PREVENTIVE MAINTENANCE TECHNIQUES FOR HVAC/R SERVICE TECHNICIANS

A Desktop Reference and Training Guide
for Preventive Maintenance Certification

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Preface

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The information in this course is intended for educational purposes only. Procedures described are for use only by qualified air conditioning and refrigeration service technicians who are already well versed in HVAC/R service techniques and who have a valid EPA Section 608 Certification. This training course is not a substitute for the required EPA Section 608 certification or for any equipment Manufacturer's Operator Manual.

Take safety precautions when using all HVAC equipment. Improper use of HVAC equipment can cause explosion and serious personal injury. Always use extreme caution when working with refrigerants; hoses may contain liquid refrigerant under pressure. Use only approved refillable storage cylinders. Do not overfill any storage cylinder beyond its rated capacity. Always wear safety glasses. Protect the skin from flash freezing. Never turn on any equipment if you do not understand its operation. Where procedures described in this manual differ from those of a specific equipment manufacturer, the equipment manufacturer's instructions should be followed.

Mainstream Engineering Corporation assumes no liability for the use of information presented in this publication. This information is presented for educational purposes only. Manufacturer's Operator Manuals must be consulted for the proper operation of any piece of equipment.

The content of this course is limited to information and service practices needed to effectively extend the operating life of vapor-compression equipment, typically utilized in the HVAC/R industry. This manual is not intended to teach fundamental air conditioning or refrigeration system techniques or safety practices. Likewise, this manual is not intended to teach safe refrigerant recovery or refrigerant handling techniques. This manual assumes the technician is well versed with these issues and possesses an EPA-Approved Section 608 certification.

PM Tech Examination Information

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The PM Tech certification exams consist of 25 questions. Technicians can take the PM Tech certification exam as many times as necessary (passing grade is 21 correct out of the 25 questions or 84%). The exams are open-book and technicians have a maximum of three hours to complete each exam. If you retake the exam, you will automatically be given a different set of questions from the test bank.

Three types of certification are available: Apprentice, Journeyman, and Master PM Tech. Prior to obtaining any of Mainstream's PM Tech certifications, the technician must have an EPA 608 certification from an EPA approved certifying agency, such as Mainstream. Only 608 CERTIFIED TECHNICIANS can obtain a PM Tech certification.

The PM tech certification exam is available on-line at www.epatest.com. You can TAKE THE EXAM ONLINE WHEN YOU ARE READY. The exam consists of 25 questions, which are related to preventive maintenance and proper use of Qwik**Products**™ to service, repair and maintain air conditioning, refrigeration, and heat pump systems.

Mainstream reserves the right to revoke the PM Tech certification given to any individual, at any time, and without prior notice, for excessive customer complaints, unethical or illegal service practices, failure to meet Mainstream's professional requirements, or any other reason deemed justifiable by Mainstream employees. Mainstream is under no legal obligation to disclose the reason for the termination.

Levels of PM Tech Certification

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Apprentice PM Tech

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This certification requires EPA Section 608 certification from Mainstream or any other EPA approved testing organization, and successful completion of the PM Tech exam with a score of 84% or better. Documentation to prove EPA certification by any organization other than Mainstream must be received and verified. For Mainstream certified 608 Technicians, we will automatically verify your EPA certification.

Journeyman PM Tech

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This certification includes all the requirements of the Apprentice PM Tech (above) plus at least 5 years verifiable experience in the HVAC/R trades. Documentation to substantiate this experience is required.

Master PM Tech

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This certification includes all the requirements of the Apprentice PM Tech plus at least 10 years verifiable experience in the HVAC/R trades. Documentation to substantiate this experience is required.

Figure 1. Certified PM Tech patch

DEFINITIONS

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Azeotrope	A blend of two or more components whose equilibrium vapor phase and liquid phase compositions are the same at a given pressure. In other words a blend that behaves as a pure refrigerant. R-5xx series refrigerants such as R-502 are azeotropes.
Biocide	Substance or chemical that kills organisms such as molds

Dew Point	If the air is gradually cooled while maintaining the moisture content constant, the relative humidity will rise until it reaches 100%. This temperature, at which the moisture content in the air will saturate the air, is called the dew point. If the air is cooled further, some of the moisture will condense.
Dry-Bulb Temperature	The temperature of the air measured with a dry thermocouple or thermometer with a dry bulb. The Dry-Bulb and Wet-Bulb temperatures can be used together to determine relative humidity.
EPA	Environmental Protection Agency
Expansion Device	The Thermal Expansion Valve (TXV), Electronic Expansion Valve (EXV), capillary tube, orifice plate or similar device, whose purpose is to drop the pressure of the refrigerant so as to lower the saturation temperature of the refrigerant. Also known as the Throttling Device.
Fractionation	The separation of a liquid mixture into separate parts by the preferential evaporation of the more volatile component. What occurs at a leak when a non-azeotropic blend has the more volatile component evaporate away faster than the less volatile components, causing a change in the blend formulation.
Fungi	Fungi are neither animals nor plants and are classified in a kingdom of their own. Fungi include molds, yeasts, mushrooms, and puffballs. In this document, the terms fungi and mold are used interchangeably. Molds reproduce by making spores. Mold spores waft through the indoor and outdoor air continually. When mold spores land on a damp spot indoors, they may begin growing and digesting whatever they are growing on. Molds can grow on virtually any organic substance, provided moisture and oxygen are present. It is estimated that more than 1.5 million species of fungi exist.
Humidity	The water vapor mixed with air in the atmosphere
Humidity Ratio	Also known as Specific Humidity, the pounds of water contained in a pound of dry air.
Hygroscopic	Substances that readily absorb moisture. POE oils are

	hygroscopic.
Isomer	One of a group of substances having the same combination of elements but arranged spatially in different ways.
Mixture	A blend of two or more components that do not have a fixed proportion to one another and that no matter how well blended, still retain a separate existence (oil and water for example).
Non-Azeotropic Refrigerant	Also known as zeotropic, these are blends comprising multiple components of different volatility that, when used as a refrigerant, change volumetric composition and saturation temperatures as they evaporate (boil) or condense at constant pressure. In other words, at a constant pressure the boiling point temperature and condensation point temperature (at the same pressure) are different. R-4xx series refrigerants such as R-404a are non-azeotropic refrigerants. Note that R-410a is a non-azeotropic refrigerant that exhibits near azeotropic behavior. Non-azeotropic refrigerants must be charged as a liquid to avoid fractionation during charging. Azeotropic refrigerants can be charged as either a liquid or vapor.
Normal Charge	The quantity of refrigerant within the appliance or appliance component when the appliance is operating with a full charge of refrigerant.
Pressure Ratio	The mathematical ratio of high-side pressure in PSIA divided by the low-side pressure in PSIA.
PSIA	The absolute pressure in pounds per square inch, where 0 PSIA corresponds to 29.9 inches of mercury vacuum and 14.7 PSIA corresponds to 0 PSIG (pounds per square inch gauge).
PSIG	The gauge pressure in pounds per square inch, where 0 PSIG corresponds to atmospheric pressure (14.7 PSIA). A positive PSIG value indicates the pressure in pounds per square inch above the ambient pressure.
Relative Humidity	The ratio of weight of water in the air relative to the maximum weight of water that can be held in saturated air
Vapor-Compression System	The general term referring to all air conditioners, heat pumps, refrigerators and chillers that all operate under

	the principle of compressing a vapor to high pressure so that it will condense (at a higher temperature), then dropping the pressure to evaporate the refrigerant (to provide cooling), followed by re-compressing the refrigerant to condense and complete the cycle.
Wet-Bulb Temperature	The temperature of the air measured with a wet thermocouple or thermometer with a wet bulb. The Dry-Bulb and Wet-Bulb temperatures can be used together to determine relative humidity.

Section 1:
The Need for Certified PM Technicians

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If you're suffering from a terrible pain, hopefully your doctor won't simply prescribe a pain killer, but instead try to find the cause of the pain and treat it. Similarly, if your car muffler fails, you hope the mechanic doesn't attempt to conceal the problem by turning up the volume on your radio. In these examples, the message is clear--treat the underlying problem, not just the symptoms.

The same message applies to problems with air conditioning and refrigeration systems. If you're changing a failed compressor without rectifying the underlying problem, or simply recharging the system without fixing the leak, you're no better than the doctor or the mechanic described above!

As a business owner in the AC/Refrigeration field, don't you think equipment owners would pay more to fix the underlying problem and avoid future hassles? If you took the time to fix the underlying cause of the problem, you can almost guarantee the customer will call *you* back for future assistance, instead of finding another contractor in the phone book.

One of your goals as a HVAC/R technician is to change your role from the business that is only called on the hottest day of the year (when the system has failed), to the one who is building a relationship with customers (and making more money and providing more value along the way). In a perfect scenario, **you want the equipment owner to appreciate the *value* of the service rendered, rather than only the *cost* of the service**.

Many technicians reading this may be saying, "I deal with residential customers and all they care about is lowest price!" This is not always true. Many of these same residential customers also bring their vehicles to a dealership, rather than a local independent mechanic, and pay much higher hourly labor rates. ***Oftentimes the equipment owner does not see a difference in the quality of the service, so they merely select the lowest cost "supplier."***

As a Mainstream Certified PM Technician, you will be trained and tested to verify that you:

- Understand preventive maintenance techniques,
- Utilize the latest diagnostic and repair techniques, and
- Provide state of the art service.

The focus of Mainstream's PM Tech certification program is to assure the equipment owner that a Mainstream certified PM Tech can obtain optimum performance, reliability, and long life from the systems they service. As a Mainstream Certified PM Tech, your name will be advertised by Mainstream as a professional who has successfully passed a higher level of certification and understands Preventive Maintenance procedures and methodology.

This manual is in a continual state of evolution and re-writing, partly because of changing technology and partly because of information feedback from technicians in the field. If you believe sections of this manual require improvement, or that additional information should be added, please write to us and we will consider your suggestions for future editions. In the past, we have received very useful comments and suggestions from HVAC/R technicians in the field. To all those who have helped in the past, we owe a sincere debt of gratitude. Suggestions on the improvement of this course or any Mainstream product are always welcome.

Some material in this text has been extracted from Mainstream's EPA 608 manual. While we have attempted to minimize the duplication, we felt that technicians certified by other EPA programs may not have been exposed to this material, and therefore it was important to include it. I apologize to those of you who have already seen this material.

For suggestions related to this course, please write to:

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Section 2:
Basic Vapor-Compression Refrigeration Principles

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Introduction

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It is not the intent of this manual to teach basic refrigeration theory. However, a simple review of some basic concepts is useful for describing the effects of non-condensable gases, moisture, and contaminants on the refrigeration system.

The most basic vapor-compression refrigeration system consists of four major components: compressor, evaporator, condenser, and expansion device. Actual practical hardware contains many other critical components for reliable, trouble-free operation, such as a control system, high-pressure and low-pressure safety controls, liquid receiver, accumulator, oil separator, crankcase pressure regulator, and so on. The four basic components are all that are needed to illustrate most of the points of this section.

The Basic Vapor Compression Cycle

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Refrigerant absorbs energy (provides cooling) as it evaporates, that is, as it boils and turns from liquid to vapor. For pure refrigerants (and azeotropic blends), if the refrigerant evaporates at a constant pressure, then evaporation (boiling) occurs at a constant temperature (while both liquid and vapor are present). Likewise, refrigerant rejects energy (gives off heat) as it condenses from vapor to liquid. For pure refrigerants (and azeotropic blends), if the condensation occurs at a constant pressure, then the condensation will occur at a constant temperature (until all the vapor has condensed to a liquid). Therefore, for evaporation or condensation, the temperature and pressure are related by the pressure/temperature saturation curve.

NOTE: A point of confusion regarding pressure units appears to frequently occur. When discussing pressure in PSI (pounds per square inch), PSIG means pounds per square inch gauge and PSIA means pounds per square inch absolute. The two numbers differ by approximately 15 PSI. A refrigeration gauge normally reads in units of PSIG, that is, in normal air it will read a pressure of zero. However, an absolute gauge would read a pressure of about 14.7 PSIA in this same location. In refrigeration, we typically talk about pressure above ambient in terms of PSI (with the ambient being at zero PSI so it would be more accurate to refer to the pressure in PSIG). Likewise, we normally use inches of mercury to discuss vacuum levels with 29.9" mercury being a complete vacuum (0 PSIA). Some of the new saturation charts for refrigerants are using the absolute pressure instead of the combination of gauge pressure and vacuum in inches of mercury. To convert PSIA to PSIG, simply subtract 14.7 (or round to 15) from the PSIA reading to get the PSIG reading. For example, a normal atmospheric pressure of 14.7 PSIA is 0.0 PSIG, and 164.7 PSIA is 150 PSIG.

As a simple rule of thumb to convert inches of mercury (the symbol for mercury is Hg) to PSIA, simply divide the value in inches of mercury by 2 and subtract it from 15 to get the approximate PSIA reading. For example, 5" Hg is about 12.5 PSIA (actually it is 12.2 PSIA), 10" Hg is about 10 PSIA (actually it is 9.8 PSIA), and finally 15" Hg is about 7.5 PSIA (actually it is 7.3 PSIA).

