Introduction to Residential Air Conditioning Sessions

Field Reference Guide

Updated September 2023

Johnson Controls

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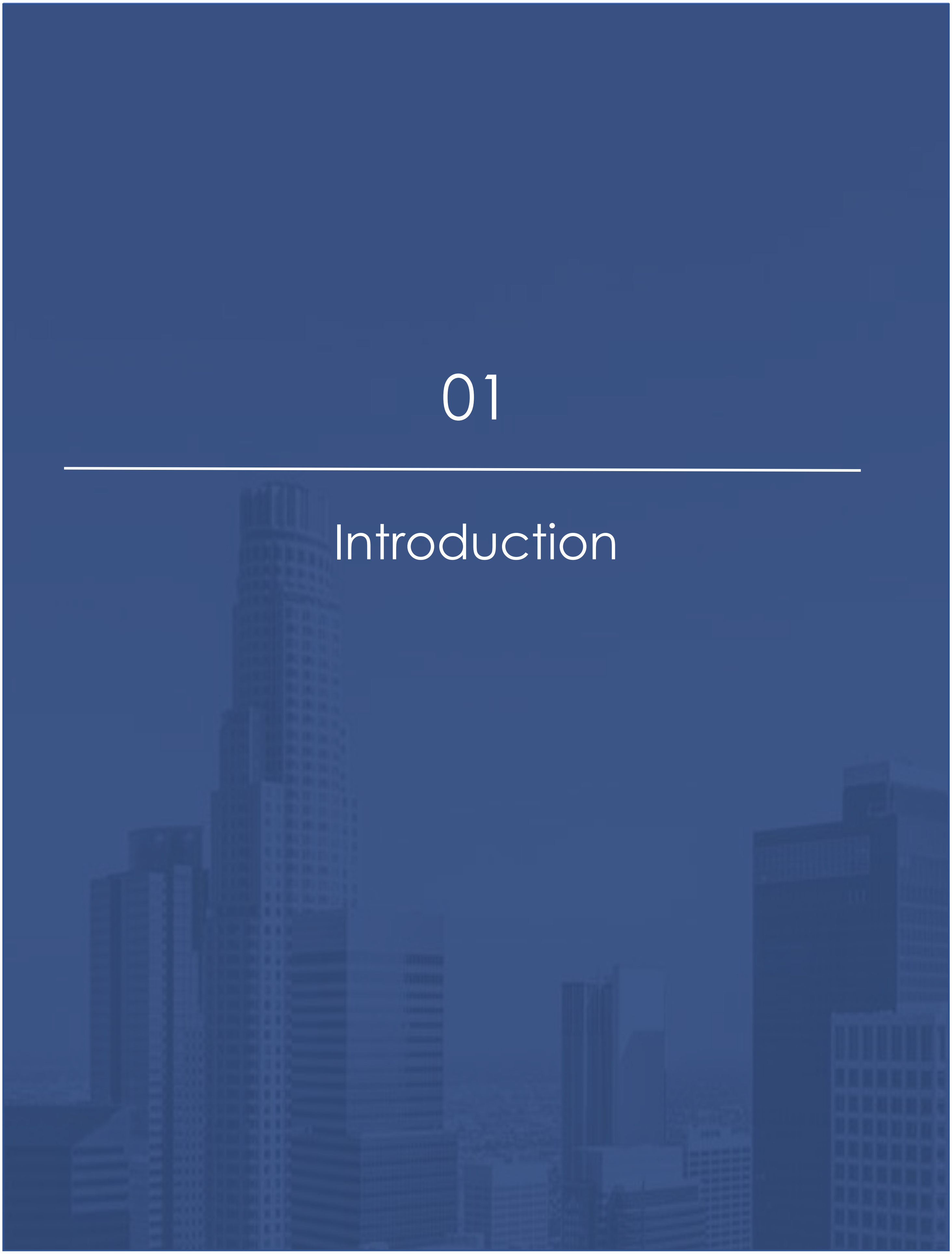


01

Introduction

Introduction

This Guide covers Ducted Systems residential air conditioning systems, detailing the operation of the refrigeration circuit, individual components, and setup and service of the system.

The systems discussed in this Guide include single stage and two stage cooling operation with cooling capacities ranging from 18 to 60 thousand BTU/h cooling capacity. Not all options discussed in this guide are available on every product line. Refer to unit specific documentation for this detail. Variable capacity air conditioning systems are discussed in a separate Guide.

This Guide is not designed to replace the documentation provided with the equipment. The technician should always refer to the installation and service instructions during the installation and service of any air conditioning equipment. Follow all local, state, and federal laws, codes, rules, and regulations when performing work on any of the equipment described in this guide.

Safety is always a concern when working on HVAC equipment. In Section 2 (Safety), many factors regarding workplace safety are reviewed. It is the employer and technician's responsibility to identify potential safety hazards in the workplace. This is not an all-inclusive safety document. Only qualified technicians with proper safety training should install, service or maintain the equipment described in this guide.

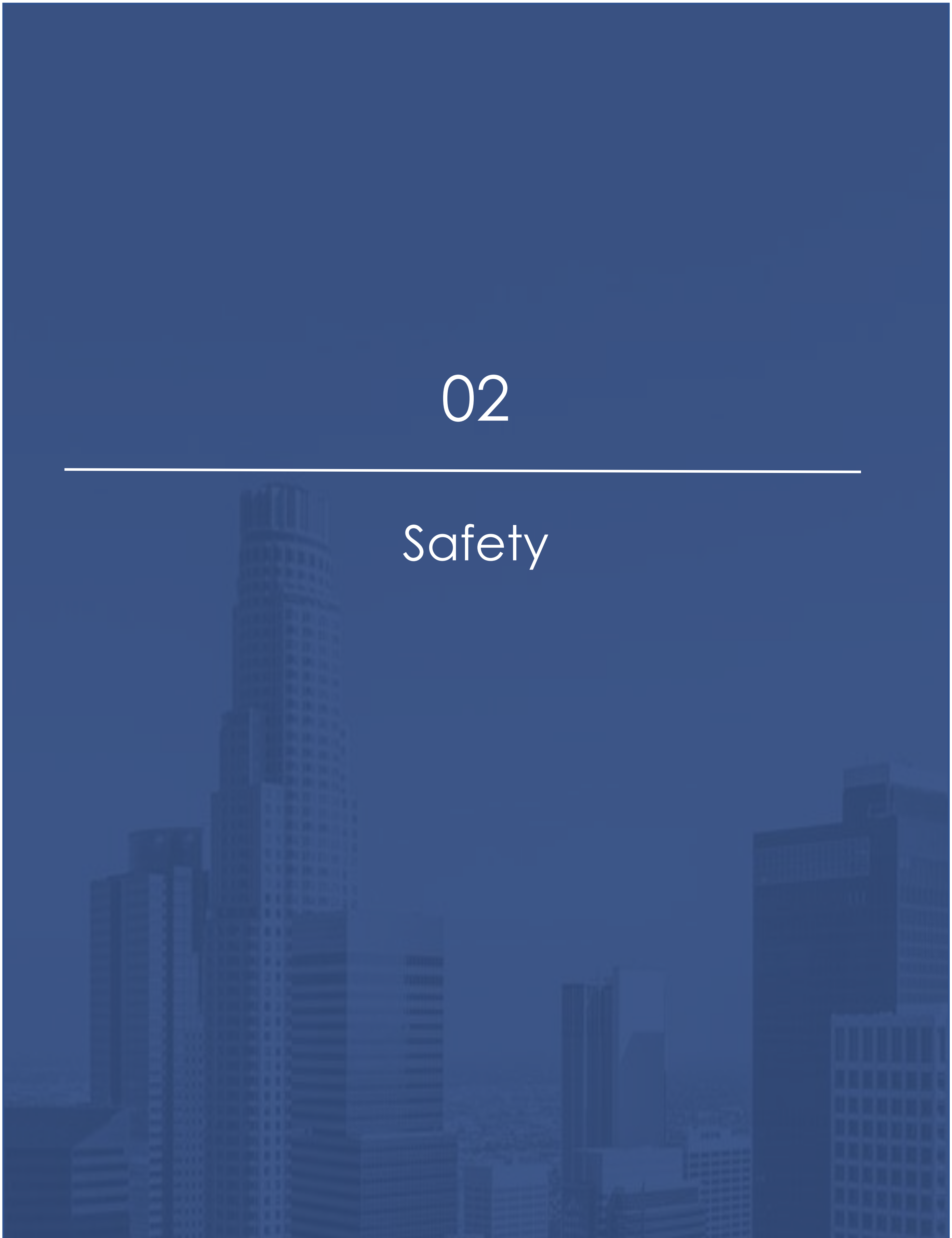
Proper installation and service of air conditioning systems requires a thorough understanding of electrical and mechanical components and system operation. In Section 3 (Component Familiarization), the air conditioning cycle, electrical components, and field installed accessories are reviewed.

In Section 4 (Installation) and Section 5 (Start Up), basic installation and start up procedures (including residential and commercial equipment) are discussed.

Section 6 (Sequence of Operation) covers the electrical characteristics and measurements of an air conditioning system. The detailed sequence of operation will review not only the major components but will provide a summary of the electrical components and voltages which will be present when a system is operating properly.

Section 7 offers insight for troubleshooting.

Section 8 (Maintenance) reviews maintenance procedures for the various components within the air conditioning unit.



02

Safety

Safety Symbols

Reminder – use this manual in conjunction with the technical literature for each product. This manual Does Not Supersede the Installation Manual and Technical Guide provided with the equipment. Always read and follow all instructions before installing equipment. Understand and pay particular attention to the signal words **DANGER**, **WARNING** or **CAUTION**.

⚠DANGER

An overpressure protection device, such as a pressure regulator, must be installed in the gas piping system upstream of the furnace and must act to limit the downstream pressure to the gas valve so it does not exceed 0.5 psig [14" w.c. (3.48 kPa)]. Pressures exceeding 0.5 psig [14" w.c. (3.48 kPa)] at the gas valve will cause damage to the gas valve, resulting in a fire or explosion or cause damage to the furnace or some of its components that will result in property damage and loss of life.

Sample Danger Label

DANGER indicates an imminently hazardous situation which could result in death or serious injury.

⚠WARNING

The duct system must be properly sized to obtain the correct airflow for the furnace size that is being installed.

Refer to the furnace rating plate for the correct rise range and static pressures or to Table 6 for the correct rise range.

If the ducts are undersized, the result will be high duct static pressures and/or high temperature rises which can result in a heat exchanger OVERHEATING CONDITION. This condition can result in premature heat exchanger failure, which can result in personal injury, property damage, or death.

Sample Warning Label

WARNING indicates a potentially hazardous situation which could result in death or serious injury.

⚠CAUTION

The indoor coil must be installed in the supply air duct, downstream of the furnace. Cooled air may not be passed over the heat exchanger.

Sample Caution Label

CAUTION indicates a potentially hazardous situation, which, if not avoided, may result in minor or moderate injury. It is also used to alert against unsafe practices and hazards involving only property damage.

Safety Specific Rules

Follow these specific safety rules for a safe application:

- Air conditioning systems utilizing gas heating can only use natural gas or propane (LP) gasses as an approved fuel. LP applications require installation of the appropriate LP conversion kit. Refer to the unit rating plate or Installation Manual for information on proper inlet and manifold pressures.
- Install air conditioning systems only in locations and positions as specified in the Installation Manual.
- Provide adequate clearances for service, combustion, and ventilation air to the unit. The recommended clearances are specified in the Installation Manual.
- Test for gas leaks as specified in the Installation Manual.
- Only connect the equipment to a duct system which has an external static pressure within the allowable range as specified in the Installation Manual.
- These unites are not to be used for temporary heating or cooling of buildings or structures under construction. Improper installation will shorten equipment life, reduce product efficiency, and void the warranty.
- Always install the systems to operate within the equipment's intended temperature and operating ranges.
- The size of the unit should be based on an acceptable and approved heat load calculation for the structure being conditioned.

Safety Requirements

Follow these safety requirements for a safe application:

- All equipment should be installed in accordance with all national and local building/safety codes and requirements, local plumbing or wastewater codes, and other applicable codes. In the absence of local codes, install in accordance with the most recent National Electrical Code, National Fuel Gas Code and/or Natural Gas and Propane Installation Code (latest editions). Furnaces have been certified to the latest edition of standard ANSI and CSA standards.
- Only approved heat accessories shall be installed on these air conditioning units local.
- Refer to the unit rating plate for the equipment model number, and refer to the Installation Manual for proper air plenum dimensions.
- Provide clearances from combustible materials as listed under Clearances to Combustibles in the Installation Manual and the equipment rating plate.
- Provide clearances for servicing ensuring that service access is allowed for both the burners and indoor fan motor.
- Provides clearances for servicing.
- Failure to carefully read and follow all instructions in this manual and the equipment Installation Manual can result in equipment malfunction, death, personal injury and/or property damage.
- Check the rating plate and power supply to be sure that the electrical characteristics match. All commercial 15 through 25-ton units distributed in North America use nominal 208/230 volts AC, nominal 460 volts AC, or nominal 575 volts AC 3 Phase, 60-Hertz power supply. DO NOT CONNECT THIS APPLIANCE TO A POWER SUPPLY OR A VOLTAGE OTHER THAN THE RANGE SPECIFIED ON THE UNIT DATA TAG.
- The equipment shall be installed so the access panels are readily available, and the electrical components are protected from water infiltration.
- Installing and servicing HVAC equipment can be hazardous due to the electrical and mechanical components. Only trained and qualified personnel should install, repair, or service HVAC equipment. When working on equipment, observe precautions in the manuals and on the labels attached to the unit and other safety precautions that may apply.
- The Installation manual covers minimum requirements needed to conform to existing national standards and safety codes. In some instances, these instructions exceed certain local codes and ordinances. These instructions are required as a minimum for safe installation and operation.

General Awareness

Safety is ALWAYS the primary concern for everyone. On the job injuries can be significantly reduced when proper guidelines are followed. Always be aware of all company, local, state and/or OSHA (Occupational Safety and Health Administration) regulations.

Jobsite Safety

Keeping the job site clean of trash, extra tools and equipment will significantly reduce the chance for injuries. Since each job is unique and has its own hazards, all new workers to the area should be made aware of the location of hire and first-aid equipment, fire escape routes, and other dangers.

Hazardous Materials

Many different chemicals and compounds are used in the service and installation of HVAC systems. Please read the directions and use caution along with PPDs whenever handling these materials. Read and understand the MSDS for all materials used.

Confined Spaces

Never enter or work in a confined space without taking the appropriate precautions. Have someone available outside the space ready to assist or summon help if necessary. Even spaces that seem relatively safe can quickly become hazardous if a pipe were to break and fill the space with refrigerant, steam, poisonous fumes or other gasses. Welding or brazing in a confined space is especially hazardous.

Pressure

High pressures have always been part of the HVAC profession. Wear the proper personal protective devices including safety glasses and gloves. Proper hose ratings and manifolds are required for high-pressure refrigerants.

Electrical Safety

Jewelry should be removed prior to any electrical work being performed. Ensure that the equipment disconnect switch removes the primary power source prior to taking resistance readings or disconnecting any wires or connections. Removal of system power should be verified with the voltage function of a multimeter. All electrical safety guidelines should be always followed. Only trained, qualified technicians should perform electrical maintenance, installation, inspections and troubleshooting of electrical equipment.

Electrocution occurs when a current as low as 6 to 200mA flows through the heart, disrupting its normal operation and causing death. Electrical shock is an injury that occurs because of exposure to an electrical current. Inspect all extension cords and power tools regularly. Fuses and circuit breakers are designed to protect equipment, not people. For personal electrical protection, GFCI or Ground Fault Circuit Interrupters are highly recommended.

Lock-Out Tag-Out

OSHA Standards cover the servicing and maintenance of machines and equipment, in which unexpected energizing or startup of the machines or equipment, or release of stored energy, could cause injury to employees.

These standards establish minimum requirements for the control of such hazardous energy. To ensure safety, put a lock that is tagged with the technician's name on the electrical disconnect or breaker of the equipment or circuit which is being serviced.

Be aware of others who may be working on the same circuit or other circuits served by the same electrical panel. The technician should also be aware that other technicians may not have used the proper Lock-Out, Tag-Out procedures.

Fire Safety & Burns

While brazing, keep the area clear of combustible material or use a heat shield to help reduce risk of fire.

Check equipment regularly and never try to modify or repair regulators.

While servicing the refrigeration circuit, improper use of equipment and tools can result in serious burns that are associated with refrigerants. This may include frostbite, which is a deep tissue injury. Proper personal protection devices must be in use when servicing the refrigeration system.

Personal Safety

Personal safety always includes remaining aware of the surroundings, using properly maintained tools, and correct use of items designed for personal protection.

Personal Protection Devices (PPD)

- Hard Hat: Hard hats must be worn when there is a danger of head injury.
- Safety Glasses: Eye protection should be worn at all times while on a job site.
- Gloves: Assist in the prevention of serious injury to the hands from serious cuts as well as injuries from high-pressure gasses such as refrigerants. Rubber gloves can protect the technician’s hands from chemicals when inspected and worn properly.
- Safety Shoes: Work shoes with steel toes for foot protection. There are also electrical safety shoes that can aid in protecting the technician against electrical shock and/or electrocution. At a minimum, leather work shoes with rubber soles are required.
- Respirator: Used in a confined space where the air can be dissipated by refrigerant which can cause asphyxiation.
- Safety Harness: Used when working above grade level. Ladders must be tied down. Ensure that PPDs provide the intended protection. They should be inspected regularly, used properly and never altered or modified in any way.

Clothing

Rotating and moving components pose a serious risk. Loose fitting clothing and ties should not be worn when servicing rotating equipment. If any clothing becomes entangled in moving parts, serious injury or death is a likely result.

Jewelry

Serious injury or death can result if jewelry contacts an energized circuit or is caught in moving parts. Leave jewelry at home or in your service bag or service vehicle.

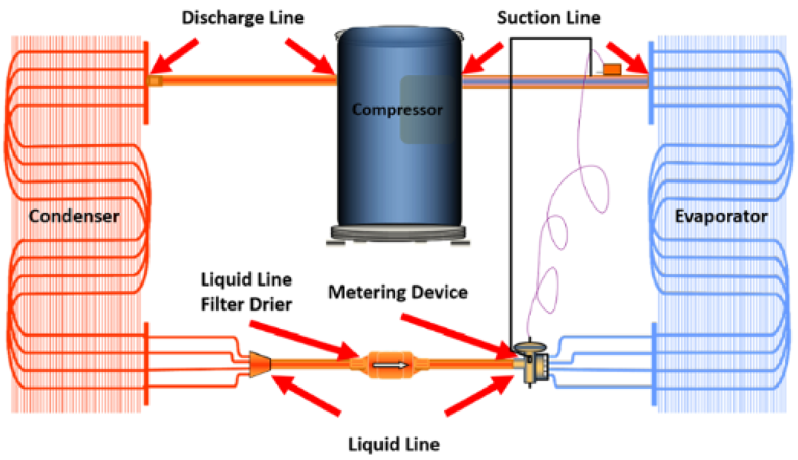
Lifting

To avoid back injuries, always adhere to proper lifting techniques. Be aware of personal limitations and seek help with items that are too heavy to safely lift. A back support belt may provide additional protection.

03

Component Familiarization

Basic Refrigeration Circuit



In the refrigeration circuit, heat is moved from a place where it is not wanted (indoors) to an area where it is less objectionable (outdoors). In an air conditioning system, there are five basic components that are used to move heat from within the structure to the outdoors: the compressor, condenser, metering device, evaporator, and refrigerant. Refrigerant absorbs heat from inside the structure and transfers it to the outdoor air.

Basic Refrigeration Circuit

Heat moves from warmer to cooler areas. During the cooling season, heat from the exterior of a structure moves inside the structure where it is cooler. This is called "heat gain". The size (capacity) of air conditioning systems are sized based on the heat gain of the structure.

Air conditioning system capacities are expressed in BTUH of cooling capacity, expressed in 'tons'. One ton of cooling capacity = 12,000 BTUH. A 'two-ton' air conditioning system is capable of moving 24,000 BTUH of heat from the indoors to the outdoors. Of course, equipment must be appropriately selected (sized) for the needs of the job by running a load calculation. Proper system installation and setup is also critical.

Compressors

The compressor moves refrigerant through the system. Air conditioning compressors compress refrigerant from a low-pressure vapor to a high-pressure vapor. The pressure of the refrigerant entering the inlet ("suction") side of the compressor is the low side pressure or suction pressure. The pressure exiting the compressor is referred to as high side pressure or discharge pressure. As the suction vapor enters the compressor, it is compressed from a low pressure to a high-pressure vapor. This increases the pressure and raises the temperature of the refrigerant above the ambient temperature of the condensing coil during cooling. The refrigerant exits the compressor as a hot discharge gas.
Hot discharge vapor is a combination of heat absorbed from the indoor coil, heat from compression, and heat from the compressor. The hot discharge gas is pumped from the compressor, through the discharge line, and to the condensing coil.

Proper refrigerant charging of the system allows cool vapor to enter the compressor to maintain designed operating temperatures. Therefore, proper installation and charging techniques must be followed when completing installation, maintenance, and repairs to the equipment.

Compressor Types

Three of the most common compressor types used in residential and light commercial air conditioning systems are the rotary, reciprocating, and scroll.

Rotary Compressor

Rotary Compressor - Internal

Rotary

There are several models of air conditioning units which use a rotary compressor. The rotary compressor uses a rotating eccentric lobe to compress the suction vapor against the cylinder walls as shown in the diagram below. The vapor is compressed as it is rotated to the discharge side of the cylinder and out of the discharge line.
As the eccentric lobe rotates, a spring-loaded blade moves with the lobe to maintain a pressure differential between the high and low side of the system.

Reciprocating

Reciprocating compressors use pistons that travel up and down (reciprocate) within cylinders to compress refrigerant vapor. On the "down stroke," a suction inlet valve is opened, and low-pressure vapor refrigerant is drawn into the cylinder. When the piston begins its "up stroke," the suction inlet valve is closed. The piston compresses low pressure vapor into high pressure vapor and the high-pressure vapor exits through the discharge port.

Reciprocating Compressor

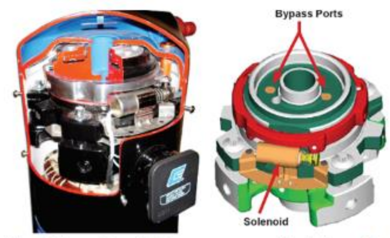
Scroll

The scroll compressor has a straightforward design and fewer moving parts than other compressor types. In a scroll compressor, an orbiting scroll moves in a circular motion within a second, fixed scroll. The low-pressure refrigerant vapor entering the suction inlet is pressurized into continuously smaller areas until the refrigerant exits through the discharge port as a high-pressure vapor.

Scroll Compressor & Internal Scroll Components

Two-Stage Scroll

Scroll compressors are available in two-stage configurations. The two-stage scroll compressor has two internal bypass ports. During a call for second stage cooling, the bypass ports are closed, and the compressor operates at 100% capacity.
During a call for first stage cooling, the bypass ports are open, reducing capacity to 67%. This is detailed in Section 6 (Sequence of Operation).
The two-stage scroll compressor has an internal 24 volts DC solenoid valve. The external rectifier located in the low voltage compressor connector converts the 24 volts AC input signal to a 24 volts DC output. The 24 volts DC output is delivered to the compressor solenoid terminals, which energizes the internal solenoid valve. Troubleshooting of the rectifier is covered in Section 7.



Two-Stage Scroll Compressor with Internal View

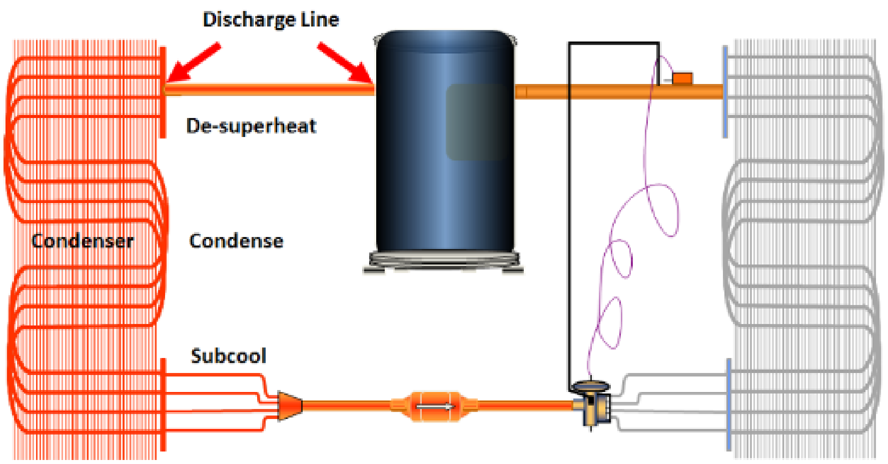
24V AC to 24 VDC Rectifier

Condenser Coil

Hot, high-pressure discharge gas from the compressor enters the condenser coil. The outdoor air, which is cooler than the discharge vapor, flows through the coil. The heat within the refrigerant vapor can only move in one direction - from warmer to cooler. Thus, heat is rejected from the refrigerant through the coil surface to the outdoor air.

As the refrigerant flows through the coil the ambient air continues to cool the refrigerant gas until it reaches the refrigerant's saturation temperature. This is known as de-superheating the refrigerant. After the refrigerant is de-superheated, the refrigerant condenses (changes state) into a liquid.

After the refrigerant has condensed to a liquid and the outdoor fan motor continues to move air across the coil, the condensed liquid refrigerant will cool below the saturation temperature. This is known as "subcooling."



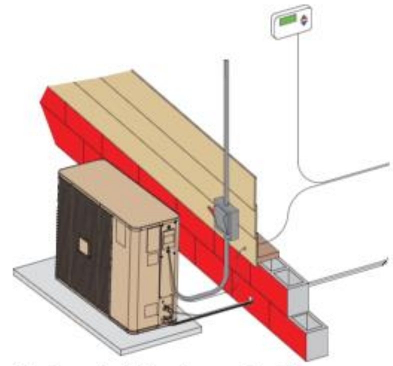
Note
Subcooled refrigerant will always be a few degrees warmer than the ambient air.

The ability of the coil to subcool the refrigerant is important to ensure that 100% liquid refrigerant is delivered to the metering device during cooling. As the liquid refrigerant leaves the condenser coil, the refrigerant is carried to the metering device in the liquid line.

A clean, unobstructed coil will maximize heat transfer capabilities and improve the overall efficiency of the system. During installation, be sure to follow all recommendations regarding minimum spacing and clearances from surrounding structures and other equipment.

Horizontal Discharge Units

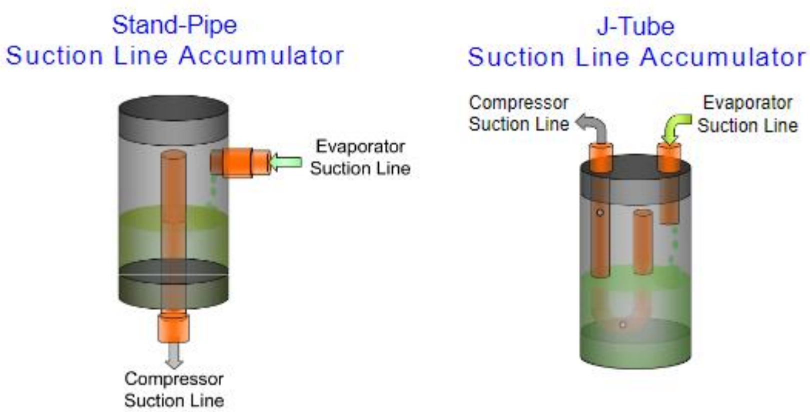
Horizontal discharge units are designed for applications with restricted space and long line-sets. These units can be installed in locations with as little as six inches of clearance around the unit and eighteen inches of service access clearance. The maximum line set is 200 feet. Some line lengths may require the installation of a liquid line solenoid valve. Refer to Application Data 247077 for more information.



Horizontal Discharge Unit

Accumulator – Horizontal Condensing Units

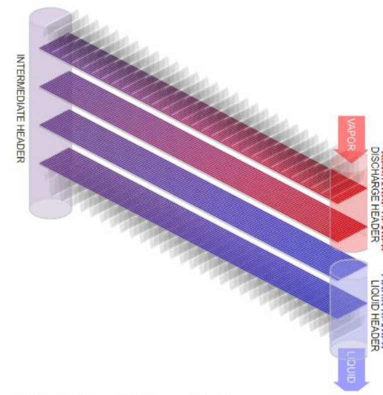
Horizontal discharge units are equipped with an accumulator, which is factory piped into the suction line between the suction line service valve and the compressor. The purpose of the accumulator is to prevent liquid refrigerant from slugging the compressor.



Stand-Pipe & J-Tube Accumulator

MicroChannel Coils

MicroChannel condensing coils have improved heat transfer capability over tube-fin condensing coils. Condensing uses a two-pass design. As the hot compressed vapor leaves the discharge line and enters the header of the condensing unit, the refrigerant disperses throughout the header and enters each row of channels moving through the top section of the coil. In the top portion of the coil, the refrigerant de-superheats, cooling the refrigerant down to the saturation point. As the condenser fan continues to promote heat removal from the refrigerant, the vapor condenses to a liquid and enters the intermediate header. As the liquid refrigerant is circulated through the common header and enters the bottom section of the condenser, the refrigerant continues to release heat to the ambient air.



2-Pass MicroChannel Coil

Important
MicroChannel coils are constructed primarily of aluminum. Aluminum cannot withstand the excessive heat from an oxy-acytylene torch. In the event of coil repair, a lower temperature repair method (such as propane) is required. See the installation section of this Guide for more information.

The refrigerant is subcooled as it passes through the bottom section of the condenser. This provides 100% liquid out of the liquid line.

Microchannel is manufactured with flat tubes and heavy-duty fin construction that makes the coil more rigid, reducing the possibility of damage due to rough handing. In addition, MicroChannel coils are typically 30% to 40% smaller than conversational tube-fin coils. This increases the installation options available in locations where space restrictions are a crucial factor.

MicroChannel coils are 20% to 30% lighter than the tube-fin coils, have less internal volume, and require up to 50% less refrigerant to charge the system. The reduction in refrigerant volume will also reduce the cost and time associated with recovering refrigerant or charging the system during service or repair.

Repair kits are available through Source 1. The MIcroChannel condenser coil repair kit includes a special soldering alloy with flux already in the solder and a brush to clean the area to be repaired.

MicroChannel End View

Metering Devices

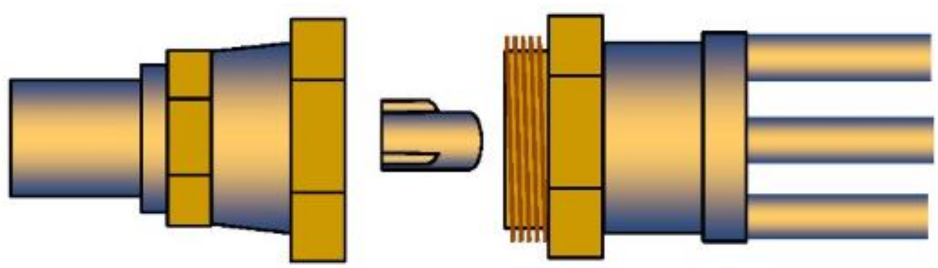
The metering device creates a pressure drop and controls the flow of refrigerant to the evaporator coil. On the inlet or upstream side of the metering device is subcooled high-pressure liquid refrigerant from the condensing unit. As the refrigerant passes through the metering device, the pressure drop reduces the boiling point of the refrigerant.

Thermostatic Expansion Valve (TXV)

Systems using TXV metering devices are charged by weight or field adjusted by the subcooling method detailed in the unit's Installation Manual, or on the unit data plate. The TXV is designed to maintain a constant superheat within the evaporator coil.

Technician Notes
The TXV only controls superheat. It DOES NOT control suction pressure. Suction pressure is a function of the load imposed on the refrigerant. The external equalizer line DOES NOT equalize high side and low side pressures. It only provides a closing force to the valve. If the TXV is applied with a reciprocating compressor, a start capacitor and potential relay (a "hard start" kit) MUST be used.

Fixed Orifice or Restrictor



Fixed Orifice

Air conditioning systems that utilize fixed orifice metering devices must be charged either by weight or superheat. The superheat readings must fall within the values listed in the Installation Manual, Tech Guide, or those provided on the unit data plate.

Use the Tabular Data Sheet to properly match the evaporator, condenser, and orifice to achieve the rated efficiency and system capacity. The Tabular Data Sheet will also list the additional charge required for the matched equipment.

The Evaporator Coil

Technician Notes
Most systems designed today require the use of a TXV. DO NOT attempt to use a fixed metering device on systems designed for a TXV.

The evaporator coil absorbs heat from the conditioned space. The return air from inside the structure is passed across the evaporator coil with the indoor blower. As the heat from the warm return air passes through the coil, the refrigerant absorbs heat from the air and begins to boil the refrigerant into a vapor. The greatest amount of heat is absorbed while the refrigerant is evaporating from a liquid to a vapor. This is called the latent heat of vaporization. As the refrigerant passes through the evaporator coil, it continues to boil until it has fully converted to vapor. As heat from the indoor air is added to the vapor refrigerant is warmed a few degrees above the boiling point or saturation temperature. This is known as "superheat". The refrigerant must be 100% vapor before it returns to the compressor to prevent liquid from flooding back (slugging) of the compressor.

