Second Edition

R-410A & R-22 Systems

Air Conditioning Service Guide

By Michael Prokup

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A Comprehensive Reference for Service and Maintenance of Residential Split System Air Conditioning Systems

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By Michael Prokup

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In Memory of

Michael Prokup

1960-2021

Michael Prokup passed away unexpectedly, at the age of 60, on Tuesday, August 3, 2021. Well before his passing, Mike had been preparing this updated *Second Edition of the R-410A & R-22 Systems Air Conditioning Service Guide* and ESCO is honored to be able to continue Mike's work and share his talent for teaching complex subjects in an easy to understand format.

Mike was an admired and highly respected author, consultant, and business leader within the HVAC industry. Mike is best known for Prokup Media, Inc., his interactive training programs, and R-410A training seminars.

Mike tirelessly wrote and produced a library of training manuals, repair guides, and software titles over his 40-year career in an effort to move the industry forward and continue to be a benchmark in the industry. We bring this manual to you with a heavy heart, and we hope, in some way, you become a better technician and diagnostician for having read and studied this book.

Rest in Peace, Michael Prokup.

Dedication

The publication of this book is dedicated to the Prokup family. Kim, Kyle, Michael, Stephanie, Joe, Andrew, and Buster.

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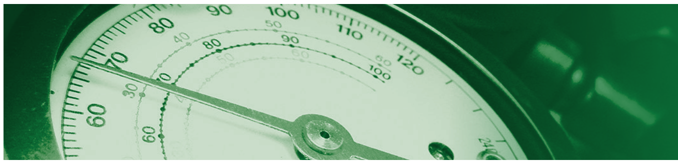

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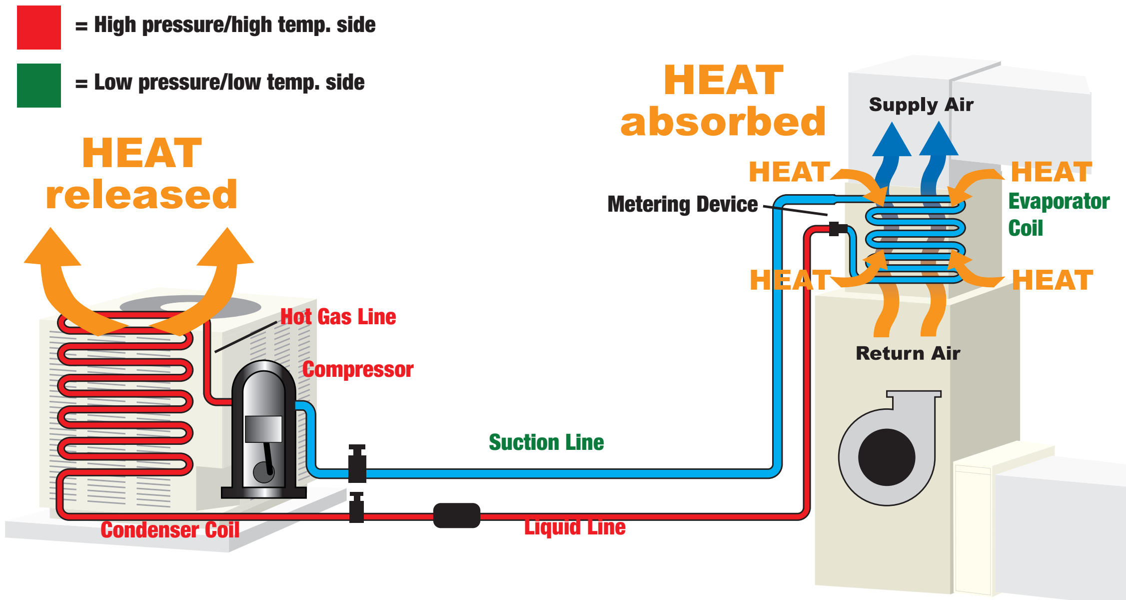
Basic Cooling System Overview

The illustration below depicts an overview of a typical refrigeration system found in comfort cooling air conditioning systems. The system consists of a metering device, evaporator coil, suction line, compressor, hot gas line, condenser coil, and liquid line. The system uses a refrigerant to transfer heat from the conditioned space (home) to the outdoor air.

The refrigeration circuit consists of a high pressure/high temperature side, and a low pressure/low temperature side. The compressor and the metering device are the pressure changing devices that separate the two sides of the system.

The high pressure/high temperature side of the system rejects heat, and the low pressure/low temperature side of the system absorbs heat. The high pressure side of the system consists of the compressor, discharge line, condenser coil, and liquid line. The low side of the system consists of the evaporator coil, the suction line, and the compressor inlet. Notice the evaporator coil connects the refrigeration system to the heat source. This connection is between the refrigerant inside of the evaporator coil and the air passing across the surface of the evaporator coil.



In an air conditioning system, heat from the home is absorbed into the cold refrigerant in the evaporator coil. The refrigerant carries the absorbed heat to the outdoor condenser coil, where the heat is released from the refrigerant by being absorbed by the cooler outdoor air passing through the condenser coil. The operation of the system works because heat always flows from a warmer object to a colder object. As the heat content of the air changes, it will have a profound affect upon the operation of the refrigeration system.

In this chapter, we will introduce the components of the system and how they work together to form the comfort cooling air conditioning system refrigeration cycle.

Refrigerant

Introduction to Refrigerants

Refrigerants are special chemicals developed as a heat transfer media for use in refrigeration systems. In nature, hot goes to cold. In other words, energy flows from high to low. Refrigerants, when warmer than air, will transfer their heat to the air. When the air is warmer than the refrigerant, the heat will flow from the air into the refrigerant.

There are two refrigerants found in modern residential air conditioning systems, R-22 and R-410A. R-22 is an ozone depleting refrigerant. R-410A is a non-ozone depleting refrigerant.

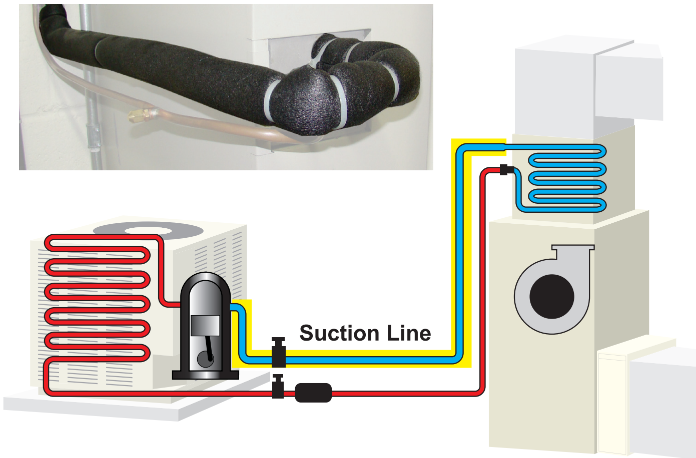
Refrigerant Saturation Temperature

Refrigerants have a special physical property called saturation temperature. Saturation temperature can be considered the temperature of the refrigerant where all the heat transfer power exists. A refrigerant that is at saturation temperature will be a mix of both liquid refrigerant and vapor refrigerant. Any addition or removal of heat from a saturated refrigerant will often cause a change of state. However, the refrigerant may also flash from a liquid to a vapor, or it may condense from a vapor to a liquid, depending on system conditions. These state changes occur when a heat exchange between the refrigerant and air takes place.

At saturation temperature the refrigerant exists as both a liquid and a vapor simultaneously.

Suction Line and Suction Line Drier

The suction line is part of the low pressure side of the system, and connects the outlet of the evaporator coil to the suction line service valve on the outdoor condensing unit. The suction line is is cold, which will cause it to attract heat from the outdoor air and other sources. To prevent this from happening and to prevent condensate from forming on the line (sweating), the suction line is insulated.



Suction lines come in different size diameters. Typical sizes are 5/8”, 3/4”, 7/8”, and 1-1/8”. The size of the line, measured by its outside diameter, or O.D., will depend upon the capacity of the system. Larger tonnage systems require larger suction lines than smaller tonnage systems. The size will also be determined by how far the line must run, and by how many elbows and other pipe fittings are installed in the piping run.

At times, a suction line filter drier is installed in the suction line. This drier is never installed by the manufacturer of the system, but rather by a servicing technician. Suction line driers are commonly used to clean up or remove contaminants from a system after a compressor motor burnout.

Suction Line Drier

Suction line filter driers typically have pressure ports on the shell so that the pressure drop across it can be measured. If the pressure drop across the filter is above allowable limits, the filter should be removed and replaced with a clean one. These filter driers come in different sizes based on the capacity of the refrigeration system they must clean.

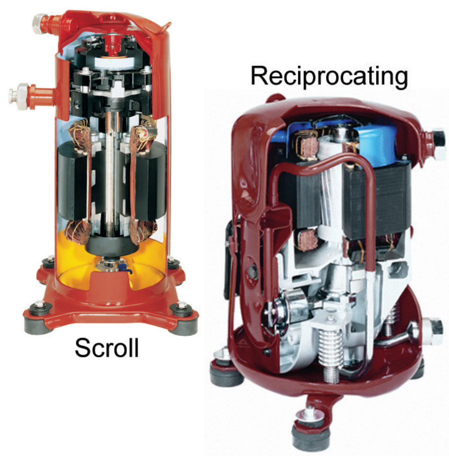
Suction Line Pressure Loss

Suction lines drop the pressure of the suction gas due to friction that occurs as the refrigerant vapor travels in the copper tubing. This pressure drop is bad for the system as it causes the capacity of the compressor to fall. This is due to the density (or weight) of the refrigerant vapor reducing as pressure reduces. The resulting lighter vapor reduces the number of pounds of refrigerant that can be pumped by the compressor each minute, resulting in a loss of system capacity. It is best to keep suction lines sized to drop no more than 3 PSIG for R-22 systems and 5 PSIG for R-410A systems. Both of these pressure drops reduce the system capacity by 3%. Causes of excessive suction line pressure loss include kinks in the line, long line sets, or undersized refrigerant piping. (See Chapter B: Refrigerant & Refrigerant Piping)

Compressor

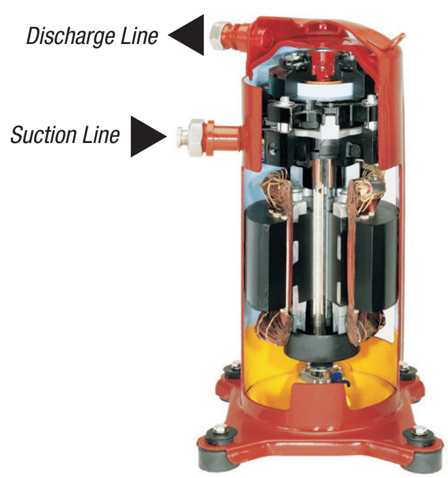
Configuration

Compressors found in newer residential split systems are typically scroll models, while older systems were commonly equipped with reciprocating compressors. Scroll compressors have orbiting scrolls that compress the refrigerant vapor. Reciprocating models have a piston and cylinder arrangement that closely resembles a car engine. Regardless of the type of compressor present in the system, both types are vapor pumps.



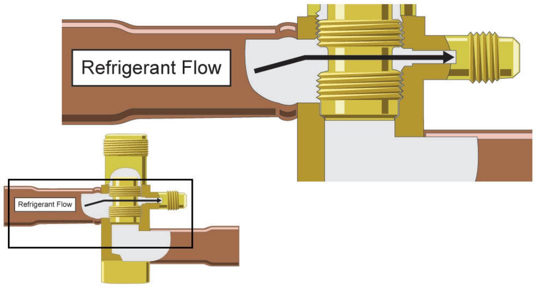
Scroll and Reciprocating Compressors. Both are sealed and unable to be serviced by a servicing technician.

The compressor has two refrigerant line connections. One connection is for the suction vapor and the other connection is the discharge line connection. These connections are typically brazed connections, but can be mechanical on some compressors.



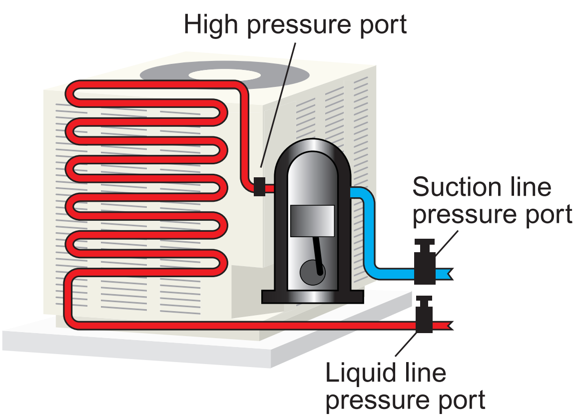
When the valve is front-seated, the refrigerant flow through the valve is blocked and the gauge access port is open to read system pressure.

King Valve (Front-Seated)



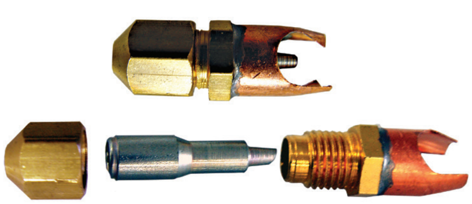
Pressure Port Locations

Residential air conditioning systems typically come with pressure access ports located at the outdoor unit service valves. These ports are located on the suction and liquid lines and used for charging and evacuation purposes. In some cases, the system may have a high pressure port located on the compressor discharge line. This port is commonly found on heat pump systems.



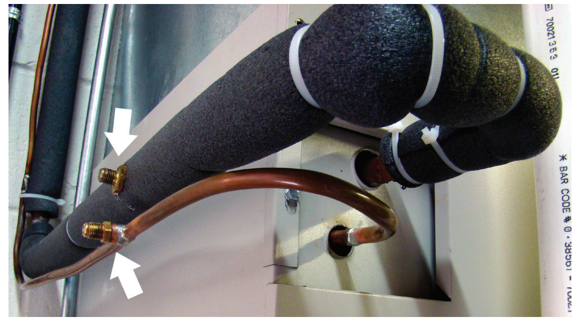
Installing Additional Pressure Ports

It is possible to add special pressure ports to systems that are already installed and have been evacuated. These ports are comprised of a saddle fitting that fits to the copper refrigerant lines. The port is brazed to the refrigerant line, and then a special piercing tool is screwed down to pierce a hole in the line. These ports may be added to a system where flash gas problems exist, or where excessive suction line pressure drop is suspected.



Exploded view of pressure port installation kit

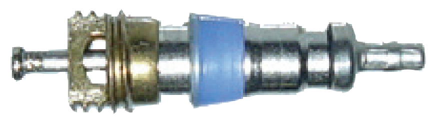
If complete access to pressure at important diagnostic positions is desired, two additional pressure access ports could be added to the system. These ports should be installed in the liquid line about 1 foot in front of the metering device, and another pressure port on the suction line at the outlet of the evaporator coil. These two additional ports will allow measurement of the system pressure at the suction line outlet to the evaporator coil, and at the point where liquid is about to enter the metering device. Pressure at these ports would then be measured and compared against the pressure at the condensing unit service valves to detect excess pressure drop in the refrigerant lines.



The indicated ports are about one foot in distance from the evaporator coil and metering device as noted above.

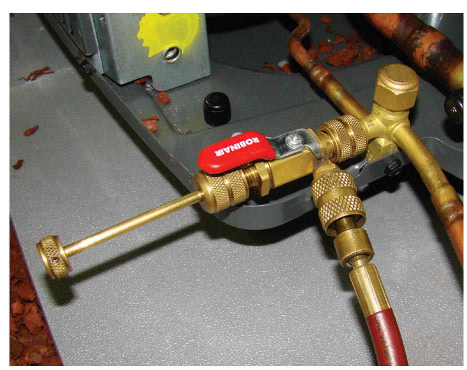
Replacing Leaking Pressure Port Cores

The valve stem cores used in pressure ports can be damaged by heat and leaked refrigerant. In the event a core is damaged, it must be replaced.



Valve Stem Core

Special valve core removal tools can be used to remove and replace a damaged core without losing system charge. The tool's ball valve is then shut to seal the refrigerant charge in the system. The damaged core is then replaced with a new core and screwed back into the system service valve.



Typical valve core removal tool

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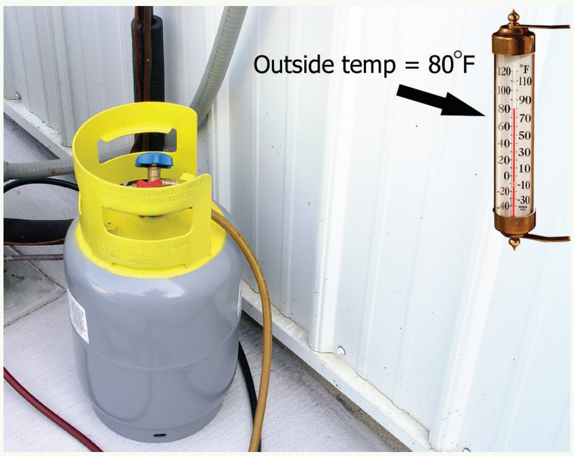
Step 3

Read the pressure in the refrigerant recovery cylinder.