A brief discussion of the operating vapor-compression cycle is helpful to indicate other potential refrigeration problems in real systems. In the basic cycle, slightly subcooled refrigerant leaves the condenser at high pressure, and the pressure is dropped via the expansion device (capillary tube, TXV, etc.) before it enters the evaporator.

NOTE: The amount of subcooling, which is reported in degrees, is the temperature difference between the saturation temperature of the refrigerant (at the condenser pressure) and the actual temperature of the refrigerant leaving the condenser.

Refrigerant enters the evaporator as a two-phase mixture (liquid and vapor), and evaporates or boils at low temperature, absorbing heat. Slightly superheated refrigerant vapor exits the evaporator and enters the compressor where the pressure and temperature are increased as the compressor compresses the refrigerant vapor, making the refrigerant even more superheated.

NOTE: The amount of superheating, which is reported in degrees, is the temperature difference between the actual temperature of the refrigerant and the saturation temperature of the refrigerant (at the same pressure). In the case of the evaporator, it is the actual temperature of the refrigerant leaving the evaporator minus the saturation temperature of the refrigerant (which is determined from the pressure of the refrigerant leaving the evaporator).

The compressor discharge is the hottest point in the cycle, and the refrigerant has the greatest superheat at this point. This refrigerant is cooled and condensed in the condenser where heat is rejected, and the refrigerant is condensed to liquid. Refrigerant actually leaves the condenser slightly subcooled to ensure condensation has been complete. Any non-condensable vapors in the system will be unable to condense in the condenser and will appear as gas bubbles in the condensed liquid stream. These non-condensables may collect in the condenser and displace refrigerant from the condenser heat exchanger, thereby reducing the effective surface area of the condenser. Non-condensables also lead to increased compressor temperatures and pressures, reduced cooling capacity, increased compressor pressure ratios, potential compressor overheating, and finally, compressor motor burn-out.

Refrigerant moisture content is also a potential problem. Visual moisture indicators should be replaced if they are washed out because moisture can result in expansion valve freezing, increased acid formation, and reduced compressor life. Any water in the system will most likely freeze in the expansion valve because this is the point where refrigerant is cooled by the evaporation occurring as a result of the sudden pressure drop, and the expansion device also represents the smallest passageway in the overall system. This is the reason why liquid line filter-driers should be located just upstream of the expansion device.

Leak Testing Techniques

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A vacuum test is not the best method of leak testing a system because it allows air, and thus moisture, to enter the system. The technician cannot determine from the vacuum where the leak is located, only that there is a leak. Also, when a vacuum is used to test for leaks, it only proves that the system will not leak under a pressure difference of 14.7 PSI. When the entire atmosphere is removed from a system, only the atmosphere's pressure is trying to get back into the system, therefore there is only a 14.7-PSI pressure difference.

When checking for a leak using a vacuum, the technician is using a reverse pressure (the atmosphere trying to get into the system) of only 14.7 PSI. However, under normal operating conditions, the system may be operating under an operating pressure of several hundred PSIG, that is, 10 to 20 times the vacuum pressure difference.

In addition, using a vacuum for leak checking may hide a leak. For example, if a pin-sized hole is in a solder connection that has a flux buildup on it, the vacuum will tend to pull the flux into the pinhole and may even hide it to the point that a deep vacuum can be achieved. However, when pressure is applied to the system, the flux will blow out of the pinhole, and a leak will exist.

The best leak-checking procedure is a standing pressure test using a pressure source that will not change an appreciable amount with temperature changes. **Nitrogen is a good gas to use. Never use compressed air or oxygen.** Compressed air is full of moisture which is very difficult to remove and both air and oxygen can support combustion which can be very dangerous, since a fire or explosion is possible. If an electronic leak detector is to be used along with this test, put a small amount of HFC refrigerant in the system and bring the system pressure up to about 10 PSIG of pressure (skip this step if an electronic leak detector is not being used). Then increase the pressure, with nitrogen, up to the system's normal working pressure, as indicated on the manufacturer's nameplate. Do not pressurize any system above the system's working pressure written on the equipment label. (Note that many large chillers and other low-pressure systems typically have a pressure relief valve set at 15 PSIG and are usually pressure tested to only 10 PSIG.) When the system has been pressurized, tap the gauge slightly to make sure the needle is free and record the pressure. If the pressure falls over time, a leak exists. **If a pressure drop is noted, remember the gauge manifold and connections may be leaking, and not the system.** The smaller the system, the shorter the standing time needed. For example, a small beverage cooler may need to stand for only an hour to be sure that the system is leak free, whereas a 20-ton system may need to stand under pressure for 12 hours.

Checking for leaks while the system is pressurized is preferred, because the leaks are easier to detect. Always use a pressure regulator on the nitrogen cylinder.

Mixtures of nitrogen and refrigerant that are used as leak-test gases are not subject to the EPA venting prohibition, when used properly. A technician may not avoid recovering refrigerant by adding nitrogen to a charged system and then calling the mixture a leak-test gas mixture. Before nitrogen is added, the system MUST be evacuated to the required level, any repairs must then be made and then the system should be charged with nitrogen to test for leaks (using a pressure decay test, for example). If a leak is discovered, then a small amount of the refrigerant normally being used in the system can be added to allow an electronic refrigerant leak detector to help identify the source of the leak. The leak-test gas should not be added to the nitrogen if an electronic refrigerant leak detector is not going to be used. Failure to recover the refrigerant to the proper evacuation levels before adding the nitrogen-refrigerant leak-test mixture is a violation of the EPA regulation and subject to fine.

Another method of improving the odds of detecting very small leaks is to use a **fluorescent oil-soluble indicator (**of course you must be sure the additive you are using is compatible with the refrigerant and oil being used). The fluorescent dye makes the oil residue at a small leak significantly more noticeable. This technique is useful on small, hard to find leaks, where the technicians can look for the leak the next time they are servicing the unit. An **ultraviolet lamp (or black light)** is used to illuminate the fluorescent indicator. This approach is recommended for detecting very small leaks that could not be found with other means, unfortunately however, the UV light does not work well in bright sunlight.

An **ultrasonic leak detector** uses an ultrasonic detector to listen for leaking gas. This method requires some advance knowledge of the location of the leak and a fairly low background noise level. This technique is used with a nitrogen test gas. An ultrasonic leak detector can also be used with a noise source of a specific frequency placed inside the equipment, and the detector tuned to the frequency.

When all else fails, a **helium leak detector** may be the answer. Helium has a low molecular weight and helium will escape easily from a small leak. Refrigerants do not escape as easily due to their higher molecular weights. Helium leak detectors can find very small leaks with amazing accuracy. However, they generally require a specially trained technician from a testing firm to operate the equipment.

When the technician is convinced the system is leak-tight, both a **standing pressure test** and a **standing vacuum test** are usually used as a final verification of the system integrity, cleanliness, and dryness. The vacuum test helps to assure that no trapped refrigerant and/or water is in the system. In the standing pressure test described earlier, the system is pressurized to the normal operating pressure with nitrogen (using a nitrogen bottle and regulator). The system is isolated from the nitrogen source and the pressure is recorded. Any drop in pressure after compensating for temperature changes indicates a leak.

As a final system check before recharging the system, a **standing vacuum test** should be performed. In a standing vacuum test, the system is evacuated to a deep vacuum. Because the quantity of gas trapped in the system is essentially zero, no compensation needs to be made for temperature changes. An increase in pressure indicates a leak **unless** the pressure increases beyond 0 PSIG, which then indicates the presence of trapped refrigerant in the system. The refrigerant continues to evaporate, causing the vapor pressure to rise above ambient pressure. Similarly, there is no leak if the pressure rises from the initial deep vacuum but stops at some vacuum level below ambient pressure. This typically represents trapped water being evaporated. With a leak in the system, the pressure would equalize at atmospheric pressure. The water or trapped refrigerant is removed by repeating the deep vacuum draw-down process until all the water or refrigerant has been boiled off and the system holds the deep vacuum. Remember, the vacuum test is not a substitute for a pressure leak test because the pressure difference on the system is too small, only 14.7 PSI.

Removing Moisture

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A vacuum pump is used to remove moisture from a system. Moisture in the unit can be in either a vapor or liquid state. When the moisture is in a vapor state, it is easy to remove. When the moisture is in a liquid state, it is more difficult to remove because it must be vaporized and the evaporation of the water cools the remaining water, which makes further evaporation more difficult.

For example, if liquid water in the system is initially at 80°F, then the saturation pressure of the water is 28.87 inches of mercury or 26,702 microns. Therefore, the vacuum pump must achieve a pressure below 28.87 inches of mercury (at the site of the water) for this liquid water to boil off (This is not the vacuum level required at the vacuum pump, it is the vacuum required at the water's location, the vacuum level at the vacuum pump must be even lower!), and at this temperature one pound of water vapor will occupy 1,022 cubic feet of space.

The evaporation of some of this water will further cool the remaining water. If the water is cooled to 70°F, then the saturation pressure of the water becomes 29.16" Hg (or 19,336 microns) and the vacuum pump must achieve a pressure below 29.16" Hg in order to boil off the remaining water. Again, continued evaporation of water will further cool the remaining water. If the water is cooled to 50°F, then the vacuum pump must achieve a pressure below 29.54" (or 9,684 microns) for the remaining water to boil off. As you can see, it becomes very difficult to remove liquid water from the system. In addition, if the water evaporates too quickly, it will cool below the freezing point and freeze, essentially halting vaporization. Table 1 contains a brief summary of the saturation temperature/pressure behavior of water.

When large amounts of moisture must be removed, the following guidelines may be helpful.

1. Use a large vacuum pump. For flooded systems up to 10 tons (for example, if a water-cooled condenser pipe ruptures from freezing), at least a 5-cfm vacuum pump is recommended. If the system is larger, a larger pump or a second pump should be used.
2. Drain the system in as many low places as possible. Remove the compressor and pour the water and oil from the system. Do not put new oil back into the system until the system is ready to be started after evacuation. If you add it earlier, the oil may become wet, making the water difficult to remove.
3. Use a heat lamp for applying heat to the system. If the system is in a heated room, the room may be heated to 90°F without fear of damaging the room, its furnishings, or the system. The entire system, including the interconnecting piping, must be heated to a warm temperature or the water will boil to a vapor where the heat is applied and condense where the system is cool. For example, if you know water is in the evaporator (inside the building) and you apply heat to the evaporator, the water will boil to a vapor. If the temperature is cool outside, the water vapor may condense outside in the condenser piping. Thus, water is only being moved around.
4. Start the vacuum pump and observe the oil level. As moisture is removed, some of the moisture will condense in the vacuum pump's crankcase. Some vacuum pumps have a feature called a gas ballast that introduces atmosphere between the first and second stages of the two-stage pump. This helps to prevent moisture from condensing in the crankcase. Regardless of the type of vacuum pump, watch the oil level. The water will displace the oil and raise the oil out of the pump. Soon, water may be the only lubricant in the vacuum pump crankcase, and damage may occur to the vacuum pump. If you evacuate water-laden systems often, you may save time and increase vacuum pump life by investing in an inexpensive cold trap to remove moisture before it reaches the vacuum pump. This process is described in the next subsection on Evacuation Procedures.

Table 1. Pressure/Temperature Saturation Relationship for Water

Temperature	**Pressure**		
[°F]	PSIA	in. Hg	Microns
10	0.031	29.83	2,318
20	0.050	29.80	3,080
30	0.081	29.73	4,858

40	0.122	29.65	6,890
50	0.178	29.54	9,684
60	0.256	29.38	13,748
70	0.363	29.16	19,336
80	0.507	28.87	26,702
90	0.698	28.47	36,862
100	0.950	27.97	49,562
110	1.275	27.30	66,580
120	1.693	26.45	88,170
130	2.224	25.37	115,602

Evacuation Procedures

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Some general rules apply to deep vacuum and multiple evacuation procedures. If the system is large enough, or if you must evacuate moisture from several systems, you can construct a cold trap to use in the field. A cold trap is a chilled accumulator in the vacuum line between the wet system and the vacuum pump. When water vapor passes through the trap, moisture freezes or condenses on the walls of the trap, which is normally chilled with ice or even better with dry ice (CO_2). The trap is drained periodically to remove the water.

Water can be trapped in or under the compressor oil. Because of the oil's surface tension, water can become trapped under the oil in a compressor. This water may stay under the oil, even when the system is under a deep vacuum. During a deep vacuum, the oil-surface tension can be broken with vibration, such as striking the compressor housing with a soft-face hammer. Any kind of movement that causes the oil's surface to shake will work. Applying heat to the compressor crankcase with a heat lamp, or by using the compressor's crankcase heater, will also help to release the water. Do not start the compressor to obtain vibration, because even a few seconds of operation can significantly damage a hermetic compressor. Starting a hermetic compressor while it is in a deep vacuum will definitely damage the motor, since there is no refrigerant flow to cool the motor.