Superheat Note
Refrigerant returning to the compressor must be superheated to ensure no liquid refrigerant enters the compressor. Liquid refrigerant entering the compressor may cause irreparable damage. Compressors are dependent upon the cool, slightly superheated refrigerant vapor to cool the compressor internal components. Excessive superheat can damage the compressor beyond repair.

Liquid Line & Suction Line Service Values

Air conditioning units contain liquid line and suction line service valves near the condensing unit's corner.

Liquid Line & Suction Line Service Valves

The condensing unit is shipped with the service valves in the fully front seated (clockwise) position. The service valves isolate and hold the refrigerant charge in the condensing unit. Refrigerant lines are brazed at the indoor and outdoor connections during installation. The lineset and evaporator coil must be leak tested and evacuated down to 500 microns. After evacuation, the service valves must be fully back seated (counterclockwise). This will release the refrigerant into the lineset and evaporator coil.

The condensing unit is shipped pre-charged with enough refrigerant for the condensing coil, 15 feet of lineset, and the smallest matched evaporator coil. If a longer lineset, TXV kit, or larger evaporator coil is required, additional refrigerant will have to be added as indicated in the Tabular Data Sheet. The air conditioner must be matched with the proper indoor unit and coil if the system is to achieve system performance ratings. If the lineset is shorter than 15 feet, it may be required to recover refrigerant to meet the proper charge for the unit.

Identify the type of refrigerant the equipment is rated for and use the corresponding manifold gauges and refrigerant when servicing any HVAC equipment. This will ensure proper operation and prevent equipment damage.

Liquid Line Filter Drier

The liquid line filter drier traps moisture, acid, and small particles within the drier, stopping the contaminants from traveling through the system and causing damage. The liquid line filter drier is located between the outlet of the condenser coil and liquid line service valve.

Liquid Line Filter Drier Cutaway

The liquid line filter drier must be installed with the arrow pointing in the direction of refrigerant flow. The arrow is pointing away from the condensing unit, and toward the evaporator coil.

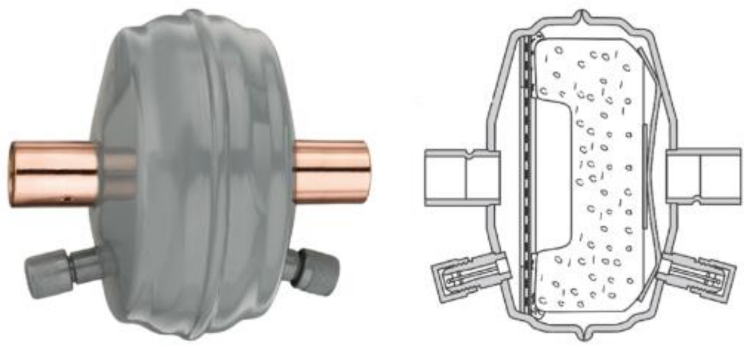
Identifying the type of drier installed is essential when making repairs. Filter driers are designed for specific refrigerants and pressures. Only filter driers designed for use on the system being serviced should be installed. Replacement driers must match the filter drier originally installed by the factory.

A restricted liquid line filter drier is diagnosed by taking a temperature measurement. Allow the system to operate for at least ten minutes and then take a temperature measurement on both sides of the drier. If the temperature differs by more than two degrees Fahrenheit, the drier must be replaced. In extreme cases, a restriction may be identified by placing both hands across the drier.

Caution
Caution must be taken when installing a liquid line filter drier in the system. Take precautions and use an approved heat sink to protect the metering device, filter drier, and service valves when brazing. The filter drier must be replaced if the refrigerant system is opened to the atmosphere. When the system is opened to the atmosphere, moisture can enter and contaminate the system causing equipment failure.

Suction Line Filter Drier

The suction line filter- drier traps moisture, acid, and small particles within the drier, preventing contaminants from traveling throughout the system. It can also provide added protection for the compressor and aid in cleaning up a system after a severe burn out. It is recommended that the suction line filter drier only be installed for system cleanup and should be removed after no more than 50 hours of operation.



Suction Line Filter Drier with Access Ports

Some suction line filter driers are manufactured with Schrader valves (gauge ports) on the inlet and outlet sides. This type of suction line filter drier must be in the suction line between the evaporator and the compressor. To evaluate a suction line filter drier with gauge ports located on both sides of the drier, take a pressure reading on both sides of the drier. If the pressure drop exceeds the pressure rating of the filter drier, the drier must be replaced.

Some driers may have been made with a Schrader valve on the inlet side only. If a suction line filter drier with only one gauge port is used, the drier must be installed in the suction line between the evaporator and the suction line service valve so that pressure is measured downstream from the filter drier.

Caution
Caution must be taken when installing a suction line filter drier in the system. Take precautions using an approved heat sink to protect the compressor and filter drier when brazing.

Electrical Wiring

All field wiring must be installed using copper conductors only and must be grounded with a separate ground wire in accordance with all local, state, and national fire, safety, and electrical codes. The electrical supply must meet the values specified on the unit data plate and wiring labels. All conductors for power wiring, control wiring, the electrical disconnect, and over-current protection must be provided by the installer and be sized in accordance with the most current National Electrical Code (NEC).

If the system is not installed in accordance with these codes all warranties will be voided.

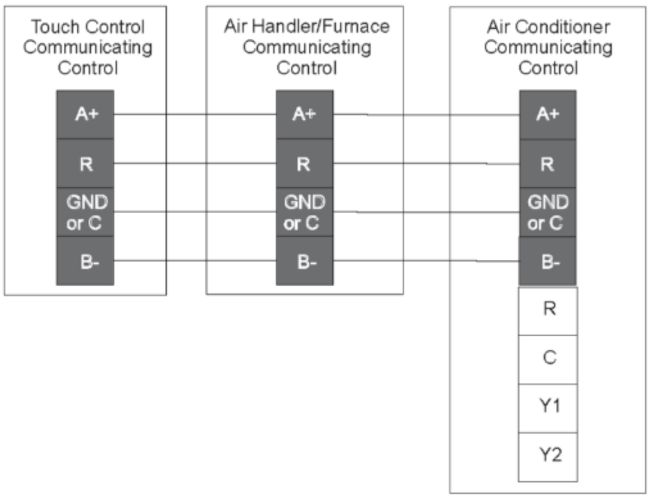
Power Wiring

All equipment must have a properly rated and sized weatherproof disconnect switch located outdoors and within sight of the unit. Some municipalities may require a licensed electrical contractor to provide the line voltage electrical connections to the condensing unit from the electrical disconnect. All equipment must be protected, either by properly sized time-delay fuses or HACR-rated circuit breakers rated in accordance with the NEC.

Control Wiring

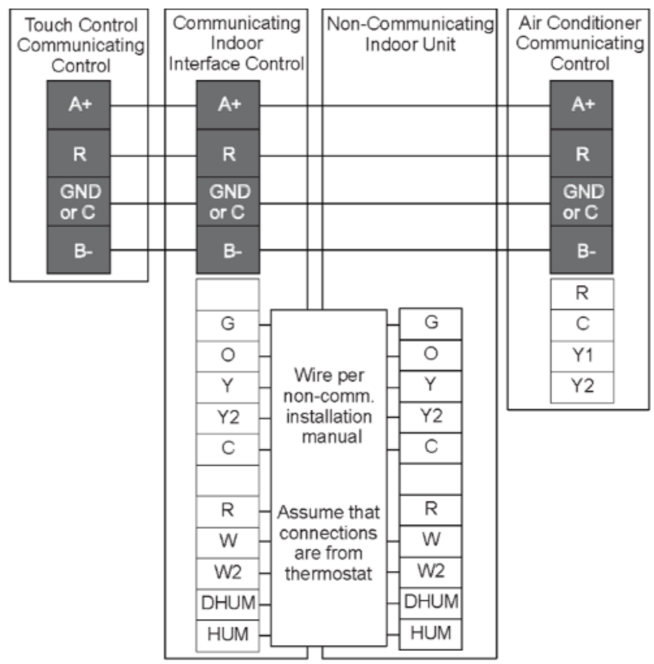
All control wiring must be installed in accordance with the National Electrical Code and/or local city or state codes, whichever is more stringent. All control wiring must be 18AWG or larger. The complete electrical wiring diagram and schematics are on the unit in the service access panel for reference.

Below are examples of the field installed, low-voltage connections that may be required depending on how the system components have been matched. The Installation Manual provides multiple low voltage configurations that must be reviewed to ensure a properly wired system.



Example of Control Wiring for Communicating Thermostat/ Indoor Unit/ Air Conditioner Unit

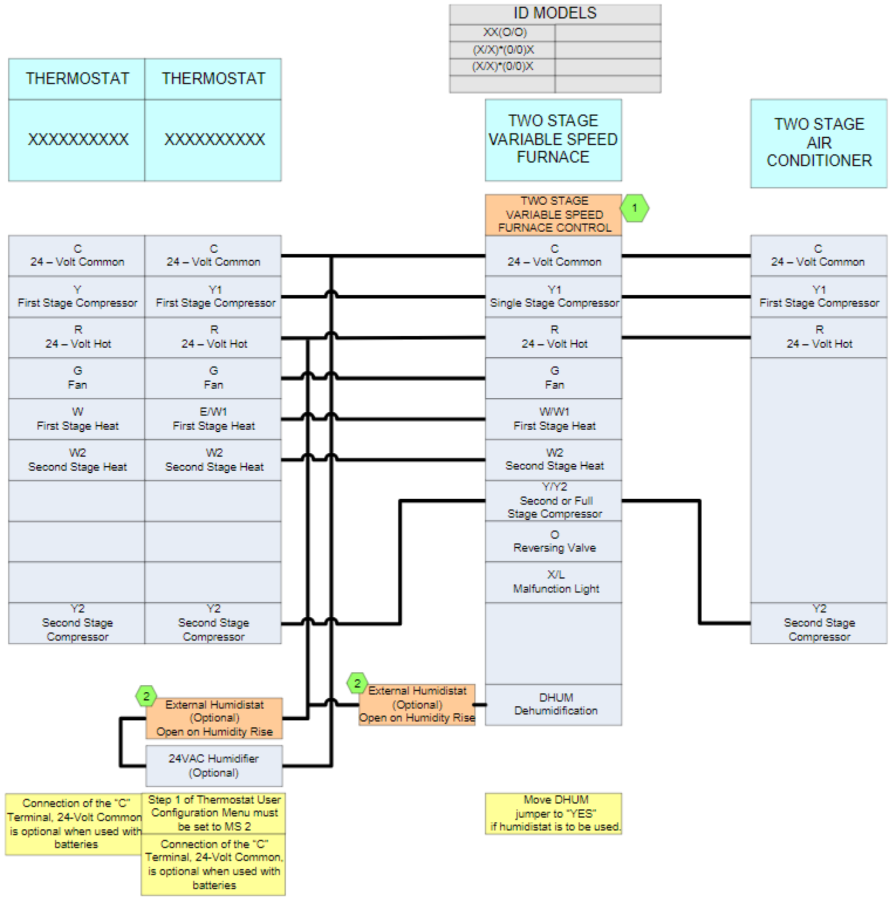
In the following example, identify the model of thermostat, the model of the indoor furnace or air handler, and the model of the condensing unit being installed. After identifying each component, the proper field wiring is identified with a similar wiring configuration in the Installation Manual.



Example of Control Wiring for Communicating Thermostat/ Indoor Interface Control/ Air Conditioner Unit

Most air conditioning systems will require 2 to 4 low voltage control wires routed to the condensing unit. The number of conductors depends on the model, and whether the system has a single or two stage compressor. These electrical connections will be discussed throughout this guide and are identified in the Installation Manual.

Note
If a thermostat is selected that is not listed in the Installation Instructions, verify that it has the same functionality as the one listed.



Thermostat Connections for Two-Stage Air Conditioner with Two Stage Variable Furnace

Thermostat

Thermostat selection is critical when matching the air conditioner with the air handler or furnace. A thermostat is a bank of switches designed to send control voltage to control devices energizing components for heating and cooling. The switches are actuated by temperature changes within the structure depending on the occupant's settings.

Thermostat

The thermostat has manual selections for the occupant to adjust settings for heating or cooling and set the indoor fan motor to ON or AUTOMATIC.

Thermostats have become more complex with two stage heating and cooling units. Many of the thermostats have programming capabilities.

Thermostat terminal designations are:

- R-24 volts AC Hot
- C-24 volts AC Common
- W1 – Heat Call (First Stage Heat on 2 Stage Heating Systems)
- W2 – Second Stage Heating Call
- Y1 – First Stage Cooling (2 Stage Cooling)
- Y/Y2 – Cooling (Single Stage Cooling System)/Second Stage Cooling (2 Stage Cooling Systems)
- G-Indoor Fan Operation

The installation technician is responsible for reading and adhering to the equipment and thermostat installation instructions to ensure that it is matched and wired properly.

Residential Air Conditioning Communicating Control Board

The Residential Air Conditioning Communicating Control Board is used on several Unitary Products condensing units. The training provided throughout this chapter will cover systems that are manufactured with and without the Air Conditioning Communicating Control Board. If an existing Unitary Product is upgraded with the Air Conditioning Communicating Control Field Kit to allow operation with the Johnson Controls Residential Communicating Control System, the instructions that accompany the kit must be followed to ensure proper operation.

Residential AC Communicating Control

The Residential Air Conditioning Communicating Control Board monitors control voltage between the "R" and "C" terminals. If the control voltage drops below 19 volts AC, the energized relays will remain energized, but no extra relays will be allowed to operate. If the control voltage drops below 16 volts AC, all relays will be de-energized until the transformer's secondary voltage supplied to the control board has increased to greater than 20 volts AC. When the control voltage drops, the appropriate flash code will be displayed to the control board's LEDs. Flash codes are published in Section 7 (Troubleshooting), and in the Installation Manual.

Ambient Sensor

A sensor is used to provide an ambient temperature display to the Johnson Controls Residential Communicating Control System (if used). When a non-communicating thermostat is used the sensor does not provide any information. If the sensor is open or shorted with a communicating thermostat, a fault code will be displayed, but the operation of the system will not be affected.

The sensor is a 10K thermistor that has 10,000 ohms of resistance at 77 degrees Fahrenheit. As the outdoor temperature decreases, the resistance increases, and as outdoor temperature increases the resistance decreases. The thermistor resistance at a given temperature can be identified by using the following table.

Ambient Sensor Location

Thermistor Temperature & Resistance

Temp.	Resistance	Temp.	Resistance	Temp.	Resistance
-30	235,155	25	40,153	80	9,299
-25	196,871	30	34,367	85	8,250
-20	166,342	35	29,986	90	7,401
-15	138,482	40	26,092	95	6,530
-10	118,108	45	23,013	100	5,774
-5	100,260	50	19,903	105	5,208
0	86,463	55	17,255	110	4,663
5	72,940	60	15,310	115	4,203
10	61,711	65	13,474	120	3,743
15	53,640	70	11,942	125	3,381
20	46,200	75	10,449	130	3,047

Duration of connection (seconds)	Control behavior with no system master signals present	Control behavior with system master signals present
Less than 2 seconds	No response	No response
Greater than or equal to 2 seconds	Display compressor type TS, UltraTech, or single stage compressor, ignore LPS	Bypass ASCD (Reduce timer to zero immediately). If Y1 (thermostat or communication) is present and the high pressure switch is closed, contactors will be energized.
	Clear soft lockout	Clear soft lockout
	Clear hard lockout	Clear hard lockout
	Reset TS anticipation mode counter to zero for TS systems	Reset TS anticipation mode counter to zero for TS systems
		Reduce TS staging delays for TS systems as described below
Connection removed	Resume normal LED display	
Connection not removed	Nothing more than previously explained	

Residential Air Conditioning Communicating Control Board Operational Modes		
Compressor Type	**LED1 (Red)**	**LED2 (Green)**
Single Stage Compressor	1 flash	---
TS Compressor	2 flashes	---
UltraTech Compressor	3 flashes	---

When the TEST pin short is removed, the LEDs will return to the normal display.

The status codes are displayed via the red, green, and yellow LEDs. These codes indicate the state of unit operation, but do not represent a fault. The status codes are represented as follows:

Residential Air Conditioning Communicating Control Board Status Codes			
Description	**Required Condition**	**LED 1 Red**	**LED 2 Green**
No power to control	No power to control	OFF	OFF
First-stage compressor operation (TS or UltraTech)	TS M & M1 energized UltraTech M energized Single Stage NA	OFF	ON
Second-stage compressor operation (TS, UltraTech, Single Stage)	TS and UltraTech M & M2 energized Single Stage M energized	ON	ON
Control normal operation - no communication or call for compressor present	No faults active, Y1 or Y2 not present	OFF	2 sec ON 2 sec OFF
Control normal operation - in ASCD period	No faults active, Y1 or Y2 present, ASCD timer not expired	OFF	0.1 sec ON 0.1 sec OFF
Note: Status codes will not be displayed when a fault code is present.			

Residential Air Conditioning Communicating Control Board Status Codes		
Description	**Required Condition**	**LED 3 Yellow**
Control powered with Johnson Controls Communicating Thermostat - active communication present	System is active and presently communicating successfully	0.1 sec ON 0.1 sec OFF
Control powered with conventional thermostat connections	System has 24 VAC present and the microprocessor is active	2 sec ON 2 sec OFF
Note: Operating condition status LED displayed at all times as described above.		

Any fault codes are displayed via the red and green LEDs. When a fault code exists, the control will display the fault code via the LEDs, pause two seconds, and display the fault again. This display will persist until the condition that caused the fault code no longer exists. The fault codes are represented as follows:

Residential Air Conditioning Communicating Control Board Flash Codes		
Operational Faults	**LED 1 Red**	**LED 2 Green**
Control Failure	ON	OFF
Operational Faults		
High-pressure switch fault (not in lockout yet)	1	OFF
System in high-pressure switch lockout	2	OFF
System in low-pressure switch lockout	4	OFF
Low voltage (<19.2 VAC) preventing further relay outputs	5	OFF
Low voltage (<16 VAC) stopped current relay outputs	6	OFF
High-pressure switch fault (with no communication for compressor operation and where Y1 and Y2 are not energized)	9	ON
Sensor or Switch Faults		
Outdoor ambient temperature sensor failure (short)	ON	1
Outdoor ambient temperature sensor failure (open)	ON	2
Wiring Related Faults		
Compressor	1	ON
Y2 present without Y1	2	ON

Note
Do not connect any other accessories or components to the "M", "M1", or "M2" terminals located on the Air Conditioning Communicating Control Board. If other accessories or components are installed the system will not operate properly and could be damaged.

If the Residential Communicating Control System is used instead of a conventional thermostat, the electrical wiring harness connected to the “Y1”, “Y2”, “C”, and “R” terminals on the bottom right side of the Residential Air Conditioning Communicating Control Board must be removed.

For additional information on the Johnson Controls Residential Communicating Control System, refer to the Filed Reference Guide for the Residential Communicating Control System.

Refrigerant Safety Controls

The Residential Air Conditioning Communicating Control Board is equipped with compressor protection lockout capabilities.

The control board has separate high and low-pressure switch terminals that provide system lockout protection with proper setup, and the board will enter a hard lockout if four soft lockouts occur within a 12-hour period.

Residential Air Conditioning Communicating Control Board Lockouts

High Pressure Switch Lockouts

When the compressor starts following a high-pressure switch fault, the control will start a six-hour timer based on accumulated compressor run time. If the high- pressure switch opens for 160 milliseconds during the six-hour timer, the Residential Air Conditioning Communicating Control Board will enter a soft lockout. If the high- pressure switch opens for less than 160 milliseconds, the compressor will be de-energized, but the unit will not enter a soft lockout.
The six-hour timer will reset if the high-pressure switch does not open again within six hours of accumulated compressor run time.

If four soft lockout conditions occur during a twelve-hour period, the board will enter a hard lockout. The four soft lockouts can be a combination of faults within a 12- hour compressor run-time period, and do not have to be high-pressure faults only. For a complete list of faults, refer to the Installation Manual.

Low Pressure Switch Lockouts

If the refrigerant pressure drops below the opening pressure for more than 5 seconds, the control board will enter a soft lockout. When a soft lockout is initiated, the control will display the appropriate fault code using the onboard LEDs and de- energize "M", "M1", and "M2" outputs from the control board.

The Residential Air Conditioning Communicating Control Board will ignore the low- pressure switch input during the following conditions:

- The first two minutes of compressor operation
- The "TEST" mode with a "Y1" or "Y2" input from the thermostat

The technician should refer to the specific equipment model to identify exact fault codes for the system being serviced.

Residential Air Conditioning Communicating Control Board Lockout Reset

The difference between a soft and hard lockout is the requirement to reset the control board once the fault or faults have been removed.

Soft Lockout Reset

A soft lockout is reset when power is cycled to the "R" or "Y1" inputs of the control board. This may occur when the thermostat is satisfied or when power is cycled "OFF" and "ON" at the thermostat. A soft lockout may also be reset when the "TEST" pins are shorted for more than two seconds. The control will stop displaying the fault and resume normal operation when the soft lockout condition has been reset.

Hard Lockout Reset

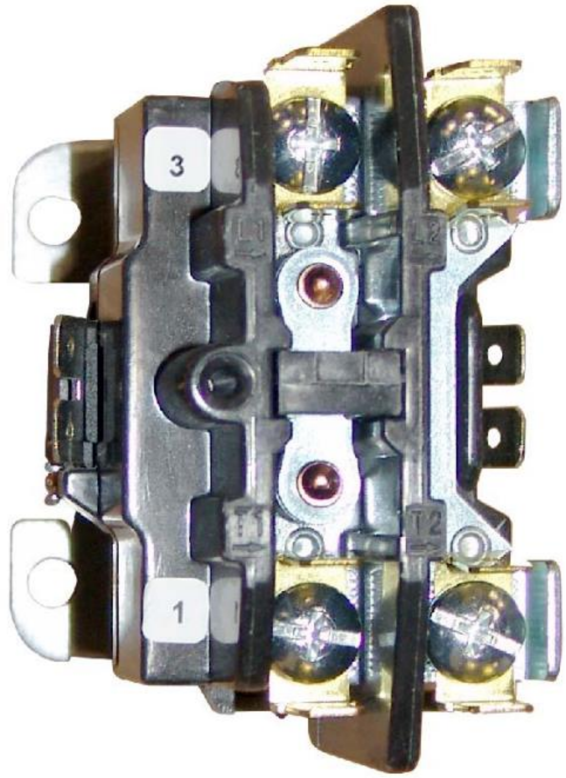
As previously stated, the control board will enter a hard lockout if four soft lockouts occur within a twelve-hour period. The control board will also provide the appropriate flash codes for the onboard LEDs. A hard lockout is reset by removing the 24 volts AC power supply from the control board "R" terminal, or if the "TEST" pins are shorted for more than two seconds.

Cycling the thermostat will not reset a hard lockout. When the fault has been repaired and the hard lockout condition has been reset, the control will stop displaying the fault and will resume normal operation.

Contactor

Contactors are either single pole for single phase equipment or three pole for three phase equipment. Contactors are heavy duty relays that are energized on a call for cooling by 24 volts AC from thermostat terminal Y.

When 24 volts AC is applied to the contactor coil, the contacts close. This allows line voltage to energize the compressor and the outdoor fan motor circuits.



Single Pole Contactor

High Pressure Switch

If a high-pressure switch (HPS) is used, it is electrically located in the control circuit and is designed to protect the system against excessive high side or discharge pressures. The high-pressure switch is piped into the discharge line between the compressor and the condenser coil.

If excessive high pressure occurs, the HPS opens the electrical circuit to the contactor coil. When the contactor is de-energized, the compressor and condenser fan are also de-energized.

There are multiple conditions which could cause this switch to open and de-energize the compressor. Excessive high side (discharge) pressure is mostly caused by poor air flow across the condenser coil (i.e., dirty coil).

High-pressure switch trips may be caused by:

- Dirty or damaged condensing coil
- Failed outdoor fan motor.
- Improper outdoor fan speed
- Non-condensable, such as air or nitrogen, circulating in the system.

The high-pressure switch opens at specific measures that are dependent on the type of refrigerant the system uses. Refer to the specific equipment model when ordering a replacement HPS.

When the high and low-pressure switches are electrically wired in series with each other, the fault will appear to be the same (not applicable on units with Air Conditioning Communicating Control Board). Appropriate steps must be taken to properly identify which of the pressure switches are open and repair the system.

High-Pressure Switch

Note
Open and closing pressures vary because of the different models of pressure switches utilized during manufacturing. The numbers may change slightly from refrigerant safety kits to factory installed pressure switches. Exact replacements must be utilized when any pressure switches have failed.

If the pressure switch opens, the system will restart if it closes, and if applicable, the ASCD 5-minute timer has expired. It is possible to have a lock-out relay if a refrigerant safety kit is field installed. If the system has a lock-out relay, the 24-volt AC control voltage to the contactor coil must be disconnected and then reconnected, or the thermostat may be cycled to reset the lock-out before the unit starts.

On condensing units utilizing the Residential Air Conditioning Communicating Control board, a high-pressure switch is wired directly to the control board at the terminals labeled "HPS". If the high-pressure switch opens, a fault code will be displayed at the appropriate onboard LED. If multiple fault codes are present, the control will only display the most recent fault.

Low Pressure Switch

Many units are equipped with a low-pressure switch (LPS) in the suction line. If the suction pressure drops below the setpoint, the low- pressure switch opens the circuit to the contactor coil, which de-energizes the compressor and outdoor fan motor. The compressor will restart only if the low-pressure switch closes, a cooling call remains present from the thermostat, and - if the unit is equipped with an anti-short cycle delay (ASCD) - the 5-minute delay expires.

Low-Pressure Switch

Low suction pressure may be caused by:

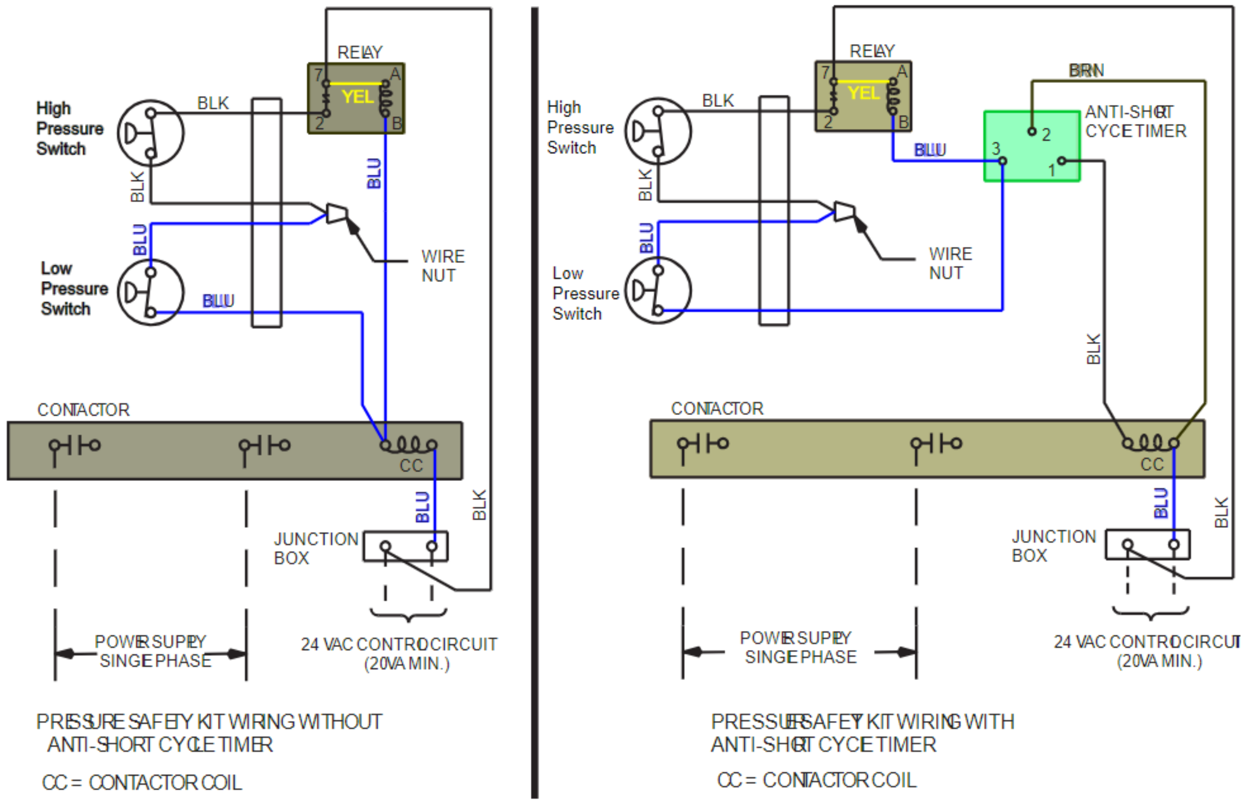
- Poor indoor airflow
- Dirty return air filter
- Dirty evaporator coil
- Failed indoor blower motor capacitor (PSC motors only)
- Failed indoor blower motor
- Dirty indoor blower wheel
- Slow or inoperative blower motor
- High side restrictions
- Faulty metering device
- Undercharge

The opening and closing pressures for the low-pressure switches are dependent on the capacity, model, refrigerant type, and location of the pressure switch. When replacing a low-pressure switch, ensure that an exact replacement is installed.

On systems utilizing the Residential Air Conditioning Communicating Control board, a low-pressure switch is wired in the control circuit and is connected to the board at the "LPS" terminal.

Refrigerant Safety Kit

Refrigerant safety kits may be added to units that do not come equipped from the factory with pressure switches. Condensing units with the Residential Air Conditioning Communicating Control Board are equipped with separate pressure switches and lockout capabilities. These units do not require accessory refrigeration safety kits or lockout relays. The addition of a refrigerant safety kit can increase the level of protection for the unit. The above diagram shows the refrigerant safety kit wiring and each component added to protect the system.



Example of Refrigerant Safety Kit Wiring

The refrigerant safety kit is provided with a lock-out relay. The lock-out relay will energize if either the high- or low-pressure switches open. When the lock-out relay coil between terminals "A" and "B" is energized, the normally closed points between terminals "2" and "7" open, which creates a lock-out. To remove the lockout and return the points to a normally closed position, the thermostat must be cycled.

The refrigerant safety kit field installed with an anti-short cycle timer. If an anti-short cycle timer is installed, it may take up to 5 minutes before condenser fan and compressor operation is allowed. It is possible to have a lockout relay with a high-pressure switch if a refrigerant safety kit is field installed. To remove the lockout and return the points to a normally closed position, the thermostat must be cycled OFF and then ON.

Note
For proper system operation, ensure that the equipment is designed for the specific application. This includes identifying the conditions the system will be operating under prior to installation. Identifying required accessories are also critical to achieve proper operation and comfort.

Lock-out Relay (LR)

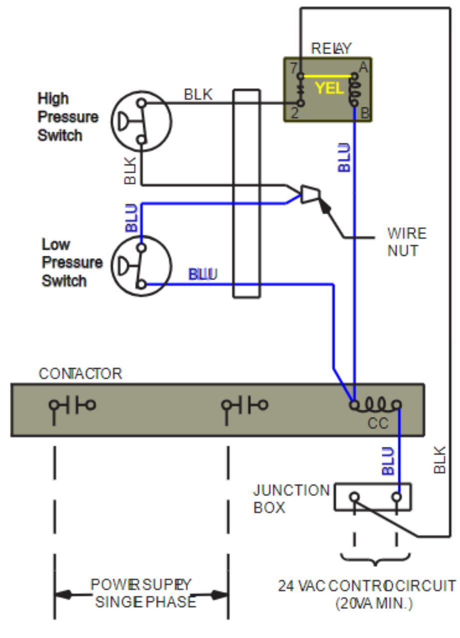
The purpose of the lockout relay (LR) is to hold the control circuit open and de-energize the contactor coil (CC) when a high-pressure switch (HPS) or a low-pressure switch (LPS) opens.

A lockout relay operates because electricity takes the path of least resistance. Using the diagram here, follow the 24 volts AC power source from the left terminal at the junction box in the diagram (counterclockwise).

The 24 volts AC would then pass through the normally closed contacts between terminals "7" and "2", the HPS, and LPS contacts. Once the control voltage has passed through each of these normally closed contacts, it is then applied to the CC terminals. This pulls in the contacts and energizes the compressor and condenser fan motor.

The contactor coil has less resistance than the lock-out relay coil. The path of least resistance is in the control circuit, through each of the closed switches, allowing the current to bypass the LR holding coil and energizing the contactor coil.

If either the HPS or LPS open, the 24 volts AC on the right terminal of the junction box will pass through the less resistive CC and provide 24 volts AC to energize the LR coil between terminals "A" and "B". Once the lock-out relay is energized, the LR contacts between terminals "7" and "2" will open. The unit will be locked out until the thermostat demand is cycled or the control voltage is removed from the system and the safety switches are returned to the normally closed position.



