Preparing for the NATE Exam

HVAC Support Technician Study Guide

NORTH AMERICAN
TECHNICIAN EXCELLENCE

CONTENTS

PREFACE

WHAT IS THE PURPOSE OF THIS STUDY GUIDE?

The purpose of this study guide is to offer an overview of components, tools, and basic terms and knowledge used by HVAC support technicians. These basics create a foundation for the intermediate information that follows—desired conditions, installation, and service. This foundation continues on to applied knowledge and concludes with the most important aspect of the job—safety. This study guide will be used to prepare for the NATE HVAC Support Technician Certificate exam.

WHAT IS NATE?

As an independent, third-party nonprofit certification body supported by industry leaders, North American Technician Excellence, Inc. (NATE) is committed to improving the HVACR industry through voluntary testing and certification. NATE supporters include contractors, distributors, education and training providers, manufacturers, technicians, utilities, and their respective trade associations. There are 21 NATE installation, service, and senior tests. Specialties include Air Conditioning, Air Distribution, Heat Pumps, Gas Furnaces, Oil Furnaces, Hydronics Gas, Hydronics Oil, Light Commercial Refrigeration, Commercial Refrigeration, and Senior HVAC Efficiency Analyst.

WHY IS IT SO IMPORTANT TO OBTAIN THE NATE READY TO WORK CERTIFICATE?

This certificate exam allows you to demonstrate to your employer or others the skills you have obtained during your HVAC technician career. It can be used as a way to benchmark your skill development as you progress in your HVAC technician career. Mastery of the knowledge areas and skills covered in this study guide and on the certificate exam are a good way to demonstrate that you are ready to progress to the next stage of your career.

The first chapter in this study guide introduces you to the system components you will encounter in your work as a support technician. A thorough understanding of the basic functions of these components is key to your success. To begin, let's look at the intricate network of ducts.

DUCT SYSTEMS

The duct systems within any HVAC system serve multiple purposes. They carry warm air during the winter, keep cool air inside during the summer, and ventilate the space to provide better air quality.

As a support technician, you will need to know the types and locations of ducts. Ducts can be rigid or flexible. *Rigid* ducts are made out of galvanized steel, polyurethane, and fiberglass. They are very durable and are usually used for main trunk ductwork. *Flexible* ducts have an insulated outer jacket surrounding a plastic film-coil spring inner liner. They are used for the ductwork that branches off from the main ductwork. They fit easily into smaller spaces and around larger items. For instance, flexible duct can be found in a crawlspace, suspended from floor joists.

You also need to know that adequate airflow is critical for the HVAC system to successfully operate. Ductwork must be of adequate size, properly sealed, and well insulated to operate properly. All of these requirements apply to the *supply ducts*, the ones that send conditioned air into each room, as well as the *return ducts*, which allow air to return to the air handler for distribution to the supply system. A good example of the importance of adequate duct sizing would be what happens if the size of the return air duct is decreased. This inadequate sizing would cause the airflow to decrease. If the air flow is decreased, then the system would not be functioning efficiently. You will learn more about ductwork later in this chapter.

COMPONENTS

Now that you know a little bit about ductwork, let's move on to specific system components. Components and their function can vary depending upon whether the system is an air conditioner and a furnace or a heat pump.

Outdoor Coils

During the cooling cycle, the *outdoor coil* works as a condenser. With heat pumps, it performs in an opposite fashion during the heating cycle. Then, the coil functions as an evaporator. The status never changes with an air conditioner. A condenser is shown in Figure 1-1.

Figure 1-1: Condenser

Indoor Coils

The *indoor coil*, during the cooling cycle, serves as an evaporator. The indoor coil of a heat pump then works as a condenser during the heating cycle. When cooling, condensation forms on the evaporator. A condensate drain is attached to drain the excess water off and away from the machinery. Damage to ceilings can occur when these drain lines are not properly installed in attics. To prevent this damage, a secondary drain of an attic mounted horizontal air handler used with a heat pump should be located on where condensate water can be seen by the occupants of the home. The visible water flow will alert them that something is wrong, and a repair can be made before too much damage is done.

Compressors

The *compressor* is the heart of a vapor compression system used for cooling (or heating, in the case of a heat pump). Compressors serve as pumps, which circulate refrigerant through tubing that connects indoor and outdoor components. The refrigeration circuit must also have a metering device to regulate the flow of refrigerant.

Refrigerants

Refrigerants boil at very low temperatures, which makes them perfect for using in vapor compression systems that cool and heat buildings. The ones used in residential and commercial systems also have an indefinite storage life.

Historically, many different refrigerants have been used to condition the air in homes and offices. These include R-12, R-500, and R-22. R-22 has been the most widely used refrigerant. R-410A is also a popular refrigerant that has been in use since the nineties. While it has a lower impact on ozone in the atmosphere than some of the early refrigerants, it has a high greenhouse gas number. The Environmental Protection Agency's low-GWP refrigerants ruling from 2015 will most likely prohibit the use of this refrigerant in stand-alone refrigeration units starting in 2019 or 2020. Some larger manufacturing and chemical companies are currently working on replacements for R-410A.

Blowers and Fans

Blowers and fans are the driving forces used to move air through ductwork. They have less ability to change air pressure. Therefore, even small changes in air flow resistance can have a big impact on the amount of air that can be moved through the ductwork. Even slightly undersized ductwork can have a large impact on the performance of the blower or fan. A loose fan belt can also have an impact because it will slip on its pulley and slow the fan speed, which reduces air flow.

Air Side Components

The air side components, some of which have been discussed already, are as follows:

- ***Evaporator***—boils refrigerant, which absorbs heat from the air inside the space
- ***Condenser***—reduces a vapor to a liquid by extracting heat
- ***Compressor***—serves as a pump, circulating refrigerant through tubing that connects indoor and outdoor components
- ***Metering device***—regulates the flow of refrigerant to achieve the desired refrigerant cooling conditions

Grilles, Registers, and Diffusers

Grilles, registers, and diffusers are all used to control air flow in HVAC systems. *Grilles* (see Figure 1-2) are coverings with small openings that allow air to pass through them. They are located in the sidewall, ceiling, or floor. The openings allow air flow but are small enough to prevent large objects from entering the system.

Figure 1-2: Grille

Registers are coverings for grilles or diffusers. There are two types—supply and return. Supply registers are usually located on outer walls or under windows. Return registers are usually installed up high on inside walls. Registers are equipped with air volume control devices, which allow them to mix air in the conditioned space.

Diffusers are mechanical devices that slow the air and enhance its distribution within the space. The placement of diffusers is important for proper air distribution. In areas that need to be heated, they should generally be placed on the floor. In a system that is mostly used for cooling, though, the diffuser should be placed high in the wall so that the cooler air will move downward and increase natural circulation.

ELECTROMECHANICAL SENSING CONTROLS

Electromechanical Wall Thermostats

Thermostats, seen in Figure 1-3, are temperature-sensing devices that control HVAC systems and maintain comfortable temperatures inside a home or building during warmer and colder months. They are usually installed near return air grilles. They must not be installed in a location where the air supply blows on them or in direct sunlight.

Electromechanical Temperature Controls

These thermostats open and close control circuits at the appropriate times to energize and de-energize system components. The following are components that are commonly controlled by these types of thermostats:

- Compressors
- Condenser fan motors
- Evaporator fan motors
- Heaters
- Reversing valve solenoids

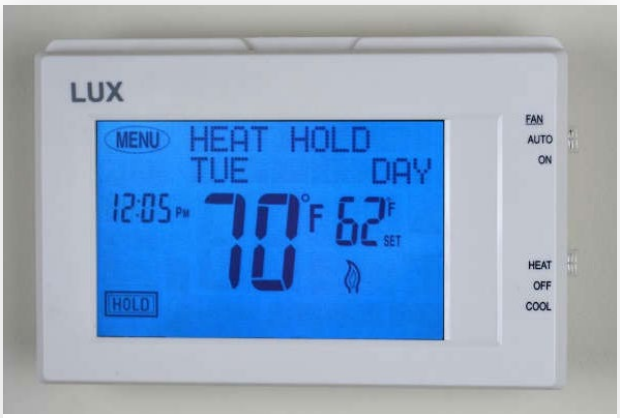

Figure 1-3: Electronic Thermostat

ELECTRONIC CONTROLS

Electronic Thermostats

Electronic thermostats are microprocessor-based controls that use temperature-sensitive resistors called thermistors. The resistance of a thermistor changes according to the surrounding air temperature. The circuitry of an electronic thermostat recognizes changes in resistance as changes in temperature. It then adjusts the system in response. When the resistance decreases, the current in the circuit increases. A higher resistance means a lower current.

This type of thermostat is rapidly replacing the electromechanical thermostat (one that uses a mercury bulb). They are more reliable and last longer because they have no moving parts that can wear out. The absence of mercury is an additional advantage, making it environmentally friendly.

AIR DISTRIBUTION

For an HVAC system to perform efficiently, it must have an adequate amount of conditioned air moving through it via its duct systems. An example of ductwork for such a system is shown below in Figure 1-4.

Duct Systems

The systems on which you will work process two types of air—supply and return. Supply air refers to air leaving the air handler. It may be conditioned if the equipment is heating or cooling but it may also be recirculated. Supply air is distributed through a section of ductwork called the *supply plenum*. Return air typically passes through a filter before entering the air handler for the conditioning process whether it is heating, cooling, or ventilating the space.

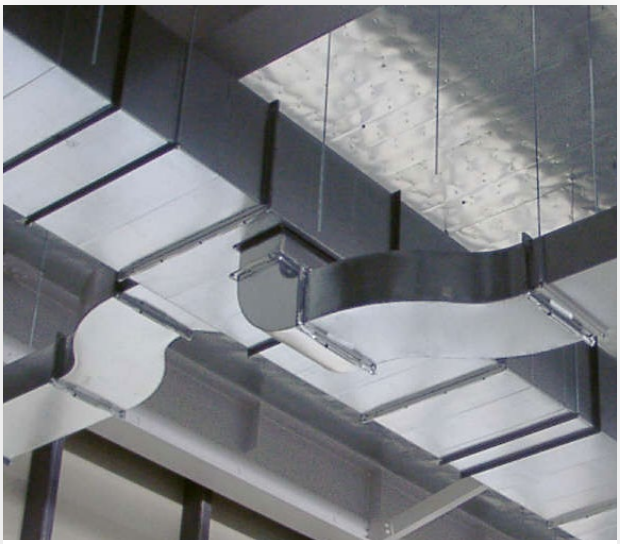

Figure 1-4: Ductwork

Certain things need to happen to the ductwork to allow it to more evenly distribute air flow and work more quietly and efficiently. A cross break, or creation of an angle, on all sides of a rectangular section of metal duct will increase rigidity and reduce vibration. This helps with noise reduction. Making sure the *duct transition*, the duct fitting connecting two duct sections of different size or shape, is seamless is another way to reduce the noise level and increase efficiency. The addition of *turning vanes* in a rectangular elbow of ductwork is yet another way to reduce pressure loss and evenly distribute air flow. Because of the more gradual, smoother change in direction, the air can keep moving with less resistance.

In the duct systems, it is also important for air flow to be balanced properly. A system could be operating with the correct total air flow volume, but still not make the customer happy. For example, the correct air flow into each room within a home may not occur if all of the balancing dampers, manual dampers enclosed in a sleeve, are completely open. You will know if the dampers are fully open if the adjustment handle on the manual damper is parallel to the air flow path of the ductwork. When all of the balancing dampers are open wide like this, some rooms may receive more air flow volume than they need, while others receive less. This is why air flow balance is important within the ducts.

Supply Blowers

Ductwork that delivers conditioned air to living spaces must be sized to match the static pressure capability of the *supply blower* being used. The supply blower, just like its name, blows the supply air through the ductwork. Most blowers used in homes can deliver the necessary air flow while developing an adequate amount of pressure. However, changes in resistance in an air distribution system that seem small might actually have a big effect on performance. This is because these supply blowers have a limited ability to create pressure.

Regardless of where ducts are installed, they should be sealed properly to reduce air loss. If they are located in unconditioned spaces, they also need to be insulated. Insulation has different R values, which indicate how well it can resist heat flow.

INDUCED DRAFT NON-CONDENSING COMPONENTS

Furnaces are important components in HVAC systems. They are used to heat the home. Specifically, induced-draft furnaces are a very efficient type. The first type is an *induced-draft non-condensing furnace*. Induced draft means that the combustion air flow is artificially created. Induced air increases efficiency. This efficient furnace has three main components—the heat exchanger, the burner, and the blower. There is also an added safety feature on both types of furnaces called the *door switch*. If the furnace door is open, the door switch opens and prevents the operation of the furnace.