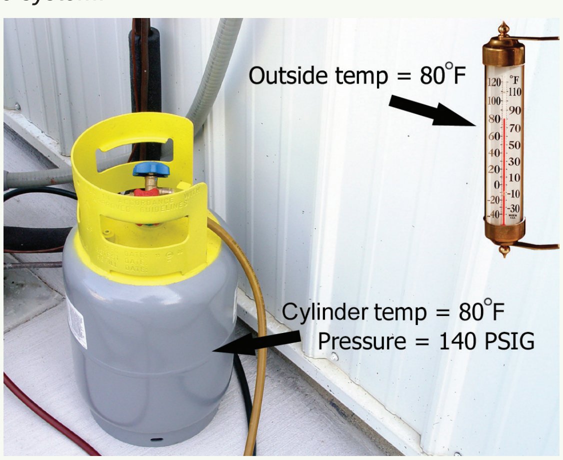
Step 4

Measure the air temperature surrounding the recovery cylinder.



Step 5

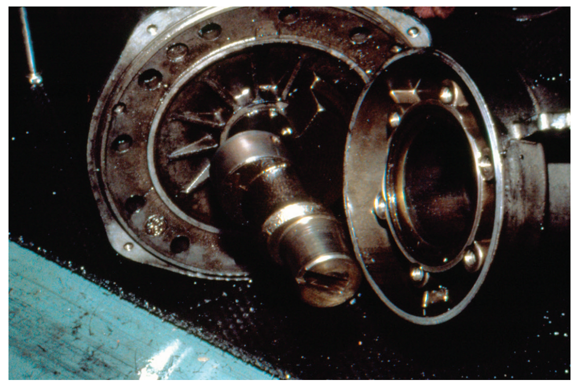
The cylinder pressure should be equal to the saturation pressure for the air temperature. If the pressure and temperature are not correctly matched for the type of refrigerant that should be in the system, mixed or incorrect refrigerant, or non-condensables are present. In this example the recovery cylinder is at a pressure of 140 PSIG @ 80°F. These temperatures and pressures are correct for R-22. If the system were an R-410A machine, this would be an example of someone putting the wrong refrigerant into the system.



Moisture & Acid

Since air contains moisture, moisture can get into the refrigeration system when the system is installed or opened for service. Moisture, when mixed with refrigerants and refrigerant oils, can produce acid. Acid in a system can cause compressor failure due to corrosion, motor winding damage, and copper plating of compressor bearing areas.

When a system is operating in an acidic condition, the acid attacks copper surfaces in the refrigeration circuit. The copper is deposited on weight-bearing areas within the compressor. Acid will also attack the compressor motor windings and cause electrical failure of the compressor motor.



This compressor damage was caused by copper plating due to excess moisture and acid formation in the system.

Moisture and POE Oil

R-410A systems use POE (polyolester oil) that is produced from organic acid and alcohol. POE oil is hygroscopic and will attract moisture at a faster rate than mineral oil based systems. When exposed to moisture, POE oil can change back into organic acids, alcohol, and water through a process called hydrolysis. The organic acid is highly corrosive and will cause damage to compressor components and internal refrigeration system surfaces.

When opening a R-410A system for servicing, the potential for oil contamination must be minimized. One way to accomplish this is to bleed a small amount of nitrogen into the system during repairs. The nitrogen will keep the system slightly above atmospheric pressure and minimize the potential for oil contamination.

When servicing a R-410A system, do not allow the system to be open the atmosphere for more than 15 minutes. If a system has been left open to atmosphere (such as if there was a catastrophic leak and the total refrigerant charge was lost), it is best to replace the compressor oil.

Evacuation of the system will not separate moisture from the POE oil. The only method of removing moisture from POE oil is through

Service Procedure: Determining Suction Line Pressure Drop

Step 1

Identify the type of refrigerant used in the system and select the proper chart.

> *Example: Let's assume the system is an R-22 unit that has been installed for a few years. We would select the R-22 Suction Line Sizing Chart.*

Step 2

Identify the line size and tonnage of the system. Use the table to determine the pressure drop that would occur at 100 equivalent feet of suction line. Note the pressure drop figure.

> *Example: The system is a 2 ton system, and the suction line size installed is 5/8. The chart indicates that a pressure drop of 8.1 PSIG would occur at 100 equivalent feet of piping.*

Suction Line Sizing Table

Tons	R-22		R-410A	
	Tube Size (in.)	Pressure Drop (PSIG per 100 ft. Equiv.)	Tube Size (in.)	Pressure Drop (PSIG per 100 ft. Equiv.)
1.5	5/8	4.7	1/2	10.8
	3/4	1.8	5/8	3.1
	-	-	3/4	1.2
2.0	5/8	8.1	5/8	5.4
	3/4	3.0	3/4	2.0
	7/8	1.3	7/8	0.9
2.5	5/8	12.7	5/8	8.2
	3/4	4.6	3/4	3.0
	7/8	2.0	7/8	1.3
3	3/4	6.5	5/8	11.7
	7/8	2.8	3/4	4.3
	-	-	7/8	1.9
3.5	3/4	8.8	3/4	5.8
	7/8	3.8	7/8	2.5
	1-1/8	1.0	-	-
4.0	7/8	4.9	3/4	7.4
	1-1/8	1.3	7/8	3.2
	-	-	1-1/8	0.9
5.0	7/8	7.5	3/4	11.5
	1-1/8	2.0	7/8	4.9
	1-3/8	0.7	1-1/8	1.3

Step 3

Measure the linear length of the suction line.

> *Example: The suction line length is 40 ft. Note this length is not the equivalent length, it is the linear length.*

Step 4

Count the number of elbows in the line and identify whether they are short radius or long radius elbows.

> *Example: The line has 6 short radius 90 degree elbows installed between the evaporator coil and the outdoor condensing unit.*

Step 5

Reference the Equivalent Length Fitting Table to find the equivalent length of each fitting.

> *Example: Each 90 degree short radius elbow is equal to 5.7 ft. of pipe.*

Equivalent Length Brazed 90^0 Elbows (Ft.)

OD Tube (in.)	Short Radius	Long Radius
5/8	5.7	3.9
3/4	6.5	4.5
7/8	7.3	5.3
1-1/8	2.7	1.9
1-3/8	---	---

Step 6

Determine the total combined equivalent length of all pipe fittings.

> *Example: There are 6 elbows in the line.*
> *5.7 ft. x 6 elbows = 34.2 ft.*

Step 7

Add the total linear length of pipe to the total equivalent fitting length. The sum is the total equivalent length of the suction line.

> *Example: 40 linear ft. of pipe + 34.2 fitting length = 74.2 ft.*

Step 8

Divide the equivalent length of the line by 100 to determine the multiplier to use in Step 9.

> *Example: 74.2/100 = .742*

Step 9

From Step 2, get the pressure drop per 100 feet of pipe for the system. Multiply this value by the multiplier calculated in Step 8. The result is the approximate pressure drop that will occur when the system is at maximum capacity.

> *Example: 8.1 x .742 = 6 PSIG of pressure loss.*

Step 10

If the pressure drop is within ASHRAE standards, the capacity loss caused by the line is within acceptable limits.

> *Example: ASHRAE standards recommend a maximum 3 PSIG of pressure drop in the suction line for R-22 systems. The estimated pressure drop in this example is far above this limit and will cause a 6% loss of system capacity.*
>
> *If operating costs are excessive, or there is a lack of cooling complaint, the line will need to be replaced.*

Liquid Line Piping

Introduction

The smaller liquid line connects the outlet of the condensing coil to the inlet of the metering device, and carries liquid refrigerant at high pressure. The small line size and high pressure result in a high pressure drop between the condensing coil and the metering device. If the pressure drop is excessive due to improper line sizing, the system may experience low capacity, compressor failure and potential damage to the metering device.

Technicians who are investigating poor system performance or compressor failure, should inspect and evaluate the liquid line circuit to rule out potential problems caused by the liquid line.

Subcooled Liquid and its Role in Proper System Operation

The role of the liquid line and subcooled liquid refrigerant is extremely important to overall system performance and reliability. When the liquid refrigerant temperature is lower than its saturation temperature at a given pressure, it is in a subcooled state. The liquid refrigerant should be subcooled late in the condenser coil circuiting, and should remain subcooled all the way from the condensing coil outlet to the inlet of the metering device. If the refrigerant at the inlet of the metering device has reached saturated or superheated temperatures, vapor refrigerant is present in the liquid line. This vapor is called flash gas. Flash gas will cause the metering device to feed an inadequate amount of refrigerant to the evaporator. The presence of flash gas will result in a system that is operating with a starved evaporator coil.

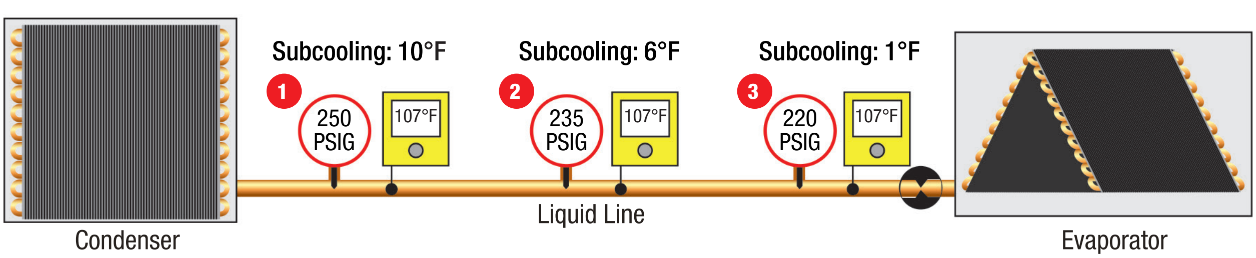
Symptoms of flash gas include noisy liquid lines, overheating compressors, high superheat, low system capacity, and intermittent comfort complaints.

How Flash Gas Forms in the Liquid Line

Referring to the figure below, the liquid line receives subcooled liquid, at 250 PSIG, from the condensing coil, Point 1. The pressure at this point in the line is 250 PSIG. At 250 PSIG, R-22 is at a condensing temperature of 117°F. In this example, the liquid line is 107°F which is 10°F cooler than the saturation temperature of 117°F. The liquid at this pressure port is therefore subcooled by 10°, and is in a pure liquid state.

At Point 2 in the figure, the liquid line pressure has dropped to 235 PSIG. At 235 PSIG, R-22 is at a saturation temperature of 113°F. The 107°F liquid reaches this port, and the subcooling has now dropped to 6°F. Since the liquid is still cooler than the corresponding saturation temperature at the second gauge port, the refrigerant is still in a subcooled state and is still pure liquid.

At Point 3, the 107°F liquid refrigerant is at a pressure of 220 PSIG. At 220 PSIG, R-22 is at a saturation temperature of 108°F. The refrigerant at this point is still subcooled by 1°F, and will remain pure liquid. However, If the pressure at Point 3 had dropped below 220 PSIG due to an undersized liquid line or excessive fittings, or if the refrigerant temperature rose above 107°F because the liquid line was run through a hot attic where the refrigerant was allowed to absorb heat, the refrigerant would return to a saturated state and flash gas vapor would form in the line.



In the example above, the amount of subcooling that is measured at the beginning of the liquid line is not the same amount of subcooling that is present at the end of the liquid line.

A sight glass may be installed on the liquid line to visualy detect flash gas. In many cases, the sight glass is installed at the outdoor unit. Other than serving as a moisture indicator, a sight glass installed at that location provides no information as to the state of the liquid as it reaches the metering device. It is best to install the sight glass at the end of the liquid line to get a look at the condition of the refrigerant as it enters the metering device.

Service Procedure: Checking for Restrictions in Condenser Circuits

Tools:

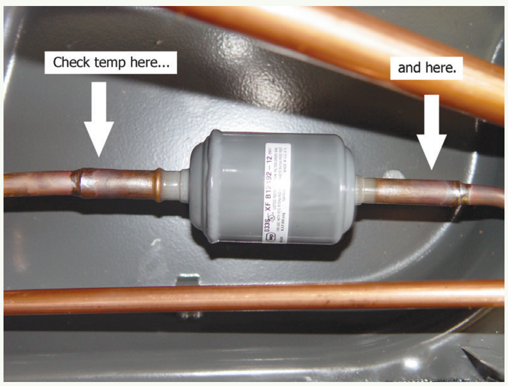
- Digital Temperature Probe

STEP 1

Run the system.

STEP 2

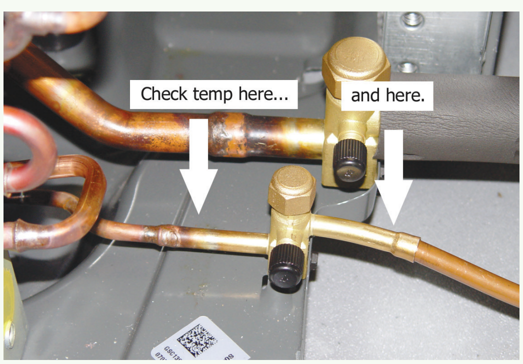
If there is a liquid line drier at the outlet of the subcooling loop, check the temperature of the liquid at the inlet and outlet of the drier.



There should be no more than a 3°F drop in temperature across the drier. Replace the drier if needed. If there is no temperature drop detected, proceed to step 3.

STEP 3

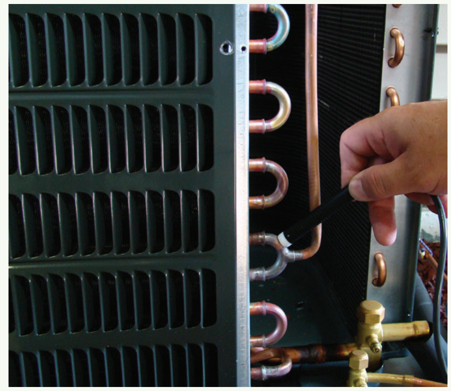
Check the temperature of the liquid as it enters and leaves the outdoor liquid line service valve.



There should be no more than a 3°F temperature change, if any. If excess temperature drop is detected, make sure the valve is completely open. If there is no excessive temperature drop, proceed to step 4.

STEP 4

Measure the temperature of the refrigerant lines at the individual outlets of the condenser coil parallel circuits.

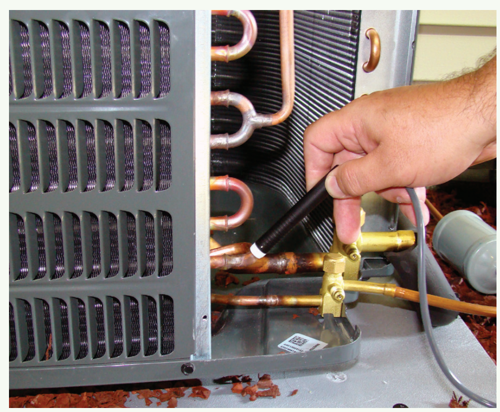


The temperatures will vary based upon the air flow pattern from the condenser fan, but no outlet temperature should be cooler than the outdoor air.

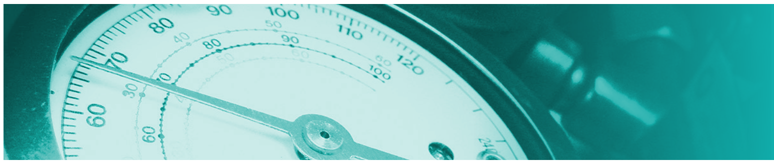
If a low temperature is detected, there is a pressure drop in the circuit where the temperature drop is detected. Repair or replace the coil as needed. If no noticeable temperature drop is found, proceed to step 5.

STEP 5

If the condenser coil has a subcooling loop, check the temperature at the exit of the subcooling loop.



The temperature of the liquid should be no cooler than the outside air temperature. If it is, there is a pressure drop in the subcooling loop circuit. If no problem is found, the condenser coil has no flow restrictions in it.



C

Superheat

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- What Affects Superheat Level C2
- How Superheat is Used by Service Technicians C3
  - Suction Vapor Superheat with a Flooded Evaporator Coil C3
  - Suction Vapor Superheat with a Starved Evaporator Coil C4
  - Suction Vapor Superheat with a Low Heat Load on the Evaporator Coil C4
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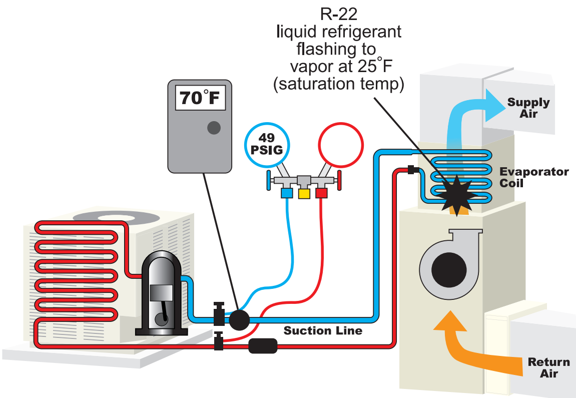
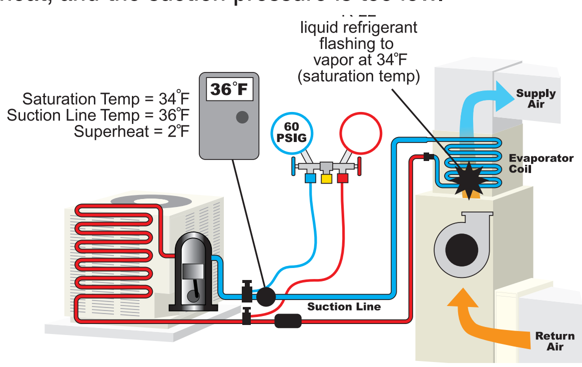
Suction Vapor Superheat with a Starved Evaporator Coil

If the refrigerant flow through the metering device is low, suction pressure will result. In this example, the refrigerant is R-22 at a gauge pressure of only 49 PSIG. R-22 at this pressure has a corresponding saturation temperature of 25°F. The temperature of the vapor leaving this coil is 70°F, which is 45°F warmer than the refrigerant saturation temperature at the outlet of the metering device. The high superheat level is a result of the liquid refrigerant completely boiling off into a vapor early in the coil circuiting, causing the vapor to travel an excessive distance in the evaporator coil circuiting.