PRESSURE SAFETY KIT WIRING WITHOUT ANTI-SHORT CYCLE TIMER

CC = CONTACTOR COIL

Example of Lock-Out Relay Electrical Wiring

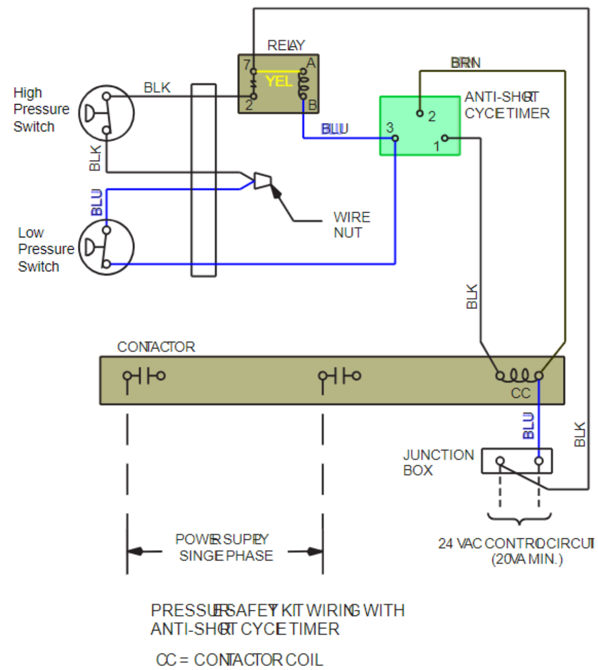
Anti-Short Cycle Delay

The anti-short cycle timer accessory, also known as the anti-short cycle delay (ASCD), is shown at the top of this diagram. This accessory has a built- in time delay designed to provide a compressor cool down period which ensures the compressor will remain off for 5 minutes between cycles. The ASCD is a field installed accessory on 1-1/2 to 5- ton units, when an ASCD is not designed into the circuitry.

Units with the Air Conditioning Communicating Control Board are equipped with a built-in ASCD and do not require field installation of an external relay and timer.

When installing the anti-short cycle delay kit, the ASCD is between terminals "2" and "3" on the anti-short cycle timer. When the conditioned space reaches the desired thermostat setting, the internal 5-minute time delay starts. At the end of the time delay, a set of points closes between terminals "1" and "3", completing a path to the "CC" terminals, if the pressure switches are closed.

If the anti-short cycle delay timer kit is installed on a system that is equipped with an ECM 142 outdoor fan motor, it may be normal to have the outdoor fan in operation prior to compressor startup during an ASCD.



Anti-Short Cycle Timer with Lock-Out Relay

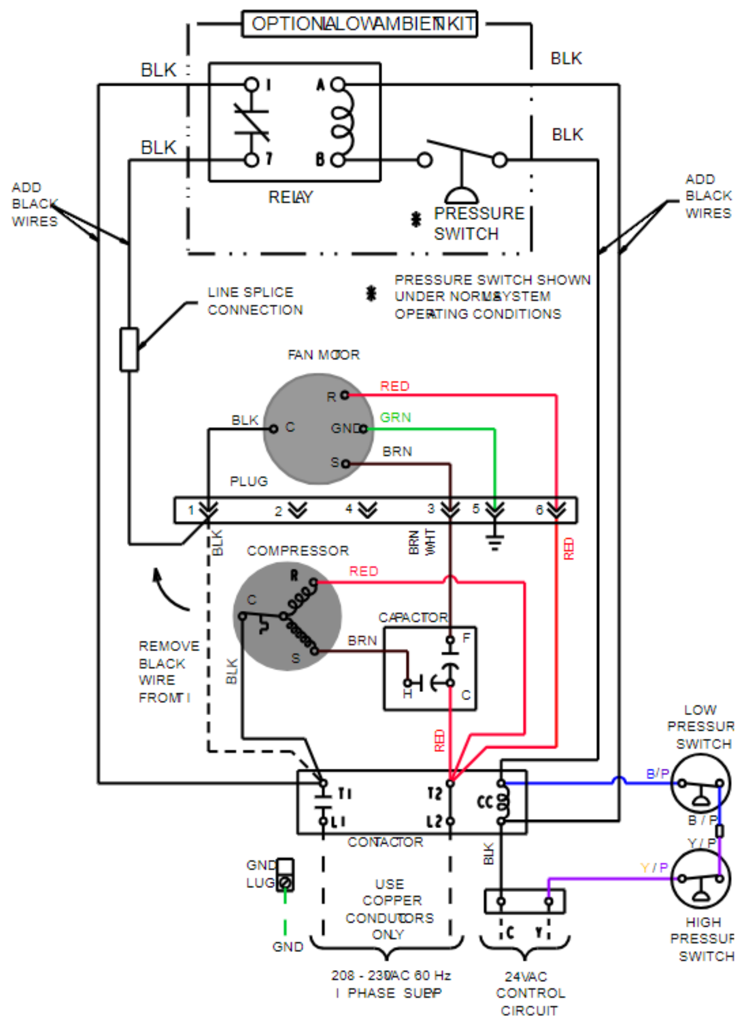
Low Ambient Kit & Accessories

The 1-1/2-to-5-ton air conditioning units can have a low ambient kit field installed if the unit is operated in low ambient conditions. The air conditioning units are designed to operate in ambient temperatures as low as 60°F. If the unit operates at temperatures below 60°F, a low ambient kit must be installed. This will allow the system to operate down to approximately 0°F ambient conditions.

The low ambient kit will cycle the condenser fan motor OFF when the high side pressure drops below the pressure switch cut-in setting.

Note
Low ambient kits can only be used on systems with a PSC condenser fan motor and are not compatible with the ECM 142 condenser fan motor.

When the high side pressure rises above the cut-out setting of the pressure switch, the condenser fan motor is cycled ON.



Low Ambient Kit Wiring Diagram

Above is an example of the electrical wiring of the low ambient kit described in this section. The low ambient pressure switch is in series with terminal "B" of the relay. The relay has a normally closed set of points between terminals "1" and "7" that allows line voltage to pass through, energizing the condenser fan motor during normal operation.

If the ambient temperature drops low enough, the condenser pressure will decrease. As the condenser pressure decreases, the low ambient pressure switch will close and the relay coil between terminals "A" and "B" will be energized. When the low ambient coil is energized, the points between terminals "1" and "7" open and the condenser fan motor is de-energized.

When the condenser fan motor is cycled OFF, the discharge pressure will increase. This will assist in maintaining the circulation of refrigerant and oil during low ambient conditions.

As the ambient temperature increases, the condenser pressure also increases causing the low ambient pressure switch to open. When the pressure switch opens, the relay coil between terminals "A" and "B" is de-energized, closing the points between terminals "1" and "7", which cycles the condenser fan ON during higher ambient conditions.
The low ambient kit is complete with a "normally open-close on fall" pressure switch. There are kits specifically for the type of refrigerant that is in the system being serviced. The pressures at which the switch will open or close depend on the type of refrigerant in the system. The following pressures are an example of those typically found in the low ambient kit. Variations may be found depending on the model and kit being serviced. Use the exact replacement parts for the low ambient kits.

Example of low ambient pressure switch (opening and closing pressures):
R-410A

- Opens at 240 +/-10 psig
- Closes at 360 +/-10 psig

R-22

- Opens at 150 +/-10 psig
- Closes at 300 +/-10 psig

Comfort Alert Module

The Emerson Comfort Alert Module is a diagnostic tool that monitors and analyzes data from the compressor and the thermostat. It can accurately detect the cause of electrical problems and system failures. This is a field installed on some units with Copeland scroll compressors for additional protection.
The Comfort Alert Module has three LEDs. The green (POWER) LED indicates that 24 volts AC is available at the power connection of the module. The yellow (ALERT) LED communicates using a series of flashes based on the system condition.

Comfort Alert Module

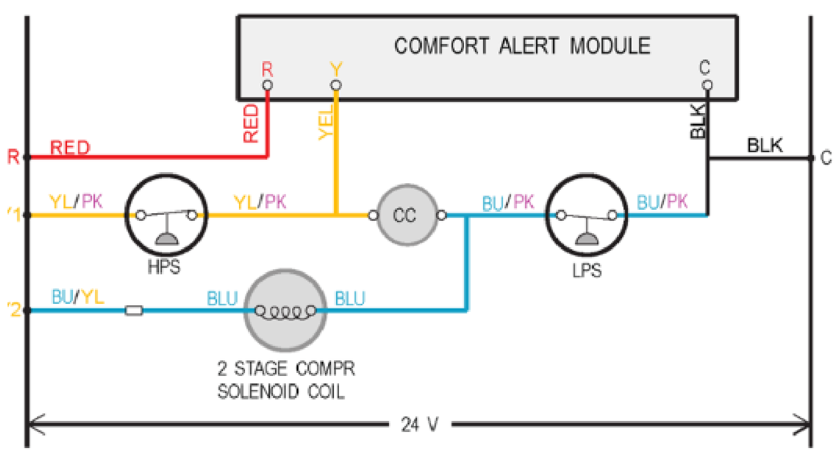
The red (TRIP) LED indicates that a demand signal is present from the thermostat, but no current is being drawn by the compressor. This may be an indication of an open internal overload in the compressor or a contactor that is not closing.
Every time the module is energized, the last ALERT flash code that occurred prior to shutdown is displayed for one minute. The module will continue to display the LED until the condition returns to normal or if 24 volts AC power is reset to the control.

The scroll compressor's "run", "common", and "start" wires are routed through the holes in the Comfort Alert Module, and are marked "R", "C" and "S".

The Comfort Alert Module is not used on systems with the Residential Air Conditioning Communicating Control Board. The control board replaces the Comfort Alert Module.

On systems retrofitted with the Residential Air Conditioning Communicating Control Board, the functionality of the control board replaces the Comfort Alert Module. In these instances, the technician must remove the Comfort Alert Module as described in the Air Conditioning Communicating Controls Field Kit Retrofit Applications Installation Manual.

The 24 volts AC "R" and "C" connections are wired directly to the "R" and "C" terminals on the terminal strip. Terminal "y" has 24 volts AC applied whenever there is a cooling demand, at which time the contactor coil is energized. This allows the 208/230 volts AC to reach the compressor and outdoor fan motor, thus starting these components.



Comfort Alert Low Voltage Wiring

The Emerson Comfort Alert Module does not have any control or lockout functions. The module does have valuable diagnostic information and can improve accuracy when troubleshooting the compressor. The fault codes are found in Section 7 (Troubleshooting).

Crankcase Heater (CCH)

The Crankcase Heater (CCH) is available as an accessory for field installation and is provided on some models from the factory.


Crankcase Heater

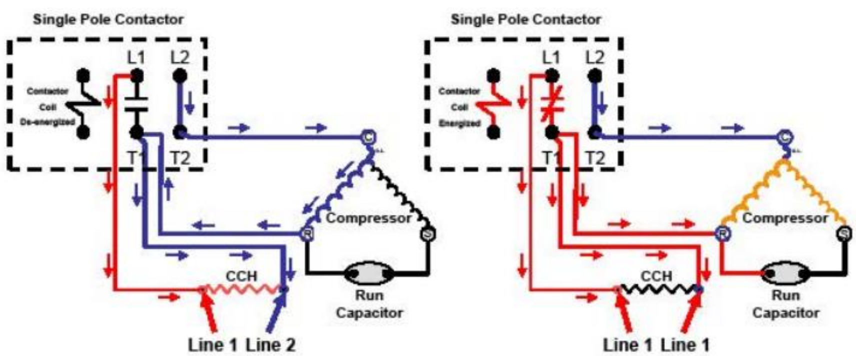
In the off cycle, refrigerant migrates to the coldest area of the system. If liquid refrigerant reaches the compressor, it will mix with the refrigerant oil in the compressor crankcase, which may lead to compressor lubrication issues. When refrigerant migration is an issue, adding a crankcase heater will warm the refrigerant oil and boil migrated liquid refrigerant to vapor.

The wiring of the CCH depends on the type of contactor used in the system.

1. If the contactor is a single pole contactor, the CCH is energized during the compressors off cycle and de-energized during the run cycle. An example of a single pole contactor wiring is shown in the diagram below.
2. If the contactor is a three-pole contactor for a three-phase compressor, the crankcase heater is energized anytime the electrical disconnect switch is in the ON position. Three phase air conditioners utilizing a three-pole contactor must be wired as indicated in the diagram below.

If the CCH is wired improperly, it can reduce the efficiency of the unit, and in some cases may cause damage to the compressor. When it is necessary to replace the compressor contactor, use an exact replacement. This helps to ensure that the crankcase heater is properly wired in the circuit.

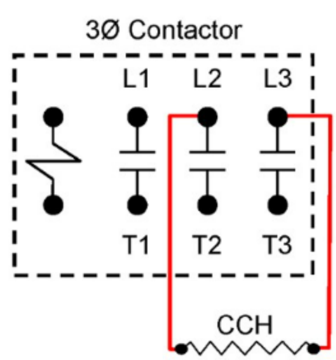
Crankcase Heater (CCH) Electrical Connections



Wiring Diagram of Crankcase Heater with 3 Pole Contactor

The single pole contactor in a later diagram illustrates that when the thermostat energizes the contactor coil, the crankcase heater is de-energized. When the contacts between "LI" and "T1" close, the crankcase heater receives the same line of power, and the CCH is not energized. When the contactor coil is de-energized, the CCH is energized. This occurs because the CCH is receiving line 1 power at the "LI" terminal and line 2 power feeding from the "L2" terminal through the run winding of the compressor.

In the three-pole contactor example, the crankcase heater is energized when the disconnect is in the ON position, and the contactor coil is de-energized.
Identify the size, voltage, and wattage rating of the heater that will be installed to make sure the CCH is properly sized.



Wiring of Crankcase Heater with Three Pole Contactor

Model	Part #	Voltage	Watts	Min. Circum	Max. Circum
Danfoss Scrolls (All)	S1-02541100000	240	70	19.625	27.125
	S1-02541100000	460	70	19.625	27.125
	S1-02541100000	575	70	19.625	27.125
Copeland Scrolls (Residential)	S1-02531959000	240	80	22	26
	S1-02531960000	460	80	22	26
	S1-02531958000	575	80	22	26
Copeland Scrolls (Commercial)	S1-02533474240	240	80	28.75	35.75
Bristol H23A	S1-02533474460	460	90	28.75	35.75
	S1-02533474575	575	90	28.75	35.75
Bristol Recips (Remainder)	S1-02537399240	240	70	21.81	29
	S1-02537399480	460	70	21.81	29
	S1-02537399575	575	70	21.81	29

CFM Selection Board/ ECM Variable Speed Fan Motor

Systems configured with an indoor unit that uses an ECM indoor fan motor and a CFM selection board will provide multiple airflow profiles. There are variable speed air handlers, variable speed furnaces, and modulating furnaces that have multiple options and profiles selected on the control board. Units with the ECM 16-pin indoor fan motor will also have the HEAT, DELAY, COOL and ADJUST pin selections on the indoor control board.

The CFM Selection Board receives input from the thermostat, and depending on pin selection, adjusts the airflow of the motor. Flash codes on the CFM Selection Board represent the amount of airflow (CFM) requested by the ECM motor. The number of flashes displayed on the green LED represents 100 cubic feet per minute (CFM) of air flow for each flash.

Example:

- 12 flashes = 1200 CFM
- 8 flashes = 800 CFM

The indoor control board has four tap selections, and four jumper sets. The tap selections are factory set for the rated cooling and heating airflow of the air handler or furnace. The tap selections are labeled COOLING, HEATING, ADJUST and DELAY. Each tap selection has four jumper positions labeled A, B, C, or D. Each will be covered in more detail in Section 5 (Start Up). The CFM Selection Board has a jumper that is labeled HP. The jumper must be in the NO position for air conditioning mode.

Capacitors

Capacitors provide enhanced motor running torque and are used on single phase motors only. Some three-phase equipment may have one or more single phase PSC fan motors and could have a run capacitor located within the unit. Capacitors are rated in microfarads and have a voltage rating on the capacitor's case. Microfarads are usually identified on the capacitor with a number and the Greek symbol "u" for micro and an "F" for farad.

Example:

- 370 volts AC / 45 µF

When a run capacitor is tested with a capacitor analyzer, the run capacitors should test to within the µF % rating on the capacitor. Start capacitors should test equal to or up to 20% greater than the µF rating on the capacitor. If the test indicates that a start capacitor has less than the rated µF, the capacitor must be replaced.

The voltage rating on the capacitor is the maximum amount of back electromotive force (BEMF) the capacitor can have applied to it during normal operation. (It is NOT the line voltage applied to the equipment.) Using a different voltage can result in damage, unless specified on the data plate. Only replace a capacitor with one having an equal or greater voltage rating.

Example:

If a run capacitor is rated at 10 µF +/-10% and 370 volts AC, it is possible to replace the capacitor with a capacitor rated at 9 µF and 440 volts AC. This is within +/-10% of the µF rating and the new capacitor is rated for a voltage the existing capacitor.

Caution
Capacitors may be stored energy even though the electrical disconnect has been locked out and line voltage has been removed from the system. A resistor should be used to bleed the stored voltage from the capacitor. The recommended resistor is a 20,00-ohm 2-watt resistor. A screwdriver should not be used to bleed the capacitor. Improper bleeding of the capacitor can cause damage to the capacitor and motor.

Run Capacitor

Run capacitors are used on single phase compressors and PSC fan motors.
The run capacitor is constructed of two aluminum plates with insulated material in between them. The insulation between the plates is a non- conductive material. This will allow the capacitor to store electricity until it has reached the capacity of the insulating material, at which time it is discharged to the second plate.

The run capacitor is in the circuit during the entire run cycle; thus, the case of the run capacitor is impregnated with oil. The oil assists in cooling the capacitor and allows the capacitor to remain in the system for the entire run cycle.

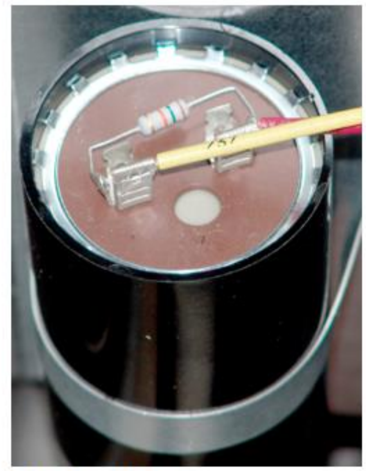
If the capacitor is wired improperly and shorts to ground, the START winding will burn open prior to tripping a breaker or blowing a fuse. On PSC multi-speed fan motors, the wiring diagram that accompanies the equipment must be used to identify proper wiring. Many PSC multi-speed fan motors are equipped with wires designated for the run capacitor.

Run Capacitor

Note
Run capacitors are usually marked with an identified terminal on the top of the capacitor. If the capacitor is marked for polarity, the identified terminal must be wired to the RUN line of power to the motor.

Start Capacitor

The start capacitor, a portion of a hard start kit, is installed on single phase compressors only. The start capacitor is used to provide additional starting torque to the compressor motor during start up.


Start Capacitor

The start capacitor is made of two aluminum plates with a dielectric material between them. The non-conductive dielectric material will let the capacitor store electricity until it reaches the material's capacity and then is discharged to the second plate.

The start capacitor is only in the circuit on startup and does not have to dissipate the same amount of heat as the run capacitor. The start capacitor is electrically removed from the circuit with a starting relay after the compressor starts.

Hard Start Kit

The hard start kit is installed on single phase compressors only. It consists of a potential relay and a start capacitor. The hard start kit may be factory installed or field installed if the system requires additional starting torque. This is common when the line voltage supplying the compressor is less than 220 volts AC. The relay is wired parallel to the start winding.

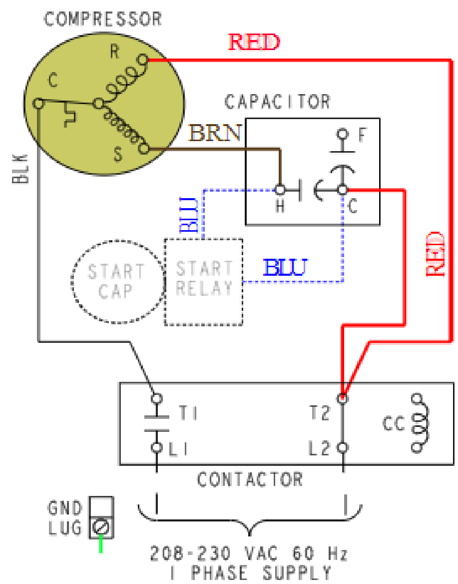
Once the motor is energized, supply voltage is applied to the start capacitor. The start capacitor increases the starting torque of the motor, and the rotor begins to turn. Once the rotor has reached approximately 75% of running speed, the potential relay coil is energized by counter electromotive force produced from the start winding. When enough counter electromotive force is produced from the start winding, the normally closed set of contacts open. When the normally closed contacts on the potential relay open, the start capacitor is electrically removed from the circuit. The start capacitor must be removed from the circuit after startup or damage to the start winding and/ or start capacitor will occur.

There are two types of hard start kits that may be factory or field installed depending on the model of the air conditioning unit. They are the "two wire" and "three wire" hard start kits.

Two Wire Hard Start Kit

The two wire hard start kit is electrically wired in parallel with the compressor run capacitor. This start relay is not sensitive to polarity unless otherwise provided in the start kit instructions.

If the unit has a three-terminal run capacitor, the two wire start kit is wired across the "C" and "H" terminals of a run capacitor as seen in this diagram.

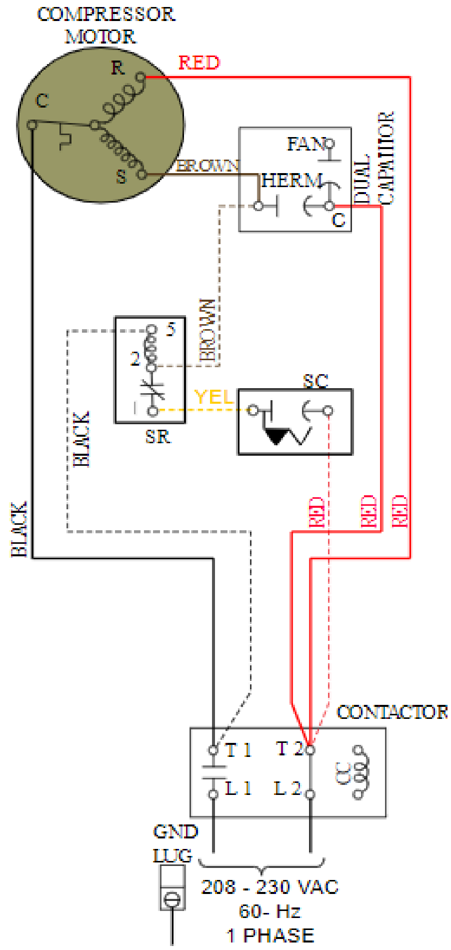


Two Wire Hard Start Relay & Capacitor

Three Wire Hard Start Kit

The three wire hard start kit has three terminals labeled 1, 2, and 5 as shown in this diagram.

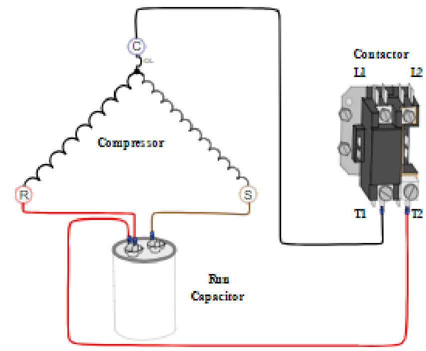
- Terminal 1 is wired to the discharge size of the capacitor.
- Terminal 2 is wired to the discharge side of the run capacitor and to the start "S" terminal of the compressor.
- Terminal 5 is wired to the same leg of power as the common "C" terminal of the compressor.



Three Wire Hard Start Relay & Capacitor

Permanent Split Capacitance (PSC) Motor

The PSC motor has a start winding and a run winding, with a run capacitor wired between these two windings as shown in this diagram.

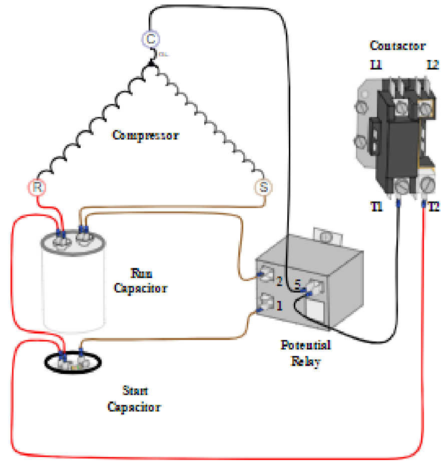


Electrical Diagram of PSC Motor

Capacitor Start Capacitor Run (CSR) Motor

The CSR motor is a single-phase compressor only. It is electrically wired the same as a PSC motor with the addition of a start capacitor and a relay wired in the circuit as seen in this diagram. This can also be identified as a PSC motor with a hard start kit. The potential relay is designed to remove the start capacitor from the circuit at approximately 75% of motor start up. Note the proper electrical wiring of each of the motors installed on the equipment. Improper wiring can result in equipment failure and is very costly.

All connections must be checked and corrected prior to energizing the system.

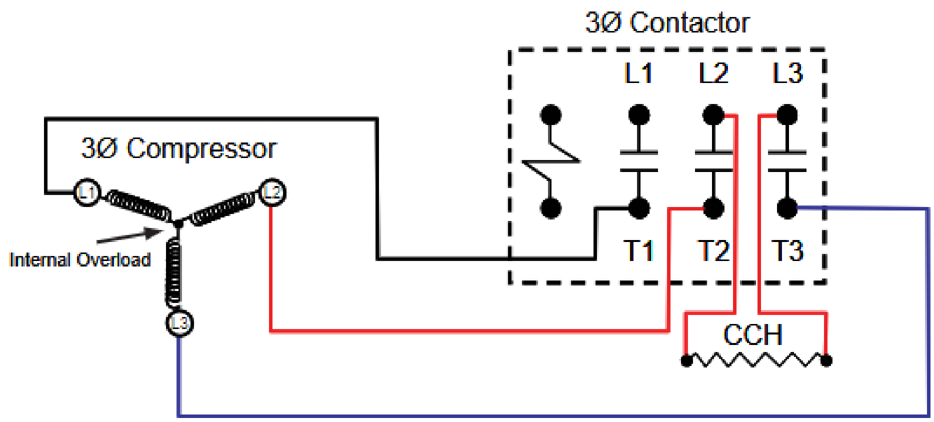


Electrical Diagram of CSR Motor

Three Phase Motor

Three phase compressor motors are manufactured with three windings equal in length and diameter. The three windings are 120 electrical degrees out of phase. This enables the windings to provide greater starting torque, so do not require the additional starting components installed on the single-phase compressors.

Three phase air conditioning systems are often installed in commercial and industrial applications. Many three phase units use single phase fan motors and components within the unit.



Electrical Diagram of Three Phase Motor

Electronically Commutated Motor (ECM)

Electrically Commutated Motors (ECM) are selected for applications that demand higher electrical efficiency, reduced operational sound level, and match two stage compressor condensing units.

The ECM motor is readily identified by the 16-pin control plug and the 5-pin high voltage connector. This motor can operate with 115 volts AC or 230 volts AC line voltage. It is controlled by 24 volts AC inputs to the 16-pin connector which provide various CFM selections dependent on the heating, cooling and indoor fan parameters set for the application.

Note
When replacing the ECM control module, the technician must have an exact replacement. The 16-pin control module has been factory programmed and the pins must be programmed with the same parameters for the unit being serviced. Each model is programmed differently, which means that replacements must be exact.

If the motor is diagnosed as good and the controller module is diagnosed as faulty, the controller module may be replaced without replacing the motor.

Proper operation and troubleshooting of the ECM motor will be covered later in this guide and can also be evaluated in the Installation Manual provided with the equipment.

Standard ECM Fan Motor

The Standard ECM is a sealed, electronically commutated motor with fewer connections and fewer capabilities than the 16 pin ECM motor control module.

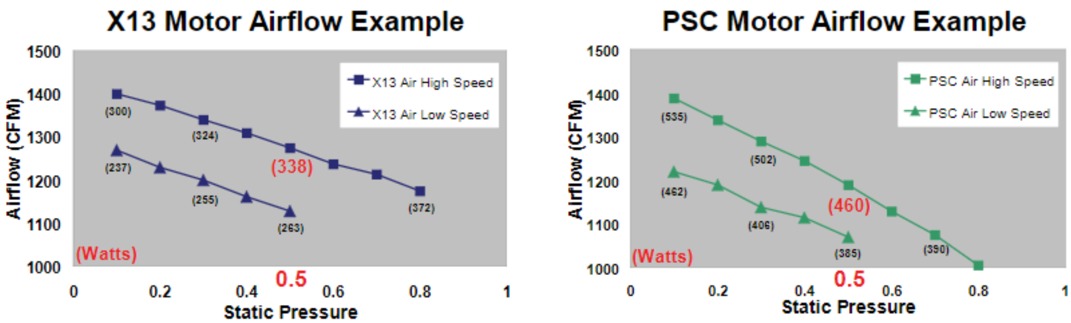
Standard ECM Motor Features:

- Available in typical horsepower (Hp) ranges of 3, 2, 4, and 1 Hp
- One piece motor design
- All electronics are housed safely inside the motor shell.
- Fully encapsulated electronics to prevent water damage.
- Ball bearings to support the speed range.
- EMI filter for surge protection and line transient issues

The allowable voltage range on these motors are:

- 98-132 volts AC on the 115 volts AC model
- 196-264 volts AC on the 230 volts AC model

The Standard ECM motor uses less energy (watts) than the PSC motor both at rated speed and constant fan mode. The charts below show airflow (CFM) on the left and external static pressure (ESP) along the bottom. Notice at 0.5" w.c. the Standard ECM is using less energy and is producing more airflow.



Standard ECM Motor Vs PSC Motor

The Standard ECM motor is programmed to provide constant torque. If the static pressure changes, the motor will only maintain the factory programmed torque. This should not be confused with constant airflow. Even though the Standard ECM can maintain torque, if static pressure increases, airflow will decrease. This is like the PSC motor curve shown above. However, airflow will not decrease as dramatically as with a PSC motor since torque is being maintained.

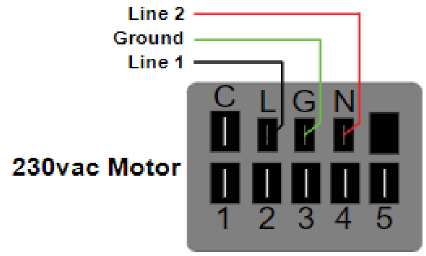
When the static pressure rises to 0.8" w.c., the Standard ECM motor will produce almost 1200 CFM, whereas the PSC motor will only produce 1000 CFM. Though the Standard ECM operates by constant torque, it still provides airflow on a curve in response to changes in static pressure, just like the PSC motor. The X-13 holds up the curve a little better than the PSC motor and the Standard ECM has a maximum of 5 speed/torque capabilities.

The Standard ECM motor has a 10-pin connector, but only utilizes nine of the pins. The line voltage terminals are labeled "L", "G" and "N". The "L" terminal is 115 volts AC hot or line 1 for 230 volts AC. The "G" terminal is the ground terminal. The "N" terminal is either the neutral for the 115 volts AC system or line 2 for the 230 volts AC system.

A reading of 115 volts AC or 230 volts AC is measured between the "L" and "N" terminals on the indoor fan section depending on the voltage being supplied to the motor.

The control terminals are labeled "C", "1", "2", "3", "4" and "5". The terminal labeled "C" is common for the 24 volts AC control voltage, while terminals labeled "1" through "5" are the torque settings programmed by the manufacturer. Each of the pins are programmed and will receive 24 volts AC signals from the thermostat or control board to engage the proper fan torque for the application.

If the motor is wired improperly, the control module and/ or the motor module may be permanently damaged, and the motor will have to be replaced.



Standard ECM 230 Volt AC Wiring

142 ECM Outdoor Fan Motor

The 142 ECM outdoor fan motor can provide greater energy savings in comparison to the PSC condenser fan motor.

The 142 ECM outdoor fan motor is a sealed motor with a remote mounted controller module. If a fault occurs with the motor, both the motor and controller module must be replaced. This is not to be confused with the 16 pin ECM indoor fan motor.

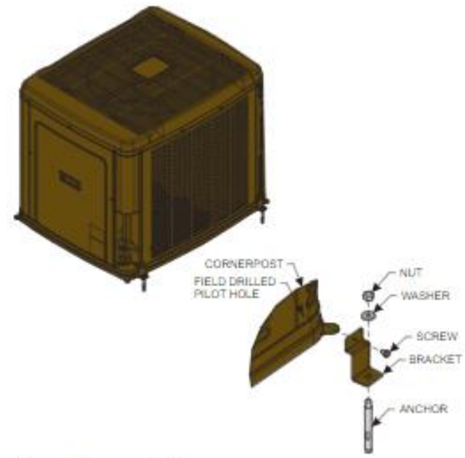
The motor receives 24 volts AC control voltage from the "Y1" and "C" terminals on the low voltage terminal strip in the condensing unit control panel. The "Y1" terminal is energized when the thermostat calls for cooling.