Heat Exchangers

This type of furnace only has one heat exchanger. The *heat exchanger* transfers the heat from the combustion chamber to the supply air that is heating the conditioned space. Most heat exchangers are made of steel, often coated with another material to reduce corrosion.

Burners

The *burner* is where the heating element, usually gas or oil, is held and burned. It is located in the middle of the furnace, just below the heat exchanger. New gas furnaces now use electrical ignition devices to light the burner because standing pilots have been outlawed. However, older homes may still use pilot lights to do this.

Induced Draft Blowers

Induced draft refers to the combustion exhaust products that are produced. Induced draft blowers force the combustion products through the heat exchanger and move them to the chimney or sidewall vent.

INDUCED DRAFT CONDENSING COMPONENTS

The second type of furnace is an *induced draft condensing furnace*. It also has three main components but is a little bit different from the non-condensing furnace.

Heat Exchangers

The *condensing furnace* differs from the non-condensing furnace in that it has two heat exchangers instead of one. The primary heat exchange is similar to a non-condensing heat exchanger where the products of combustion leave the primary heat exchanger. The combustion products then travel through the secondary heat exchanger to remove additional heat and cause condensation in the flue gasses. These two heat exchangers transfer the heat to the indoor airstream distributed through the supply air system.

Burners

The burner in this type of furnace functions the same way as the one in the non-condensing furnace does. This burner, however, is located at the top of the furnace.

Induced Draft Blowers

These blowers serve the same purpose in this type of furnace. They force the combustion products through the heat exchanger.

Now that you have been introduced to some of the main components of the HVAC system, we can move on to the tools that will enable you to perform your job well.

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TOOLS AND SCALES BASIC MATH MEASUREMENT

As a technician in a supporting role, you will need to be familiar with and know where to use a variety of tools. You will also be required to use the basic math skills, covered previously in the Ready to Work Certificate Study Guide, along with some additional skills. This knowledge will be used for taking measurements and creating drawings as well.

Rulers, Compass, Square, Protractor, etc.

During your daily routine, you will take measurements of components, spaces, and locations. You will use measuring tools such as rulers, compasses, squares, and protractors. You will use a ruler, or measuring tape, to find length and height. You will use a compass and protractor, as seen in Figure 2-1 and Figure 2-2, to draw and measure angles, such as elbows in ductwork.

Figure 2-1: Compass

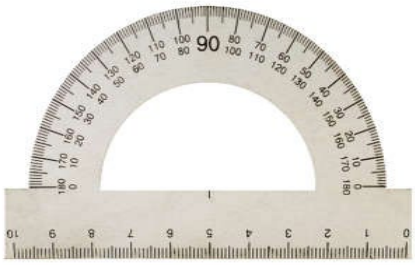

Figure 2-2: Protractor

Measurement—Inches, Feet, Centimeters, Millimeters, etc.

Depending on the project, you may be taking and recording measurements in inches, feet, centimeters, or millimeters. You may also need to convert one unit of length into another unit of length. The following chart (Table 2.1) gives you a handy guide to some of these conversions.

Table 2.1 - Equivalents; Linear Measure			
1 inch =	25.4 millimeters 2.54 centimeters	1 millimeter =	1,000 microns 0.394 inches
1 foot =	12 inches 30.48 centimeters 0.3048 meters	1 centimeter =	10 millimeters 0.3937 inches
1 yard =	3 feet 91.44 centimeters 0.914 meters	1 meter =	1,000,000 microns 1,000 millimeters 100 centimeters 39.37 inches 3.28 feet
1 micron =	0.0000394 inches 0.000001 meters	1 kilometer =	1,000 meters 0.6214 miles

Basic Scale Drawings

Another tool you should know is computer-aided design. Computer-aided design programs can help you create basic scale drawings of heating, ventilation, and cooling ductwork. You can create these plans from scratch or layer them on top of an existing floorplan. Planning is one very important aspect of your job, and basic scale drawings can help you create those plans.

FABRICATION TOOLS

Sheet metal is used often in the HVAC industry. As a support technician, you will be creating, or fabricating, ducts and duct fittings for large and small HVAC systems. There are several specific fabrication tools with which you will need to be familiar.

Screwdrivers and Nut Drivers

A number of tools make metal work more efficient. A screwdriver, seen in Figure 2-3, can quickly insert screws into the metal. Nut drivers, seen in Figure 2-4, tighten and loosen screws, bolts, and nuts.

Figure 2-3: Screwdriver

Figure 2-4: Nut Drivers

Wrenches, Pliers, and Allen Wrenches

Wrenches are tools with a handle and one end designed to hold, twist, or turn a nut or bolt, such as the one seen in Figure 2-5. These can be handy for connecting and securing ductwork. Allen wrenches, also known as hex keys, are used for tightening and loosening but can be used in tighter spaces. They are pictured in Figure 2-6. Pliers can be used to crimp the metal so that the pieces of ductwork will fit together properly. They can also be used to grip, twist, bend and cut wire and cable.

Figure 2-5: Wrench

Figure 2-6: Allen Wrenches

Socket Sets

Socket sets are used to remove bolts, sockets, and screws. A 12-piece set is pictured in Figure 2-7. The socket wrench itself has attachments with varying sizes to fit on specifically sized bolts. A bolt that needs to be removed may have a 1/4", 3/8", 1/2" hex head on it, for example. You would match the attachment with the size of the bolt head.

Figure 2-7: Socket Set

Levels and Squares

Levels and squares are good examples of layout tools. They are used to measure and mark the metal before cutting or drilling. Squares are somewhat similar to rulers because they also have measurements on them. They are used to measure a section of metal and then draw straight lines so that the cutting instrument can follow along them exactly, making a precise cut. Levels, such as the one in Figure 2-8, ensure that each duct is installed level or plumb.

Figure 2-8: Level

Saws and Files

You will need to cut various items during fabrication. Hacksaws can be used to cut PVC piping, but should never be used to cut copper tubing. The saw leaves behind some metal chips that can damage components and clog metering devices. A tubing cutter (Figure 2-12) should be used on copper instead. Aviation snips are used for cutting sheet metal, and would be recommended for cutting an opening in a metal cabinet.

You can use a triangular file or a knife-edge file to cut capillary tubing. Capillary tubes are very small in diameter and very long. They are used as a refrigerant metering device.

Drills, Countersink, Reamers, and Bits

Drilling holes for connecting piping is a very important step in fabrication. Certain drill bits, such as the ones seen in Figure 2-9 are made for working with copper. The twist drill bit works best on metals. Don't apply too much pressure when using the drill with this bit because it can make it overheat and dull the bit. A countersink bit is used to enlarge and bevel the drilled hole. The reamers are then used to clean up the mess made by the drilling.

Figure 2-9: Bits

Punches, Taps, and Dies

Holes can be drilled into metal with other tools as well. The center of the hole is marked in the metal using a center punch, seen in Figure 2-10. This mark makes it easier to guide the drilling of a pilot hole. Taps are tools used to thread a hole in the metal. Dies are used to thread the outside of rods.

Figure 2-10: Center Punch

Hammers

A hammer is used in fabrication for bending the metal. Combined with a shaping dolly, you can use the hammer to bend the metal around different shapes.

Metal Tools

You should also be aware of some other tools used on sheet metal. Metal snips are used for cutting. Shears are also used for cutting, but are a better choice for longer, straight cuts. Staplers are used to secure insulation around metal piping.

Measuring tools are also important. Measure twice, cut once is an applicable phrase in metal work. If you have the right measuring tool, then your cut will be accurate, and no materials will be wasted. Examples of these measuring tools are calipers and rulers. Some digital calipers are available as well, making the measurement even more precise.

TUBING TOOLS

Benders—Spring, Lever, etc.

Bending tools, as seen in Figure 2-11, are used to cleanly bend soft-copper tubes to fit around corners. They can only be used on this type of tubing. Both spring-type and lever-type benders are pictured.

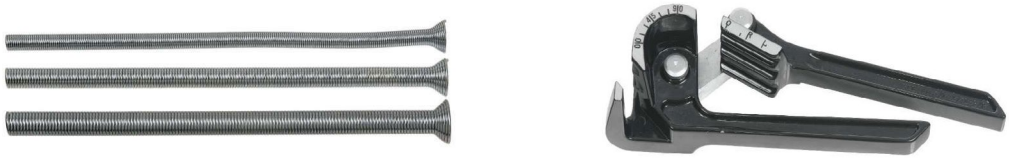

Figure 2-11: Bending Tools

Flaring Tools

Flaring tools allow you to join soft-copper tubing mechanically. One end of the tubing is flared into a cone at about a 45° angle. The flared end fits up against the face of a flare fitting. A flare nut then presses the tubing against a machined seat, forming a seal. If you start with too much height (the tube too high above the flaring tool base), then the flare will be too large for the flare nut.

Tube Cutters

Tube cutters, like the one seen in Figure 2-12 produce a square, clean cut. They leave no shavings behind in the system. A tube cutter can also be used to remove a sweat type filter-drier from an HVAC system.

Figure 2-12: Tube Cutter

Swaging Tools

A swaging tool expands tubing to the size of a fitting. This allows tube to be joined together without the use of a coupling. It can be seen in Figure 2-13.

Reamers

The process of cutting a tube with a tubing cutter leaves a ridge on the inside of the tube which must be removed. Some tube cutters have a reamer blade mounted on top of them. This reamer blade removes the burrs from the inside of the tubing after cutting. This reduces turbulence and pressure drops within the piping.

Figure 2-13: Swaging Tool

Tool Maintenance and Care

As an HVAC support technician, your tools will become like members of your family. You must select them with care. You should choose only those tools that meet the highest performance standards and inspect them regularly. Make sure they are all accounted for and stored properly after each job.

ILLUSTRATION CREDITS

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FIGURE 2-11: KLEIN TOOLS
FIGURE 2-12: ELEARNING BROTHERS STOCK ASSETS LIBRARY
FIGURE 2-13: RITCHIE ENGINEERING CO., INC.—YELLOW JACKET PRODUCTS DIVISION

TOOLS AND SCALES BASIC MATH MEASUREMENT

You will not be directly involved in the construction of buildings, but you must have a basic knowledge of some of the terms used in construction. You must also be aware that your actions, as a support technician, can affect the structures.

CEILINGS - *Construction and Materials*

Many HVAC components are located up high, near ceilings. Beams and joists are two major ceiling components. A beam, one of the main horizontal wood or steel components of a building, runs parallel with the ceiling. It is exposed and acts as a central support. A *joist* is a small rectangular section of wood that runs parallel from wall to wall in a building. Joists rest on beams and support the ceiling and floors, as seen in Figure 3-1.

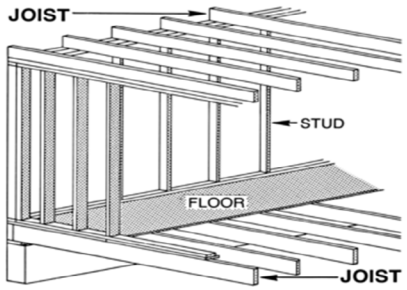

Figure 3-1: Joists Supporting Ceiling and Floor

WALLS - *Construction and Materials*

The next structural components are walls. Starting at ceiling level, *ceiling joists* rest directly on wall top plates. A *plate* is a piece of wood placed on wall surfaces that acts as a fastening device. The bottom member of a wall is called a sole plate. *Wall studs*, also seen in Figure 3-1, are attached to this plate. Horizontal pieces, such as beams and joists, are nailed to the studs. Studs are usually spaced 16 to 24 inches apart. In residential construction specifically, these 2 x 4 load-bearing studs should be spaced 16 inches apart. *Load-bearing walls* are capable of supporting weight, such as that of a roof.

FLOORS - *Construction and Materials*

Joists are also used in floor foundations. *Floor joists* are framing pieces that rest on outer foundation walls and interior beams. *Bridging* is a brace made of wood or metal pieces, which is placed diagonally between the floor joists. These hold the joists in place. A *chase* is a groove that goes through the floor to accommodate pipes or ducts. Chases may be important to you when you are installing ductwork.

GIRDERS AND TRUSSES - *Construction and Materials*

Girders and trusses are also used for support in construction. Both can be made from various types of wood or metal. A *girder* is a main component in a framed floor and supports the joists that hold the flooring boards. A *truss*, pictured in Figure 3-2, is a combination of structures creating a framework to connect load-bearing walls.

