evaporator leaving air dry bulb temperature is 57° F and the actual evaporator leaving air temperature measured in step 4 is 57° F. This means that the airflow is within the 400 to 450 CFM per ton range and no adjustment to the blower speed is needed. A tolerance of ±3° F is allowed.* If the evaporator leaving air temperature measured in step 4 is above 60° F (proper evaporator leaving air dry bulb temperature of 57° F read from calculator plus 3° F = 60° F), decrease the blower speed. If the evaporator leaving air temperature measured in step 4 is below 54° F (proper evaporator leaving air dry bulb temperature of 57° F read from calculator minus 3° F = 54° F), increase the blower speed.

Figure SP-14-3.
Cooling System Proper Airflow Range



THE PROPER EVAPORATOR LEAVING AIR DRY BULB TEMPERATURE SHOWN ON THE CALCULATOR IS 57° F AND THE MEASURED (ACTUAL) EVAPORATOR LEAVING AIR DRY BULB TEMPERATURE IS 57° F. THIS MEANS THAT THE AIRFLOW IS WITHIN THE 400 TO 450 CFM PER TON RANGE AND NO ADJUSTMENT OF THE BLOWER SPEED IS NEEDED. A TOLERANCE OF ±3° F IS ALLOWED.

SERVICE PROCEDURE SP-15

AIRFLOW MEASUREMENT IN A FAN COIL WITH ELECTRIC HEAT

Purpose – This procedure describes how to calculate the quantity of airflow in cubic feet per minute (CFM) being delivered by a fan coil containing electric heating elements. Having the correct quantity of airflow is important in order to maintain heating comfort in the conditioned space and for efficient and safe equipment operation. Airflow measurements are normally made when a fan coil is initially installed and when troubleshooting.

Calculating Airflow

The volume of airflow in a fan coil with electric heat can be calculated using measured values for the amount of temperature rise across the heating elements, along with the input voltage and the total (including blower motor) current flow through the air handler. Temperature rise is the difference between the return air temperature entering and the supply air temperature leaving the fan coil. While the measurements are being taken, the system must run continuously. The method for calculating airflow, including a typical example, is provided in the detailed procedure at the end of this section and briefly outlined here.

Before making any measurements, check that the air filter is clean, all supply and return registers are open and unrestricted, and that any zone dampers are fully open. Also, let the system run long enough to make sure the system temperatures have stabilized.

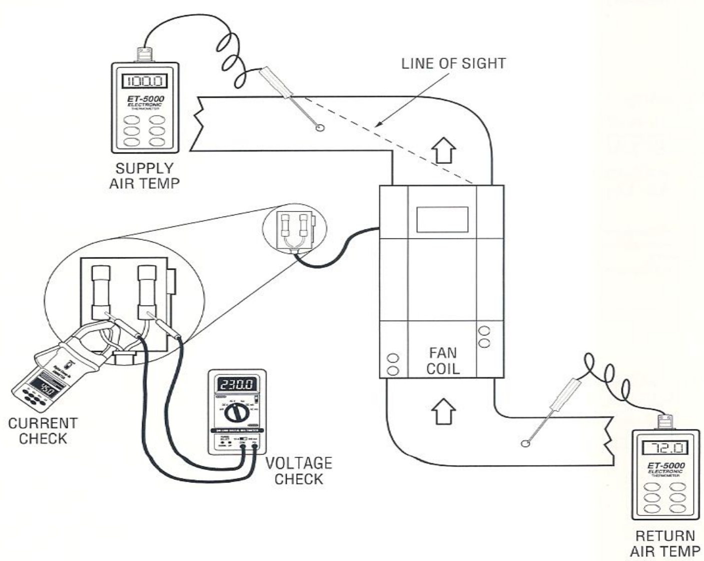
After the system is stabilized, the temperatures entering and leaving the unit are measured with an accurate electronic thermometer (Figure SP-15-1). Next, the temperature rise is calculated by subtracting the return air temperature from the supply air temperature. When measuring the discharge or supply air, the thermometer must be out of the line of sight of the heater elements to prevent radiant heat from affecting the reading.

After the measurements have been made, the data is used with the temperature rise formula shown below to calculate the airflow in CFM. For an example calculation, refer to the detailed procedure given at the end of this section. The formula states that: CFM equals volts times amps times 3.414 (Btu's per watt) all divided by 1.08 times the temperature difference (ΔT). Stated mathematically:

$$\text{Airflow CFM} = \frac{\text{Volts x Amps x 3.414}}{1.08 \times \Delta T}$$

If the quantity of airflow in CFM is within the range specified by the equipment manufacturer, no adjustment of the airflow is required. If the flow is too low, the blower speed should be increased to increase the airflow. If it is too high, the blower speed should be decreased to decrease the airflow.

▼ Figure SP-15-1.
Temperature Rise Method to Measure CFM



Safety Precautions

When making measurements and/or repairs on equipment, always follow the precautions listed below.

- Read and follow all safety instructions given in the manufacturer's installation instructions and/or service manual for the specific system being serviced.
- Always turn off the main power to a system before making any repairs. There may be more than one disconnect switch. If applicable, turn off the accessory power. Tag and lock out all disconnect switches.
- Always remove rings, watches, and other jewelry to lessen the chance of electrical shock.
- Do not override or bypass safety controls such as electrical interlocks, unless directed by the manufacturer's service literature.
- Be extremely cautious when working around energized heating elements.

PROCEDURE

Before performing the following troubleshooting procedure, refer to the manufacturer's installation instructions and/or service manual for specific instructions about the system being serviced. If differences exist between our procedure and the manufacturer's instructions, always follow the manufacturer's instructions. Review the safety instructions and precautions given in this procedure and in Section 2 of this manual.

SP-15. INSTRUMENT OR DEVICE REQUIRED	REFERENCE
Volt-ohm-milliammeter (VOM/DMM) and test leads with alligator clips so the leads can be attached to the test points without the need for the technician to hold them in place	Section 1, Item 11
Clamp-on ammeter	Section 1, Item 10
Electronic thermometer	Section 1, Item 2
Electric drill and bits – used to drill temperature measurement holes in the fan coil supply and return air ducts	N/A
Plastic plugs or duct tape used to seal holes drilled in duct	N/A

SERVICE PROCEDURES 4

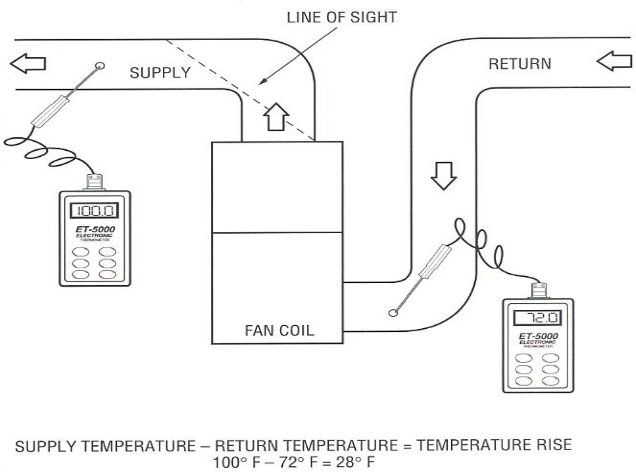
SP-15. AIRFLOW MEASUREMENT IN A FAN COIL WITH ELECTRIC HEAT (STEPS 1 THROUGH 6)

Step	Expected Result/Action
NOTE: This procedure describes the airflow measurement for a single-phase fan coil with electric heat. Steps 1 through 4 measure the temperature rise. 1. Drill a hole in the return air duct near the fan coil as shown in Figure SP-15-2. Drill a second hole in the supply air duct out of the line of sight of the heating elements to prevent radiant heat from affecting the readings.	Holes drilled in the supply and return air ducts in preparation for measurement.
2. Turn on power to the fan coil and set the thermostat to call for heat. Allow it to run about ten minutes to stabilize the temperatures. Set the thermostat high enough to cause the fan coil to run continuously during the measurement.	Fan coil on and temperatures stabilized.
NOTE: Before making temperature rise measurements, make sure that: • The air filter is clean. • All supply and return registers are open and unrestricted and any zone dampers are fully open. 3. Using the electronic thermometer, measure and record the return and supply air temperatures. Make sure the thermometer readings have stabilized for the measurement.	Supply and return air temperatures measured and recorded. **For our example assume:** *Supply temperature = 100° F* *Return temperature = 72° F*
4. Using the measured values of supply and return temperatures, calculate the temperature rise using the formula below: Supply Temperature - Return Temperature = Temperature Rise	Temperature rise is calculated. **For our example assume:** *100° F - 72° F = 28° F*
NOTE: Step 5 measures the fan coil input voltage. 5. Set up VOM/DMM to measure AC volts. Select a range high enough to measure the fan coil input voltage. At the unit disconnect box or unit terminal board, measure and record the input voltage as shown in Figure SP-15-3.	Input voltage measured and recorded. **For our example assume:** *The measured input voltage is 230 volts.*
NOTE: Step 6 measures the total current of the air handler. 6. Set up the clamp-on ammeter to measure current on the highest range scale. Measure and record the total current of the air handler as shown in Figure SP-15-3.	Input current measured and recorded. **For our example assume:** *The measured current is 45 amperes.*

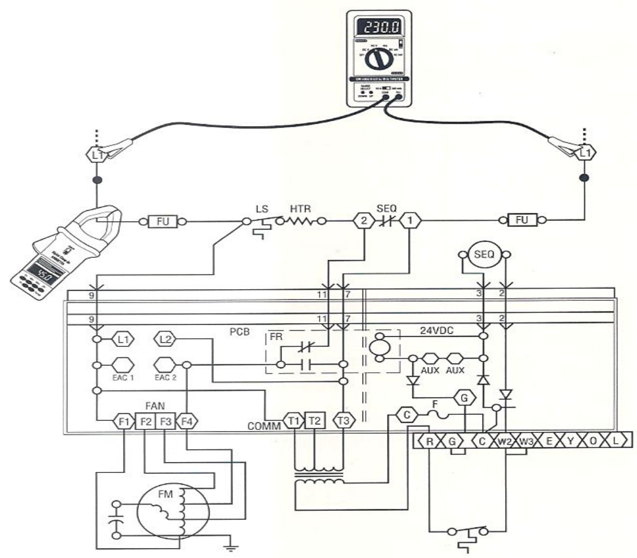
SP-15. AIRFLOW MEASUREMENT IN A FAN COIL WITH ELECTRIC HEAT (STEPS 7 AND 8)

Step	Expected Result/Action
7. Using measured values of volts, amperes, and temperature rise, calculate the airflow in CFM using the formula below: $$\text{Airflow CFM} = \frac{\text{Volts x Amps x 3.414}}{1.08 \times \Delta T}$$	Airflow in CFM is known after calculation using the temperature rise formula. **For our example assume:** $$\frac{230 \times 45 \times 3.414\ Btu/Watt}{1.08 \times 28} = \text{Approx. 1,170 CFM}$$
8. Compare the calculated airflow to the manufacturer's recommended airflow for the fan coil. Refer to the manufacturer's service instructions for the recommended values of airflow in CFM.	If the airflow is within the range recommended by the manufacturer, no adjustment of the airflow is required. If the airflow is too low or too high, increase or decrease the blower speed to change the airflow. Follow the fan coil manufacturer's instructions for changing the blower speed.

▼ Figure SP-15-2.
Temperature Rise Measurement



▼ Figure SP-15-3.
Fan Coil Voltage and Current Measurements



AIRFLOW MEASUREMENT – VELOCITY PRESSURE METHOD

Purpose – This procedure describes how to calculate the quantity of air being delivered in HVAC air distribution duct systems. Having the correct quantity of air supplied to each area of a conditioned space is important in order to maintain human comfort. Airflow measurements in duct systems are normally made after the initial installation of a system, when balancing air distribution systems, or when troubleshooting airflow problems in a system.

This procedure presents a method for calculating the airflow in a duct in cubic feet per minute (CFM) based on the air velocity measured in feet per minute and the area of the duct in square feet (Figure SP-16-1). The value for the air velocity is obtained by measuring the air velocity pressure in the duct using an inclined manometer and pitot tube (Item 18). A detailed description for both of these instruments is given in Section 1. Additional information about their use is given in this procedure.

▼ Figure SP-16-1.
How to Calculate Airflow

CFM = AREA x VELOCITY

Square Feet — Feet/Minute

Relationship of Duct Air Pressures

Accurate measurement of air pressures within a duct requires an understanding of the relationships among the various air pressures that exist within a duct. The total air pressure within a duct is the sum of its two components: velocity pressure and static pressure. Expressed mathematically:

$$T_p = V_p + S_p$$

Where:

T_p = **Total Pressure**
V_p = **Velocity Pressure**
S_p = **Static Pressure**

The velocity pressure is the pressure required to give the air its velocity or speed. Velocity pressure acts in the direction of airflow only. Static pressure is that pressure required to overcome the friction or resistance to airflow in the duct. Static pressure acts in all directions within the duct and causes no movement of air.

