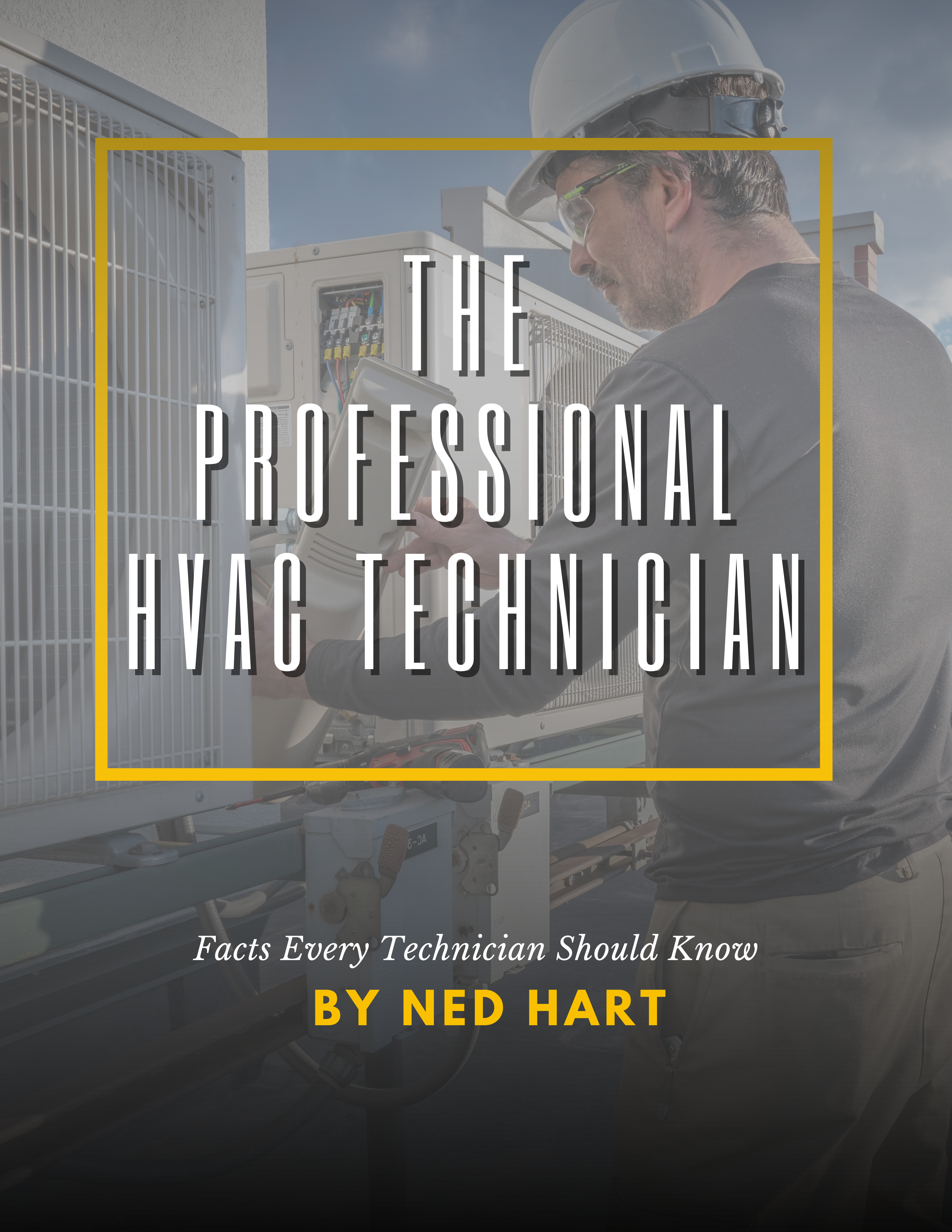


THE PROFESSIONAL HVAC TECHNICIAN

Facts Every Technician Should Know

BY NED HART

THE PROFESSIONAL HVAC TECHNICIAN

Facts Every Technician Should Know

The foundational guide to technician competence drawing from 500 years' combined experience of industry professionals.

Published by:

esco institute

This manual is published by The **ESCO INSTITUTE**
Mount Prospect, IL 60056

ESCO Institute
P.O. Box 521
Mount Prospect, IL 60056

Phone: (800) 726-9696 **Fax:** (800) 546-3726
Website: www.escogroup.org **E-Mail:** customerservice@escogroup.org

The Professional HVAC Technician
Second Edition

Printed in the United States of America

ISBN Print Edition: 978-0-9849858-1-4

Ver: 2.0 100722

Table of Contents

Introduction

What kind of troubleshooting problems will you, as a new technician, encounter once employed? Wouldn't it be nice to get a "peek behind the curtain" before employment on the real-world issues *you are actually going to see*? What if someone compiled a list of all the problems new student-technicians regularly encountered? What if each problem also included a solution prepared by a master technician? Imagine your confidence entering a job site KNOWING you're prepared for whatever comes your way because you already know what to expect AND what to do about it! Such a knowledge-database would provide the equivalent of years of on-the-job experience – all before joining the workforce.

So, how does a person find out what problems new technicians are encountering? We wondered the same thing. So, to find out, we undertook an extensive and time-consuming survey of over 700 HVAC students over 10 years. The target students were enrolled in a one-year program receiving 960 hours of in-person instruction covering all areas of the industry utilizing six nationally-recognized texts. Where applicable, roughly half of each 5-hour class session was spent doing hands-on lab work. The instructors were all very experienced technicians (25+ years each), and most were business owners still working in the industry. When students became employed as a technician or installer, they were given a cell phone number to a special Master Technician with whom they could talk, day or night, about any problems they encountered. Thousands of calls were received from the students over the 10 years of the survey, and their inquiries were all recorded. In addition, thousands of photos of each of their "problems" were taken to precisely identify the issue and to facilitate a clear explanation of the solution.

An important observation immediately became apparently from these calls: all the new technicians were experiencing the same problems with the same issues. Interestingly, once a solution was described to them by the Master Technician, they never called again about the same problem (although most called multiple times about other issues). To discover whether this information can be taught, new students were shown the problems the other techs were encountering, along with the solution from the Master Technician. When the new students entered the workforce, they were easily able to deal with these same "problems" without calling the Master Technician. So yes, it can be taught.

With the 10-year survey completed, all the calls recorded from the students were tabulated and categorized into their respective work divisions (gas heating, AC questions, motor problems, heat pump issues, compressor diagnostics, etc.). Only the most repeated problems were included. The responses from the Master Technician were also transcribed and included with each question. Knowing what kind of problems were encountered by new technicians is critical, but perhaps more important is the explanation they were given – whatever they were told by the Master Technician seemed to permanently solve the problem for those new technicians. This textbook is the result of the 10-year survey and includes both the problems encountered AND the answers provided, along with many photographs, charts, and graphs.

A natural question arose, "How complete is this list"? To find out, we contacted a group of professional technicians with 500+ years combined experience and asked them to provide the top 10 facts they thought every new technician should know. Their submissions were then compared to the student list, and nearly every item was already there. That was solid confirmation that the survey data was thorough and complete. But we used the word *nearly*. Just as with the student problems, those rare, once-in-a- lifetime issues were not included because they were either unique or highly unlikely to be encountered in an entire career. These rare events would not be valuable to a new or experienced technician, i.e., lightning striking a condenser and literally blowing it up! Really? The answer is to drop the condenser into the nearest dumpster and buy a new one.

So here we are… the survey is complete, the data has been assembled, the answers are all in. What now? Study the information in this book as though you're going to need it tomorrow, because the odds are very high that you will. These are the very issues other new techs had problems with, but you now have the benefit of an "advanced look" at the problem with the added assistance of a Master Technician who has seen everything at least a hundred times. It is not uncommon that employers will test a new tech's knowledge by throwing them a spectrum of jobs their first week or two just to see how they perform. Technicians who demonstrate their ability to deal with whatever comes their way can expect higher starting pay, more frequent raises, and faster advancement within the company. Greater knowledge translates directly into more money in this industry… it's simply a fact of life.

A typical HVAC service technician will go on roughly 1400 service calls a year. After a few months on the job, the technician starts to notice that service calls are repetitive in nature… the same thing goes wrong on every brand of furnace or AC over and over again. Therefore, the information in this text becomes applicable to every technician regardless of their experience level. A new tech won't encounter every issue described in this book their first week on the job, but they will over time. This information is what they would have discovered for themselves after years in the industry. ALL TECHNICIANS SHOULD KNOW THE FACTS CONTAINED IN THIS MANUAL OFF THE TOP OF THEIR HEAD! It is a minimum benchmark for any service technician or installer in the industry.

The United States Department of Homeland Security has classified the HVACR industry as an essential sector of the economy. Lockdowns don't apply to HVAC technicians. We keep data centers cool, protect the food distribution and supply systems, design and maintain negative pressure rooms in labs, purify and condition air in hospitals, keep vehicles / trucks / homes / offices comfortable summer and winter, and OUR industry affects EVERY other sector of the economy in some way. When the economy falls, demand for service techs rises. When the economy rises, the HVACR industry flourishes because of pent-up demand and economic expansion. When a furnace goes out in the middle of the winter, the owner will move heaven and earth to get it repaired / replaced because it simply cannot be ignored until a more convenient time. We are recession-proof, always in demand, and geographically universal (where in the world is there no need for heating / AC / refrigeration / humidification / dehumidification / air purification and circulation, etc.)? This is a pretty great industry!

Chapter 1 Foundational Principles

Chemistry, thermodynamics, physics, electricity, mechanics – These are not simply theoretical subjects in the life of the HVAC technician. We are touched by each of them all day every day in this industry. In fact, the professional HVAC technician must become a master of specific, specialized areas within each field in order to do his or her job effectively. Early in the 20th Century when air conditioning was in its infancy, a common tune-up technique was to physically touch the liquid line and the suction line: If the suction line felt like a cold beer and the liquid line was body temperature, then the system was deemed to be "in tune". Today, gauge temperature, line temperature, superheat, subcooling, split temperatures, indoor and outdoor heat and humidity, thermal transfer rates, air stratification within the home, Energy Recovery Ventilators, duct airflow, etc. are all critical functions of the HVAC technician. To do a good job in this industry, you must understand the applicable principles of each of these fields as they apply to refrigeration, air conditioning and heating systems.