Figure 3-2: Truss

You may often need to cut holes to install piping and ductwork. Now that you are aware of some of the basic construction terms, you will understand the following advice to follow when you make those cuts:

- All holes cut through joists should be limited to the center one-third of the joist. If the joist is cut incorrectly, the building's entire structure can be weakened.
- Posts and beams should never be cut without the approval of a qualified structural engineer.
- All original walls should be considered load-bearing until they have been verified otherwise by a qualified structural analysis.

Now that you have a little background on tools, components, and construction, you will need to add science and math to your knowledge tool set.

ILLUSTRATION CREDITS

FIGURE 3-1: https://upload.wikimedia.org/wikipedia/commons/thumb/c/c4/Joist_%28PSF%29.png/300px-Joist_%28PSF%29.png FIGURE 3-2: MORGUEFILE/creative/morethanordinary

CHEMISTRY BASICS

The basics of chemistry will give you an introduction into what happens within an HVAC system. Combined with basic math skills, this knowledge can be a stepping stone to more detailed information.

Properties of Matter

The first building block of chemistry is matter. Matter has three phases, or states—solids, liquids, and gases.

- ***Solids*** are the phase of matter with the least energy. The molecules that make up solids mostly vibrate in place, giving them a definite size and shape.
- ***Liquids*** have a definite volume and are not easily compressed. Liquid molecules can move around with other molecules because they have more energy than those in solids. These molecules will fit the shape of any container.
- ***Gases,*** also known as vapors, contain the most energy of all of the phases. This gives them the ability to move faster and further apart. Gas molecules can actually break apart from each other. This allows the gas to expand and fill the whole volume of any container. You will have a lot of experience with gases during installation, maintenance, and repair.

Mass and Density of Materials

Mass is one of the basic properties of matter. It is the measure of the *amount* of matter in something. Weight, which is sometimes confused with mass, is the measure of the *force* that gravity has on something. Because weight and mass are directly related, and gravity is about the same everywhere on Earth, weight is just as convenient a term for an HVAC support technician to use as mass.

Density is another basic property of matter. It can be either weight density or mass density. The operating definition of density, when it applies to the HVAC profession, is weight per unit of volume. With weight being expressed in pounds (lb) and volume expressed in cubic feet (ft^3), density is stated in units of pounds per cubic foot (lb/ft^3). Considering the density of air is important in monitoring and improving performance in HVAC systems.

How Chemicals React with Each Other

A chemical reaction happens when two or more substances, or chemicals, combine to form a new substance. A good example of a chemical reaction is rusting. This happens when the iron in metal pipes, for example, mixes with the oxygen in the atmosphere. The end product is iron oxide, or rust.

Oxidation and Combustion

Oxidation and combustion are two very important chemical reactions related to the HVAC profession. *Oxidation* is a chemical reaction that always involves oxygen. You can see how the iron on the pipes in Figure 4-1 has rusted, as previously mentioned, because of oxidation.

Figure 4-1: Oxidation

When an ignition source is present, the process of combining fuel and oxygen results in the release of heat. This is called *combustion*. As stated, three things must be present for combustion to happen—fuel, oxygen, and heat. These three ingredients are often called the "fire triangle". If you remove any one of these three components, the fire will go out.

Role of Chemistry on the Job Site

Chemistry is involved in many aspects of work as a support tech. Most importantly, you need to know some basics of chemistry if you want to stay safe on the job site. You need to know which chemicals react with other chemicals and how severe those reactions might be. Basic chemistry knowledge will also help you understand different processes that may affect HVAC system performance. For instance, if you know that oxidation might cause tubing clogs, you will know to use nitrogen to purge the tubing to prevent excess oxides from forming inside.

MATHEMATICS

Both science and math have their place in your knowledge base. Math is one of the foundations of the HVAC industry. It is the language used to interpret data and pass that data on to coworkers. To be successful in this industry, you must have a working knowledge of arithmetic, algebra, and geometry. You will also need to be comfortable reading and applying the information found in charts, graphs, and tables.

Arithmetic

As a support tech, you will use basic arithmetic to answer many questions in your work, from temperature change to pricing of materials. Let's start with temperature change. You may take temperature readings at one point in time, then one hour later, then an hour after that, and so on. You will note the time and the temperature with each measurement. By finding the difference between one set of temperatures (subtracting the lower temperature from the higher one), you can find that change. You can then make note of the trend in temperature changes and predict what the temperature might be at a later time by adding the change to your last measurement.

Basic arithmetic can also help you with pricing of materials. You may find yourself in need of some piping for a drainage job. Each piece of pipe cost $3.57. If you needed eight of these pipes to finish the job, how much would all of the pipes cost? This can be solved using simple multiplication, as seen below.

$3.57 x 8 (number of pipes) = $28.56

The numerical values of $3.57 and 8 are *factors*, and the numerical value of $28.56 is called the *product*. It is a good idea to become comfortable with these descriptive words because they are common to all areas of mathematics.

Algebra

The equations that you will be using every day to evaluate technical measurements taken during services calls are a little more involved than basic arithmetic. When taking physical measurements of spaces or equipment, for example, you will also need to incorporate some principles from algebra. You might need to use fractions to find a smaller measurement or a portion of a measurement. For instance, you might need to convert 1/8th of an inch into 16ths. The question you'd ask yourself is, "what is 1/8th of 16?" The equation to use would look like this:

$$\frac{1}{8} = \frac{x}{16}$$

$$8x = 16$$

$$x = 2$$

So, to solve the equation, you would find what number (x) multiplied by 8 equals 16. And the answer is 2 (8 × 2 = 16).

Operations (add, subtract, multiply, and divide) must be performed in the correct sequence as you work through an equation. If you perform them in the wrong order, you will get an incorrect answer, even if you are using an electronic calculator. The phrase, “Please excuse my dear Aunt Sally” will help you easily solve equations with more than one step. The correct order of operations that follows will help you solve this problem:

$$z = (20 - 10)^2 \times 2 + 12 - 4 \div 2$$

Please (Step 1): Solve all operations in the ***parentheses*** first.

$$z = (10)^2 \times 2 + 12 - 4 \div 2$$

Excuse (Step 2): Solve all ***exponents*** (the superscripted number) next.

$$z = 100 \times 2 + 12 - 4 \div 2$$

My (Step 3): Solve all ***multiplication*** operations next.

$$z = 200 + 12 - 4 \div 2$$

Dear (Step 4): Solve all ***division*** operations next.

$$z = 200 + 12 - 2$$

Aunt (Step 5): Solve all ***addition*** operations next.

$$z = 212 - 2$$

Sally (Step 6): Solve all ***substraction*** operations next.

$$z = 210$$

Geometry

The branch of math focused on points, lines, angles, surfaces, and solids is geometry. Geometry works its way into a tech's daily schedule in many different ways. Reading any type of basic scale drawing of an HVAC system requires the knowledge of points, angles, and shapes. An awareness of surfaces can help you plan drainage systems or install ductwork. The cylinder, a shape studied in geometry, is pivotal in the HVAC industry. Refrigerant is stored in a container shaped like a cylinder.

Graphs, Charts, and Tables

The physical representation of data found in graphs, charts, and tables will also be very helpful to you in your job. Relative humidity information could be plotted on a graph and used to troubleshoot a system, for example. A psychrometric chart is commonly used by technicians. It is a graphical representation of the parameters relating to water moisture in the air. It will also be important to learn to use performance tables provided by the equipment manufacturer. These will help you with installation and repair.

MECHANICS

Simple Machines

Simple machines are the smaller mechanisms, or pieces, that make up all larger machines. They can change the direction or magnitude of a force. The following are some examples of simple machines:

- ***Lever:*** strong bar used to lift and move heavy items (eg, hammer)
- ***Wheel and axle:*** wheel with a rod (axle) through its center used to lift or move loads
- ***Pulley:*** wheel or set of wheels using a rope or chain to raise and lower heavy objects
- ***Inclined plane:*** slanting surface connecting a lower level to a higher level (eg, ladder)
- ***Wedge:*** object with an inclined plane ending in a sharp edge, used for pushing objects apart
- ***Screw:*** inclined plane wrapped around a pole that can hold things together or lift things

Complex Machines

Complex machines are a combination of two or more simple machines working together. HVAC systems are composed of different complex machines with many moving parts. A blower or fan, for example, is a combination of a pulley (belt-driven fan or motor), a wheel and axel (in the motor and the fan blades), and screws, which hold the whole assembly together.

Conservation of Energy

The law of conservation of energy is a principle from physics. It states that energy is conserved over time. It is not created or destroyed. It only changes form. You will often see energy changing its form when you are doing your job.

Basics of Fluid Mechanics

A substance that is in the liquid or gas phase is called a *fluid*. Fluid mechanics focuses on the properties of fluids. HVAC piping and ducting systems are designed based on principles of fluid mechanics.

ILLUSTRATION CREDITS

FIGURE 4-1: ELEARNING BROTHERS STOCK ASSETS LIBRARY

Working with electricity is definitely in the job description of an HVAC support technician. Between 75 and 80% of all service calls involve electrical components in one way or another. Because of this, it is important for you to have a good understanding of electrical systems. This starts with meters and instruments used to measure electricity.

DIGITAL ELECTRICAL METERS

Identify Meters and Instruments

You will need to be able to identify several electrical measuring instruments to do your job well. These instruments are voltmeters, ohmmeters, and multimeters.

Figure 5-1: Analog Voltmeter

The voltmeter, seen in Figure 5-1, measures potential difference, the amount of energy required to move electricity from one point to another. The units displayed on the voltmeter are volts.

Figure 5-2: Ohmmeter

The ohmmeter, pictured in Figure 5-2, is used for measuring resistance and for checking the continuity of electric circuits. Continuity indicates that there is a complete electrical path. Ohms are the units displayed on an ohmmeter.

A good multimeter, the third type of meter, is probably the most versatile meter that can be used for troubleshooting. The multimeter combines the functions of many different meters, such as a voltmeter, an ammeter, an ohmmeter, and others. A digital multimeter can be seen in Figure 5-3. It can measure both voltage and resistance, so you do not need to use separate meters. The units displayed on a multimeter change based on the setting. If it is set to voltmeter, it will display in volts, if it is set to ohmmeter, then ohms, and so on.

Figure 5-3: Digital Multimeter

Each meter can be either analog or digital. Analog meters are used to observe changes and peak or dip indications when making adjustments in the HVAC system. A digital meter shows readings as numbers rather than a moving meter needle. A digital multimeter is very accurate and can be automatically set to read voltage, resistance, or current. The meter will automatically select the proper range.

ELECTRICAL BASIC TERMS

Just as in chemistry, algebra, and geometry, electricity also has its own terminology. Before you begin your support technician role, you need to be familiar with all of the following terms.

Voltage

Voltage is the force or pressure that pushes electrons through an electric circuit. It is also known as electromotive force (EMF) or potential difference. When you are using practical electrical notation, voltage will be represented by the symbol *"E"*. Voltage can be created in the following ways:

- Friction
- Pressure
- Heat
- Light
- Chemical reaction
- Magnetism (the movement of a magnetic field through a conductor)

Amps

An ampere, or "amp," is an electron flow rate equal to one coulomb per second. A coulomb is a measurement of the quantity of electrical charge. Electrical current is measured in amps.

Resistance

Electrical resistance is the opposition to the flow of an electric current caused by certain physical characteristics of a conductor. The symbol for resistance is *"R"*. It is measured in ohms. The symbol used to represent the ohm is "Ω". All electrical loads, such as heating elements, lamps, motors, and transformers, have resistance.

Power

Power is equal to the amount of work per unit of time. Electrical power is measured in watts.

AC AND DC CIRCUITS

Working with air conditioning units and heat pumps requires an understanding of the electrical basics of the HVAC system. This begins with a discussion of circuits, controls, and loads.

Simple DC Circuit

The flow of electrons through a conductor is called *electric current.* An electrical current can flow continuously in either of two directions. If it flows in one direction only, it is called *direct current,* or DC. Virtually all solid-state equipment, including the HVAC system, requires dc voltage to operate.

Introduction to AC Circuits

A current that alternates (changes direction or polarity at regular intervals) is called an a*lternating current,* or AC. AC is usually produced by rotating a coil in a magnetic field, as shown in Figure 5-4.