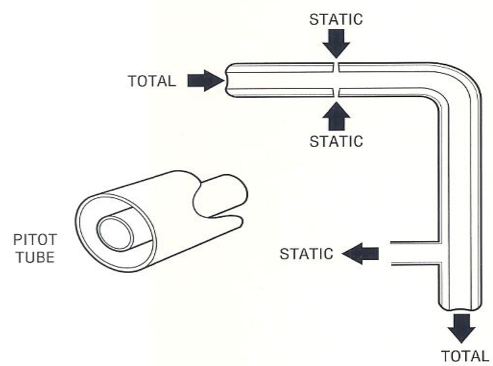
QUICK NOTE

Other instruments commonly used to measure and balance airflow in residential systems are the anemometer and velometer. (Refer to Section 1, Items 14 and 15.)

Measuring Duct Air Pressures with an Inclined Manometer and Pitot Tube

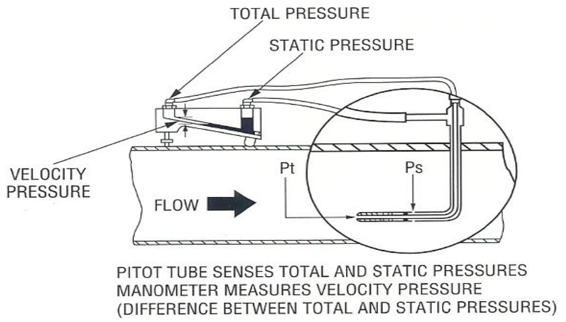
The pitot tube (Figure SP-16-2) is a tube within a tube. The standard pitot tube used for taking measurements in ducts 8 inches and larger has a 5/16-inch outer tube with eight equally spaced 0.04-inch diameter holes used to sense static pressure. For measurements in ducts smaller than 8 inches, use of pocket-size pitot tubes with a 1/8-inch outer tube and four equally spaced 0.04-inch diameter holes are recommended. The pitot tube consists of an impact tube which receives the total pressure. The impact tube is fastened concentrically inside a second tube of slightly larger diameter which receives static pressure input from the radial sensing holes around the tip. The space between the inner and outer tubes permits the static pressure that enters the sensing holes to pass through the tube and exit at a side connection at the opposite end. The total pressure of the duct system enters the tip of the pitot tube as it faces the airstream, then passes through the inner tube and out the bottom output connection.

▼ Figure SP-16-2.
Pitot Tube



The pitot tube is connected to an inclined manometer as shown in Figure SP-16-3. The total pressure output is connected to the left side of the manometer, while the static pressure output is connected to the right side. Pressure forces on each side of the manometer fluid column cancel each other out, indicating velocity pressure measured in inches of water column (in. w.c.).

▼ Figure SP-16-3.
Manometer and Pitot Tube Connected to Measure Velocity Pressure



The following steps are necessary to ensure a correct reading:

- The tip of the pitot tube inside the duct must be pointed directly into the airstream. The pitot tube inside the ductwork is correctly positioned when the static pressure outlet connection visible outside the duct is pointed in the direction of airflow. Also, the pressure indication will be at its maximum.
- Make sure that the hose connections to the manometer are not kinked or leaking.
- Mount, zero or calibrate, and operate the manometer as directed in the manufacturer's instructions.
- To obtain accurate velocity readings through a duct, take several readings across the duct cross-section (traverse readings) and average the readings.

How to Take Traverse Readings

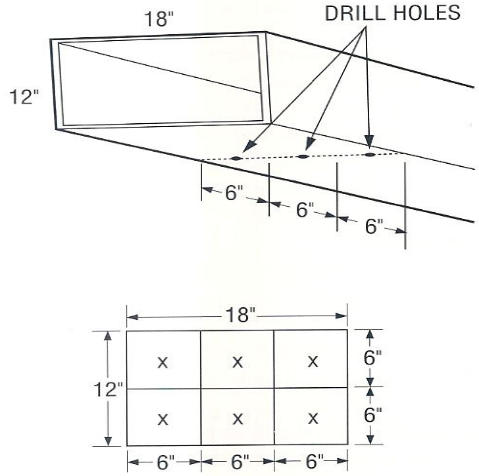
The velocity of the airstream is not uniform across the cross-section of a duct. Friction slows the air moving close to the walls, so the velocity is greater in the center of the duct. To obtain the average total velocity in ducts, a series of velocity pressure readings must be taken at points of equal area. A pattern of pitot tube sensing points across the duct cross-section, called a traverse, must be made.

Figure SP-16-4 shows an example of the traverse for a rectangular section of 12-inch by 18-inch ductwork. As shown, the longest dimension (18 inches) is divided into 6-inch increments and a hole is drilled in the center of each increment. The goal is to take a velocity pressure measurement at the center of each 6-inch square marked "X" on the figure. For this duct, 6 measurements are needed. Regardless of the duct size, 6 inches should be the maximum distance between measurement points. The pitot tube is marked with a graduated height scale to aid in positioning the tube in the duct to the desired depth.

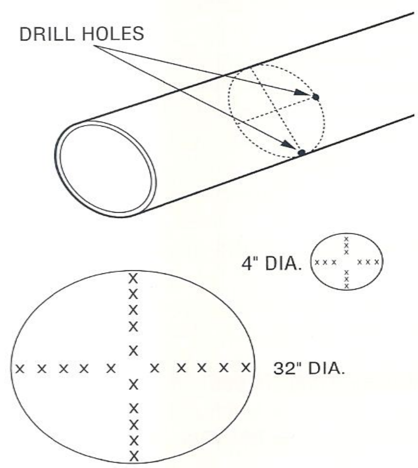
The location of the pitot tube in the traverse is not as easy to determine on round ductwork. As shown in Figure SP-16-5, two holes are drilled at right angles (90 degrees) to each other.

The number of pitot tube measurements required depends on the duct diameter. The larger the duct, the more measurements that must be made to ensure a good average. A 4-inch diameter duct requires six measurements on each diameter, while a 32-inch diameter duct would require 10 measurements on each diameter. The depth that the pitot tube is inserted for each measurement depends on the diameter of the duct. A tabulation of the required measurement depths used for different diameter ducts is given in the detailed procedure at the end of this section.

▼ Figure SP-16-4.
Example of Traverse Readings in a Rectangular Duct

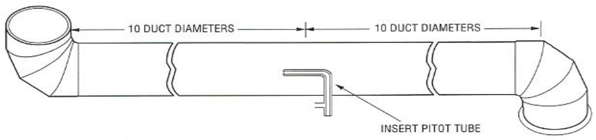


▼ Figure SP-16-5.
How to Take Traverse Readings in a Round Duct



Because accurate measurements cannot be taken in a turbulent airstream, the pitot tube should be inserted at least ten times the diameter of the duct downstream from elbows, bends, or other obstructions which can cause turbulence (Figure SP-16-6).

Figure SP-16-6.
Pitot Tube Location to Avoid Measurement of a Turbulent Airstream



PITOT TUBE LOCATION

In small ducts, or where taking a traverse is impossible, an approximate velocity pressure reading can be obtained by placing the pitot tube in the center of the duct and making a single measurement. Measure the velocity and multiply the reading by 90%. If this method is used, the measurement must be taken where there is the least amount of turbulence in the airstream.

Calculating Airflow

The method for calculating airflow, including a typical example, is provided in the detailed procedure at the end of this section and briefly outlined here.

First, a location in the duct system is selected where the full airflow can be sensed and turbulence is at a minimum. The duct is then divided into equal areas of no more than 6 inches on center, and a hole for the pitot tube is drilled at the center of each area. The manometer is calibrated, then the pitot tube is inserted into the holes and the manometer readings taken and recorded for each point in the traverse.

Each of the recorded velocity pressure readings (in. w.c.) must then be converted to velocity in feet per minute (FPM). One method to do this is to use a chart that directly converts the value of measured velocity pressure (in. w.c.) to velocity in feet per minute (FPM). A velocity chart is provided in the detailed procedure at the end of this section. Another method is to calculate velocity using an electronic calculator and the velocity formula: Velocity equals 4,005 times the square root of the velocity pressure (Figure SP-16-7). Stated mathematically:

$$\textbf{Velocity (FPM)} = 4{,}005\sqrt{\textbf{Velocity Pressure (in. w.c.)}}$$

For example, a pitot velocity pressure reading of .04 in. w.c. equals a velocity of about 800 FPM, calculated as follows:

$$\begin{aligned}\textbf{Velocity (FPM)} &= 4{,}005\sqrt{.04}\\ &= 4{,}005 \times .2\\ &= 801 \text{ FPM} = 800 \text{ FPM (rounded)}\end{aligned}$$

Figure SP-16-7.
How to Calculate Air Velocity

OUR PITOT READINGS ARE	SO DO THIS		TO GET FT./MIN.
.04	$4{,}005\sqrt{.04}$	=	800
.05	$4{,}005\sqrt{.05}$	=	895
.06	$4{,}005\sqrt{.06}$	=	980
.07	$4{,}005\sqrt{.07}$	=	1,060
.05	$4{,}005\sqrt{.05}$	=	895
.06	$4{,}005\sqrt{.06}$	=	980
			5,610

THEN AVERAGE

$$\boxed{\frac{5{,}610}{6} = 935 \text{ FT./MIN.}}$$

After the velocity for each reading is calculated, the velocity values are averaged. Next, the cross-sectional area of the duct must be determined. For a rectangular duct, the area in square feet is equal to the duct length in inches times the width of the duct in inches divided by 144 square inches. Stated mathematically:

$$\textbf{Area (ft.}^2\textbf{)} = \frac{\textbf{Length (in.) x Width (in.)}}{\textbf{144 in.}^2}$$

For example, a rectangular duct that is 24 inches by 8 inches has an area of 1.3 square feet, calculated as follows:

$$\textbf{Area (ft.}^2\textbf{)} = \frac{\textbf{Length (in.) x Width (in.)}}{\textbf{144 in.}^2}$$

$$= \frac{24 \times 8}{144} = \frac{192}{144} = 1.333 \text{ ft.}^2$$

$$= 1.3 \text{ ft.}^2 \text{ (rounded)}$$

When working with a round duct, the area can be determined in either of two ways. One way is to use a chart that directly converts round duct diameters to area in square feet. A velocity chart is provided in the detailed procedure at the end of this section.

Another way is to calculate the area. The area of a round duct in square feet is equal to Pi (3.1416) times the diameter squared all divided by 4 times 144. Stated mathematically:

$$\textbf{Area ft.}^2 = \frac{\pi D^2}{4 \times 144}$$

For example, the area of a 16-inch diameter round duct is 1.4 square feet, calculated as follows:

$$\text{Area ft.}^2 = \frac{\pi D^2}{4 \times 144}$$

$$= \frac{3.1416 \times 16^2}{4 \times 144}$$

$$= \frac{3.1416 \times 256}{4 \times 144}$$

$$= \frac{804.25}{576} = 1.396 \text{ ft.}^2$$

$$= 1.4 \text{ ft.}^2 \text{ (rounded)}$$

The last step in the procedure is to calculate the airflow in CFM. Using the area of the duct and the velocity, the airflow in CFM is found by multiplying the area of the duct (ft.^{2}) times the air velocity (ft./min.). Stated mathematically:

$$\text{CFM} = \text{Area (ft.}^2) \times \text{Velocity (ft./min.)}$$

For example, using the rectangular duct area of 1.3 ft.^{2} and the velocity of 800 FPM, the quantity of air is 1,040 CFM, calculated as follows:

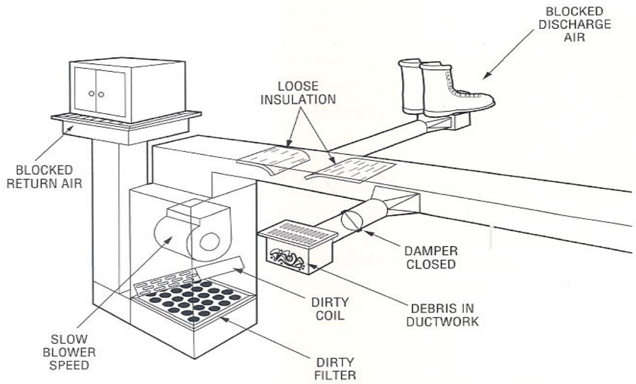
$$\text{CFM} = \text{Area (ft.}^2) \times \text{Velocity (ft./min.)}$$
$$= 1.3 \times 800$$
$$= 1{,}040 \text{ CFM}$$

Causes of Insufficient Air

Insufficient airflow causes a loss of efficiency and performance for the entire system and must be corrected. If the quantity of airflow is less than specified, check for:

- Dirty coil, dirty fan blades, or dirty air filter (Figure SP-16-8).
- Inlet air blocked.

▼ Figure SP-16-8.
Causes of Insufficient Air



- Discharge air blocked or dampers closed.
- Restrictions in the ductwork.
- Fan speed too low or fan rotating in the wrong direction.

Safety Precautions

When making measurements and/or repairs on equipment, always follow the precautions listed below.