Conduction, Convection, Radiation – When heat is transferred directly to or from our bodies, like standing barefoot on a tile floor or wrapped in an electric blanket, this is **Conduction**. For conduction to take place, we must be in physical contact with the object. Conduction is <u>not</u> a practical method of providing heat to a home or business, but still requires attention since a freezing floor or hot furniture directly affects comfort.

Convection is the most common type of heating system in the world, where the furnace heats the air and the air heats everything else. The air is moved around with the aid of a blower, although convective rise and fall of heated/cooled air can also create circulation. For example, an electric or hydronic baseboard heater placed under a window doesn't have a blower, but the heated air rises up the face of the window, across the ceiling, and as it cools it falls down to the floor and is drawn back to the baseboard heater where the circulation process starts again. The air circulation is so pronounced it can create a noticeable draft in the room, all without a mechanical blower.

Radiation is where heat is transferred to the body without direct contact with the heat source and without a blower. Standing in the sun on a cold winter day, heat is transferred directly to the person even though the surrounding air might be below freezing. Standing under an overhead radiant heater at the check-out stand at Home Depot feels warm, even though the overhead door is open and 25-degree air is streaming in. A radiant floor heating system directly heats the person via radiation, not by convective heat from warm air rising from the floor. In fact, a radiant ceiling will heat the occupants just as effectively as a radiant floor system… it's radiation doing the heating, not convectively-heated warm air. In a car, all three transfer methods are experienced: Conduction from the steering wheel to the hands; convection from the air coming out of the registers; and radiation from the sun streaming through the windshield.

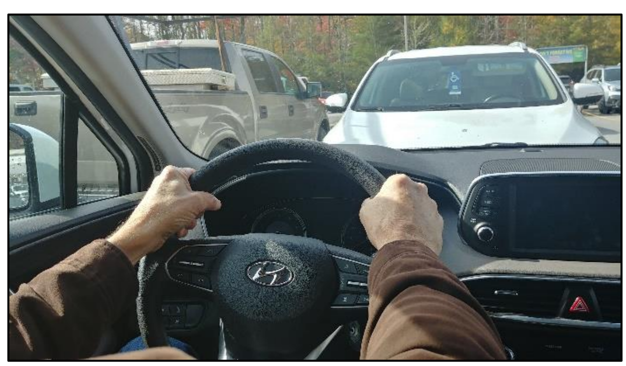


Figure 1-1 Conduction, convection, and radiation are all experienced when we drive a car.

outside-access mechanical room. Flue pipes don't simply "pop" apart… something happened to cause the break: the flue pipe might have been too short in the first place, or the flue stack could have been moved.

Figure 1-15 A 12-foot section of unsupported flue pipe became dislodged, venting flue gas directly into the attic.

Figure 1-16 The single-wall water heater flue pipe broke apart at the seam, venting flue gas into the mechanical room.

In Figure 1-17, a 3-story flue stack was hanging on two screws attached to the roof flashing (instead of supported every 8 feet) … until the screws rusted out and the entire flue stack dropped. Notice the repair job performed by the homeowner! As a technician, you might only be there for an AC tune-up, but always take the time to look for problems which will affect the safety of the occupants – and correct them.

Figure 1-17 The entire flue stack fell over 3 feet from a faulty installation. Although creative, the re-connection of the water heater was completely illegal.

Figure 1-18 It is said that an air conditioner can't kill, but a furnace can. Although not strictly true, *every* technician should check *every* residence for carbon Monoxide on *every* service call. Around 500 people a year die of CO poisoning, with 50,000 sent to the hospital.

Chapter 3 HVACR Controls

Wherever you have a control circuit, you also have control faults. Anything to do with an HVACR control system means that electricity is involved. Being able to properly troubleshoot electrical faults is the cornerstone of a service technician's life, since most problems are electrical in nature. To provide a detailed explanation of electrical fault troubleshooting, a special article on "Electrical Faults" has been included in the Appendix of this book.

Electrical Faults
(Appendix)

Thermostat Wire Colors – One of the most basic pieces of knowledge for the HVAC technician is thermostat wire colors. The four basic colors are:

- **Red** (incoming power from the air handler)
- **White** (outgoing power for heat)
- **Yellow** (outgoing power for cool)
- **Green** (outgoing power for the blower)

All a basic thermostat does is re-route incoming power from the air handler back down the appropriate wire for the requested function.

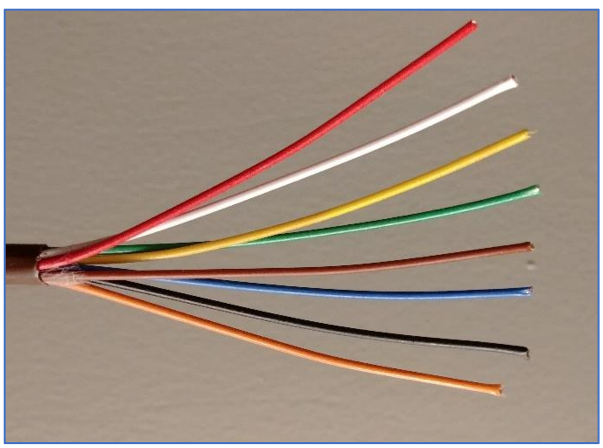


Figure 3-1 Basic thermostat wire colors are tied to specific functions, and the color pattern is the same worldwide.

The thermostat does not process the incoming signal in any way – it simply switches power from one wire to another. Communicating thermostats (where the power is processed into a signal and the signal is transmitted to a receiver) will be discussed shortly. For heat pumps, there is an orange or blue wire controlling the reversing valve, depending on the type of equipment used for the outdoor unit. For two-stage thermostats, there can be additional wires for second-stage heat and second-stage cooling. If the thermostat is powered, there will be a dedicated wire for Common. As a general rule, any new thermostat installations should be made using a minimum 8-wire cable.

Thermostat Operations – A single-stage thermostat is very simple and basic. When there's a call for heat, the connection is made between the R and W terminals internally. With a call for cool, the connection is made between R and Y. To operate the blower (fan), the connection is made between the R and G wires. However, with two-stage thermostats, things become more complicated. What dictates when the first stage of heat is needed verses the second stage of heat? Generally, if the temperature on the thermostat is adjusted so that the set temperature is greater than 3 degrees above the room temperature, the thermostat skips the first

Figure 3-2 Thermostats control every aspect of heating, cooling, and fan function. **Honeywell Home RTH6580WF**

stage of heat completely and jumps directly to the second stage of heat. This can happen manually two wires. The thermostat is installed at the usual location hooked to the two existing wires. The other end of the thermostat wires is attached to the air handler board power source (R and C terminals) to provide power to the thermostat, not to communicate. Communication is done over the WIFI system within the home or via a dedicated radio signal to an Equipment Interface Module (EIM) mounted at the furnace. The EIM also gets its power directly from the air handler board.

A communicating thermostat provides every possible function available on any thermostat in the world: 3 stages of heating, 4 stages of cooling, constant-intermittent-auto fan, heat pump, radiant heat, humidification, dehumidification, fresh air ERV, air purification, UV lights, etc. A remote outdoor temperature probe can be added to control the heat pump switchover and display outdoor conditions, plus multiple indoor sensors can be added to control zoning, and internet interface to allow complete remote operations on a computer or smart phone from anywhere on the planet.

Nest / Ecobee Thermostats – Smart thermostats are a boon to the HVAC industry as well their bane. Smart thermostats can do practically any function required of a thermostat IF they are properly installed and programmed by the technician. They are highly appealing to homeowners because they are Wi-Fi enabled and controlled via any smart

Figure 3-8 The Nest (left) and Ecobee thermostats are highly-rated by consumers but must be correctly installed and programmed to function properly.

phone from anywhere in the world, and they are very intuitive. The thermostat recognizes what kind of equipment is installed by where the wires are attached to the thermostat base. But the installer must enter the "PRO" portion of the menu and tell the thermostat *exactly* what kind of equipment is installed. If a heat pump is involved, the thermostat must be programmed with the type of heat pump (O or B), and the crossover temperature (the temperature below which the heat pump is turned off and the furnace is turned on). The only problem with heat pumps and smart thermostats is that most smart thermostats get their outside temperature not from an actual temperature probe, but from the nearest NOAA weather station, which could be up to 10 degrees off the actual local outdoor temperature. Due to this problem, more and more smart thermostats come with a temperature probe option. If a smart thermostat is installed, it is the responsibility of the technician to become familiar with the

Figure 3-9 Where thermostat wires are attached to the base tell the smart thermostat what equipment is installed. The thermostat must then be programmed to refine the equipment selection (gas or electric heat, when to switch between multiple stages of heat / cool, what type of heat pump is installed, balance point, dead zone, etc.).

Chapter 4 Motors and Capacitors

An inducer fan motor expels flue gas from the furnace to the outside of the building. A compressor motor makes the AC system work. Blower motors move air for heating and air conditioning. Condenser fan motors remove heat from an AC system. Water pumps move hot and chilled water throughout the building. Booster fans help air reach difficult locations. Bathroom and garage exhaust fans; Energy Recovery Ventilators; radon abatement fans; appliance cooling fans; attic ventilator fans; swamp coolers, all of them have motors. To help understand the basic operation of the motors found in the HVACR industry, a special article on "Motors and Capacitors" has been included in the Appendix of this book.