142 ECM Outdoor Fan Motor

Remote Mounted ECM 142 Controller Module

Hurricane Kit

In locations with the risk of hurricane-force winds, it may be required to install a hurricane kit to provide additional support for the condensing unit. Hurricane kits are not available on all models.



Hurricane Kit

The kit includes:

- Four corner post brackets
- Five sheet metal screws

The parts required to attach the brackets to the unit are provided in the kit but will require field supplied anchors to attach the unit to the concrete or metal pad. Each component in the kit must be installed as recommended in the Installation Manual. When this kit is installed, using the recommended anchors and an adequately designed hard concrete or metal support, the unit can withstand up to 150 mph winds.

R-410A

With the phase-out of HVAC systems containing HCFCs such as R-22, the industry has shifted to HFC refrigerants which contain no chlorine.

The most common of these non- chlorinated refrigerants for residential air conditioning is R-410A. R-410A is a mixture of R-32 and R-125 and is considered a near azeotrope. This means that it is not as susceptible to fractionation or separation into individual components if a leak occurs in the system.

R-410A Refrigerant Drum

The air conditioning cycle with R-410A is the same as it is with an R-22 system; however, there are some major differences listed below.

- R-410A pressures are approximately 60% higher than a comparable R-22 system. All components in the system must be rated to handle higher pressures. This includes a manifold gauge set and a refrigerant recovery machine designed to handle the higher pressures of R-410A.
- Due to the higher pressures, all field connections must be made with a brazing rod that has a minimum of 5% silver content. Soft solder must not be used for connections in R-410A systems.
- Components designed for use with R-410A are usually tagged with a rose-pink label the same color as a cylinder of R-410A.
- R-410A is not compatible with mineral based refrigerant oil as used in R-22 systems. R-410A systems use synthetic oil called polyol Ester (POE) Service tools that touch the refrigerant side of the system, such as the manifold gauge set, recovery cylinders and recovery machine must be dedicated to a single refrigerant only. Do not risk mixing the oils as it may compromise the system.
- POE oil is very hygroscopic, which means that it has a great affinity for water. Any moisture in the system will cause system problems. This is where good service techniques really become important, especially regarding proper evacuation of the lineset and evaporator coil prior to system startup. A liquid line filter drier must be installed with every R-410A system installation.

Caution
Caution should be exercises when retrofitting an existing system to prevent mixing mineral and POE refrigerant oils. If possible, a new lineset and evaporator coil should be installed with the new air conditioner. This ensures there is no residual mineral oil that could affect system operation.

- Expansion valves that are compatible with R-410A must be used with these systems. Do not use a non-approved metering device.
- When adding refrigerant to an R-410A system, the refrigerant must be taken out of the cylinder in liquid form. This eliminates any possibility for the refrigerant to fractionate (separate into its individual components). A quick-charge adapter will flash the liquid R-410A into vapor before it enters the suction line. Alternately, the liquid may be "throttled" into the suction line. Use caution when letting the liquid refrigerant enter the suction line while throttling the low side manifold valve. Throttling the valve properly allows the refrigerant to flash to vapor prior to entering the suction side of the compressor.

04

Installation

Introduction

Install air conditioning units according to all current local, city, state and national laws and code requirements. If the equipment is installed outside of the United States, adhere to all laws and codes within the country. Follow the installation procedures specified in the Installation Manual. If the specifications are exceeded by code, or if code is exceeded by the specifications, adhere to the most restrictive code requirements.

Thermostat

Mount thermostats horizontally level, five feet high on an interior wall. Thermostats mounted on perimeter walls will not sense accurate temperatures and the length of the run cycles will increase. This will cause overshooting of the thermostat settings, decreased comfort levels, and inefficient system operation.

Mount thermostats away from supply air registers. Thermostats that are in the supply air stream will short cycle the equipment and result in uncomfortable temperatures and equipment failure.

Electrical Wiring

All electrical connections and components must be installed in accordance with current national electrical code requirements within the United States, or current national codes within the country where the equipment is being installed.

The power supply must be a dedicated circuit with the proper equipment grounding and circuit protection. Failure to provide adequate wire sizing, circuit protection, and equipment grounding will result in improper system operation, property damage, personal injury, and/ or loss of life.

Seal all electrical conduits entering the controls section of the indoor and outdoor unit with an approved, non-conducting electrical sealant. This will prevent moisture from being pulled through the conduit and corroding electrical components within the controls section.

If the transformer is not wired properly, electrical component failure will occur. Prior to connecting the main power supply to the unit, make sure the primary voltage taps to the transformer are wired properly for the voltage being applied.

Control Wiring

Select a thermostat that is compatible with the system's modes of operation. Provide control wiring to the appropriate control boards and terminal strips as indicated on the electrical wiring diagrams. All control wiring should have a minimum of 18-gauge wire. Install the field supplied thermostat following the installation instructions that accompany the thermostat and electrical wiring diagrams shipped with the equipment.

With the thermostat and the electrical disconnects set to the "OFF" position and locked- out, connect the thermostat wiring to the terminal strip, as indicated in the Installation Manual. Electronic thermostats may require a common wire between the transformer's 24 volts AC secondary side and the "C" terminal. The digital display and electronics within the thermostat are powered by the transformer at the "R" and "C" terminals of the thermostat.

Ductwork Installation

Use approved methods of installation and properly match the ducts to the equipment. Improperly sized duct systems will result in loss of efficiency, equipment damage, structural damage, and indoor air quality problems.

Size, install and insulate the duct work in accordance with industry recognized procedures and manufacturer specifications. To properly design the duct for the structure, refer to the ASHRAE Fundamentals Handbook chapter on "Duct Design", or Air Conditioning Contractors of America (ACCA) "Manual D".

Location & Clearances

The condensing unit must be installed with proper clearances for airflow, servicing, and operation. Proper clearances are described in the Installation Manual that accompanies the unit.

All condensing units installed at ground level must be on a level pad or slab. The pad or slab location and dimensions must also meet local code requirements.

The indoor unit will also have minimum clearances for proper operation, service, and safety. Follow the Installation Manual shipped with the indoor unit. All applicable city, state, and national codes must be followed. Each indoor unit may have different clearance requirements depending on whether the indoor unit is an electric air handler or furnace. Additional clearances may also depend on whether the system is installed in a crawl space, attic, garage, or closet application.

Lineset

Proper sizing of the lineset must be in accordance with the Piping Application Guide or the Comfort Cooling Piping Software. The Comfort Cooling Piping Software, located on UPGNet, can assist in properly sizing copper tubing for various applications. The air conditioner will not be capable of operating to capacity if the lineset is undersized or oversized. In addition to a reduction in system capacity, improper line sizing will cause refrigerant and oil circulation problems that will result in reduced operating efficiency and shorten the life of the equipment.

Refrigeration or ACR copper is manufactured to meet the installation requirements for heat pumps and air conditioners. The tubing is cleaned internally, dehydrated, and capped at each end. The copper tubing should never be left uncapped for a prolonged period of time. If the copper is open to the atmosphere, moisture can accumulate within the tubing. This moisture can cause oxidation, extended evacuation and cleanup time, and damage to the system by producing acid.

The lineset must be installed where access is permitted to any portion of the equipment that may require future service or repair. Install the lineset with as few bends or elbows as possible to ensure that the refrigerant and oil will flow without being restricted. Use proper bending techniques when installing soft drawn copper. Any copper tubing that is distorted or kinked must be replaced.

Insulate the suction line using closed cell foam rubber with at least 1/2" wall thickness. Insulation of the liquid line may also be required if the line is exposed to direct sunlight or extreme temperatures, which may cause the refrigerant to flash before entering the metering device.

Special Considerations

There are special considerations when installing a lineset:

- The use of approved conduit, such as PVC, must be used for all underground piping installations.
- The length of buried lineset must be kept to a minimum.
- The vapor in the suction line can condense during shutdown and cause liquid flood back on start up.
- Proper suspension of copper tubing with approved hangers is required to isolate and reduce vibration.
- If the lineset is installed through a wall, an approved protective sleeve and sealing compound must be used to seal the penetration and protect the lineset

Brazing

All evaporator and condenser coil connections are copper-to-copper, which require brazing. Brazing temperatures exceed 800 degrees Fahrenheit. At these temperatures, oxidation will form inside of the copper tubing if dry nitrogen is not used to displace oxygen during brazing. If oxidation forms, it will be released in the refrigerant flowing through the system during normal operation. It will accumulate in the filter drier and metering device causing improper operation and component failure.

Oxidized Fitting

Condensing units have both liquid and vapor service valves located on the corner post. The service valves are provided with 1/4" flare fittings to connect a service manifold gauge set, which is used to assist in purging the lineset with nitrogen. Use heat sinks to prevent heat damage to the service valves, metering devices, filter driers, compressors, and the MicroChannel coil. Wrap a wet rag around smaller components to provide protection during brazing. Use heat shields to protect property and equipment, including the structure, painted panels, wiring diagrams, data plates, and aluminum fins.

Braze joints using a phosphorous copper alloy material, such as Silfos-5, or an equivalent brazing alloy with at least 5% silver content. Do not use soft solder.

When connecting the lineset, use the following procedures:

- Remove the Schrader valve cap and core from the liquid and vapor service valves at the new condensing unit.
- Low-pressure nitrogen must be slowly released through the liquid line service port into the lineset, and out of the vapor service port while brazing. A pressure regulator and safety valve must always be used on the nitrogen tank to ensure only low pressure is applied to the system. Nitrogen must be flowing continually while brazing.
- The liquid line must be brazed to the liquid line service valve on the condensing unit. The valve body must be wrapped with a wet rag to minimize the amount of heat the valve is exposed to.
- The plugs/ caps must be carefully removed from the evaporator coil connections and the pressure carefully bled off.
- The liquid line must be brazed to the evaporator coil liquid line connection. Dry nitrogen must be flowing through the evaporator coil.
- The Installation Manual must be referred to for detailed instructions regarding the installation of an indoor TXV.
- The grommet must be pulled away from the vapor connection at the evaporator coil. The vapor line is then brazed to the evaporator coil vapor connection. After the brazed connection has cooled gradually, the grommet would be moved back into the original position.
- The vapor valve must be protected with a wet rag and the vapor line connection brazed to the condensing unit. The flow of dry nitrogen must be exiting the system from the vapor service port connection.
- After the connections have been brazed and the joints have cooled gradually, the nitrogen is valved off and removed from the liquid line service port.
- The Schrader valve cores must be replaced in the liquid and vapor valves.
- A leak test must be performed on all the refrigerant piping connections including the service port flare caps to be sure they are leak tight. The caps should not be over-tightened.

Silfos 5

MicroChannel Condenser Coils

The MicroChannel condensing coils were discussed in Section 3. Technicians have been installing condensing units with tube-fin coils for many years and now must become familiar with the installation and repair of the MicroChannel condensing units.

When installing the MicroChannel coil, the service valves and fittings are copper connections and must be brazed. Using the proper heat sinks and purging the lines with nitrogen are important when brazing any connections. This will assist the technician in providing strong connections and prevent contamination from oxidation.

In the event of damage, the all-aluminum MicroChannel coils may be repaired with a propane gas torch. Do not use oxyacetylene when performing MicroChannel repairs. The "MicroChannel Condenser Coil Repair Kit," available through Source 1, includes a special soldering alloy with flux already in the solder and a brush to clean the repair area.

MicroChannel Repair

These steps are followed to repair MicroChannel coil damage.

1. Locate the damaged coil section.
2. Connect a vacuum pump and manifold gauge set at the liquid line and suction line service valves.
3. Use a slotted screwdriver to move the fins away from the damaged section of the coil.
4. Clean the affected area using the brush supplied with the repair kit.
5. Turn on the vacuum pump with both service valves open.
6. Apply heat to the affected area with a propane torch while applying the soldering alloy. Do not overheat (solder will be pulled into the damaged channels)
7. Remove heat and allow the coil to cool.
8. Remove the manifold gauge set and vacuum pump.
9. Pressure tests the coil to ensure proper repair.

Pressure Testing

The lineset and evaporator coil are pressurized up to 250 psig with dry nitrogen and leak tested with a bubble type leak detector. Do not use refrigerant to purge or leak test the system. Do not exceed the rated test pressure located on the evaporator coil data plate when pressure testing the system (nitrogen charge can be released into the atmosphere).

Evacuation

The vapor line, evaporator coil, and liquid line must be evacuated to 500 microns or less. This will ensure that moisture and non-condensables are evacuated from the system.

Post Evacuation

On a new installation, after the system has been pressure tested and evacuated, the following procedures must be completed to release the refrigerant into the indoor unit:

- The vapor line (larger line) connection is opened first. Service valves are opened by removing the cap, and using a hex wrench on the stem, carefully turning counterclockwise until the stem touches the retaining ring. Allow the pressure to equalize. The liquid line service valve may then be opened in the same manner.
- The cap must be finger tight and then tightened an additional 1/12th of a turn.

Caution
If there is any chance that liquid refrigerant is present in the compressor crankcase, the crankcase heater should be powered up for 24 hours prior to operating the compressor.

- Replace the caps on the service ports to prevent leaks. Remove the flare caps from the service ports and connect gauges only during start up, and when servicing the system. Approximately 3/4 ounce of refrigerant is lost each time gauges are connected. If gauges are connected unnecessarily, the system could become undercharged over an extended period.

If the refrigerant tubing, evaporator coil or condensing coil develops a leak or is opened to the atmosphere during service, evacuate the system to at least 500 microns. This will eliminate contamination and moisture in the system.

R-410A Considerations

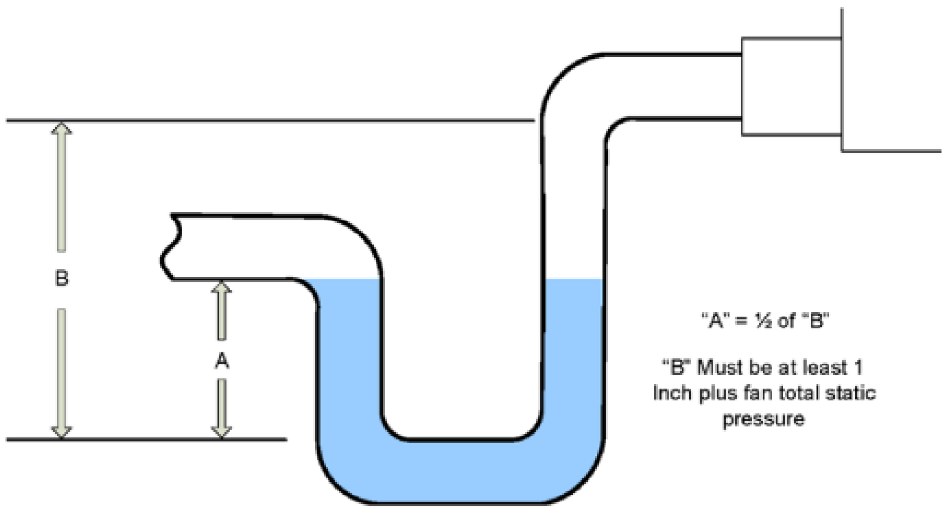
Polyol ester oil (POE) is used with R-410A systems. In the past, R-22 systems used mineral or alkylbenzene oil (AE) as the system lubricant. POE is NOT compatible with mineral (MO) or alkylbenzene oils. It is imperative that proper service practices are performed during installation, particularly in retrofit applications, to ensure there is NO intermixing of the oils.

The MO/AB oils are not miscible with R-410A refrigerant and will be pushed through the system as a liquid blob, which can create a restriction at metering devices, and subsequent pressure fluctuations. POE oil is very hygroscopic, meaning that it readily absorbs moisture (about 15 times faster than mineral oil). This emphasizes the importance of using the necessary tools and installation procedures required for R-410A systems.

Proper installation procedures include, but are not limited to:

- Brazing (with nitrogen purge)
- Pressure testing (with nitrogen up to 250 psig)
- Evacuation (500 microns)
- Purging manifold gauge set (with refrigerant)
- Charging methods
    - Weight (TXV or Fixed Orifice)
    - Subcooling (TXV)
    - Superheat (Fixed Orifice)

Condensate Drain



Proper Condensate Drain

The condensate drain line must be trapped. If an open drain is not available, identify the local building code requirements for drainage before installing a condensate drain. A plugged drain can cause property damage; therefore, properly size the condensate drain and seal the fittings and connections with an approved sealing compound. Sealing compounds are not to be used at the connection to the drain pan because this will cause pan failure. After installation, prime the trap with water.

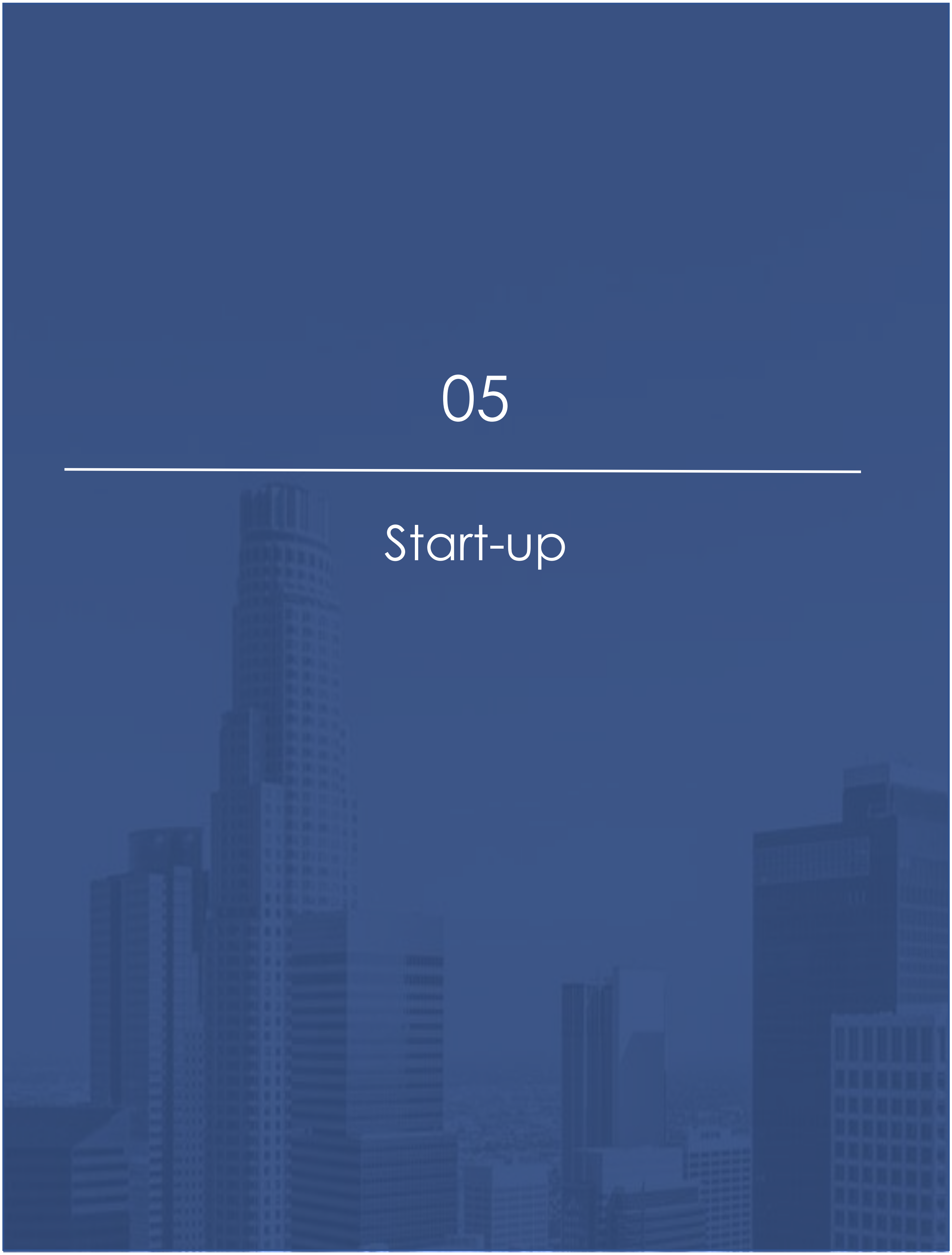
In many municipalities, it is required to have an auxiliary drain pan and/ or float switch installed to provide additional protection for the property. When the coil is installed in an attic or above a finished ceiling, or any area where water damage has the potential to occur, install an auxiliary drain pan under the coil. The evaporator coil must be installed level or slightly pitched toward the drain end of the pan with no more than 1/4" per foot of slope. When a secondary drain pan is utilized, the drain must be piped to a location that will provide a visual warning to the occupant if the primary drain becomes restricted. If a float switch is installed, the switch must be electrically wired to de-energize the compressor if a restriction occurs preventing the condensate from draining properly.

Filters

Filters must be installed with an approved filter kit that is properly sized for the installed system. The filter sizes must be entered on the startup sheet when the system is installed. Never operate the system without a suitable air filter.

Equipment Sizing

Equipment sizing must be based on the heat gain calculations and completed in accordance with industry recognized procedures that are identified by the Air Conditioning Contractors of America (ACCA).



05

Start-up

Ducted Systems Residential Start-up Form

Startup Forms are found at the back pages on all Ducted Systems residential product installation manuals.

Prior to start-up, all the installation procedures outlined in the indoor and outdoor equipment Installation Manuals must be completed. This includes proper installation of the indoor unit, outdoor unit, thermostat, electrical wiring, and accessory kits.

Required Tools & Information

After physical installation is complete, the following tools and instruments are required to properly start- up air conditioning units:

- Magnehelic© gauge, U-tube manometer, or digital manometer to measure static pressure on both the supply and return side of the air distribution system. This is essential to provide proper airflow across the evaporator prior to evaluating or adjusting system charge.
- Thermometer or portable digital thermometer to measure the supply air, return air, air entering the condenser, liquid line, and suction line temperatures. For best accuracy when measuring temperatures, use thermocouple-type probes.
- Manifold gauge set to measure high side and low side pressures.
- Psychrometer (digital or sling) to measure return air wet bulb temperatures, which are required for use with both superheat and subcooling charging charts. The required charging chart is dependent on the type of metering device installed in the system.
- Digital multimeter for various electrical measurements
- 1/4" and 5/16" nut driver to remove service access panels.
- 3/16" and 3/8" Allen wrenches for liquid line and suction line service valve access
- Philips head screwdriver
- Personal Protective Devices (PPD) as recommended in Section 2 (Safety)

Airflow

The airflow must be set up properly BEFORE attempting to evaluate the system refrigerant charge. Condensing units must be matched with the appropriate evaporator and an air handler or furnace that provides the required airflow. If the duct system is not designed properly, it will not be possible to obtain design efficiency of the air conditioning unit.

Cooling Blower Set-up

It is often believed that the cooling blower speed should always be set on "high", but this is not true for every application. If the airflow is set too high, proper dehumidification of the return air will not occur, and the desired temperature drop across the evaporator coil will not be obtained. If the airflow is set too low, frost and ice may form on the evaporator coil, which will lead to customer complaints and eventual refrigerant flood back to the compressor.

The blower speed must be selected based on the requirements of the installed system.

For the best possible comfort and equipment longevity on systems with non-ECM blower motors, the external static pressure (ESP) must be measured and used with the blower charts to determine the best speed to use for the application. Blower charts are located in the furnace or air handler Installation Manuals.

Setup of airflow for systems with ECM blower motors suggests selecting the proper blower jumper settings to deliver 400 CFM of airflow per ton of cooling capacity. More detail on ECM setup is here.

For optimum performance, 400 CFM (+/-50 CFM) per ton of condensing unit capacity is generally used for cooling. In high humidity applications, reduced airflow may be desired to remove more latent heat, absorbing moisture from the air. In dry applications, it may be desirable to increase airflow to remove more sensible heat and remove less moisture. Adjustments made to the system must be in accordance with the indoor unit Installation Manual.

Airside

This section covers measuring and evaluating total external static pressure.

In the airside section of the startup form, an area is provided to log the type of indoor blower motor, the external static pressure, and the speed selection for X-13 or PSC indoor blower motors for cooling operation. If the unit contains an ECM motor, log the jumper positions instead of speed selections.

External static pressure is a force that is exerted in all directions on the duct system. On the supply side of the indoor blower, the pressure is pushing out in all directions on the interior of the supply system. On the return side of the indoor blower, the pressure is pulling inward on the interior of the return system.

Systems with variable speed blower operation do have airflow limitations. Most residential systems, including those with variable speed motors, are designed to provide their rated airflow at external static pressures up to .5" w.c. ESP values more than .5" w.c. will result in reduced airflow, greater electrical consumption, and increased system operational sound.

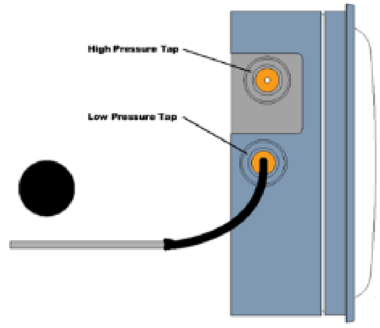
Restrictions in the duct system, such as an undersized duct, dirty filters, dirty evaporator coil and closed or blocked registers, will cause the external static pressure to increase.

Using the Magnehelic

A common tool of choice for measuring ESP is the Magnehelic© gauge. The example in the diagram below illustrates the use of the Magnehelic© gauge. Keep in mind that the measurement procedure and probe placement will be identical with an incline manometer.

The Magnehelic© gauge has two ports, labeled "high" and "low". The "high" port causes the value shown by the needle to increase if pressure is being put into the port. This port is connected to the supply side of the system, as will be discussed.

The port marked "low" causes the value shown by the needle to increase if there is a negative pressure on the port. This port is connected to the return side of the system as close to the unit as possible.



Magnehelic© Gauge Side View

Supply Static Pressure Measurement

To measure the supply static pressure, the Magnehelic© gauge probe is connected to the port marked "high". The probe should be inserted immediately off the supply duct connection or as close to the "take off" as possible. This will allow the measurement of the supply static pressure and resistance to airflow imposed by the evaporator coil, supply duct, fittings, and registers. A common supply value for a properly designed supply duct system with a clean, dry evaporator coil is .3" to .35" w.c.

Return Static Pressure Measurement

To measure the return static pressure, the Magnehelic© probe should be connected to the port marked "low". The probe should be inserted in the return air duct as close to the unit as possible, between the return air filter and the indoor unit. This will allow the measurement of the return static pressure and resistance to airflow imposed by the filter, return drop, return ductwork, fittings, and grilles. If access cannot be obtained between the unit and the filter, an alternative location for return static measurement is through a grommet on the side of the blower section.

Total External Static Pressure (ESP) Measurement

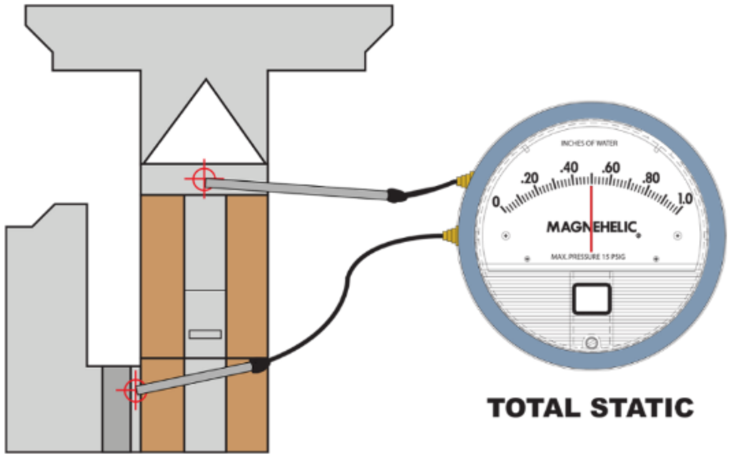
To measure the total external static pressure, the supply air static pressure and the return air static pressure measurements are added together.

Example:

Supply Air Static:	.3” w.c.
Return Air Static:	+ -.2” w.c.
= Total ESP	= .5” w.c.

If the total pressure exceeds the designed maximum allowable ESP on the equipment data plate, the duct system must be evaluated to ensure that it is sized properly.

Speed Adjustments: PSC Blower Models



Static Pressure Measurement Locations

Operate the system blower at the speed intended for use with air conditioning and refer to above diagram for static pressure measurement locations. When the total external static pressure has been determined, apply the total static pressure to the blower performance chart for the furnace or air handler model being serviced. The CFM being delivered will be where the ESP reading intersects with the blower speed being used. Remember that 350 to 450 CFM per ton is the target value. If required, change the blower speed to get as close to the appropriate airflow for the application as possible. After a blower speed change, re-check the total ESP and consult the blower performance chart to verify CFM.

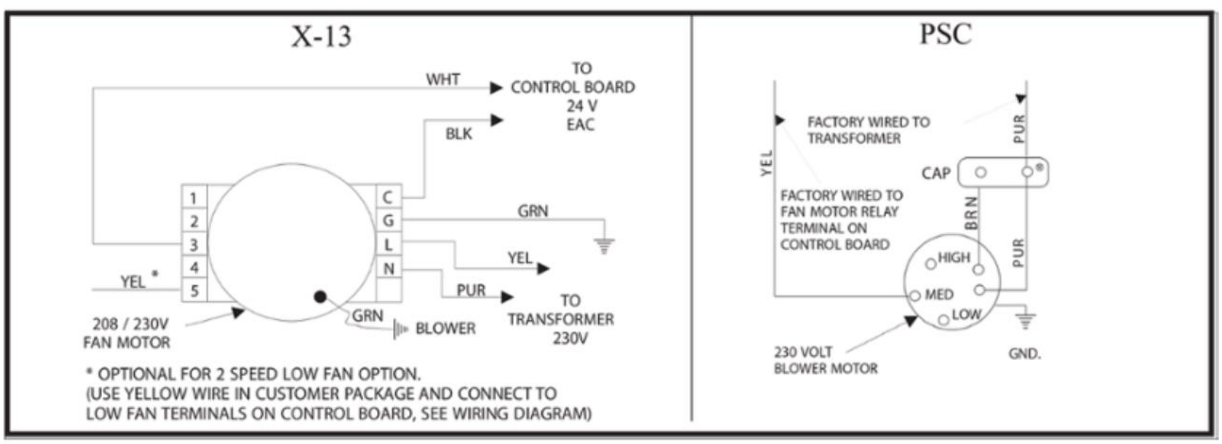
Standard ECM & PSC Indoor Fan Motors

Speed tap adjustments are made at the terminal block for PSC or Standard ECM motors. Units designed with ECM motors are adjusted utilizing the CFM selector on the indoor unit control board. Use the blower performance data in the Installation Manual or Tech Guide to set-up proper air flow. The chart below is an example of a blower performance chart used to identify the proper blower selection for cooling operation.

External Static Pressure, Inches W.C.

Speed Tap	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1.0
High	1635	1590	1535	1480	1415	1340	1280	1185	NR	NR
Medium High	1179	1171	1160	1140	1135	1098	1048	1026	NR	NR
Medium Low	969	967	967	959	938	905	860	802	NR	NR
Low	774	753	745	726	698	674	652	612	NR	NR
High	1687	1652	1631	1595	1557	1511	1456	1382	1313	1211
Medium High	1193	1183	1173	1162	1142	1115	1076	1036	982	950
Medium Low	933	933	921	911	902	872	825	793	771	712
Low	752	745	731	718	698	652	602	580	536	496
High	1686	1658	1623	1572	1534	1465	1391	1305	1202	1091
Medium High	1257	1223	1218	1203	1177	1142	1094	1026	939	874
Medium Low	977	982	976	955	934	899	843	791	738	686
Low	775	777	757	733	698	663	627	584	549	490

To achieve the desired indoor airflow, connect the motor wires to the corresponding motor speed tap receptacle located on the motor housing. Motor wiring details are located on the unit wiring label. The diagram below is an example of a Standard ECM and a PSC motor wiring diagram.



Wiring Diagram of a Standard ECM & a PSC Fan Motor

ECM Indoor Blower Motors

Furnace and air handlers that have control boards with onboard jumper selection pins must only be adjusted by moving the pin(s) to the desired speed selections.

The airflow and comfort setting selection must be set properly at the time of installation and start-up for proper system operation. The jumpers must be placed in the proper locations based on the information shown in the Installation Manual.

Use the Installation Manual to identify the proper jumper selection for the specific model being serviced or installed. The tap selections are labeled "cooling", "heating", "adjust", and "delay" (see table under "Comfort Delay Profile Selections"). Each of these tap selections has four jumper positions labeled "A", "B", "C", or "D". Both the "cool" and the "adjust" tap selections must be set for the cooling airflow (CFM). For the system to operate at design efficiencies, nominal cooling air flow must be set at 350 to 450 CFM with a maximum of 0.5" w.c. total ESP.