- Read and follow all safety instructions given in the manufacturer's installation instructions and/or service manual for the specific system being serviced.
- Always turn off the main power to a system before making any repairs. There may be more than one disconnect switch. If applicable, turn off the accessory power. Tag and lock out all disconnect switches.
- Always remove rings, watches, and other jewelry to lessen the chance of electrical shock.
- Do not override or bypass safety controls such as electrical interlocks, unless directed by the manufacturer's service literature.

PROCEDURE

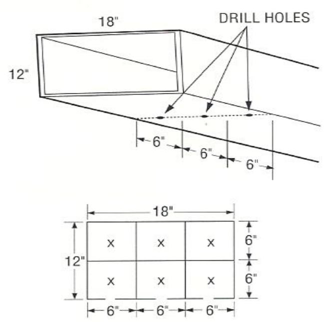
Before performing the following troubleshooting procedure, refer to the manufacturer's installation instructions and/or service manual for specific instructions about the system being serviced. If differences exist between our procedure and the manufacturer's instructions, always follow the manufacturer's instructions. Review the safety instructions and precautions given in this procedure and in Section 2 of this manual.

SP-16. INSTRUMENT OR DEVICE REQUIRED	REFERENCE
Inclined manometer or electronic manometer	Section 1, Item 18
Pitot tube	Section 1, Item 18
Electric drill and bits – used to drill pitot tube measurement holes in the air distribution system ducts	N/A
Plastic plugs or duct tape to seal holes drilled in duct	N/A

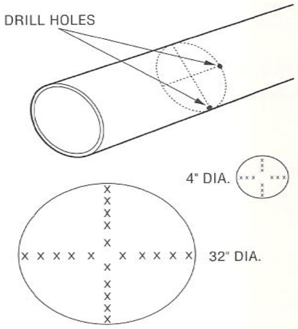
SP-16. AIRFLOW MEASUREMENT – VELOCITY PRESSURE METHOD (STEPS 1 THROUGH 4)

Step	Expected Result/Action
NOTE: Since the pressure taps installed in a duct can be used for both static and velocity pressure readings, the location along the length of duct must be carefully considered. Taps should be at a location where air turbulence is at a minimum. 1. Drill pitot-size access holes in the duct to enable traverse readings of velocity pressure across the duct. If taking measurements on a rectangular duct, divide the longest dimension into 6-inch increments and drill a hole in the center of each increment as shown in Figure SP-16-9, View A. For a round duct, drill two holes at right angles to each other as shown in Figure SP-16-9, View B.	Pitot tube access holes used to make traverse measurements drilled in duct. **For our example assume:** *Pitot measurement holes are drilled in a 12-inch x 18-inch rectangular duct as shown in Figure SP-16-9, View A.*
2. Turn power on. Set the unit thermostat so that the blower runs continuously during the measurement. Make sure that all supply and return registers are open and unrestricted.	Unit running and prepared for initial measurement.
3. Mount and level an inclined manometer near the traverse measurement holes. Zero the manometer reading. Using tubing, connect the pitot tube total pressure output and static pressure output to the manometer high-pressure and low-pressure ports, respectively, as shown in Figure SP-16-9, View C.	Manometer leveled and set up for velocity pressure measurements.
NOTE: To aid in getting consistent readings, put tape on the pitot tube at the required insertion depth increments, such as 4 inches, 8 inches, 12 inches, etc. 4. Insert the pitot tube into the first pitot access hole drilled in the duct and at the depth for the first measurement (center of first 6-inch increment). Make sure the pitot tube is directly facing the airstream. This is the position that gives the maximum velocity pressure reading on the manometer. Record the reading. At each of the remaining pitot tube access holes, take the required traverse measurements and record readings. For a round duct, refer to Figure SP-16-10 to identify the number of measurements needed, and their depth, based on the diameter of the duct. Take measurements as necessary.	All velocity pressure readings taken. **For our example assume:** *The measured velocity pressures are .04, .05, .06, .07, .05, and .06 in. w.c., as shown in Figure SP-16-9, View D.*

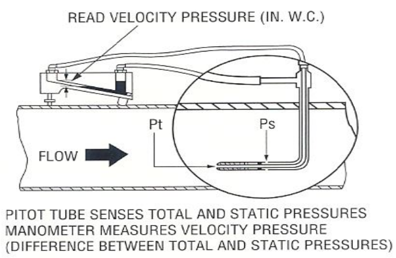
Figure SP-16-9.
Airflow Measurement — Traverse Readings



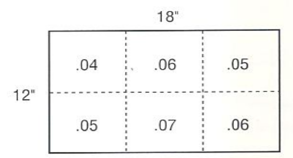
A. TRAVERSE FOR RECTANGULAR DUCTS



B. TRAVERSE FOR ROUND DUCTS



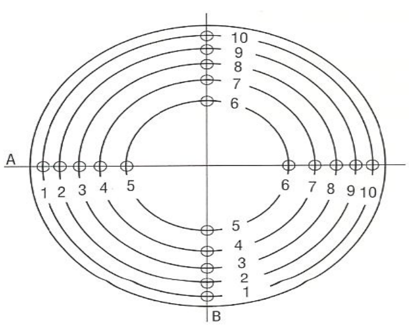
C. MANOMETER CONNECTIONS



D. EXAMPLE VELOCITY PRESSURE READINGS

Figure SP-16-10.
Pitot Tube Insert Depths for Traverse Readings in Round Duct

DEPTHS TO INSERT PITOT TUBE FOR TRAVERSE READINGS IN ROUND DUCTWORK



DUCT DIAMETER (inches)	POINTS IN ONE DIAMETER	DISTANCE FROM INSIDE OF DUCT (POINT A AND B) TO PITOT TUBE TIP									
		1	2	3	4	5	6	7	8	9	10
4	6	-	-	1/4	5/8	1-1/4	2-7/8	3-1/2	3-7/8	-	-
6	6	-	-	1/4	7/8	1-3/4	4-1/4	5-1/8	5-3/4	-	-
8	6	-	-	3/8	1-1/4	2-3/8	5-5/8	6-7/8	7-3/4	-	-
9	6	-	-	3/8	1-3/8	2-3/4	6-3/8	7-3/4	8-5/8	-	-
10	8	-	3/8	1-1/8	2	3-1/4	6-3/4	8-1/8	9	9-3/4	-
12	8	-	3/8	1-1/4	2	3-7/8	8-1/8	9	10-3/4	11-5/8	-
14	10	3/8	1-1/8	2-1/8	3-1/4	4-3/4	9-1/4	10-7/8	12	12-7/8	13-5/8
16	10	1/2	1-3/8	2-3/8	3-6/8	5-1/2	10-1/2	12-3/8	13-5/8	14-3/4	15-5/8
18	10	1/2	1-1/2	2-5/8	4-1/8	6-1/8	11-7/8	14	15-3/8	16-1/2	17-5/8
20	10	1/2	1-5/8	3	4-1/2	6-7/8	13-1/4	15-1/2	17-1/8	18-3/8	19-1/2
24	10	5/8	2	3-1/2	5-1/2	8-1/4	15-7/8	18-1/2	20-1/2	22-1/8	22-3/8
28	10	3/4	2-1/4	4-1/8	6-3/8	9-5/8	18-1/2	21-3/4	24	25-3/4	27-1/4
32	10	7/8	2-5/8	4-3/4	7-1/4	11	21-1/8	24-3/4	27-1/4	29-3/8	31-3/8

For other duct diameters, use the following table:

POINTS IN ONE DIAMETER	CONSTANTS TO BE MULTIPLIED BY DUCT DIAMETER FOR DISTANCES OF PITOT TUBE TIP FROM INSIDE OF DUCT (POINT A AND B)									
	1	2	3	4	5	6	7	8	9	10
6	-	-	.0435	.1465	.2959	.7041	.8535	.9564	-	-
8	-	.0323	.1047	.1938	.3232	.6768	.8052	.8953	.9677	-
10	.0257	.0817	.1465	.2262	.3419	.6581	.7738	.8535	.9133	.9743

SP-16. AIRFLOW MEASUREMENT – VELOCITY PRESSURE METHOD (STEPS 5 THROUGH 7)

Step	Expected Result/Action
5. Using the velocity pressure chart shown in Figure SP-16-11, convert each recorded velocity pressure reading to its equivalent airflow velocity in feet per minute (FPM). Add all the values for velocity, then calculate the average velocity within the duct.	All velocity pressure readings (in. w.c.) are converted to velocity (FPM) and the average velocity is calculated. **For our example:** *Pitot Velocity Pressure Reading (in. w.c.)* — *Velocity (FPM)* *.04* — *800* *.05* — *895* *.06* — *980* *.07* — *1,060* *.05* — *895* *.06* — *980* 5,610 *5,610 ÷ 6 = an average velocity of 935 FPM.*
6. Determine the area of the duct in square feet ($ft.^2$). For a rectangular duct measure the length (l) and width (w) in inches, then calculate the area using the formula below. $\text{Rectangular Duct Area ft.}^2 = \frac{\text{Length (in.)} \times \text{Width (in.)}}{144 \text{ in.}^2}$ If working with a round duct, measure the diameter, then refer to the chart in Figure SP-16-11 for a conversion of round duct diameters to area.	Area of duct in square feet is known. **For our example:** $\text{Area ft.}^2 = \frac{\text{Length (in.)} \times \text{Width (in.)}}{144 \text{ in.}^2}$ $= \frac{18 \times 12}{144} = 1.5 \text{ ft.}^2$
7. Using the values for average velocity and the area of the duct, calculate the airflow in cubic feet per minute (CFM) using the formula below. $\text{CFM} = \text{Area (ft.}^2) \times \text{Velocity (FPM)}$	Airflow in the duct is known. **For our example:** $\text{CFM} = \text{Area (ft.}^2) \times \text{Velocity (FPM)}$ $= 1.5 \times 935 = 1{,}403 \text{ CFM}$ If the quantity of airflow is less than specified, check for: • Dirty coil, dirty fan blades, or dirty air filter. • Inlet air blocked. • Discharge air blocked or dampers closed. • Restrictions in the ductwork. • Fan speed too low or fan rotating in the wrong direction.

Figure SP-16-11.
Velocity Pressure and Round Duct Conversion Data

VELOCITY PRESSURES

VELOCITY PRESSURE (in. w.c.)	VELOCITY (ft./min.)	VELOCITY PRESSURE (in. w.c.)	VELOCITY (ft./min.)	VELOCITY PRESSURE (in. w.c.)	VELOCITY (ft./min.)	VELOCITY PRESSURE (in. w.c.)	VELOCITY (ft./min.)
.01	400	.29	2150	.58	3050	1.28	4530
.02	565	.30	2190	.60	3100	1.32	4600
.03	695	.31	2230	.62	3150	1.36	4670
.04	800	.32	2260	.64	3200	1.40	4730
.05	895	.33	2300	.66	3250	1.44	4800
.06	980	.34	2330	.68	3300	1.48	4870
.07	1060	.35	2370	.70	3350	1.52	4930
.08	1130	.36	2400	.72	3390	1.56	5000
.09	1200	.37	2440	.74	3440	1.60	5060
.10	1270	.38	2470	.76	3490	1.64	5120
.11	1330	.39	2500	.78	3530	1.68	5190
.12	1390	.40	2530	.80	3580	1.72	5250
.13	1440	.41	2560	.82	3620	1.76	5310
.14	1500	.42	2590	.84	3670	1.80	5370
.15	1550	.43	2620	.86	3710	1.84	5430
.16	1600	.44	2650	.88	3750	1.88	5490
.17	1650	.45	2680	.90	3790	1.92	5550
.18	1700	.46	2710	.92	3840	1.96	5600
.19	1740	.47	2740	.94	3880	2.00	5660
.20	1790	.48	2770	.96	3920	2.04	5710
.21	1830	.49	2800	.98	3960	2.08	5770
.22	1880	.50	2830	1.00	4000	2.12	5830
.23	1920	.51	2860	1.04	4080	2.16	5880
.24	1960	.52	2880	1.08	4160	2.20	5940
.25	2000	.53	2910	1.12	4230	2.24	5990
.26	2040	.54	2940	1.16	4310	2.28	6040
.27	2080	.55	2970	1.20	4380	–	–
.28	2120	.56	2990	1.24	4460	–	–

NOTES: 1. Data for standard air (29.92 in. Hg and 70° F)
2. Data derived from the following equation: $V = 4{,}005 \sqrt{V_p}$

CONVERSION OF DUCT DIAMETER TO AREA

Duct Diameter (inches)	Area (square feet)
4	.0872
5	.1363
6	.1962
7	.2671
8	.3488
9	.4415
10	.5451
11	.6596
12	.7850
14	1.0685
16	1.3955
18	1.7662
20	2.1805
22	2.6384
24	3.1399
26	3.6851
28	4.2738
30	4.9062
32	5.5821
34	6.3017
36	7.0648

AIRFLOW MEASUREMENT – PRESSURE DROP METHOD

Purpose – This procedure describes another method for calculating the quantity of airflow being delivered in a typical split cooling or heat pump system. Airflow measurements are normally made after the initial installation of a system, when balancing the system airflow, or when troubleshooting.