A technician that evacuates many systems must use time-saving procedures. For example, a typical gauge manifold is not the best choice for use because it has very small valve ports and small diameter hoses that will slow the evacuation and recovery process. Many technicians use small-diameter hoses with 1/4" flare connectors and valve-core depressors in the hose. The valve core depressor significantly restricts the flow area, and therefore the evacuation or recovery rate. We recommend using 3/8" or even 5/8" hoses for evacuation and recovery. Remember it is the vacuum level at the water's location not at the vacuum pump or gauge, which effects the evaporation rate, and small hoses and valve-core depressors can be a significant flow restriction.

In addition, we recommend using four-hose and four-valve manifolds instead of the more traditional three-hose, two-valve design. The extra two valves are used to control the refrigerant and the vacuum pump lines. When using this manifold, you do not need to disconnect the vacuum pump and switch the hose line to the refrigerant tank to charge refrigerant into the system. Instead, close one valve and open the other. Besides being much easier, the vacuum pump can be used to evacuate the charging hose.

Most gauge manifolds have valve core depressors in the end of the gauge hoses. The depressors are used for servicing systems with Schrader access valves. These valves are much like the valve and stem on an automobile tire. These depressors are a restriction to the evacuation process. When a vacuum pump pulls down to the very low ranges (1 mm), these valve depressors slow the vacuum process considerably. The valve depressors can be removed from the ends of the gauge hoses, and adapters can be used when valve depression is needed.

A system with Schrader valves for gauge ports will take much longer to evacuate than a system with service valves. Removing water will take much longer to evacuate if Schrader valve stems are in the service ports. A solution is to remove the valve stems during evacuation and replace them when evacuation is finished. These valve stems are designed to be removed for replacement, so they can be easily detached.

A special tool, called a field service valve, can be used to replace Schrader valve stems under pressure or it can be used as a control valve during evacuation. The tool has a valve arrangement that allows the technician to evacuate a system through the tool with the stem backed out of the Schrader valve. The stem is replaced when evacuation is completed.

Schrader valves are shipped with a special cap that is used to cover the valve when it is not in use. This cover has a soft gasket and should be the only cover used for Schrader valves. If a standard flare cap is used and tightened too much, the Schrader valve top will be distorted and valve stem service will be very difficult, if it can be done at all.

Deep Vacuum

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The deep vacuum method involves reducing pressure in the system to about 50 to 200 microns. When the vacuum reaches the desired level, the vacuum pump is valved off and the system is allowed to stand for a time period to see if the pressure rises. If the pressure rises and stops at some point, a material such as water is boiling in the system. If this occurs, continue evacuating. If the pressure continues to rise up to ambient pressure (and stabilizes), a leak exists, and the atmosphere is leaking into the system. In this case, the system should be pressurized and leak-checked again.

Evacuation is a very slow process on a large system. The evacuation process seems to take forever to pull the last portion of the vacuum. The technician should have other work planned and let the vacuum pump run. Most technicians plan to start the vacuum pump as early as possible and finish other work while the vacuum pump does its work. Some technicians leave the vacuum pump running all night, and the vacuum should be at the desired level the next morning. This is a good practice, ***if precautions are taken*** (discussed below).

When the vacuum pump pulls a vacuum, the system becomes a large volume at low pressure with the vacuum pump between this volume and the atmosphere. If the vacuum pump shuts off during the night because of a power failure, the vacuum pump oil will be drawn into the system. Vacuum pump oil is typically mineral based and is incompatible with POE or PAG oils and HFC refrigerants. When power is restored and the vacuum pump starts back up, it could be operating without adequate lubrication and can be damaged. This can be prevented by installing a normally closed solenoid valve (with a large orifice) in the vacuum line entering the vacuum pump, and wiring the solenoid valve coil in parallel with the vacuum pump motor. The solenoid valve should have a large port to keep from restricting the flow. Now if the power fails, or someone disconnects the vacuum pump, the solenoid valve will close, the vacuum will not be lost, and the vacuum pump will not leak its oil into the system.

Replacement Refrigerants

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Key considerations for any new refrigerant are chemical stability in the system, toxicity, flammability, thermal characteristics, efficiency, ease of detection when searching for leaks, environmental effects, compatibility with system materials, compatibility with lubricants, and cost. In general,

- R-123 has replaced R-11,
- R-134a and R-401A have replaced R-12 and R-502,
- R-410A has replaced R-22.

No "drop-in" substitute refrigerants are available for any equipment category. This means that some changes in a system's equipment or materials of construction are always necessary when converting the equipment to using a replacement refrigerant. An existing refrigerant cannot simply be removed from a system and replaced with another. Usually the changes involve replacement of incompatible seals and changes in lubricant. Sometimes it involves changing an impeller wheel, increasing a heat exchanger surface area, or replacing an expansion device. Filter-driers, compressors, and seals that are compatible with CFCs, HCFCs, and HFCs have been developed. While some companies may be claiming direct drop in replacement capability, this is **simply not true**. Many equipment warranties are invalidated with the use of any refrigerant or oil other than those approved by the manufacturer specifically for the system. Some chemical companies are offering blends of working fluids as a "direct" replacement for a particular CFC or HCFC refrigerant. While these fluid blends may have the same general pressure-temperature saturation behavior as the refrigerant they are replacing, they will not have the same density, specific heat, or latent heat of vaporization. More importantly, if any leaks develop, a greater concentration of the more volatile components will escape disproportionately, resulting in potentially dramatic changes in the replacement refrigerant's characteristics. This is why blends generally must be charged as a liquid and if charge needs to be replaced, the refrigerant cannot be topped off. Instead, the old charge must be recovered and a new charge added as a liquid. There are some exceptions to this general statement on blends. R-410A, for example, is termed a near-azeotropic, meaning it behaves almost like an azeotropic refrigerant (the glide or difference between the boiling and condensation temperatures is less than 1°F). That means R-410A can be charged as a liquid or vapor and systems using R-410A can be topped off. If any questions concerning charging occur, follow the compressor or system manufacturer's guidelines exactly. Do not rely on recommendations from third-party sources selling replacement refrigerants. Failure to follow the equipment manufacturer's guidelines on proper refrigerant and oil can invalidate a warranty.

Some blends use a flammable hydrocarbon (such as propane, or butane) as one of the components in the blend.

Table 2 contains a list of blends and the composition of the mixture. The EPA has not made it illegal to use flammable blends in refrigeration systems, but it may be a violation of state laws.

Some refrigerant blend manufacturers have also chosen trademarks that may give the impression that the "New" refrigerant is a drop-in for R-12 and have even incorporated the "12" or “22” as part of their name. Always obtain the ASHRAE refrigerant number for any refrigerant you might be planning to use. Any refrigerants beginning with 4xx (such as 401 - 411) are non-azeotropic (or zeotropic) blends and any 5xx are azeotropic blends. However, refrigerant R-410A, which is a non-azeotropic blend, is considered a near-azeotropic blend. This means it behaves very much like an azeotropic blend and can be charged as a vapor without concerns of fractionalization. Refrigerants containing HCFCs can no longer be provided as the refrigerant in new equipment.

Table 2. Refrigerant Blends Containing at Least One Flammable Component

FX-40 HFC-32 (10%) HFC-125 (45%) HFC-143a (45%)	**R-401A** HCFC-22 (53%) HCFC-124 (34%) HFC-152a (13%)
R-401B HCFC-22 (61%) HCFC-124 (28%) HFC-152a (11%)	**R-401C** HCFC-22 (33%) HCFC-124 (52%) HFC-152a (15%)
R-402A HCFC-22 (38%) HFC-125 (60%) HC-290 (2%)	**R-402B** HCFC-22 (60%) HFC-125 (38%) HC-290 (2%)
R-403A HCFC-22 (75%) HC-290 (5%) FC-218 (20%)	**R-403B** HCFC-22 (56%) HC-290 (5%) FC-218 (39%)
R-404A HFC-125 (44%) HFC-134a (4%) HFC-143a (52%)	**R-405A** HCFC-22 (45%) HCFC-142b (5.5%) HFC-152a (7%) FC-C318 (42.5%)
R-406A HCFC-22 (55%) HCFC-142b (41%) R-600a (Isobutane) (4%)	**R-407A** HFC-32 (20%) HFC-125 (40%) HFC-134a (40%)
R-407B HFC-32 (10%) HFC-125 (70%) HFC-134a (20%)	**R-407C** HFC-32 (23%) HFC-125 (25%) HFC-134a (52%)
R-408A HCFC-22 (47%)	**R-409A** HCFC-22 (60%)

HFC-125 (7%) HFC-143a (46%)	HCFC-124 (25%) HCFC-142b (15%)
R-410A HFC-32 (50%) HFC-125 (50%)	**R-410B** HFC-32 (45%) HFC-125 (55%)
R-411A HCFC-22 (87.5%) HFC-152a (11%) HC-1270 (1.5%) (propylene)	**R-411B** HCFC-22 (94%) HFC-152a (3%) HC-1270 (3%) (propylene)
R-412A HCFC-22 (70%) HCFC-142b (25%) FC-218 (5%)	**R-507** HFC-125 (50%) HFC-143a (50%)

Retrofitting

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Never attempt to put any replacement refrigerant into an existing system without first retrofitting the system. Retrofit changes may include larger condenser surface areas to control head pressures, a high-pressure cut-out device for safety concerns, newly designed filter-driers, a new compressor, and/or different internal seals in the compressor or other internal parts. R-134a cannot be used as a direct drop-in replacement for R-12. Serious system problems will result if the proper retrofit guidelines are not followed.

The EPA's Significant New Alternatives Policy [SNAP] program requires that ALL alternative refrigerants be approved prior to use. However, **SNAP approval does not mean the refrigerant is suitable for a particular application.** Much more information about the SNAP program and about retrofitting procedures is available from the EPA Hot Line (800-296-1996) or the EPA Internet site, www.epa.gov.

Lubricants

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When servicing a system, it is imperative to assure that air and moisture contamination to polyol ester (POE) lubricants and polyalkylene glycols (PAG) does not occur. These oils are very hygroscopic, meaning they readily absorb moisture when left exposed to the air. Keep the oil containers closed and hoses sealed-off when not in use. Cross contamination of the oil can result in unwanted chemical reactions in the system, refrigerant breakdown, sludge formation and material corrosion.

Lubricant Change-Over

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In a retrofit application, one of the most important system changes is the lubricant. The lubricant used in a system should always be identified on the unit because of potential lubricant incompatibilities. The mineral oil lubricant used with HCFC and CFC refrigerants will not mix with the polyol ester (POE) lubricant which is used with HFC refrigerants. Polyalkylene glycols (PAGs) mix properly with HFCs at low temperatures, but have high temperature problems, as well as incompatibility with aluminum bearings and polyester hermetic motor insulation. Ester-based synthetic (POE) lubricants for HFC refrigerants resolve these problems, but are incompatible with existing PAG or mineral oils.

Refrigerant Contamination

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A potential death-blow to your system is refrigerant contamination. One quick, easy, and admittedly crude check for non-condensable gasses is to compare the measured high-side pressure with the saturation pressure at the condenser coil temperature. If the refrigerant charge is correct, then saturated conditions exist in the condenser. By comparing the saturation pressure to the actual high-side pressure, you can determine if there are any non-condensable gasses present in significant quantities in the refrigerant. Non-condensable gasses will raise the actual pressure above the saturation pressure. However, this method requires an accurate measurement of condensing refrigerant temperature so that the saturation pressure can be determined from a saturation pressure/temperature chart. It also requires an actual condenser pressure measurement. Typically, a pressure more than 20 PSI above the saturation pressure indicates that a non-condensable gas problem may exist. If non-condensable gases are trapped in the system, recovering vapor from the condenser should remove these non-condensable gasses and reduce the pressure discrepancy. To detect small quantities of non-condensable gas requires a detailed laboratory analysis and is not justifiable except in larger systems.

Flammability Hazards

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Never pressurize any refrigeration system with air or oxygen because this could result in an explosion! Some technicians may be tempted to pressure-test systems by using compressed air with refrigerant added to permit use of a refrigerant halide leak detector. This is a very hazardous practice. An article titled "Flammability Characteristics of Chlorodifluoromethane (R-22) - Oxygen - Nitrogen Mixtures" by Fedorko, Fredrick, and Hansel, was published in ASHRAE Transactions, Vol. 03, Part 2, 1987. This paper reports flammability studies with various mixtures of R-22 and air, with and without added oxygen. These mixtures can be flammable, and the possible hazards should be recognized. Some of the findings reported in the above article and elsewhere are summarized here. No flammability or explosive hazard is connected with the use of R-22 or any other CFC, HCFC, and HFC if the following good practices are observed.

- Never use oxygen or compressed air inside a refrigeration system.
- Never heat any part of a refrigeration system containing refrigerant with an open flame or high-temperature heater.

Figure 2. Standard Compressed Gas Labels

Look for the "Non-Flammable Gas" label on any compressed gas containers you use for pressurizing a system.

SDS

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Refer to the Safety Data Sheet (SDS) for warnings about exposure to a specific refrigerant, oil, or chemical compounds. SDS's are available wherever the product was purchased, and must be available to the purchaser upon request.