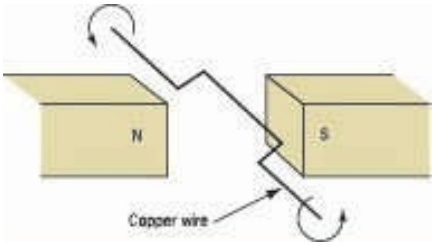

Figure 5-4: Generating Alternating Current

Basic Control and Loads

A *circuit* is a closed loop with a source of electricity and a load. A *load* is a device that uses electricity to do some type of useful work, such as generate heat. Examples of loads are motors, heaters, lights, or other pieces of equipment, such as the relay coil in the heat pump. A *control* is any device used for the regulation of a system or component in normal operation. *Switches* are devices that act as gatekeepers in an electric circuit. A closed switch allows electrical current to pass, and an open switch prevents the flow of electrical current. Figure 5-5 shows how loads and switches work together.

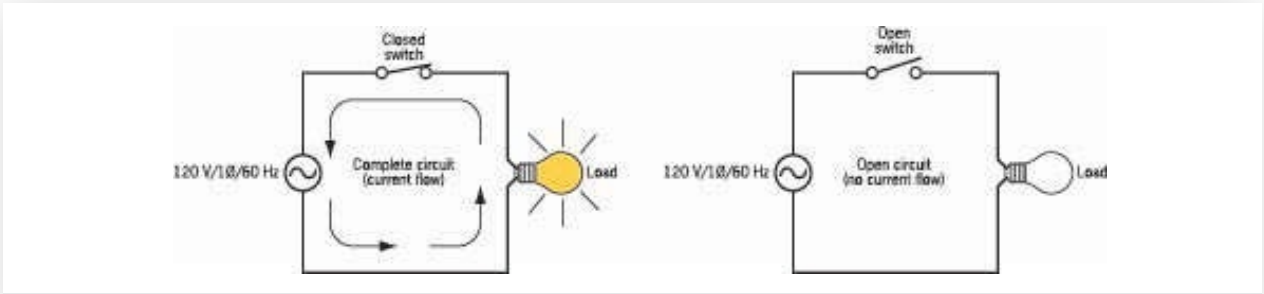

Figure 5-5: Loads and Switches

Both loads and switches can be checked by measuring voltage. As mentioned previously, you would use a voltmeter to do this. Voltage readings can be used to determine if switches are open or closed in an energized circuit. If you are reading voltage across a switch, that means that the switch is open. The rest of the circuit is complete. A reading of 0 V may mean that the switch is closed.

Once you understand the basics, you can move on to troubleshooting. You might be working with the electrical connections in the system and notice that there is a loose control voltage connection. You should know that any loose connection will cause problems, such as erratic operation, for the loads in the electrical circuit. Overheating can also be an issue within the electrical system. An undersized electrical conductor under load can make the electrical wiring excessively hot. A loose line voltage connection can also result in a melted connection.

Effects of AC on Control and Loads

The majority of the electrical measurements that you will take as a support technician are readings of alternating current (AC). Motors, electric heaters, magnetic coils, transformers, and most other electrical loads in HVAC equipment operate on alternating current.

The electricity in an HVAC system powers the components, controlling conditions in a home or commercial setting. There are many factors that contribute to a perfectly conditioned space. Those will be covered next.

ILLUSTRATION CREDITS

FIGURE 5-1: ELEARNING BROTHERS STOCK ASSETS LIBRARY
FIGURE 5-2: By Cyberius (English Wikipedia) [Public domain], via Wikimedia Commons
FIGURE 5-3: ELEARNING BROTHERS STOCK ASSETS LIBRARY
FIGURE 5-4: CORE ESSENTIALS: PREPARING FOR THE NATE EXAM
FIGURE 5-5: GAS AND OIL HEATING: PREPARING FOR THE NATE EXAM

Comfort is the goal of HVAC systems. This means keeping the customer cool in the summer and warm in the winter. It also means keeping the air inside a home or building as fresh and clean as possible. It is the responsibility of a support technician to design, install, and maintain systems that achieve those desired conditions.

TEMPERATURE

Role of Temperature in Comfort

Temperature is one of the basic factors contributing to human comfort in a conditioned space. The ideal indoor environment is regulated by the correct temperature. An ideal temperature for one customer may not be the ideal temperature for another. For this reason, you must listen to each customer carefully and install, adjust, maintain, or repair a system based on these needs.

HUMIDITY

Role of Humidity in Comfort

Humidity, another basic factor contributing to comfort, is a measure of moisture in the air. *Relative humidity* is an important part of HVAC work because it significantly impacts comfort and health. Humidifiers are used with heating systems to raise relative humidity. By raising relative humidity, evaporation of moisture from the body is slowed, making the customer feel warmer. When the customer is warmer during the winter, their comfort is increased.

Relative humidity is also important during the hotter months. Reducing relative humidity increases the evaporation of moisture from the body, making the customer feel cooler. Proper humidity levels also reduce the growth of bacteria and molds, which is good for overall health of the occupants. You will learn more about measuring humidity in Chapter 7.

Adjusting System Performance for Humidity Control

As the support tech, you will need to know how to adjust the system to maintain control of humidity. Some adjustments and changes are important to remember. If you slow down the evaporator fan, which blows air through the system, it can increase moisture removal. This will be especially important during the summer. However, you must be well-trained before performing this type of adjustment because fan speeds are very important in an air conditioning system. If you notice that the air conditioning system is short cycling, when it shuts off before the cooling job is complete, this can have a negative effect. This short cycling can decrease humidity control and have an effect on customer comfort. You will need to look for things like this when you move on to troubleshooting

AIR QUALITY

A complete comfort system not only controls temperature and humidity, but also focuses on air quality. It filters or cleans the air of materials that can accumulate on the cooling coil and other mechanical components, as well as on items inside the home or building.

Ventilation

Fresh air ventilation also contributes to human comfort. Ventilation in an HVAC system is the mechanical process of supplying or removing air to and from a space. An important function of the ventilation system is to bring fresh air from outside into the conditioned space. The fresh air dilutes contaminants, such as carbon dioxide and other chemicals, that can be produced within the space.

In today's homes and buildings, construction is tighter. One effect of this is reduced air infiltration for ventilation. Proper ventilation is an important aspect of indoor air quality.

Air Cleaning

Filtration is important for achieving clean air because it reduces the tiny particles of matter carried in the air. Filtration type can vary greatly. It depends on the needs of the customer. The most basic filter, such as a 1-inch fiberglass filter, can keep the equipment clean. A more high-quality filtration system, one that uses a 4-inch pleated filter, can reduce dust and allergen levels. This type of system can be very helpful to a person with allergies to airborne particles. Electronic air cleaners are also beneficial for people with allergies.

Filters and surrounding equipment should be properly maintained as well. A dirty filter increases static pressure, which can decrease the quantity of air delivered by the fan. Air velocity that is too powerful can cause particles to pass through the filter, decreasing the overall filtration and negatively impacting the indoor air quality.

Odor Control

Filters and electronic air cleaners work to purify the air inside the space, but they do not generally eliminate odors. Depending upon where the odor is coming from and what is causing it, some odors can be eliminated with activated charcoal filters, ventilation air and some other means. If the odor is coming from the supply duct, these measures may not help.

SOUND

The customer wants to experience a comfortable environment, but not necessarily hear the system doing its job to supply that comfort. Much of the sound in modern HVAC equipment has been suppressed, but there are steps you can take during installation to reduce sound level even further.

Equipment Source

A very effective sound-reduction strategy is to keep the equipment as far away from the occupants as possible. Units should be located far away from quieter rooms in the home, such as bedrooms. Instead of installing equipment in a closet near a bedroom or living room, it should be installed in a basement, crawl space, utility room, attached garage, or attic, to minimize added noise. Outdoor units should also be placed as far away as possible from the closest building.

Airflow Source

Loud equipment is one cause of noise complaints, but another common cause is high air velocity. Too much air might be moving past the damper, or the damper might not be closed all the way. This is something you will check for when you troubleshoot a noise complaint like this one.

Now that you know the basics of temperature and humidity, let's learn how each is measured.

PHYSICAL MEASUREMENTS—TEMPERATURE AND HEAT

No matter the project, temperature and heat will be two important elements in the support technician's day. *Heat* is a form of energy, which means it can do work. It can also be stored. *Temperature* is a measure of the average kinetic energy of the molecules in any specific amount of matter. Kinetic energy is energy due to motion.

Latent Heat

Latent heat is the specific type of heat that *does not* produce a change in *temperature* when it is added to or removed from a material. It will, however, produce a change in *state*. For example, it could change a solid to a liquid, a liquid to a gas, and so on.

Latent heat is very important to a support technician because of the large quantity of heat energy that is absorbed or released during a change in state in an HVAC system. Latent heat describes why a large amount of heat can be absorbed when refrigerant is boiled in the evaporator and released when refrigerant is condensed in the condenser.

Sensible Heat

Sensible heat is heat energy that *will* produce a change in *temperature* when added to or taken away from a material. This type of heat energy can be measured, or "sensed".

BTu—Definition and Use

Understanding Btu, the abbreviation for British thermal unit, will help you determine how much heat is being put out or absorbed by an HVAC system. Specifically, a Btu is the amount of heat that must be added to 1 lb of water to raise its temperature 1°F at standard conditions. To calculate Btu, you would use the equation,

$$\text{BTU} = \text{weight} \times \text{change in temperature}$$

Temperature

As mentioned previously, *temperature* measures the average kinetic energy of the molecules in a certain amount of matter. In the United States, temperature measurements are expressed in Fahrenheit. Most of the rest of the world uses Celsius, the metric version.

A theoretical point has been calculated where heat no longer exists and all molecules stop moving. This is called *absolute zero*. Only absolute temperatures can be used to get correct results with scientific formulas. When using scientific formulas in calculating temperatures, you will need to convert Fahrenheit temperatures to Rankine (°R) temperatures. On the metric side, Celsius temperatures will need to be converted to Kelvin (°K) temperatures. The conversion chart (Table 7.1) found on the next page will help you do this:

Table 7.1 - Temperature Conversions	
°F = (°C × 1.8) + 32	F = Fahrenheit
$°C = \frac{(°F - 32)}{1.8}$	C = Celsius
°R = °F + 460	R = Rankine
K = °C + 273	K = Kelvin

Fundamentals of Humidity

Humidity is a measure of moisture content in the air. Moisture within a structure flows from wet to dry. Humidity may be expressed as *absolute, mixing ratio, saturation deficit, relative, and specific*. You will concentrate mostly on relative humidity in your support role. The higher the relative humidity is, the more slowly moisture evaporates.

Variations in humidity can cause a number of issues. High humidity can cause sweating on windows and mildew on walls and items within the space. A dehumidifier may be needed to keep the humidity down. Low humidity can cause breathing issues and skin irritations for the occupants of the space. A humidifier is used to address low humidity. It can add to and control the moisture in the air and maintain a specific humidity within a conditioned space.

Conduction

Conduction is where heat is transferred from a warmer substance to a cooler substance. The transmission of heat occurs whenever two objects (A and B) of different temperatures are in direct contact with each other. Heat will flow from A to B if A has a higher temperature than B. For example, heat energy in outdoor air that is at a temperature of 95°F will transfer (or *conduct*) through an insulated wall to cooler indoor air that is at a temperature of 75°F.

Convection

The process of heat transfer by which gases and liquids move due to changes in temperature and/or pressure is called *convection*. The heat transfer occurs at a faster rate than with conduction. A gas, indoor air for example, in contact with a warmer surface (the wall of a room in the summer) gains heat energy, begins to float, and rises. The warmer, rising air is then replaced with cooler air that absorbs more heat from the surface and also begins to rise. The movement of this air increases the rate at which heat is removed from the material that makes up the surface that is in contact with the air.

Radiation

Radiation is the third way heat energy is moved through the environment. With radiation, the heat source and the thing that is being heated never touch, and nothing needs to move between the two. You have probably experienced the effect of radiation by sitting in sunlight that is coming through a window.

THERMOMETERS

Instruments and gauges used to measure temperature and pressure are some of the most common tools in a support technician's toolbox. You should be familiar with the ones that follow.

Mechanical Thermometers

Mechanical thermometers are ones that have dials that you will have to read. They do not show a digital reading. The *glass-stem thermometer* has a liquid-filled tube marked off with a gradual temperature scale, in Fahrenheit or Celsius. This type of thermometer is the most accurate, but it is also very fragile.

Figure 7-1: Dial-Stem Thermometer

The *dial-stem* thermometer, shown in Figure 7-1, is not quite as accurate but is often chosen because it's more affordable and more durable. Both of these types of thermometers measure dry-bub temperature. This is the type of temperature that relates to human comfort.