Airflow Problems

Too much air across the evaporator coil results in poor humidity control. If air moves too fast across the evaporator, moisture is not effectively removed. To correct the problem of too much air, decrease the blower speed.

While too much air can be a problem, the problem of too little air is more widely seen. The usual symptom is a frozen evaporator coil. Refrigerant flooding can result from low airflow and this in turn may cause compressor failures. To correct the problem of too little air, increase blower speed. However, before adjusting the blower speed, always make sure that:

- The system air filter is clean.
- The blower wheel is clean.
- The evaporator or fan coil is clean.
- There are no loose or worn belts on belt-driven blowers, and that the belt tension is correct.
- The blower is rotating in the right direction.

QUICK NOTE

To maintain proper airflow, it is important that the evaporator coil is clean. Most have an inspection port that allows you to inspect the inside of the coil for accumulated dirt. If cleaning is necessary, use a mild detergent and water solution to clean the coil, then rinse well with clear water.

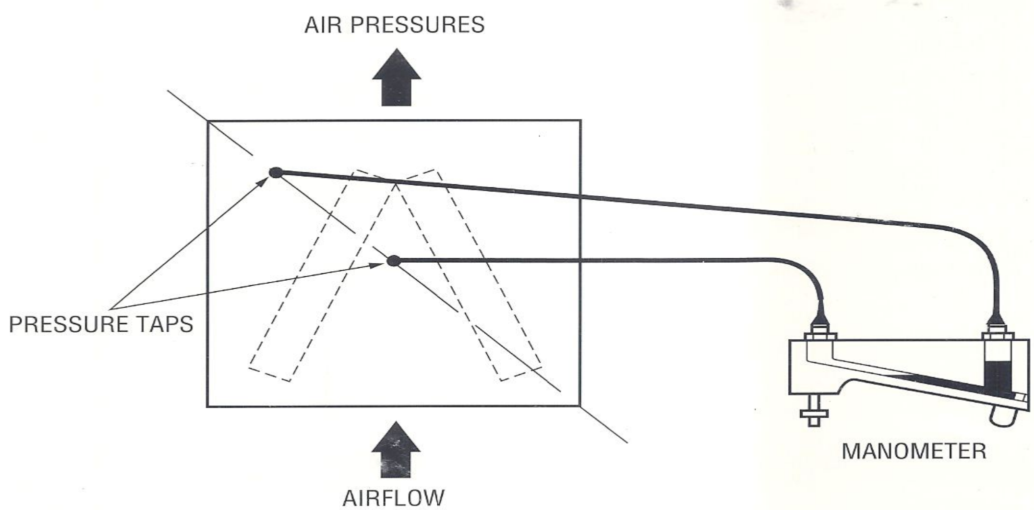
Airflow Measurement

The procedure for determining airflow described here uses a manufacturer's performance data chart to convert the static pressure drop measured across the system evaporator coil to CFM. A detailed procedure for determining airflow using the pressure drop method is provided later in this section and a brief overview is given here.

First, holes are drilled in the duct on either side of the coil, with the exact location being determined by the type of coil used: A-coil or slab (slope) coil. *Be careful when drilling these holes to prevent puncturing the refrigerant circuit.*

Next, 1/4-inch diameter tubes are inserted into the holes to a depth of about 2 inches. The open ends of the tubes are connected to an inclined manometer, with the tube in the supply side of the duct connected to the lower end of the manometer

▼ Figure SP-17-1.
Evaporator Coil (A-Coil) Static Pressure Measurement



and the tube in the return side of the duct connected to the higher end of the manometer. For measurements in residential systems where low pressure levels exist, a manometer with a scale ranging between 0.1 and 1.0 inches of water column will give the most accurate readings. Make sure that the manometer is leveled and calibrated. The manometer (Item 18) is described in detail in Section 1, with additional information provided in Service Procedure SP-16.

With the unit blower running, the manometer will indicate the static pressure drop across the coil in inches of water column. This value of pressure drop is then compared to the manufacturer's performance data charts for the unit to find the associated quantity of airflow in CFM.

Safety Precautions

When making measurements and/or repairs on equipment, always follow the precautions listed below.

- Read and follow all safety instructions given in the manufacturer's installation instructions and/or service manual for the specific system being serviced.
- Always turn off the main power to a system before making any repairs. There may be more than one disconnect switch. If applicable, turn off the accessory power. Tag and lock out all disconnect switches.
- Always remove rings, watches, and other jewelry to lessen the chance of electrical shock.
- Do not override or bypass safety controls such as electrical interlocks, unless directed by the manufacturer's service literature.

PROCEDURE

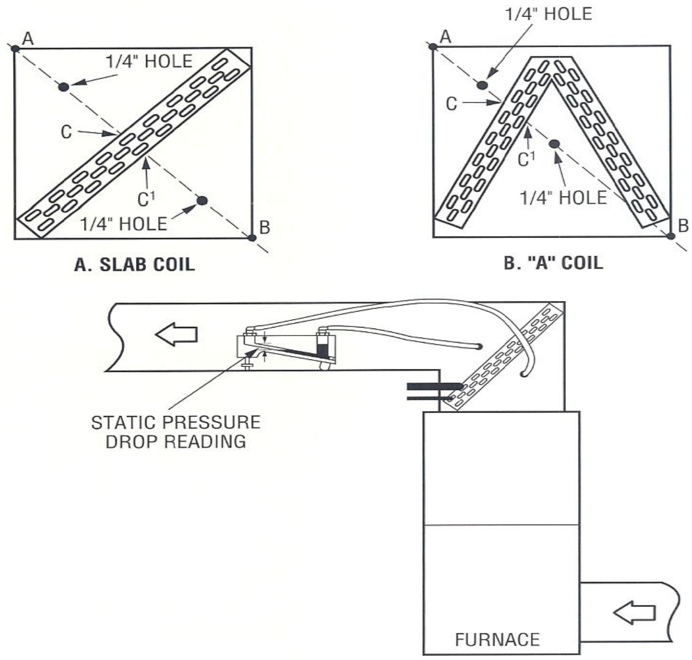
Before performing the following troubleshooting procedure, refer to the manufacturer's installation instructions and/or service manual for specific instructions about the system being serviced. If differences exist between our procedure and the manufacturer's instructions, always follow the manufacturer's instructions. Review the safety instructions and precautions given in this procedure and in Section 2 of this manual.

SP-17. INSTRUMENT OR DEVICE REQUIRED	REFERENCE
Inclined manometer	Section 1, Item 18
Two 1/4-inch diameter tubes – used to connect manometer to pressure taps in the duct (Keep the length of the tubes as short as possible)	N/A
Electric drill and bits – used to drill pitot tube measurement holes in the air distribution system ducts	N/A
Plastic plugs or duct tape to seal holes drilled in duct	N/A

SP-17. AIRFLOW MEASUREMENT – PRESSURE DROP METHOD

Step	Expected Result/Action
CAUTION ➡ ***Be careful not to drill into nearby piping or the coil.***  1. Drill 1/4-inch holes on either side of the evaporator coil per the manufacturer's instructions, or as shown in Figure SP-17-2, View A or B.	Pressure tap holes drilled in the ductwork in preparation for measurement.
2. Turn on power to the system. Set the thermostat so that the compressor and system blower run continuously during the measurement.	Compressor on and blower running continuously.
3. Level the inclined manometer. Insert a 1/4-inch tube about 1 to 2 inches into each hole. Seal the tubes at the insertion points. Connect the open ends of the tubes to the manometer as shown in Figure SP-17-2, View C. The tube from the hole at the output side of the coil should be connected to the lower end of the inclined manometer.	Manometer connected for measurement.
4. Read and record the static pressure drop across the coil.	The static pressure drop across the coil is known. **For our example assume:** *The static pressure drop measured for a wet coil (compressor operating) is .05 inches of water column (in. w.c.)*
NOTE: A wet coil occurs during compressor operation as the coil removes humidity from the air. A dry coil occurs when there is no compressor operation. 5. As applicable, refer to the manufacturer's product performance data chart for the wet or dry coil CFM. Using the manufacturer's chart (Figure SP-17-2, View D), convert the measured pressure drop to airflow in cubic feet per minute (CFM).	Airflow in CFM is known. **For our example assume:** *We will use the pressure drop chart for a model 30 coil as shown in Figure SP-17-2, View D. For this model, a wet coil static pressure drop reading of .05 in. w.c. converts to an airflow of 1,300 CFM.* If the quantity of airflow is less than specified, check for: • Dirty coil or dirty air filter. • Discharge air blocked or dampers closed. • Restrictions in the ductwork. • Fan speed too low or fan rotating in the wrong direction.

▼ **Figure SP-17-2.**
Airflow Measurement — Pressure Drop Method



A. SLAB COIL

B. "A" COIL

C. MANOMETER CONNECTION

PERFORMANCE DATA

COIL STATIC PRESSURE DROP (in. w.c.)

UNIT MODEL	AIR QUANTITY (CFM)								
	300	**400**	**500**	**600**	**700**	**800**	**900**	**1000**	**1100**
024	–	–	.08	.14	.21	.28	.36	.16	.28
	–	–	.07	.11	.15	.20	.25	.10	.24
030	**700**	**800**	**900**	**1000**	**1100**	**1200**	**1300**	**1400**	**1500**
	.12	.17	.22	.28	.34	.42	.50	–	–
	.09	.12	.16	.20	.24	.28	.33	–	–
036	–	.09	.13	.17	.21	.25	.30	.35	.42
	–	.07	.10	.12	.15	.18	.21	.25	.28
042	**1000**	**1100**	**1200**	**1300**	**1400**	**1500**	**1600**	**1700**	**1800**
	.10	.13	.17	.20	.24	.28	.32	.36	.42
	.08	.10	.13	.15	.17	.20	.22	.25	.28
048	**1200**	**1300**	**1400**	**1500**	**1600**	**1700**	**1800**	**1900**	**2000**
	.17	.20	.24	.28	.32	.36	.42	.47	.52
	.13	.15	.17	.20	.22	.25	.28	.32	.34
060	**1600**	**1700**	**1800**	**1900**	**2000**	**2100**	**2200**	**2300**	**2500**
	.30	.34	.38	.42	.46	.51	.56	.62	.75
	.20	.22	.24	.27	.30	.33	.36	.40	.50

☐ = Wet Coil
▩ = Dry Coil

D. PRESSURE DROP CHART

COOLING SYSTEM CAPACITY MEASUREMENT

Purpose – This procedure describes how to calculate the capacity of a cooling system using the property of air called *enthalpy*. Enthalpy is the total heat content of the air and water vapor mixture as determined from a predetermined base or point. Enthalpy is measured using a wet bulb thermometer and is expressed in Btu's per pound.

When dealing with heat, such as in heating, humidification, or cooling, the change in enthalpy can be used to calculate how many Btu's per hour the temperature of air has been raised or lowered across a device. This is useful when you need to determine the capacity of a system.

Enthalpy

Enthalpy can be found by using a psychrometric chart (Figure SP-18-1) and a measured value for wet bulb temperature. The measured value of wet bulb temperature is found on the chart's wet bulb temperature line, then a line is plotted from this point out to the enthalpy scale.

▼ Figure SP-18-2.
Plot of Wet Bulb Temperature to Enthalpy on Psychrometric Chart

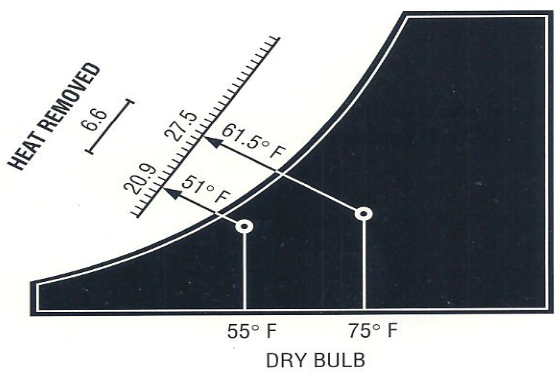


Figure SP-18-2 shows an example of dry bulb and wet bulb temperatures measured across a cooling coil. For the example, the wet bulb temperatures of 51° F and 61.5° F are shown plotted to their corresponding enthalpy values of 20.9 and 27.5 Btu's per pound of air. The enthalpy scale is shown at the extension of the wet bulb temperature lines and the values for enthalpy are read directly where the extended lines intersect the scale. The total difference in heat content (change in enthalpy) is the difference between the two readings in Btu/lb. of air. As shown in the example, the difference in enthalpy between the two readings is 6.6 Btu's per pound of air. This value represents the heat removed by the cooling coil.

Enthalpy tables are also available to provide a direct conversion between values of wet bulb temperatures and enthalpy. Their use eliminates the need to use a psychrometric chart to plot values for enthalpy. A typical enthalpy table is found in the detailed procedure at the end of this section.