Most halogenated compounds will decompose at high temperatures, such as those associated with gas flames or high-temperature electric heaters. The chemicals that result under these circumstances always include hydrogen fluoride, which is acidic. If the compound contains chlorine, hydrogen chloride will also be formed. If a source of water or oxygen is present, a smaller amount of phosgene will be formed. Fortunately, the halogen acids have a very sharp, stinging effect on the nose and can be detected by odor at concentrations below their toxic level. These acids serve as warning agents that decomposition has occurred. If they are detected, the area should be evacuated until the air has been cleared of decomposition products. Read the manufacturer's warnings carefully and take the precautions seriously.

Section 3:
Sources of Potential Failure

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There are essentially three subsystems to an operating vapor compression system.

1) The **Refrigerant Circuit Subsystem** contains four basic components. These are the evaporator, condenser, expansion device and compressor.

The refrigerant circuit also contains other key components such as:

- **A)** The **filter-drier**, which serves to remove acid, water, and other impurities from the refrigerant. Even if you have not added a filter-drier, there is usually a small copper spun-metal drier that is installed by the manufacturer to capture any moisture that may have been added during system fabrication and charging in the factory. On any split system, a filter-drier should always be added, even if a factory-installed drier is present. Split systems are prone to more leaks because of the field-installed piping.
- **B)** A **liquid receiver**, which holds a reservoir of excess refrigerant to compensate for the density changes of the refrigerant as the system changes from operating in cold weather to operating in warm weather. This also allows the system to operate with a small loss in charge. The liquid receiver is sometimes simply incorporated into the condenser by over sizing the condenser. That is the last few rows of the condenser act as a liquid receiver.
- **C)** **Service access valves**, or means for attaching the service manifold.

The refrigerant circuit may also contain other components which are not necessary in all applications, such as:

- **D)** A **Suction Line Accumulator**, upstream of the compressor suction (inlet), to trap liquid refrigerant that might be returning to the compressor.
- **E)** A **Reversing Valve**, which changes the direction of flow in a heat pump, to switch the operation from heating to cooling.
- **F)** **Vibration isolators**, to isolate the compressor's vibration from the remaining plumbing and lower the stress and strain on the tubing.
- **G)** A **Muffler**, to reduce the noise generated by the compressor.
- **H)** A **Sight Glass,** upstream of the expansion device, to verify a complete charge and many times, to check for moisture (if equipped with a moisture indicating paper).

Note: Sure-fire killers to the Refrigerant Subsystem are acid, water, and improper charge.

Typical Mainstream QwikProducts™ that might be used on the Refrigerant Circuit to improve performance or increase life are:

A) Qwik**Check®** on the low-side Service Valve, to identify potential acid problems.

Figure 3. QwikCheck® before acid test

Figure 4. QwikCheck® after acid test if acid is present

B) Qwik**Shot® Acid Flush**, to remove acid in the system by dramatically accelerating the transport of acid to the filter-drier. Qwik**Shot®** leaves no residue and is guaranteed safe.

Figure 5. QwikShot® being poured into QwikInjector® for use

Figure 6. QwikInjector® connected inline for use

2) The **Air-Side Subsystem** contains two critical components: the evaporator blower and the condenser fan. The evaporator blower, being part of the indoor air system, and the condenser fan, which is part of the outdoor air section.

The Air-Side also contains other key components such as:

C) The **indoor air filter**, **condensate drain pan** and **condensate drain line**. A clogged indoor air filter will cause reduced indoor airflow, and this will result in a lower evaporator operating temperature. This will cause increased strain on the compressor due to the higher operating pressure ratio. It can also result in cooler compressor operation. This is typically not good, because it can result in liquid slugging, decreased oil viscosity, and/or increased compressor wear.

D) The **condenser** or **outside fan grill**, which serves to keep debris from clogging the condenser airflow path, and the condenser pad, which serves as a mounting platform (to level the unit) and also serves to lift the outdoor section above the soil (to minimize entrainment of soil into the condenser and keep the condenser coil away from string-edgers).

Typical products that might be used on the Air-Side to improve performance or increase life are:

A) Qwik**Clean**® **Foaming Coil Cleaner** a water-based heavy duty alkaline detergent, to clean and degrease the evaporator and condenser coils, thereby improving heat transfer and airflow.

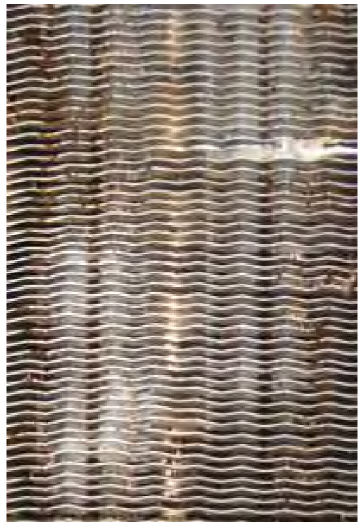

Figure 7. Coils Before cleaning with QwikClean® Foaming Coil Cleaner

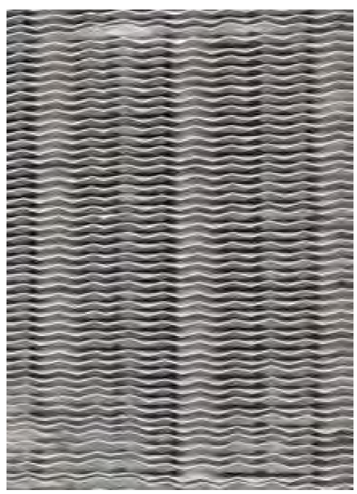

Figure 8. Coils After cleaning with QwikClean® Foaming Coil Cleaner

B) Qwik**Treat® Condensate Pan Treatment Tablets** to keep the condensate pan and humidifiers free from scum and to also keep the drain line flowing freely.

C) Pura**Clean® Filter Spray,** applied to the air filter, to improve filter performance.

Figure 9. PuraClean® Example of Treated vs. Untreated Filter

3) The **Electrical Subsystem,** which typically consists of the low-voltage control circuit and line-voltage power circuits.

The Electrical Subsystem typically contains key components such as:

A) A transformer, to convert the supply line voltage to the 24 VAC power used in the low-voltage control circuit.
B) A compressor contactor, which when closed will provide line power to the compressor (and the condenser fan in a split system).
C) An evaporator blower motor contactor, to provide line power to the evaporator blower motor.
D) A thermostat or other control device.
E) High-pressure and low-pressure cut-off switches that open the low-voltage control circuit when system pressure is too high or too low.

Excessively high pressures can be caused by a clogged or failed condenser fan, a clogged refrigeration circuit, a dirty condenser, an overcharged system, or operation outside of the system's operating range.

Insufficient charge, a clogged or failed evaporator fan, a dirty evaporator, or operation outside of the system's operating range can cause **low-pressures** and icing of the evaporator coil.

F) **Run and Start capacitors** and a **Starting Relay**, to increase the starting torque of single-phase motors. Note that both Run and Start capacitors are wired into the Start Windings of single-phase motors. A Start capacitor only remains in the electrical system during starting, whereas a Run capacitor is always wired into the Start Winding circuit. The Starting or Potential Relay switches the Start capacitor out of the circuit after starting.

Figure 10. Worn out capacitor

G) Compressor Current/Temperature Cut-Out Switch. This safety switch is not typically wired into the low-voltage control circuit. Instead, it is typically located on the external surface of the compressor and breaks the line voltage circuit (opens on a combination of current draw and temperature). The compressor may also have an internal pressure by-pass.

H) Time delay, to prevent compressor short cycling. A Delay on Break time delay will keep the circuit open for a prescribed time after the time delay is no longer energized (this is the best means for preventing short cycling). The Delay on Break will keep a compressor that was recently operating from short cycling. A Delay on Make will also keep the compressor from short cycling, because it will keep the circuit open for a prescribed time after the time delay is energized. The difference between the two approaches is that the Delay on Make will delay the starting every time, whereas the Delay on Break only delays restarting after the unit has already been running. If the time for the restart is sufficiently long afterward, no delay will be performed because the Delay on Break period has passed.

Typical Mainstream QwikProducts™ that might be used in the Electrical Subsystem to improve performance or increase life are:

A) Qwik**Lug**® to replace compressor lead wires when the compressor spade terminals are damaged or corroded.

Figure 11. QwikLug®

B) Qwik**SEER**+® **WattSaver**®, an electronic control that works with existing system hardware to automatically adjust the airflow of your air conditioner or heat pump to maximize performance, increase humidity removal, and save energy.

Figure 12. QwikSEER+® Wattsaver®

Section 4:
Refrigerant Circuit Subsystem Maintenance

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Four simple checks should be performed on the refrigerant subsystem to avoid potential problems:

1) Check Superheat and the System Charge.
2) Check for Acid.
3) Check for Moisture.
4) Check for Corrosion.

Check Superheat and System Charge

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Proper superheat is important, since it is an indication of the proper operating conditions for the system. A lack of superheat means that saturated, and therefore potentially partial liquid refrigerant, could be entering the compressor. That means the compressor could be trying to compress a liquid, which will lead to unnecessary strain on the compressor. In a suction-line cooled hermetic compressor, this incoming liquid refrigerant could also be causing the oil to foam, and decreasing the lubrication qualities of the lubricant, both of which will limit the life of the compressor. Foaming oil also leads to increased circulation of oil in the system, which can decrease heat transfer and lower performance.

Alternatively, excess superheat means the compressor inlet is warmer than normal and may cause compressor overheating. It also means that the portion of the evaporator designed for two-phase cooling has been reduced, and therefore cooling capacity has been reduced. Proper superheat should be determined by comparing the actual temperature (which should be warmer) with the saturation temperature at the same point (which is determined from the saturation pressure and the saturation pressure-temperature relationship), the difference in temperature is the superheat.

Table 3. Saturation Pressure-Temperature Chart for Common Refrigerants

	Saturation Pressure [psig]									
Saturation Temperature [°F]	CFC-11	CFC-12	HCFC-22	HCFC-123	HFC-125	HFC-134a	HFC-410A	CFC-500	CFC-502	CFC-503
-20	27.0[a]	0.6	10.1	27.7[a]	20.0	3.7[a]	26.2	3.2	15.3	161.0
-15	26.5[a]	2.4	13.2	27.4[a]	24.1	0.0	31.0	5.4	18.8	177.0
-10	26.0[a]	4.5	16.5	26.9[a]	28.6	1.9	36.3	7.8	22.6	194.0
-5	24.5[a]	6.8	20.1	26.4[a]	33.4	4.1	42.0	10.4	26.7	212.0
0.0	27.70[a]	9.2	24.0	25.8[a]	39.6	6.3	48.4	13.3	31.1	230.0
10.0	23.1[a]	14.6	33.8	24.4[a]	50.4	11.6	62.4	19.7	41.0	271.8
20.0	21.1[a]	21.0	43.0	22.7[a]	64.0	18.0	78.7	27.2	52.5	318.5
30.0	18.6[a]	28.5	54.9	20.8[a]	79.6	25.6	97.4	36.0	65.6	370.6
40.0	15.6[a]	37.0	68.5	18.0[a]	97.4	34.5	118.8	46.0	80.5	428.2
50.0	12.0[a]	46.7	84.0	14.9[a]	117.6	44.9	143.2	57.5	97.4	491.7
60.0	7.8[a]	57.7	101.6	11.0[a]	140.4	56.9	170.7	70.6	116.4	561.0[b]
70.0	2.8[a]	70.2	121.4	6.6[a]	166.0	70.7	201.8	85.3	137.6	
80.0	1.5	84.2	143.6	1.2[a]	192.6	86.4	236.5	101.9	161.2	
90.0	4.9	99.8	168.4	2.5	226.4	104.2	275.4	120.5	187.4	
100.0	8.8	117.2	195.9	6.1	261.7	124.3	318.5	141.1	216.2	

For systems using TXV and EXV expansion devices, superheat is actively controlled by these feedback control devices and if the superheat is incorrect then:

A) The expansion valve is not properly adjusted,
B) The sensing bulb or indicator is not firmly attached, or
C) The expansion device is faulty.

For systems using fixed orifice expansions devices or capillary tubes (that are correctly sized), the refrigerant charge affects the superheat. If the system is low on charge, the refrigerant completes evaporation too early in the evaporator passages, causing reduced cooling capacity and increased superheat. If the system has been overcharged, the refrigerant completes evaporation too late. That is too far down the evaporator passages, leaving little heat exchanger area for superheating the refrigerant, resulting in reduced superheat.

Acid in Systems

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The development of acids in the refrigerant and lubricant can severely shorten the life of the compressor and compromise the integrity of the HVAC system. Acids can be formed by reaction of one chemical component (*e.g.*, lubricant, refrigerant and/or impurities) with another, or by reaction of a chemical component with the materials of construction. The formation of acids inside the HVAC system is accelerated by elevated temperatures, which is exacerbated by issues such as a failed condenser fan or clogged airflow path. Higher concentrations of moisture also accelerate the chemical breakdowns of many of the chemical components, resulting in additional acid formation. Thus, checking the system for acid is a **MUST DO** maintenance procedure that must be regularly performed; early detection and treatment of the acidic condition can prevent damage to the HVAC system.