Motors & Capacitors
(Appendix)

LRA, RLA and FLA Ratings – On every AC nameplate is stamped the LRA, RLA and FLA ratings for that particular unit. LRA means "Locked Rotor Amperage". This is the maximum amp draw when the compressor is starting and can be 5-7 times the running amp draw. Ever wonder why the lights dim when the AC starts-up? On this 2 ½ ton unit, the compressor will draw 73 amps when starting! Over 100 amps on some AC units is common. The RLA is "Rated Load Amperage" and

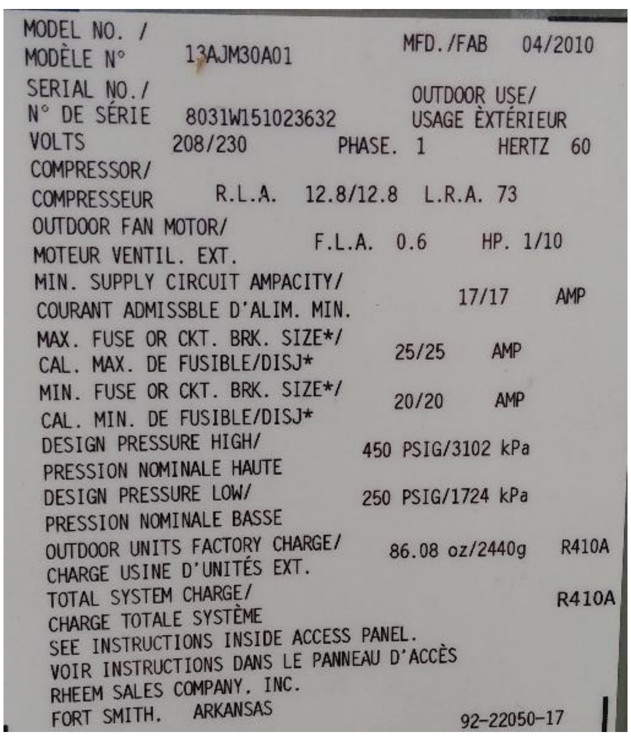


Figure 4-1 This equipment nameplate gives the LRA, RLA, and FLA settings for the air conditioning equipment.

means the maximum current draw once the compressor is running without tripping the motor's protection device. If you put an amp clamp on one of the compressor wires (Run or Common), the amp draw should not be above this number, in this case 12.8 amps. FLA means "Full Load Amperage" and is the amount of current the condenser fan motor is expected to draw when running at its full horsepower rating (0.6 amps). Many other things are on this nameplate including the phase (1 or 3), voltage rating, minimum and maximum breaker sizes, and the type of refrigerant / factory charge quantity. By the way, mini-splits don't have LRA spikes because they are fully modulating. The compressor, condenser fan motor, and blower motors are all DC, and simply rise and fall smoothly without abrupt startup peaks. If a customer is trying to run their AC unit off of solar / battery backup, mini-splits are a must.

Two Capacitors to Replace a Dual-Run Cap – You're in a remote location and a condenser has a 35/5 microfarad (µf) dual-run capacitor where the "5 µf" portion for the condenser fan motor is dead, but the "35 µf" portion for the compressor is still functioning. The problem is you don't have a new 35/5 on the truck. Rather than driving for a couple of hours just to replace a capacitor, install a separate 5 µf capacitor just for the condenser fan motor. This is a perfectly acceptable practice which does not compromise any portion of the AC there is an international convention on motor rotation. Stamped onto the motor nameplate are the letters CCWLE, CWLE, CCWSE, or CWSE, meaning clockwise (or counter-clockwise) Shaft or Leads End. This removes any ambiguity about which end of the motor to look at when determining motor rotation. The nameplate may also have an arrow indicating the direction or rotation.

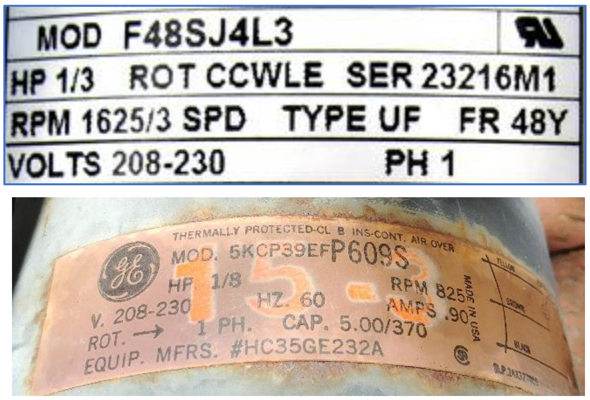


Figure 4-12 Fixed motor rotation is printed on the upper nameplate (CCWLE). A "direction of rotation" arrow might also be shown (bottom photo) on some motors.

Adjustable Motor Rotation – Most replacement motors are reversible allowing you to choose the direction of rotation in the field. They have a 2-wire coupling where the motor rotation can be switched. If the direction of rotation is not correct for your application, simply unplug the coupling, rotate it 180 degrees, and re-couple it. The motor will now run the opposite direction. As with all motor installations, make sure all wires are tied down, so the squirrel cage or fan blade won't come in contact with live wires. Reversible motors are available for air handlers and for condenser fan motors of various horsepower. For three-phase motors, reversing any two of the power wires will change the direction of rotation. Three-phase motors do not require capacitors since the phase separation is sufficient to get the motor running from a stationary position.

Figure 4-13 A motor with adjustable rotation allows the technician to make field adjustment as needed. Be sure to secure the adjustment coupling when installing. **Genteq**

370 VAC Versus 440 VAC Capacitors – Single and dual-run capacitors come in two sizes, 370 volts and 440 volts. It's okay to replace a 370 VAC capacitor with a 440 capacitor, because the 440 has a higher rating than the system will impose on the capacitor. However, replacing a 440 with a 370 is asking for fireworks. A universal replacement would therefore always be the 440 VAC capacitor of the designated capacitance. On many capacitors, a 440 VAC capacitor is printed with "440/370 VAC" so the technician knows it's okay to install this capacitor in either 370 VAC or 440 VAC applications. If space is limited on your service van, only purchase 440 VAC capacitors since they are universal.

Figure 4-14 A universal capacitor is the 440 VAC version. The technician must still match capacitance precisely.

Chapter 5 Refrigerants

The air conditioning and refrigeration industries are based upon the use and handling of a wide spectrum of refrigerants. Understanding how to safely and legally handle refrigerants, how to properly install and service a system using refrigerants, and how to get the greatest possible performance from a refrigeration system is a foundational principle of being a professional HVAC technician. Unfortunately, far too many technicians either don't understand proper handling practices, and/or are completely ignorant of modern servicing techniques. Imagine how an employer views two technicians: one stumbles through a service call, eventually getting the system running again after spending hours on the job site with perhaps one or two callbacks to get it right; another technician correctly and accurately diagnoses the problem in mere minutes getting straight to the problem, correcting the issue without a callback. Not only will the second technician continue to be employed over the long haul but will make 2-3 times the money due to more efficient use of time and to the inevitable pay raise for being a valuable employee. Being proficient in refrigerants is not just a "rule" but is absolutely required to be ***professional****.*

Line sets, King Valves, and Gauge Hook-Ups – On all AC systems except mini-splits, line sets include one tube which is insulated and one which is not. These pipes run from the condenser outdoors to the evaporator indoors. The bare pipe is smaller and carries high-pressure liquid from the condenser to the metering device at the evaporator and is referred to as the Liquid Line. The larger pipe is insulated and carries low-pressure vapor from the evaporator to the compressor. This low-pressure pipe is referred to as the Suction Line. The line sets attach to the condenser at a pair of valves called the King Valves. When closed, King Valves isolate the condenser from the rest of the system. Gauges should be attached to the King Valves with the low-pressure blue hose on the insulated (suction) side and the high-pressure red hose to the bare (liquid) side. A gauge manifold is designed to read saturated refrigerant temperatures, meaning refrigerants which are in balance between their liquid and vapor states. When the King Valves are closed, the gauges read the pressure in the line set /evaporator side of the system, not the condenser side. With the AC system off, the pressure within the system will be the same as the pressure within a refrigerant cylinder at the same temperature.

Figure 5-1 King Valves with service ports on a condenser where the line sets attach.

When the compressor is running, the pressure in the low side becomes lower than the pressure in the refrigerant cylinder, and the high side becomes higher pressure than the refrigerant pressure in the cylinder. When servicing a running system,

Pressure-Check with Nitrogen – When an air conditioning or refrigeration system has been opened to the atmosphere during installation or for repairs or upgrading, a system-wide pressure check is required. This must only be done using dry nitrogen. Compressed air contains oxygen and moisture, both of which are contaminants to an AC system. The presence of water in a system is the primary cause of acid buildup inside the system resulting in catastrophic compressor failure. Dry nitrogen is relatively inexpensive, plus it will be needed for any brazing of the refrigeration system as well.

Figure 5-11 Nitrogen comes in a variety of sizes for use on the job site for brazing and pressure checks. Never use compressed air on a refrigeration system.

Metering Devices – There are three main types of metering devices currently on the market for use in residential AC equipment: Fixed, Thermostatic Expansion Valve (TXV), and Electronic Expansion Valve (EEV). Fixed metering devices include capillary tube, flowrater or piston devices where a fixed-sized opening allows a set volume of refrigerant to flow through the system regardless of the environment conditions of the system. The orifice is located inside a compression fitting at the very end of the liquid line at the evaporator coil (Figure 5-12). Capillary tubes are not used in residential AC equipment. A TXV has a temperature bulb which attaches to the suction line and measures the actual amount of heat being absorbed by the evaporator coil. The temperature bulb comes filled with the same refrigerant as the system (the two should match). Unlike a fixed orifice, the TXV throttles open or close to react to changing conditions in the system, producing higher operating efficiencies. A system can be converted from fixed to TXV by opening the compression fitting, removing the orifice, and installing the TXV between the two fittings. The EEV operates like the TXV – reacting to temperature changes in the system – but does so electronically instead of mechanically. An EEV system is extremely accurate and produces the highest operating efficiencies currently available. They are also quite expensive. A coil cannot be converted from Fixed to EEV but must be purchased that way due to the extensive electronics involved. An EEV is only used in conjunction with a modulating condenser capable of adjusting the volume of refrigerant.