Figure 7-2: Infrared Thermometer

Electronic Thermometers

There are many electronic instruments available that measure temperature (and other conditions) and display the results digitally. The digital psychrometer reads dry-bulb temperature, wet-bulb temperature, and relative humidity. An infrared thermometer, seen in Figure 7-2 and sometimes called a laser thermometer, is used to check the efficiency of equipment. This type of thermometer has an advantage because it can measure temperatures in hard-to-reach areas or from a distance.

Gauge/Meter Calibration

Temperature is a measurement usually taken from the outside of the system, but you will also need to know what's going on inside the system. You must take pressure readings to do this. Most readings are taken in reference to atmospheric pressure and are referred to as gauge pressure. A manifold gauge set, like the one in Figure 7-3, is one of the support technician's most important tools for measuring pressure.

Figure 7-3: Manifold Gauge Set

Meters can also take pressure measurements. A differential pressure meter can simultaneously show pressure and flow measurements. This is useful for finding any pressure drops across a filter. These pressure drops can tell you how clean or dirty the filter is.

Recording Thermometers

Recording thermometers allow you to monitor temperature and humidity even when you are not on the job site.

ILLUSTRATION CREDITS

FIGURE 7-1: By Palagiri (Own work) [CC BY-SA 3.0 (http://creativecommons.org/licenses/by-sa/3.0)], via Wikimedia Commons , FIGURE 7-2: ELEARNING BROTHERS STOCK ASSETS LIBRARY , FIGURE 7-3: ROBINAIR/SPX CORPORATION

Installation is a major part of a support technician's job. You will be installing all of the pieces of the cooling and heating puzzle. Whatever the piece may be, two general rules will guide you before you even begin the install. First, after you open the piece of equipment or accessory, check for any damage that may have happened during transport. Report any damage to your supervisor immediately so that the carrier can be notified of the damage and claims can be filed. Second, follow all of the manufacturer's instructions that are included with the item you are installing. These instructions are tailored specifically for that installation.

Ductwork is essential in any HVAC setup. Before you install any ductwork, the sheet metal must be fabricated. Following are the many steps of fabrication.

FABRICATING COPPER TUBING

Refrigerant Line Installation

Refrigerant lines need to be installed first before you can work on the ducts. The following guidelines describe a process you can use to do so:

- At the job site, figure out the most practical way to run the lines.
- Think about the types of bends (discussed next) that must be made, while considering s pace limitations.
- Determine the best starting point for routing refrigerant tubing—inside or outside of the structure.
- Provide a pull-through hole that is big enough for liquid and vapor lines to pass into the building.
- Make sure the tubing is long enough.
- Uncoil the tubing, but do not kink or dent it.
- Route the tubing, making all required bends, and properly secure it before making any connections.

Bending Copper Tubing

Soft-drawn tubing used for refrigerant lines can be bent with bending springs or appropriately sized bending tools, such as those introduced in Chapter 2. These tools can form gradual turns that cause little resistance to refrigerant flow. When you bend the soft-copper tubing, pictured in Figure 8-1, it is important that you do not affect the pipe diameter. If you attempt to bend the tubing without using the right bending tools, it will reduce the diameter of the tube by causing it to take an oval shape. This would create an unnecessary pressure drop that could reduce system capacity by decreasing the flow rate of the refrigerant.

Figure 8-1: Soft Copper Tubing

Copper Tubing Preparation

Copper tubing must be prepared before it is ready to be installed. You will use many tools to work with the tubing. These tools, discussed in Chapter 2, include snips, shears, benders, and calipers, to name a few.

Brazing

Brazing, a form of welding used to heat the base metal to temperatures above 700°F but below its melting point, prepares the tubing for installation. Brazing can join most metals. However, the proper filler rod and flux must be used. Sometimes, *flux* is applied to the tube as a guide for brazing. When brazing or soldering, flux reduces oxidation within the tubing. When brazing copper to brass, you must use an approved flux, such as one with a silver brazing alloy. When joining copper to copper, you would use a brazing alloy versus a soft solder, such as ones used in plumbing. This is because the brazing alloy is stronger.

Purging gases, such as nitrogen, are also used when brazing piping. Nitrogen, while it is being heated, displaces oxygen from the inside of the system. This prevents oxides from forming on the interior surfaces of the piping.

Flare Fittings

Flare fittings are used on copper, which is the material you will be working with, but also on other metals, such as welded steel, brass, and aluminum. The flare fitting produces a seal that is resistant to pressure and won't leak. To install these fittings, you will follow this basic procedure:

- Inspect the tubing to make sure it is squarely cut and free of damage and debris, such as burrs or paint.
- Slide the nut on the tube end with the threads facing outward.
- Flare the end with the flaring tool, discussed in Chapter 2.
- Make sure the end is evenly flared and free of imperfections.
- Thread the flare nut on to the fitting, and then secure it with two adjustable wrenches, also discussed in Chapter 2.

Brazing and Soldering Equipment

The most common methods of joining copper tubing are soldering and brazing. A tubing joint may be *soft-soldered or hard-soldered*. These refer to the relative melting temperatures of the solder. While brazing is used to prepare the metal in the tube to be joined, soldering is the mixing of the metals and insertion of those metals into the joints to hold the tubes securely together.

Both of these processes are completed using torches. *Oxy-acetylene torches* are used for brazing because of their higher flame temperatures compared with those of an *air-acetylene system*. The gauges on oxy-acetylene torch regulators display the tank pressure and regulator outlet pressure of each gas that you are using. A successfully brazed or soldered joint depends on the uniform heating of the pipe and the socket, and these torches will help you achieve this. Safe use of this equipment will be discussed in Chapter 11.

DUCT INSTALLATION

The Air Conditioning Contractors of America (ACCA) publishes the ACCA *Manual D Residential Duct Systems* and the ACCA *Manual Q Commercial Duct Systems* for use in designing residential and commercial ductwork. You should consult these manuals when you are selecting ductwork fittings and duct sizes before installation. Installation of different types of ducts and duct accessories will be explained in the sections that follow.

Installing Metal Duct

A number of considerations are used when installing metal duct in a home or commercial setting. Ductwork must be properly sealed and supported. Adequate support is necessary because if the duct sags, the sagging opens the joints. Using the proper joining methods is also critical for joints to remain leak-free. Figure 8-2 illustrates some common joining methods for sheet metal ductwork.

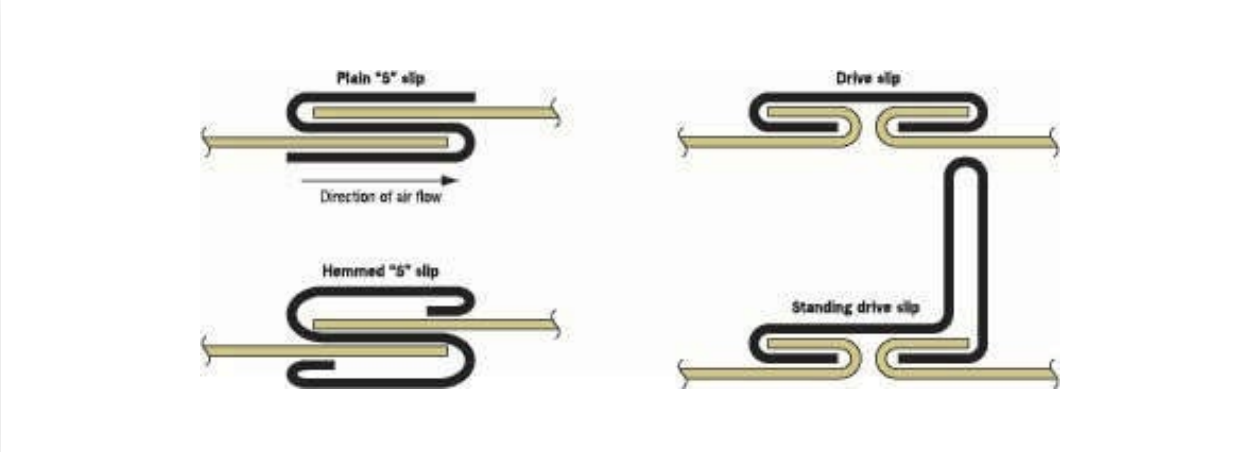

Figure 8-2: Common Sheet Metal Duct Joint Designs

The drive cleat, also known as the drive slip seen in Figure 8-2, should be installed on the shorter side of a rectangular duct. “S” slips, such as the plain and hammered “S” slips seen in Figure 8-2, should be installed on sheet metal ductwork. When you are inserting these two S drives to connect sections of the ductwork, you should bend the drive ends over the duct. This will create a seal between the top and bottom of the ductwork.

Installing Flexible Duct

Flexible duct branches out from the main ductwork, taking conditioned air to different spaces within the home or building. It must be supported at regular intervals, no greater than 4 feet apart. These intervals should have approved supports or straps to prevent stress and sagging. The supports should be installed to avoid creating a thermal bridge, where the heat transfer is much higher than at other points around them, at their connecting points. If these supports become cool, condensate can form on them and then drip onto structural material.

Installing Ductboard

Rigid fiberglass ductboard is lightweight and easy to fabricate into a variety of configurations. Insulation is located inside of the duct. The outside of the duct is a foil vapor barrier that reflects heat and moisture. For ductboard applications, the outside of the duct surface temperature should not be higher than 150 degrees Fahrenheit. The temperature inside the duct should not be higher than 250 degrees.

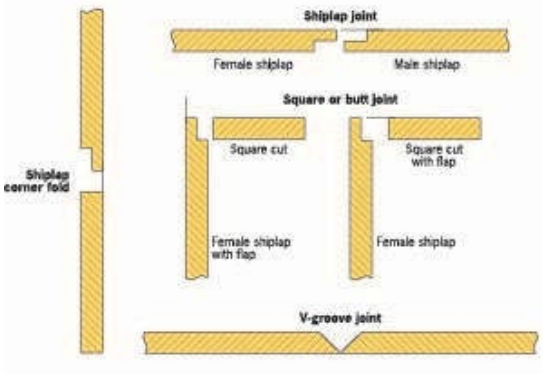

Figure 8-3: Ductboard Joints

Working with ductboard requires relatively little special training. It can be cut to size in the shop or at the installation site. There are four ways to fabricate a duct section from ductboard: one-piece duct, two-piece duct, two-piece L-duct, and four piece duct. In Figure 8-3, you can see the methods for making corner joints, called shiplap joints, V-groove joints, and butt joints.

When fastening ductwork with screws, use screws that are at least a half-inch longer than the board thickness. If you are securing ductboard to a metal surface, use #10 sheet metal screws along with 2 and one-half square washers.

Various materials are approved for sealing ductboard, including pressure-sensitive or heat activated aluminum foil tape, glass fabric tape, and mastic. All sealing materials must conform to UL Standard 181. Use aluminum foil tape over a stapled shiplap joint. Staple the flap of the shiplap seam every two inches on center, then apply tape over the flap. The tape must overlap the joint a minimum of one inch on both sides. For seams and joints without staple flaps (butt joints), taped cross tabs may be used instead of staples. Cross tabs must be at least eight inches long, and should be placed perpendicularly across the taped joint at intervals of 12 inches.

Other general guidelines to be observed when sealing ductboard include:

- If either the aluminum foil tape or the surface of the ductboard is below 50°F at the time of application, preheat the tape.
- Pressure-sensitive aluminum foil tape must be at least 2 ½ in. wide.
- Heat-activated aluminum foil tape must be at least 3 in. wide.
- Heat-activated aluminum foil tape must be heated to a temperature of 550 to 600°F after being applied to the duct.

Tie rods often are used on larger ductboard systems to increase rigidity and ensure structural integrity. Tie rods are made of 12-guage galvanized wire. They should be spaced no more than 16 inches apart across the duct dimension. The washer that terminates a tie rod may be either square or round. The tie rod should be 4 inches away from the female end of a shiplap joint. Tie rods may be located 3 inches from either side of a butt joint.

Installing Grilles, Registers, Diffusers, and Dampers

Return *grilles* are visible parts of the system with small enough openings to allow air flow, but no debris into the system. They are installed in floors, ceilings, or sidewalls. *Supply registers* are installed on outer walls or under windows, and *return registers* are installed on inside walls close to the ceiling. *Diffusers* slow the air, allowing it to mix into the environment efficiently. In colder areas, diffusers should be installed on the floor. In hotter areas, they should be installed higher up toward the ceiling. *Fire dampers,* specifically static fire dampers, are used in duct systems. Building codes will specify where these dampers should be installed, so be sure to read those first.