There are many oil test kits on the market; however, we recommend the Mainstream Qwik**Check**® 2-second acid test for a regular test of the refrigerant because it is

- Accurate
- Fast
- Inexpensive

It has the ability to detect acidity well before it reaches a harmful level, which is important since the early detection and treatment of acid build-up is the best preventive maintenance. Qwik**Check**® works with all refrigerants and oils, thereby removing the need to match a specific test to a given refrigerant/lubricant combination. Of particular concern is the testing of polyol ester-based (POE) oils, lubricants exhibiting amphoteric chemical properties. As a result, many oil acid test kits give a false acid reading because the oil behaves like an acid to the test kit. Because it is not sensitive to the type of oil or refrigerant used, Qwik**Check**® will not give a false reading when used with POE (polyol ester-based) oils.

A positive test for acidity should be treated immediately before damage results. A variety of treatment options are available, depending on the nature of the acidity. In cases where strong inorganic acids are generated, such as is found in R22/mineral oil systems, the acid should be removed, not neutralized. Attempts to neutralize inorganic acids within the system can result in formation of insoluble salts, which will lead to rapid failure of the compressor.

No matter what the actual cause of the failure, the *burn out* of a compressor typically results in the oil achieving a high level of acidity. If all of the generated acid is not removed prior to installation of the new compressor, residual acid will aggressively attack the new compressor and hasten compressor *burn out*. If the presence of acid is detected early, prior to compressor failure, acid cleanup will involve changing the compressor oil and the refrigerant to reduce the acid level. Unfortunately, removal of the oil contained in the compressor does not remove all the acid in the system, since acid is carried throughout the vapor-compression loop by flowing refrigerant and misted oil. Since acid can *catalyze* the breakdown of oil and/or refrigerant, leading to the generation of more acid, even a small amount of residual acid has been shown to significantly shorten system life. This has been supported by experimental evidence that after a *burn out*, the frequency of subsequent *burn outs* increases. It can be concluded that in these cases, either the acid was not completely removed or because the underlying problem that caused the original *burn out* and generation of acid was never corrected.

A discussion of the types of acids present in the system is necessary to fully understand the acid treatment and removal processes. Depending on the refrigerant and oil being used in the system, an HVAC or refrigeration system can contain two types of acids.

- Organic acids, such as *oleic* acid, can be present, particularly as the result of the chemical breakdown of polyol ester oils. These are higher molecular weight oils, and as a result are nonvolatile and highly soluble in the oil.
- Inorganic (or *mineral*) acids, such as hydrochloric acid, typically result from the breakdown of the refrigerant. They are only slightly soluble in the oil, particularly mineral oil. Their lower molecular weights and high vapor pressures mean they are not confined to the oil reservoir and can travel extensively throughout the system.

Both inorganic and organic acids are corrosive. Inorganic acids typically have high dissociation constants, making them strong and very reactive acids. The combination of acidity and a strong anionic species, such as chloride, leads to predominantly (but not exclusively) *pitting* corrosion. Organic acids are weaker acids and therefore react more slowly. Organic acids more typically are associated with *formicary* corrosion, particularly on copper and alloy components of the system.

Within a sealed HVAC system, mineral oil will initially thermally decompose, polymerizing into *sludge* and releasing smaller organic gases (primarily methane, ethane, and ethylene) and hydrogen. In the presence of air/oxygen, decomposition products of mineral oils can include organic acids. In the absence of air or moisture, synthetic oils such as polyol esters will polymerize into *sludge*. At elevated temperatures and in the presence of moisture, the esterification process will reverse, returning the polyol ester to its alcohol and organic acid forms. Since polyol esters are produced through the esterification of alcohols and carboxylic acids, organic acid may be initially present (up to 8 PPM). This residual acid can catalyze the breakdown of synthetic oils.

Thermal decomposition of the refrigerant results in the formation of the strong inorganic acids. Because of their low solubility in the oil and their high vapor pressures, inorganic acids remain primarily in the vapor phase and can react quickly when they come into contact with the materials of construction. These acids will be removed from the vapor phase by a properly functioning filter-drier. Experiments have shown that, with an operating filter-drier, the amount of inorganic acid vapor decreases by 85% in a matter of hours. The concentration of inorganic acids contained within the oil, however, remains dangerously high and can result in compressor burn out. The actual concentration of acid trapped in the oil is a function not only of the solubility of the acid in the oil, but also of acid trapped in the oil due to the oil's foaming and agitation, and of acid dissolved in any trapped moisture. The inorganic acid content in the oil is slow to diminish without treatment, and so long as it is retained by the oil, the acid will be in contact with the compressor components, including the motor windings. Etching of the lacquer insulation of the motor windings causes an electrical short, and a subsequent motor *burn out*. **It has been demonstrated that an acid concentration of only 50 PPM will cause a hermetic compressor motor to *burn out* in a matter of days!**

A treatment employing several flushes of the vapor-compression system with the appropriate refrigerant can be effective at reducing the acidic residue throughout the system. However, compliance with EPA-mandated refrigerant recovery requirements makes this approach time-consuming and costly with respect to both labor and materials (*i.e.*, refrigerant).

An *unacceptable* alternative approach is to neutralize the acid by introducing a basic solution, prepared by dissolving a base such as potassium hydroxide in a liquid carrier. As dissolved solids, the bases cannot vaporize; this severely limits the effectiveness of this approach to address the presence of acid located throughout an HVAC/refrigeration system. Putting this limitation aside, there are at least two additional reasons why this approach is deemed unacceptable:

- The first obstacle with any acid neutralization of this manner is that a rather precise amount of base must be added. If an insufficient amount of base is introduced, the refrigerant and oil will remain acidic. An excess of base will ensure that the system becomes damagingly basic. **Both acidic and basic paths to corrosion will lead to the inevitable failure of the compressor.**
- The reaction of a strong acid with a strong base always results in the formation of a salt and water. Assuming the filter-drier has the absorption capacity, water will be removed during system operation. On the other hand, the salt likely remains in the compressor reservoir. In addition to the corrosive nature of salts, low solubility in the lubricant could create other problems.

Some acid neutralization manufacturers have proposed that the neutralization solution be introduced in the compressor discharge so that it will be forced through the condenser, filter-drier, TXV, and evaporator, before getting trapped in the compressor's oil supply. They explain that the liquid neutralization solution is thereby forced to travel throughout the system before becoming trapped in the compressor oil. However, the flashing at the TXV could also cause the solvent to vaporize leaving a deposit of the solid base material, such as KOH, to clog the TXV. Even if the basic solution passes through the TXV, the solvent will likely evaporate in the evaporator, leaving the solid basic material in the evaporator.

Some have proposed the use of a weaker base such as sodium bicarbonate. Every strong acid neutralization reaction will result in the formation of a salt residue; it is fundamental chemistry that cannot be changed. The use of bicarbonate, however, will also produce carbon dioxide, a gas whose thermodynamic properties make it incompatible with an HVAC or refrigeration system.

Finally, these neutralization approaches are only chemically compatible with mineral oils and alkylbenzene oils. Polyol ester oils exhibits amphoteric characteristics that make the oil behave as a base in the presence of an acid and vice versa. Consequently, the added base can initiate breakdown of the ester oil instead of performing its intended acid neutralization.

The filter-drier does an excellent job of removing acid and it does so by *adsorption* not by neutralization. **The problem with relying on the filter-drier to remove the acid is that the significant portion of acid that is trapped on the hard surfaces and in the oil never gets to the filter-drier to be removed.** The performance of the filter-drier can be dramatically improved by actively *encouraging* the acid to abandon its dissolved and adsorbed conditions and then to proceed to the filter-drier. A note concerning filter-driers, not all filter-driers are the same. Filter-driers employing molecular sieves rather than activated alumina are recommended, because molecular sieves have much greater acid and water adsorption capacities compared to activated alumina. However, activated alumina is far less expensive, so these filter-driers are less expensive to manufacture.

If a compressor does burn out, the oil becomes extremely acidic. If all this acid is not removed when the compressor is replaced, the elevated acid levels will attack the new compressor and cause another compressor motor burn-out. After a compressor *burn out* and subsequent compressor *change out*, concentrations of inorganic acids far above 200 PPM have been measured in the new compressor's oil. These high concentrations exceed expectations of what would be simply dissolved and trapped in the residual oil, in part because some inorganic acid is adsorbed onto the surfaces of solid particulates that were created during the prior *burn out* and which could not be completely removed from the system. In some cases, this acid is also dissolved in water that is trapped in the residual oil. In particular, this can be a concern for polyol ester oils which typically have much higher levels of water than other refrigeration oils.

Simple agitation of the oil has not been found to release this trapped acid. In order to demonstrate this, an oil sample with an initial acidity value of 133 PPM (inorganic acid) was **vigorously** stirred for 32 hours using a stir plate/magnetic stirrer. This method was chosen as it would provide agitation of the oil far exceeding what would be expected during normal operation of the compressor. The acidity dropped 45 percent to 73 PPM. While this may seem like a significant drop, it should be pointed out that the compressor would have burned out in less than 33 hours of operation at this acid level. Therefore, without a treatment approach to accelerate the removal of the acid from the oil and regardless of how good the filter-drier performed, the replacement compressor would have failed. If inorganic acid could be freed and flushed from the oil, and from its adsorbed state, in a reasonable time, then a functional filter-drier in the system would remove this acid. Qwik**Shot**® **Acid Flush**™ was designed for the purpose of freeing and flushing the trapped acid from the oil and acid-contaminated surfaces. Qwik**Shot**® **Acid Flush**™ itself vaporizes, so that it can travel throughout the system and help convey the acid to the filter-drier. The experiment described at the onset of this paragraph, the agitation of the acidic-oil, was repeated with Qwik**Shot**® added to the oil prior to stirring. After 20 minutes, the acid was completely (100 %) stripped from the oil by Qwik**Shot**® **Acid Flush**™! The ordinary filter-drier is an adsorption bed which clears both the flushed acid and the QwikShot additive from the vapor-compression stream.

To verify the effectiveness of Qwik**Shot**® **Acid Flush**™to flush acid from an actual refrigeration/air conditioning system, Qwik**Shot**® was introduced into a system set up with a known level of compressor oil acidity. Initially, the compressor oil in this test had a strong acid (SA) concentration of 120 PPM; the amount of oil in the crankcase was 450 grams. Qwik**Shot**® was introduced into the compressor's oil sump through the low side valve of the compressor **(using a QwikInjector®)** so that it could thoroughly mix with the oil during the lubrication of the compressor. The amount of Qwik**Shot**® introduced was 4.5 grams (one percent of the oil weight). QwikShot® facilitated liberation of the trapped acid from the oil within 2 hours of operation. For the *control* experiment a system with comparable acidity was operated without the addition of the Qwik**Shot**® **Acid Flush**™, and the compressor burned-out after less than 12 operational hours with no measurable decrease in the acid level observed.

QwikShot® should NOT be introduced directly into a new compressor's oil prior to installing the new compressor. The evacuation process will remove the QwikShot® additive before the unit is ever turned on without providing any benefits. Instead add QwikShot® to an operating system, after it is charged with refrigerant.

When introduced into an HVAC compressor, the Qwik**Shot**® concentration will be less than 1% and will not affect the lubrication properties of the oil. As Qwik**Shot**® mixes with the oil, it liberates acid and water from the oil and interior surfaces. The acid, water and Qwik**Shot**® are vaporized (thereby leaving the oil) and travel through the system where they become adsorbed in the filter-drier. (Molecular sieve-based filter driers are recommended, but carbon and activated alumina filter-driers will also work.) The net result is that acid and water are removed and no residue is left in the system. The Qwik**Shot**® dosage charts are formulated so that the Qwik**Shot**® will not use up the total capacity of the filter-drier, but will leave more than half the filter-drier's capacity for future cleanup of water or acid.

By using Qwik**Shot**®, a system can be thoroughly cleaned of acid without leaving any residue. This has been verified by gas chromatographic analysis of the refrigerant and oil in the system.

Using QwikCheck® to Check for Acid

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Qwik**Check**® gives you the ability to quickly perform refrigerant acidity tests on operating compressors that don't have an oil drain, such as is the case *hermetic* compressors. Qwik**Check**® is universal, working with all refrigerants and all oils. This provides you with the ability to service your customers more effectively. On an operating HVAC or refrigeration system, you can detect acid levels which would lead to compressor damage, cause the formation of sludge in the system, and catalyze the production of undesirable non-condensable gases.

Qwik**Check**® is truly the easiest of all *in-field* acid testing tools available today. To test the refrigerant acid content in an operating unit, simply remove Qwik**Check**® from its package and insert the valve core depressor tip of the Qwik**Check**® into the center of the low-side refrigerant (vapor) service valve of an operating system.