Procedure for Determining Capacity Using Enthalpy

Using the value for the change in enthalpy (heat loss) and the value for the airstream velocity in cubic feet per minute, the capacity for the equipment can be calculated. The formula for calculating capacity, called the *total heat formula*, is written: Capacity equals 4.5 times the CFM times the change in enthalpy. The 4.5 is a factor derived by multiplying the specific density of standard air times 60 minutes per hour (.075 x 60 = 4.5). Stated mathematically:

$$\textbf{Total Heat (Btu/Hr.)} = 4.5 \times \text{CFM} \times \Delta h$$

Where:

4.5 is a constant
CFM = Velocity of airflow in cubic feet per minute
Δh = Change in enthalpy (Btu/lb.)

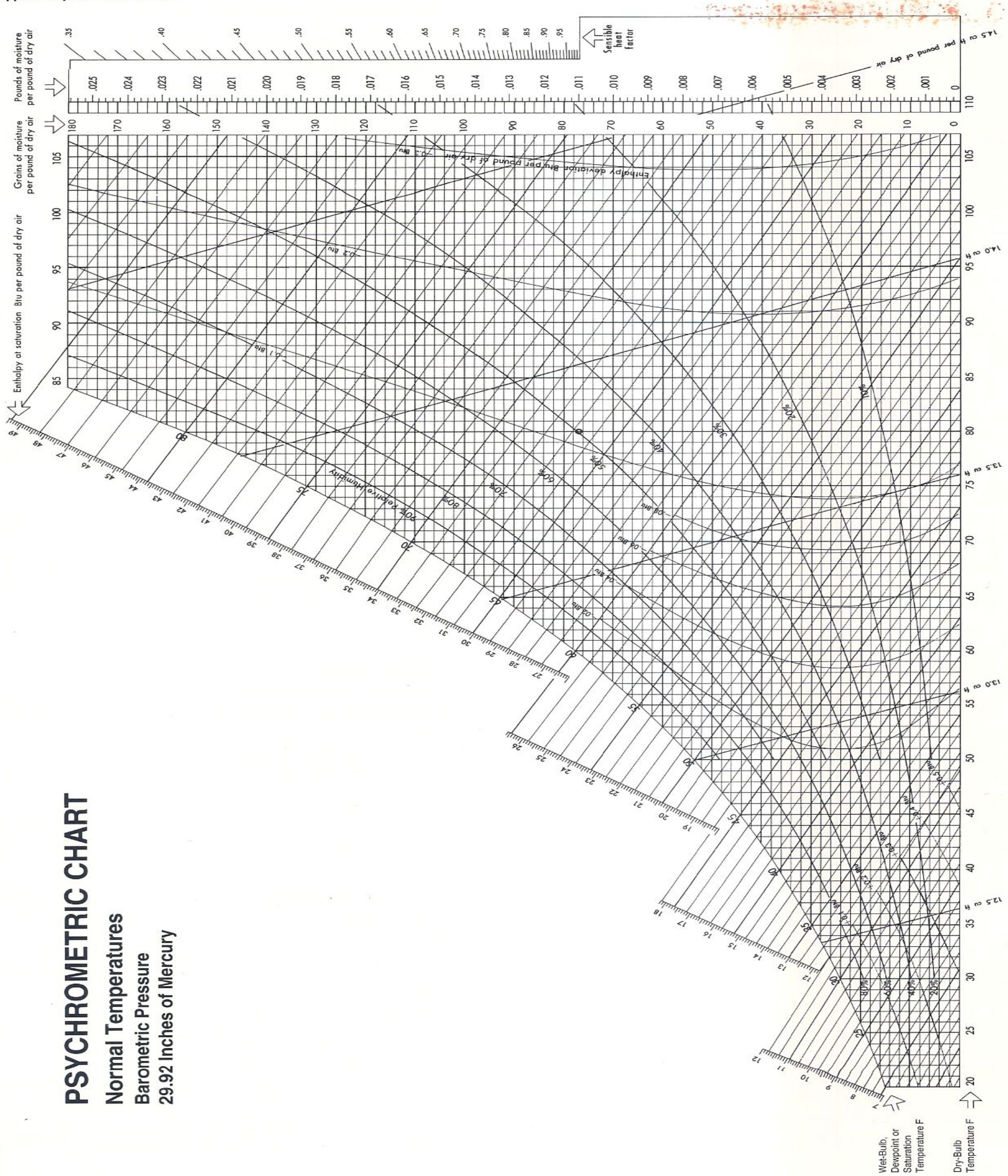
Capacity Problems

Low capacity results from the evaporator's inability to absorb the heat load. Heat from the space to be cooled must be transferred to the evaporator and into the refrigerant in order for cooling to occur.

Low capacity can be caused by too low a heat load entering the evaporator, or a low refrigerant charge in the system. An airflow problem may exist that prevents the transfer of heat from the air to the refrigerant in the evaporator. Or, the airflow may be restricted by dirty filters, a dirty coil, or closed dampers.

If all the system operating parameters are within limits and the customer still complains about the cooling capacity, the problem may be that the unit is undersized.

▼ Figure SP-18-1.
Typical Psychrometric Chart



PROCEDURE

Before performing the following troubleshooting procedure, refer to the manufacturer's installation instructions and/or service manual for specific instructions about the system being serviced. If differences exist between our procedure and the manufacturer's instructions, always follow the manufacturer's instructions. Review the safety instructions and precautions given in this procedure and in Section 2 of this manual.

SP-18. INSTRUMENT OR DEVICE REQUIRED	REFERENCE
Psychrometer or electronic thermometer	Section 1, Items 2 and 3

SP-18. COOLING SYSTEM CAPACITY MEASUREMENT

Step	Expected Result/Action
1. Using a psychrometer or electronic thermometer, measure the wet bulb temperatures of the air entering and leaving the unit cooling coil.	**For our example assume:** *The wet bulb temperature entering the coil is 61.5° F and leaving the coil it is 51° F.*
2. Using a psychrometric chart or conversion table (Figure SP-18-3), find the values for enthalpy that correspond to the measured wet bulb temperatures of the air entering and leaving the unit cooling coil.	**For our example assume:** *The conversion table (Figure SP-18-3) is used. It shows that the entering wet bulb temperature of 61.5° F corresponds to an enthalpy value of 27.5 Btu/lb.; the leaving wet bulb temperature of 51° F corresponds to an enthalpy value of 20.9 Btu/lb.*
3. Calculate the difference in enthalpy.	**For our example assume:** *The difference in enthalpy is 6.6 Btu/lb. as shown below.* *27.5 - 20.9 = 6.6 Btu/lb.*
4. Calculate the capacity using the total heat formula: Total Heat (Btu/Hr.) = 4.5 x CFM x Δh Where: 4.5 is a constant CFM = Velocity of airflow in cubic feet per minute Δh = Change in enthalpy (Btu/lb.)	**For our example assume:** *1,000 CFM of air is being circulated over the coil, which removes this heat, then 29,700 Btuh is removed. In other words, the coil provides 29,700 Btuh of total cooling capacity.* *Total Heat (Btu/Hr.) = 4.5 x CFM x Δh* *= 4.5 x 1,000 x 6.6* *= 29,700 Btuh* If the capacity is low, check for: • Low heat load entering evaporator • Low refrigerant charge • Dirty filters • Dirty coil • Closed dampers • Undersized unit

Figure SP-18-3.
Wet Bulb Temperature to Enthalpy Conversion Table

ENTHALPY OF MOIST AIR AT SATURATION (SEA LEVEL)
(BTU's PER POUND OF DRY AIR)

Wet Bulb (F)	.0	.1	.2	.3	.4	.5	.6	.7	.8	.9	Wet Bulb (F)
40	15.23	15.28	15.32	15.37	15.42	15.47	15.51	15.56	15.61	15.65	40
41	15.70	15.75	15.80	15.84	15.89	15.94	15.99	16.04	16.08	16.13	41
42	16.17	16.22	16.27	16.32	16.37	16.42	16.46	16.51	16.56	16.61	42
43	16.66	16.71	16.76	16.80	16.85	16.90	16.95	17.00	17.05	17.10	43
44	17.15	17.20	17.25	17.30	17.35	17.40	17.45	17.50	17.55	17.60	44
45	17.65	17.70	17.75	17.80	17.85	17.91	17.96	18.01	18.06	18.11	45
46	18.16	18.21	18.26	18.32	18.37	18.42	18.47	18.52	18.58	18.63	46
47	18.68	18.73	18.79	18.84	18.89	18.95	19.00	19.05	19.10	19.16	47
48	19.21	19.26	19.32	19.37	19.43	19.48	19.53	19.59	19.64	19.70	48
49	19.75	19.81	19.86	19.92	19.97	20.03	20.08	20.14	20.19	20.25	49
50	20.30	20.36	20.41	20.47	20.53	20.58	20.64	20.69	20.75	20.81	50
51	20.86	20.92	20.98	21.03	21.09	21.15	21.21	21.26	21.32	21.38	51
52	21.44	21.49	21.55	21.61	21.67	21.73	21.78	21.84	21.90	21.96	52
53	22.02	22.08	22.14	22.20	22.26	22.32	22.38	22.44	22.50	22.56	53
54	22.62	22.68	22.74	22.80	22.86	22.92	22.98	23.04	23.10	23.16	54
55	23.22	23.28	23.34	23.41	23.47	23.53	23.59	23.65	23.72	23.78	55
56	23.84	23.90	23.97	24.03	24.10	24.16	24.22	24.29	24.35	24.42	56
57	24.48	24.54	24.61	24.67	24.74	24.80	24.86	24.93	24.99	25.06	57
58	25.12	25.19	25.25	25.32	25.38	25.45	25.52	25.58	25.65	25.71	58
59	25.78	25.85	25.92	25.98	26.05	26.12	26.19	26.26	26.32	26.39	59
60	26.46	26.53	26.60	26.67	26.74	26.81	26.87	26.94	27.01	27.08	60
61	27.15	27.22	27.29	27.36	27.43	27.50	27.57	27.64	27.70	27.78	61
62	27.85	27.92	27.99	28.07	28.14	28.21	28.28	28.35	28.43	28.50	62
63	28.57	28.64	28.72	28.79	28.87	28.94	29.01	29.09	29.16	29.24	63
64	29.31	29.39	29.46	29.54	29.61	29.62	29.76	29.83	29.91	29.98	64
65	30.06	30.14	30.21	30.29	30.37	30.45	30.52	30.60	30.68	30.75	65
66	30.83	30.91	30.99	31.07	31.15	31.23	31.30	31.38	31.46	31.54	66
67	31.62	31.70	31.78	31.86	31.94	32.02	32.10	32.18	32.26	32.34	67
68	32.42	32.50	32.59	32.67	32.75	32.84	32.92	33.00	33.08	33.17	68
69	33.25	33.33	33.42	33.50	33.59	33.67	33.75	33.84	33.92	34.01	69
70	34.09	34.18	34.26	34.35	34.43	34.52	34.61	34.69	34.78	34.86	70
71	34.95	35.04	35.13	35.21	35.30	35.39	35.48	35.57	35.65	35.74	71
72	35.83	35.92	36.01	36.10	36.19	36.28	36.38	36.47	36.56	36.65	72
73	36.74	36.83	36.92	37.02	37.11	37.20	37.29	37.38	37.48	37.57	73
74	37.66	37.76	37.85	37.95	38.04	38.14	38.23	38.33	38.42	38.51	74
75	38.61	38.71	38.80	38.90	39.00	39.09	39.19	39.28	39.38	39.47	75
76	39.57	39.67	39.77	39.87	39.97	40.07	40.17	40.27	40.37	40.47	76
77	40.57	40.67	40.77	40.87	40.97	41.08	41.18	41.28	41.38	41.48	77
78	41.58	41.68	41.79	41.89	42.00	42.10	42.20	42.31	42.41	42.52	78
79	42.62	42.73	42.83	42.94	43.05	43.15	43.26	43.37	43.48	43.58	79
80	43.69	43.80	43.91	44.02	44.13	44.24	44.34	44.45	44.56	44.67	80
81	44.78	44.89	45.00	45.11	45.23	45.34	45.45	45.56	45.67	45.79	81
82	45.90	46.01	46.13	46.24	46.36	46.48	46.59	46.70	46.81	46.93	82
83	47.04	47.16	47.28	47.39	47.51	47.63	47.75	47.87	47.98	48.10	83
84	48.22	48.34	48.46	48.58	48.70	48.82	48.95	49.07	49.19	49.31	84
85	49.43	49.55	49.68	49.80	49.92	50.04	50.17	50.29	50.41	50.54	85
Wet Bulb (F)	.0	.1	.2	.3	.4	.5	.6	.7	.8	.9	Wet Bulb (F)

NOTES:

GLOSSARY OF TERMS

Absolute Pressure – Pressure measurements which are compared to absolutely no pressure at all, not even atmospheric pressure; e.g., psia and in. Hg abs.

ACR Tubing – Air conditioning and refrigeration tubing that is cleaned, dried, and sealed to keep contaminants from entering the tubing. It is often charged with dry nitrogen.

AFUE – Annual Fuel Utilization Efficiency; the annualized average efficiency of a fuel-fired appliance, taking into account the effect of on-off operation.