Suction Vapor Superheat with a Low Heat Load on the Evaporator Coil

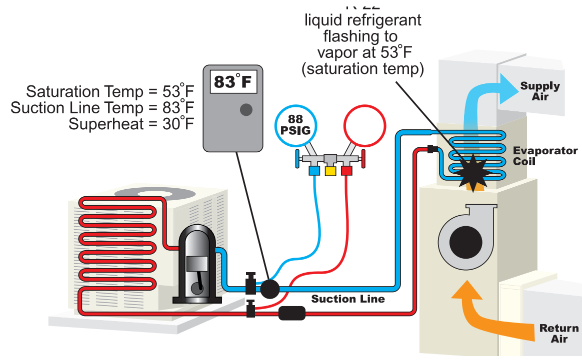
When the evaporator coil lacks heat to absorb, the refrigerant pressure will be below the charging chart requirement and the evaporator coil will struggle to vaporize the cold liquid refrigerant. The liquid will travel at a low pressure deeper into the evaporator circuiting. For example, let's say we had a suction pressure of 60 PSIG. The corresponding saturation temperature is 34°F. The temperature probe at the suction line outlet of the coil indicates a suction vapor temperature of only 36°F. There is only 2°F of superheat, and the suction pressure is too low.



With a low heat load, the refrigerant will run at a lower pressure into the evaporator and will have low superheat.

Suction Vapor Superheat with a High Heat Load on the Evaporator Coil

When the refrigerant in the evaporator is absorbing too much heat, pressures will be high and the liquid refrigerant in the evaporator will completely vaporize early in the circuiting. In this example, the system suction pressure is up to 88 PSIG. At 88 PSIG the saturation temperature of the refrigerant is 53°F. The suction line temperature at the outlet of the evaporator coil is at a temperature of 83°F, which is 30°F warmer than saturation temperature. If the coil had too much refrigerant, the superheat would be low, but in this case, it is too high.



With a high heat load, the refrigerant will run at a higher pressure into the evaporator and will have a much higher superheat temperature.

Service Procedure: Calculating Suction Vapor Superheat

Tools:

- Digital Temperature Probe
- Refrigerant Gauges

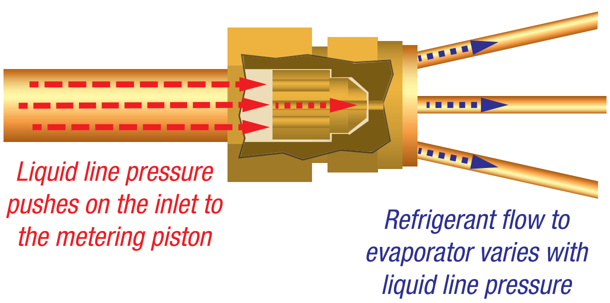
STEP 1

Run the air conditioner and allow system pressures and temperatures to stabilize.

Fixed Metering System Charging Using Superheat

Fixed Metering Systems and Superheat

Fixed metering devices are dependent on liquid line pressure. When the high pressure liquid travels through the piston hole, the liquid pressure at the outlet of the piston is much lower than the liquid pressure at the inlet of the piston. The amount of refrigerant that flows through the piston is affected by the pressure difference between the liquid line pressure at the inlet of the piston and the pressure at the outlet of the piston. The larger the pressure difference, the greater the rate of refrigerant flow through the piston.



The operation of a fixed metering piston is very similar to the operation of a garden hose with an attached nozzle. When the pressure on the hose is high, the flow out of the nozzle is also high. When the pressure is reduced, the flow is reduced. Fixed metering pistons operate in a similar manner with changes in liquid line pressure. At high liquid line pressure levels, the flow is high. When the liquid line pressure is low, the flow out of the piston is reduced.

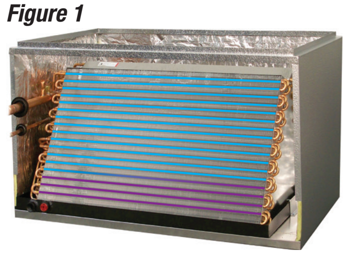
The resulting change in flow out of the piston results in fluctuations of refrigerant level in the evaporator coil circuiting. In other words, the evaporator coil will flood and starve based on the pressure in the liquid line.

Since a fixed-type metering device allows an inconsistent flow of refrigerant into the evaporator coil when the liquid pressure changes, the actual efficiency of the evaporator coil is affected both positively and adversely.

On a cool day, the liquid pressure falls, causing the flow of refrigerant into the evaporator coil to decrease. The lack of adequate refrigerant flow in the evaporator coil will cause the liquid to boil off (vaporize) early in the evaporator circuit. The remaining vapor travels through the evaporator circuiting and becomes highly superheated. This is poor for efficiency since no change of state is taking place in a large area of the evaporator coil.

On hot days with high liquid pressure, the evaporator coil is flooded with cold refrigerant. The liquid boils off very late in the evaporator circuit, which leaves very little circuiting for superheating. In this state, the capacity of the evaporator is high since most of the coil circuit is being used to boil off cold liquid to a vapor. Both evaporator coil conditions are illustrated below:

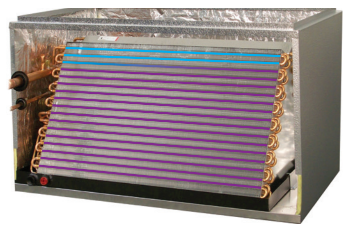
Figure 1



STARVED STATE
Cool outdoor air temperature drops the head pressure and corresponding liquid pressure.

Vapor refrigerant
Liquid refrigerant

Figure 2



FLOODED STATE
Hot outdoor air temperature increases the condensing pressure and corresponding liquid pressure.

Vapor refrigerant
Liquid refrigerant

The major cause of liquid pressure change is a change in outdoor air temperature. Superheat charging tables exemplify how superheat changes with changes in the outdoor air temperature. These tables are used to determine how much superheat should be present when operating with a correct system charge.

Typical Superheat Charging Table

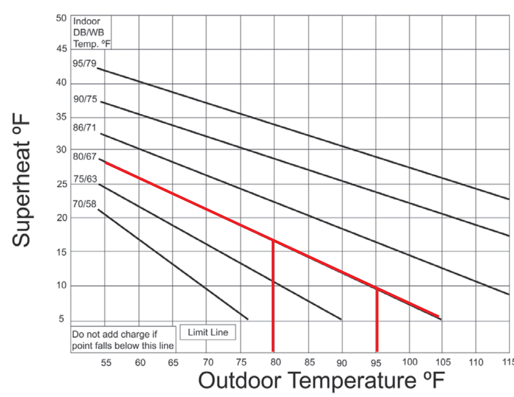


Table is courtesy of The Trane Company

In this superheat chart example, the 80°/67° indoor air temperature line has been highlighted. This line will be used to illustrate how outdoor air temperature affects the superheat level requirement on the chart.

The first example shows that at an outdoor air temperature of 95°F, the suction vapor superheat requirement is 10°F.

At 80°F outdoor air temperature, the superheat requirement is 17°F.

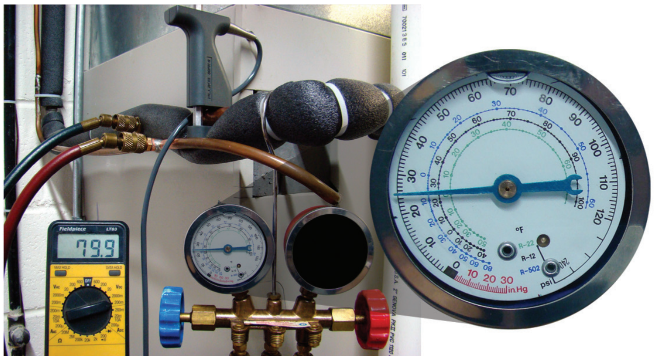
The superheat requirement is rising as the outdoor air temperature is dropping.

Based on the above examples, it should be clear that the outdoor air temperature must be measured and plotted onto a superheat charging chart to determine how much superheat should be present when the fixed metering system is operating with the correct charge.

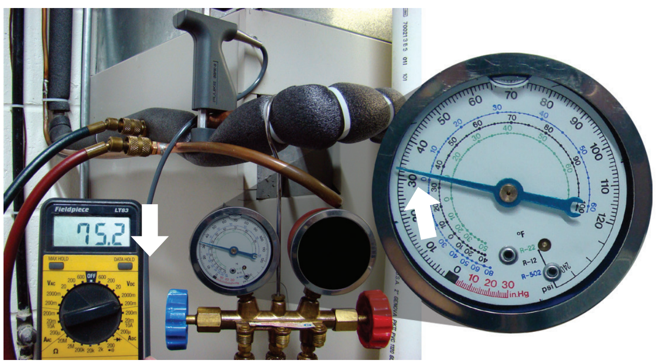
Superheat and Suction Pressure Changes as the Charge is Increased

When adding refrigerant to the system, the suction pressure will rise and the suction vapor superheat level will fall. The following series of figures show the changes to suction line temperature and suction pressure as charge is added to a piston equipped system.

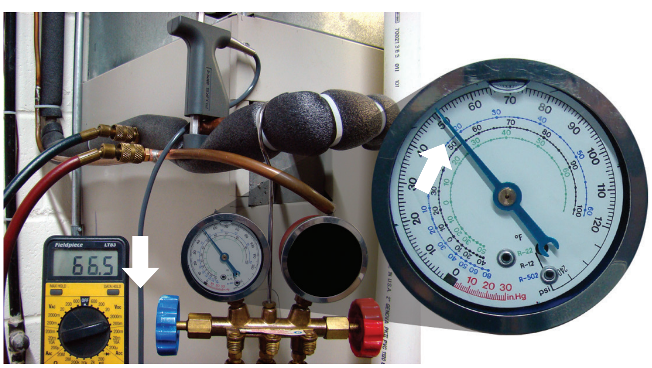
Suction pressure and suction line temperature before charge is added:



Suction pressure and suction line temperature after addition of 1/2 Pound of R-22:



Suction pressure and suction line temperature after addition of 1 Pound of R-22:

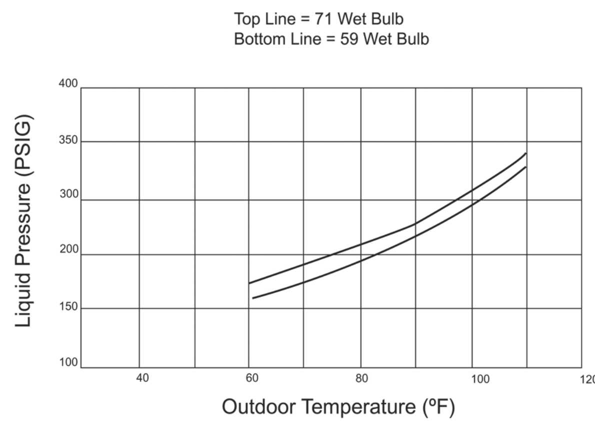


Liquid Pressure

The correct amount of liquid pressure must be present for the fixed metering device to flow the correct amount of refrigerant into the evaporator coil. The pressure level is affected by cleanliness of the condenser coil, the outdoor air temperature, and charge level.

Some systems include liquid pressure charts that plot the required liquid pressure at a given outdoor air temperature and indoor heat load level. Other systems may not include these charts.

Typical Liquid Pressure Chart



If the system comes with a liquid pressure chart, charge the system to the required superheat level. Then compare the operating liquid pressure to the value indicated by the liquid pressure chart. If the indicated chart value pressure and the measured pressure are far apart, the metering piston may be the wrong size, the air volume incorrect, or suction line pressure loss is out of the acceptable range.

Notice the outdoor air temperature range on the chart only goes as low as 60°F. At temperatures below 60°F, liquid pressure is too low to properly charge the system.

If system operating pressure charts are unavailable, make certain that suction vapor superheat is operating at the correct level and that suction pressure falls within ranges that equal typical evaporator coil saturation temperatures as indicated elsewhere in this chapter.

If the correct suction vapor superheat range cannot be reached, and the suction pressure appears to be off, check for correct piston sizing, air volume, and suction line sizing.

Liquid Pressure versus Piston Bore Size

Make certain the metering piston is the correct size when charging a fixed metering system. Piston sizes are matched to the operating head pressure of the outdoor condensing unit. Low SEER units with high head pressure will have smaller bore requirements than high SEER units operating with lower head pressure.

D

Subcooling

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- The Importance of Subcooling D2
- How Subcooling Changes D2
- Subcooling and Heat Load D3
- Condenser Coil Size and Subcooling Design Levels D3
- Overcharging for More Subcooling May Result in Abnormal Condensing Pressure D3
- Getting the Right Amount of Subcooling D4
- Condensing Pressure and Liquid Subcooling use in Diagnostics D4
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- Subcooling Charging Charts D8
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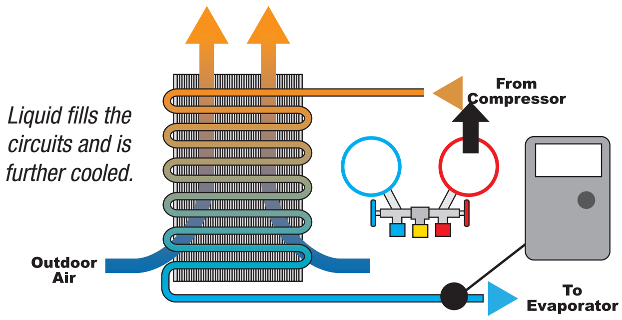
- Undercharged TXV Systems D10
- Overcharged TXV Systems D10
- Service Procedure: TXV Charging D11

The vapor refrigerant will condense to liquid early in the condenser circuiting, thus the refrigerant travels farther as a liquid in the condenser. The farther it travels as a liquid, the more its temperature will drop.

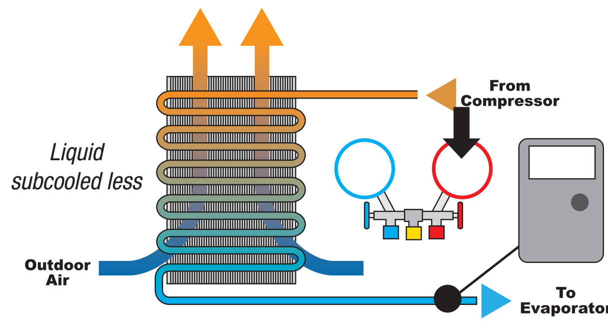
If the refrigerant level is low, the pressure in the condenser will be low, and less liquid will be condensed from the hot vapor. The vapor refrigerant will condense to liquid late in the condenser circuiting, thus the refrigerant travels farther as a vapor into the condenser circuiting. The farther it travels as a vapor, the less its temperature will drop.

At high charge levels, the subcooling will be high. At low charge levels the subcooling will be low.

Adding charge increases subcooling level



Removing charge reduces subcooling level



Subcooling and Heat Load

If the metering device is a fixed piston type, changes in the indoor air heat load will also change the subcooling level. As heat load changes and suction pressure changes, the amount of subcooling will fluctuate. For example, at low heat loads on the evaporator coil, the indoor coil will flood and the condenser will starve. The result will be low subcooling.

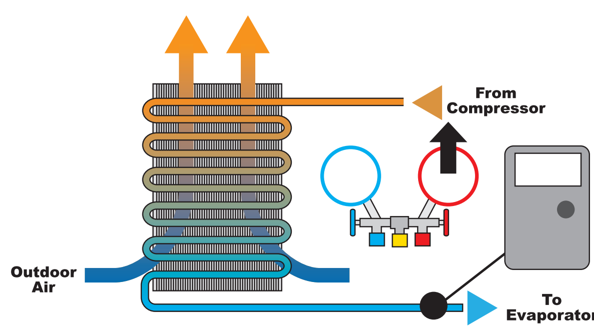
Condenser Coil Size and Subcooling Design Levels

To reach higher energy efficiency ratings, manufacturers of air conditioning systems keep the condensing pressure as low as possible without reducing liquid line pressure to a level that prevents the metering device from flowing adequate refrigerant into the evaporator circuiting. To lower condensing pressure, the size of the condenser coil is increased. The increase in size of the coil has resulted in higher levels of subcooling due to the large amount of refrigerant in these systems. It is common to see subcooling levels under normal charge levels in the range of 10°F to 20°F. Subcooling requirements are typically printed on the condensing unit dataplate.

Overcharging For More Subcooling May Result In Abnormal Condensing Pressure

The condenser coil has a limited amount of piping to hold refrigerant. If the system liquid line pressure drop is found to be excessive and flash gas is forming in the liquid line, compensating by adding charge to the system to increase the liquid subcooling level may cause the condensing pressure to rise too high. The system will then operate with poor compressor performance and capacity. In that case, the pressure drop in the liquid line will need to be reduced by increasing the line set size, or reducing the number of elbows and fittings if possible.