The valve core depressor tip should depress the low-pressure (vapor) service valve, allowing vapor refrigerant to pass through the Qwik**Check**®. Allow the vapor refrigerant to discharge while you slowly count to two. Stop counting if the indicator turns red. This process does not violate any EPA venting restrictions; the process of removing oil to test for acid actually vents more refrigerant than Qwik**Check**® and therefore the use of Qwik**Check**® is allowable by the EPA.

- If the yellow indicator paper does not change color, you may want to hold it on the system for another count of two to double the exposure. If it remains yellow, you have no acid problem.

Figure 13. QwikCheck® is yellow before acid test.

- If the yellow indicator paper turns orange (even slightly), the refrigerant contains some acid. You must, as minimum steps, add Qwik**Shot**® and change the filter-drier in the system. See the Qwik**Shot**® instructions for more details. If it is an old system, it may be wiser to talk to the equipment owner about installing a new high-efficiency unit.
- If the yellow indicator paper turns red, the acid problem is severe. A change of the filter-drier, refrigerant and oil is recommended. Also, it is likely time to add a suction-line filter drier if one is not already installed. See the Qwik**Shot**® instructions for more details. Once again, it may be time to consider the installation of a new high-efficiency unit.

Figure 14. QwikCheck® is orange to red after acid test if acid is present.

Qwik**Check**® takes seconds to perform and will save your customers aggravation, money, and downtime. Every service call should include a Qwik**Check**® as part of a conscientious preventive maintenance program.

Filter-Drier Types and Locations

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Small concentrations of acid left in a system from a prior problem can very quickly accelerate the formation of additional acids. This acid formation is further accelerated if moisture is present in the system. Changing the filter drier will allow the filter to remove any acid that reaches the filter-drier. Molecular sieves have a much greater acid and water adsorption capacity than activated alumina, but activated alumina is much less expensive and widely used by some manufacturers to save money. Always choose a drier with at least 80% molecular sieve. Carbon in the mixture will also aid in the removal of a wide variation of contaminants and therefore a small concentration of carbon is also recommended.

The purpose of the liquid line filter drier is to remove any moisture and/or contaminants just before the expansion device (TXV, Capillary Tube, or orifice plate). These expansion or throttling devices have a small restriction or opening, thereby causing the pressure to drop as the refrigerant is forced to flow through this restriction. The sudden drop of pressure quickly cools the refrigerant to the saturation temperature of the refrigerant (at the low side pressure). That is, the refrigerant quickly cools to the evaporation temperature. Any moisture in the refrigerant could freeze at this point, and the resultant ice could clog the expansion device and thereby stop the unit from cooling.

Experienced technicians are all very familiar with the refrigeration unit that initially works, and then stops working. They know the cause of the problem is moisture in the system, which freezes, clogging the expansion device and stopping the operation of the system (the ice then melts when the system is off and warms allowing the unit to initially work again). However, moisture levels much lower than the amount necessary to cause ice ball formation can cause very rapid acceleration of the acid formation in the system. This problem is further exaggerated by the new POE oils that have a much greater tendency to absorb moisture (hygroscopic).

After a burnout, a suction line filter is added to the system for a different purpose than the liquid line drier. When a compressor burns out, highly acidic oil is formed, and while the majority of this oil remains in the compressor, some oil is always present in the plumbing and remaining components of the system. Prior to EPA regulations, technicians would flush the system with refrigerant to wash these contaminants out of the system. This is no longer a legal or economical practice due to the high cost of the newer refrigerants. One very effective alternative, and the method endorsed by all major manufacturers, is to install a suction line filter drier in the system. That way, the residual acidic oil remaining in the system after a new compressor is installed will be trapped by the suction line filter drier, instead of working its way back into the new compressor's oil reservoir. Without the suction line filter-drier, this acidic oil would work its way back to the compressor and would accelerate further acid formation.

When Qwik**Shot**® **Acid Flush** is used in the system it **does not neutralize** any acid in the system, because a neutralization reaction will **always** form products of the neutralization reaction, namely a salt and water. Both things we don't want in a refrigeration system. The unique, patented formulation of Qwik**Shot**® does not neutralize the acid. Instead, it carries the acid (flushes the acid) and any water to the filter drier, where it is removed. Since typical oil transport is between 0.5% and 2% of the total mass flow rate through the system, without Qwik**Shot**® a relatively low acid level will still etch the insulation off the motor windings before sufficient quantities of the acidic oil can be transported to the filter drier for removal of the acid. Qwik**Shot**® increases the rate at which the acid is carried to the filter drier because it has a high affinity (attraction) for the acid and water and rapidly carries this acid and water to the filter, where they can be adsorbed by the filter-drier (it is not neutralized).

The use of any water-based flush will add moisture to the system and **should never be used**.

WARNING:
The use of any water-based flush will add moisture to the system and should ***NEVER*** *be used under any circumstances.*

Instructions for Using QwikShot® Acid Treatment

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Step 1. Check for Acid

- If the compressor has burned out, don't waste a Qwik**Check**® checking for acid. The system is loaded with acid. Change the compressor, refrigerant, filter-drier and oil. Add a Suction Line filter-drier. After charging the system, add the proper dose of Qwik**Shot**®. Go to step 2.
- If the compressor has not burned out, use a Mainstream QwikCheck® to determine if the refrigerant is acidic.
    - The first thing to determine if the system is worth saving! The labor involved with treating for acid along with the addition of a filter-drier and so on, could be substantial and the system may be old and inefficient. It may be better for the equipment owner to invest the labor expense in the installation of a new more efficient unit. Therefore your first step is to discuss any replacement options with the equipment owners. To repair an old unit that then fails later on the hottest day of the year, when you are up to your neck in emergency service calls, is a sure-fire way to lose

customers. If the unit is old or inefficient, you can schedule a time to replace the unit, and explain to the owner that the unit is operating on its last leg. If the unit should fail before you install the new unit, it is not an unexpected occurrence and they will still call you for the replacement. If the unit does not fail then you have assured that you get the change-out job when it is convenient for you and avoided yet another service call on the hottest day of the year.

- If the refrigerant tests highly acidic (Qwik**Check**® indicator turns red), change the refrigerant and oil. Also, change the filter-driers (adding a suction-line filter-drier if one is not already installed). *Go to Step 2*.

Figure 15. Red QwikCheck® indicates acid is present.

- If the refrigerant tests mildly acidic (Qwik**Check**® indicator turns orange), you need not change the refrigerant or the oil, but you should change the filter-driers. *Go to Step 2*.
- If the refrigerant does not test acidic (Qwik**Check**® indicator stays yellow), skip all subsequent steps. No acid treatment is necessary.

Figure 16. Yellow QwikCheck® indicates no acid is present.

Step 2. Determine the Size of the Filter-Drier in the System

- Determine the recommended filter-drier for the system. If the equipment manufacturer does not make any specific recommendations, any filter-drier compatible with the refrigerant being used is recommended.

Step 3. Determine the amount of QwikShot® Acid Flush™ to use

- Use the half-ounce bottle of QwikShot® to treat up to a 5-ton system (filter capacity of up to 200 drops of water, or up to a 20-cubic inch drier).

Step 4. Add QwikShot® Acid Flush™ to the Compressor Oil

- Add Qwik**Shot**® through the low-pressure service valve using a Qwik**Injector**®.

Figure 17. Adding QwikShot® to QwikInjector® for use

Figure 18. QwikShot® injected into system using QwikInjector®

- **<u>Never add QwikShot® directly into the oil of a compressor being installed, the subsequent system evacuation will evaporate and remove all the QwikShot®!</u>** The Qwik**Injector**® is filled with 0.5 ounce (one bottle) of Qwik**Shot**®, then service hoses are connected between the high and low side service ports so that the Qwik**Shot**® is pushed into the operating system by the compressor's head pressure.

Step 5. <u>(Optional)</u> After at least 16 hours of operation, recheck the system for acid.

- For highly acidic systems, after at least 16 hours of operation, but typically not more than seven days of operation, it is recommended that the system be re-tested for acid with another QwikCheck. If any sign of acid remains, repeat Steps 1-4.

Moisture in a System

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Early detection of moisture in a system is critical to avoiding corrosion, acid, and related problems. If a sight-glass with moisture indicator is present in the system, check it at every service call.

In the new systems that use POE oil for lubrication, the moisture problem is worse than most technicians realize. POE oils are manufactured from organic acids and when water is present in the POE, a hydrolytic decomposition of the POE lubricants with water (reverse esterification) produces mild organic acids usually carboxylic acids and results in the formation of sludge. To explain another way, POE oil is made from acid in an esterification reaction and when exposed to water the reaction can reverse and the POE lubricant decomposes back to the acid. The amount of acid generated from POE hydrolysis is primarily dependent on the amount of water available; more water means more acid is formed. Unfortunately POE (polyol ester), PVE (polyvinyl ether), and PAG (polyalkylene glycols) are very hygroscopic with saturation values of 2500, 6500, and 10000 parts per million (ppm) water compared to 25 ppm for mineral oil (Thomas and Pham 1989, Hiodoshi et al. 1999). While PVE and PAG are not subject to hydrolysis they are prone to oxidative degradation which also forms acidic by products.

The hydrolysis of POE is worse with improper evacuation. Cavestri et al. showed that in POE systems, low levels of organic acid and water both contributed to system corrosion but the degradation process was **greatly accelerated** in the presence of air (Calvestri, R.C., and Schooley, D.L., “Test Methods for Inorganic Acid Removal Capacity in Desiccants Used in Liquid Line Driers,” ASHRAE Trans. Vol. 104, PT 1B, pp 1335-1340, 1998). That means good system evacuation is even more critical in these newer HFC systems.

Check for Corrosion

During your service call or tune-up, check the exterior condition of the compressor, filter-drier, accumulator, receiver, or any other steel components. These housings are typically painted steel and can easily rust in humid environments. A can of paint or rust proofing can slow the corrosion process and extend the life of the unit. Of course, be sure to inform the equipment owner about the rust proofing service you have performed. One other potential problem is a corroded condenser fan. Spending its life in an outdoor, potentially humid environment, causes the steel motor shaft to rust. When the rusted shaft surface contacts the permanently lubricated sintered-metal bearings in the fan motor, it significantly shortens the life of the bearing. A light coat of spray-on lubricant on the fan motor shaft will extend the life of the fan motor. In higher-end refrigeration units or rooftop AC units, ball or roller bearings may be used. Check for grease fittings on these bearings.

Section 5:
Air Side Subsystems Maintenance

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Seven simple checks should be performed on the air-side subsystems to avoid potential problems:

1. Check for clogged or dirty airflow paths.
2. Check/Treat for mold or other IAQ problems
3. Clean the condenser and evaporator coil.
4. Change and treat the air filter.
5. Clean and treat the condensate pan and drain lines.
6. Check for air leaks.
7. Check for free spinning operation of the blower and fan motors.

Check the Airflow Paths, Check for Mold and Clean the Coils

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Outdoors

- Check the condenser airflow path and wash the outdoor coils with Qwik**Clean**® **Foaming Coil Cleaner** to clean the condenser coil and aid in the removal of corrosion products, thereby improving heat transfer and outdoor airflow. A clogged or dirty condenser coil can reduce efficiency of the unit, increase the pressure ratio of the compressor and reduce the subcooling at the exit of the condenser.

Indoors

- **Check the evaporator airflow path and clean the indoor coil** with Qwik**Clean**® **Foaming Coil Cleaner** to clean and degrease the evaporator coil, thereby improving heat transfer and airflow. No rinsing of the coil is required in this application. An alkaline cleaner is best suited to remove cooking oils, grease, and dirt from the indoor coil ***without accelerating or initiating any corrosion*** of the aluminum fins. A clogged or dirty evaporator coil can reduce efficiency of the unit, increase the pressure ratio of the compressor and reduce the superheat at the inlet of the compressor.
- **Check for mold**. You should suspect hidden mold if a building smells moldy, even if the source cannot be seen, or if there has been water damage and

residents are reporting health problems. Humidifiers and condensate drain pains provide both a growth medium and a distribution system for mold and mildew and should always be inspected and cleaned. Qwik**Treat® Condensate Pan Treatment Tablets** should be used to prevent scum build-up in the condensate pan or clogging of the condensate drain line (follow all label directions).

If mold is discovered, clean the mold and mildew from hard surfaces with a foaming coil cleaner or other hard surface cleaner. If any mold or mildew is present or the building smells moldy then verify that the AC unit is operating properly. Humidity must be maintained below 55% (ideally 30% to 50%). If humidity is a problem, consider installing a dehumidifier into the existing system.