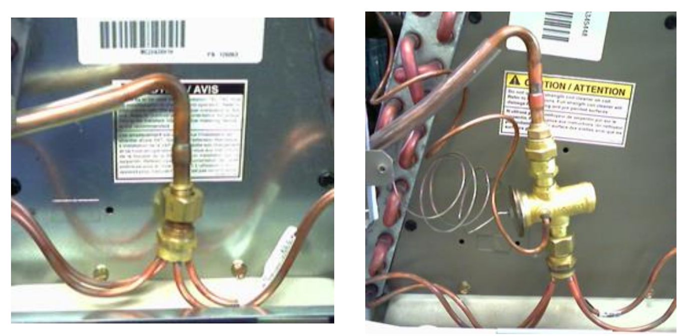


Figure 5-12 A fixed orifice (left) and a TXV metering system. Both fit between the end of the liquid line fitting and the start of the evaporator distributor tubes.

No Nameplate – Occasionally a technician will run across an AC or refrigeration system where the nameplate is missing, painted over, or faded beyond recognition. Before the system can be serviced, the type of refrigerant must be known. Although there are very expensive machines which analyze the chemical composition of the refrigerant in the system, a much simpler method is available to every technician in the field. Attach the gauges to the system while the equipment is off and note the pressure as well as the environmental

Figure 5-18 Refrigerant locks attach to the service ports making them inaccessible to unauthorized personnel**.**

a person in the industry is most likely to already possess a set of keys! However, it does protect the equipment from pranksters intentionally venting refrigerant, or from entrepreneur thieves wanting to sell refrigerant to a third party.

Tools in the Bag – There are some absolute tool choices every technician should carry on every job. One of these is a Schrader core tool (Figure 5-19). Occasionally, a technician removes a dust cap on one of the service ports only to be blasted by refrigerant due to a loose Schrader core. If the core tool is sitting in the cab of the service van, a pound or two of refrigerant will be lost by the time it is retrieved. It should be in the pocket or tool bag at all times. These tools are provided free of charge by most wholesalers and includes a small reversible screwdriver which just happens to be perfect for thermostat terminals.

Figure 5-19 A Schrader core tool should always be readily available to every service technician.

New techs will attempt to haul every tool they own into every job. It's like moving a steamer trunk around! After a few weeks of this, it dawns on them that there are some tools they only need once or twice a month, but others they need every day. By paring-down the tool bag to carry only the tools needed for 95% of the jobs, the load is lightened dramatically. A technician needs to crawl through dirt in a crawl space, slip through a small opening into the attic, and stand atop a ladder while working on equipment. After doing a survey of experienced technicians, we've included a list in the Appendix of the tools they carry in their tool bags and also the tools they leave in the truck until needed.

Chapter 6 Air Conditioning Systems

The following information applies to all residential and commercial air conditioning systems, as well as most commercial refrigeration systems as well. After all, every AC and refrigeration system in the world has a compressor, condenser, evaporator, and metering device. Many times, a technician will enter the equipment room of a new customer to find a completely unknown configuration of equipment. By taking a few minutes to identify the individual components, it quickly becomes obvious that, although unique, it still contains the same four major components. After that, it's simple to connect gauges, temperature sensors, and monitoring devices to pinpoint any problem just as with any other system in the field. There are, however, some specialized applications which are unique to refrigeration industry. These will be discussed in the following Chapter.

Compressor Damage – There are a limited number of issues which can destroy an otherwise perfectly-operating compressor. As we already know, compressors only pump vapor, not liquid. On reciprocating compressors, the flow of refrigerant is controlled by one-way valves. If liquid reaches the head of the compressor, there is a 100% chance the valves will be destroyed. On hermetic compressors, this means dropping the old compressor into the trash and purchasing a new one. Scroll compressors are slightly more forgiving, but they too can be destroyed due to the incompressibility of liquids.

Figure 6-1 Evaporator coil icing can occur from airflow restrictions: dirty filter, coil, blower, secondary heat exchanger, or too many registers closed.

Under what conditions can liquid refrigerant be introduced into the compressor? We need to know these things so we don't inadvertently destroy a compressor. Turning a refrigerant cylinder upside-down and fully opening the gauges to charge a running system will destroy the compressor in less than 20 seconds. Likewise, opening both the high and low side gauges simultaneously on a running system – allowing liquid refrigerant to travel from the high side through the gauge manifold to the low side – does exactly the same thing. These are things we can control because we are the ones doing them. But issues which develop in our

Figure 6-2 Once the evaporator coil begins to freeze, ice will develop on the suction line and slowly spread until it reaches the condenser.

happens, a negative feedback loop starts, namely that as the coil ices up, the airflow slows down even more causing the temperature to continue to drop which causes more icing, causing even lower temperature, etc. Since the house isn't getting cooled, the thermostat never gets satisfied making the cycle continue indefinitely until the cycle gets broken by shutting off the equipment or repairing the problem. Yes, low refrigerant can cause icing, but this occurs in less than 5% of the cases.

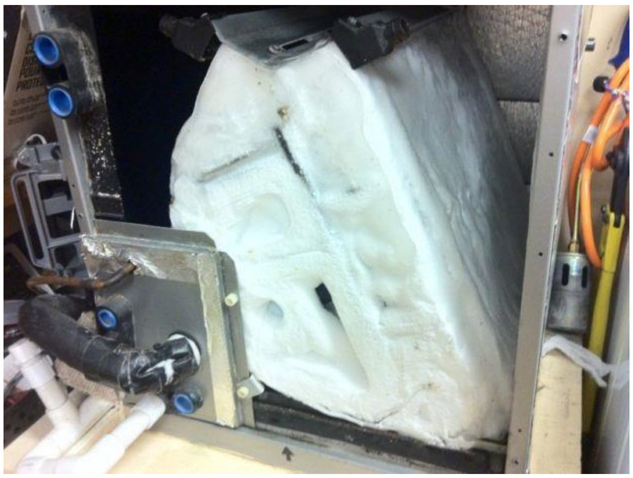


Figure 6-33 Ice on an evaporator can be many inches in thickness. The tell-tale sign (other than the obvious "hot house") is that the blower is running but no air is coming out the registers. This coil would take at least 12 hours to thaw using the "fan-on" function, or a few minutes using a space heater directly onto the coil.

If a coil has iced up, the refrigerant level cannot be checked until regular airflow has been restored. Many technicians make the mistake of starting their troubleshooting out at the condenser when it should <u>always</u> start indoors. By starting outside, when they see low-side temperature levels below freezing, they assume the system is low on refrigerant and add even more, driving up the temperature until it's above freezing. They then go on their way to the next appointment, not realizing that the cause of the low temperature was a dirty filter which already caused the coil to ice up. Eventually the coil will ice again, and when the dirty filter is finally discovered and the coil thawed out, the system is found to be *pounds* overcharged.

When an iced coil is found, first, defrost the coil by adding heat or by simply turning off the cool and turning on the fan overnight. Once thawed, check these FIVE areas: the filter, blower, evaporator coil, secondary heat exchanger (if a 90%+ furnace), and the duct registers. A dirty evaporator or secondary heat exchanger will cause icing as effectively as a dirty filter (the dirt being held in Figure 6-35 is from a secondary heat exchanger, not a filter or coil). The secondary heat exchanger is a fine-fin radiator located directly above the blower assembly, which must be removed to get access to the underside of the secondary heat exchanger.

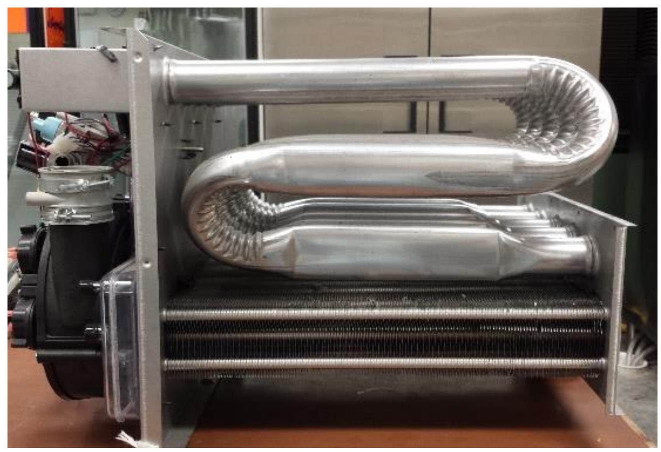


Figure 6-34 A primary and secondary heat exchanger for a 90%+ furnace. The larger primary tubes feed into the secondary heat exchanger on the bottom which can collect lint and dirt. The blower must be pulled to clean a secondary heat exchanger.

Too many closed registers can cause icing in the matter of minutes. Once the airflow is confirmed to be clear, then and only then check the refrigerant level.

A very common cause of icing is a dirty blower motor / squirrel cage. NEVER simply wipe off the dirt from the end of a motor which looks like the one in Figure 6-36. If the exposed motor end looks this bad, then the other end will be just as bad, nitrogen in the meantime. The reason is that an installation during a rain or snow storm practically guarantees there will be moisture in the system, and the time to sublimate-out all the moisture from a system which is below freezing could literally take days, versus minutes when it's warm. If you do leave a winter-installed AC system pressurized with nitrogen, be sure the service disconnect is locked-out with a tag warning the customer NOT to attempt to start the system. Also, leave the pressure reading on the tag so the technician can compare the current reading in the spring to the original pressure from the winter as a final leak check.