Sample ECM Indoor Fan Motor - High-Capacity Cooling and Heat Pump Airflow (CFM)

ECM blower motors deliver a constant airflow (CFM), even when external static pressure (ESP) in the duct system exceeds the recommended 0.5" w.c. value. Therefore, if a restriction in the duct work exists (dirty filter, closed supply registers, etc.), the motor will automatically operate at a higher speed and torque to compensate for the increased ESP. This will result in a higher operating sound level and reduced electrical efficiency. All airflow (CFM) is shown at 0.5" w.c. external static pressure. Variable speed ECMs automatically adjust to provide constant CFM from 0.0" to 0.6" w.c. static pressure. From 0.6" to 1.0" w.c. static pressure, CFM is reduced by 2% per 0.1" w.c. increase in external static pressure. Operation on duct systems with greater than 1.0" w.c. external static pressure is not recommended.

Model								Jumper Setting	
24B		36C		48D		60D			
High	Low	High	Low	High	Low	High	Low	Cool	Adjust
1380	897	1400	910	2200	1430	2400	1560	A	B
1024	666	1162	755	1925	1251	2232	1451	B	B
1200	780	1375	894	2175	1414	2375	1544	A	A
890	579	1010	657	1750	1138	1975	1284	B	A
1080	702	1238	804	1958	1272	2138	1389	A	C
742	482	1121	729	1623	1055	2034	1322	C	B
801	521	909	591	1575	1024	1778	1155	B	C
627	408	776	505	1403	912	1893	1230	D	B
675	439	975	634	1475	959	1800	1170	C	A
545	354	675	439	1275	829	1675	1089	D	A
581	378	878	570	1328	863	1620	1053	C	C
491	319	608	395	1148	764	1508	980	D	C

Comfort Delay Profiles Selections

DELAY Tap Selection

The "delay" tap provides four profiles. Each of the four profiles have unique blower cycling characteristics that allow the blower to maximize comfort levels in various climates for cooling operation. "Delay" tap selection does not apply and is not to be adjusted for heating mode.

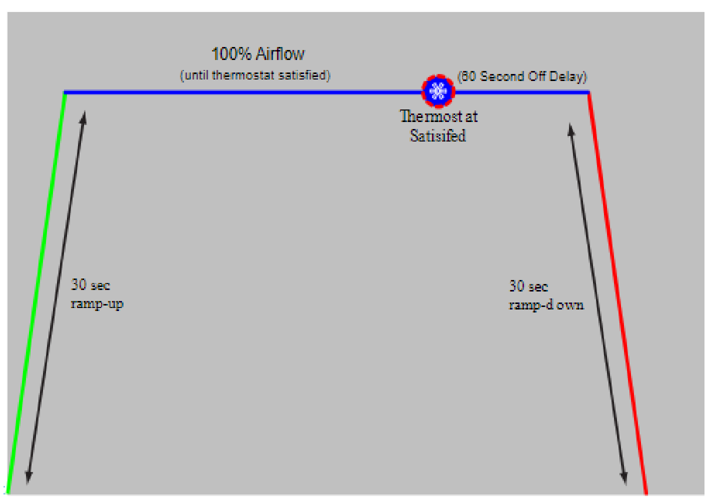
Delay Tap	Comfort Setting
A	Normal
B	Humid
C	Dry
D	Temperate

Throughout this section, "ramp-up" and "ramp-down" times are either 15 to 30 seconds or 30 to 60 seconds, depending on the model of the equipment and the control board on the indoor unit.

Delay Tap A- Normal Climate Profile

- Thermostat call: 15 to 30-second ramp-up to 100% CFM
- Thermostat satisfies: 60-second off-delay and then a 15 to 30-second ramp-down to zero CFM.

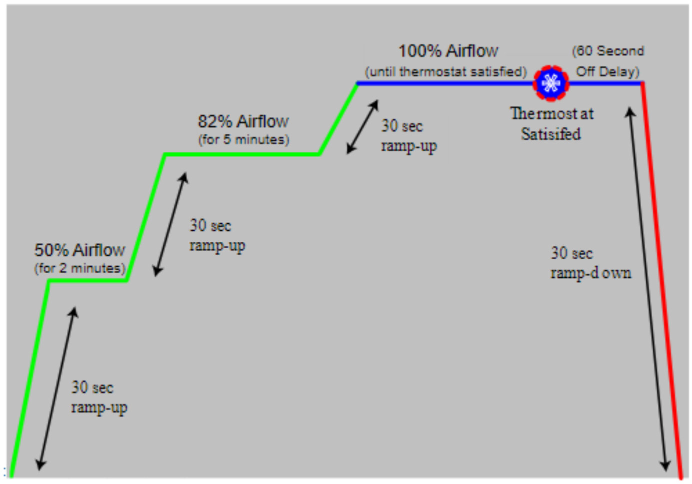
Delay Tap A is the "normal climate profile" and is the "as shipped/default" setting. The "Normal" setting provides a 15 to 30-second ramp-up from zero airflow to full capacity, and 15 to 30-second ramp-down from full capacity back to zero airflow. Whenever there is a change in the airflow mode, such as a call for cooling, the motor takes 15 to 30 seconds to ramp from one speed to the other. After reaching cut-off, the motor has a 60-second off-delay, and then ramps-down to zero airflow.



Delay Tap A - Normal Climate Profile

Delay Tap B- Humid Climate Profile

- Thermostat call: 15 to 30-second ramp-up to 50% CFM for 2 minutes
- After 2 minutes: 15 to 30-second ramp-up to 82% of CFM for 5 minutes
- After 5 minutes: 15 to 30-second ramp-up to 100% of CFM until the conditioned space reaches the desired thermostat setting.
- Thermostat satisfies: 60-second off-delay and then a 15 to 30-second ramp-down to zero CFM.

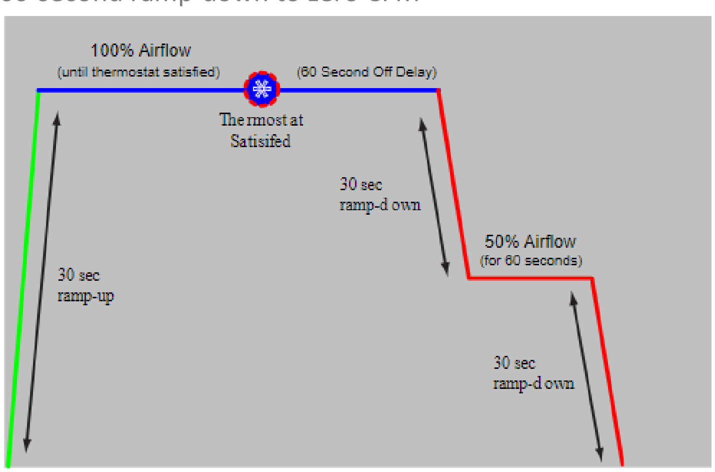


Delay Tap B - Humid Climate Profile

The "humid" setting is best suited for applications where the indoor humidity is frequently very high during cooling season. On a call for cooling, the blower ramps-up to 50% of full capacity for 60 seconds. After operating at half capacity for 60 seconds the unit will then ramp-up to 82% of full capacity for five minutes, and then up to full capacity. It will remain at full capacity until the conditioned space reaches the desired thermostat setting. The motor has a 60-second off-delay. During every transition, the motor takes 15 to 30 seconds to ramp from full capacity back to zero airflow.

Delay Tap C-Dry Climate Profile

- Thermostat call: 30-second ramp-up to 100% CFM until the conditioned space reaches the desired thermostat setting.
- Thermostat satisfies: 60-second off-delay and then a 30 to 60-second ramp-down to 50% CFM for 60 seconds.
- After 60 seconds: 30 to 60-second ramp-down to zero CFM

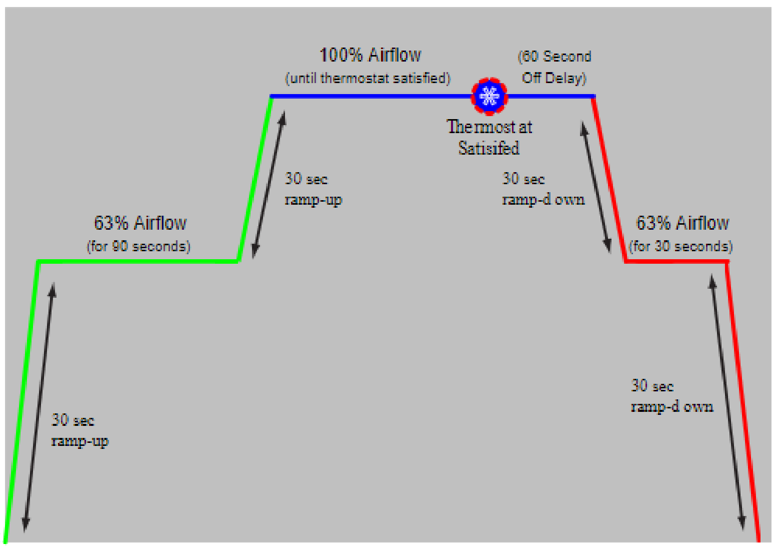


Delay Tap C - &/ Dry Climate Profile

The "dry" setting is best suited where indoor relative humidity levels are low during cooling operation. On a call for cooling, the motor ramps-up to full capacity and remains there until the conditioned space reaches the desired thermostat setting. At the end of the cooling cycle, the motor has a 60-second off- delay. After the off-delay, the blower ramps-down to 50% of full capacity for 60 seconds, and then ramps-down to zero. During each transition, the motor takes 30 seconds to ramp-up from one capacity to another and takes 30 to 60 seconds to ramp-down to a lower speed or down to zero.

Delay Tap D-Temperate Climate Profile

- Thermostat call: 15 to 30-second ramp-up to 63% CFM for 90 seconds
- After 90 seconds: 15 to 30-second ramp-up to 100% of CFM until the conditioned space reaches the desired thermostat setting.
- Thermostat satisfies: 60-second off-delay and then a 15 to 30-second ramp-down to 63% CFM for 30 seconds.
- After 30 seconds: 15 to 30-second ramp-down to zero CFM



Delay Tap D - Temperate Climate Profile

The "temperate" setting is best suited where neither excessive humidity nor extremely dry conditions are normal. On a call for cooling, the motor ramps-up to 63% of full capacity for 90 seconds, then ramps- up to full capacity. At the end of the cooling cycle, the motor has a 60-second off-delay. After the off- delay, the blower motor ramps-down to 63% of full capacity for 30 seconds, and then ramps-down to zero. During each transition, the motor takes 15 to 30 seconds to ramp from one capacity to another.

Temperature Drop

An air conditioning unit that is within normal operating temperatures has approximately an 18°F to 20°F temperature drop across the evaporator coil during cooling. The temperature drop is measured by subtracting the supply air dry bulb temperature from the return air dry bulb temperature. High humidity applications result in a lower temperature drop across the evaporator.

Example:	Return air dry bulb	75ºF
	Supply air dry bulb	-55ºF
	=Temperature Drop	= 20ºFΔT - Drop

Proper Leaving Air Temperature Cooling Mode

During cooling operation, the temperature drop may be increased or decreased depending on the return air wet bulb temperatures. The conditions listed in the table below show the proper leaving air temperature on the bottom right, for a ratio of 400 CFM per ton of cooling capacity produced. If the air temperature leaving the evaporator is 3°F or warmer than the posted leaving air temperature, airflow is greater than 450 CFM per ton and blower speed can be reduced.

Proper Leaving Air Temperature Cooling Mode +/- 3°F								
ID Entering WB °F	ID Entering DB °F							
	70°	72°	74°	76°	78°	80°	82°	84°
57°	51	52	53	54	55	56	57	
58°	51	52	53	54	55	56	57	58
59°	52	53	53	54	55	56	57	59
60°	52	53	54	55	56	56	57	59
61°	53	54	55	55	56	57	58	60
62°	53	55	55	56	57	58	59	60
63°	54	55	56	57	57	58	60	61
64°	55	56	57	57	58	59	60	61
65°	55	57	58	58	59	60	61	62
66°	56	57	58	59	60	61	62	63
67°	57	58	59	60	61	62	63	63
68°	58	59	60	61	62	63	64	64
69°	59	60	61	62	63	64	65	65
70°	60	61	62	63	64	65	66	66
71°		62	63	64	65	66	67	67
72°		63	64	65	66	67	68	68
73°			65	66	67	68	69	69
74°				67	68	69	70	70
75°					69	69	71	71
Leaving Air Temperature +/- 3°F for Nominal 400 CFM Per Ton of Cooling								

If the air temperature leaving the evaporator is 3°F or cooler than the posted leaving air temperature, airflow is less than 350 CFM per ton and blower speed should be increased. The chart may also be used as a gauge for cooling capacity when the airflow quantity is known to be 400 CFM per ton of rated cooling capacity.

Air Temperature Rise Method

The heating temperature rise is a calculation that measures how many CFM of airflow is being provided by the unit during the heating mode. This is demonstrated in the "Airflow Calculation" section.
It is possible to use this calculation to identify cooling CFM if the blower selection can be temporarily moved to cooling speed during heating operation. This is dependent upon the model of the indoor unit being serviced.

Temperature rise is measured by subtracting the return air dry bulb temperature from the supply air dry bulb temperature as seen in the following example. Supply and return air temperatures should be measured as close to the indoor unit as possible, without being in direct view of the heat exchanger or electric heating elements. If the readings are taken in direct line of sight to the elements, the temperature will be of the radiant heat generated, rather than the air temperature entering, or leaving the unit.

Example:	Supply air dry bulb	115ºF
	Return air dry bulb	-70ºF
	=Temperature Rise	= 45ºFΔT – Rise

Air Flow Calculation

$$\text{Formula:} \quad \frac{\text{BTU output}}{1.08 \text{ X Temp Rise}} = \text{CFM}$$

This formula measures the CFM produced during heating operation. To calculate CFM, find the BTU output from the heating unit and the temperature rise across the heating section.

Electric Heat (Single Phase)

To calculate CFM with electric heat, the number and rating of the energized heating elements must be known. Note the formula to calculate the BTU/h output of a heating element with different voltages applied.
A heating element rated at 5 kw with a 240 volts AC power supply will provide:

Example 1: 5000 watts/240 volts AC = 20.83 amps
240 volts AC/20.83 = 11.52 ohms of resistance
5000 watts X 3.413 BTU/h = 17,065 BTU/h
3 strips X 17,065 BTU/h = 51,195 BTU/h Output

In example 1, if the BTU/h output is 51,195 and the unit has a 35°FAT (Temperature Rise), the result is an air flow of 1354.36 CFM.

$$3 \text{ X } 17{,}065 \text{ BTU/h} = \frac{51{,}195 \text{ BTU/h Output}}{1.08 \text{ X } 35^{\circ}\text{F}\Delta\text{T}} = 1354.36 \text{ CFM}$$

The same heating element will produce less heat if the voltage is decreased. A 5 kw heating element, rated at 240 volts AC, has a resistance of 11.52 ohms. If a heating element has a resistance of 11.520 and a voltage of 208 volts AC is applied, the result is 3755 watts, instead of 5000 watts.

Example 2: 208 volts AC/11.52 ohms of resistance = 18.05 amps
208 volts AC X 18.05 amps = 3755 watts
3755 watts X 3.413 BTU/h = 12,816 BTU/h
3 Strips X 12,816 BTU/h = 38,448 BTU/h Output

In example 2, if the BTU/h output is 38,448 and the unit has a 35°FAT (Temperature Rise), the result is an air flow of 1017.14 CFM.

$$3 \text{ X } 12{,}816 \text{ BTU/h} = \frac{38{,}448 \text{ BTU/h Output}}{1.08 \text{ X } 35^{\circ}\text{F}\Delta\text{T}} = 1017.14 \text{ CFM}$$

There is a large difference in the BTU/h output and CFM air flow from example 1 to example 2. This difference is produced when the voltage input changes. Proper voltage readings must be used to calculate CFM.

Electric Heat (Three Phase)

To calculate the BTU output of a three-phase electric heating system, the voltage applied to one element is multiplied with the amperage of one leg feeding the element. It is then multiplied by 1.73 (square root of 3).

Example: 460 volts AC X 10 amps X 1.73 = 7,958 watts
7,958 watts X 3.413 BTU/h 27,160 BTU/h
27,160 BTU/h X 2 Banks of Heater = 54,321 BTU/h

Output:
In this example, if the BTU/h output is 54,321 and the unit has a 45°FAT (Temperature Rise), the result is an airflow of 1117.72 CFM.

$$2 \text{ X } 27{,}160 \text{ BTU/h} = \frac{54{,}321 \text{ BTU/h Output}}{1.08 \text{ X } 45^{o}\text{F}\Delta\text{T}} = 1117.72 \text{ CFM}$$

Gas Heat

To measure the CFM on a gas heating system, the BTU content of the fuel supplying the furnace must be known. The BTU content may vary depending on the supplier of natural gas. BTU content can be verified by contacting the local utility. In this example, the BTU content of the fuel is 1030 BTU per cubic foot of natural gas.
If the furnace has a BTU input rating of 60,000 BTU/h and has an 80% Annual Fuel Utilization Efficiency (AFUE) rating, the unit has a 48,000 BTU/h output.

Formula: 60,000 BTU/h Input X.80 = 48,000 BTU/h Output
In this example, if the BTU/h output is 48,000 and the furnace has a 45°FAT (Temperature Rise), the result is an airflow of 987.65 CFM.

$$60{,}000 \text{ X } .80 = \frac{48{,}000 \text{ BTU/h Output}}{1.08 \text{ X } 45^{o}\text{F}\Delta\text{T}} = 987.65 \text{ CFM}$$

Calculating Gas Heat Input (Clocking the Meter)

One method to clock the gas meter and confirm the input to the furnace is to perform the following:

- All other gas appliances must be in the "OFF" position to calculate the exact input to the furnace.
- The furnace must be firing at full capacity.
- Log the cubic feet of gas utilized in 6 minutes of operation. Keep in mind, 6 minutes is 1/10th of one hour.
- Multiply the cubic feet of gas by 10.

  If the unit uses 5 cubic feet of gas in 1/10th of one hour, the 5 cubic feet is multiplied by 10. The result is an input of 50 cubic feet of gas in one hour.
  10 x 5 = 50 cubic feet per hour input
- Multiply the BTU content of the fuel by the cubic feet per hour.

  If the BTU content was verified to be 1030 BTU per cubic foot, the 1030 BTU per cubic foot would be multiplied by 50 cubic feet input per hour.
  1030 x 50 = 51,500 BTU/h Input
- Multiply the BTU/h input by the AFUE rating.

  This would indicate a 51,500 BTU/h input to the unit.
  If this furnace had an AFUE rating of 80%, the output is approximately 41,200 BTU/h.
  51,500 x .80 = 41,200 BTU/h Output

Total System Charge

The factory charge in the condensing unit provides enough refrigerant for the condensing unit, a 15 ft. (4.6m) line set, and the smallest matched evaporator coil. Some evaporator coil matches may require additional charge.
The total system charge is the sum of the condensing unit charge, the evaporator charge, and the recovery or adder charge for the lineset adjustment. The total system charge is determined as follows:

1. Determine the condensing unit charge from Tabular Data Sheet
2. Determine the evaporator coil adjustment from Tabular Data Sheet
3. Calculate the line charge adjustment using the refrigerant adder in the Tabular Data Sheet
    a. If line length is greater than 15 feet (4.6 m), add refrigerant using the adder listed, multiplied by the number of additional feet
    b. If line length is less than 15 feet (4.6 m), subtract refrigerant using the adder listed, multiplied by the number of feet the lineset is reduced
4. If the system charge is adjusted using superheat or subcooling on initial setup, the amount of refrigerant added or recovered is also used to adjust the total system charge
5. The total system charge must be written on the unit data plate with a permanent marker

The two alternatives to charging a system by weight are the superheat and subcooling methods. The charging method is determined by the type of metering device matched with the system.
Fixed Orifice metering devices are charged using the superheat charging charts provided with the equipment.
Thermostatic Expansion Valve (TXV) metering devices can be charged using the subcooling values listed on the equipment or in the Installation Manual. Do not charge a TXV system by the superheat method. If a system using a TXV metering device has the wrong amount of superheat, the system must be evaluated to verify that it is properly charged.
Identify the following conditions prior to evaluating the system for proper refrigerant charge:

- Proper airflow has been established and does not exceed the total external static pressure listed on the unit data plate.
- All major components are operating including the compressor, outdoor blower motor, and indoor blower motor.
- The evaporator and condensing coils are clean and free of debris.
- The return air filter is clean.
- The supply air vents are in the open position.
- Temperature probes are installed and insulated on the appropriate refrigerant lines.
- The appropriate refrigerant gauge manifold set is properly purged and installed.
- The system has operated in the cooling mode at 2nd stage cooling, (full) capacity, for a minimum of 15 to 20 minutes.
- The system's metering device was located to verify which of the charging methods will be used.
- The proper superheat or subcooling refrigerant charge was identified on the equipment data plate or in the equipment Installation Manual

When evaluating a system for acceptable refrigerant charge, refer to the published superheat and subcooling values. If the required values do not exist, the following generic charging values may be used. These values should only be used if there are no other charging methods available for the unit.

Generic Superheat Calculator for “R-410A” Non-TXV (Cooling Only)

R-410A Superheat | Cond. Entering Air Dry Bulb °F | Return Air Wet Bulb °F | Calc. Superheat Value

R-410A	°F	Return Air Wet Bulb Temperature													
		50°	52°	54°	56°	58°	60°	62°	64°	66°	68°	70°	72°	74°	76°
Condenser Entering Air Dry Bulb Temperature	55°	9	12	14	17	20	23	26	29	32	35	37	40	42	45
	60°	7	10	12	15	18	21	24	27	30	33	35	38	40	43
	65°	*	6	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°	*	*	*	*	*	*	*	*	*	*	9	14	18	23

* Do Not Charge Unit When Conditions Fall within the * Blocks

Generic Subcooling for “R-410A” TXV (Cooling Only)

Seer Rating	11-12	13	15	15 (Two Stage)
Generic Subcooling Value	15°	12°	15°	15°

Generic Superheat Calculator for “R-22” Non-TXV (Cooling Only)

R-22 Superheat | Cond. Entering Air Dry Bulb °F | Return Air Wet Bulb °F | Calc. Superheat Value

R-22	°F	Return Air Wet Bulb Temperature													
		50°	52°	54°	56°	58°	60°	62°	64°	66°	68°	70°	72°	74°	76°
Condenser Entering Air Dry Bulb Temperature	55°	9	12	14	17	20	23	26	29	32	35	37	40	42	45
	60°	7	10	12	15	18	21	24	27	30	33	35	38	40	43
	65°	*	6	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°	*	*	*	*	*	*	*	*	*	*	9	14	18	23

* Do Not Charge Unit When Conditions Fall within the * Blocks

Generic Subcooling for “R-22” TXV (Cooling Only)

Seer Rating	13 - 15	10 - 12
Generic Subcooling Value	8° to 12°	10° to 15°

Superheat Verification

The required superheat values on a fixed orifice metering device can vary greatly, depending on the heat load of the evaporator and ambient conditions. Often, it is necessary to measure the indoor wet bulb and the outdoor dry bulb temperatures. The "target" superheat value must be known for the conditions present during service or initial setup. To verify superheat proceed as follows:

1. Operate the system until conditions stabilize, usually 10 to 15 minutes.
2. Measure the suction pressure by attaching the low side of the manifold gauge set to the low side valve port.
3. Convert the suction pressure to temperature using a temperature/ pressure chart like the chart below. This chart shows the boiling point or saturation temperature in the "Temp "F" columns, and the pressure (psig) under the refrigerant column.

Temperature / Pressure Chart

Temp °F	R-22 psig	R-410A psig	Temp °F	R-22 psig	R-410A psig
36	63	110	100	196	317
38	66	114	102	202	326
40	68	118	104	208	336
42	71	123	106	214	345
44	74	128	108	220	355
46	78	133	110	226	365
48	80	138	112	233	375
50	84	143	114	239	386
52	87	148	116	246	396
54	91	153	118	253	407
56	94	159	120	260	418
58	98	164	122	267	429
60	102	170	124	274	441
62	105	176	126	282	452
64	109	182	128	289	464
66	113	188	130	297	476
68	117	194	132	305	489
70	121	201	134	312	502
72	126	208	136	321	514
74	130	214	138	329	528
76	135	221	140	337	541
78	139	228	142	346	555
80	144	236	144	354	569
82	148	243	146	363	583
84	153	251	148	372	598
86	158	258	150	381	613
88	163	266	152	391	628
90	168	274	154	400	*
92	174	283	156	410	*
94	179	291	158	420	*
96	185	300	160	430	*
98	190	308	162	440	*

R-410A is Liquid Pressure

4. Measure the suction temperature by attaching an electronic thermometer to the suction line approximately 6 inches from the suction service valve. To obtain an accurate measurement, the thermometer must be insulated and in solid contact with the suction line.
5. Subtract the converted temperature from the suction line temperature. If superheat is too low, the unit may be overcharged. If it is too high, the unit may be undercharged.
6. After adding or removing charge, allow the system to operate 10 to 15 minutes prior to rechecking the superheat value.

Subcooling Verification

The "subcooling method" is used to charge systems with a TXV metering device. The subcooling charging charts are in the Installation Manual and are often located on a corner post of the condensing unit.

Refrigerant Charge Adjustment

If additional refrigerant is needed, R-410A is removed from the cylinder as a liquid and charged into the suction line during equipment operation. This is accomplished with a liquid charging adapter, which causes the liquid refrigerant to flash to a vapor prior to entering the system.

If refrigerant is removed, use approved refrigerant recovery techniques. This includes the use of a refrigerant recovery machine dedicated to refrigerant R-410A recovery.

After adding or removing charge, allow the system to operate for 10 to 15 minutes prior to rechecking the subcooling value.

Refrigerant Charge & Metering Device

The "Refrigerant Charge and Metering Device" section of the start-up sheet provides a checklist for the type of refrigerant and metering device utilized on the unit. This is also the location to record the measured superheat and subcooling values, along with the necessary amount of refrigerant added.

Total (Current) Amperes

The total amperes must be measured and recorded after the unit has operated in the cooling mode (second stage on two stage equipment) for at least 10 minutes. The total amperes are measured either at the equipment electrical disconnect or at the unit's contactor.

After the unit has operated for approximately 10 minutes, the amp draw is measured and recorded on the start-up sheet. The current for each leg of power must be close to the run load amps (RLA) or full load amps (FLA) rating on the equipment data plate when the system is operating at design conditions. When the system is operating under light load conditions, the run amperages will be lower.

Compressor Current (Amperes)

The compressor amperes should be measured and recorded on the start-up sheet when the unit has been operating in the cooling mode for at least 10 minutes (second stage for two stage equipment). The compressor amperes should be measured at the unit's contactor or at the compressor high voltage terminal block.

The current for each leg of power "common" and "run" should be recorded. Operation below rated load amps (RLA) can be expected for most unit loading conditions. Operation at RLA occurs at maximum unit loading conditions. The RLA may briefly be exceeded following start-up under high unit loading conditions; however, extended operation above RLA will cause compressor overheating and motor protector trips. If the compressor amps exceed the rating on the data plate, the system must be evaluated to prevent damage.

Possible causes of excessive compressor current:

- Low voltage to compressor
- Pitted or dirty contacts on the compressor contactor
- Poor electrical connections
- Poor airflow across the condenser coil
- Extremely high return air temperatures
- Extremely high airflow across the evaporator coil
- Failed start relay
- Open or shorted start capacitor
- Open or shorted run capacitor
- Grossly overcharged.
- Single phasing on three phase compressor
- Failed compressor

Cycle Test

The system must be cycled through each of the operational modes to verify proper system operation. The Appendix Section provides a checklist for each mode of operation.

Clean Up

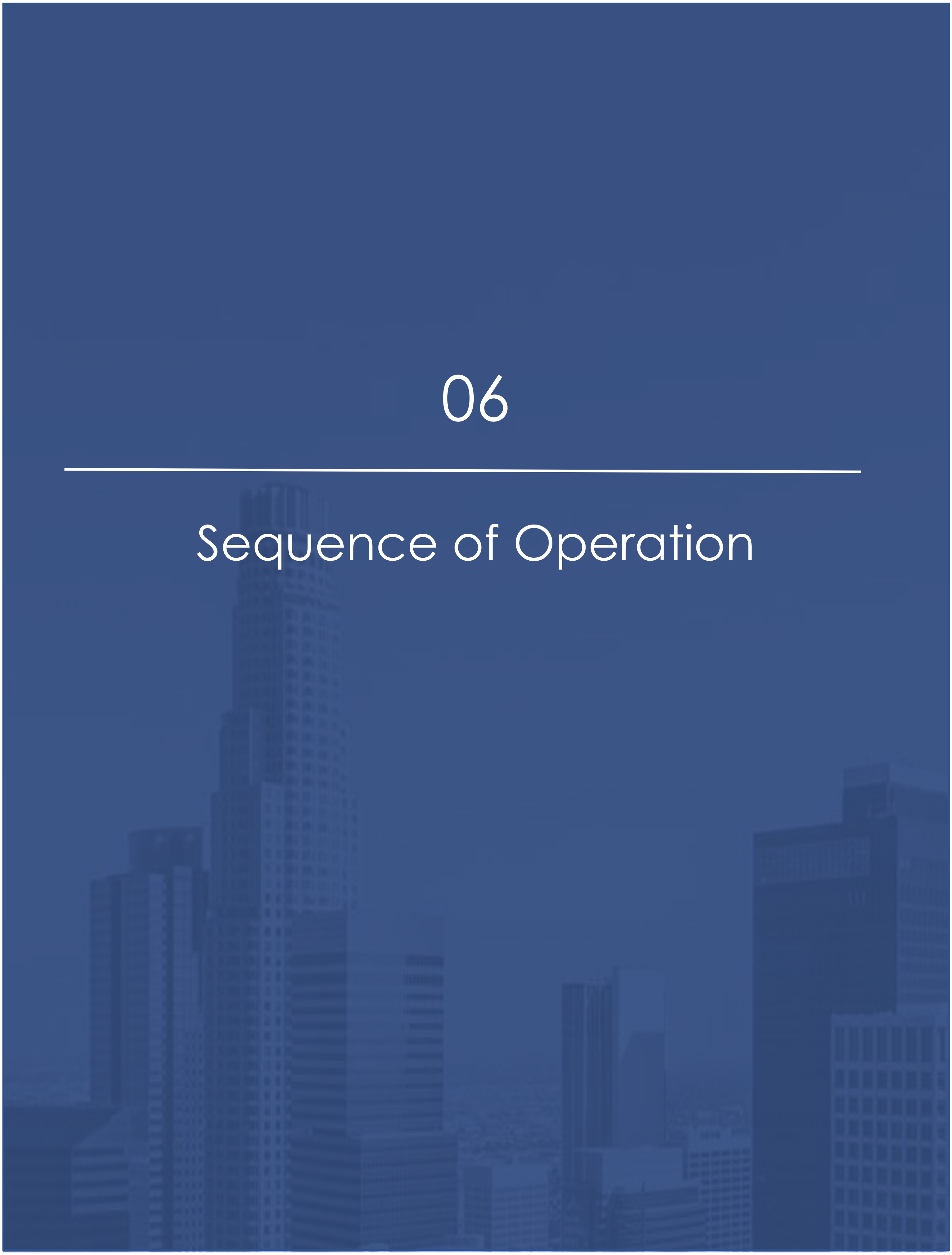
It is the technician's responsibility to ensure a safe and clean working environment. It is also important to dispose of any debris and keep the area around the equipment clean.

Owner Education

It is the technician's responsibility to provide the customer with an owner's manual and to explain proper:

- System operation
- Thermostat programming
- Maintenance - filter replacement

The customer must be informed of the importance of regular service to ensure equipment longevity and peak performance.



06

Sequence of Operation

Introduction

This section will present the normal sequence of operation for the 1-1/2 to 5-ton single and two stage air conditioning units.

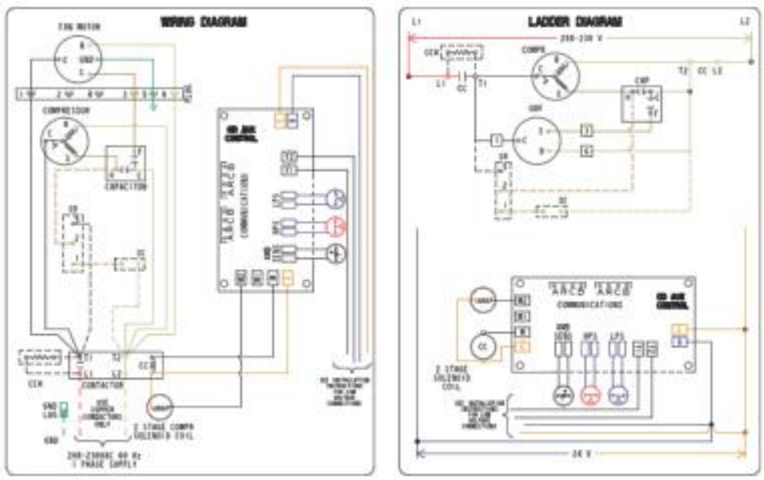
The sequence of operation may vary depending on additional controls or accessories which may have been installed with the unit. This may include fossil fuel or electric heating.

Always use the existing electrical wiring diagrams that accompany both the indoor and outdoor equipment being serviced. These diagrams will assist in identifying components that are cycled during a specific sequence of operation.