Reconnecting Duct when Replacing Equipment

After you have installed new equipment in the system, you will need to reconnect the ductwork. This can be easily accomplished. First, you'll connect the two sections of round metal duct. Then, you will secure the pieces together with screws in a new location on the duct. Finally, you will seal the duct with mastic tape or sealant.

Installing Plenums and Duct

The *plenum*, a larger squared duct, will be installed on top of the evaporator coil or the air handler. You will secure it near the ceiling with screws. Plenums in air conditioning systems need to be insulated and include a vapor barrier. Flexible duct should not be used as a plenum. You can check local building codes to see what type of duct is needed.

INSTALLING ACCESSORIES

Accessories in an HVAC system are those that are not part of the main equipment or ductwork. They may not be doing any behind-the-scenes work, but they are still very important.

Installing Thermostats

A thermostat is the main operating control for the furnace or air conditioning system. It tells the furnace or AC when to start and stop to maintain a desired temperature. It should be installed approximately 5 feet above the floor on an interior wall. Do not mount the thermostat:

- Where it will be exposed to direct sunlight
- Near supply registers or other sources of heat
- Near outside doors or on an exterior wall
- In or near the kitchen

Installing Electronic Air Cleaners

An *electronic air cleaner (EAC)* can remove very small particles from the air, often benefitting people with allergies. They work by electrically charging particles as they pass through ionizing wires, causing them to be attracted to oppositely charged collector plates. In a forced-air system, EACs should be installed on the return air side.

Installing Humidifiers

Humidifiers increase the relative humidity within a conditioned space. Several types of humidifiers can be attached to the system to create this increase. Two of the most common types are bypass humidifiers and fan-powered humidifiers. *A bypass humidifier* is connected between the supply side of the furnace and the return side. A *fan-powered humidifier* is connected to the supply plenum.

FIELD WIRING

Wiring Units and Control Wiring

When you are installing HVAC equipment, you should always use caution to avoid electric shock. These guidelines should be followed when working with wiring:

- Power wiring and equipment grounding must comply with all applicable codes.
- Make sure the supply power is off before connecting the line voltage wiring to an indoor air handler or furnace.
- The total length of low-voltage wiring used to connect the outdoor unit, the thermostat, and the indoor unit should comply with the guidelines in Table 8-1. The most commonly used wire size for low voltages is 18 AWG.

Table 8.1 - NEC Class II Control Wiring

Wire Size	Maximum Wire Length
18 AWG	150 ft
16 AWG	225 ft
14 AWG	300 ft

A supply circuit ampacity chart can also be used to choose appropriate wire size. Table 8-2 is an example of one. You would use the chart to find the minimum wire size by first finding the amps for the circuit (under the *Supply Circuit Ampacity* columns). For example, if the circuit with which you are working is 30 amps, you'd go to the corresponding column. You'd then need to know how far away from the power source you are. In this example, say you were 100 ft away. You'd then find the corresponding row (under the *Supply Wire Length in Feet* rows). The minimum wire size you'd need for the load would be a 6 gauge (by moving down the 30-amp column until you got to the 100-ft row).

SUPPLY WIRE LENGTH IN FEET	SUPPLY CIRCUIT AMPACITY							
	15	20	25	30	35	40	45	50
50	14	12	10	10	8	8	6	6
100	10	8	8	6	6	6	4	4
150	8	6	6	4	4	4	3	3
200	6	4	4	4	3	3	2	2

COPPER WIRE SIZE - AWG.

Table 8-2: Supply Circuit Ampacity Chart

REFRIGERANT CIRCUIT TOOLS

After you've installed a refrigeration system, you'll need certain tools to test various components within the system to see if they are working correctly. The following are some examples.

Manifold Gauge Set

A manifold gauge set, introduced in Chapter 7, will be one of your most important tools. It will help you achieve more accurate and improved diagnostics. There are digital and analog versions of this tool as well. You can test the calibration of an analog manifold gauge set by setting the gauges to the pressure of a known refrigerant, such as R-22, mentioned previously. Before you can begin to install these gauges on a unit, you must first purge the hoses.

Evacuation Tools

A deep evacuation procedure is necessary to remove air and contaminants from the system before use. A vacuum pump does most of the evacuation work. One instrument that is also vital for this procedure is the micron gauge. You can use it to determine whether a leak exists or whether there is remaining water vapor in the system.

Charging Tools

The process of charging is adding refrigerant after a system has been installed or repaired. An *electronic charging scale* is an important device used to charge a system. It does so with a specified amount of refrigerant, often measured in ounces. A manufacturer's instruction sheet will tell you the amount of ounces, for each foot of refrigerant line length, to be added to the system. You will have more than one foot of line length in the system, so you will have to use the arithmetic skills discussed in Chapter 4 to calculate how much refrigerant you'd actually need. You'd multiply the amount (in ounces) by the length of the lines. Then you'd know exactly how much refrigerant to add.

RECOVERY/RECYCLING MACHINES

Recovery, or recycling, machines are needed to remove refrigerant from a system properly. These do so without testing the refrigerant's purity or venting any refrigerant into the atmosphere. These are used during the evacuation process.

INSTALLING GAS FURNACES

Now that you've gotten an overview of installation on the air conditioning side of things, we can move on to the heating side.

Mounting Furnaces

A furnace location is usually decided, somewhat, by the construction of the building. Because there is not a lot of floor space that can be used, furnaces are mounted in the following locations:

- Basements—most of these installations use upflow units, with discharge through the floors overhead
- Crawl spaces—unit is frequently hung horizontally from floor joists
- Attics—horizontal unit frequently hung from roof rafters; in some cases, unit sits on ceiling joists
- Closets—location allows for central return air through the wall, eliminating return duct system; location reduces installation costs, but does not always provide best air distribution
- Garages—unit must be mounted off the floor to reduce risk of igniting gas fumes that tend to settle near the floor

Installation of Metal and PVC/ABS Venting Systems

All HVAC systems must be vented to ensure that the system remains efficient and that no combustion products, which can cause severe illness or even death, are leaked into the air. It is very important that you follow the manufacturer's instructions to determine the proper materials for the venting system. Most applications use PVC or ABS pipe for both combustion air intake and venting. You should know that if you are using PVC pipe, it should be glued at all joints. The manufacturer may also use other metals, such as stainless steel, that will remain strong even when they come in contact with the condensate. This type of material usually provides a gasketed or welded joint to ensure a tight seal.

Installation of Condensate Drains for Condensate Furnaces

Condensate drain piping carries condensate from condensate furnaces to the drain. The piping is usually made out of PVC. It should be at least 3/4 inch in diameter and sloped toward the drain at a minimum pitch of 1/8 inch per foot. The drain line should be open-vented. You should never pipe the drain line solidly into the sewer because it can cause backups into the furnace.

You will be called on to install components, but you will also be spending a lot of your time troubleshooting those components. Service, another important aspect of an HVAC support technician's job, is discussed next.

ILLUSTRATION CREDITS

FIGURE 8-1: ELEARNING BROTHERS STOCK ASSETS LIBRARY , FIGURE 8-2: GAS AND OIL HEATING: PREPARING FOR THE NATE EXAM , FIGURE 8-3 GAS AND OIL HEATING, PREPARING FOR THE NATE EXAM

Now that you've learned the basics of installation, you should know how to maintain and repair different parts of an HVAC system. First, let's learn about the different types of systems on which you'll be working. Then we'll briefly introduce the different types of maintenance.

INTRODUCTION TO SYSTEMS

Heat Transfer and the Basic Cooling Cycle Principles

You've already learned a little bit about heat transfer in Chapter 7. The basic process is used by heating and cooling systems to move heat energy from spaces where it is not needed to areas where it is needed or of no concern. For example, in the summer, when a heat pump operates in cooling mode, the refrigerant carries heat energy absorbed from indoor air by the indoor coil (the evaporator). When the refrigerant reaches the outdoor coil (the condenser), the heat is released into the outdoor air.

In the winter, the cycle is reversed. The refrigerant carries heat energy that is absorbed from outdoor air or soil and transfers it to indoor air, which will be used to warm the rooms in the house or building.

The basic cooling cycle, illustrated in Figure 9-1, is as follows:

- Heat is absorbed into the refrigerant, discussed in Chapter 1, from the surrounding air as the pressure inside the evaporator is reduced.
- The refrigerant vapor formed by evaporation is pushed into the condenser through the connecting tubing.
- The pressure inside the condenser is increased by the compressor, pushing much of the heat in the refrigerant vapor into the surrounding air (which is warmer than the air around the evaporator).
- The condensed liquid is then pumped back to the evaporator to start the process again.

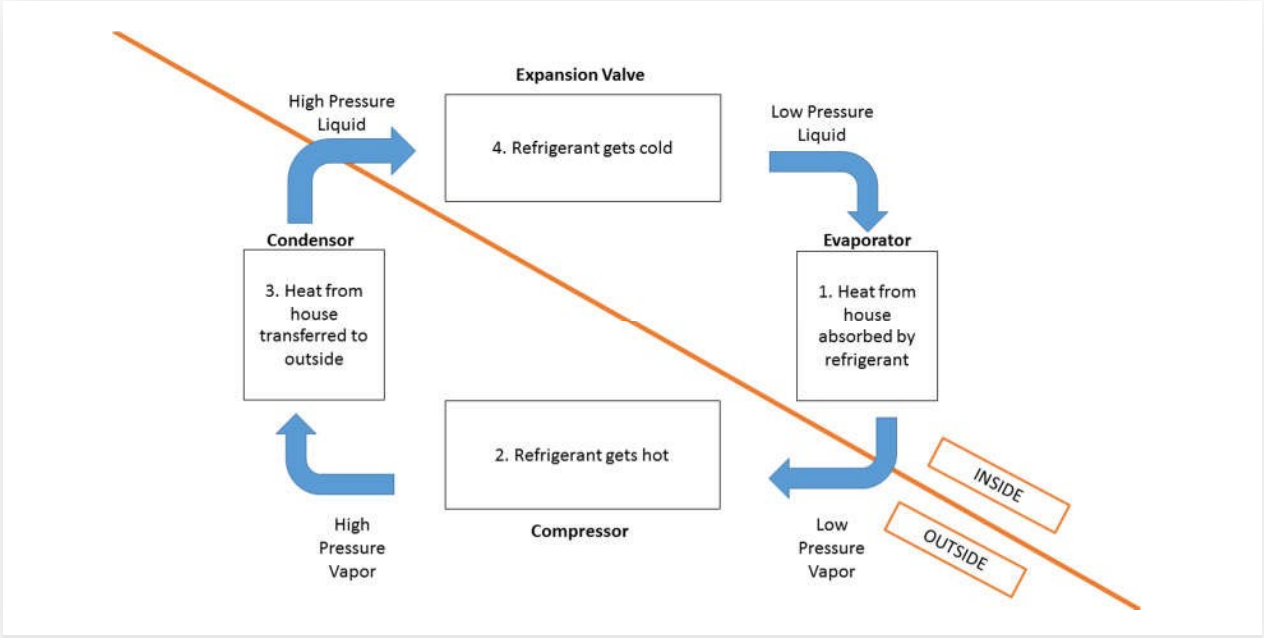

Table 9-1: Basic Air Conditioning Refrigeration Cycle

Split Systems

A split HVAC system is one that has both indoor and outdoor components. Most residential central air conditioning systems are split systems. The outdoor metal cabinet contains the condenser and compressor, and the indoor cabinet contains the evaporator. Split systems are usually more efficient than the next type of system, packaged systems.

Packaged Systems

A packaged system is a preassembled unit that has both heating and cooling components. Because everything is already assembled together, you may find that installation is easier on this type of system. However, because all of the electrical and mechanical components are located outside the home or building, this type of system may not last as long as a split system. This is because those parts are exposed to the elements.

The Basic Heat Pump Refrigerant Cycle

Both sensible heat energy and latent heat energy are removed from the refrigerant by the condenser. Most of the work done on the refrigerant, however, is transferred as latent heat energy. When the indoor coil functions as the condenser in the winter, small variations in air flow and refrigerant charge can have a major effect on how well the HVAC system performs.

Refrigerant condenses in the indoor coil during the heating cycle. The coils used in the outdoor section of a heat pump system usually have more circuits than those used in cooling-only systems. As the temperature outside decreases, the heat pump capacity, when it is in heating mode, also decreases.