Overcharging for more subcooling



Liquid subcooled but circuit is too full

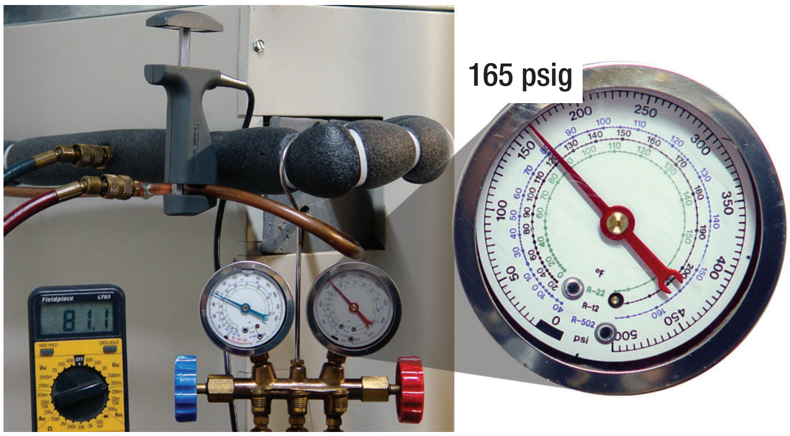
Excessively large liquid line pressure loss is due to high liquid lifts, under-sized refrigerant lines, and too many liquid line accessories.

System Subcooling Level Requirements

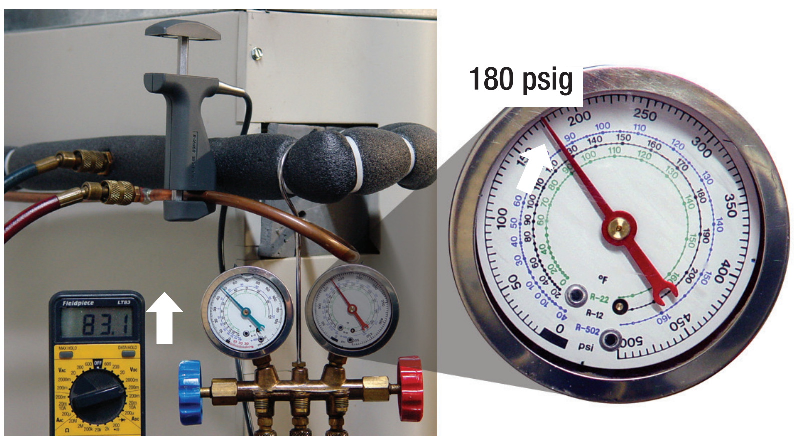
Every system requires a different amount of liquid subcooling based on the pressure drop in the liquid line and the design and size of the condenser coil. In some cases, the subcooling level required for correct operation of the system is printed on the nameplate of the condensing unit. As previously stated, 10°F of subcooling will overcome design pressure drop for most properly sized liquid lines. However, some systems may require more subcooling. These systems are typically high efficiency models where the outdoor condenser coil is very large. The large coil may require significant refrigerant charge to reach the required condensing pressure. The high subcooling is a result of the large amount of refrigerant in the condenser coil.

Liquid Subcooling Levels as Charge is Added

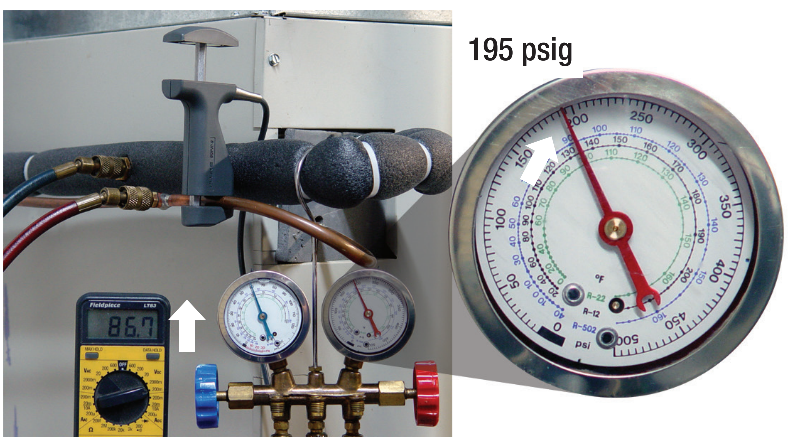
In the following series of figures, liquid line pressure and liquid line temperature are shown as refrigerant is added to an R-22 system. An interval of 15 minutes was allowed between each change in charge to allow for stabilization of liquid line temperature and pressure.



Liquid Line pressure and Liquid Line temperature before charge is added.



Liquid line pressure and liquid line temperature after addition of 1/2 pound of R-22.



Liquid line pressure and liquid line temperature after addition of 1 pound of R-22.

Undercharged TXV Systems

The Evaporator Coil

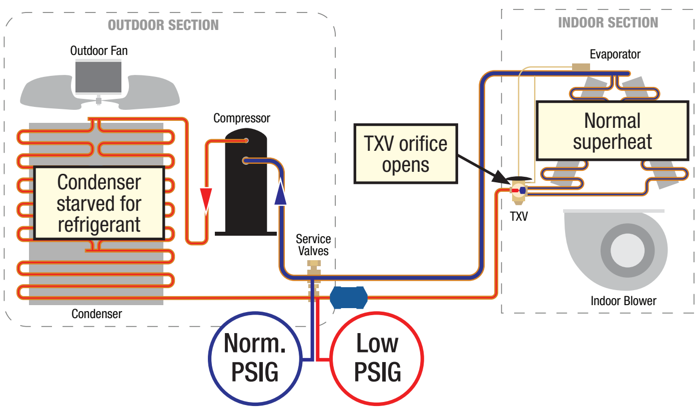
The evaporator coil may operate normally with the correct suction pressure and suction vapor superheat. During periods of high liquid line pressure drop, the system may lack adequate subcooling, resulting in flash gas forming in the liquid line. The flash gas will cause fluctuations in suction pressure and suction vapor superheat.

The Compressor

If the charge level is low enough to cause high suction vapor superheat, the compressor will run hot and may overheat. The compressor motor internal temperature protection may trip and shut down the compressor. High operating temperatures may cause oil breakdown and bearing wear or damage.

The Condenser Coil and Liquid Subcooling Levels

The condenser coil will operate at lower than required pressure. The lack of charge will result in lower than required liquid subcooling level. The low subcooling level may cause flash gas to form in the liquid line.



Summary: TXV Metering System & Undercharge

- Normal and stable suction pressure if charge is slightly low. Suction pressure will fall to low levels if charge is excessively low.
- Superheat may be normal or high.
- Compressor will be hot.
- Condensing pressure will be low. Liquid subcooling will be low.

Overcharged TXV Systems

The Evaporator Coil

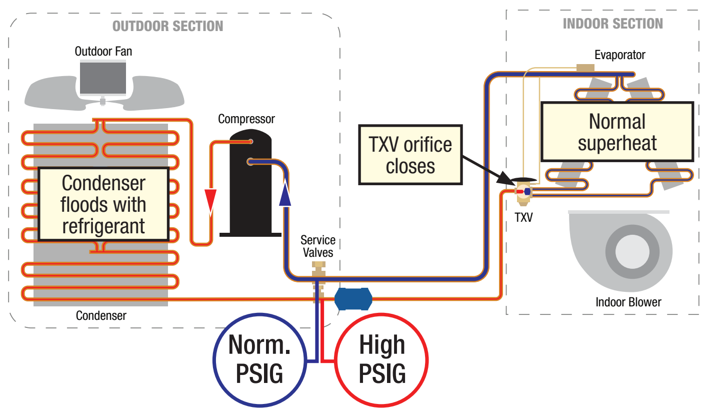
The evaporator coil may operate normally with the correct suction pressure and suction vapor superheat. The expansion valve will throttle back flow of refrigerant in an attempt to maintain the correct suction vapor superheat levels.

The Compressor

The compressor will lose capacity due to elevated condensing pressure caused by an overcharge condition in the condenser. The expansion valve will prevent excessive flooding of the evaporator coil.

The Condenser Coil and Liquid Subcooling Levels

The condenser coil will operate at higher than required pressure. The excess charge will cause high condensing pressure and low compressor capacity. The liquid subcooling level will be abnormally high.



Summary: TXV Metering System & Overcharge

- Suction pressure will be normal or slightly elevated.
- Superheat will be normal.
- Compressor capacity will be low.
- Condensing pressure and liquid subcooling will be high.

E

Refrigeration Circuit Diagnostics

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- Service Procedure: Diagnosing Excessive Suction Line Pressure Loss E2
- Service Procedure: Diagnosing Low Heat Load E3
- Service Procedure: Diagnosing a Starved Evaporator Coil E3
- High Suction Pressure E5
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- High Suction Pressure with High Superheat E10
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- High System Charge: Fixed Metering Device and TXV E14
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- TXV E24

Troubleshooting the Refrigeration Cycle

Introduction

To properly troubleshoot refrigeration circuit problems, a technician must understand, among other things, how the system works, why refrigerant pressures rise and fall, and how to calculate - and the importance of - suction superheat and liquid subcooling. It is recommended that readers have a firm understanding of the topics, lessons, and procedures covered in the previous chapters of this book before exploring the topics and procedures discussed in this chapter. This chapter references terms, concepts, and procedures covered earlier in the book. Referring back to the appropriate sections, as needed, might prove to be helpful.

Refrigeration cycle troubleshooting begins with determining what the system should be doing when it is operating properly. This includes using charging charts to determine what the optimal pressures should be for a given environment. Once the optimal operating conditions are known, the system can be analyzed by comparing what should be happening to what is actually happening. Be aware that for every one-pound deviation from the required suction pressure, the system capacity will be reduced by approximately 1% if R-22, and by 0.6% if R-410A.

Diagnosing Fixed Metering System Problems

Fixed metering refrigeration cycle problems can exhibit the following symptoms:

- Low suction pressure.
- High suction pressure.

The following diagnostic procedures will help identify the cause of low suction or high suction pressure in a fixed metering system.

For fixed metering systems, the suction vapor superheat requirement should be calculated, and liquid subcooling should be 10°F to 15°F degrees, depending on the specific piece of equipment.

Low Suction Pressure

If the system suction pressure is too low, there are three potential causes:

- Excessive pressure loss in an undersized or kinked suction line.
- Low heat load (this could be a dirty evaporator coil, a lack of indoor air volume, or simply a cold return air temperature).
- A starved evaporator coil due to a restriction or charge-related problem.

Note that low suction pressure may cause ice or frost to form on the surface of the evaporator coil.

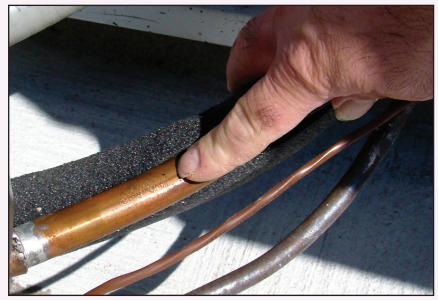
Service Procedure: Diagnosing Excessive Suction Line Pressure Loss

Tools:

- Refrigeration Gauges
- Thermometer

STEP 1

Inspect the suction line for any obvious kinks. If no kinks are seen, the line size may be the problem, install a pressure tap on the suction line at the outlet of the evaporator circuit.



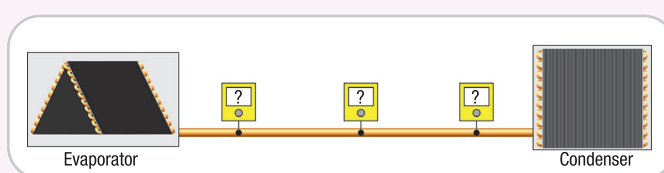
STEP 2

Run the system and compare the pressure at the outlet of the evaporator circuit to the suction pressure at the outdoor condensing unit.

If there is a pressure drop in excess of 3 PSIG for R-22 (5 PSIG for R-410A), the line is either undersized, or may be kinked. Evaluate the suction line to determine if it is undersized.

STEP 3

To check for an unseen kink or obstruction in the suction line, measure the temperature of the suction line at various points on the line. If a temperature drop in excess of 3°F is detected across two points, there is a pressure drop between those points. Locate the problem and repair the line as needed.



Check the temperature at different points along the suction line in order to find an excessive drop in temperature.

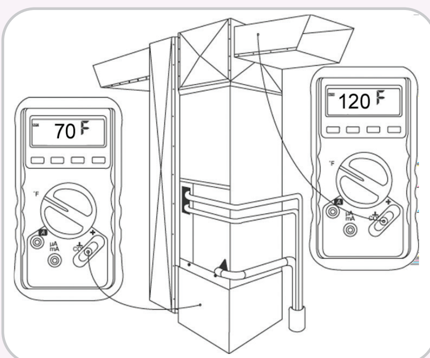
STEP 3

Check the temperature of the liquid line at the inlet and outlet of the field installed liquid line drier, and 1 foot before the TXV device.

There should be no noticeable difference in liquid line temperature between these points. If there is a noticeable temperature drop, flash gas may be forming in the liquid line. The drier may be restricted, or the liquid line may be undersized or kinked. Evaluate the liquid line to determine if the line is undersized, and check for and repair any kinks or restrictions in the liquid line. Proceed to the next step if the liquid line checks out OK.

STEP 4

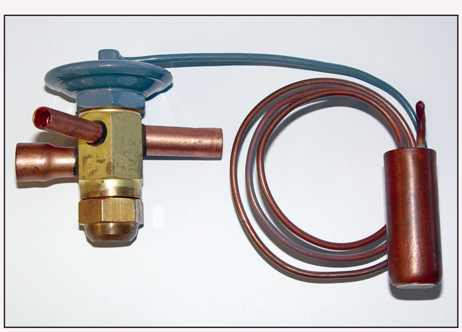
Inspect evaporator coil for dirty surface and clean if needed. Adjust air volume to 350-450 CFM for each ton of cooling.



Proceed to the next step if air volume and heat load check out OK.

STEP 5

If the TXV continues to hunt, even after the air volume, a clean evaporator coil, and a properly sized and unobstructed liquid line have been verified, The TXV may be oversized or overfeeding. Ensure the TXV sensing bulb is properly positioned and insulated as per manufacturer requirements. Check the size of the TXV and compare to the manufacturer's specified size requirement. Replace the TXV with one that matches the manufacturer specifications.



Low Suction Pressure with High Superheat

Possible Causes:

- Low charge.
- Restriction in the refrigeration system.
- Undersized or Underfeeding TXV.

Systems operating in this condition lack refrigerant in the evaporator circuits. First, confirm the system is properly charged. If the addition of charge does not significantly change system pressures, or if the discharge pressure rapidly rises, there is likely a restriction in the system or a problem with the TXV.

Service Procedure: Correcting Low Suction Pressure
with High Superheat

Tools:

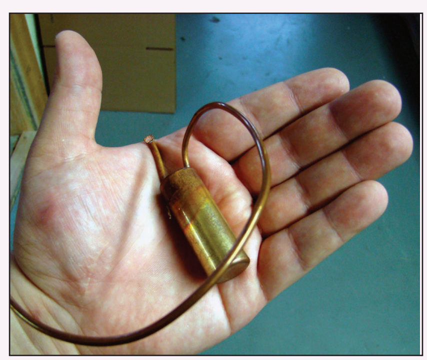
- Refrigeration Gauges
- Thermometer

STEP 1

See Service Procedure: Correcting Pressure Hunting with Fluctuating Superheat, and perform Steps 1 through 3 to determine if any line restrictions are present.

STEP 2

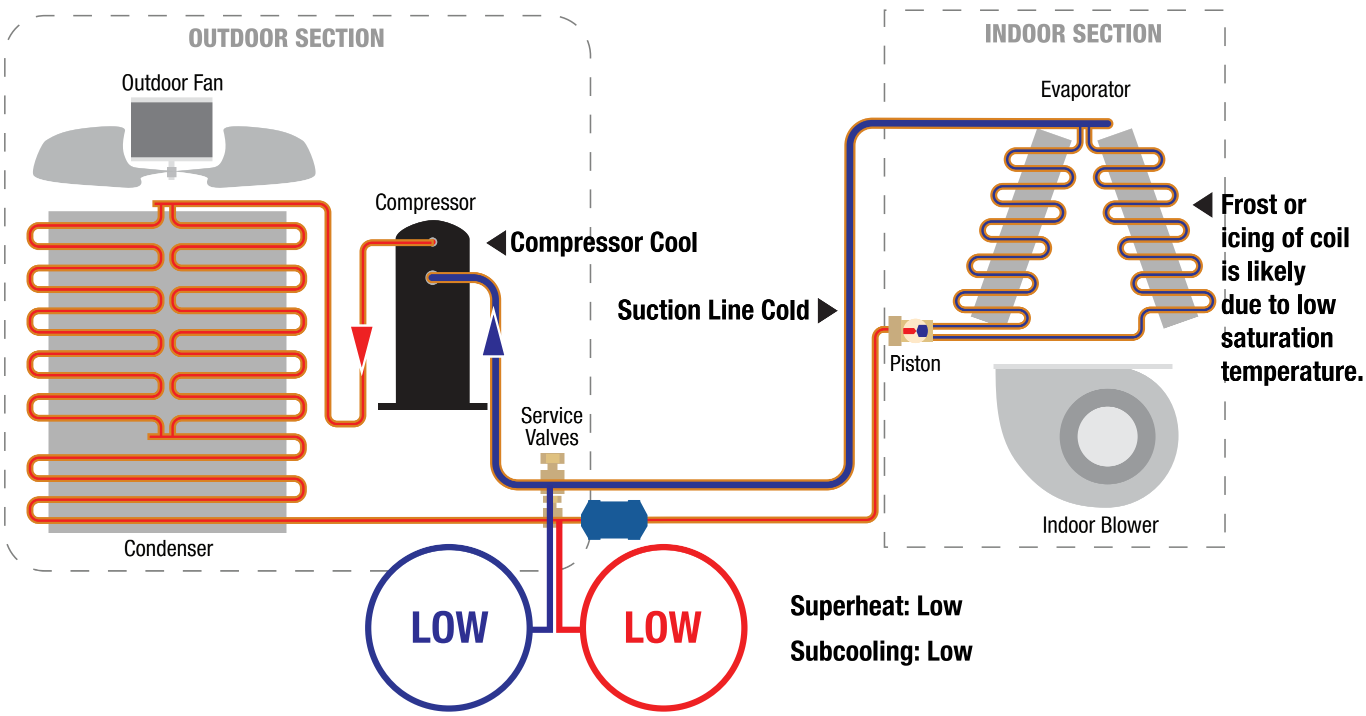
If no restrictions are present, remove the TXV sensing bulb from the suction line. With the system running, warm the TXV sensing bulb in your hand. The heat from your hand should momentarily cause an increase in the flow of refrigerant into the evaporator coil as noted by an increase in suction pressure. You might also be able to hear the intensity of refrigerant flow into the evaporator increase. Note: A line pressure tap may need to be installed at the evaporator coil to observe this pressure fluctuation.