Hard Start Kit – Most manufacturers of air conditioning systems require the installation of a Hard Start Kit on their condensers to keep the equipment under warranty. This is because most compressor wear occurs at startup. Strangely, these same manufacturers don't sell their equipment with the Hard Start Kit installed. A Hard Start Kit contains another capacitor which gives the compressor a boost getting it up to speed. A potential relay then cuts out the start capacitor once the motor is running. Because compressors can draw over 100 amps during the start-up cycle, speeding up this process reduces stress on the internal compressor wiring and can double the useful life of the compressor. As compressors age, they become harder and harder to start, and a Hard Start Kit gives them the boost they need to get running each time (thus the name). If a compressor won't start but the internal wiring Ohm's-out okay, add a Hard Start Kit to see if it will run. If it still won't start, then the compressor must be replaced.

Figure 6-51 A Hard Start Kit consists of a capacitor (in addition to the dual-run capacitor) plus a potential relay. The relay cuts-out the capacitor once the compressor is running. **Goodman CSR-U-1**

Compressor Cooling – Compressors are cooled by the refrigerant flowing through them, not by air around them. Part of the heat being dissipated by the condenser coil is from the compressor. When a condenser coil is dirty and can't get rid of the heat, the greatest danger is to the compressor because it can overheat to the point where the overload switch trips or the motor itself burns out. Many high-end condensers come with a compressor blanket wrapped around the compressor to reduce mechanical noise. A compressor blanket completely shields the compressor from the surrounding air, and is only possible because the refrigerant itself is cooling the compressor motor internally.

Figure 6-52 The compressor can be completely enclosed for soundproofing because the compressor motor is cooled by the same refrigerant it is pumping.

Another mouse crawled up the warm board until its nose touched the 120-volt terminals at the top. Both board and capacitor required replacement. A larger question is how did a mouse get into the ductwork in the first place? A condenser located next to a canal received a visit from a water snake. It wrapped itself around the warm condenser fan motor just as the next call for cool hit. Its head was pinned between the fan blade and the motor housing, burning out the motor. Roots invaded the sewer line and caused a backup into the basement. The ensuing flood reached a foot deep before discovered, submerging the control board. Don' t even bother to clean or test a board which has gotten wet… just replace it. If by some miracle it did work, it will fail within a month (and probably on the coldest holiday weekend of the year) and guess who's going to be asked to go out and replace it?

Figure 6-63 A snake burned out a condenser fan motor.

Figure 6-64 A bird in the flue at the inducer fan motor.

Figure 6-65 Flood-damaged control boards should always be replaced.

Chapter 7 Commercial AC & Refrigeration Systems

Although there are universal components found in all residential, commercial, and industrial systems, some mechanisms are only found in commercial AC and in refrigeration systems. Having a good understanding of these unique components is essential to troubleshooting and diagnosing issues found in commercial equipment. By understanding how these unique components work and why they are present in commercial equipment will save tons of time on the job trying to reverse-engineer what a component is, how it works, and whether it's working correctly or not. Take the time to understand the unique components before you run into them in the field. That's the difference between a laborer and a professional.

Low Ambient Control – It is a very common need in commercial applications for the air conditioning equipment to run in the winter. This is true even if residential equipment is installed in a commercial environment. Most commercial or industrial buildings get their heat from people, equipment, and lights – they air condition year 'round. The problem in running air conditioning in the winter is that the condenser is outdoors where the temperatures are very low. This makes it extremely efficient at rejecting the indoor heat… to the point where the evaporator ices up. A low ambient kit is simply a fan control which attaches to the high-pressure side of the system at the King Valves and controls the outdoor condenser fan motor. If the internal pressure of the system drops too low (the system starts to ice up), the fan control turns off the condenser fan motor until the pressure builds back up from the heat being absorbed in the evaporator. It is common for the condenser fan to run only 15 seconds every 1-2 minutes because of the speed at which the heat transfer occurs when outdoor temperatures are low. If a low ambient kit is installed, consider adding a crankcase heater to the compressor as well. This depends upon how frequently the equipment is going to run.

Figure 7-1 Residential equipment installed in a commercial environment will many times require operation in the winter.

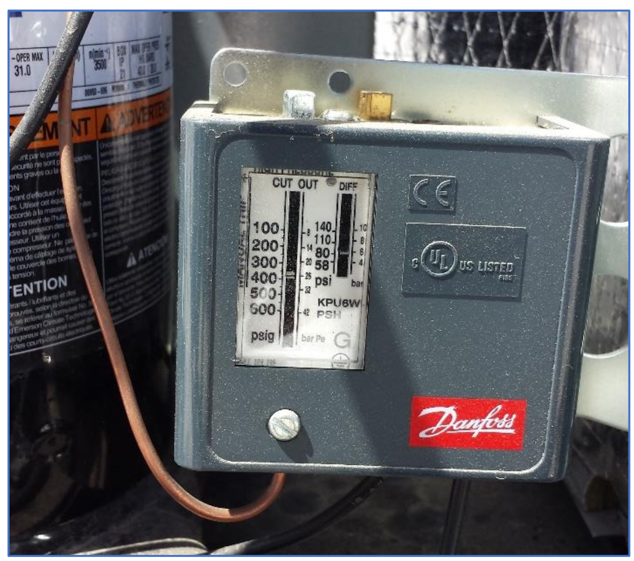


Figure 7-2 A fan cycling control senses the drop in pressure as an evaporator coil begins to ice and shuts off the condenser fan motor until the pressure rises again. Installed at the condenser and attached to the service port using a tee fitting. A pressure transducer will do the same thing electronically as the mechanical switch pictured here.

Figure 7-9 Walk-in evaporators require the same attention as residential coils. Even though the system automatically defrosts on a regular schedule, a dirty evaporator will cause icing to be much more frequent and severe, plus the box temperature will be impossible to keep stable.

Mullion & Door Heaters – If ice is forming around the door jamb of a refrigerator or freezer, the Mullion heater has failed. Mullion heaters keep the door opening free from ice. Mullion heaters are required since the gasket around the door makes it more susceptible to icing due to the lack of insulation at that point. On commercial glass-door refrigerators and freezers (such as found in supermarkets), there are heat coils in the glass itself to keep it free from ice so the patrons can see the food inside. Try opening a freezer glass door and watch it fog up almost instantly from the moisture in the room air. Upon closing, the fog disappears in seconds. If you take a non-contact voltage detector and hold it to the glass door, it will register voltage (showing the door heater is working).

Figure 7-10 Grocery store freezer and refrigerator display case doors and door jambs are heated to prevent icing and fogging.

Figure 7-11 A Mullion heater in the door jamb keeps the door from icing closed.

Accumulator vs. Receiver – Every heat pump has an accumulator. Most commercial refrigeration equipment has a receiver. It's important to understand the difference between the two, how to install them correctly, and understand their function.

ACCUMULATOR: An accumulator is installed in the low side of the system, collecting liquid refrigerant to prevent it from going to the compressor. Remember, compressors only pump vapor. Liquid in a compressor leads to catastrophic damage almost instantly. Since heat pumps run in cold temperatures, there is a very high likelihood that liquid refrigerant will eventually make its way back to the compressor. To prevent this, an accumulator is placed between the coil and the compressor to catch all liquid refrigerant. The small tube at the bottom of the cylinder is a drain

Chiller or Boiler? – Since chilled water is used to cool the building in summer (described above), hot water from a boiler can be used through the very same pipes to the very same terminal units to heat the building in winter. The biggest issue with most large buildings is when to make the switchover from cooling to heating. In the spring and fall, temperatures can be cold at night but warm in the day. Since it takes hours to make the crossover from heating to cooling, it's not uncommon to be uncomfortably cool at times and uncomfortably warm at others – on the same day. The delay in crossover is the cause. Large commercial boilers will be millions of BTUs in size with thousands of gallons of water in the tank. Heating such a large quantity of water simply takes time.

In addition to the factors listed above, there is also a Dead Band to deal with, namely, it must be significantly above the set temperature before the equipment switches to cooling. Similarly, it must be significantly below the set temperature before the equipment switches back to heating. Once fully into the summer or winter, the system should perform predictably without any of the large swings typical of Spring and Fall.

Figure 7-18 Commercial boilers are typically millions of BTUs with thousands of gallons of water involved. The initial heating process takes time and building switch-over from cooling to heating puts stress on the equipment.

Clean, Clear, and Cleanse– Look for air flow blockages everywhere. Coils are obvious, but what about: control panel cooling grates, cold air return grilles, combustion air intakes, fan grilles, computer equipment air access, server room intakes and exhausts, and so forth. Sometimes the areas needing help are not the HVAC equipment but the controls for the HVAC equipment.

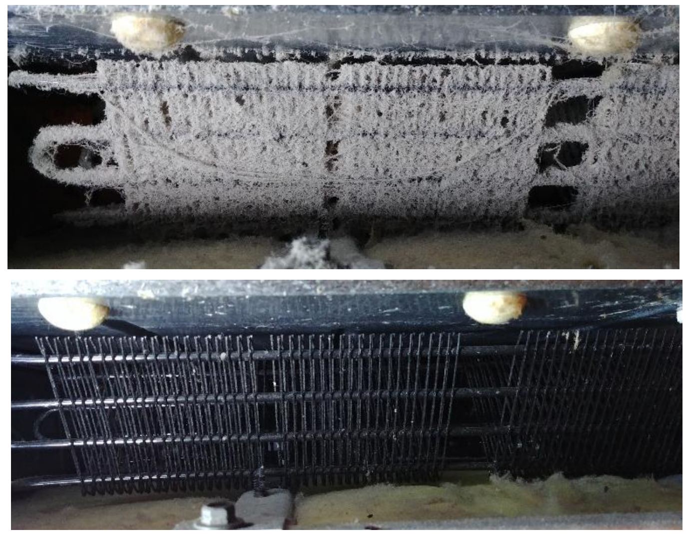


Figure 7-19 Cooling grille before and after cleaning. Electricity consumption was 3 times normal when dirty.

Figure 7-20 A server room condenser placed adjacent to a warehouse wall on the leeward side of the building which concentrated the snow in this exact spot. After several large storms, the condenser was enclosed inside a cave of snow and ice. Less than 10 feet away, the snow was only a few inches in depth. Location, location, location!