Air Conditioning – The treatment of air temperature, humidity, cleanliness, and circulation so as to achieve a controlled desired result.

Air-Cooled Condenser – The heat exchanger coil in an air-cooled refrigeration system that receives heat from the compressor and transfers it to the surrounding air.

Air Sensor – A device that detects changes in air conditions, such as pressure, temperature, or moisture content.

Alternating Current – An electrical current that reverses (alternates) its direction of flow at regular intervals. AC is the primary source of energy for homes and businesses and is used when large amounts of energy are required. (See DC.)

Ambient Temperature – Temperature of fluid (usually air) surrounding an object.

Ammeter – A device, calibrated in amperes, that is used to measure electric current.

Ampere or Amp (A) – A unit of electric current.

Anemometer – An instrument used to measure the velocity of air flow.

Atmospheric Pressure – The pressure exerted on all things on the Earth's surface that are a result of the weight of our atmosphere.

Automatic Changeover Thermostat – A thermostat that selects either heating or cooling, depending on room temperature and the heating and cooling setpoints.

Azeotropic Mixture – A mixture consisting of two or more refrigerants which behave like a compound when changing state from liquid to gas (evaporating) and gas to liquid (condensing).

Back-Seated – The condition of a service valve in which the valve stem is turned fully counterclockwise and the valve is fully open.

Barometric Pressure – Same as atmospheric pressure. The absolute pressure read on a barometer in inches of mercury.

Boiling Point – For a liquid exposed to an absolute pressure, the temperature at which the vapor pressure of the liquid equals the absolute pressure. The liquid will 1) boil at this condition, changing its state to a vapor with the addition of latent heat, or 2) the vapor will condense at this condition, changing its state to a liquid with the removal of latent heat; e.g., at sea level, water will boil at 212° F with the addition of heat, or water vapor will condense with the removal of heat. See also Latent Heat of Vaporization.

Brazing – A method of joining metals using a nonferrous (no iron) filler at a temperature above 800° F.

Btu (British Thermal Unit) – The amount of heat required to raise the temperature of 1 pound of water 1° F. A quantity of heat.

Btuh (Btu's per hour) – The basic unit for measuring the rate of heat transfer.

Burning Speed – The velocity at which a flame propagates through a flammable gas-air mixture, usually expressed in feet per second; also Flame Velocity or Ignition Velocity.

Capacitive Circuit – Any circuit that contains at least one capacitor.

Capacitor – An electrical storage device consisting of a layer of insulation (a dielectric) sandwiched between two conductive metal plates.

Capacitor Start (CS) Motor – A single-phase induction motor with a capacitor that is switched out of the circuit immediately after starting torque has been achieved.

Capacitor Start-Capacitor Run (CSR) Motor – A motor that combines the PSC and CS characteristics, having both a start capacitor that switches out of the circuit when the motor comes up to speed, and a run capacitor.

Capillary Tube – A copper tube with a small, calibrated inside diameter used to create the pressure drop between the high-side and low-side. Often used in small systems where there are relatively constant loads.

Celsius or Centigrade Scale (Represented as degrees C) – The scale of temperature measurement most commonly used worldwide.

CFM – Cubic Feet per Minute. The unit of measure of the volume rate of air flow, as in a heating system.

Change of State – The condition in which a substance changes from one physical state to another, due to the addition or removal of heat.

Charging – The storing of electrical energy. Also the addition of refrigerant to a system.

Circuit – An electron path that completes a loop. Circuits generally consist of a power source, conductors, a load, and a switch to control current flow.

Circuit Breaker – A protective device that opens an electrical circuit when an overload occurs. There are thermal and magnetic types.

Combustion – The rapid oxidation of fuel gas accompanied by the production of heat, or heat and light.

Combustion Products – The gases that result from combustion; also called flue gases.

Compound Gauge – A service gauge that has both pressure and vacuum scales.

Compressor – A pump in a refrigeration system that takes refrigerant vapor at low temperature and pressure and raises it to a higher temperature and pressure.

Condensation – The process by which a gas is changed into a liquid at constant temperature by heat removal.

Condenser – A heat exchange coil within a mechanical refrigeration system used to reject heat from the system. The coil where condensation takes place.

Condensing Furnace – A high-efficiency gas or oil forced-air furnace that uses a second condensing heat exchanger to extract the latent heat in the flue gas.

Condensing Temperature – The temperature inside a condenser at which refrigerant vapor releases its latent heat of vaporization and becomes a liquid. This varies with the pressure inside the condenser.

Conductor – A substance or body that allows electricity or heat to pass through it.

Contactor – A device consisting of a coil and one or more sets of contacts used to connect or disconnect a high-voltage circuit.

Contaminant – Any substance, such as air or moisture, that is foreign to a sealed refrigerant system.

Control Circuit – That portion of the total circuitry containing devices that apply power to or remove power from a load.

Cooling Capacity – The rate at which a device can remove heat from a substance, expressed in Btuh; for an air conditioner, it is the maximum rate at which it removes heat from a space.

Cooling Load – Heat which flows into a space from outdoors and/or indoors.

Current – The rate of electron flow in a circuit. Current is measured in amperes.

Cut-In – The temperature or pressure value at which a protective device closes.

Cut-Out – The temperature or pressure value at which a protective device opens.

Cycle – A series of events that tend to repeat in the same order. E.g., the rotation cycle of a coil in a magnetic field.

Dehumidifier – A device used to remove moisture from the air.

Density – The mass (weight) of a substance per unit volume, measured in pounds per cubic feet (lbs./cu.ft.).

Design Temperature – The location-specific temperature used to calculate heat losses or gains of a structure.

Dew Point – The temperature of air at which the water vapor content is saturated.

Dilution Air – Air that enters a draft hood of a natural draft gas-fired furnace and mixes with the combustion products.

Diode – A semiconductor device that permits current flow in one direction only.

Direct Current (DC) – An electrical current in which the electron flow is in one direction. DC is used for low energy applications and allows for precise control.

Direct Digital Control (DDC) – The use of a computer to execute automatic control operations in a total Energy Management System.

Direct Vent System – A vent system for a fuel gas-fired appliance which is constructed so that all the air for combustion is drawn directly from the outside atmosphere and all the flue gases are discharged to the outside atmosphere.

Disconnect – A manual switching device used to remove power from a circuit. Usually mounted on or near air conditioning equipment.

Draft – The pressures difference that causes the flow of flue gases through a chimney or vent, see also Natural Draft and Induced Draft.

Draft Gauge – An instrument used to measure air movement by measuring very small air pressure differences.

Draft Hood – A device built into a natural-draft gas-fired appliance to de-couple the heat exchanger from the natural-draft vent so that updrafts, downdrafts, or blockages do not adversely affect the heat exchanger or combustion operation.

Duct – A sealed channel through which air is moved.

Efficiency – The ratio of the output of a device, system, or activity to the input required to generate that output.

Electric Heater – A device constructed of high resistance wire or other material which produces heat when a current is passed through it.

Electromagnet – A coil of wire wrapped around a soft iron core. Magnetic force is created when a current is passed through the coil.

Electronically-Commutated Motor (ECM) – A DC motor with continuously-variable speed control.

Enthalpy – Total heat content expressed in Btu's per pound of the substance (Btu/lb.).

Evacuation – The process of removing air, moisture, and other gases from the inside of a refrigeration system.

Evaporator – A heat exchange coil within a mechanical refrigeration system used to absorb heat into the system. The coil where evaporation takes place.

Excess Air – In gas combustion, the amount of air in excess of that needed for complete (stoichiometric) combustion; see stoichiometric combustion.

External Static Pressure – The total static pressure difference of the duct system as measured between the furnace air outlet and inlet connections; see Static Pressure.

Fahrenheit Scale (Represented as degrees F) – The scale of temperature measurement most commonly used in the United States.

Fault Directory – A lookup table or equipment label used to translate numeric or alpha-numeric fault codes into messages.

Filter – A device used to eliminate the ripple produced by a rectifier. Also a device used to remove dust particles from the air.

Filter-Drier – A device in refrigeration systems that removes foreign particles and moisture from refrigerant.

Flame – The zone in which the combustion reaction between a fuel gas and oxygen takes place with the intense release of light and heat.

Flame Impingement – A condition which exists when the flame of a combustion reaction comes into contact with a cooler interior surface of the combustion chamber that causes the reaction to stop in the impingement area.

Flame Rectification – The phenomenon by which an electrical current flows through a flame. Used to prove the presence of a flame.

Flash Gas – The pressure drop in an expansion device causes some refrigerant liquid to evaporate very quickly (flash) and cool the remaining liquid to the desired evaporation temperature.

Flue – The passage that carries combustion gases from a heating system.

Flue Gas – Products of combustion plus excess air plus dilution air (on natural-draft appliances) that pass through the vent.

Flux – A substance applied to surfaces that are to be joined by soldering or brazing. It prevents oxidation during the heating process.

Freezing Point – For a liquid exposed to an absolute pressure, the temperature at which 1) the liquid will solidify, changing its state to a solid with the removal of latent heat, or, 2) the solid will melt, changing its state to a liquid with the addition of latent heat; (e.g., at sea level, water will freeze into ice at 32° F with the removal of heat, or ice will melt with the addition of heat. See also Latent Heat of Fusion.

Fuse – A safety device in which a metal link melts when it receives excessive current, thereby opening the circuit.

Gas Valve – A device used to start, stop, or regulate the flow of gas.

Gauge Manifold – A device containing compound and high-pressure gauges, with a valve arrangement to control fluid flow. Used to measure pressures and perform other service procedures in a refrigeration system.

Gauge Port – An opening or connection used to attach a gauge during service procedures.

Gauge Pressure – The pressure measured on a gauge, expressed as psig or in. Hg vac. Pressure measurements which are compared to atmospheric pressure.

Generator – A device used to convert mechanical energy into electrical energy.

HACR Circuit Breaker – A circuit breaker with a built-in trip delay commonly used in air conditioning installations due to the power surge on start-up.

Hard Start Kit – A kit consisting of a start capacitor and start relay used to provide high starting torque.

Heat – A form of energy that causes the random motion of molecules and raises the temperature of a substance.

Heat Content – The amount of heat energy possessed by a substance.

Heat Exchanger – A device which provides a means for transferring heat between two fluid streams while keeping them physically separated.

Heat Gain – The heat that is transferred into a structure through its outside surfaces and cracks when the outside temperature is higher than the inside temperature; see also Heating Load.

Heat Loss – The heat that is transferred out of a structure through its outside surfaces and cracks when the outside temperature is lower than the inside temperature.

Heat Pump – A comfort system in which the refrigeration cycle is reversed by a four-way valve to supply heating as well as cooling.

Heat Transfer – The movement of heat from one place to another, between two substances, or within a substance.

Heat Value – The amount of heat released by the complete combustion (oxidation reaction) of one unit volume of a gaseous fuel, usually expressed as Btu's per cubic foot.

Heating Capacity – The rate at which a device can add heat to a substance, expressed in Btuh.

Heating Load – The total heat that is transferred into a structure through its outside surfaces and cracks when the outside temperature is at the Winter Outdoor Design Temperature and the inside is held at the Indoor Design Temperature, minus any internal heat gains. Used to select the proper furnace heating capacity.

Hermetic Compressor – A type of compressor in which the compressor and its drive motor are enclosed in a welded shell.

Hertz (Hz) – A unit of electrical frequency (cycles per second).

Hg (Mercury) – A heavy, silver-colored metallic element that is liquid at room temperature.

High-Side – The components of a refrigeration system that are under condensing pressure.

High-Voltage Circuit – The upper section of a wiring diagram showing distribution of primary AC power to the load devices.

Holding Circuit – A set of relay contacts used to keep the relay coil energized. Generally used when the relay is initially energized by a momentary switch closure.

Hopscotching – A circuit troubleshooting method that begins with checking voltage across the entire circuit, then jumping over contacts to determine which components are open or closed.

Horsepower (HP) – A unit of power. One HP represents 33,000 ft. lb. of work per minute and is equal to 746 watts of electrical power.

Humidifier – A device used to add moisture to the air.

Humidistat – An electrical control that is operated by a change in humidity.

Humidity – The moisture content of air.

Hydrocarbon – A compound composed solely of atoms of carbon and hydrogen (e.g., methane, propane, and butane).

Hygrometer – An instrument used to measure the degree of moisture in the air.

Ignition Temperature – The minimum temperature at which a gas and air mixture will ignite.

Ignitor Pack (IGN) – A control device for gas heat that provides a voltage to operate the flame ignitor and a flame sensor to signal the gas valve to open or close.

Impedance – The opposition to current flow in an AC circuit.

Inches Mercury, Absolute (Expressed as in. Hg abs.) – The scale used to measure absolute pressures equal to or below atmospheric pressure. Also used for weather reporting and forecasting.

Inches Mercury, Vacuum (Expressed as in. Hg vac.) – The scale used to measure gauge pressures equal to or less than atmospheric pressure.