PLANNED MAINTENANCE

To keep HVAC systems working efficiently, you must help maintain their components. In general, as suggested in Chapter 8, always consult the manufacturer's instructions for the component on which you are performing that maintenance. It will always be a good starting point.

Mechanical Planned Maintenance

The majority of the mechanical planned maintenance you will perform involves cleaning or unclogging various pieces within the system. On the heating side, a dirty filter can cause a high temperature rise in a heat pump. The filter will need to be removed and cleaned or replaced completely.

On the air conditioning side, any number of issues can be caused by dirty components. A dirty or clogged air filter can cause inadequate cooling. The poor performance in the air conditioner is caused by those dirty filters. The dirty or clogged filters will need to be cleaned or replaced. Dirty condenser coils can also cause an increase in head pressure, the discharge pressure from the compressor. To clean a stacked condenser coil, you will need to separate the two rows of coils, spray all of the surfaces with the right coil cleaner (you can check the manufacturer's recommendations for this), and then flush them with water. Dirt and debris that build up on the vanes of air distribution blower wheels, which happens when air filters are not changed regularly, can reduce air flow as well. To remedy this, remove and rinse them.

Electrical Planned Maintenance

Electrical maintenance involves checks on the energy source and operation of the primary HVAC components. This is one area of maintenance where safety should be your first priority. Electrical safety will be discussed later in Chapter 11. To conduct your electrical planned maintenance, you will be using the electrical meters, such as the voltmeter and the ohmmeter, discussed in Chapter 5. You will need to be able to identify control devices and loads in an electrical circuit. You will also need to know the sequence of

operations within the system. You will examine a circuit to determine if each component within the circuit is working correctly. Some of the components you will be checking in your planned maintenance include fuses, room thermostats, transformers, and relays, to name a few.

Combustion Planned Maintenance

Another area you will focus on in maintenance is gas burner combustion efficiency. The following steps are used to check efficiency:

- Make sure that the firing rate of the burner is correct by verifying that the manifold pressure matches manufacturer's requirements.
- When it is available, check the gas meter for actual rate of gas usage as well.
- In oil burners, check the oil pressure.
- After stabilized operation, test the products of combustion with a combustion efficiency analyzer and note the results. Then adjust settings to maximize efficiency.

The overall objective of this type of maintenance is to obtain all the heat possible in the conditioned space from the potential amount of gas without creating conditions that are undesirable.

All of the information you've learned so far can be applied to system design. Each piece can be used to create the most effective system for the customer.

ILLUSTRATION CREDITS

FIGURE 9-1: Castle Worldwide

DESIGN CONSIDERATIONS—COMFORT

As you know by now, customer comfort is an HVAC support technician's first priority. Many variables, such as temperature, humidity, indoor air quality, and sound level can affect that level of comfort.

Temperature

You've already learned in Chapter 6 that temperature is one of the basic factors that contributes to human comfort. The correct temperature creates the perfect indoor environment for the occupants. You will need to consider placement of components and materials, so that they will all work in harmony to create that perfect indoor temperature.

Humidity

Humidity is another important consideration when designing an HVAC system. You learned how it affected human comfort in Chapter 6. A short-cycling heat pump system, caused by a system that is oversized for the load, will have poor moisture control. This will lead to too much humidity within an air-conditioned space, and occupants of that space will be uncomfortable.

Humidity also affects systems based on the region in which they are located. A very humid region requires a lower evaporator air flow from a cooling system than one in a dryer climate. In drier regions, humidity removal is not necessary. A higher indoor air flow volume in hotter months will reduce the amount of humidity removed from the space. When designing, you will need to consider how location affects humidity, and how humidity in turn, affects comfort.

Indoor Air Quality

Not only does the customer want the right temperature and a comfortable environment, but they also desire clean air. Electronic air cleaners, mentioned in Chapter 6 and Chapter 8, are accessories that improve indoor air quality (IAQ) by removing biological material and particulate matter from the air. They do not, however, remove odors. Even though they are innocent looking, these EACs can have maximum output voltages of 5,000 volts or more. Because of this output, you should respect this particular accessory component and work around it with care.

Sound Level

Noise reduction is another important element in human comfort. When you are designing the system, you will need to consider sound level when you decide where equipment and components will be located. Customers often complain about noisy indoor units. For this reason, you will need to isolate the indoor section from the building's structural material to prevent noise transmission into the conditioned space. One way to do this is to mount the air handler cabinet, installed in a closet, on a rubberized isolation pad. Because excessive noise from a condensing unit might be disruptive to the customer, you will need to consider this operating sound when you decide on a location for the unit. These are just a few examples of how you can reduce the sound level to improve customer comfort.

DESIGN CONSIDERATIONS—EXTERNAL COMPONENTS

When designing the HVAC system, external components need to be considered as well.

Diffusers, Registers, and Grilles

One important consideration in HVAC design is ductwork. Ductwork must be designed so as to limit resistance. This means that you will need to consider the geometry of the ductwork (its twist and turns) as well as diffusers, registers, grilles, and other components that may be installed in the airstream. System efficiency depends on a design that considers these components.

Accessories

Auxiliary components, or accessories, are important for you to be familiar with as well. These include expansion and metering devices, such as the thermostatic expansion valve (TEV). TEV is a component in the system that controls the amount of refrigerant flow into the condenser. It is connected to the condenser by a liquid line filter-drier. These also include air ducts, pipes, blowers, and dampers, which you have learned about previously.

Blueprint Reading

It will be extremely important, once you get comfortable in your support role, to know how to read blueprints. You will use these to assemble and install many main and auxiliary components within the system. You will also refer to them during maintenance and repair. An example blueprint is shown in Figure 10-1.

In all three main responsibilities of an HVAC support technician—installation, maintenance, and repair—safety will be of utmost importance. Chapter 11 will cover everything from general jobsite safety to understanding HAZMAT. You will use this information every day.

Figure 10-1: Blueprint

ILLUSTRATION CREDITS

FIGURE 10-1: ELEARNING BROTHERS STOCK ASSETS LIBRARY

PERSONAL SAFETY AND WORK PRACTICES

Safety is the most important aspect of your job as an HVAC support technician. Your work can be dangerous. For this reason, it will be very important to focus on your own safety and the safety of those around you. You will use safe practices from the Occupational Safety and Health Administration (OSHA) and your employer.

Safe Practices

You can achieve a safe workplace by remembering to do the following:

- Use applicable codes and regulations for a specific job.
- Use or wear the appropriate equipment, protective devices, and clothing that are required.
- Report to your employer or supervisor any problem with equipment that may harm other workers or people in the area.
- Report to your employer or supervisor any violation of applicable regulations and any hazards on the job site.
- Never work in a way that will make you or anyone else unsafe. This includes pranking, showing off, unnecessary running, and rough conduct on the job site.
- Always practice good judgment and use caution.

One important overall way you can promote safety on any new job site is to have regular job safety briefings with your supervisor. He or she should instruct you about access to projects both above and below ground on the job site. You should also discuss work methods and work limitations. Most importantly, you will talk about work hazards and emergency procedures. You will also be introduced to the health and safety representative on the project.

Safe Driving Practices

As an HVAC support technician, you will have a service vehicle. It may be loaned to you by your employer, or it may be your own personal vehicle. Either way, there are certain things to remember when operating this very large machine.

- Use common sense when driving, and keep service vehicles in good condition.
- Make sure equipment and materials are evenly distributed inside the vehicle before driving.
- Secure any cargo that could shift during travel, especially cylinders containing compressed gas.
- If your vehicle is heavily loaded, increase the distance required to stop it.
- Check blind spots before backing up the vehicle, especially in tight spaces.
- Clean waste and debris out of the vehicle regularly.
- Do not drive the vehicle if you have been using drugs or alcohol.

Clothing, Safety Equipment, and Hard Hats

The right uniform is important in many jobs. In HVAC, this uniform is called personal protective equipment, or PPE. Consistent use of PPE, such as protective eyewear, hearing protection, gloves, hard hats, and boots, can prevent or minimize injuries. Some of these PPE pieces are seen in Figure 11-1.

Figure 11-1: Personal Protective Equipment

When working around electrical equipment, you will need to wear long pants and a long-sleeved shirt. To protect yourself from equipment or heavy machinery that could fall, you should wear a sturdy pair of ankle-length, steel-toed boots. You will also need to wear a hard hat for jobs where there is a low clearance, when you are working on and around scaffolding, or when there are other workers above you.

Specific components in HVAC require specific personal protection as well. When working with sheet metal, such as that used in ductwork, you will need to wear gloves and safety glasses to protect your hands and eyes. If you are working around toxic chemicals, you will need to wear a respirator, such as the one seen in Figure 11-2.

Figure 11-2: Half-Face Respirator

Safety Glasses

During your day, there are many instances where you need to protect your eyes. When cutting sheet metal, some bits can fly into the air and potentially into your eyes. This is why you'll need safety glasses, such as the ones in Figure 11-1.

Hearing Protection

Protecting your hearing is also important. Earplugs or ear muffs, like the ones seen in Figure 11-1, are necessary when you are fabricating sheet metal, as discussed in Chapter 8, or working with small machines.

Using Warning Symbols

Warning symbols on the job site can be life-saving. When you arrive, check for these symbols, and read the accompanying warning entirely. They will help you choose the right PPE. They will also help you to proceed with caution. Figure 11-3 shows some warning symbols that will alert you to the chemical hazards to which you may be exposed.

Figure 11-3: Warning Symbols

Safe Handling of Hazardous Materials

Most accidents with hazardous materials can be prevented by using the chemicals in the way they were intended to be used and using the proper PPE when working with those chemicals. It is important to read the labels for each chemical or material. When you are reading these labels, pay close attention to flammability, how to handle a spill, and what to do if it gets on your skin or in your eyes.

Safety with Hand Tools

Before, during, and after a project, a technician needs to focus on a few things to ensure a safe workplace. Housekeeping is maintaining a functional workplace. One way you can maintain a functional workplace is to immediately store hand tools when you are finished working with them. This can keep them from falling and causing injury and can also prevent falls caused by tripping over the tools.

Using Ladders and Scaffolds

An HVAC support technician will use often use a stepladder or extension ladder on the job. The proper selection, use, and care of ladders are important parts of job safety.

The following guidelines will assist you with the responsibility of ladder safety:

- All portable ladders must have non-slip bases. Rubber safety feet pivot so that they are flat on the ground to prevent slipping.
- Set ladders up on a firm, level surface. Use a mud sill on soft soil. Make sure that both feet of the ladder are secure. If one leg sinks into the soft ground, the ladder can fall sideways.
- Make sure that the base of the ladder is at a distance from the wall equal to ¼ of the working height of the ladder, as shown in Figure 11-4. For example, if the working height of the ladder is 16 feet, its base should be 4 feet away from the wall.

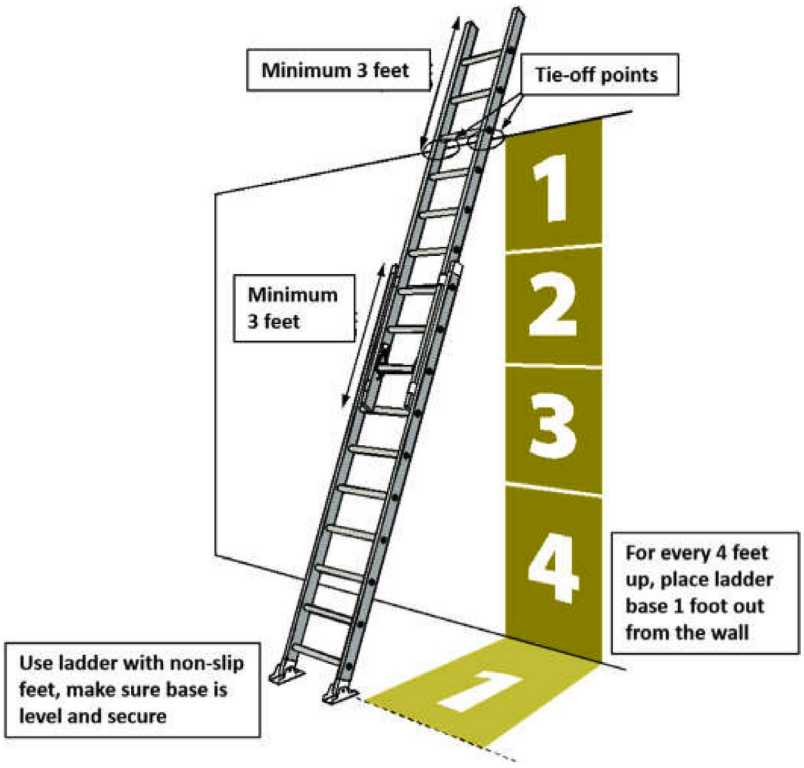

Figure 11-4: Proper Ladder Setup

- Tie off or secure ladders to prevent movement. If this is not possible, another worker should hold the base of the ladder while you use it.
- All ladders erected between levels (see Figure 11-4) must be securely fastened, extend 3 feet above the top landing, and have clear access at the top and bottom.
- Do not set up ladders in passageways, doorways, driveways, or other locations where they can be bumped. You can use a ladder in these areas only if you have set up suitable barricades or protection around the ladder.
- Do not erect ladders on boxes, carts, tables, scaffold platforms, manlift platforms, vehicles, or garbage bins.
- When using an extension ladder, it should be long enough to stand on the rung no higher than the fourth from the top.
- When using a stepladder, you should never stand higher than the second step from the top.
- Never straddle the space between a ladder and another object, such as a ledge or a table.
- When climbing up or down a ladder, always maintain three points of contact—two feet and one hand or one foot and two hands—and always face the ladder.