Chapter 8 Heating Systems

Throughout history, wood has been the most common source of heat. It's abundant, renewable, and ubiquitous, and the campfire is still a mainstay of recreational living. The Romans used wood for central heating and community baths 2,000 years ago, drawing hot flue gas under a stone floor (firebox on one side of the building and the chimney on the other). Although the art was lost with the fall of Rome, it wasn't until 1800's England before central heating reappeared on the scene. Although wood and coal are still used today to heat some homes, electricity/heat pumps, fuel oil, natural gas and propane constitute over 95% of the heating systems in the world. Gaseous fuels are by far the most common forms of heating in the United States due to their abundance and relative cleanliness. Although extremely explosive, modern gas burning equipment has tamed these fuels and made them the backbone of residential and commercial heating. Heat pump efficiencies have now risen to the point where they rival or surpass natural gas. From a rocky start in the 1800's to the modern furnaces of today, modern heating has become sophisticated, reliable, and highly efficient.

Electric Heat

Electric resistance heat is simple to operate and easy to service but is by far the most expensive way to heat. There are three ways the heat from an electric resistance heating element can be introduced into a structure: baseboards, forced air heating, or radiant. The biggest advantage of electric heat is that it is 100% efficient, meaning that 100% of the power consumed by the heating element is converted into heat used within the building. The biggest disadvantage is that electricity is the most expensive form of fuel.

BASEBOARDS: Electric baseboards are relatively inexpensive to purchase and are controlled by a line voltage thermostat. Additions to a structure are most easily heated using baseboard heat, and occasional-use needs (like a garage or bonus room) are easily retrofitted with baseboards. Most baseboard heaters are 240 volts, and the thermostat literally controls the flow of power to the baseboard. This means that a high voltage line must be run to the wall thermostat and then to the baseboard. The thermostat can also be located in the baseboard itself, eliminating the wall thermostat but requiring that each individual baseboard be controlled with its own internal thermostat. Such line voltage thermostats are mechanical in nature and have very limited functionality. It is possible to use a conventional thermostat to control baseboard heaters using a relay, but few people actually do this. Baseboard heaters should be placed under a window to counteract the cooling effect of the glass.

Figure 8-1 A electric baseboard heater is inexpensive to purchase, but expensive to operate. **CADET**

FORCED AIR HEATING: An electric furnace operates just like a gas furnace except the source of heat is a series of heating elements placed in the airflow from the blower. If more than one heating element is employed, a sequencer is used so that all the heating elements don't come on at the same time. You should never see the heating elements in a furnace glow. This means there is insufficient

Natural Gas & Propane

Development of Pilots – Initially, gas burning equipment was manually lit every time heat was required. Many people received burns lighting their equipment, with the occasional explosion which leveled the building. Then a solenoid valve was invented to turn the main gas burner on and off using a thermostat, with a small auxiliary flame which stayed lit to light the main burner (the pilot). After several buildings were destroyed from pilots which went out but continued to flow gas, safety measures were instituted to cut-off the gas to the pilot if the pilot

Figure 8-4 A pilot heating a thermocouple. The pilot stays on all the time, summer and winter, to be ready to light the main burner. This can cost an additional $10 per month in heating costs. The thermocouple converts heat into electricity (about 10 millivolts) which is used to keep the pilot gas solenoid open. If the pilot blows out, the electricity stops, and the solenoid closes the port to the pilot.

blew out (the thermocouple, still found today in old, piloted furnaces). Then spark and hot surface igniters were invented to light the pilot which in turn lights the main burner (they couldn't seem to let go of the pilot idea). These intermittent gas valves are still being sold today for older equipment. Finally, it dawned on engineers that the pilot is an unnecessary component for a gas furnace, since the spark or hot surface igniter could directly light the main burner ("direct ignition" systems). This is the standard for today's furnace designs. Pilots are still widely used in gas fireplaces, boilers and older furnaces, but are rapidly being eliminated as older equipment is upgraded.

Natural Gas vs Propane – Natural gas is lighter than air… a lot lighter with a specific gravity of only .63 compared to air at 1.0 specific gravity. If there is a natural gas leak, the gas will eventually make its way out of the structure (if it doesn't encounter a spark first). Natural gas has no smell, so an odorant is added to help detect leaks. Natural gas is non-toxic but can still kill by asphyxiation or by explosion. At sea level, natural gas contains 1,000 BTUs per cubic foot. It also has a very narrow range of flammability of 5% to 15%, meaning that above or below this range, the gas will not burn. This literally means that if a home was filled with natural gas and a spark was present, it wouldn't explode… until diluted down to 15% (through air infiltration) at which time the house would be reduced to kindling. This happens every winter, where a natural gas leak destroys a

Figure 8-5 Natural gas is the most common form of heating fuel in the U.S. A gas meter measures the amount of gas being used by each customer.

Figure 8-55 The balance point is where the capacity of the heat pump is reached. The thermostat will then switch control away from the heat pump to the gas or electric furnace. Ultra-low heat pumps don't need a backup system.

the technician programs the balance point at 30 degrees with a 3-degree differential. When the temperature drops to 30, the heat pump shuts off and the gas/electric furnace takes over. Once the outdoor temperature rises above 33 degrees (30 + 3), the heat pump takes over again. A differential is required so that the equipment doesn't short-cycle between heat pump and gas/electric heating modes. Depending upon the efficiency of the heat pump, this balance point can be anywhere from +40 degrees to -20 degrees F. For your information, there are ultra-low temperature mini-split heat pumps available where the balance point is never reached. In such a case, there is no need for backup heat of any kind. This class of heat pumps is the most expensive of any heating system in the world, but they are also an air conditioner in the summer and require no ductwork. For new construction, ultra-low temperature mini-split heat pumps are competitive in price to a ducted central heat pump with gas furnace.

How Defrost Controls Work –In heat pump mode, the outside coil, acting as an evaporator, is operating far below freezing in order to absorb heat from the surrounding air. There is always moisture in the air, and as a result, the outside coil is going to ice up. This is a normal event for a heat pump. Eventually it must be thawed-out in order to continue operating efficiently. This procedure is controlled by a defrost timer in the outdoor unit and is based upon time AND temperature. The time is usually adjustable by the technician in 30-minute increments. The temperature is controlled by a sensor attached to the outside coil. Let's say the time is set at 60 minutes. Every 60 minutes, the defrost control board will look at the coil temperature. If it is above 50 degrees, it skips the defrost cycle and waits another 60 minutes to check again. This time, if the coil temperature is below 50

Figure 8-56 Whenever an outside coil becomes iced to this extent, the problem usually lies with the defrost control board. Take a hose to the condenser to remove all the ice (and to get access to the control panel) before attempting to re-start the system.

degrees, the control initiates a defrost cycle which involves three steps: it switches the reversing valve to air conditioning mode, turns off the outdoor fan motor, and calls for auxiliary or supplemental heat. For a few minutes, the air conditioner is running in the middle of the winter, but it is being counteracted with auxiliary heat from the gas or electric furnace. It absorbs heat from the home and reading. Which has lower amps, the good air flow or the blocked airflow? Virtually all technicians say the cardboard blocking the airflow will have the higher amp reading. This is wrong! Without any airflow, the motor isn't doing any work and so the amp reading is lower. If you have duct restrictions, the amps will be lower than expected. As duct restrictions are removed, the amps will rise because the motor is doing more work.

Duct Losses – Anything which restricts airflow is bad (especially with air conditioning), and anything which improves airflow is desirable. Flex ducts add restrictions because of their uneven walls. Right angle turns cause turbulence and turning vanes should be installed to ease the air around large corners. Main trunks reduce in size every 10 feet to maintain air velocity /pressure and ensure even airflow from every register. Registers should be open, especially in summer, to reduce restrictions. Every joint should be sealed with mastic and/or tape. The number of elbows / hard turns should be kept to a minimum. Ducts in unheated attics or crawl spaces should be well-insulated. The air handler should be centrally located so that duct runs are as short as possible providing even airflow. Taking time to install or upgrade the ductwork can make all the difference to the overall system performance.

Figure 9-16 Bad ductwork can doom an otherwise good equipment installation. In this case, each duct is only 4 inches, there are too many separate runs, and none are insulated. Half of the capacity of the furnace was lost due to poor duct installation. Duct pressure is measured in Inches of Water Column.

Heating / Cooling Load Calculations – Never blindly replace an old furnace / AC with the same capacity system without first doing a heating / cooling load calculation on the home. It's possible the original contractor installed whatever equipment was on sale rather than the correct sized unit, resulting in excessive utilities for the life of the equipment. In the same sense, a homeowner holding onto their old equipment could easily pay for new equipment from the utility savings alone. A load calculation (referred to as **Manual J**) can be done manually using open forms found on the internet. Similarly, **Manual D** computes the size and lengths of supply and return ducts and registers. **Manual S** computes the type and size of residential HVAC equipment. Computer programs do a better job than paper forms, but must be purchased. If a permit is required for a job, the inspectors will want the full Manual J, D, and S printouts which can be 35 pages in length. The computer program is the only way to go and is ACCA-certified.