Induced Draft – The draft developed in the heat exchanger of a gas-fired furnace by a fan located at the outlet of the heat exchanger. May be used with a natural-draft vent, or with a direct vent system; also called fan-assisted or mechanical draft.

Inductive Circuit – Any circuit that contains at least one inductive load.

Infiltration – The leakage of outside air into a structure through doors, cracks, windows, and other openings.

Integrated Circuit Chip – A micro-miniature electronic circuit on which all components are placed on a tiny "chip" of semiconductor material.

Interlock – A spring-loaded switch that breaks the circuit when a unit access panel is opened.

Ladder Diagram – A simplified method for portraying an electrical diagram.

Latent Heat – The energy of molecular separation and arrangement; cannot be measured with a thermometer; associated with the change of state of a substance.

Latent Heat of Fusion – The heat required to change one pound of a substance from a solid to a liquid at its melting temperature, measured in Btu's.

Latent Heat of Vaporization – The heat required to change one pound of a substance from a liquid to a vapor at its boiling temperature, measured in Btu's.

Legend – An explanation of the component abbreviations on a diagram.

Light Emitting Diode (LED) – A semiconductor component that produces light when a current passes through it.

Limit Switch – A protective device used to open or close electrical circuits when temperature or pressure limits are reached.

Line Duty Device – A protective device that opens the motor winding circuit under conditions of excess current or temperature.

Load – The resistance that uses the energy in a circuit.

Locked Rotor Current – The high current produced when voltage is applied to a motor and the rotor is not turning. (Also known as the instant-of-start current.)

Low-Side – The components of a refrigeration system that are under evaporating pressure.

Low-Voltage Circuit – The control circuit portion of a wiring diagram, termed "low voltage" because it generally operates from a stepped-down voltage.

LPG (LP Gas) – An acronym for Liquified Petroleum Gas, refers to those fuel gases that remain a liquid under pressure, including propane and butane.

Magnetic Overload Device – A protective device that disconnects a circuit when excessive current creates a magnetic field sufficient to open the contact. Magnetic overload devices are not affected by the ambient temperature.

Manometer – An instrument used to measure low positive, negative, or differential air and gas pressures.

Manual Reset – A type of safety control that automatically opens an electrical circuit on a signal, but requires someone to physically actuate the switch to close the circuit again when the signal terminates; (e.g., a roll-out safety switch must be reset by a service person to assure that the original roll-out problem is corrected.)

Methane – The first member of the methane family of hydrocarbons used as a fuel gas. A molecule of methane is composed of one atom of carbon and four atoms of hydrogen.

Microfarad (MFD) – One-millionth of a Farad. The standard unit of measurement for a capacitor.

Microprocessor – A micro-computer chip consisting of integrated circuits which accept, store, and process information and control output devices.

Milliamp – A unit of electric current equal to 1/1,000 of an ampere.

Motor – A device used to convert electrical energy into mechanical energy.

Multimeter – A combination meter used to measure voltage, current, and resistance.

Natural Draft – The draft developed in a chimney or vent of a gas-fired appliance by the difference in density of the hot flue gas and the outside atmosphere caused by their temperature difference; see also Density Current.

Natural Gas – A naturally occurring fuel gas composed of about 95% methane gas with other gases, such as ethane, hydrogen, carbon dioxide, and nitrogen making up the remainder.

Negative Temperature Coefficient (NTC) Thermistor – A sensing element in which the resistance decreases as the temperature increases. NTC thermistors are used as temperature sensors and as protective devices in motors.

Normally Closed Contacts – Contacts that close when a relay or contactor is deenergized.

Normally Open Contacts – Contacts that open when a relay or contactor is deenergized.

Ohm – A unit of electrical resistance.

Ohm's Law – A law involving electrical relationships that is stated as follows: voltage (E) equals current (I) times resistance (R), or $E = I \times R$.

Ohmmeter – A device that measures electrical resistance in ohms.

Oil (Refrigeration) – A specially-formulated compressor lubricating oil used in refrigeration systems.

One Hundred Percent Shutoff Valve – An automatic valve that shuts off all gas to the pilot and prevents gas valve operation if the pilot is extinguished.

Orifice – A precision hole used to measure or control the flow of a fluid; a gas orifice is a precision drilled hole in a spud that is used to control the flow of gas to a burner.

Overload Protector – A device operated by temperature, pressure, or current that shuts the system off when limits are exceeded.

Ozone – A form of oxygen, O_3, usually produced by a discharge of electricity in the air. A layer of ozone in the outermost part of the Earth's atmosphere shields the Earth from the sun's harmful ultraviolet rays.

Packaged Unit – A complete refrigeration system in which the compressor, condenser, metering device, and evaporator are located in the same cabinet.

Parallel Circuit – An electrical circuit that provides more than one path for current flow.

Permanent Split Capacitor (PSC) Motor – A single-phase induction motor with a split-phase capacitor that remains in the circuit during normal operation.

Phase Shift – The phase angle difference between the current and voltage waveforms in an inductive or capacitive circuit.

Pilot – A small flame that is utilized to ignite the gas at the main burner(s).

Pilot Duty Device – A protective device that opens the motor control circuit under conditions of excess current or temperature.

Pitot Tube – A tube used with manometers and differential pressure gauges to measure air velocities and static pressures.

Polarity – The characteristic of exhibiting both positive and negative charges.

Positive Temperature Coefficient (PTC) Thermistor – A sensing element in which the resistance increases as the temperature increases. PTC thermistors are used as temperature sensors and as start assist devices for motors.

Potentiometer – A variable resistor, such as a dimmer switch or heat anticipator, that allows the current flow to be adjusted to alter the operation of a circuit.

Pounds per Square Inch Absolute (Expressed as psia) – The scale used to measure absolute pressures.

Pounds per Square Inch Gauge (Expressed as psi or psig) – The scale used to measure gauge pressures.

Power – The amount of energy consumed by a load in an electrical circuit. Power is calculated using the equation:

$$P = E \times I$$

Where: P = Power
E = Voltage
I = Current

Power Circuit – That portion of the total circuitry allocated to the distribution of primary AC power.

Power Factor (PF) – A factor used in the power equation to compensate for the current lag in an inductive circuit.

Pressure – Force per unit of area.

Pressure Drop – The pressure difference between two points.

Pressurestat – A pressure switch often used as a protective device for compressors. A bellows or diaphragm in the switch responds to pressure changes, breaking the circuit if the pressure goes beyond a set value.

Primary Air – Combustion air that is mixed with gas in a bunsen-type burner before leaving the port.

Printed Circuit Board – A support for electronic circuits that generally consists of electrical components linked by chemically etched (pre-printed) copper foil conductors.

Process Tube – A length of tubing fastened to a refrigeration system. Used in the manufacturing process to evacuate and charge the system.

Propane – A member of the methane family of hydrocarbons used as a fuel gas. The propane molecule is composed of three atoms of carbon and eight atoms of hydrogen.

Psychrometer – An instrument used to measure the relative humidity of the air.

Psychrometric Chart – A chart that displays the relationships of air temperature, pressure, and humidity.

Psychrometrics – The study and control of air/moisture mixtures.

Re-Ignition Pilot – A pilot that is equipped with a device to re-light the pilot gas, either when the pilot is extinguished or, on furnaces with 100% shutoff valves, each time the furnace is turned on.

Redundant Automatic Gas Valve – An automatic gas valve that employs two or more valves in series, so that if one should fail to close properly, the closure of the other(s) would ensure that the flow of gas is stopped; a safety requirement.

Refrigerant – A fluid (liquid or gas) that picks up heat by evaporating at a low temperature and pressure. It gives up heat by condensing at a higher temperature and pressure.

Refrigerant Reclaim – The reprocessing of refrigerant to new refrigerant specifications. This requires chemical analysis and usually refers to the processes available at a reprocessing or manufacturing facility.

Refrigerant Recovery – The removal of refrigerant and placement in a cylinder without testing.

Refrigerant Recycling – The cleaning of refrigerant for reuse by removing moisture, acids, and particulate matter. Usually applies to procedures performed at the job site or local service shop. The cleaned refrigerant does not meet new refrigerant specifications.

Relative Humidity – The ratio of the amount of vapor contained in the air to the greatest amount the air could hold at that temperature. Normally expressed as a percentage.

Relay – A magnetically operated device consisting of a coil and one or more sets of contacts used to connect or disconnect a low voltage circuit.

Resistance – The ability of a device or material to obstruct the current flow within a circuit.

Resistive Circuit – Any circuit that contains at least one resistive load.

Resistor – A device or material that impedes the current flow within a circuit.

Rollout Switch – A heat-sensitive protective device that opens the circuit if flame migrates away from the burner box.

Rotor – The rotating element of an electric motor.

Run Capacitor – An electrical storage device that helps motors run more efficiently.

Run Winding – The stator winding in a motor that has current flowing through it while the motor is running.

Saturated Air – Air that contains the maximum amount of water vapor possible at the specified temperature and pressure.

Saturated Liquid – A liquid that contains all the heat it can hold without changing into a vapor.

Saturated Vapor – A vapor that contains all the heat it can hold without becoming superheated.

Saturation Temperature – The boiling point of a refrigerant. It is dependent upon pressure.

Schrader Valve – A spring-loaded device similar to a tire valve that allows refrigerant to be added to or removed from the system.

Secondary Air – Combustion air that mixes with the burning gas-primary air mixture in the flame zone.

Semi-Hermetic Compressor – A hermetic (airtight) compressor that can be opened or disassembled by removing bolts and flanges. Also known as a *serviceable hermetic*.

Sensible Cooling Capacity (Expressed in Btuh or tons) – The rate at which a refrigeration system can remove sensible heat.

Sensible Heat – The energy of molecular motion. Measured with a thermometer. Associated with a change in temperature.

Series Circuit – An electrical circuit that provides a single path for current flow.

Series-Parallel Circuit – An electrical arrangement containing both series (single path) and parallel (multiple path) circuits.

Setpoint – A preset temperature at which a temperature-sensitive switch will open or close.

Shaded-Pole Motor – A small AC motor used for light loads.

Short Circuit – A situation where the conductors bypass the load and cause a dangerous high current condition. Fuses are used to prevent damage from short circuits and overloads.

SI – International System of Units which includes the common metric units of measure, such as meters, grams, Celsius, Kelvin, pascals, and watts.

Sightglass – A glass tube or window in a liquid line. It shows refrigerant or oil in the system and indicates the presence of gas bubbles in the liquid line.

Single-Phase Voltage – The potential difference produced by a single conductor output from a generating source. Single-phase voltage produces a single waveform.

Single-Pole, Double Throw (SPDT) Switch – An electric switch with one blade and two contact points.

Single-Pole, Single Throw (SPST) Switch – An electric switch with one blade and one contact point.

Sling Psychrometer – A device with wet and dry bulb thermometers that is whirled rapidly in the air to measure sensible wet and dry bulb temperatures.

Slow Blow Fuse – A fuse with a built-in trip delay commonly used in HVAC installations due to the power surge on startup.

Soldering – The process of joining two metals by using a third metal, a filler, with a melting temperature of less than 800° F.

Solenoid – A magnetic device that is used to convert electrical energy into mechanical energy. Many valves are solenoid-activated.

Specific Gravity – Of a gas, the ratio of the weight of a given volume of the gas to the weight of the same volume of standard air, (i.e., air at standard temperature and pressure); for a liquid or solid, the ratio of the weight of a given volume of the substance to the weight of the same volume of water at 4° C. See also Density.

Specific Heat (Expressed in Btu/lb./°F) – The amount of heat required to raise 1 pound of a substance 1° F.

Split System – A refrigeration or air conditioning system in which the condenser and evaporator are in separate locations, joined by refrigerant piping.

Split-Phase Motor – A motor with a start winding that is out of phase with the run winding.

Start Capacitor – An electric storage device that helps to overcome motor starting torque.

Start Winding – The stator winding in a motor that is used briefly to provide additional starting torque.

Static Pressure – The pressure exerted by a fluid at rest; for a flowing fluid, as air in a duct, it is the total pressure minus the velocity pressure.

Stator – The stationary element in an electric motor.

Steady State Efficiency – The ratio of the output energy to the input energy, measured under steady conditions.

Stepped-Down Voltage – A voltage decrease produced by a transformer with more windings in its primary than in its secondary.

Stepped-Up Voltage – A voltage increase produced by a transformer with more windings in its secondary than in its primary.

Subcooled Liquid – A liquid at a temperature below the saturation temperature of the substance.

Suction Side – The low-pressure side of a refrigeration system, extending from the metering device through the evaporator to the inlet valve of the compressor.

Superheated Gas – A gas at a temperature above the saturation temperature of the substance.

Swaging – Enlarging one end of a tube so that another tube of the same size can fit within it for a solder or braze connection.

Temperature – The measure of the intensity of heat that a substance possesses.

Temperature Rise – The positive change in temperature of air passing through a heat exchanger as a result of heat transfer.

Thermal Overload Device – A bimetal protective device that acts as a switch contact, disconnecting the circuit under conditions of excessive current.