Cooling Operation: Single & Two Stage Overview

Single and two stage cooling units are very similar in operation, and attention must be given to differentiating between various units. Be aware of the compressor motor type and control functions of the unit prior to service or troubleshooting.

Residential Air Conditioning Communicating Control Board w/ Conventional Non-Communicating Thermostat



Example Wiring Diagrams of Residential Air Conditioning Communicating Control Board with Conventional Non-Communicating Thermostat

1st Stage Cooling Call Initiated

When a call for cooling is initiated, 24 volts AC is sent from terminal "R" to the "Y1" and "G" terminals on the thermostat.

When the Air Conditioning Communicating Control Board receives a "Y1" input from the thermostat and the high- and low-pressure switches are closed, the control board will provide 24 volts AC out of the "C" and "M" terminals. This will energize the "Contactor Coil" for first stage compressor and condenser fan operation.

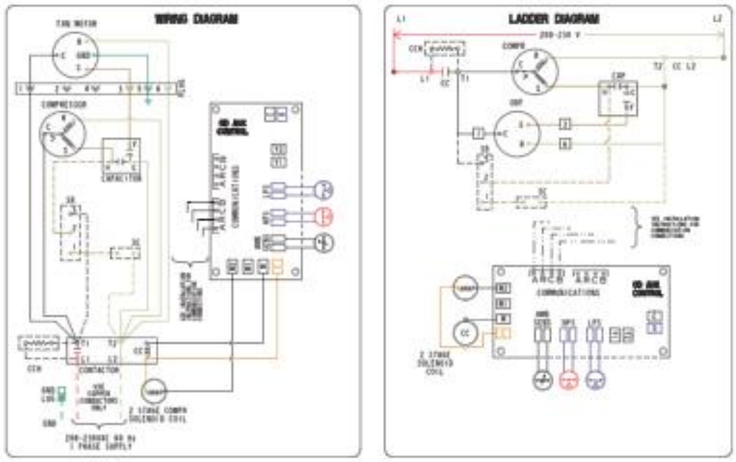
24 volts AC will be measured between the "C" and "Y1" terminals and can also be measured between the "C" and "M" terminals on the Air Conditioning Communicating Control Board.

2nd Stage Cooling Call Initiated

When the control board receives a "Y1" input from the thermostat, and the high- and low-pressure switches are closed, the control board will provide 24 volts AC out of the "C" and "M" terminals. This energizes the "Contactor Coil" for first stage compressor and condenser fan operation. When the control board receives a "Y2" input from the thermostat, 24 volts AC is provided out of the "M2" terminal on the control board to the "Rectifier" on the compressor for second stage (full capacity) operation.

24 volts AC will be measured between the "C" and "Y2" terminals and can also be measured between the "C" and "M2" terminals on the Air Conditioning Communicating Control Board.

Residential Air Conditioning Communicating Control Board w/ Johnson Controls Residential Communicating Thermostat



Example Wiring Diagrams of Residential Air Conditioning Communicating Control Board with Communicating Thermostat

When the Johnson Controls Residential Communicating System is matched with a condensing unit equipped with the Residential Air Conditioning Communicating Control Board, the 24-volt AC wiring harness that is on the bottom right side of the control board must be removed to prevent system damage.

1st Stage Cooling Call Initiated

When the control board receives a communicated "Y1" input from the communicating thermostat, and the high- and low-pressure switches are closed, the control board will provide 24 volts AC out of the "C" and "M" terminals. This energizes the contactor coil for first stage compressor and condenser fan operation.

24 volts AC is measured between the "C" and "M" terminals on the Air Conditioning Communicating Control Board.

2nd Stage Cooling Call Initiated

When the control board receives a communicated "Y1" input from the communicating thermostat, and the high- and low-pressure switches are closed, the control board will provide 24 volts AC out of the "C" and "M" terminals. This will energize the contactor coil for first stage compressor and condenser fan operation. When the control board receives a communicated "Y2" input from the communicating thermostat, 24 volts AC is provided out of the "M2" terminal on the control board to the rectifier on the compressor for second stage (full capacity) operation.

24 volts AC will be measured between the "C" and "M" terminals, and between the "C" and "M2" terminals on the Air Conditioning Communicating Control Board.

Two Stage Cooling Anticipation Mode

The Residential Air Conditioning Communicating Control Board has two-stage cooling anticipation mode capabilities. This is possible when installed with the Johnson Controls Residential
Communicating Thermostat. To enable the two-stage cooling anticipation mode, the technician must set the "Y2 Lock" function on the communicating thermostat to "YES".

This feature can force second stage compressor operation with a high load demand, even if the thermostat is only calling for first stage operation.

For example, if the control board receives two consecutive second stage cooling calls from "Y1" and "Y2", the third cooling call will energize second stage cooling. This occurs even though the thermostat is calling for first stage cooling at the "Y1" terminal.

The control board will continue to energize second stage compressor operation with a first stage call until one of the following occurs:

- The thermostat satisfies after operating less than 10 minutes in the cooling mode prior to receiving a "Y2" signal from the thermostat.
- The 24 volts AC power to the control is removed.
- The "TEST" pins are shorted together.

Cooling Call Initiated – Conventional Thermostat w/out Residential Air Conditioning Communicating Control Board

When a call for cooling is initiated, 24 volts AC is sent from terminal "R" to the "Y" and "G" terminals on the thermostat. 24 volts AC is then sent from the "y" terminal on the thermostat through the closed contacts of the pressure switches to the compressor contactor coil "CC" terminals. 24 volts AC is measured at the contactor coil "CC" terminals.

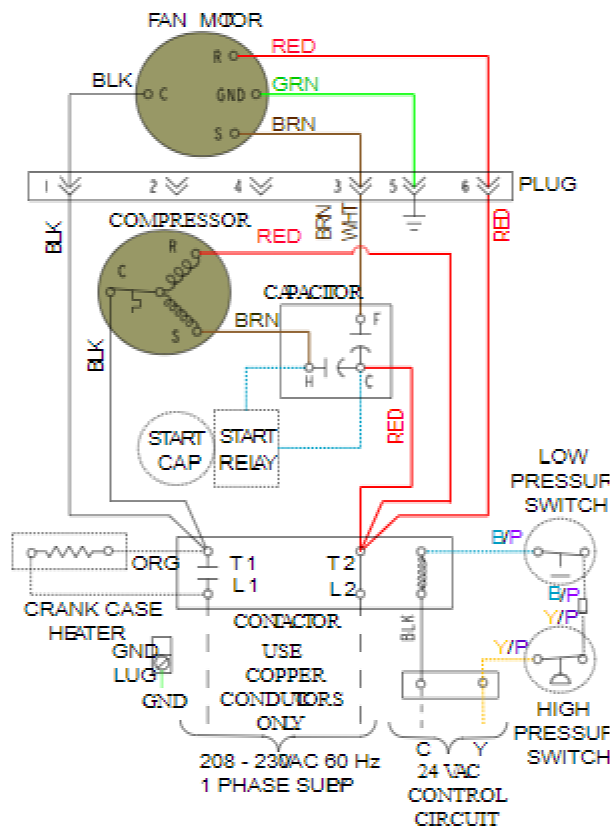
When the "y" terminal energizes the contactor coil, the contacts between terminals "T1" and "L1" close. This sends 208/230 volts AC out of terminals "T1" and "T2", energizing the compressor and outdoor fan motor.
208/230 volts AC is measured between the "T1" and "T2" terminals of the compressor contactor and can also be measured between the "L1" and "12" terminals on the contactor.

When the compressor is energized, the discharge gas is circulating to the condensing coil.

The 24 volts AC from terminals "Y" and "G" of the thermostat are also sent to the indoor unit to operate the indoor fan motor at cooling speed.

24 volts AC will be measured between the "C" and "G" terminals on the indoor unit control board.

The cooling cycle will continue until the conditioned space reaches the desired thermostat setting and the thermostat opens the circuit from "R" to "Y" and "G".



Example Wiring Diagram of a Non-Communicating Single Stage Air Conditioner

Cooling Call Satisfied – Conventional Thermostat w/out Residential Air Conditioning Communicating Control Board

Single Stage Overview

When the conditioned space reaches the desired thermostat setting, 24 volts AC is removed from the "y" and "G" terminals on the thermostat (thermostat set to the fan "auto" selection and in cooling mode).

At the same time, 24 volts AC is removed from the "Y" terminal on the thermostat, 24 volts AC is removed from the"CC" terminals, de-energizing the compressor contactor coil.

A reading of 0 volts AC would be measured between the "C" and "Y" terminals on the terminal strip of the condensing unit.

When the "CC" terminals of the compressor contactor are de-energized, the contacts between terminals "LI" and "T1" open, de-energizing the compressor and condenser fan motor.

Note
Although the contacts between “L1” and “T1” have been opened, line voltage is still present at the compressor and outdoor fan motor from the “T2” terminal of the contactor.

230 volts AC is measured between the "L1" and "T1" terminals of the compressor contactor. This measurement exists due to line voltage from "L2" back feeding through the motor windings of the compressor and condenser fan motor to terminal "T1".

The 24 volts AC signal from terminals "Y" and "G" are also removed from the indoor unit, which begins the off cycle for the indoor fan motor.

Zero volts AC will be measured between the "C" and "G" terminals on the indoor control board if the thermostat is in the fan auto selection, and in cooling mode.

When the indoor fan motor comes to a stop, the system remains idle until the next thermostat call is initiated.

When the conditioned space reaches the desired thermostat setting, the 5-minute ASCD timer starts (if applicable).

If a crankcase heater is present across the "L1" and "T1" terminals, the crankcase heater must be energized. To verify crankcase heating, 230 volts AC must be measured across the crankcase heating element.

Cooling Call Initiated – Conventional Thermostat w/out Residential Air Conditioning Communicating Control Board

Two Stage Cooling Overview

It must be noted that on the air conditioning systems, the two-stage compressor solenoid coil is internal to the compressor with an external rectifier that receives 24 volts AC. The rectifier is depicted here. The rectifier receives 24 volts AC and converts the voltage to DC voltage. The internal solenoid is controlled by DC voltage.

When a first stage calls for cooling is initiated, 24 volts AC is sent from terminal "R" to the "Y1" and "G" terminals on the thermostat.

24 volts AC is sent from the "Y1" terminal on the thermostat to the compressor contactor coil "CC" terminals. 24 volts AC is measured at the contactor coil "CC" terminals.

The compressor will be operating at 67% of the cooling capacity. When the "Y1" terminal energizes the contactor coil, the contacts between terminals "L1" and "T1" close. This sends 230 volts AC out of terminals "T1" and "T2", energizing the compressor and condenser fan motor. 230 volts AC is measured between the "T1" and "T2" terminals of the compressor contactor. When the compressor is energized, the discharge gas is circulated to the condensing coil.

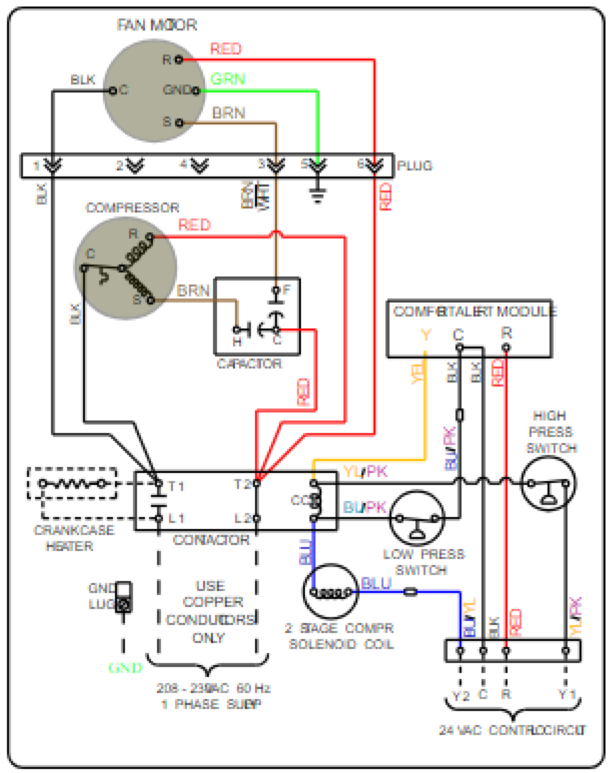
The 24 volts AC signal from terminals "Y1" and "G" of the thermostat are also delivered to the indoor unit. This operates the indoor fan motor at cooling speed.

24 volts AC is measured between the "C" and "Y1" terminals and between the "C" and "G" terminals on the indoor unit control board.

The cooling cycle will continue until the conditioned space reaches the desired thermostat setting or a second stage call for cooling is sent from the thermostat.

On a first stage cooling call, the following components are energized:

- Contactor coil "CC"
- Compressor - 67% cooling capacity.
- Condenser fan
- Indoor blower motor - low cooling speed



Wiring Diagram of a Non-Communicating Two Stage Air Conditioner

When a second stage call for cooling is initiated, 24 volts AC is sent from terminal "R" to the "Y2" terminal on the thermostat. 24 volts AC is sent from the "Y2" terminal on the thermostat to the compressor rectifier labeled "2 STAGE COMPR SOLENOID COIL". 24 volts AC is measured at the inlet of the rectifier.

If the rectifier is removed from the compressor, the voltage reading would be 24 volts DC at the outlet of the rectifier supplying the internal second stage compressor solenoid. 24 volts AC could also be measured between the "C" and "Y2" terminals on the indoor unit control board.

The compressor will be operating at 100% of the cooling capacity.
The following components will be energized with a second stage cooling call from the thermostat:

- Contactor coil "CC" - first and second stage cooling
- Second stage compressor solenoid coil/ rectifier
- Compressor - 100% cooling capacity.
- Condenser fan
- Indoor blower motor - high cooling speed

Cooling Call Satisfied – Conventional Thermostat w/out Residential Air Conditioning Communicating Control Board

Two Stage Cooling Overview

When the conditioned space reaches the desired thermostat setting, the thermostat removes the 24 volts AC signal from the "Y1", "Y2" and "G" terminals.

When "Y1" and "Y2" are de-energized, 24 volts AC is removed from the "CC" coil and rectifier.

When the contactor coil is de-energized, the contacts between "L1" and "T1" will open. When the contacts open, 230 volts AC will be removed from the load side of the contactor at terminal "T1" and will de-energize the compressor.

While the contactor coil and second stage rectifier are de-energized, one leg of the 230 volts AC is also removed from the condenser fan motor, de- energizing the fan.

Although the contacts between "L1" and "T1" have been opened, line voltage is still present at the compressor and outdoor fan motor from the "T2" terminal of the contactor.

When the "L1" and "T1" terminals open the crankcase heater is energized. This is because the line voltage from "L2❞ is back feeding through the motor windings of the compressor and condenser fan motor and is present at terminal "T1".

The 24-volt AC signal from terminals "Y1", "Y2" and "G" are also removed from the indoor unit. This begins the off cycle for the indoor fan motor. When the indoor fan motor comes to a stop, the system waits for the next cooling call.

Note
If the thermostat is set to fan ON operation, the fan will continue to run.

If the second stage cooling call is satisfied, but the first stage call remains, the rectifier for second stage compressor operation is de-energized. The compressor will operate at 67% capacity until either a second stage call is re-initiated, or the first stage thermostat setting has been achieved. While the rectifier is de-energized, the indoor blower is reduced to the first stage cooling airflow.

When the conditioned space reaches the desired thermostat setting, the 5-minute ASCD timer starts (if applicable).

07

Troubleshooting

Flash Codes

Many control boards installed in air conditioners, furnaces, and air handlers have flash codes to assist in troubleshooting the system.

Residential Communicating Control Board Flash Codes

Duration of Connection (seconds)	Control Behavior with No System Master Signals Present	Control Behavior with System Master Signals Present
Less than 2 seconds	No response	No response
Greater than or equal to 2 seconds	Display compressor type TS, UltraTech, or single stage compressor, Ignore LPS	Bypass ASCD (Reduce timer to zero immediately). If Y1 (thermostat or communication) is present and the high-pressure switch is closed, contactor's will be energized.
	Clear soft lockout	Clear soft lockout
	Clear hard lockout	Clear hard lockout
	Reset TS anticipation mode counter to zero for TS systems.	Reset TS anticipation mode counter to zero for TS systems.
		Reduce TS staging delays for TS systems as described below.
Connection removed	Resume normal LED display	
Connection not removed	Nothing more than previously explained	

Residential Air Conditioning Communicating Control Board Operational Modes		
Compressor Type	**LED1 (Red)**	**LED2 (Green)**
Single Stage Compressor	1 flash	---
TS Compressor	2 flashes	---
UltraTech Compressor	3 flashes	---

g

Residential Air Conditioning Communicating Control Board Status Codes			
Description	**Required Condition**	**LED 1 Red**	**LED 2 Green**
No power to control	No power to control	OFF	OFF
First-stage compressor operation (TS or UltraTech)	TS M & M1 energized UltraTech M energized Single Stage NA	OFF	ON
Second-stage compressor operation (TS, UltraTech, Single Stage)	TS and UltraTech M & M2 energized Single Stage M energized	ON	ON
Control normal operation - no communication or call for compressor present	No faults active, Y1 or Y2 not present	OFF	2 sec ON 2 sec OFF
Control normal operation - in ASCD period	No faults active, Y1 or Y2 present, ASCD timer not expired	OFF	0.1 sec ON 0.1 sec OFF
Note: Status codes will not be displayed when a fault code is present.			

Residential Air Conditioning Communicating Control Board Operation		
Description	**Required Condition**	**LED 3 Yellow**
Control normal operation with Johnson Controls Communicating Thermostat - active communication present	System is active and presently communicating successfully	0.1 sec ON 0.1 sec OFF
Control powered with conventional thermostat connections	System has 24 VAC present and the microprocessor is active	2 sec ON 2 sec OFF
Note: Operating condition status LED displayed at all times as described above.		

Residential Air Conditioning Communicating Control Board Flash Codes		
Operational Faults	**LED 1 Red**	**LED 2 Green**
Control Failure	ON	OFF
Operational Faults		
High-pressure switch fault (not in lockout yet)	1	OFF
System in high-pressure switch lockout	2	OFF
System in low-pressure switch lockout	4	OFF
Low voltage (<19.2 VAC) preventing further relay outputs	5	OFF
Low voltage (<16 VAC) stopped current relay outputs	6	OFF
High-pressure switch fault (with no communication for compressor operation and where Y1 and Y2 are not energized)	9	ON
Sensor or Switch Faults		
Outdoor ambient temperature sensor failure (short)	ON	1
Outdoor ambient temperature sensor failure (open)	ON	2
Wiring Related Faults		
Compressor	1	ON
Y2 present without Y1	2	ON

Emerson Comfort Alert Module Diagnostic Flash Codes

The Comfort Alert Module has multiple flash codes to assist the technician during troubleshooting.

Status LED	Status LED Description	Status LED Troubleshooting Information
Green "POWER"	Module has power	Supply voltage is present at module terminals
Red "TRIP"	Thermostat demand signal "Y1" is present but the compressor is not running	1) Compressor protector open 2) Outdoor unit power disconnect open 3) Compressor circuit breaker or fuse(s) open 4) Broken wire or connector is not making contact 5) Low pressure switch open 6) Compressor contactor failed open
Yellow "ALERT" Flash Code 2	System Pressure Trip Low pressure switch fault	1) Low refrigerant charge 2) Indoor blower is not running 3) Evaporator coil is frozen 4) Faulty metering device 5) Condenser coil is dirty 6) Liquid line restriction (possible filter drier)
Yellow "ALERT" Flash Code 3	Short Cycling Compressor is running only briefly	1) High pressure switch fault 2) Dirty, blocked or damaged condenser coil 3) Outdoor fan not running 4) Return air duct has substantial leakage 5) Thermostat demand signal is intermittent
Yellow "ALERT" Flash Code 4	Locked Rotor	1) Run capacitor has failed 2) Low line voltage 3) Liquid refrigerant present in compressor 4) Compressor bearings are seized
Yellow "ALERT" Flash Code 5	Open Circuit	1) Outdoor unit power disconnect is open 2) Compressor circuit breaker or fuse(s) open 3) Compressor contactor failed open 4) Low pressure switch open 5) Open circuit in compressor supply wiring or connections 6) Unusually long compressor protector reset time due to extreme ambient temperatures 7) Compressor windings are damaged
Yellow "ALERT" Flash Code 6	Open Start Circuit Current only in run circuit	1) Run capacitor has failed 2) Open circuit in compressor start wiring or connections 3) Compressor start winding is damaged
Yellow "ALERT" Flash Code 7	Open Run Circuit Current only in start circuit	1) Open circuit in compressor run wiring or connections 2) Compressor run winding is damaged
Yellow "ALERT" Flash Code 8	Welded Contactor Compressor always runs	1) Compressor contactor has failed closed 2) Thermostat demand signal not connected to module
Yellow "ALERT" Flash Code 9	Low Voltage Control circuit has less than 17 VAC	1) Control circuit transformer is overloaded 2) Low line voltage

CFM Indicator

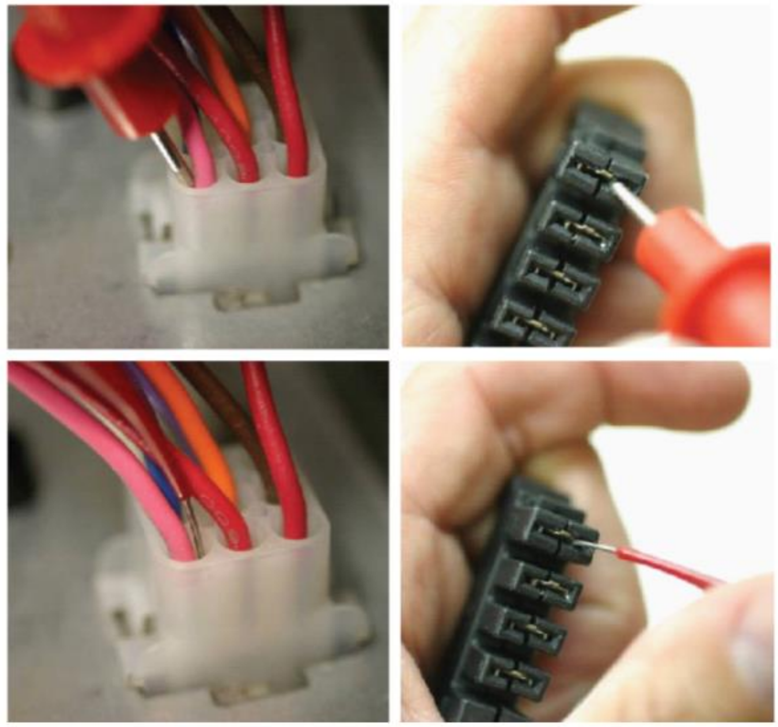
The number of flashes on the Unit Control Board indicates the amount of CFM (in hundreds) that the control board is requesting. The number of flashes on the green LED represents 100 cubic feet per minute of air flow for each flash.

Example:

- 12 flashes indicate 1200 CFM.
- 8 flashes indicate 800 CFM.

Test Lead Section

Standard meter lead test pins are typically larger than the terminals or sockets on the plug connections being checked for voltage. Use thinner test pins to prevent the terminals from being damaged. The above images show an example of a standard meter lead test pin (top) and a thinner one (bottom). These test pins are also available in 90-degree angles for tight areas. These types of leads are available from most meter manufacturers.



Meter Test Leads

Troubleshooting the ECM, Standard ECM, & ECM 142 Motors

Troubleshooting the ECM motor is not just an on or off solution. The following four problems will not allow the motor to run:

1. There is no important power to the motor controller (high voltage inputs)
2. There is improper or no communication to the motor controller (low voltage inputs). This problem could be in the interface board or the low voltage connector.
3. The motor controller has failed.
4. The motor module has failed.
5.

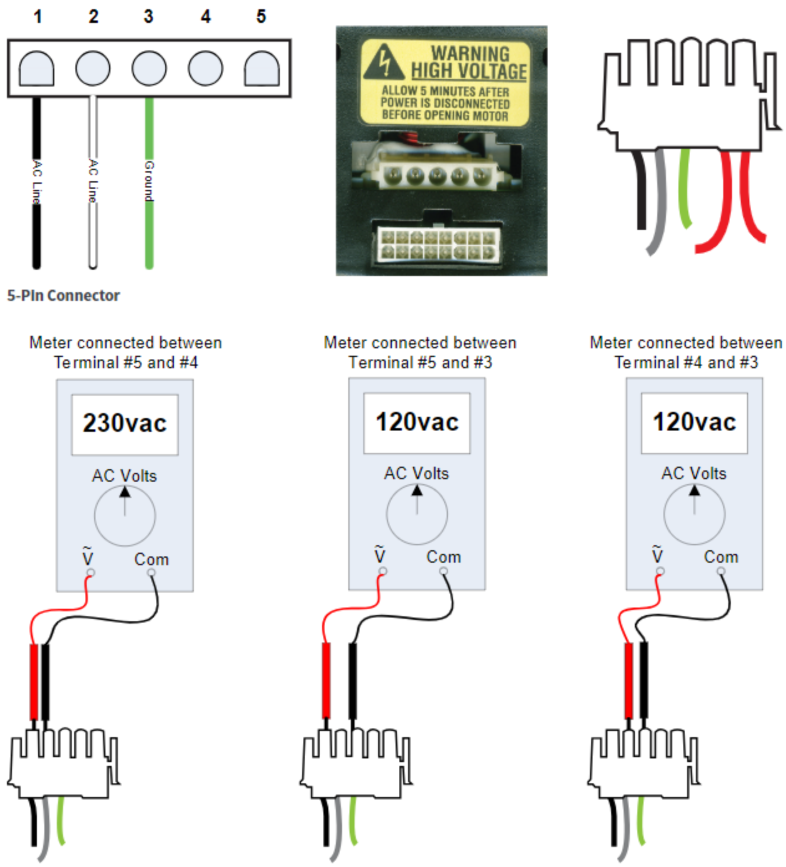
40% of ECM field returns are "No Problem Found." Do not simply assume the motor has failed because it is not running!

Measure the input power (high voltage) to the motor controller by following these steps:

1. Disconnect the power to the system.
2. Disconnect the 5-pin (high voltage) connector.
3. Restore power to the system.
4. Check for proper input power.

ECM 5-Pin Plug Connector

When the main power is restored, take a power measurement at the 5-pin connector.



Motor Test 230 volts AC & 120 volts AC

Reconnecting the Plug

After all the input high voltage power connections have been confirmed or corrected, turn the power off and reconnect the plug to the motor control. The plug connector is keyed and must be reconnected properly. Do not force the plug in the wrong direction or it will cause permanent damage to the motor. Fully insert the plug to prevent arcing or vibration, which may cause the connection to be broken. When the plug is fully inserted, it will slide gently, all the way in until clicks are heard on both sides.

Motor Grounding

A motor must have a properly grounded connection from the connector to the main ground. This will ensure proper operation and safety. Disconnect the power to the system before checking the resistance. Evaluate the continuity between the two connections with an ohm meter. The resistance reading must be zero between the two connections. If any other readings are indicated, correct the problem immediately. Although the motor may run despite not being properly grounded, this is a safety concern that must be corrected.

Checking the ECM Indoor Fan Motor

On ECM motors, using Thermostat Mode, the motor control is checked with the TECMate TM Service Tool from GE ECM.

This tool makes short work of the big question - is it the motor or the communication?

The TECMate TM was manufactured in two versions. The TECMate XLTM is a 4-switch version (discontinued but may still be available through some distributors). The TECMate PROTM is a single switch version. Both perform the same basic function of sending artificial communication to the motor controller, telling it to run.

TECMate Pro

Connecting the TECMate TM

The following procedures may be used to connect both TECMate TM models:

1. Disconnect the AC power from the system and wait for the motor to come to a complete stop.
2. 2. Remove the 16-pin connector from the motor and connect the 16-pin connector from the TECMate TM to the motor. Removing the 5-pin AC connector will make it easier to access the 16-pin connector latch, but it must be reconnected prior to testing. Reconnect the 5-pin connector once the TECMate TM is connected.
3. Connect the two alligator clips from the TECMate TM to a 24 volts AC power source (terminals "R" and "C" on most units represent 24 volts AC power and 24 volts AC common respectively). These two wires are not polarity sensitive. If these wires are connected to any voltage greater than 24 volts AC +/- 10%, permanent damage may be done to the motor control and the TECMate TM
4. The switch(s) on the TECMate TM must be in the OFF position.
5. Reconnect the AC power to the system.

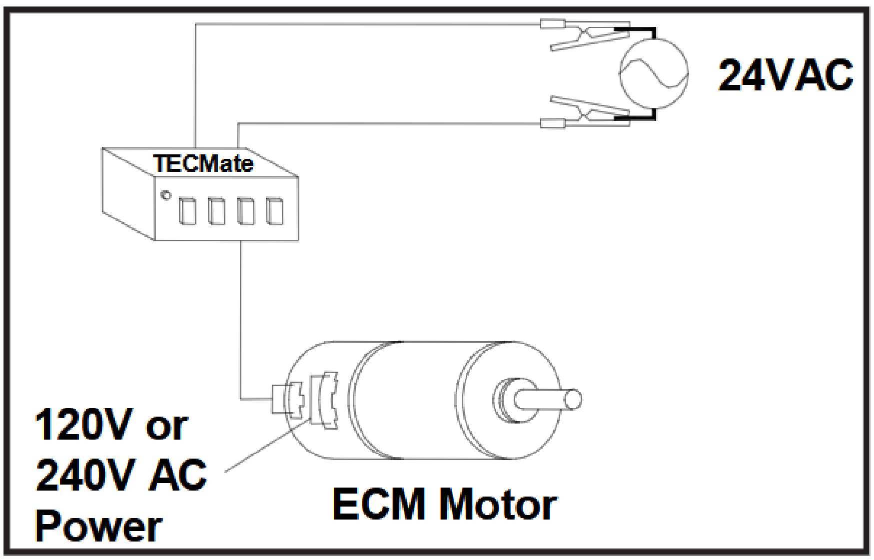
Although the ECM motor can be evaluated while the blower housing is in or out of the unit, it is preferred that the blower be left in the unit when possible. The motor operation should never be checked without the blower wheel attached or the motor will oscillate up and down.

If the motor is checked with the blower out of the unit, take precautions to provide a safe and secure operating surface and work area to test the motor. Follow all safety precautions when servicing equipment that could release potential energy and cause personal injury or damage to property.

TECMate XL™

When the power is turned on to the system, the TECMate XLT power LED light will illuminate.
The correct switches must be placed in the ON position and the motor observed for 15 seconds. The table on the back of the TECMate XLT displays switch selections of the various test mode settings.

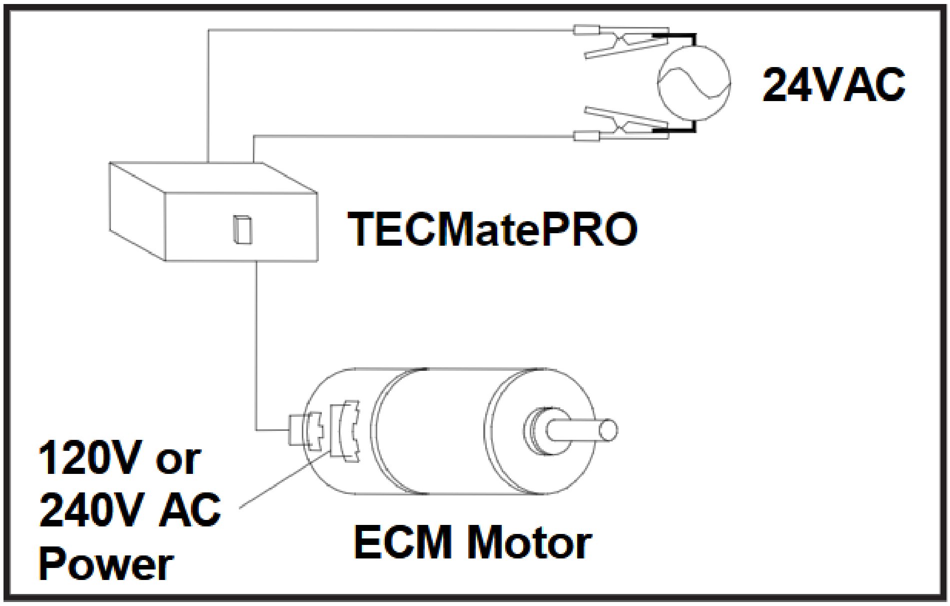
Settings for Thermostat Mode and Variable Speed Mode					
Test Mode	Switch Selections				Expected Result of Typical System
	Continuous Fan [G]	Heat [W / W1]	Cool [Y]	[BK / Pwm]	
Fan-only	ON	OFF	OFF	OFF	Motor runs at fan airflow
Heating	ON	ON	OFF	OFF	Motor runs at Heating airflow (higher than Fan only)
Cooling	ON	OFF	ON	ON	Motor runs at Cooling airflow (higher than fan only)
Dehumidification	ON	OFF	ON	OFF	Motor runs at Dehumidification airflow (lower than cooling airflow)
Variable Speed	ON	OFF	OFF	ON	Motor runs



TECMate XL Connection Diagram

TECMate PRO™

Place the switch in the ON position. The LED light on the switch will illuminate when connected properly to 24 volts AC. Observe the motor for 15 seconds. Refer to the table on the back of the TECMate PROTM for operation guidelines.