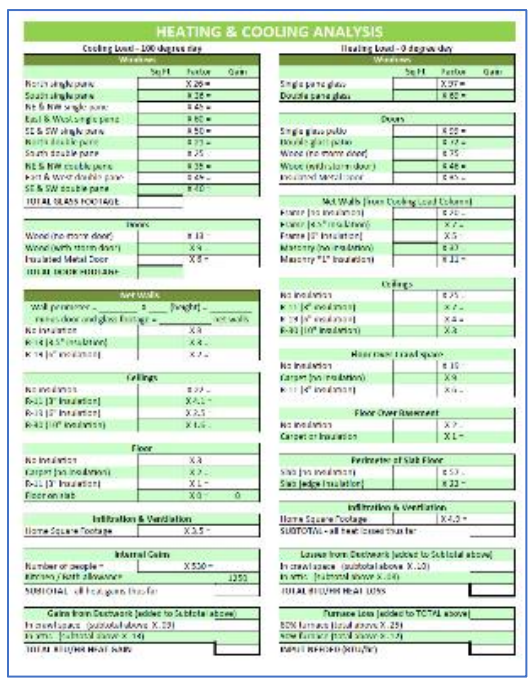
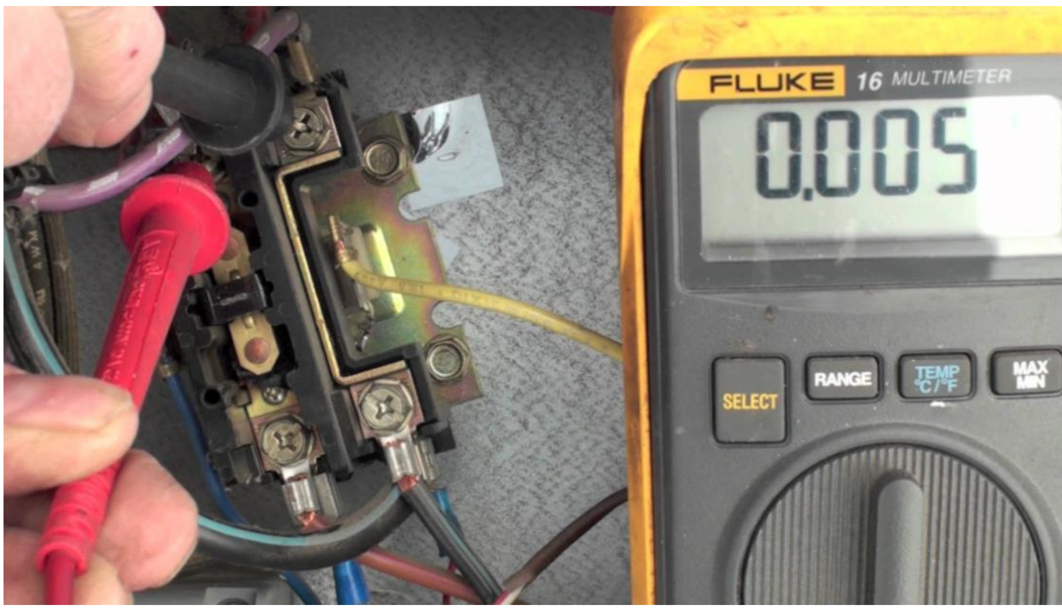


Figure 9-17 A manual heating & cooling load calculation sheet which can be completed on-site to provide a quick determination of the size of equipment needed. This sheet is provided in the Appendix with permission to copy.

Appendix

ELECTRICAL FAULTS

THE PROFESSIONAL HVAC TECHNICIAN | ELECTRICAL TROUBLESHOOTING



ABOUT ELECTRICAL TESTING

Every modern furnace, boiler, air conditioner, ventilation system, and refrigeration unit runs on electricity or has electronic parts. Even direct vent heaters with no blowers or power input have a millivolt thermostat controlling the gas valve. Understanding how to correctly troubleshoot electrical systems is the foundation of a Service Tech's trade, and can make the difference in tens of thousands of dollars of compensation each year for those who master these skills.

Topic 01

Service Calls

- Owner conversation
- Sequence
- Error codes / testing

Topic 02

Nothing is Working

- Trace the problem
- Line voltage
- Low voltage
- Error codes
- Operation sequence
- Options

TOPIC 03

Control board vs…

Error Codes

- Trace the fault
- Possible errors
- Solutions

MOTORS & CAPACITORS

THE PROFESSIONAL HVAC TECHNICIAN | MOTORS & CAPACITORS

ABOUT MOTORS & CAPACITORS

Hot and cold air is moved through ductwork with blower motors. Refrigerant is pumped with compressor motors. Furnace and boiler exhaust is expelled using an inducer fan motor. Ventilators, hot water, chilled water, condenser fans, and virtually every aspect of the HVAC industry employs motors in some capacity or another. Understanding how motors work, why they operate the way they do, and the limitations of one class of motor over another will not only help troubleshoot a motor but will also make sense of the power supply needed, the capacitors to be used, and the wiring configurations required to make a particular motor operate at peak efficiency.

Topic 01

Operation

- History
- Magnetism
- Hertz

Topic 02

Types of Motors

- Split phase
- CSIR
- PSC
- CSCR
- Shaded-pole
- Three-phase
- ECM

TOPIC 03

Start Switches

TOPIC 04

Capacitors

DIAGNOSING COMPRESSORS

THE PROFESSIONAL HVAC TECHNICIAN | HERMETIC COMPRESSOR FAULTS

Topic 01

Compressor Facts

- Hermetic defined
- Reciprocating
- Scroll

Topic 02

Normal Operation

- Ohm readings
- Amp readings
- Temperature
- Pressure
- Safety devices
- Options

TOPIC 03

Compressor Faults

- Internal faults
- External faults
- 3 phase faults

ABOUT HERMETIC COMPRESSORS

The heart of every refrigeration system is the compressor. The failure of the compressor instantly takes the entire system offline. For homeowners this is uncomfortable; for business owners it equates to the immediate loss of income. Because hermetic compressors are sealed, no internal components can be replaced. This leaves the service technician with a very limited number of repair options other than outright replacement.

SUPERHEAT & SUBCOOLING

THE PROFESSIONAL HVAC TECHNICIAN | PROPER TUNE-UP TECHNIQUES

ABOUT PRESSURE / TEMPERATURE

A fact of physics is that pressure and temperature are inseparably linked. If the pressure changes, the temperature HAS to change also. Pressurizing a cylinder heats it up; placing a refrigerant cylinder in the back of a van at 125 degrees will cause the pressure to increase as well. You cannot change one without also changing the other. This relationship is predictable and is the entire basis for the air conditioning and refrigeration industries.

Topic 01

P / T Basics

Pressure & Temperature

- Always linked
- Predictable

Topic 02

An Ideal AC Cycle

- Superheat
- Subcooling
- Temperatures
- Pressures

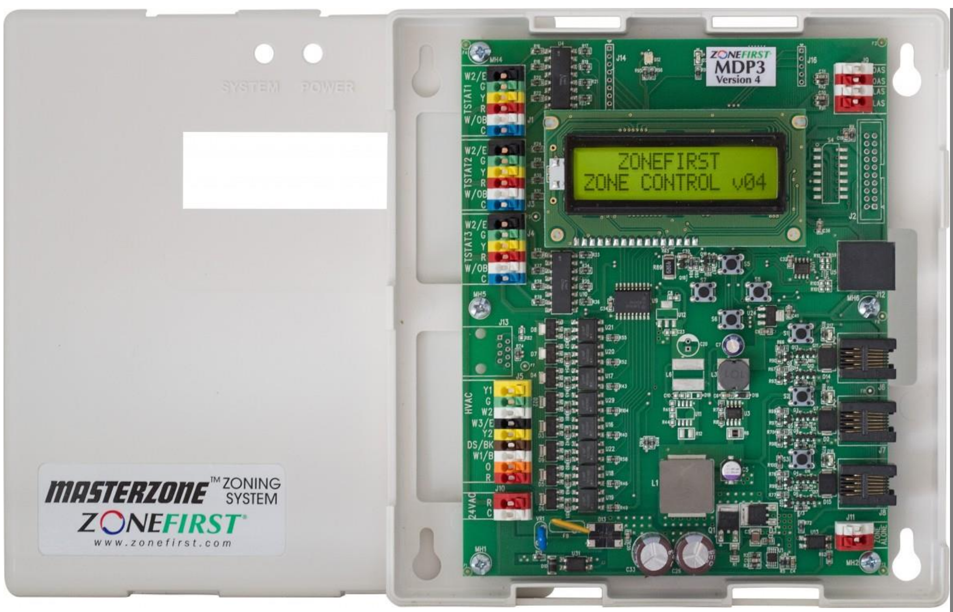
TOPIC 03

A Standard Tune-up

- Gauge Temperature
- Line Temperature
- Overcharging
- Undercharging
- Non-condensables

ZONE CONTROLS

THE PROFESSIONAL HVAC TECHNICIAN | ZONE CONTROL SYSTEMS



ABOUT ZONE CONTROLS

In a typical home with one furnace and AC, changing the thermostat setting changes the temperature in every room of the home. To have different areas of the home at different temperatures requires manual or automatic zone control. "Zoning" means the selective heating or cooling of different areas in a home or business. Unused rooms can be left idle while occupied areas can be heated or cooled as needed, thus saving energy. Although registers can be manually opened or closed to control airflow, an automatic system is preferable.

Topic 01

Zoning Options

- Equipment options
- Number of zones
- New construction

Topic 02

Operations

- Zone control panel
- Dampers
- Thermostats
- Wiring
- Damper motor types
- Function

TOPIC 03

Additional Zoning Options

- Motorized Registers
- Radiant / Electric
- VRF Systems
- Mini-Splits

REFRIGERANT MANAGEMENT

THE PROFESSIONAL HVAC TECHNICIAN | REFRIGERANT MANAGEMENT

ABOUT REFRIGERANTS

Understanding refrigerants and how they function is one thing, but knowing how to handle, charge, recover, and recycle refrigerants is a completely different matter. All substances exist as either a solid, liquid, or a gas. Most compounds can exist in all three states depending on temperature and pressure. For example, at atmospheric pressure, water is a solid below 32° F, a liquid between 32° F and 212° F, and a gas above 212° F. However, in a vacuum water boils at room temperature and at two atmospheric pressure water boils at 250° F. A surprise may be to discover that the entire mechanical-refrigeration industry is based not upon the liquid or gaseous states of a refrigerant, but instead upon what happens ***between*** these states of matter.