If the suction pressure increases, ensure the TXV sensing bulb is properly positioned and insulated as per manufacturer requirements. If no pressure change is detected, replace the TXV with one that matches the manufacturer specifications.

Quick Reference Diagram

Low Evaporator Heat Load: Fixed Metering Device and TXV



Problem Overview

Low evaporator heat loading occurs when there is not enough heat being absorbed by the refrigerant in the evaporator coil.

Symptoms (Fixed Metering)

Systems running with low evaporator heat load will run at pressures below factory required levels. Abnormally low superheat and subcooling levels will be present when the evaporator coil lacks heat load.

The low heat load condition may cause the evaporator coil temperature to be very cold. Ice or frost may form on the evaporator surface and suction line surface. The compressor shell may sweat and the hot gas temperature will be cool. In extreme cases, superheat may fall to zero degrees and liquid can flood back to the compressor.

Symptoms (TXV Metering)

Same as above but TXV may hunt in an attempt to maintain proper superheat.

Causes

- Dirty return air filter.
- Dirty indoor fan blower assembly.
- Indoor fan motor not on high speed (incorrect air volume).
- Undersized ductwork.
- Dirty evaporator coil.
- Thermostat setpoint too low.

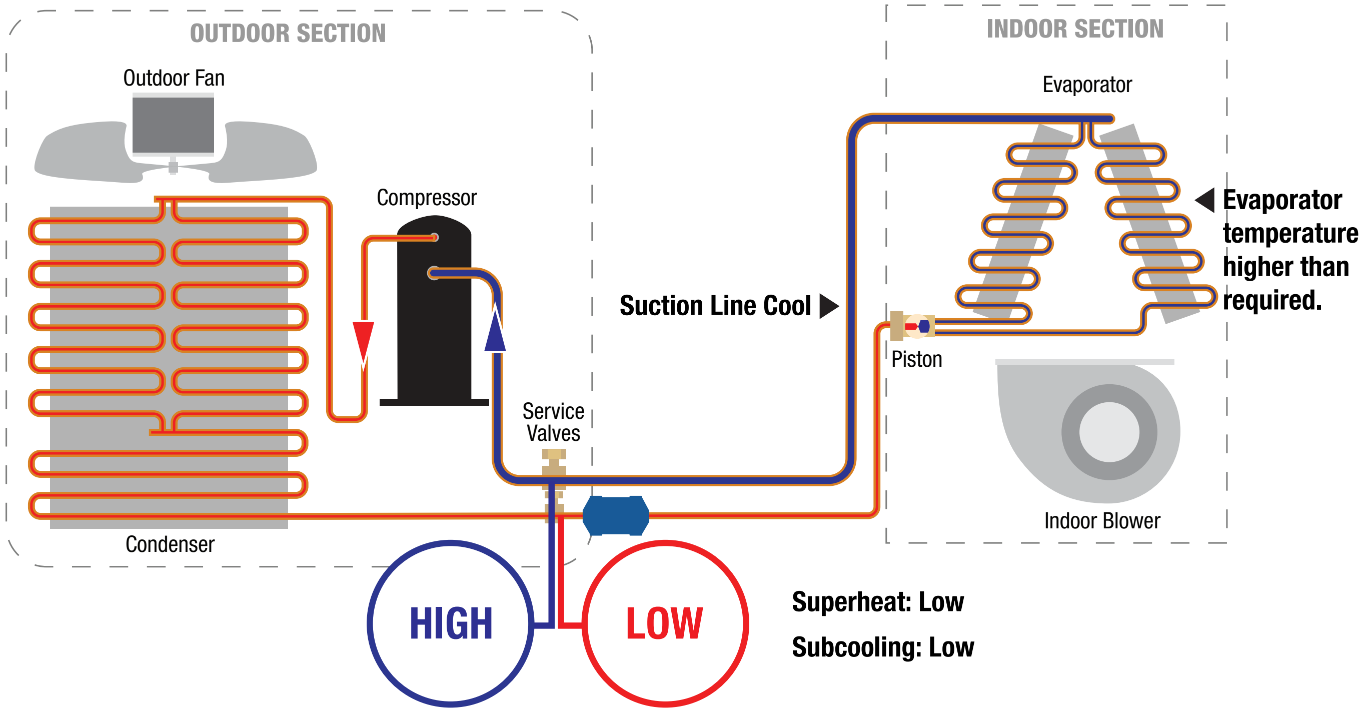
Recommended Procedures:

Diagnosing Low Head Load (See page E3)

Air Volume Measurement (See Chapter J: Air Volume)

Quick Reference Diagram

Over-Feeding Metering Device: Fixed Metering Device and TXV



Problem Overview

An evaporator coil that is receiving a higher than normal flow of refrigerant through the metering device will operate in a flooded condition. The system may experience high humidity complaints, compressor starting problems, or compressor failure.

Symptoms

The metering device separates the high-pressure side of the system from the low-pressure side of the system. When an overfeeding condition is present, the low side of the system operates in a flooded state, while the high side of the system operates in a starved state. The suction pressure will be high and the superheat low. The liquid pressure and subcooling will be low.

If the system is using a reciprocating type of compressor, it may appear that the compressor valves are leaking.

Causes

- Oversized piston (Fixed Metering).
- Dirty piston seat not allowing metering device to seat properly.
- TXV sensing bulb not insulated or in good contact with suction line.

Recommended Procedures:

1. Call for cooling.
2. Close the liquid line service valve and pump the system down. If the system does not hold a pump down, and the liquid line service valve is properly closed, replace the compressor. (Reciprocating Only)
3. If the system holds a pump down, inspect the metering device to determine if it is seated properly or too large. (Fixed Type)
4. If the system is using a TXV, make sure the sensing bulb is properly insulated and in good contact with the suction line. If it is not, correct the problem. If it is, replace the TXV.

F

High Voltage Circuit

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Sump(Crankcase) Heater Circuit

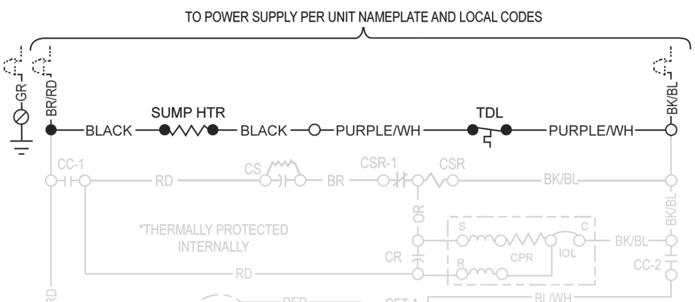
Introduction

Refrigerant will move to the coldest point in a refrigeration system when the system is not calling for compressor operation. If the system is off and the outdoor air temperature is cooler than the temperature of the air at the evaporator coil, the refrigerant migrates to the cold compressor. The liquid refrigerant must be boiled out of the compressor shell prior to the compressor starting. If liquid refrigerant is present during compressor start-up, damage to the compressor could occur.

The sump (crankcase) heater circuit prevents liquid refrigerant from migrating to the compressor shell during the off cycle. The circuit protects the compressor by energizing a high voltage heater that warms the compressor shell during periods when the compressor is not running.

Circuit Operation

This schematic diagram of a typical single-phase condensing unit shows a highlighted area for the sump heater circuit.



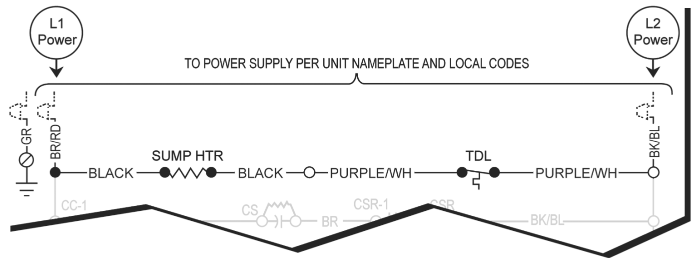
The circuit consists of two components, a heater labeled SUMP HTR, and a normally closed heat activated switch labeled TDL. The TDL switch is a discharge line thermostat that closes its contacts when the compressor is off, and the discharge line is cool, to energize the heater. When the compressor is operating, the discharge line gets hot and the TDL opens its contacts to de-energize the heater. Electrically, the heater and temperature-activated switch are wired in series with each other.

The circuit operates the heater by applying both L1 and L2 power to each side of the heater when switch TDL closes. This means the heater is a 240VAC heater, since the voltage between L1 and L2 is 240VAC. When switch TDL is open, the electrical circuit to the heater is broken and the heater remains off.

The wires that connect the heater and switch are identified by color. The heater has two black wires at either side connected to a wire labeled PURPLE/WH (purple wire with a white stripe). The other side of the switch also has a purple wire with white stripe. This wire is connected to wire BK/BL (black wire with a blue stripe). On the L1 side of the circuit the sump heater's black wire is connected to a wire labeled BR/RD (brown wire with a red stripe).

Notice that L1 is supplied to the circuit via the BR/RD wire. By following the wire color code and schematic diagram shown, the circuit can be easily traced out.

L1 power is applied directly to the left side black heater lead via the BR/RD wire. L2 is supplied to the right hand side of switch TDL via the PURPLE/WH wire. With power present at both L1 and L2, the heater is ready to operate when switch TDL closes.



In this diagram the brown wire with red strip can be found supplying L1 power on the left side.

If this switch were to stick and remain in the closed position, the heater would remain on during compressor operation. The compressor would likely overheat and would open its motor winding temperature protector.

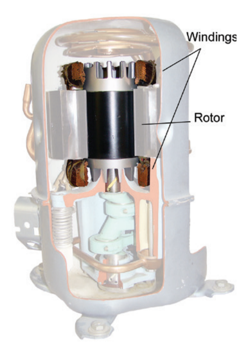
The TDL shown here is used to shut the heater off when the discharge line reaches a specific temperature during compressor operation.

Single-Phase Compressor Circuit

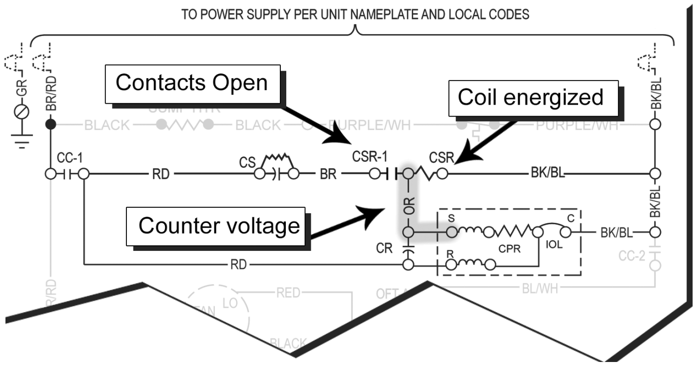
Introduction

A single-phase compressor electrical circuit provides power to the compressor's motor whenever a call for cooling operation is received from the thermostat circuit.

Some motors used in single-phase compressors are Permanent Split Capacitor type motors, or more commonly referred to as PSC motors. The PSC motor is hermetically sealed in the compressor shell. The motor's capacitor is located in the condensing unit's electrical box. The other component used in the circuit is the electrical contactor, which is also located in the unit's electrical control box.



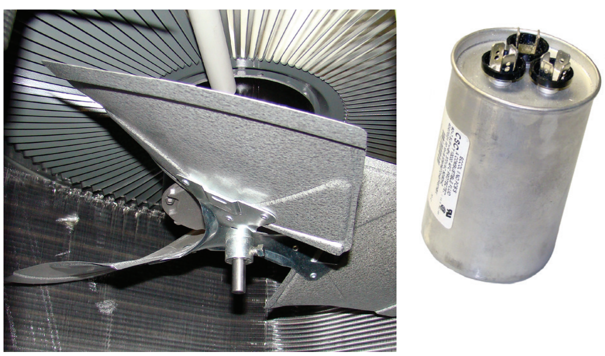
The PSC motor of the compressor is hermetically sealed and is inaccessible to service technicians.



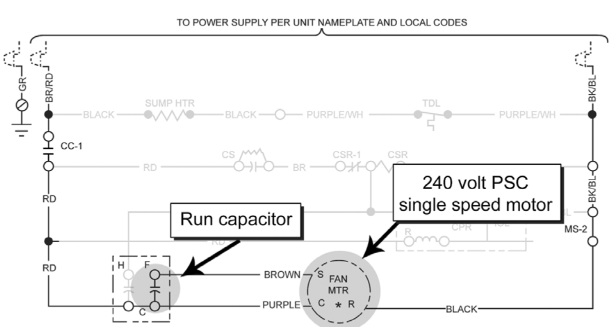
Single-Speed Condenser Fan Circuit

Introduction

The condenser fan circuit energizes the condenser fan motor on a call for cooling operation. The circuit is comprised of a 240VAC PSC single speed motor and run capacitor. The speed of this motor will remain constant regardless of the outdoor air temperature; therefore head pressure problems can be encountered when outdoor air temperature falls below the minimum allowable level. In the case of residential condensing units, the typical minimum allowable run operation for this type of circuit is 55° F.



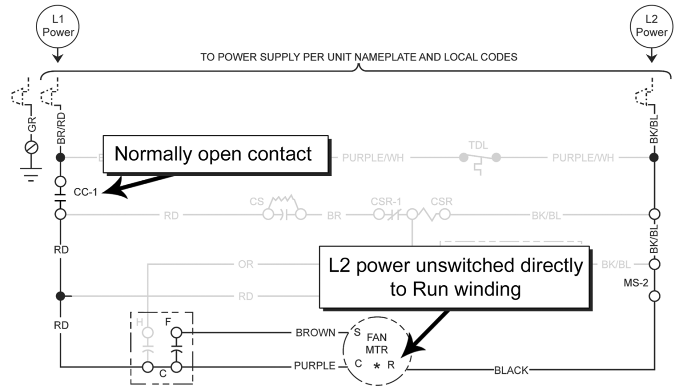
The single speed condenser fan circuit consists of a 240VAC PSC single speed motor and a run capacitor. The diagram below shows the wiring configuration of the circuit.



Circuit Operation

The L2 leg of the supply voltage is wired directly to the condenser fan motor's run winding terminal via a connection on the load side terminal of contact L2.

Since the L2 signal is not switched, there will be 120VAC potential to ground from the run terminal of the condenser fan motor whenever line voltage is applied to the condensing unit.



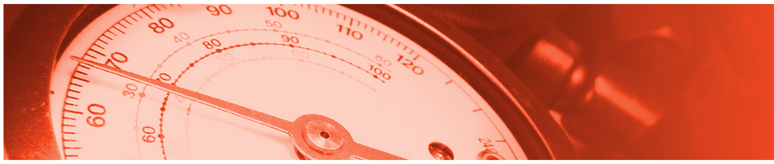
The L1 leg of the supply voltage is delivered to the line terminal of the cooling contactor by the BR/RD (brown and red) wire. A normally open set of contacts labeled CC-1 prevents the L1 voltage from reaching the condenser fan motor when no call for cooling is present.

A red wire (RD) is connected to the load side terminal of the CC-1 contacts. The wire delivers the L1 power to the condenser fan motor's common winding when a call for cooling occurs. When de-energized, some voltage will be present from the start and common windings to ground when there is 120VAC potential applied to the run terminal of the condenser fan motor by the L2 leg.

On a call for cooling, 24VAC is applied to the cooling contactor's 24VAC solenoid coil, which causes the contactor to close its normally open set of contacts. The contactor's CC-1 contact closes and allows the L1 120VAC voltage to pass to the load side terminal.

The red wire carries this voltage to the common winding terminal on the condenser fan motor. With L1 and L2 voltage now at the motor's common and run terminals, the motor starts.

When the call for cooling ends, 24VAC is removed from the cooling contactor's 24VAC solenoid, which causes the contactor to de-energize. The L1 120VAC voltage is removed from the common winding terminal, causing the motor to de-energize.



G

Compressors

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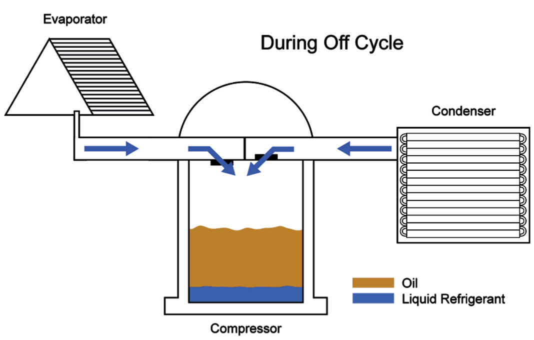
Why Compressors Fail Mechanically

Whether the compressor is a scroll or reciprocating model, causes of mechanical failure are similar for both compressor types. Mechanical failure can typically be isolated to damage from liquid refrigerant entering the compressor, moisture, and high discharge gas temperatures due to abnormal refrigeration circuit operation. The potential for each problem to cause damage can be minimized by proper installation and service practices.