TECMate PRO 24 Volts AC Connection

If the motor starts with the TECMate TM the system malfunction is not caused by an ECM control or motor problem. When you have finished testing with the TECMate TM, place the switch(s) in the "OFF" position and wait for the motor to completely stop. Depending on the program, the motor may not shut off immediately after a test; this is normal.

1. Once the motor comes to a complete stop, turn the system power "OFF" before removing the TECMate TM. Reconnect the 16-pin connector to the system before proceeding with the diagnosis. The connector is keyed and has one clip that should click when the connector is inserted properly.

The next step is to check the low voltage communication on the 16-pin connector. If control voltage is not present, the problem is the communication from the control board or the communication through the 16-pin connector. Check the connections at both ends of the 16-pin connector and the wires to the connector for damage. Make sure the sockets are not distorted, bent, or pushed out of the connector.

If the motor does not start with the TECMate TM, the electronic control (motor control) must be replaced. Before replacing the electronic control module, test the motor module to ensure it is not also damaged. Procedures for testing the motor module are included in "Replacing the ECM Module" below.

1. Make sure the TECMatePRO and HVAC units are OFF.
2. Unplug 16 pin Connector from ECM Motor.
3. Plug in 16 pin Connector from TECMatePRO to ECM motor.
4. Attach blue and black clips to 24VAC source and power ON HVAC unit.
5. Turn TECMatePRO on.
6. Motor should start within 15 seconds.
7. Turn power OFF to TECMatePRO and HVAC unit.

TECMate Pro™ Table

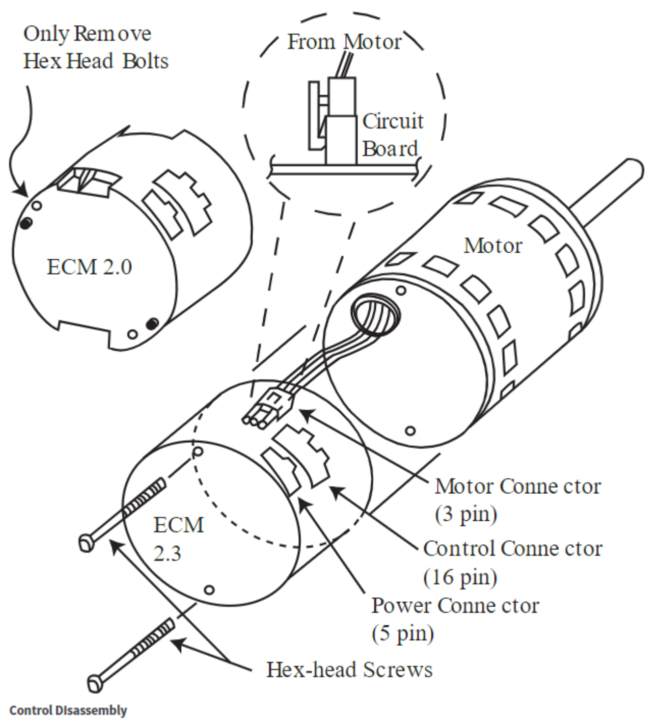
Replacing the ECM Control Module

1. Lock-out and tag-out the electrical disconnect, and ensure the motor is de-energized for 5 minutes.
2. Unplug the 5-pin connector and the 16-pin connector from the motor control.
3. Remove the blower assembly from the HVAC system.
4. Remove the two (2) hex-head screws from the back of the control.
5. Unplug the 3-pin connector from the inside of the control module by squeezing the latch and gently pulling on the connector.
6. Ensure the motor module is not damaged by performing the "Module Tests" below.

ECM Motor Control Disassembly Review

1. Unplug the 16-pin connector and the 5-pin connector from the motor control.
2. Remove the blower assembly from the HVAC system.
3. Remove the two (2) hex-head screws from the back of the control.
4. Unplug the 3-pin connector from inside the control by squeezing the latch and gently pulling on the connector.

Control Disassembly



Motor Module Tests

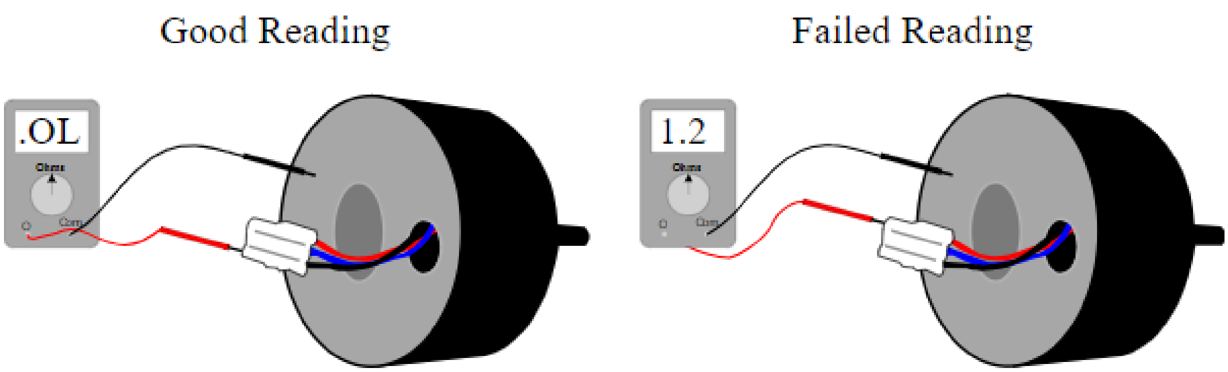
These tests are no different than taking resistance readings on a 3-phase compressor motor. Confirm that the windings are not shorted to ground, and that the resistance is equal when tested phase to phase.

Test A:

Measure the resistance between each of the 3 motor leads to the unpainted part of the end shield (Winding to Ground Resistance). Typically, a good motor will read infinite ohms to the ground on all leads. A grounded motor would read a measurable resistance from any one of the motors that leads to ground. For this test, the meter is set to the highest ohms scale unless it is auto-ranging. Meg-ohm meters should not be used for this test.

If the motor has a resistance of less than 100k ohms between any one motor lead to ground, the motor must be replaced with an exact replacement.

If the resistance is greater than 100k ohms, then perform Test B.



Sample Good Motor Readings and Failed Motor Readings (Test A)

Test B:

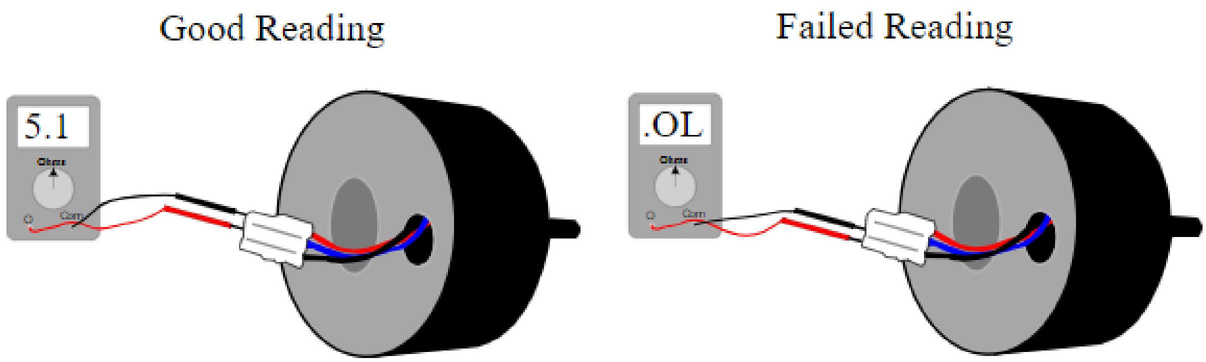
Measure the motor phase-to-phase resistance by checking these combinations of the 3-pin motor connector with an ohmmeter. For this test, either end of the connector may be used as Lead 1, the center Lead may be used as Lead 2, and the opposite end as Lead 3.

- Resistance between Lead 1 and Lead 2
- Resistance between Lead 1 and Lead 3
- Resistance between Lead 2 and Lead 3

The values for each lead-to-lead resistance reading must be measured with the meter set to the highest ohms scale unless it is auto-ranging.

The resistance across any two leads must be less than 20 ohms. All resistance readings measured between either two of the three leads must be no greater than +/-10% of each other. If any of the three resistance measurements are greater than 10% from the other readings, the motor module must be replaced with an exact replacement.

The motor must pass both tests to be good. If the motor passes both tests, the motor control must be replaced (control module) only. If the motor fails either test, it must be replaced.



Sample Good Motor Readings and Failed Motor Readings (Test B)

When replacing a failed motor or reinstalling the existing motor, make sure that the belly band is not covering any vents and is not installed on the motor control. The motor module does not have a specific orientation, however, the motor control does. The three-wire plug must be oriented properly, allowing the plug to reach the motor control. This must be aligned properly prior to tightening the belly band.

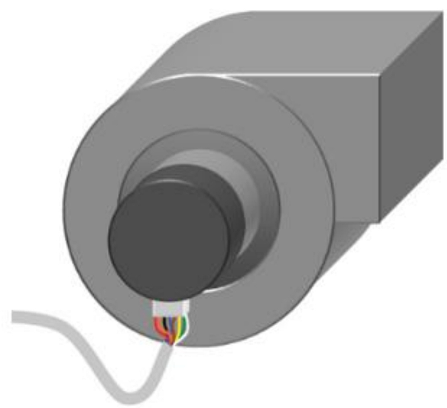
Always make sure to tighten the wheel key on the flat side of the motor shaft with the blower wheel centered in the housing. If the wheel sits too close to the motor when centered or cannot be centered because it hits the motor, the motor must be adjusted in the belly band.

Attaching the New Control Module

The 3-pin connector is inserted into the new control module. A slight click will be heard when inserted properly.

If the ECM 2.3 control module is replaced, the new control must be oriented to the motor's end shield with the connectors facing down, and with the bolts inserted and tightened.

The 16-pin connector and the 5-pin connector must be plugged back into the motor. The keyed connectors must be inserted properly and securely until they click.



Drip Loop Cable

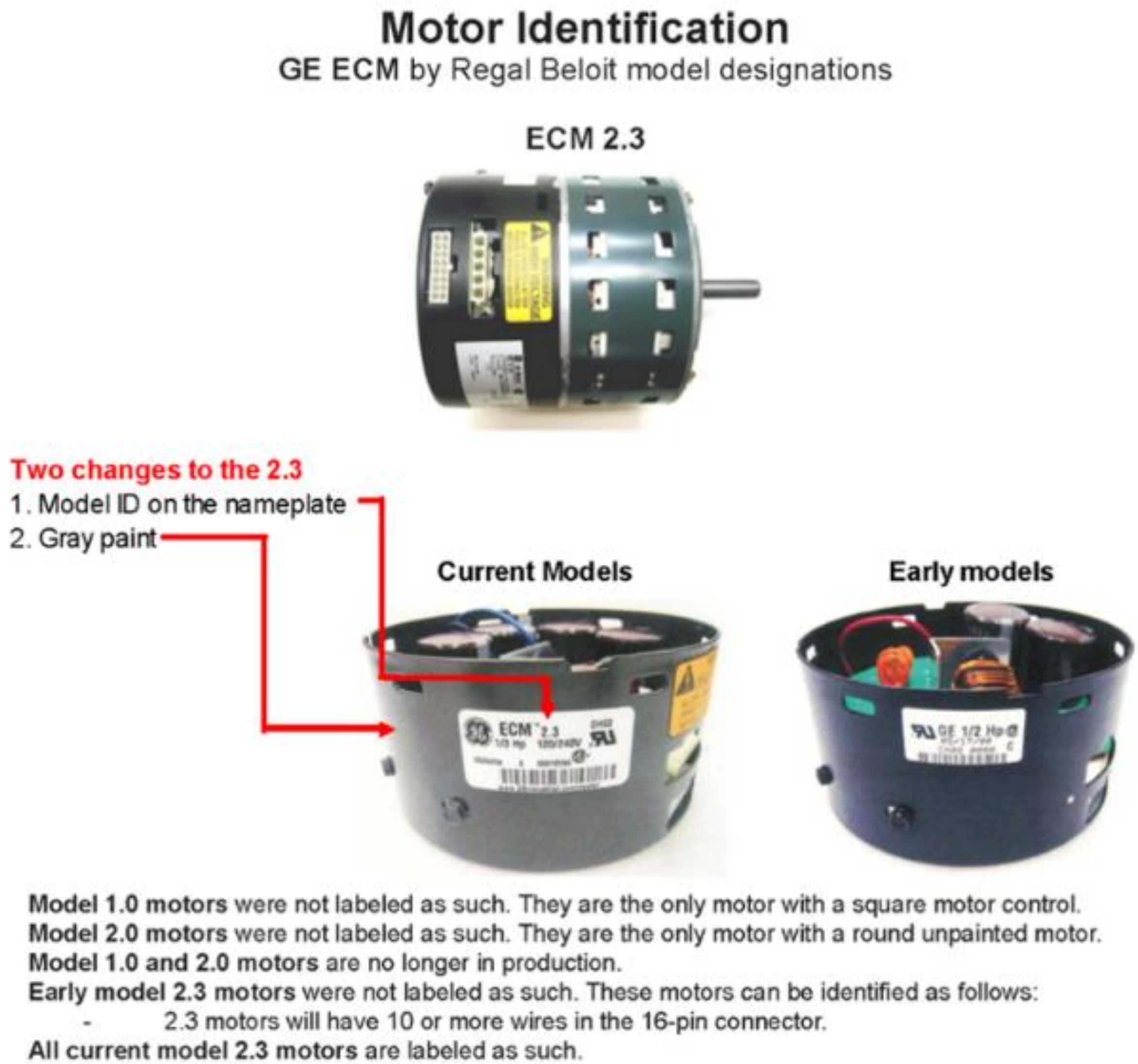
The blower/motor assembly must be re-installed into the HVAC system.

A drip-loop must be formed so that water cannot enter the motor by draining down the cables. Condensate or droplets can accumulate in the harness and may eventually travel into the motor.

ECM Motor Failure Footnotes

All repair parts for ECM motors must be obtained as a specific match to the existing motor or control module. Even if the new part looks like a direct replacement, all literature that comes with the new part must be read. There may be a small but important change in mounting, programming, or wiring that could make the difference between a long-term repair and a short-term call back.

Model 2.3 - If this motor is suspect, instructions on the TECMate TM and in the ECM Service Guide must be followed to determine if the motor, the motor control, or both have failed and require replacement.



ECM Motor Identification

Standard ECM Motor - Connections & Communications

There is one connection block on the X-13 motor with two rows of terminals and two distinct size terminals used. The power inputs (high voltage) to the motor connect through the 3/16" terminals on the following terminals:

- (L) - Line 1
- (G) - Ground
- (N) - Neutral or Line 2

The line voltage is present at these terminals whenever the system is powered regardless of thermostat demand. The Control Inputs (Low Voltage Inputs) to the motor connect through the 1/4" terminals. Terminal C is used for common and terminals 1-5 are used to select airflow settings programmed into the motor.

Communication to the Standard ECM motor is the low-voltage 24 volts AC provided to taps 1 through 5. The purpose of this voltage is to communicate to the motor only, not to operate it. The 24 volts AC provided to each tap is a communication signal used to select five different torque values. The motor's control board uses this signal to determine which torque value it should deliver and then uses the line voltage (high voltage that is continuously connected) to operate the motor according to that program.

Each motor has a unique program. Changing taps on one motor will have different results than any other. The tap settings must never be changed to adjust airflow without checking the air flow charts for the system installed.

Example 1:
If tap 1 is to provide airflow for the heating mode and the torque required to provide the airflow for a proper temperature rise in that furnace is 76% of the maximum torque ability of the motor, that will be the value programmed into the tap.

Example 2:
If tap 2 is to provide the airflow for the cooling mode and the torque required to provide the airflow for a specified tonnage is 88% of the maximum torque ability of the motor, then that will be the value programmed into the tap.

Even though changing tap connections does change the speed of the motor, it is important, in theory at least, to understand that these are programmed levels of torque. Each tap can have a unique amount of torque programmed for a specific purpose.

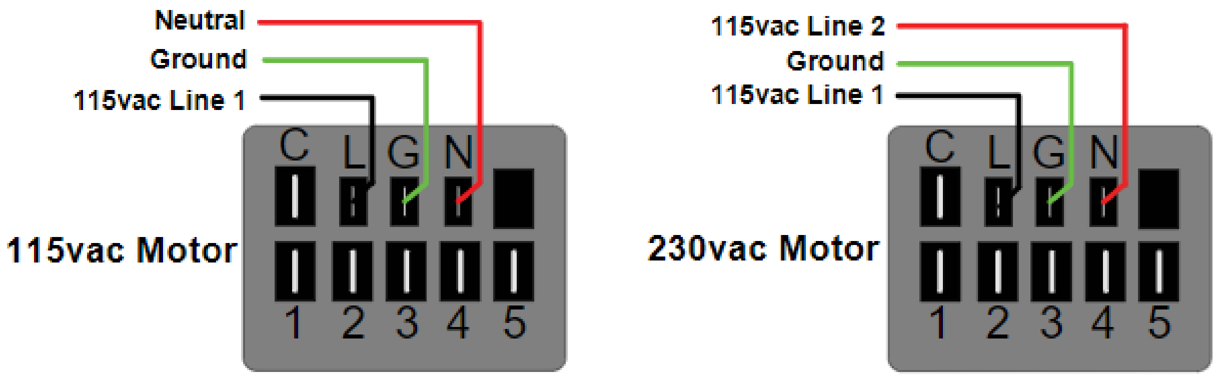
Example 3:
Switching from tap "C" to tap "B" may increase the airflow, but not necessarily at a specific interval, like changing from low speed to medium speed on a PSC motor.

These examples also do not show a tap specifically programmed for continuous fan selection. Depending on the application, the heating or cooling selection may be used for continuous fan blower speed. The percentage used for continuous fan operation is found in the Installation Manual for each unit.

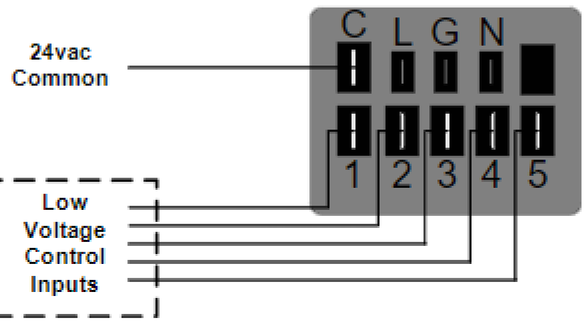
Standard ECM Connections

Connectors:

The high voltage connections contain the three terminals labeled "L", "G", and "N" and the low voltage connections contain one terminal labeled "C" for the 24 volts AC common and the five torque settings labeled terminals "1" thru "5" as discussed in Section 3.



115 volts AC / 230 volts AC Inputs



Low Voltage Control Inputs

The high voltage plug is used when troubleshooting the low voltage input to the motor, since the 24 volts AC common terminal "C" is in this plug.

The plugs are designed to prevent improper connection. The high voltage plug has a full blank tab on the opposite end from the "C" terminal. This prevents it from being installed on the low voltage terminals.

Both the high and low voltage plugs, if equipped, have tabs on the bottom of them. When the high voltage plug is installed properly, the low voltage plug can only be installed with its tab down, or opposite from the high voltage plug. This will properly orient the low voltage terminals 1-5.

Servicing the Standard ECM Motor

The Standard ECM motor can be operated by 115 volts AC or 230 volts AC; however, these are two different motor models. Unlike the ECM motor, the X-13 is not a dual voltage motor. Applying incorrect line voltage to the Standard ECM motor may prevent the motor from operating, or even cause damage to the motor.

The Installation Manual, diagrams and wiring schematics must be consulted for proper set up, wiring, operation, and all troubleshooting. Checking all system limits, rollouts, and safety switches before troubleshooting the motor is important.

Troubleshooting this motor will be simple if the following information is known:

1. Which tap(s) have programs and what are their purposes (heating airflow, cooling airflow, continuous fan airflow)?
2. Where on the controls or circuit board do the line voltage and control voltage come from?
3. What is the sequence of operation of the controls or circuit boards (when the control voltage is sent to the motor from each thermostat demand and if there are any delays).

Troubleshooting the voltage at the X-13 motor comes down to two simple factors:

1. Line voltage (115 volts AC or 230 volts AC), which must be present with or without a demand for heating, cooling or continuous fan. Make sure proper line voltage is present between the "L" and "N" terminals as shown for the specific model being serviced.
    a. If there is no high voltage present at the motor, the voltage loss must be traced back towards the wiring and controls.
       Line voltage must be present at the motor with or without a demand from the thermostat. The allowable voltage variance is between:
        i. 98-132 volts AC on the 115 volts AC models
        ii. 196-264 volts AC on the 230 volts AC models
2. 24 volts AC low (control) voltage at the appropriate tap, with the appropriate thermostat demand call. Control voltage is present between terminals 1-5 and the "C" terminal, depending on which terminal is receiving control voltage.
    a. If there is no low (control) voltage present at the motor, the voltage loss must be traced back towards the wiring and controls. It may be necessary to confirm that there is a proper demand from the thermostat.

The allowable voltage variance can be as much as +/-10% of the nominal 24 volts AC. If this voltage is present below this range, confirm that the control voltage is present at the unit transformer, and at the thermostat low voltage connections on the unit control board.

- If high voltage is present at the motor, the low (control) voltage is present on a programmed tap, and the motor is operating, then any airflow issues, such as high or low temperature rise, tripping main limit, freezing coils, or compressor overload tripping, must be addressed as an airflow issue first.

The X-13 is not a constant CFM motor. Airflow will decrease if static pressure rises too high in the system.
The Installation Manual provides low voltage wiring connection diagrams.

All obvious airflow restrictions such as closed or blocked registers, grilles, dampers, blower wheel and dirty filters or evaporator coils must be corrected. The external static pressure (ESP) must be evaluated, and any airflow restrictions corrected.

Potential causes of high static pressure are:

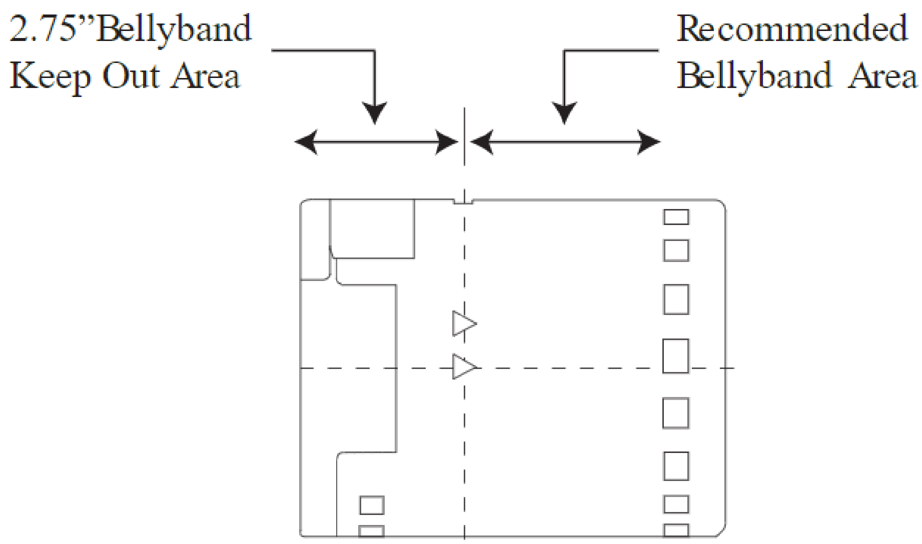
- Blocked, crushed, or dented ductwork.
- Undersized ductwork

If the high voltage and the low (control) voltage are present at the appropriate electrical connections but the motor will not operate, the motor must be replaced. A direct replacement motor from the manufacturer for the same model and size unit is required.

Replacing the Standard ECM Motor

The Standard ECM motor is a one-piece motor that is replaced as a whole and is not field repairable.

The Standard ECM motor replacement is specific to the model. When using a bellyband for mounting, the band should not be in the area identified in the diagram below as the "Keep Out Area".



Bellyband Keep Out Area

The wheel key must be tightened on the flat side of the motor shaft with the blower wheel centered in the housing.

If the wheel sits too close to the motor when centered or if the wheel cannot be centered because it hits the motor, the motor must be adjusted in the belly band. The blower/ motor assembly must be reinstalled into the HVAC system.

All wires and plugs must be reconnected to the motor confirming connection to proper terminals per demand.

A drip-loop must be formed so water cannot enter the motor by draining down the cables. Condensate or droplets can accumulate in the harness and may find their way into the motor.

Checking the 142 ECM Outdoor Fan Motor

ECM 142 outdoor fan motors are equipped with a control module that is physically separate from the motor.

The ECM 142 fan motor cannot be evaluated using any of the TECMate TM, TECMate XLT, or TECMate PROTM testing equipment. Evaluate the motor control module using a multi-meter.

The following are expected measurements when testing the ECM 142 outdoor fan motor:

- 24 volts AC will be present at the inlet of the ECM control.
- A "Y1" (first stage cooling) call will result in 24 volts AC measurable between the "Y1" and "C" terminals.
- 230 volts AC must be present at the motor line voltage connections when the electrical disconnect is energized.

If the ECM 142 motor is not operating when all required inputs are present, the motor and controller must be replaced.

Final Installation Checks - ECM, X-13, & 142 ECM Motors

Perform a visual inspection of all wiring and connections, especially those removed while servicing.

The system is setup as follows:

- Reconnect the AC power to the HVAC system.
- Verify that the motor control module is working properly.
- Plug and seal all leaks in the return ducts and equipment cabinet, using approved methods. Verify that the system is operating quietly and smoothly in all modes (heating, cooling, and continuous fan) and all stages (if applicable)
- Return the thermostat setting to the customer's preference.

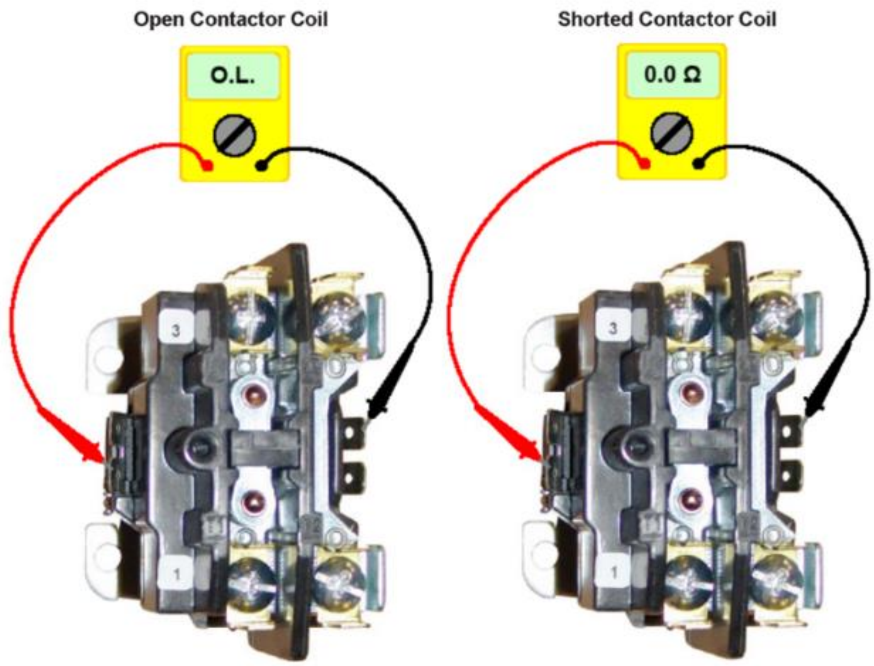
If this is a repeat failure, check the following:

- Check for moisture and correct the problem.
- Question whether the area is subject to considerable amounts of lightning strikes, if so, the use of additional transient protection may be helpful.

Tech Tips

- Line voltage must be within +/- 10% of the value indicated on the equipment rating plate.
- A True-RMS meter is not required to check input voltage to this motor. Any standard AC voltmeter, analog or digital, will work if it can read voltage up to at least 500 volts AC.
- If the polarity is reversed on the 115 volts AC connection, the motor may still run, but this must be corrected.
- The 115 volts AC applications requires a jumper on the ECM motor, and the 230 volts AC applications must have this jumper removed. This is not applicable on the X-13 motor.

Contractor Troubleshooting



Contactor Troubleshooting Measurements

If 24 volts AC is present at the contactor coil and the contactor does not pull in, further evaluation of the contactor coil should be completed. Proper Lock-Out Tag-Out procedures for both the indoor and outdoor units are essential to provide a safe work environment when attempting to use an ohm meter to troubleshoot a system. The unit should be locked out at the equipment disconnect before any resistance readings are taken. Depending on the model, and the thermostat settings; it is possible that 24 volts AC is present at the contactor coil.

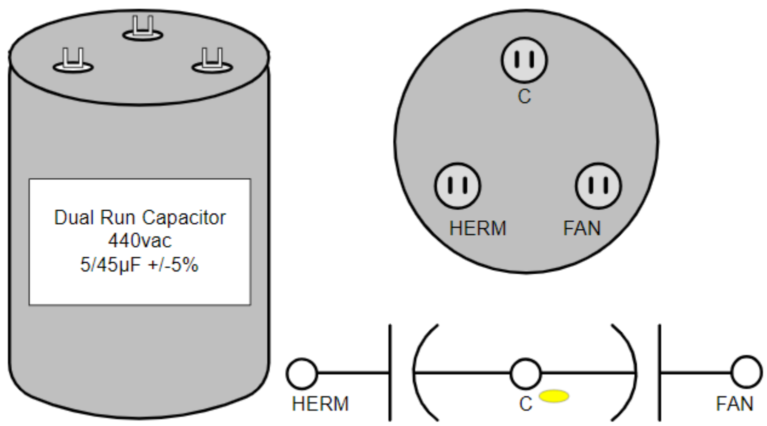
At least one of the control wires feeding the contactor coil should be disconnected prior to taking a resistance reading. Use an ohmmeter to evaluate the resistance reading across the contactor coil. An infinite reading indicates that the coil is open, and a reading of zero ohms indicates a shorted coil.

If it has been determined that the coil is open or shorted, the contactor must be replaced. The voltage on the load side of the contactor should match the voltage on the line side of the contactor. If it does not, evaluate the contacts for pitting, dirt, or corrosion.

Capacitors

Air conditioners, furnaces and air handlers are available with many different wiring configurations. The three-phase units are manufactured with PSC or ECM fan motors depending upon the required application. The single-phase units are manufactured with both PSC fan motors and compressors and may have a CSR compressor. The motors were covered in Section 3 (Component Familiarization). Improper troubleshooting of these motors and capacitors has resulted in condemning the motor when the capacitor itself was the faulty component.

Three Terminal Capacitors

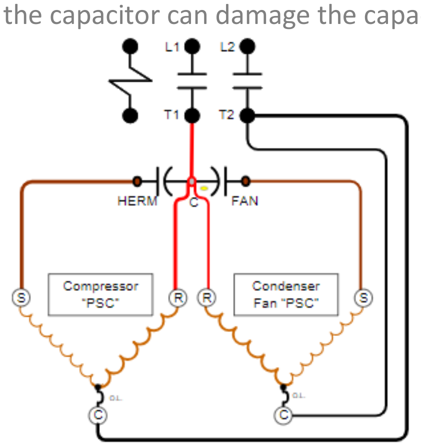


3-Terminal Capacitor

The technician should understand the three-terminal capacitor. The three terminal capacitors have two capacitors built into one housing - one capacitor for the compressor and one capacitor for the condenser fan motor. Each of the three terminals on the capacitor are labeled with "HERM", "FAN" and "C" as indicated in the following illustration. Some manufacturers of capacitors will label them as "H", "F" and "C" or "HERM", "FAN" and "COM". The "C" or "COM" terminal is the common point between the two capacitors and must be utilized as the identified terminal for both capacitors. This is the terminal that is wired to the run leg of power. The "HERM" terminal stands for "hermetic" and is wired to the "S" or start terminal of the compressor. The "Fan" terminal stands for the "outdoor fan motor" and is wired to the start terminal of the outdoor fan motor as indicated in the above diagram.

Three Terminal Capacitor Connections

Before using a multi-meter or capacitor analyzer to evaluate a run or start capacitor, the capacitor must be discharged using a bleed resistor. The bleed resistor must be a 20,000 ohm 2-watt resistor. Do not use a screwdriver to bleed the capacitor. Using a screwdriver to discharge the capacitor can damage the capacitor.

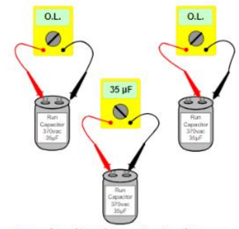


Example Wiring for 3-Terminal Capacitor

Capacitor Testing & Troubleshooting

The use of a capacitor analyzer or multimeter has become quite common when troubleshooting capacitors. The three main faults to test for are: open, shorted, or grounded capacitors.

Functional capacitors will have an infinite reading between any of the terminals to the shell of the capacitor and will have a measured microfarad reading between terminals that is within the percentage rating on the capacitor data label.