Molds gradually destroy the things they grow on. The simple way to prevent damage to building materials and furnishings, save money, and avoid potential health risks caused by mold formation is to control moisture and thereby eliminate mold growth. **The key to mold control is moisture control.** Molds are part of the natural environment. Outdoors, molds play a part in nature by breaking down dead organic matter, such as fallen leaves and dead trees, but indoors, mold growth should be avoided. Molds reproduce by means of tiny spores; the spores are invisible to the naked eye and float through outdoor and indoor air. **Mold may begin growing indoors when mold spores land on surfaces that are wet**. **There are many types of mold but none of them will grow without water or moisture.** Mold spores are usually not a problem indoors, unless these mold spores land on a wet or damp spot and begin growing into mold. Molds have the potential to cause health problems. Molds produce allergens (substances that can cause allergic reactions), irritants, and in some cases, potentially toxic substances (mycotoxins). Inhaling or touching mold or mold spores may cause allergic reactions in sensitive individuals. Allergic responses include hay fever-type symptoms, such as sneezing, runny nose, red eyes, and skin rash (dermatitis). Molds can also cause asthma attacks in people with asthma who are allergic to mold. In addition, mold exposure can irritate the eyes, skin, nose, throat, and lungs of both mold-allergic and non-allergic people.

Instructions for Using QwikClean® Foaming Coil Cleaner on Evaporator Coils

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Step 1. Turn off power to the unit being serviced.
Step 2. Spray until the surface is completely covered and thoroughly saturated. As the foam breaks down, condensation in the evaporator will rinse the emulsified dirt from the surface of the evaporator coil.
Step 3. Using a fin comb, straighten any fins that are bent or damaged.

Figure 19. QwikClean® Foaming Coil Cleaner

Instructions for Using QwikClean® Foaming Coil Cleaner on Condenser Coils

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Step 1. Turn off power to the unit being serviced.
Step 2. Spray until the surface is completely covered and thoroughly saturated. Wait until the foam begins to break down before proceeding to Step 3.
Step 3. The condenser should be hosed off after the foam begins to break down. Use a garden hose to wash the cleaning solution off the coils. The preferred spray direction is from inside to outside.
Step 4. Repeat Steps 2 and 3 if necessary.
Step 5. Using a fin comb, straighten any fins that are bent or damaged.

Instructions for Using PuraClean® Filter Spray

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Pura**Clean**® enhances the performance of any filter improving the capture of airborne allergens, dust, lint, and house mite debris. Pura**Clean**® will improve the filter's MERV rating up to 65%. A more effective filter will keep the indoor coil cleaner and will improve system efficiency.

Step 1. Remove old filter.
Step 2. Using a new disposable pleated or blown-glass filter, or a clean metal mesh filter, spray both sides of the filter with Pura**Clean**®. Be sure to sufficiently cover all areas of the filter on both sides.
Step 3. Let filter dry for at least five minutes.
Step 4. Install the Pura**Clean**® treated filter in the air handler.
Step 5. Record filter install date.

Clean and Treat the Condensate Flow Path

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Check the condensate drain pan for sediment or scum build up and clean all exposed pan surfaces using Qwik**Clean® Foaming Coil Cleaner** using the instructions on the can. Be sure the condensate drain line is clean and free flowing.

Place a Qwik**Treat® Condensate Pan Treatment Tablet** in the drain pan.

Check the Indoor Fan Coil Unit for Air Leaks

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Look for air leaks around the air filter; look for leaking air ducts, and check the airflow and air distribution in the building. Inspect for moisture on the exterior of ducts, this can indicate an air leak in unconditioned spaces which is condensing moisture from the surrounding air.

Check for Free Spinning Operation of the Blower and Fan Motors

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1. Inspect the outdoor fan motor shaft for corrosion.
2. Spin the fan blade to check the bearing conditions and verify the motor is freely spinning.

3. Turn the unit on and immediately off to check for proper spin up and listen for bearing noise and out-of-balance vibration as the fan coasts to a stop.
4. Check for a solid mounting and visually check for bent fan blades.
5. Lubricate the motor shaft to minimize shaft corrosion.
6. Check for exposed or loose fan wires.
7. Repeat the above procedure for the indoor blower motor.

Section 6:
Electrical Subsystem Maintenance

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Three simple checks should be performed on the electrical subsystem to avoid potential problems:

1. Check that the compressor leads are securely fastened.
2. Check the contactors.
3. Check for proper starting of the compressor.
4. Check the capacitors

Check that the Compressor Leads are Securely Fastened

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Check to see if the wire leads to the compressor are tight. A loose spade connector will arc, causing pitting and other damage to the spade. If the wire leads are loose or damaged, reattach the compressor lead wires with a QwikLug® wire terminal adapter. Check the run and common wire leads, since these typically fail before the start winding lead. If only one lead looks bad, change all the leads, since the others may be very close to failing as well. There is nothing worse than a system failing a few weeks after you performed a preventive maintenance service. If the original three (run, start, common) female spade connectors attaching the wire leads to the compressor are tight, you may want to cover these spade terminal connectors with an oxide inhibiting compound that is available at most electrical supply houses and can help prolong the life of these original spade connectors. The use of an oxide-inhibiting compound is not necessary when using QwikLug®.

Instructions for Using QwikLug®

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Step 1. Disconnect the power.

Step 2. Clean damaged or corroded terminals. A good electrical contact between the Qwik**Lug**® and the compressor terminal post is necessary. Failure to clean the terminal posts before installing Qwik**Lug**® will cause a poor electrical connection, and may cause overheating and damage to the wire insulation and the Qwik**Lug**®.

Step 3. Verify that the crimped spade connector on the Qwik**Lug**® wire is inserted into the Qwik**Lug**® body with the Spade pressed against the long flat side of the opening.

Step 4. Slide the Qwik**Lug**® over the terminal and tighten the screw with a Phillips screwdriver. The Spade should be located between the cleaned compressor terminal and the Qwik**Lug**® screw. For tight spaces, smaller hex-head set-screws are available, in the Qwik**Lug**® packaging, instead of the Phillips screws. These hex-head screws provide additional clearance.

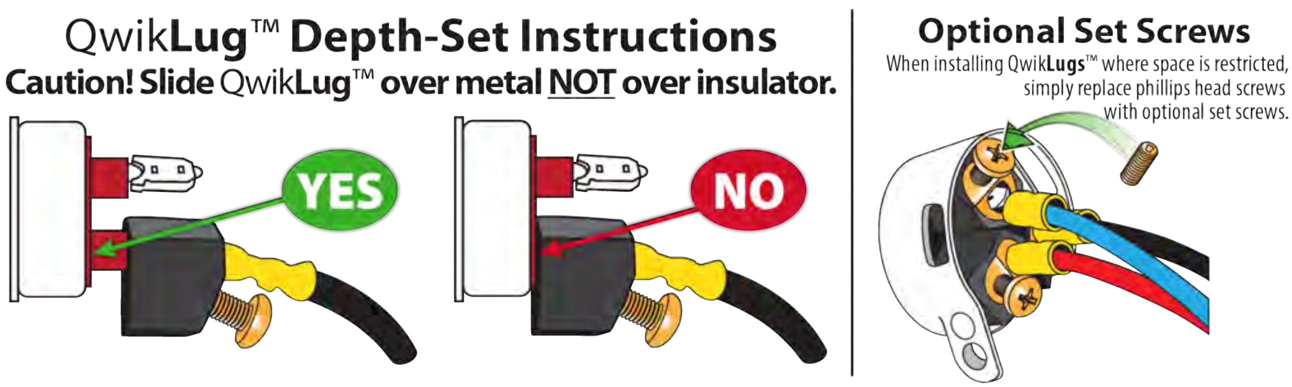

Figure 20. QwikLug® instructions

Check the Contactor

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The Contactor, also known as a Relay, is simply an electromagnetic switch that is activated (closed) by a 24 Volt AC control circuit (Coil), thereby completing the line voltage electrical circuit to the compressor, blower, or fan motor. The electrical contacts on the line voltage connection are many times referred to as the points. There are typically two contactors on AC and heat pump systems. One activates the compressor and condenser fan (located in the outdoor section of a split system) and the second activates the indoor blower (located in the indoor air handler of a split system). On some newer indoor air handlers that use X-13 or ECM motors, there is no contactor to activate the blower motor, that is the blower motor is powered directly from the line power (always hot) and the blower motor is turned on and off via the 24 VAC control lines going to the motor from a controller circuit board in the air handler or sometimes for X-

13 motors directly from the green (Blower) and Common thermostat leads. The ECM or X-13 motors are activated by the 24 VAC control signal. For X-13 motors the motor is activated by supplying 24 VAC to the common and one or more of the 5 low-voltage terminals on the X-13. The actual function of each of the low voltage terminals on the X-13 motor is programmed by the air handler manufacturer and not all the positions may be active. There is also no uniform standard relating to how any of the five 24 VAC control terminals are used for any particular function. However, the AC high voltage connections on the X-13 motor are uniform, with L being for Line 1, G for Ground and N for Neutral on 115V motors and N being Line 2 for 208-240 motors. Also note that for X-13 motors, they cannot be field wired for a different input voltage. However, ECM motors can typically be field wired for either 115VAC or 208-240 VAC operation.

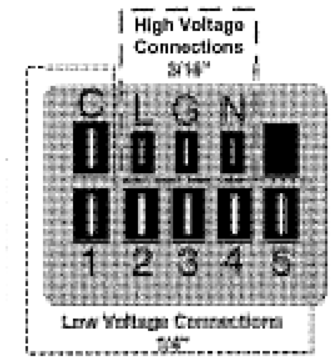

Figure 21. Connection Terminals on X-13 Type Motors

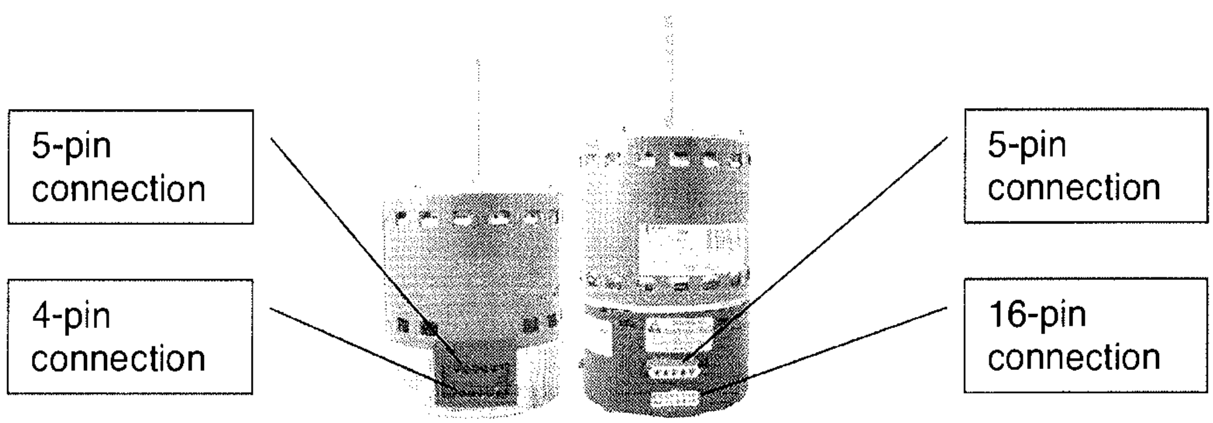

Figure 22. Connection Terminals on ECM Motors

When a contactor (relay) is used, the contactor can be a Double-Pole, meaning both line voltages of a single-phase 220 VAC circuit are opened or closed by the contactor; Single-Pole, meaning that only one of the two line voltages of a single-phase 220 VAC circuit is opened and closed by the contactor (and the other line is always connected and hot), or Three-Pole, meaning that all three line voltages of a three-phase (240 or 480 VAC) circuit are disconnected. Since the horsepower and starting surge current draw of the compressor contactor is the largest, it is the contactor in the outdoor unit that typically fails first.

WARNING:

When a Single-Pole Contactor is used on a Single-Phase 220 volt circuit, the compressor is still electrically hot even when the contactor is open, since only one of the 220 volt lines is being disconnected and either line has a voltage to ground of 110 volts.

WARNING:

When a Single-Pole Contactor is used on a Single-Phase 120 volt circuit, the hot lead and not the neutral should be wired through the contactor.

WARNING:

When connecting a three-phase circuit, check for proper rotational direction of the compressor. This is easily done by checking the high- and low-side pressures developed when the compressor is operating. If the compressor is not rotating in the proper direction, reverse any two of the three-phase wires to change the direction of rotation. Do not check for proper rotation, and therefore proper wiring, by inspecting the condenser fan, since the fan is probably single-phase and will rotate correctly, regardless of the wiring of the three-phase circuit.

Check that the Contactor Points are Clean

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Check the status of the relay contacts, which are also called the points. If the relay contacts are pitted, the relay should be replaced, not simply cleaned. Once pitted, the surface will quickly degrade after a clean-up, since the hard coat on the contact has been removed. If they are severely pitted, try to determine if the pitting is due to age, or if the unit is cycling repeatedly for some reason. Safety controls (low pressure, high pressure, case temperature, motor current, or thermostat anticipators) could be causing the short cycling. This is a problem you should resolve, because if the unit is short cycling, the compressor will fail sooner rather than later. If you just performed a preventive maintenance service and this happens, I doubt the customer will call you back. For air conditioning applications, suggest a delay on break time delay of at least 5 minutes.