Liquid Migration into the Compressor Oil during Shut Down Periods

Liquid refrigerant entering the compressor will cause lubrication problems. Because liquid refrigerant will migrate to the point of lowest pressure and temperature, which is usually the compressor oil, liquid refrigerant enters the compressor during off cycle periods. When the compressor is started, the liquid refrigerant that has migrated into the compressor oil vaporizes, which causes the refrigerant oil to foam. The oil foam is then carried out of the compressor along with the vapor refrigerant. The oil enters the refrigeration circuit coils and tubing. The compressor is now operating with a lack of oil reaching its internal weight bearing surfaces. Bearings are scored, and the compressor motor must work harder. This additional work results in an increase in the amperage draw of the compressor. Additionally, the bearing damage may cause compressor starting problems.



During off cycles, the liquid refrigerant will move from areas of higher pressure, the Evaporator and Condenser, to areas of lower pressure, namely the compressor.

The amount of liquid refrigerant migration increases as the charge level of the system is increased. High-efficiency systems with very large condenser coils, often have larger than expected refrigerant charges. These larger charges have the potential to increase the amount of liquid migration. Long line set applications will also result in higher charge levels.

To minimize liquid migration, a crankcase heater should be installed on the compressor. Crankcase heaters will keep the compressor oil warm and prevent excessive liquid migration from occurring during periods where the system is off. Most air conditioning system manufacturers equip their systems with a factory-installed crankcase heater.

This well type heater should be installed in the heater well under the compressor.

The recommended level of charge requiring a crankcase heater to be installed is surprisingly low. In some cases, scroll compressors -due to their small shell- require a crankcase heater installed when as little as 7 lbs. of refrigerant charge is present the system. To determine the charge level where a crankcase heater is required, consult the manufacturer of the system. If in doubt, install a crankcase heater on the system as a preventative measure.

Liquid Flood Back during System Operation

Liquid refrigerant may leave the evaporator when the system heat load is low, when the system is overcharged, or when the metering device is overfeeding the evaporator. When liquid refrigerant leaves the evaporator coil, the suction line carries it back to the compressor. If liquid refrigerant is present in the suction vapor, the liquid refrigerant will be vaporized by the compressor motor windings. Like in the case of liquid migration, the vaporizing refrigerant will foam the refrigerant oil. The refrigerant oil will travel with the discharge vapor into the condenser coil and through the refrigeration circuit. As the oil travels through the system, the compressor operates without proper lubrication, resulting in potential bearing damage inside of the compressor.

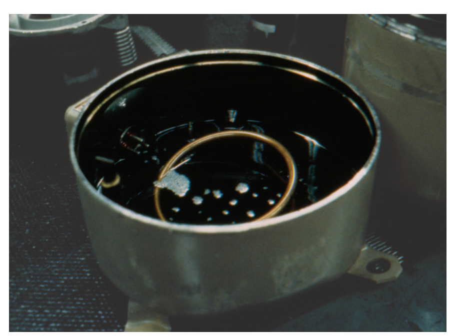


Image Courtesy of Trane

If there is liquid refrigerant present in the suction vapor, it will be vaporized by the compressor motor windings and will foam the refrigerant oil.

Unique Features of Scroll Compressors and Reciprocating Compressors

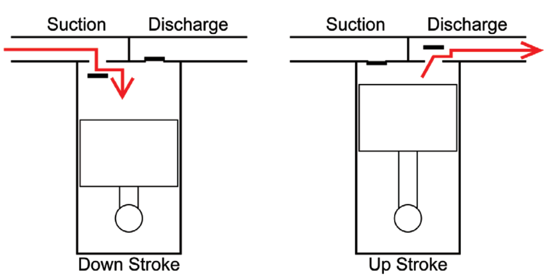
First of all, it must be pointed out that internal components on hermetically-sealed compressors cannot be acessed. All diagnostic information must be gathered from the motor winding terminals and from the refrigerant gauge ports. From the gauge ports, the system pressures can be monitored and the oil can be tested. Beyond that, the compressor components are beyond reach. Therefore, diagnostic decisions must be made based on the external information gathered at the electrical terminals and pressure ports.

Reciprocating Compressor Process

Reciprocating compressors have one or more pistons that move up and down within one or more cylinders. At the top of the cylinder are tensioned valves that open and close based on the pressure difference across the valve as well as whether the piston is moving up or down within the cylinder. These valves are called the suction and discharge valves. When the piston travels downward, the suction valve is drawn open to allow refrigerant to enter the cylinder. When the piston travels upward, the suction valve is forced closed and the discharge valve opens to allow the refrigerant to escape into the discharge line of the compressor.

Reciprocating Compressor

Image courtesy of Trane



The piston does not travel all the way to the top of the cylinder. There is a small volume of clearance left that allows droplets of liquid to clear the cylinder without causing damage to the compressor due to the fact liquid cannot be compressed. This liquid may be refrigerant or oil. The area of clearance is called the clearance volume.

Scroll Compressor Process

Scroll compressors rotate two nested, helix-type assemblies, called scrolls, that compress the refrigerant vapor trapped between them. One scroll is stationary, while the other orbits or wobbles. When energized, the compressor motor rotates the rotor assembly, which is attached to the scroll. Refrigerant is drawn into the space between the scrolls, where it is compressed, and discharged from the compressor via the discharge line.

Scroll Compressor

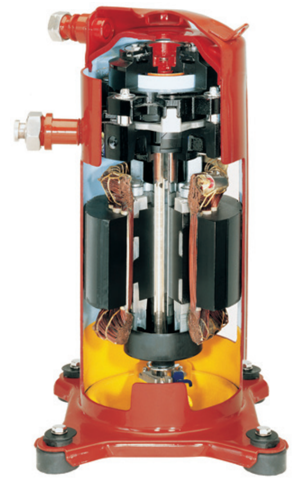


Image courtesy of Trane

Scroll Separation

Most scroll models have an internal safety device that allows the scrolls to separate if excessive liquid refrigerant or oil slugs enter the scrolls. The scrolls will not compress the liquid, and the liquid will pass without damaging the scroll compression assembly. This is called separating. During scroll separation, a loss of pumping efficiency is experienced.

Discharge Check Valve

A discharge line check valve is located inside the compressor shell. This check valve will help prevent hot discharge from circulating back through the scrolls during an off period. The check valve will keep the discharge pressure high, yet internally, the compressor is in an unloaded state. This means the suction and discharge sections of the compressor are at the same pressure.

Low Vacuum Protection

Pulling a compressor into a vacuum can damage the compressor. Starting a compressor in a vacuum may cause the motor to fail electrically, and could cause serious injury if one of the motor terminal pins were to come loose from the compressor shell. To prevent low vacuum operation, modern scrolls have an internal safety feature that will cause the scrolls to equalize pressure if the discharge gas pressure is 10 times higher than the suction pressure. The equalizing of discharge gas to the suction side of the system will open the compressor internal temperature protector and shut the compressor off.

Pressure Test Limits

When leak testing systems with nitrogen, the maximum pressure used should not exceed 150 PSI. If exposed to excessive nitrogen pressure, compressor shells can and have exploded. UL ratings require the compressor shell to be able to withstand a specific amount of pressure based upon the type of refrigerant in the system. This pressure can be pretty low considering many nitrogen regulators can supply 500 PSI. In fact, R-12 compressors by UL

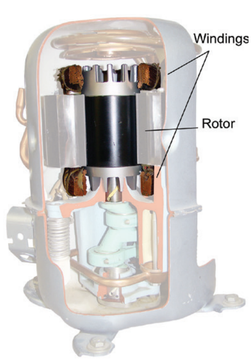
Compressor Features Summary

- Both reciprocating and scroll compressors have the ability to handle small amounts of liquid refrigerant in the compression process.
- Compressors in residential systems should not be operated in a vacuum.
- Do not leak test compressors above 150 PSIG nitrogen pressure.
- Compressors may not start at voltages below 90% of their rated minimum voltage.
- Crankcase heaters are required when required system charge is above specified limits by manufacturers.
- Internal bearing damage can be diagnosed when compressor manufacturer performance data is available. Contact compressor manufacturers for information on obtaining performance data tables.
- Some reciprocating compressors were not designed to hold a pump down of refrigerant in the condenser.
- Two-step scroll compressors should never have the unloading solenoid energized if the low pressure switch is opened.

Compressor Electrical Operating Characteristics (208/230 Single Phase Reciprocating and Scroll Models)

Compressor Permanent Split Capacitor (PSC) Motors

Other than in high efficiency variable speed air conditioning systems, most residential air conditioning systems use PSC motors inside the compressor shell. Compressor motors used in residential systems are single-speed type. The motor uses an external run capacitor and may also have a start assist device in the electrical circuit.



In this picture of a cutaway reciprocating compressor the rotor and copper windings of the PSC motor can be seen. The run capacitor is mounted externally.

How PSC Compressor Motors Work

PSC motors have two motor windings, a START winding, and a RUN winding. The windings are located around the compressor motor rotor. When electrical power is applied to the motor, a circular rotating magnetic field is created by the windings that pull and push on the rotor, causing the rotor to rotate. The rotor will continue to rotate as it is attracted to, and repelled by, the magnetized coils of wire. This motion will continue until power is disconnected.

PSC Motor Run Capacitor

A run capacitor is an energy storage device that will charge and discharge with changes in the electrical polarity of the applied voltage. When a capacitor is applied to the motor winding circuit, it creates a time delay where the applied voltage to the winding must first charge and then discharge through the capacitor. PSC motors use run capacitors to create the best possible magnetic hold on the motor rotor by changing the timing of the magnetic field generated by the start winding.

A continuous duty run capacitor is wired in series with the start winding. The capacitor stores and discharges power, and will change the timing of the start winding's magnetic field. This is done to shift the electrical field to the optimum position in relationship to the run winding magnetic field. With both magnetic fields in proper place, the motor operates at its most efficient power performance level.

This continuous duty run capacitor is wired in series with the Start Winding in order to create the best magnetic hold possible on the motor rotor.

Capacitors are rated by microfarad range (storage capacity) and voltage range. Each PSC motor model will have a matched run capacitor rating to provide maximum performance. If a capacitor is replaced with one of incorrect microfarad range, the position of the magnetic field will be affected, and motor performance will decrease. The voltage rating of the capacitor should always be equal to, or greater than, what is specified for the motor.

Checking Internal Motor Winding Overload Protector Switch

When measuring compressor motor winding resistance, power to the condensing unit must be turned off.

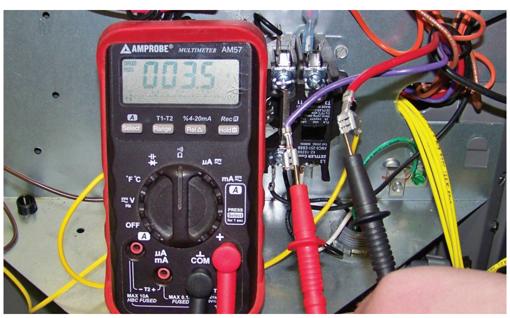
DISCONNECT POWER TO THE OUTDOOR UNIT. FAILURE TO FOLLOW THIS INSTRUCTION CAN RESULT IN PERSONAL INJURY OR DEATH.

Inside the compressor, an internal motor overload protection switch will open when excessive temperature occurs in the motor windings. This switch is wired in series between the connection point for the run (R) and start (S) windings, and the common (C) pin on the fusite plug.

If the overload switch is in an open position, the motor will not start when power is applied to the compressor. When checking the resistance of the motor windings when the internal overload switch is open, infinite resistance will be measured between the R and C terminals, as well as between the S and C terminals.

If the overload switch has opened, allow time for the compressor to cool. This switch is an automatic reset type that should close after the motor has cooled. If the switch fails to reset, the compressor must be replaced.

To be sure the motor windings have not burned out (opened), measure the resistance between the R and S winding leads. A resistance should be measured if the windings have continuity. If infinite resistance is measured, one of the windings is open. An open winding cannot be repaired and the compressor would need to be replaced.



Checking the resistance of the motor windings.

Always perform this check on the compressor winding wire leads only. Do not perform check directly on compressor terminals. Terminal venting may cause serious injury or death.

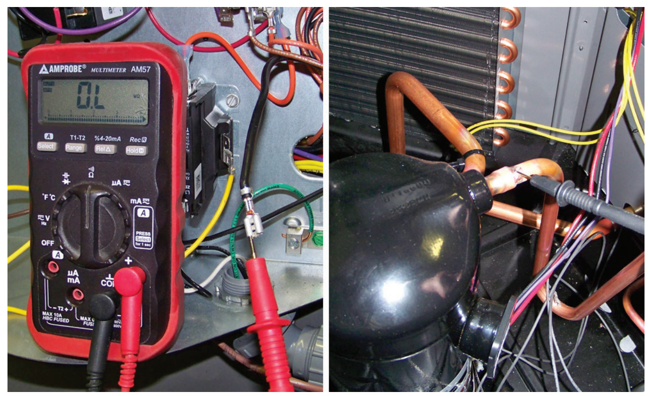
Checking for a Grounded Motor Winding

When measuring for a grounded motor winding, power to the condensing unit must be turned off.

DISCONNECT POWER TO THE OUTDOOR UNIT. FAILURE TO FOLLOW THIS INSTRUCTION CAN RESULT IN PERSONAL INJURY OR DEATH.

The compressor motor windings can develop a short circuit to ground. This short circuit is caused by a motor wiring coming in direct contact with a ground-connected metal portion of the compressor. This will result in excessive electrical current flow, causing either the circuit breaker or fuse to open and disconnect power from the condensing unit.

To test for a grounded compressor motor, measure the resistance from each wire connected to the fusite plug to the discharge line of the compressor. (Remember, measure the resistance at the opposite end of the wires connected to the fusite plug, not directly at the plug pins.)



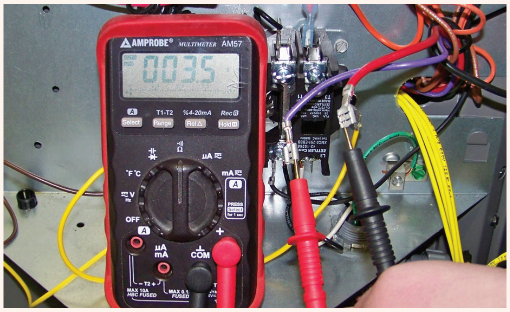
Testing for a grounded compressor

Always perform this check on the compressor winding wire leads only. Do not perform check directly on compressor terminals. Terminal venting may cause serious injury or death.

Check the resistance between the compressor discharge line and the common wire (C), the run wire (R), and the start wire (S). There should be measurable resistance somewhere above 1,000,000 OHMS. If the resistance is below this level, contact the manufacturer of the condensing unit to determine if resistances below 1,000,000 OHMS is acceptable. In some older compressors, manufacturers have published acceptable OHMS to ground as low as 500,000 OHMS. If a compressor motor is shorted to ground, the compressor must be replaced.

STEP 4

If steps 1 through 3 check out OK, disconnect power to the condensing unit and make sure all capacitors are discharged. Find the wires that lead to the compressor motor fusite plug terminals: run (R), start (C) and common (C). Take a resistance reading between each motor windings at the end of these wires. If a winding is open, replace the compressor. If they are OK, continue.



STEP 5

Install a hard start kit on the compressor. If the compressor runs, measure the amperage of the compressor motor on the common (C) wire to the compressor motor and note the refrigerant pressures. Contact the system manufacturer to confirm what the amperage should be. If it is 15% higher than it should be, bearing damage may be present and the compressor may need to be replaced.

Amperage should read within normal parameters

STEP 6

If the system starts and runs with normal amperage, compressor is OK.

When the Circuit Breaker Trips or a Line Fuse Opens

If a condensing unit is tripping the circuit breaker or opening a line fuse, there is excessive electrical current to the outdoor unit, or the fuse/breaker size is incorrect. If the outdoor unit is under a heavy heat load (such as when it is very hot outside, with a high indoor air temperature), the compressor may overload and operate with excessive amperage. A dirty condenser coil will also cause excessive condensing pressure and higher than normal amperage draw. If there is no obvious external reason for the circuit breaker or fuse to open, the high current may be caused by a direct short to ground in the outdoor condensing unit. This short can come from any electrical component in the high voltage circuit, including the crankcase heater, wiring, contactor, capacitors, condenser fan motor, and compressor.

In any instance where the circuit breaker or line voltage fuses have opened, the compressor must be checked for a short to ground before the circuit breaker or fuse is reset/replaced. Failure to follow this instruction may result in injury or death.

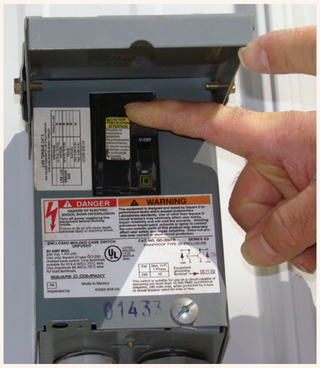
Service Procedure: Testing for a Grounded Compressor

Tools:

- Multimeter

STEP 1

Disconnect power to the outdoor condensing unit and discharge all capacitors.