Topic 01

Physical Characteristics

- Latent heat
- Water issues
- Non-Condensables
- Sublimation

Topic 02

Field Procedures

- Pump Down
- Recovery
- Critical Charging
- Recycling
- Brazing v. Flaring
- Unknown Refrigerants
- Substitutions
- Filter/dryer
- Evacuation
- Using a compressor to recover

HVAC TOOLS – In the Bag

Gauge set(s) – (R-22 / R-410a)
Manometer – (digital w/ adapters)
Multi-meter w/ leads, & temp. probe
Digital Rh / wet-bulb thermometer
Non-contact voltage detector
Service wrench
Hex drivers* 1/4", 5/16", 11/32", 3/8", & 7/16" (the 3 largest are for blowers)
Hex drivers* 1/4" & 5/16" stubby
Ratcheting hex wrench (tiny ¼" & 5/16")
Screw drivers (or multi-head 11-in-1)
Screw drivers (stubby Phillips & slotted)
Screw drivers – long (large & small slotted)
Needle nose pliers
Diagonal cutters
Channel lock pliers
Crescent wrenches – small & medium
Allen wrench set - loose
Aviation snips
Scissors
Utility knife
Cleaner spray bottle
Cleaning cloths
Zip ties
Inspection mirror
Torpedo level
Tubing cutter – small
Alligator clips
Tape measure (12')
Resettable fuse

Wire stripper/crimper
Awl (to align holes in cabinets)
Electrical tape
Teflon tape
PVC cutter (non-ratcheting)
Small clamps (for safety switches)
Snout lighter (BBQ lighter)
Flashlight – small
File
Oil bottle – Zoom spout
Coil cleaning brush
Temperature / Pressure charts
Schrader core tool/screwdriver
Sharpie pen
Thin gloves
Can of Dust-off
Sandpaper
Drywall saw
Nut & screw box
- Fuses – ATC 3 & 5 amp
- Wire nuts
- Hose clamps
- 1/4" & 5/16" screws
- Wood screws
- Nails
- Wire staples
- Crimp-on wire connectors

* ¼" & 5/16" magnetic, larger sizes hollow shaft

HVAC TOOLS – In the truck

Vacuum pump
Micron gauge
Torch set w/ brazing rods + extra tanks
MAPP gas torch w/ solder
Refrigerant tanks
Nitrogen tank
Nitrogen manifold
Extension cords
Combustible gas detector
Leak check: refrigerant detector, soap
Refrigerant scale
Inspection camera (borescope)
Recovery machine w/ extra hose
Recovery tanks
Caulk & gun: Clear, Silver, RTV, foam
Angled snips / folding bar / hand seamer
Motorized snips
Hole cutters – wood & sheet metal
Shop lights + extra bulbs
Thermostat wire / condenser wire
Drill – cordless regular / impact
Drill – rotary hammer w/ core bits
Sawzall & blades / hacksaw
Circular saw
Rope
Wrench & socket set
Lineman's pliers
Sprayer (pump-up)
Heat gun
Garden hose
Tubing cutters – large
Ladder / step stool
Battery box
Pipe wrenches – selection of sizes
Adjustable wrenches – large
Torque wrench (for flare fittings)
Hammer(s)
Hub puller
Tubing bender / expander / flaring tool
Shovel
Pry bar(s)

Drop cloths
Schrader core removal tool
Knee pads, gloves, safety glasses
Air sprayer hose (for nitrogen tank)
Drill index set
Spare parts for furnace and AC
Coil cleaner
Tape: Foil, foam, electrical, Teflon, duct
Gas: orifices, plugs, CSST fittings
Screws: sheet metal, Tapcon, wood
Hanging strap (plumber's tape)
S-clips / drive cleats
Hose clamps, saddle valves
Cartridge fuses
Nitrogen adapter (cone shaped – fits into tubing)
Nitrogen purge tool (controls gas flow rate)
Wire: 10 & 12 ga Romex + 14/4 (mini-splits)
Liquid tight & fittings
PVC pipe, parts and glue
Flue pipe, fittings, and flue caps
Tubing: vinyl, line set scraps, drain, ¼"
Wire / cable stapler
Sheet metal
Duct zip ties / insulation
Line set cover / fittings
Hand truck
Stud sensor
Heat gun
Dust masks
Broom / dustpan / garbage bucket / vacuum
Fish tape / rod
Water bucket w/ rags (for brazing)
Portable heater / Propane heater
Copper pipe fittings *
Black iron fittings + pipe dope *
Electrical fittings *
Flare fittings *
Plumbing: SharkBite, T&P, fittings *
* Box or bins w/ every part needed for any job

River-Wiring Exercise

(From Chapter 3)

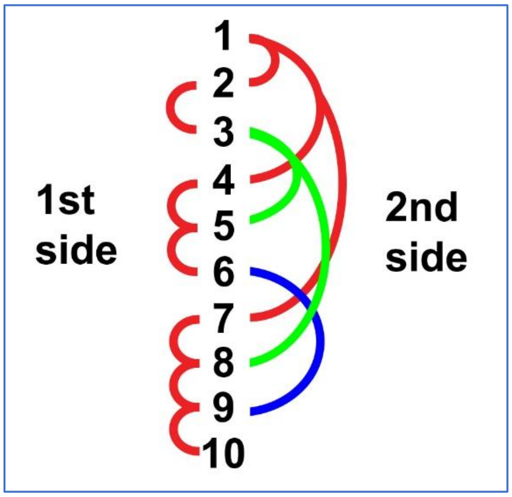
HINTS

Forget about trying to identify all 10 wires – how can you positively identify just one wire? How can you configure the wires on the first side of the river so that when you travel to the other side, you can identify with absolute certainty a single wire? (Wire-nut nine wires together… the only wire without continuity to any other wire is the lone wire).

Now try connecting groups of wires together in a way which will allow you to figure out these same groups on the other side. You can then use these groups to re-wire new bundles prior to the return trip.

ANSWER

On the first side of the river, leave #1 unattached but wire nut #2-3, wire nut #4-5-6, and wire nut #7-8-9-10 (see drawing). On the far side of the river, you'll be able to determine the single wire, the pair, the triple, and the quad wiring bundles using continuity, although you won't be able to determine which wire is which within each bundle. The only wire you can identify with absolute certainty is the single wire. Tag the single wire as #1. Wire nut #1 to one wire in each bundle, marking them as #2, #4, and #7 respectively (only one wire in each bundle will show continuity with #1). Since you know which of the pair of wires is #2, then by default you know which is wire #3 (mark it), then use it just like we used the #1 wire above, namely by wire nutting wire #3 to #5 and to #8 (mark them). By default, you now know wire #6 (mark it), and wire nut it to #9, leaving #10 loose (mark them). Returning to the first side of the river, remove the wire nuts but keep the separate wires segregated into their original bundles. We can now test and mark each of the ten wires based on continuity tests, numbering them 1 through 10.



Rare Troubleshooting Problems

The following are actual troubleshooting issues encountered by new techs in the field. They are not addressed in the textbook because they are unlikely to be encountered again in a lifetime of service calls. They are, however, interesting from an investigative perspective to see what we would do if we were the tech in the field. Read the problem first and see if you can figure out the cause before looking at the solution.

Problem 1: A customer called on a hot July day to say that her air conditioning wasn't working. However, when she turned her thermostat on, all the lights in the house came on, and when she turned her thermostat off, all the lights in the house went off.

Solution: The tech was told the above information over the dispatch radio, but didn't believe a word of it (too weird). Arriving at the home, he went to the thermostat and turned the temperature down to cause the AC to turn on. Sure enough, the house lights came on. When the temperature was turned up to cause the AC to turn off, all the lights in the house went off. Turning the temperature down again, the tech checked out the air handler but found nothing which could explain the bizarre phenomenon. Going out to the condenser, he found the contactor closed, but the compressor wasn't running and the condenser fan was moving very slowly. Checking the voltage at the L1, L2 terminals of the contactor, he only found 120 volts – one leg of power was missing. Tracing the power back to the AC service disconnect showed the same missing leg of power. Tracing it back to the breaker in the breaker panel also showed a missing leg of power for the entire panel. Checking the incoming power line at the meter base, it was found that one of the main lugs (on the house side of the meter) was completely melted. The wire in the lug had become loose, and the resulting arcing had melted the lug. The local utility company was contacted, but the homeowner was told that this was her problem since the melted lug was on her side of the meter (the utility has responsibility up to and including the meter, but from the meter on belongs to the homeowner). What was causing the thermostat to control the lights was that when the contactor was closed (during a normal call for cool), power from the good leg of power was cross-connecting through the compressor wiring to the missing leg of power. Half of a home is on one leg of 120-volt power and half on the other. The thermostat/contactor was not turning on <u>every</u> light in the home, but only half of them (through the compressor wiring when the contactor was closed). No 240-volt appliances in the home would be able to function without a second leg of power. The tech informed the homeowner that this was not something HVAC techs are allowed to repair. The homeowner called a licensed electrician who installed a new meter base for $2,500. Once installed, the tech came back and discovered that the contactor, dual-run capacitor, compressor and condenser fan motor were all undamaged.

INDEX

THE PROFESSIONAL HVAC TECHNICIAN

Facts Every Technician Should Know

Ned Hart has been a technician instructor for the last 18 years working in the field and the classroom with thousands of students, installing over 500 furnace & AC systems in commercial and residential locations as part of field training with students.

Mr. Hart's credentials include:

- Program Chair HVAC Department Fortis College for 11 years
- Conducted the "10-year HVAC Survey" to determine retained student knowledge
- Manager of the Utah Solar Test Home, a 50-year-old zero-energy home with nine heating systems, three AC systems, atmospheric water generator, year-round greenhouse, 16 kW solar input, whole-house LFP battery backup system, etc.
- Contractor / owner since 1979 in Virginia, North Carolina, Utah and Nevada
- Inventor of the Step Generator (Rankine-cycle system for home use), Equinox thermal storage system (reduces heating costs by 75%), and Oasis Air filtration system (removes 100% of airborne contaminants without creating an airflow restriction)
- Published author of several HVAC technical books and numerous articles

esco institute

9 780984 985814