Thermocouple – An electrical circuit comprised of two dissimilar metals that either generates an electrical potential when the two junctions of dissimilar metal are held at different temperatures, or generates a temperature difference between the two junctions when a current is imposed.

Thermometer – A device used to measure temperature.

Thermostat – A device which connects or disconnects a circuit in response to a change in the ambient temperature.

Thermostatic Expansion Valve (TEV) – A valve used to control superheat in refrigeration systems by regulating the correct flow of liquid refrigerant flow to the evaporator.

Three-Phase Voltage – The potential difference produced by three conductors spaced 120° apart in a generating source. Three-phase voltage produces three waveforms, each out of sync with the others by one third of a cycle.

Time Delay Relay – A relay in which there is a delay between the time the coil is energized or deenergized and the contacts open or close. Often used to control fans for greater heating or cooling efficiency.

Ton – The basic large unit for measuring the rate of heat transfer (12,000 Btuh).

Torque – The force that must be generated to turn a motor.

Total Cooling Load (Expressed in Btuh or tons) – The rate at which total heat enters a space.

Total Heat – Sensible plus latent heat.

Transformer – A device used to raise and lower AC voltage levels.

Transient – An instantaneous voltage surge through a circuit that may be caused by lightning, static electricity, or the activation of inductive loads.

Vacuum – The pressure range below atmospheric pressure.

Vacuum Pump – A pump used to remove air and moisture from a refrigeration system at a pressure below atmospheric pressure.

Velometer – An instrument that measures the velocity of air or water.

Vent – A passageway used to convey flue gases from gas utilization equipment, or their vent connectors, to the outside atmosphere.

Vent Connector – A pipe or duct which connects a gas-burning appliance to a vent or chimney.

Vent Damper – A device intended for installation in the venting system at the outlet or downstream of a gas-burning appliance to automatically open the vent when the appliance is in operation and to automatically close off the vent when the appliance is off.

Venturi – The flared-shape portion of a burner nearest the gas orifice that is designed to assist the gas jet in injecting air into the burner.

Viscosity – The measurement of the thickness of oil or its resistance to flow.

Volt – A unit of electrical potential.

Voltage – An electrical measurement of the potential for electron flow within a circuit.

Voltage Drop – The amount of voltage required for a single load in a circuit.

Voltage Regulator – A device used to maintain a constant voltage when there are variations in the source voltage or the load circuit.

Watt – A unit of electrical power.

Wet Bulb – A device used to measure relative humidity. Evaporation of moisture lowers the temperature of the wet bulb compared to the dry bulb temperature of the same air sample.

Wet Bulb Temperature – A measure of humidity in the air.

Wiring Diagram – Also known as a wiring schematic diagram, a wiring diagram is that portion of a label diagram which illustrates the internal wiring of the unit.

Zeotropic Mixture – A mixture consisting of two or more refrigerants that change volumetric and saturation temperatures as they evaporate or condense. For a given system pressure, the zeotropic refrigerant will have one temperature at which it evaporates and a different one at which it condenses. This characteristic is called *temperature glide.*

Zone Valve – A thermostat-controlled valve used in heating and cooling systems to control the temperature in a certain area or zone.

Zoning – The practice of heating and cooling areas within a structure independently of each other.

PRESSURE/TEMPERATURE CHARTS

CFC REFRIGERANTS

TEMP (°F)	Vapor Pressure (PSIG)* CFC 11	CFC 12	CFC 500
-100.00	**29.7**	**26.9**	**26.3**
-90.00	**29.6**	**25.7**	**24.8**
-80.00	**29.5**	**24.0**	**22.8**
-70.00	**29.4**	**21.8**	**20.2**
-60.00	**29.1**	**19.0**	**16.9**
-50.00	**28.8**	**15.4**	**12.7**
-40.00	**28.3**	**10.9**	**7.5**
-35.00	**28.1**	**8.3**	**4.5**
-30.00	**27.7**	**5.4**	**1.1**
-25.00	**27.4**	**2.3**	1.3
-20.00	**26.9**	0.6	3.3
-15.00	**26.5**	2.5	5.5
-10.00	**25.9**	4.5	7.9
-5.00	**25.3**	6.8	10.5
0.00	**24.6**	9.2	13.3
5.00	**23.9**	11.8	16.4
10.00	**23.0**	14.7	19.8
15.00	**22.1**	17.7	23.4
20.00	**21.0**	21.1	27.3
25.00	**19.8**	24.6	31.5
30.00	**18.5**	28.5	36.0
35.00	**17.1**	32.6	40.9
40.00	**15.6**	37.0	46.1
45.00	**13.8**	41.7	51.6
50.00	**12.0**	46.7	57.6
55.00	**9.9**	52.1	63.9
60.00	**7.7**	57.7	70.6
65.00	**5.3**	63.8	77.8
70.00	**2.7**	70.2	85.4
75.00	0.1	77.0	93.4
80.00	1.6	84.2	102.0
85.00	3.2	91.8	111.0
90.00	4.9	99.8	120.5
95.00	6.8	108.2	130.6
100.00	8.8	117.2	141.1
105.00	10.9	126.5	152.3
110.00	13.2	136.4	164.0
115.00	15.7	146.8	176.3
120.00	18.3	157.6	189.2
125.00	21.1	169.0	202.8
130.00	24.0	181.0	217.0
135.00	27.1	193.5	231.9
140.00	30.5	206.6	247.4
145.00	34.0	220.3	263.7
150.00	37.7	234.6	280.8

NON-CFC REFRIGERANTS

TEMP (°F)	Vapor Pressure (PSIG)* HCFC 22	HCFC 123	HFC 134a
-100.00	**25.0**	**29.9**	**27.9**
-90.00	**22.9**	**29.7**	**27.0**
-80.00	**20.1**	**29.6**	**25.7**
-70.00	**16.5**	**29.5**	**23.9**
-60.00	**11.9**	**29.3**	**21.6**
-50.00	**6.1**	**29.1**	**18.5**
-40.00	0.6	**28.7**	**14.6**
-35.00	2.6	**28.5**	**12.3**
-30.00	4.9	**28.3**	**9.7**
-25.00	7.4	**28.0**	**6.7**
-20.00	10.2	**27.6**	**3.5**
-15.00	13.2	**27.3**	0.1
-10.00	16.5	**26.8**	2.0
-5.00	20.1	**26.3**	4.2
0.00	24.0	**25.8**	6.5
5.00	28.2	**25.1**	9.2
10.00	32.8	**24.4**	12.0
15.00	37.7	**23.6**	15.1
20.00	43.1	**22.7**	18.5
25.00	48.8	**21.7**	22.2
30.00	54.9	**20.6**	26.1
35.00	61.5	**19.4**	30.4
40.00	68.5	**18.0**	35.1
45.00	76.0	**16.5**	40.1
50.00	84.0	**14.9**	45.5
55.00	92.6	**13.1**	51.2
60.00	101.6	**11.1**	57.4
65.00	111.2	**8.9**	64.1
70.00	121.4	**6.6**	71.1
75.00	132.2	**4.0**	78.7
80.00	143.6	**1.2**	86.7
85.00	155.7	0.9	95.3
90.00	168.4	2.5	104.3
95.00	181.8	4.2	114.0
100.00	195.9	6.1	124.2
105.00	210.7	8.1	135.0
110.00	226.3	10.3	146.4
115.00	242.7	12.6	158.4
120.00	259.9	15.1	171.2
125.00	277.9	17.7	184.6
130.00	296.8	20.6	198.7
135.00	316.5	23.6	213.6
140.00	337.2	26.8	229.2
145.00	358.8	30.2	245.6
150.00	381.4	33.8	262.9

Vapor pressures are shown as PSIG. **Bold figures are shown as inches of mercury vacuum.**
*Data supplied by Allied-Signal Inc.

Chemical Names and Formulas

	Chemical Name	Formula	Boiling Point (°F)
CFC-11	trichlorofluoromethane	CCl_3F	74.9
CFC-12	dichlorodifluoromethane	CCl_2F_2	-21.6
CFC-500	azeotrope of CFC-12 and CFC-152a		-28.3

Chemical Names and Formulas

	Chemical Name	Formula	Boiling Point (°F)
HCFC-22	chlorodifluoromethane	$CHClF_2$	-41.4
HCFC-123	dichloro-trifluoroethane	$CHCl_2CF_3$	82.2
HFC-134a	tetrafluoroethane	CF_3CH_2F	-15.7

Recovered/Contaminated Refrigerants for Transit

Department of Transportation (DOT) requires that recovered/contaminated refrigerants be labeled with refrigerant type and transported in grey containers with a yellow band.

REQUIRED SUCTION-TUBE TEMP (°F)*

Required Superheat Temp (°F)	Low-Side (Suction) Pressure (PSIG) at Service Fitting 61.5	64.2	67.1	70.0	73.0	76.0	79.2	82.4	85.7
0	35	37	39	41	43	45	47	49	51
2	37	39	41	43	45	47	49	51	53
4	39	41	43	45	47	49	51	53	55
6	41	43	45	47	49	51	53	55	57
8	43	45	47	49	51	53	55	57	59
10	45	47	49	51	53	55	57	59	61
12	47	49	51	53	55	57	59	61	63
14	49	51	53	55	57	59	61	63	65
16	51	53	55	57	59	61	63	65	67
18	53	55	57	59	61	63	65	67	69
20	55	57	59	61	63	65	67	69	71
22	57	59	61	63	65	67	69	71	73
24	59	61	63	65	67	69	71	73	75
26	61	63	65	67	69	71	73	75	77
28	63	65	67	69	71	73	75	77	79
30	65	67	69	71	73	75	77	79	81
32	67	69	71	73	75	77	79	81	83
34	69	71	73	75	77	79	81	83	85
36	71	73	75	77	79	81	83	85	87
38	73	75	77	79	81	83	85	87	89
40	75	77	79	81	83	85	87	89	91

*For required superheat at indicated low-side pressure (HCFC–22)

NOTES: 1. Measure suction-tube temperature at low-side service fitting by using an accurate superheat, thermocouple, or thermistor-type thermometer.

2. To obtain required superheat temperature at specific low-side pressure, add refrigerant if suction-tube temperature is higher than indicated in table or recover refrigerant if lower. (Allow tolerance of ± 5°F.)

REQUIRED LIQUID-TUBE TEMP (°F)*

High-Side Pressure (PSIG) at Service Fitting	Required Subcooling Temperature (°F) 0	5	10	15	20	25
134.4	76	71	66	61	56	51
141.3	79	74	69	64	59	54
148.4	82	77	72	67	62	57
155.7	85	80	75	70	65	60
163.2	88	83	78	73	68	63
171.1	91	86	81	76	71	66
179.1	94	89	84	79	74	69
187.4	97	92	87	82	77	72
195.9	100	95	90	85	80	75
204.8	103	98	93	88	83	78
213.8	106	101	96	91	86	81
223.2	109	104	99	94	89	84
232.8	112	107	102	97	92	87
242.6	115	110	105	100	95	90
252.9	118	113	108	103	98	93
263.5	121	116	111	106	101	96
274.3	124	119	114	109	104	99
285.4	127	122	117	112	107	102
296.8	130	125	120	115	110	105
308.6	133	128	123	118	113	108
320.6	136	131	126	121	116	111
331.1	139	134	129	124	119	114
345.8	142	137	132	127	122	117
358.9	145	140	135	130	125	120

*For required subcooling at indicated high-side pressure (HCFC–22)

NOTES: 1. Measure liquid-tube temperature at high-side service fitting by using an accurate thermocouple or thermistor-type thermometer.

2. To obtain required subcooling temperature at a specific high-side pressure, add refrigerant if liquid-tube temperature is higher than indicated in table or recover refrigerant if lower. (Allow tolerance of ± 3°F.)

FIELD CHARGING TABLE (Units with Fixed Restrictor)*

Condenser Entering Air Temp (°F DB)	Evaporator Entering Air Temperature (°F WB) 54	56	58	60	62	64	66	68	70	72	74	76
65	10	13	16	19	21	24	27	30	33	36	38	41
70	7	10	13	16	19	21	24	27	30	33	36	39
75	–	6	9	12	15	18	21	24	28	31	34	37
80	–	–	5	8	12	15	18	21	25	28	31	35
85	–	–	–	–	8	11	15	19	22	26	30	33
90	–	–	–	–	5	9	13	16	20	24	27	31
95	–	–	–	–	–	6	10	14	18	22	25	29
100	–	–	–	–	–	–	8	12	15	20	23	27
105	–	–	–	–	–	–	5	9	13	17	22	26
110	–	–	–	–	–	–	–	6	11	15	20	25
115	–	–	–	–	–	–	–	–	8	14	18	23

*Required superheat temperature (°F) at indicated entering air conditions.

NOTES: 1. Determine superheat temperature at low-side service fitting by using an accurate superheat, thermocouple or thermistor-type thermometer.

2. To prevent slugging, do not attempt to adjust charge at conditions in table that are indicated with a dash (–).

3. To adjust charge, add refrigerant if superheat temperature is higher than indicated in table or recover refrigerant if lower.