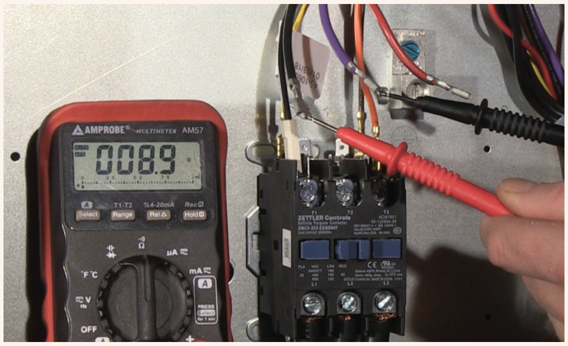


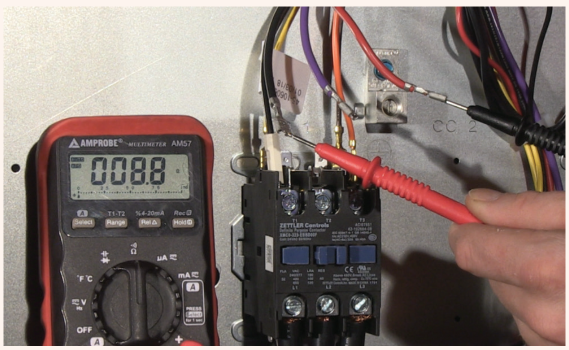
STEP 2

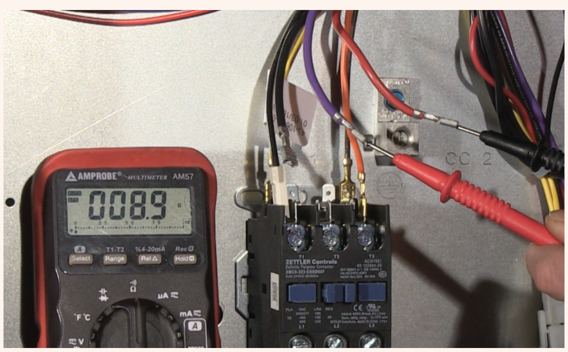
Set electrical multimeter to read OHMS at the highest resistance scale.

STEP 2

Set your ohmmeter to read low ohms. (Down to 1/2 of an ohm may be read.) Check resistance between all combinations of motor terminals. For example, between terminals 1 to 2, 1 to 3, and 2 to 3.







Equal resistance should be measures between all terminal combinations. If infinite resistance is measured between any terminals, the IOL may be open. Allow time for the motor to cool down and the IOL to re-close. This may take up to four hours. If the IOL does not re-close, replace the compressor.

If infinite resistance is measured between any combination of 2 terminals, yet have resistance between the other terminals, the compressor has an open winding. Replace the compressor.

> *NOTE: some three phase compressors have separate terminals for the IOL. Check the schematic drawing to determine which electrical configuration being worked with.*

Three-Phase Voltage Imbalances

When three-phase power is supplied to a commercial building, electricians take off power from different phase legs to power 230VAC single-phase equipment. If the same leg is used for the majority of the single phase equipment, that leg may drop its voltage too far below the other legs. In practice, a maximum voltage imbalance of 2% is all that is allowed. This is due to the fact that large voltage imbalances generate excessive heat in a three phase motor winding, such as those found in expensive three phase compressors.

We can determine the voltage imbalance present at a job site by performing the following test.

Service Procedure: Calculating Voltage Imbalance

Tools:

- Calculator
- Multimeter

Step 1

Run the condensing unit and measure the voltage being supplied to the compressor contactor on all three legs. Make sure the compressor is running.

> *Example:*
> **Leg 1 = 235 Leg 2 = 227 Leg 3 = 229**

STEP 2

Add the three measured voltages and divide by three. This is the average voltage.

> *Example:*
> **(L1)235 + (L2) 227 + (L3) 229 = 691**
> **691 ÷ 3 = 230**

STEP 3

Identify the leg with the largest difference from the average.

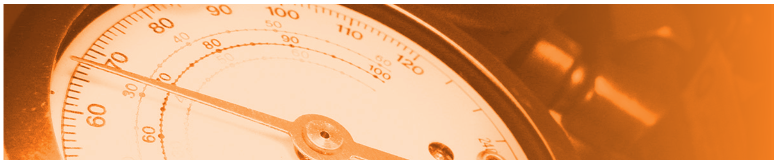
Example:

L1 = 235	**L2 = 227**	**L3 = 229**
-230	**-230**	**-230**
5	**-3**	**-1**

STEP 4

Divide the largest difference by the average voltage and multiply the result by 100.

> *Example:*
> **5 ÷ 230 = .0217 × 100 = 2.17%**



H

ECM Blower Motors

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Motor Control H2

Motor H2

ECM Motor Diagnostics **H3**

Service Procedure: Motor Not Running H3

Service Procedure: Motor Running Poorly H4

Service Procedure: GE ECM™ TECMate PRO ECM Motor Troubleshooting H5

Service Procedure: Replacing the ECM Control Module H7

Service Procedure: Replacing the ECM Motor Module H9

Final Checks **H10**

Some information in this chapter is provided courtesy of Regal-Beloit Corporation

Overview of ECM Motor Technology

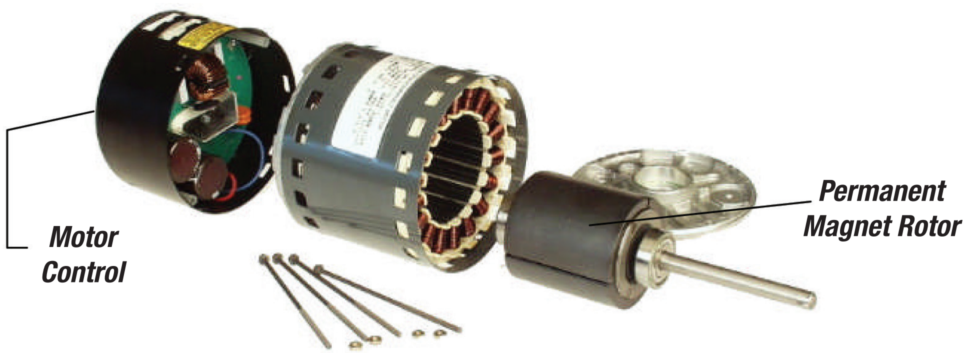
PSC Motor

ECM Motor

What is ECM technology? ECM (Electronically Commutated Motor) technology is based on a brushless DC permanent magnet design that is inherently more efficient than the shaded-pole and permanent-split-capacitor (PSC) motors commonly found in air handlers, furnaces, heat pumps, air conditioners and refrigeration applications throughout the HVACR industry. By combining electronic controls with brushless DC motors, ECMs can maintain efficiency across a wide range of operating speeds. Plus, the electronic controls make the ECM programmable, allowing for advanced characteristics that are impossible to create using conventional motor technologies. The benefit of all of this technology is increased electrical efficiency and the ability to program a more precise operation of the motor, over a wide range of HVAC system performance needs, to enhance consumer comfort.

Early HVAC literature listed these motors as ICM (Integrated Control Motor), meaning that a control was integrated or used in conjunction with a motor to control its operation. This was later changed to ECM (Electronically Commutated Motor) as they are typically referred to today. The definition of commutate is to reverse the direction of an alternating electric current (the means by which all electric motors rotate). In an ECM, this process is controlled electronically by a microprocessor and electronic controls, which provide the ability to program and control the speed and/or torque of the motor.

The GE ECM™ motor, currently used by most residential HVAC systems is a brushless DC, three-phase motor with a permanent magnet rotor. Motor phases are sequentially energized by the electronic control, powered from a single-phase supply. These motors are actually made of two components, a motor control (control module) and a motor, sometimes called a motor module.



Motor Control

The motor control is the brains of the device, where single phase (1Ø) 120VAC or 240VAC 60 cycle (Hertz/frequency) power is connected. The control then converts AC power to DC power to operate the internal electronics, thus the name DC motor. The microprocessor in the motor control is programmed to then convert DC power (by means of electronic controls) to a three phase (3Ø) signal to drive the motor, thus the name Three Phase Motor. It also has the added ability to control the frequency (which controls the speed in revolutions per minute) and the amount of torque (current/power) it delivers to the motor.

Motor

The motor is essentially a three-phase motor with a permanent magnet rotor. The permanent magnet rotor contributes to the electrical efficiency of the ECM and also to its sensor-less ability to control the rpm (revolutions per minute) and commutation (when to alternate the cycle). Typical DC motors require brushes to provide the commutation function. This is where the motor gets the name brushless DC motor.

ECM Motor Diagnostics

When servicing ECM blowers, do not automatically assume that the ECM motor has failed. Follow these step to test the ECM motor and ECM motor control before replacing these components.

WARNING: Working on the motor with power connected may result in electrical shock or other conditions that may cause personal injury, death or property damage.

WARNING: On Models 2.0/2.3/2.5 always disconnect power from the HVAC system and wait at least 5 minutes before opening the motor, i.e. removing the two bolts from the motor control (end bell) and disconnecting the 3-pin plug to the motor. This to allow the capacitors to dissipate for safety.

WARNING: Always disconnect the power from the HVAC system before removing or replacing connectors, servicing the motor, removing the high voltage plug, and before reconnecting.

WARNING: Disconnect AC power from the system and make sure the blower wheel has come to a complete stop.

WARNING: Do not operate motor without blower wheel attached. Such operation will cause motor to oscillate up and down.

WARNING: The failed module must be replaced with the correct direct replacement module from the manufacturer. USING THE WRONG MODULE VOIDS ALL PRODUCT WARRANTIES AND MAY PRODUCE UNEXPECTED RESULTS.

Before troubleshooting the ECM motor, check these system basics:

- Confirm that the correct thermostat input and ONLY the correct input voltage is present at the main control board on the furnace/air handler. Loose or broken low-voltage wires are also potential problem areas and can cause intermittent problems. Use the manufacturer's guide to confirm proper demands (heat or cool), especially on multi-stage systems. Use Sequence of Operation charts and thermostat wiring diagrams to confirm proper wiring and operation.
- Check the setting of the jumper pins or DIP switches on the manufacturer's control board. Do not assume they are correct; use the manufacturer's guide to select the proper airflow, delays, and profiles. Always disconnect the main power to the unit when making these adjustments.
- Check all terminal/plug connections both at the furnace/air handler control board and at the motor. Always disconnect power to the system before disconnecting and reconnecting plugs. Look for loose plugs and/or loose pin connections in the plug, and for burnt, bent or loose pins or seats.
- Confirm there are no limits, rollouts, or safeties tripped. Also check for any fault codes present on the furnace/air handler control boards. If fault codes are present, follow the manufacturer's recommendations to resolve the problem.
- It is normal for the motor to rock back and forth on start up. Do not replace the motor if this is the only symptom identified.

Service Procedure: Motor Not Running

Tools:

- Multimeter
- TECMate PRO

STEP 1

Check for proper high voltage and ground at the 5-pin connector at the motor. These are dual voltage motors capable of operating in 120 or 240 volt systems. Input voltage within +/- 10% of the nominal 120VAC or 240VAC is acceptable. Correct any voltage issues before continuing.

STEP 2

If the motor is a 2.0/2.3 motor and has proper high voltage and ground at the 5-pin connector, go to procedure "GE ECM™ TECMate PRO ECM Motor Troubleshooting". If the motor is a 2.5 motor and has proper high voltage and ground, reference the equipment manufacturer's manuals for further check procedures.

Service Procedure: Motor Running Poorly

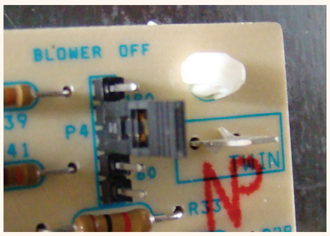
Perform this procedure if the system is excessively noisy, does not appear to change speeds in response to a heat or cool demand, or is having symptoms during the cycle such as a tripping limit or freezing coil.

Tools:

- Multimeter
- TECMate PRO

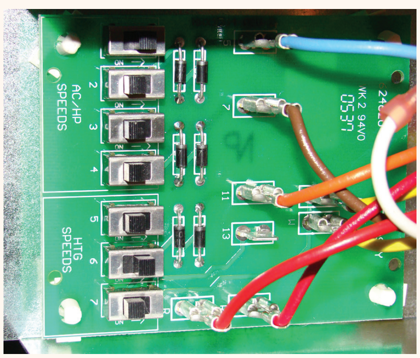
STEP 1

Wait for programmed delays to time out. If delays are too long, then reset them using the manufacturer's charts.



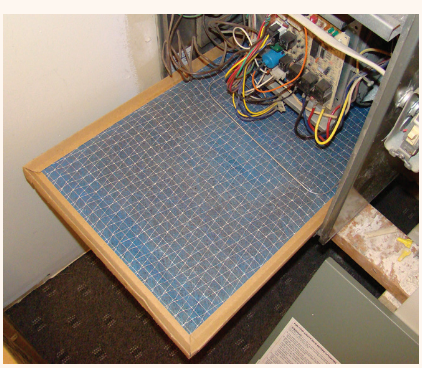
STEP 2

Ensure the airflow settings are correct for the installed system using the manufacturer's charts. Remember that the change in airflow between continuous fan and low stages of operation may be very slight depending on the size of the system.



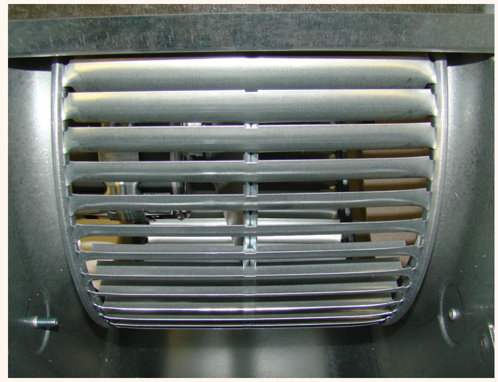
STEP 3

Remove the filter and check that all of the dampers, registers, and grills are open and free flowing. If removing the filter corrects the problem, replace with a clean or less restrictive filter.



STEP 4

Check and clean the blower wheel, secondary heat exchanger (if applicable), and evaporator coil (if applicable).

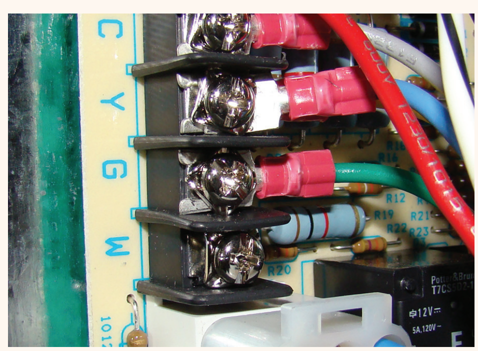


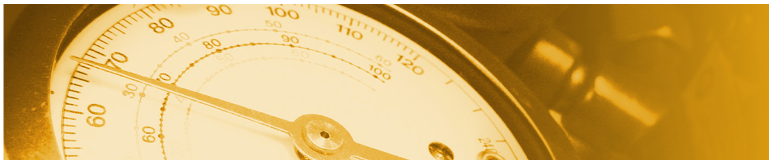
STEP 5

Check the external static pressure (See Chapter J: Air Volume). If it is higher than the manufacturer's recommendations, correct the airflow restriction.

STEP 6

If the motor does not shut off at the end of the cycle, check the delay times and wait for the delay to time out. Also, make sure there is no call for continuous fan" on the G terminal. The motor may take a while to come to a complete stop with the selected delays and normal ramp down time.





I

PSC Blower Motors

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- Operating Characteristics of a PSC Motor I2

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- Service Procedure: Testing for Electrical Failure I2
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Summary **I4**

PSC Blower Introduction

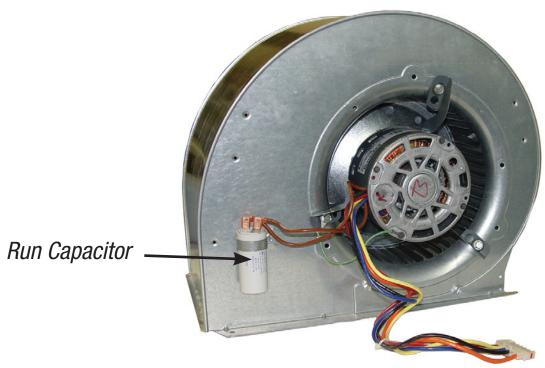
Permanent Split Capacitor (PSC) blower motors are the most common type of motor found in residential HVAC systems. These motors are used to power compressors, condenser fan assemblies, and indoor air blower assemblies. The motors used in residential systems are fractional horsepower motors.

Indoor fan assemblies feature multi-speed PSC motors that are directly coupled to the blower wheel. These motors are called direct drive motors and consist of the motor and matching run capacitor.

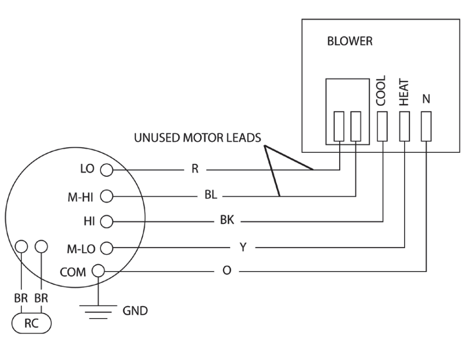
Operating Characteristics of a PSC Motor

Permanent split capacitor motors have two internal motor windings, a run winding, and an auxiliary start winding. The two windings, when energized, create a powerful magnetic field that rotates around the rotor of the motor. The magnetic field alternately pushes and pulls the motor rotor in a circular motion to turn the motor shaft.