Activate the Contactor and Listen for Contactor Hum and/or Vibration

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A common problem with contactors is that the lower-voltage AC control circuit is typically obtained from a transformer on the line voltage. When the contactor closes bringing the compressor onto the line, this causes a temporary drop in line voltage. Since the control circuit voltage is obtained from a transformer off the line voltage, as the line voltage drops, (that is, as the voltage input to the primary side of the transformer drops), the voltage produced at the secondary of the transformer also drops. A transformer's voltage output is a fixed fraction of the input voltage, based on the ratios of turns in the primary and secondary windings, therefore as the primary side voltage drops the output voltage also drops.

In some cases, this secondary transformer voltage may drop low enough for the contactor to no longer have sufficient magnetic force to remain closed, and the contacts open (disconnecting the load from the line). For example, a typical 24 VAC contactor coil will open if the coil voltage is below about 19 volts, if this 24 VAC is obtained from a 10 to 1 transformer connected to a single-phase 220-240 VAC line, a drop to below 190 volts (a voltage drop of 13% to 21%), will cause the secondary-side voltage to be below 19 VAC, and the contactor will open.

Once the contactor re-opens, the line voltage once again returns to the unloaded higher voltage (240 volts in the case of our example). The transformer secondary voltage likewise increases and the contactor one again closes, dropping the voltage and repeating the cycle. This causes the contactor to repeatedly open and close, either at low speeds (causing a clicking noise), or at speeds high enough to cause a loud buzzing sound. If the cycling is severe, the compressor may not start, and will thermally overload due to the repeated inrush current characteristic of motor starting.

Alternatively, the unit may start and operate with a continuous chatter due to the repeated inrush current of motor starting without the motor ever obtaining its normal running speed.

In even less severe cases, the contactor will simply hum or buzz. However, the rapid oscillation open and closed can lead to contactor arcing and pitting, reduced compressor voltage (resulting in increased compressor current draw), excessive contactor voltage drop, contactor heating and excessive compressor heating.

It is therefore important to start the unit with the compressor heavily loaded, and listen for this hum, vibration, or contactor-clicking problem. If the problem occurs, there are several possible solutions to the problem. Some possible solutions include;

1. Rewire the transformer so that the primary-side of the transformer is obtaining its input electrical power from a different circuit which is not experiencing a voltage drop upon compressor start up,
2. Rewire the compress secondary, that is the 24 VAC wires using a larger wire with less voltage drop, or
3. Install a larger transformer, since the overall load on the transformer may be dragging down the secondary side voltage.

Another solution that **might** solve the problem is to use a new contactor (which may have less internal friction or a stronger coil).

This problem occurs less often in split AC systems because the transformer is normally powered from the indoor fan coil unit and the compressor is powered from the outdoor condensing unit (and therefore on a different circuit). However, even in these residential split system applications, when the electric service is marginal, as indicated by the AC unit causing the house lights to flicker, the problem may exist.

With any Alternating-Current (AC) contactor coil, the magnetic closing force will be zero twice during the normal sinusoidal variation of the AC power. Therefore, there will always be some portion of the AC cycle where the spring force to open the contacts exceeds the magnetization closing force. Therefore, some level of hum or vibration will occur. As the net spring force increases with time, due to the wearing-in and loosening of the sliding contacts, the period of the cycle where the spring force exceeds the magnetic force will increase, further increasing the vibration or chatter. This vibration, or 60-cycle hum as it is commonly referred to, is neither good for the life of the contactor nor good for the components electrically connected to the load side of the contactor. The rapid oscillation increases contactor heating, contactor wear, electrical resistant, and causes an unpleasant sound.

Check for Proper Starting of the Compressor

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If the electrical connections are sound and the contactor is properly closing, the compressor should start quickly and reach the desired operating speed, even under a reasonable pressure head. If the compressor fails to start, check the compressor windings with an ohmmeter. Also check for a short to the case (all three terminals should show no conductivity at all, that is open circuit, to the case). If the windings test OK on a single-phase compressor, the capacitor start circuit may be the problem. On a three-phase system, the compressor may be attempting to run backwards (simply switch any two power source leads of the three phase circuit to change the direction of rotation).

For the single-phase compressors, improper operation of the starting circuit (start capacitor and start relay if present or a faulty run capacitor) could keep the compressor from starting properly. ***The best method of checking the capacitor is under load, since this will also detect a capacitance-leaking capacitor, see the next subsection below.***

Note: Both a Run Capacitor and Start Capacitor are wired into the Start Windings of a compressor. However, the Start Capacitor is only in the circuit for a short period of time, and is cut out of the circuit by the Start Relay (also referred to as the Potential Relay). Alternatively, the Run Capacitor is always wired into the Start Winding and is not disconnected from the circuit. Failure of the Start Relay to cut the Start Capacitor out of the circuit could burn out the Start Windings. Improperly sized Run and Start Capacitors can also burn out the motor windings, or provide insufficient starting torque.

To reduce cost, many AC systems do not have a start capacitor circuit to boost compressor-starting torque. Instead, these systems rely on only the Run Capacitor. In these cases, compressors operating in very warm climates may have trouble restarting against the excessive head pressure of operating on warm days. Systems with TXV and EXV expansion devices drop their head pressure rapidly, as do system with pressure unloaders. However, fixed orifice and capillary tube systems can maintain the head pressure for quite some time, making restarting difficult. There are two ways to avoid this problem. Use a time delay to allow the head pressure to dissipate or add a Start Capacitor Circuit, typically provided as a Hard Start retrofit kit, to provide the additional starting boost necessary to start the compressor against the head pressure on the compressor. I recommend using both, but if you are only going to add one device, I recommend the Hard Start kit. Adding a time delay will decrease cooling capacity since the system will cycle off for longer periods of time, thereby reducing the total operating time and therefore, reducing the total cooling capacity. This can be an undesirable and noticeable effect on an undersized system.

Check the Run Capacitor Under Load

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Capacitors don't always fail all at once. Many times they fail as a result of a slow degradation, and this degradation will reduce starting torque. The end result is that the compressor fails on the next hot summer day, when the compressor's start-up pressure head is the highest. Even though a compressor seems to be starting properly, you should check the capacitance. The capacitor's microfarad rating slowly drops until the stress put on the compressor and associated starting system causes them to overheat or some other component to fail.

The best method of checking a capacitor is under load, and there is a simple and reliable way to test this. See the figure below:

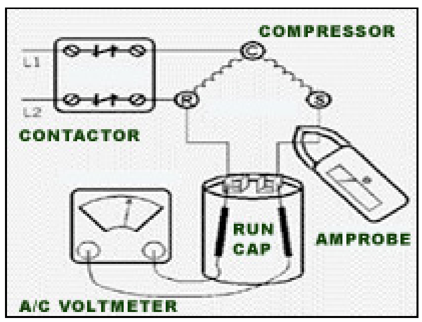

Figure 23. Diagram illustrating method of checking a capacitor

While the compressor is running, measure the ac voltage **across the run capacitor**. You will be reading the voltage that the compressor is generating. The term for this is "back electromotive force" or "Back EMF." Measure the amperage being drawn through the **start windings** (use a clamp-on amp meter on the start wire which runs between the capacitor and the compressor start terminal).

Note: Be careful to keep the clamp-on amp meter away from other components or wires in the control box since that can distort the amperage reading considerably.

Use the voltage and amperage readings in the following formula:

Actual Capacitance in micro-farads = Measured Amperage Reading *multiplied by* **2,650** *divided by the* **Measured Voltage Reading**

If the actual measured microfarad reading is more than 10% below the capacitor's labeled rating you must change the capacitor. Of course, if the run capacitor is swollen or is leaking oil there is no need to test it. Just replace it.

Some Run Capacitors have an identifying terminal which should be connected to the wire that feeds power to the capacitor, i.e. this terminal should be connected to the Run terminal, while the other capacitor terminal is connected to the Start terminal of the compressor. This is because these particular Run capacitors contain an internal fuse that will blow if the capacitor is shorted to the container. If the Run capacitor wiring is reversed and a short occurs, current can flow through the motor windings to ground during the off cycle and overheat the motor without blowing the fuse. Other capacitors contain a pressure-sensitive interrupter, which will open like a fuse in the event of increased internal pressure caused by high internal resistance. This protection prevents the possibility of the capacitor bursting.

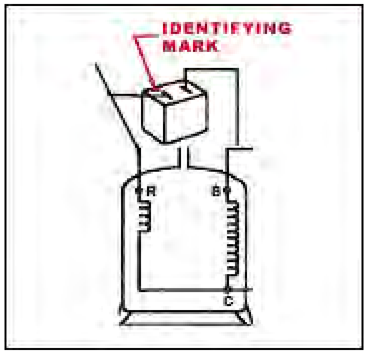

Figure 24. Capacitor identifying mark

Check the Start Capacitor

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To check the start-capacitor or electronic start-assist components (Hard Start kit) for proper operation, use the clamp-on amp meter on the wire leading to either side of the start capacitor or solid-state start-assist device and watch for an amperage spike for about .25 sec as the compressor starts. If there is no amperage spike when the compressor starts, replace the modular start kit if that is used or check the Startling Relay (AKA Potential Relay). If the starting relay tests ok, meaning it temporarily closes during start up, and then opens, replace the start capacitor. This should fix the start-capacitor circuit, unless there is a wiring problem.

Section 7:
Compressor Burnout Procedures

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This procedure should be used after a compressor burnout if the compressor or the entire condensing unit is being replaced. The first question to be asked is, should a new higher efficiency system be installed because the failed unit is old or inefficient? If you are simply repairing the old system, have you repaired the source of the burn-out?

Also note that if the unit being serviced is a split system replacing only the condensing unit with a high efficiency condensing unit without replacing the entire indoor unit will not provide the intended efficiency improvements. It is a waste of the owner's money to spend the additional money for a high efficiency condensing unit without also replacing the indoor unit. Of course if you are switching from R-22 to R-410A you must switch both the indoor and outdoor units, and the plumbing between them, if it is practical to replace the tubing runs. If the tubing cannot be replaced, it must be properly flushed, with Qwik **System Flush**®.

When a compressor burns out, highly acidic oil is formed, and although the majority of this oil remains in the compressor, some oil is always present in the plumbing and remaining components of the system. If you are changing the entire system, including any piping between components in a split system, then there are no issues. **However, if you are not replacing the piping between the components or other parts of the system, then perform the following steps.**

1. Recover any refrigerant in the system
2. Open the system and cut out the following components: filter driers, expansion valves, and compressor. In a burnout/change out the filter drier and compressor would need to be replaced anyway. If it is practical, the best method for cleaning piping or system components is to replace all the piping and system components. However, if replacement is impractical, it has to be cleaned by something more effective than nitrogen. A nitrogen purge is not capable of removing all of the contaminated oil, acid and moisture from the inside surfaces and should only be the start of a thorough cleaning.
3. Place a waste container where both nitrogen and dirty Qwik **System Flush**® will be exiting the system. **When possible flush from the inside of a building to the outside.**
4. Connect a nitrogen gas supply, using a regulator set to under 150 psig, to the component or tube being flushed and perform a nitrogen purge at each area that you intend to flush. Let the nitrogen flow as long as any liquid waste is still flowing out.
5. The ideal use for the nitrogen is to physically blow as much contaminated oil out of the system as you can. Use your judgment to open the system anywhere you suspect oil or water is trapped, and then use the nitrogen to blow this oil and

other debris from the system. Never purge through an expansion device (capillary tube, orifice plate, TXV, etc.) as this will likely clog the device.

6. Next use Qwik **System Flush**® (Qwik-**SF**®) to clean wherever you used nitrogen as an initial purge. The Qwik-**SF**® solvent exceeds R-11 and other products, in its ability to flush acid, moisture and contaminates; therefore a relatively small amount of Qwik-**SF**® is needed, but the more contamination that you remove with the initial nitrogen purge before using the Qwik-**SF**®, the less Qwik-**SF**® will be wasted cleaning contamination that does not require a solvent. Nitrogen is much less expensive than any flushing solvent and should be used liberally in comparison.
7. Repeat a 150 psig maximum nitrogen purge on all areas where Qwik-**SF**® was introduced into the line set. When you purge these areas, you will see the solvent exiting the line as a liquid. Continue purging the line for an additional minute after you no longer can see any solvent or other impurities exiting the system.

WARNING:

A flushing solvent cannot be used for components such as the compressor, filter-drier, and expansion device. Always remove filter driers when performing a flush, and never try to flush through expansion devices.

8. Connect the new components, installing BOTH a new liquid-line filter/drier and a new suction-line filter/drier into the system if there was a burn-out. The purpose of the suction line drier is to catch residual acid remaining in the system before it can enter the suction line of the compressor and contaminate the compressor oil, leading to a premature compressor failure.
9. Leak test, evacuate and charge the system with refrigerant.
10. Using a Qwik**Injector**®, introduce Qwik**Shot**® **Acid Flush** into the **operating system**. One bottle will treat up to a 5-ton system.
11. Allow the system to operate for a minimum of 15 minutes, and then use Qwik**Check**® to test for acid. If acid is detected, add an additional treatment of Qwik**Shot**® and wait an additional 30 minutes and retest for acid. If acid is still detected, then install new filter driers again as discussed in Step 8 and repeat steps 9-11.