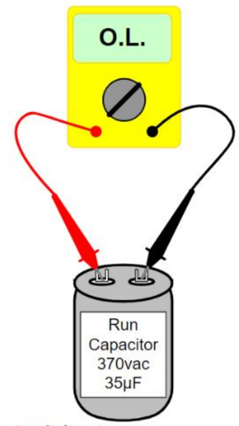


Examples of Good Capacitor Readings

Use a capacitor analyzer to read the number of microfarads the capacitor is producing. Some multimeters have this capability. If the readings are outside of the rating on the capacitor data plate, replace the capacitor.

Open Capacitors

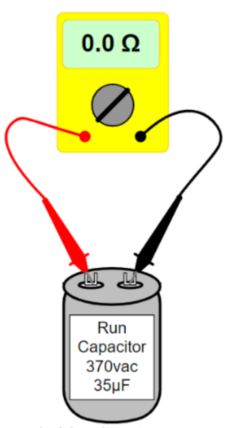
Open capacitors will have an infinite reading between the terminals on the capacitor when using an ohm meter on the highest resistance scale to troubleshoot the capacitor. This is an infinite reading or O.L. on the multimeter as shown in this diagram. If a capacitor analyzer is used, the instructions with the meter must be followed.



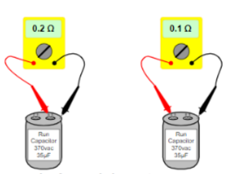
Example of Open Capacitor

Shorted Capacitors

Shorted capacitors will have a reading of low ohms of resistance between the terminals of the capacitor as shown in this diagram. If a capacitor is shorted, the readings between terminals will not fluctuate. Instead, the readings between the terminals will stay steady, and in most situations, will read less than 1 ohm of resistance. The readings are verified by reversing the meter leads to the capacitor terminals. If the resistance begins to increase or decrease, the capacitor is not shorted.



Example of Shorted Capacitor



Example of Grounded Capacitor

Grounded Capacitors

Grounded capacitors will have a measurable resistance from any of the capacitor terminals to the shell as shown in the diagram.

If the capacitor has become grounded, replace the capacitor, and evaluate the motor.

Frozen Evaporator Coil

Many "no cooling" calls come from a neglected air filter or other causes of restricted airflow. As airflow is reduced, the temperature of the evaporator coil during cooling operation decreases below the freezing point of water and the moisture in the return air will freeze on the coil surface.

If left running long enough in this condition, the evaporator coil will become a block of ice. As a result, minimal heat transfer will occur between the return air and the refrigerant within the coil. The liquid refrigerant entering the evaporator coil cannot boil to a vapor and will pass into the suction side of the compressor. If liquid refrigerant flows back to the compressor, the compressor may fail.

To prevent such an occurrence, customers must be advised to replace filters regularly and refrain from closing off rooms not in use. Closing off registers or rooms does not save operational costs. Rather, it increases static pressure in the system and the possibility of liquid refrigerant flood- back. The technician should take the time to explain to the customer that the equipment will continue to run until the conditioned space reaches the desired thermostat setting, regardless of if the unused rooms are open or closed.

When airflow is properly set up and the customer is educated about his/her role in system upkeep, "no cooling" calls due to airflow restrictions are avoided.

The appearance of frost can also indicate low system refrigerant charge or a restriction. If frost appears on or immediately downstream of a specific component in the refrigeration system (such as the filter drier or metering device) there is a restriction within that component. A low system refrigerant charge causes a portion of the evaporator coil to drop below 32°F during cooling operation. This causes the moisture in the return air to freeze on the surface of the coil.

If a frozen evaporator coil is encountered during cooling operation, allow the coil to completely defrost. When the coil has defrosted, proper airflow must be verified. Review the methods covered in the External Static Pressure (ESP) section. Then, the refrigerant charge may be verified. If the system has a low system refrigerant charge, the system must be leak checked. Any leaks present must be repaired prior to attempting to adjust the system refrigerant charge.

High Discharge Pressures

Many "no cooling" calls are identified with high discharge pressures. High discharge pressures can result in the following problems:

- Inefficient operation
- Internal overload tripping
- High Amperes
- Lubrication failure
- Compressor failure

If the internal overload continues to trip, the overload will be permanently damaged and could require compressor replacement. Excessive discharge pressures can reduce the life of the oil and lubrication failure can occur.

There are three common problems associated with high discharge pressures:

1. Poor airflow across the condenser coil
2. System overcharge
3. Non-condensable in the system

The most common of these problems is poor airflow across the coils. If the coil is dirty, the equipment cannot reject the heat from the refrigerant properly and high discharge pressures will be present.

To save valuable time when troubleshooting a system, evaluate the condition of the evaporator and condenser coils. If the coil is dirty, clean it prior to installing the manifold gauge set. This will eliminate poor airflow across the coil as the cause of poor system operation and high discharge pressures.

If the coils have proper airflow, and the manifold gauge readings indicate the high side pressure is excessive, evaluate if the unit is properly charged. A grossly overcharged system will produce high discharge pressures and must be corrected immediately. Proper charging methods were covered earlier in Section 5. If the unit continues to operate with high discharge pressures, despite proper airflow across the coils and a proper charge in the system, then it is possible that non-condensable gases are present in the system.

Non-condensable are gases that will not condense into a liquid state. This is usually air, water vapor, or dry nitrogen that was used to pressure test or purge the refrigeration system while brazing copper tubing. Non-condensable gases are pumped to the condenser coil during cooling. The non-condensates are trapped at the top of the coil. This reduces the capacity of the unit and increases high side discharge pressure.

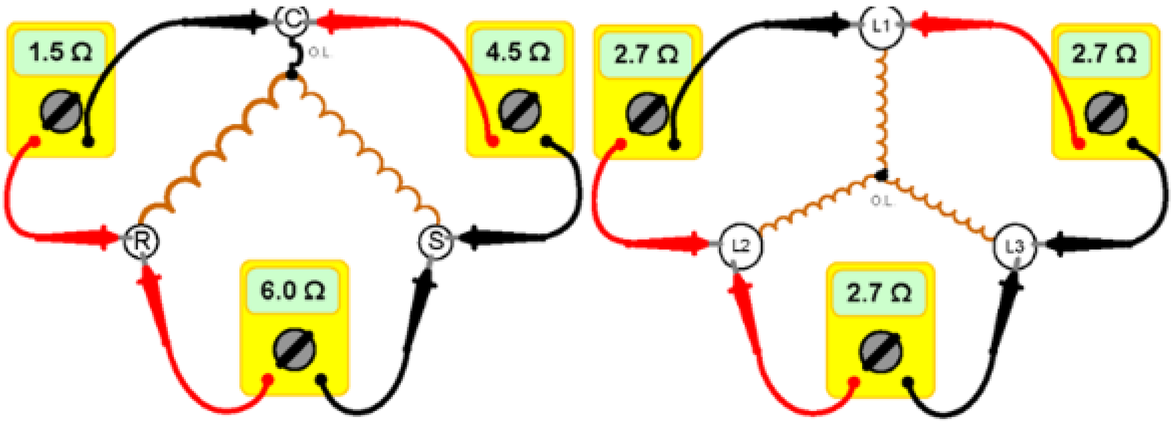
Non-condensable are usually introduced in the system by improper manifold gauge installation. They can also be introduced by improper evacuation of the unit after a major repair or component replacement within the refrigeration circuit. It is rare that the non-condensable are introduced in the system during normal operation. It is possible that the non-condensable gases are pulled into the low side of the system when the unit has a leak on the low side and was allowed to operate with negative pressure.

To properly remove non-condensable from the unit, first perform a leak test on the system. After identifying any leaks that may be present, recover the system's entire refrigerant charge and perform an acid test to determine if the refrigerant oil is contaminated. If acid is detected, the system must be cleaned using approved methods. This may include flushing the system, replacing contaminated copper, adding a suction line filter drier to protect the compressor, and performing a triple evacuation prior to charging. All leaks must be repaired, and new filter driers installed.
When filter driers have been installed, the system must be evacuated to 500 microns or less and then charged to the recommended weight, superheat, or subcooling methods provided on the unit or in the Installation Manual.

If a severe burnout is detected with the acid test kit, a suction line filter drier should be installed to help clean up the system. It is also recommended that a suction line filter drier be removed after no more than 50 hours of compressor operation.

Compressor Electrical Troubleshooting

A good understanding of the electrical layout of the compressor is extremely important when diagnosing compressor faults. This section will cover the single phase and three phase compressors utilized in air conditioning units.



Example of Electrical Layout of Single Phase and 3 Phase Compressors

Two Stage Compressor Solenoid Valve & Rectifier

The two-stage scroll compressor has an internal 24 volts DC solenoid valve that is energized to close the bypass ports on the scroll. A 24 volts AC to 24 volts DC rectifier is externally mounted on the compressor to energize the solenoid valve. If the compressor operates in the first stage at 67% capacity but will not close the bypass ports to fully load the compressor on a second stage call, the isolation relay, the rectifier, and the solenoid valve must be evaluated.

Verify that 24 volts AC is present at the rectifier. If 24 volts AC is not present, evaluate the output voltage and electrical connections from the terminals at the condenser control panel and from the second stage call from the thermostat. The rectifier is on the compressor and must receive a 24 volts AC input. If the rectifier is working properly, it will produce a 24 volts DC output to the second stage solenoid valve. If 24 volts AC is present to the rectifier and 24 volts DC is present at the output of the rectifier, the compressor solenoid is faulty, and the compressor must be replaced. If 24 volts AC is present to the rectifier and 24 volts DC is not present at the outlet of the rectifier, the rectifier is faulty and must be replaced.

Single Phase Compressor

The single-phase compressors described in this guide have been manufactured with a run winding, a start winding, and an internal overload connected in series with the common terminal of the compressor. Single phase compressors may be installed in systems which require the compressor to start under high pressures. The greater the pressure differential, the greater the starting torque required to start the motor. The start and run windings are wound a few electrical degrees out of phase and provide minimal starting torque. The system may require a starting relay and capacitor to provide greater starting torque, because of these characteristics. The starting components for single phase motors were discussed in Section 3 (Component Familiarization).

In single phase air conditioners, the compressors have a "run winding" and a "start winding", which are indicated by "R" and "S" on the compressor terminal block. In addition to the "R" and "S" terminals, the compressor has a "C" terminal. The "C" terminal represents a "common" point between the start and run windings as indicated in the diagram below. There is an internal thermal overload wired in series between the "C" terminal and the run and start windings. The internal thermal overload is installed to provide additional protection for the compressor's windings when the motor is subjected to overheating.

When troubleshooting electrical equipment, there are a few checks that are made and many safety guidelines that must be followed. When troubleshooting the compressor, it is important to take a voltage reading to verify that the compressor is receiving the supply voltage +/-10% of the rated voltage on the equipment data plate.
If the supply voltage to the compressor was verified and the compressor is not operating, the following procedures must be followed:

- Lock-out and tag-out the electrical supply voltage at the equipment disconnect.
- Verify that the voltage is disconnected with a voltage meter.
- Bleed the capacitors as described in the capacitor topic of this section.
- Evaluate the compressor windings using an ohm meter.

Compressor Resistance Readings

The resistance readings in this section's examples are used as a reference point to help understand the internal configuration of the compressor. Resistance readings in the field will vary from one compressor to the next; however, the relationship between the start, run, and common terminals will remain the same.

Example:

- The highest resistance reading is between Start (S) and Run (R)
- The lowest resistance reading is between Run (R) and Common (C)
- The middle resistance reading is between Start (S) and Common (C)

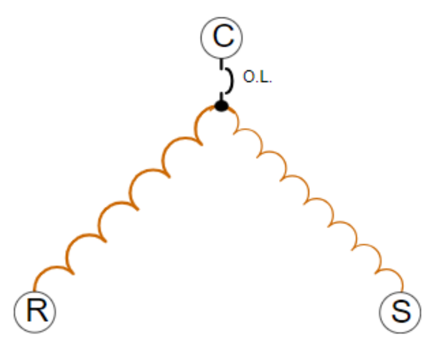
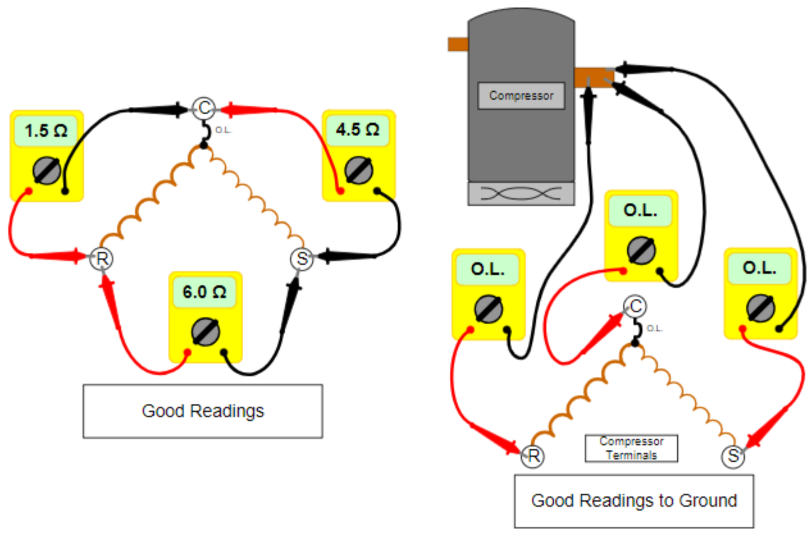


Diagram of S, R, C Windings

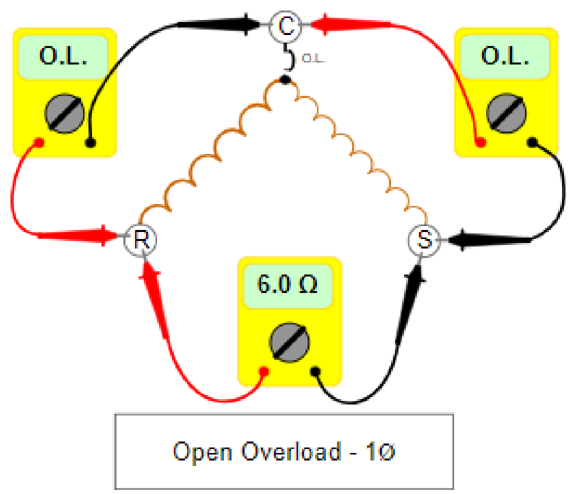


Example of Good Resistance Readings for Single Phase Compressor

Internal Overload

Terminal "C" is common for both windings. A thermal overload is wired internally between the "C" and "R" terminals and the "C" and "S" terminals and is often indicated as "O.L." on a wiring schematic. In the event of an over temperature condition, the normally closed overload opens and takes both the run and start windings out of the circuit to protect the compressor. This is often misdiagnosed as a faulty compressor.

To determine if the internal overload has opened, an ohmmeter is used to read the resistance between each of the three terminals. If an open or infinite reading is measured between "C" and "R" and between "C" and "S", but resistance is read between "R" and "S", the internal overload has opened and must be given time to cool off and reset.



Example of Open Internal Thermal Overload on Single Phase Compressor

Example: Open Internal Overload

- "C" to "R" = Open
- "C" to "S" Open
- "R" to "S" = 6 Ωs

Common issues that may cause an internal overload to open include:

- Low refrigerant charge, causing high superheat and inefficient cooling of the compressor.
- Excessive airflow across the evaporator coil
- Excessive indoor heat load across the evaporator coil
- Restricted airflow through the condenser coil
- Excessive refrigerant charge
- Non-condensable within the system
- Faulty capacitors
- Faulty starting relay
- Poor electrical connectors
- Pitted or corroded contacts on the contactor

After the internal overload resets, the system must be started and monitored to determine the cause of the internal overload opening. The problem must be corrected prior to starting the system.

Both the "RLA" and "LRA" values for the compressor are listed on the compressor and the unit's rating plate. The RLA (Rated Load Amperage) is the current the compressor will draw, measured in amps, on a properly set up system under design test conditions. The compressor current draw is read using a clamp style ammeter around the "C" or common lead to the compressor. The compressor current draw reading on a system will vary depending on the ambient conditions and the system charge.

The LRA (Locked Rotor Amperage) value is the electrical current the compressor will draw when the rotor is stationary. On systems with balanced pressure at the compressor pumping unit, an adequate supply of voltage and properly sized conductors, the LRA period is short after the compressor starts. If the compressor is struggling to start, the compressor will draw high current for a longer period. This can also be verified with an ammeter clamped around the "C" lead of the compressor.

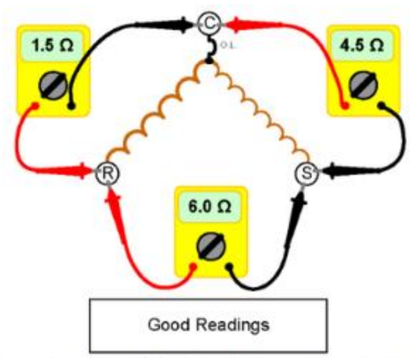
When a compressor fails to start, the current draw of the compressor is at or near to LRA, then drops to zero amps. This indicates that the compressor's internal overload is momentarily opening. This may repeat until the compressor's internal overload opens and takes both the run and start windings out of the circuit. If the compressor has cooled down and the internal overload will not reset, the compressor must be replaced.

Typical Readings

The first reading in the example is the total combined resistance of the start winding and the run winding, which is the resistance reading between "R" and "S" in the diagram, or 6 ohms.
The second reading in the example is taken between "C" and "R". This indicates that the run winding has 1.5 ohms of resistance. This also indicates that the start winding should have a resistance reading of 4.5 ohms when a reading is taken between "C" and "S".

Example: Single Phase Compressor

- "R" to "S" = 6.0 ohms
- "C" to "R" = 1.5 ohms
- "C" to "S" 4.5 ohms



Example of Good Readings Between Terminals on Single Phase Compressor

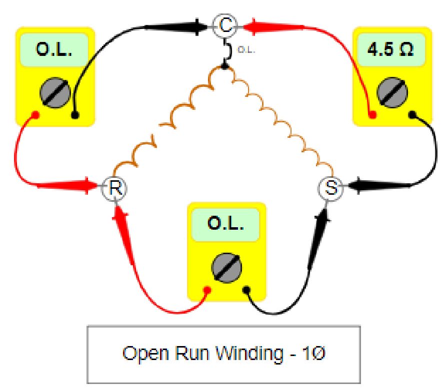
Run Winding

The run winding is the main winding in a single-phase compressor. The run winding is "in" the circuit 100% of the time the compressor is operating. To evaluate the run winding, the electrical disconnect must be locked out and an ohm meter used to measure the resistance of the compressor. The compressor should have a resistance reading between "R" and "S" and a reading between "R" and "C". The run winding will have the lowest resistance reading on a good compressor.

If the resistance reading between "C" and "S" is 4.5 s, then the start winding has continuity, and the internal overload is closed. If a second reading is taken between "C" and "R" and the ohm meter indicates "open", the compressor has an open run winding.

Example: Open Run Winding

- "C" to "S" = 4.5 s
- "C" to "R" = Open
- "R" to "S" Open

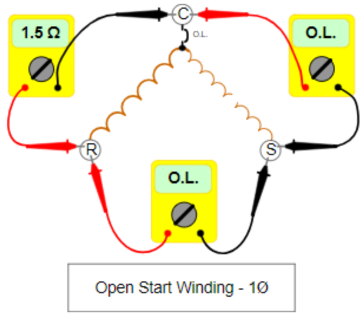


Example of an Open Run Winding on a Single Phase Compressor

Start Winding

Example: Open Start Winding

- "C" to "R" = 1.5 ohms
- "C" to "S" = Open
- "R" to "S" = Open

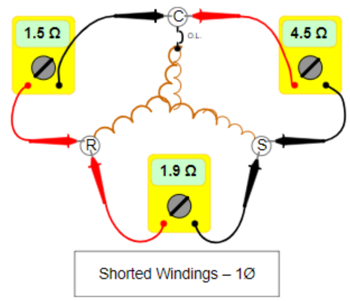


Example of an Open Start Winding on a Single Phase Compressor

The start winding has the smaller diameter and highest resistance wire of the two windings on a single-phase compressor.
If the resistance reading between "C" and "R" was 1.5 Qs, the run winding has continuity, and the internal overload is closed. If the second reading between "C" and "S" is "open", the compressor has an open start winding as indicated in the Start Winding diagram above.

Shorted Windings

The highest resistance reading on a single-phase compressor must be between the "R" and "S" terminals because the reading is of both the run and start windings in series with each other.



Example of Shorted Windings on a Single Phase Compressor

The second highest reading will be of the start winding between terminals "S" and "C" and the lowest resistance reading must be between terminals "C" and "R". The resistance readings between "C" and "R" and between "C" and "S" should add up to the resistance indicated between "R" and "S". If the resistance is significantly less than each of the windings added together, then the windings are shorted together as indicated in the diagram below.

Example: Single Phase Shorted Windings

- "C" to "R" = 1.5 ohms
- "C" to "S" = 4.5 ohms
- "R" to "S" = 1.9 ohms

Grounded Compressor

If the circuit breaker blows immediately on compressor startup, verify that the breaker size, wire size, and supply voltages are all correct and within the equipment tolerances according to the unit rating plate and Installation Manual.

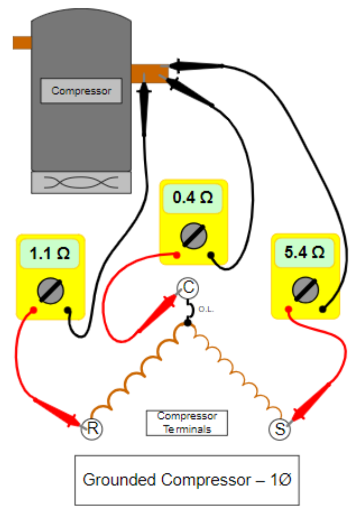
If all are correct, an ohmmeter is used to determine if a compressor winding is shorted to ground. To do so, lock-out and tag-out the equipment disconnect. The three leads to the compressor must be disconnected and a resistance reading measured from each terminal to the shell of the compressor. When taking resistance readings, good contact with the compressor shell, the suction line, or discharge line attached to the compressor is essential. This is because the compressor has a heavy layering of paint on the shell and could give a false reading.

All readings should read "open" or "infinite" when measured from the compressor shell to any of the terminals. If continuity is read between any lead and the compressor shell as indicated in the diagram below, a winding is shorted to the shell and the compressor is grounded. Any time a motor has become grounded, it must be replaced.

Example: Grounded Compressor

- "C" to "R" = 1.5 ohms
- "C" to Shell = 0.4 ohms
- "C" to "S" = 5.0 ohms
- "S" to Shell = 5.4 ohms
- "R" to "S" = 6.5 ohms
- "R" to Shell = 1.1 ohms

A compressor can have what appears to be normal readings between the windings and be grounded at the same time.

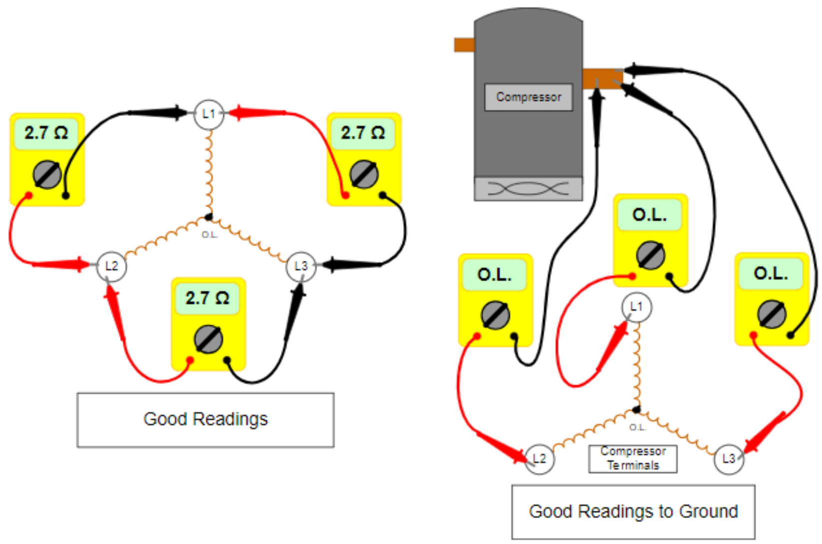


Example of a Grounded Single Phase Compressor

Three Phase Compressor

Three phase compressors have three equally sized windings. When measuring the resistance of the three windings, the ohm readings will be approximately the same resistance between any two terminals. The diagram below is an example of equal resistance readings between windings.

Good Readings



Examples of Good Resistance Readings on a Three Phase Compressor

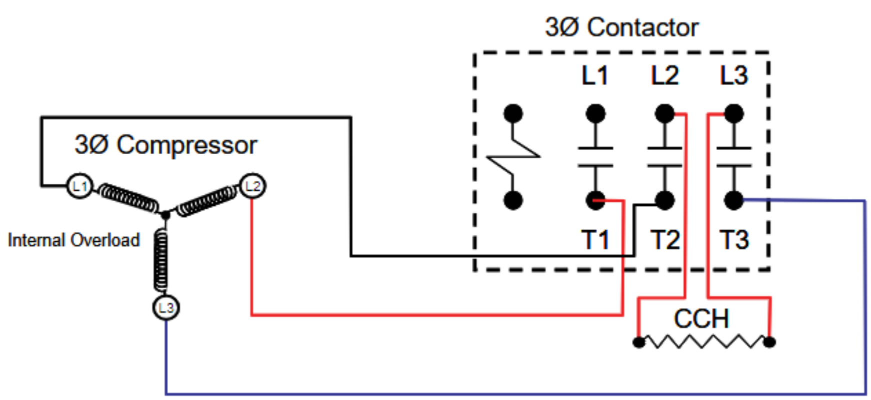
Example: Three Phase

- "L1" to "L2" = 2.7 Qs
- "LI" to "L3" = 2.7 Qs
- "L2" to "L3" = 2.7 Qs

If the windings of a three-phase motor do not have similar resistance readings, the readings may be used to determine if the motor has failed or if the thermal overload has opened to protect the motor.

Note
Proper rotation of three phase compressors must be established to prevent damage to the compressor.

Three-phase scroll compressors operate in only one direction. If the scroll is drawing low amperage, has similar suction and discharge pressures, or is producing a high noise level, the scroll is out of phase. If the rotation is not correct, reversing any two of the three lines of power supplying the compressor will reverse the rotation of the compressor.



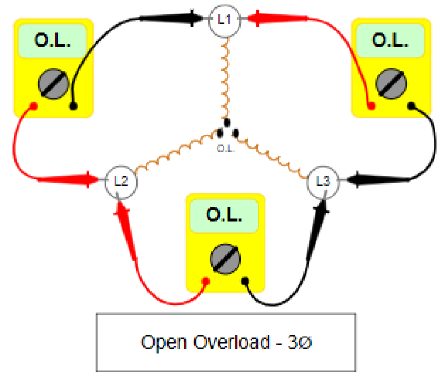
Electrical/ Reversing Two Legs of Electrical Power

Open Overload

When the internal overload of a three-phase compressor is open, the resistance readings between the
"L1", "L2" and "L3" terminals will all read open as shown in the diagram below.
Example: Three Phase Open Internal Thermal Overload

- "L1" to "L2" = Open
- "L2" to "L3" Open
- "L1" to "L3" Open

When an open overload is identified, the compressor should have adequate time to cool down and reset the overload.
If the overload does not reset, the compressor must be replaced. Although it would be unusual, this could also represent that all three windings have burned open.

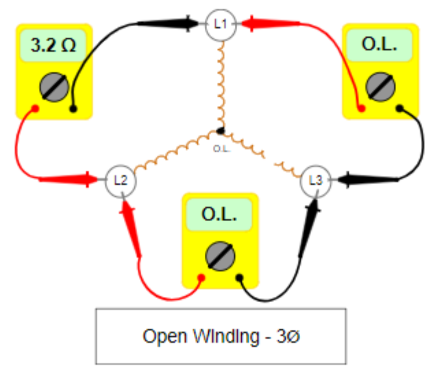


Example of Open Internal Thermal Overload on Three Phase Compressor

Open Winding

An open winding on a three-phase compressor will usually be indicated by continuity between two of the terminals and an open measurement between the remaining terminals as shown in the diagram below.
Example: Three Phase Open "L3" Winding

- "LI" to "L2" = 3.2 ohms
- "L2" to "L3" = Open
- "L1" to "L3" Open



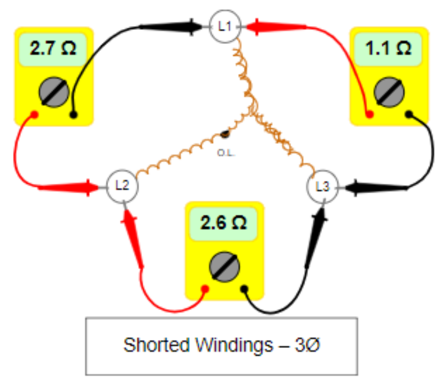
Example of Open Winding on Three-Phase Compressor

Shorted Windings

On 3-phase compressors each of the three resistance readings between any two terminals will be approximately the same. When a 3-phase compressor has shorted windings the resistance readings between two of the compressor terminals will be less than the other two readings. In this example, the reading between terminals "L1" and "L3" indicates a resistance of 1.1 ohms of resistance.

This is less than the other two readings of 2.7 and 2.6 ohms of resistance, which indicates that there is a short between the "L1" and "L3" windings.
Example: Shorted Windings

- "LI" to "L2" = 2.7
- "L2" to "L3" = 2.6
- "LI" to "L3" = 1.1



Example of Shorted Windings on a Three Phase Compressor

Grounded Compressor

As identified in the single-phase compressor section, any resistance reading to the compressor shell indicates a grounded compressor. In the below diagram, although the resistance readings between windings may appear normal, the readings between each terminal and the compressor shell are of concern. The only readings measured from any of the three terminals to the compressor shell are "Open" or "Infinite".

Example: Grounded Compressor

- "L1" to "L2" = 3.6 ohms
- "L1" to Shell = 2.5 ohms
- "L2" to "L3" = 3.6 ohms
- "L2" to Shell = 2.5 ohms
- "L1" to "L3" = 3.6 ohms
- "L3" to Shell = 1.1 ohms

Compressors with open, shorted, or grounded windings are usually caused by problems external to the compressor. A thorough evaluation of the electrical system must be completed prior to installing a new compressor.

An acid test should also be completed to evaluate the compressor oil for acid content. If acid is present, the system has experienced a severe burnout and must have a thorough cleanup to remove the contaminated oil before installing a new compressor.

08

Maintenance

Introduction

Preventative maintenance is crucial to proper system operation, consumer comfort, and system durability. The technician should provide the owner with the owner-operator maintenance procedures that accompany the equipment. The technician should also discuss maintenance programs to have the system cleaned and serviced on a regular schedule.

General Maintenance

It is recommended that the system be inspected once a year by a qualified service person. Air openings or clearance around the unit must not be blocked or obstructed. Overhanging structures or shrubs must not be permitted to obstruct the condensing unit air discharge.

Thermostats & Control Boards

Thermostats and control boards must be inspected during the annual maintenance inspection. The thermostat must be level and tightly secured to the wall. This is aesthetically important with electronic thermostats and is required for proper operation with existing mercury bulb thermostats. Dust accumulation must be gently blown out and exposed contacts checked for deterioration. The integrity of all electrical connections and terminals on the thermostat and control boards must be inspected. Any loose or corroded connections must be repaired and properly tightened. Corroded or lost control wiring connection can cause improper equipment operation and component failure.

Return Air Filters

Return air filters must always be used. Filters must be checked monthly. Dirty filters reduce system efficiency and increase energy consumption. The Installation Manual lists the proper filter sizes and filter/frame kits for the specific unit.

Dirty filters restrict airflow during the cooling cycle and may open the limit switch during heating when air flow is restricted across the heat exchanger or electric elements (when applicable).

Evaporator Coils

The evaporator coil removes heat from the conditioned space during cooling operation. It is essential that the coil is kept clean and free of debris to ensure that the equipment has unrestricted airflow across the coil.

The evaporator coil is kept clean by continually changing return air filters and through periodic coil cleaning. The coil should only be cleaned according to the manufacturers approved methods, which include:

- Coil brushes
- Vacuum cleaner attachments.
- Water and/or approved, non-acid coil cleaners.

The drain pan and drain trap must be inspected and cleaned to prevent odors and assure proper drainage.

Note
If water or cleaners are used to clean the coil, lock-out tag-out procedures must be followed to remove the supply voltage from the unit to prevent personal injury. The Material Safety Data Sheets (MSDS) should be read and the proper Personal Protective Devices (PPDs) utilized prior to and during the application of chemical cleaners.

Condensing Coils

The condensing coil rejects heat from the refrigerant to the outdoor air during cooling operation. The equipment must have a designed airflow across the coil to reject the proper amount of heat and maintain system efficiency. The condensing coil must be kept clean and free of debris. The coil must be cleaned according to approved methods, which include:

- Coil brushes
- Vacuum cleaner attachments.
- Water and/or approved, non-acid coil cleaners.

Motors

Outdoor and indoor motors in air conditioning systems are permanently lubricated and require no maintenance.