The run capacitor discharges voltage in time with the voltage coming into the motor. When the AC sinewave changes polarity, the capacitor charges and discharges. The discharged voltage generates the best alignment of magnetic fields to increase motor power. The run capacitor is selected by the motor manufacturer to have a microfarad rating range that will get optimum performance from the motor.



In the illustration below, a typical PSC blower motor circuit is shown. The motor has various speed taps that can be energized to change blower speeds. Be aware that when the blower is running, or when voltage is applied to the motor, all of these taps will have voltage present! Voltage cannot be applied to more than one speed tap at a time. If this happens, the motor windings will fail.



PSC Motor Failures

Bearing Seizure

PSC motors can suffer bearing seizure if excessive strain is placed on the motor due to issues like blower wheel problems or excessive dirt buildup. If the motor has a bearing problem, the bearings are not replaceable. The motor must be replaced.

To test for a motor bearing problem, turn power off to the furnace or air handler. Reach into the blower housing and spin the blower wheel. The wheel should freely spin. If the motor does not spin, make sure the blower wheel is not dragging on the blower housing. If it is, repair the problem.

If no blower wheel issues are found, yet the motor will not spin, or makes grinding noises as it turns, replace the motor.

Electrical Failure

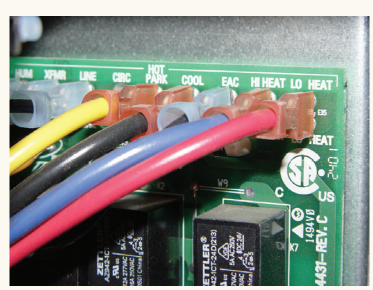
PSC motors can have an electrical failure of the motor windings. One of the windings could be broken (open), or the internal overload can open and fail to reset. The motor could have an electrical winding short to ground. The run capacitor can also fail, which will cause the blower to run slow or trip its internal overload protection.

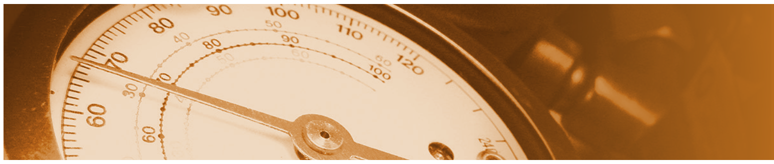
Service Procedure: Testing for Electrical Failure

Tools:

- Multimeter

Check for proper line voltage to the motor as it tries to start. If voltage is incorrect, find the cause of the problem. It is likely to be in the furnace control board. If proper voltage is present at the motor, yet the motor hums and goes off on internal overload, remove power to the furnace.





J

Air Volume

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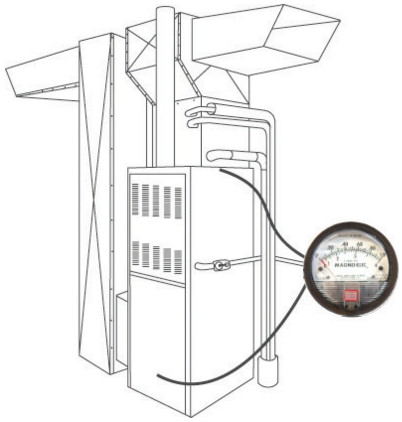
External Static Pressure Method

In the external static pressure method, a manometer is used to measure the air pressure at the inlet and outlet of the indoor blower assembly. The measured air pressure is compared to charts provided by the equipment manufacturer to determine how much air volume is flowing in cubic feet per minute (CFM).



External Static Pressure Method

Determining BTUH Output

Gas Furnace BTUH Output

In this series of steps, it is necessary to know the heat content level of the natural gas being delivered to the home. The heat contained in a cubic foot of natural gas can range from just below or above 1050 BTU per cubic foot. To obtain the specific heat content of the natural gas in your area, contact the local gas provider.

Furnace Nameplate

If it is not possible to obtain the heat content of the gas from the gas provider, the furnace nameplate BTUH input should be used to determine the BTUH output of the furnace. Be aware that calculated air volume will not be precise (Deviation will be due to fluctuations in heat content of the fuel).

If the furnace nameplate lists BTUH Input, use the following formula:

BTUH Input x Furnace Efficiency = BTUH Output

Furnace Nameplate Example

CATEGORY 1 FORCED AIR FURNACE FOR INDOOR INSTALLATION ONLY IN A BUILDING
CONSTRUCTED ON-SITE
INSTALLATION
ELECTRIC 115 V. 60 HZ 1 PH, MAXIMUM TOTAL INPUT 8.5 AMPS
FACTORY EQUIPPED FOR NATURAL GAS
EQUIPPED WITH NO. 45 DRILL SIZE ORIFICE

HOURLY INPUT RATING		MANIFOLD PRESSURE		NATURAL GAS PROPANE
BTUH/H	(KW)	INCHES W.C. PO/ (KPA)		INCHES W.C. (KPA)
80,000	(23.44)	3.5	(87)	

MAXIMUM PERMISSIBLE GAS SUPPLY PRESSURE TO FURNACE
MINIMUM GAS SUPPLY PRESSURE FOR PURPOSES OF INPUT ADJUSTMENT
LOW INPUT
LIMIT SETTING
DESIGN MAXIMUM

In this example Input BTUH 80,000 BTUH times .80 efficiency = 64,000 BTUH OUTPUT (Estimated)

Clocking the Gas Meter

This method is the most accurate way of determining the BTUH Output of a gas fired furnace. The furnace will be operated to determine how many cubic feet of natural gas enter the furnace burners. The input will then be multiplied by the efficiency of the furnace to determine BTUH Output.

The heat content of a cubic foot of gas should be found by contacting the local gas company. It may be difficult to obtain this information from the local gas company as the heat content of 1 cubic foot of natural gas fluctuates from day to day. If the heat content of the fuel can be determined by making a phone call, it is well worth the effort as the accurate BTUH Input of the gas furnace can be found.

If the actual heat content of the gas cannot be obtained, use a default value of 1050 BTU/cubic foot of natural gas for calculations. Be aware, there will be some inaccuracy in the calculations performed in this procedure if using the default value.

When clocking the gas meter, all other gas appliances in the home should be off. Keep any pilot lights lit. The furnace should be operating at proper manifold pressure as stated on the furnace nameplate. The furnace should be calling for heat with all stages of capacity firing.

Service Procedure: Determine BTUH Output by Clocking the Gas Meter

Tools:

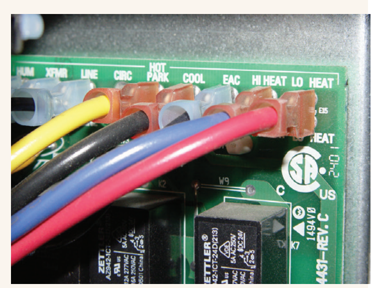
- Gas Pressure Manometer
- Watch/Timing Device

STEP 1

Find the BTUH content of a cubic foot of natural gas. This information is available from your local gas company. The default average used in generating air volume tables is 1050 BTU per Cubic Foot.

STEP 2

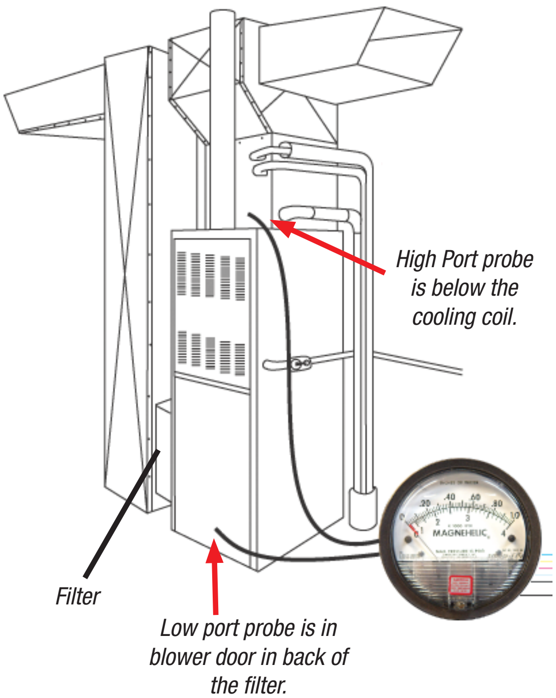
Shut off all gas appliances in the home. Do not shut off the pilot lights to any appliances. The only gas appliance that should be operating in this test is the gas furnace.



Set the blower to operate at cooling speed during heat mode operation. This can be accomplished by simply setting the fan switch on the thermostat to the ON position.

To measure the total external static pressure, the probe that connects to the HIGH PORT of the pressure gauge is inserted into the supply air side of the fan blower. The probe that connects to the LOW PORT of the pressure gauge is inserted into the return air inlet to the fan. The gauge will now read the total external static pressure.

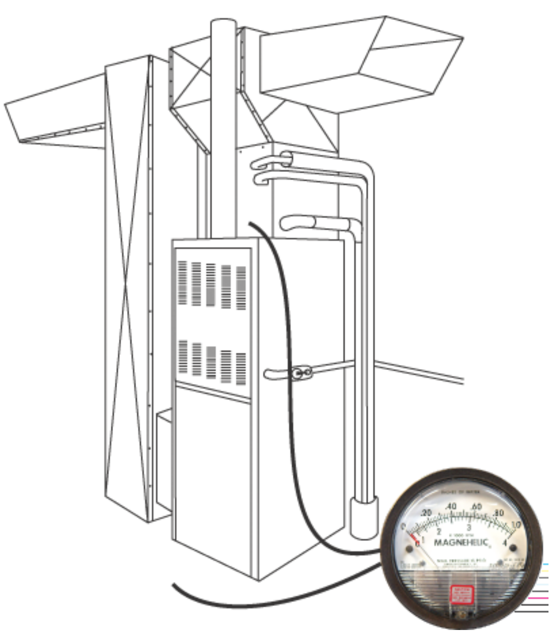
Gas furnace configured to measure total external static pressure



Reading Each Duct Static Pressure Independently

The pressure gauge can be used to find the static pressure of the supply ducting or the return ducting individually. To measure the supply ducting static pressure, remove the probe from the return air and leave it exposed to atmosphere. Leave the supply air probe in its place. The gauge will read only supply air static pressure.

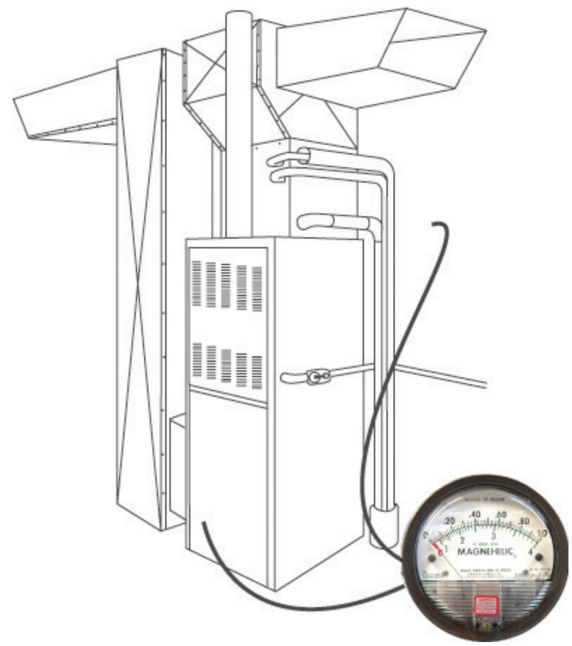
Measuring supply air static pressure



To measure return air ducting static pressure, leave the return air probe in its place and remove the supply air probe, leaving it exposed to atmosphere. The gauge now reads only return air static pressure.

Add the two readings together to get total external static.

Measuring return air static pressure



Checking the return and supply static pressure individually is useful when trying to determine which duct may be causing high static pressure and low air volume levels. One or both of the ducting systems may have an excessive pressure drop that is hurting blower air delivery performance.

When Measured External Static Pressure is Excessively High

What is too high? What is considered too high will depend upon what type of motor is in the air handling component. If it is a variable speed ECM type motor, typically around 0.9" external static pressure is the limit. If the blower is a PSC type blower, above 0.50" is typically too high if the blower is not oversized for the cooling system. In other words, if a 3-ton system has a 4-ton air handler, the air handler can usually deliver 1200 CFM for a 3-ton system at external static pressure that is above .50". If the system is a gas furnace with a 3-ton blower, 1200 CFM will usually be achieved at 0.50" external static pressure. Anything above that will typically cause air volume to be below required levels.

When Excessive External Static Pressure is Present

Check the static pressure in the supply duct by removing the probe from the return air. Next, check the static pressure in the return air by inserting the return air probe back into place and removing the supply air probe.

The duct with the higher of the two readings should be investigated for air volume restrictions and proper duct dimension sizing. Make duct corrections as needed. It may be necessary to remove components from the duct system such as high efficiency filters.

Some high efficiency air filters can drop over 0.2" of static pressure. This is almost half of the available pressure from a gas furnace using a PSC blower motor.

Finding Static Pressure Loss Across Duct Components

When trying to determine how much a duct component, a filter for example, is contributing to the total static pressure loss, a pressure drop can be taken across the component. The high port probe is placed in front of the component in the direction of entering air into the component. The low port probe is positioned where the air leaves the component. The pressure drop is displayed on the pressure gauge.

Air Volume CFM: External Static Pressure Method Summary

- Total external static pressure is the return and supply air static pressures added together.
- Static pressure is measured with special probes.
- Pressure drops across components can be measured.
- Be careful of the small print on CFM charts. (Check if filter is included.)
- Do not drill a hole into an air handler or furnace door without checking clearances.
- ECM type motors can deliver required air at higher external static pressures than PSC type motors (unless grossly over-sizing furnace/air handler blowers).

Air Conditioning Service Guide

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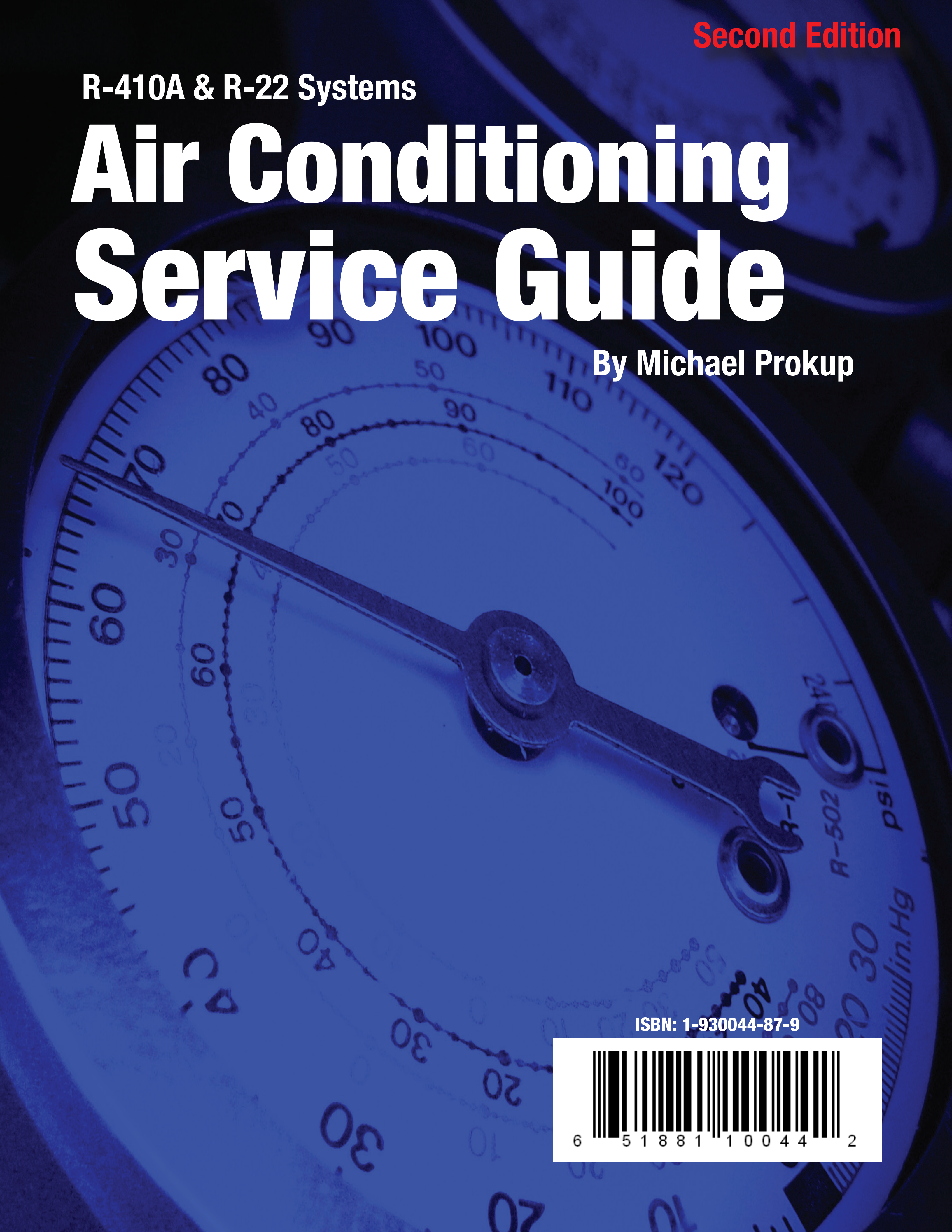

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