Once you are comfortable with ladder safety, you can move on to safe scaffolding practices. The following guidelines are for scaffold safety:

- Unstable objects, such as boxes, concrete blocks, or barrels, should not be used to support scaffolds.
- Scaffolds should not be altered or moved horizontally while they are being used.

- Do not overload the scaffold.
- If you are working on a new residential construction site, and you are any higher than 6 feet above the ground, fall protection is required.
- Any damaged or weakened scaffolding needs to be immediately repaired and cannot be used until repairs are completed.

Safety Within Confined Spaces

A great deal of HVAC work is done within confined spaces. Because of the dangers associated with hazardous atmospheres—flammable, toxic, irritant and corrosive, and asphyxiating—you must plan carefully for work in these spaces. The following tips will help you with that planning:

- Always communicate with the standby person outside the confined space.
- Make sure you have a source of light that will make everything visible.
- Consider using a harness or safety line if there is any chance you will need to be removed from the space quickly.
- If a hazard is detected, leave the space immediately.
- Always use extreme caution.

OSHA, the Occupational Safety and Health Administration, has a set of regulations to follow when working in confined spaces. You should always refer to those regulations to ensure your safety. You can reference this standard and the regulations to follow on their website, www.osha.gov/confinedspaces.

Refrigerant in Confined Spaces

Most commonly used refrigerants are considered to be nontoxic and nonflammable, but that does not mean that they are without hazards. If a refrigerant leaks from a system, especially in a confined space, you must not inhale the vapor. If you inhale it, it can cause dizziness, nausea, heart irregularities, unconsciousness, or even death. Even though the refrigerant itself is considered nontoxic, it replaces oxygen and causes suffocation.

Vacuum pumps used to evacuate refrigerant circuits must have their oil changed often because the pump oil absorbs moisture from the system. It may be necessary to change the vacuum pump oil after each evacuation to keep the pump operating effectively and to keep the tight work area safe.

Safe Practices in Troubleshooting and Repair

When you are troubleshooting a system complaint, you should always follow a defined procedure each time. You must complete each stage of the procedure without skipping over any step. This will help you improve your troubleshooting skills and help you locate the issue more quickly. When you are adept at troubleshooting, you become a more efficient, safer worker.

After you have isolated the issue, you can correct it with a repair. As you work, be sure to observe all safety guidelines, as well as government laws and regulations. You should adhere to the following general safety guidelines as they apply to the repair:

- Remove jewelry and loose-fitting clothes.
- Tie back long hair.
- Wear appropriate fire-rated clothing and use PPE such as safety glasses, impervious gloves, etc.
- Disconnect power to equipment when repairing or replacing defective components. Use lock out and tag out procedures whenever possible.

PERSONAL SAFETY AROUND MOVING MACHINERY

Every HVAC system has moving parts. These moving parts represent a potential hazard to you. If you are working over dangerous machinery, there is no minimum height requirement for fall protection. If you could potentially fall into this machinery, you either need some type of fall protection, or the machinery needs a guard installed around it.

Blowers and Pulleys

Blowers are one of the most dangerous types of machinery because they are so powerful. You should never wear loose clothing around machinery that rotates. Make sure to stand clear of the couplings or pulleys within a motor. Keep all tools, such as wrenches, away from the machinery as well. If the tools fall into the machinery, they could be thrown from the motor and cause serious injury.

Clothing Requirements

Because of the danger of being injured by these moving parts, you must dress accordingly. As mentioned above, you should remove any jewelry and loose-fitting clothes. If your hair is long, you should tie it back as well.

ELECTRICAL SAFETY

Overview of Electrical Safety

Electricity is used to operate the major components in HVAC systems. The fact that electrical energy can be harnessed in such a way is an amazing development. However, you cannot afford to take electricity for granted. There are risks involved with electrical systems. Some of these include unconsciousness, cessation of breathing, muscle paralysis, burns of every degree, and even death.

When you are working around electrical equipment, you need to follow several important safety guidelines:

- Always be careful. Pay close attention to what you are doing.
- Never touch bare electrical wires or “hot” connections (those with electrical power inside them).
- Always turn off the power before doing any work, even if only making the smallest changes that require touching exposed terminals or wires.
- Treat all circuits as if they are energized.
- Always lock out any disconnect that cannot be controlled.
- As an entry-level technician, you should not work on “hot” parts or lines.
- After you have more experience, if you must operate on a piece of equipment with “hot” lines, use every possible caution.
- Do not stand on wet ground or floors.
- Do not lean against wet or damp walls or grounded machines.
- Always keep your hands and gloves dry.
- Do not put your hands on “live” parts.
- Always use grounded or double-insulated power tools.
- Never use extension cords that are worn or frayed. Immediately remove those cords from service.
- Do not bypass fuses. Always use only the properly sized fuse for the system.

Grounding—GFCI Requirements

Any time you are using an electrical tool with a cord, you should always connect that tool to the ground-fault circuit interrupter (GFCI). The GFCI is a very important device that must be used on any job site. It disconnects the device where the power is delivered (the load) from the power source. By doing this, it protects you from an electrical shock caused by contact with the load or by tools, appliances, or power cords that are broken. Using this device is especially important when you are working on a wet surface.

Personal Protection

Many electrocutions are caused by workers failing to disconnect the power because it is inconvenient for them to stop and do so. They are attempting to save time by working with circuits that are live (energized). Other injuries happen when workers use defective or damaged power tools (see Figure 11-5) and/or extension cords that are plugged into a defective outlet. To prevent injury, take the time to disconnect the power first. Also, stop and check all of your tools and extension cords. The use of insulated gloves and insulated tools can also prevent many of these electrocution injuries.

Figure 11-5: Damaged Electrical Cord

SAFE BRAZING AND SOLDERING PRACTICES

Overview of Safety

There are two types of hazards that you can encounter when brazing and soldering. One involves the heat coming off of the materials you are using. Gloves will protect your hands from the heat, and safety glasses or goggles will protect your eyes from any damage from the brightness of the torch. The other involves the fumes from the gases used in each process. Those types of hazards are discussed further in the next few sections.

Oxygen and Acetylene Safety

Oxygen is used to support any burning process, such as brazing. Combined with a fuel gas, it produces the operating flame. By itself, it is not flammable. However, the presence of pure oxygen supports combustion. It can turn a small spark into a huge flame or explosion. Never allow oxygen to come into contact with oil, grease, or flammable substances. You could be seriously injured if you use oxygen as a purging gas.

Acetylene is a versatile industrial fuel gas used in brazing and soldering. It becomes unstable when compressed in its gaseous state above 15 pounds per square inch gauge (psig). This means that 15 psig is its maximum safe operating pressure. Filling acetylene cylinders requires special equipment and training. Only authorized gas distributors should refill them. They must also never be transfilled—the practice of filling up one tank from another tank, rather than getting it recharged at a location where it can be done safely. If the filling is done improperly with acetylene, the pressure could be too high, making it explosive.

Using Purging Gases (Nitrogen, Carbon Dioxide, etc)

As an HVAC support technician, you must be familiar with the gases, such as carbon dioxide and nitrogen, used in brazing and soldering. Specifically, whenever nitrogen is used for purging, you must always ensure that a regulator is used on the nitrogen cylinder. The regulator reduces the pressure within the cylinder to a safe level for operation. You should set the regulator to 1 to 2 (pounds per square inch (psi) when you are brazing.

Fire Extinguishers

Fire prevention will be an important task for you. Because the conditions during brazing and soldering pose the threat of injury and destruction by fire, it is vital to keep a fire extinguisher near you during the entire process. A Class B fire extinguisher, one made for chemical fires, should be used.

Documentation for Hazardous Materials—SDS

Before you work with any of the gases involved in brazing and soldering, you should read the Safety Data Sheet (SDS) for each gas to obtain information on proper use, safety precautions, personal protective equipment, and treatment information.

SAFE HANDLING OF CONTAINERS

Proper Container Filling

Refrigerants are stored in cylinders, or containers. These containers are designed and constructed to hold quantities of refrigerant at definite maximum pressures based on a specified maximum temperature of 125°F. When a container is filled to 80% capacity by weight, the liquid in the container will expand as the temperature rises. At 130°F, the liquid will expand to fill the container completely. Extremely high hydrostatic pressures develop, and the container could burst. Never fill a container beyond 80% by weight, and never use a container for any refrigerant other than the one for which it is approved.

Securing Containers for Transport

Due to the very high pressures involved with containers, you must ensure that caps are placed on containers to protect valves and that the containers are properly secured for transport. The Department of Transportation (DOT) controls the shipping and labeling of refrigerant containers. Always follow DOT guidelines when handling or transporting these chemicals.

Proper Storage

The DOT also controls the storage of these containers. Remember that the maximum allowable temperature for storing charged refrigerant containers is 125°F.

Disposal

Containers must be properly disposed of based on the Environmental Protection Agency's regulations. Their requirements help minimize refrigerant emissions and protect the environment.

UNDERSTANDING HAZMAT

Signage for Hazardous Materials

Acetylene is a Class 2.1 flammable gas. Gases in this category (hydrogen is another example) ignite on contact with an ignition source. You will find the HAZMAT sign on a tank containing either acetylene or hydrogen. Make sure to look for the HAZMAT signage on all containers with which you are working.

Securing Hazardous Materials for Transport

Containers with hazardous materials should be properly secured for transport. Again, the DOT offers guidelines to follow for this. It is also very important to have the SDS for each hazardous material that you are transporting. These documents will help ensure your safety and the safety of those around you.

Worker Requirements for HAZMAT Training

OSHA offers HVAC support technicians training in hazardous materials, or HAZMAT. Their course topics are flammable and combustible liquids, compressed gases, liquefied petroleum gases, and cryogenic liquids. It also discusses the use of electrical equipment in hazardous locations. When you have completed this class, you will be able to assess compliance with OSHA hazardous materials standards, determine hazardous (classified) locations, and properly move, store, and handle those hazardous materials.

ILLUSTRATION CREDITS

FIGURE 10-1: ELEARNING BROTHERS STOCK ASSETS LIBRARY

CONCLUSION

You should now be prepared for the NATE Support Technician Certificate exam. You have learned about the components involved in an HVAC system and which tools work best with each component. You have learned about the academic building blocks of the profession—math and science. You have also taken this information and applied it to design, installation, maintenance, and service. And finally, and most importantly, you have learned how to do the work of a support technician safely. Good luck in this next step in your career!

SUPPORT TECHNICIAN CERTIFICATE EXAM STUDY PLAN

It is helpful to have a study plan to identify what you need to study most and to organize your time. Then you can decide what methods will help you study best. If you follow your plan, you are more likely to get into a studying routine, learn the material, and remember it better.

1. Start to plan as soon as you register to give yourself as much time to study as you need.

2. Begin by reviewing the content areas, and decide how confident you feel about each. You may want to look through the study guide to see what information will be covered. Rate each of them using the table below.

Table 1	
CONTENT	**CONFIDENCE LEVEL** (1 = very, 2 = mostly, 3 = somewhat, 4 = not at all)
System components: duct systems, components, electromechanical sensing controls, electronic controls, air distribution, induced draft non-condensing components, induced draft condensing components	
Tools: tools and scales basic math measurement, fabrication tools, tubing tools	
Basic construction terms: room specs, ceilings, walls, floors, girders and trusses	
Using basic science: chemistry basics, mathematics, mechanics	
Introduction to basic electricity: digital electrical meters, electrical basic terms, AC and DC circuits	
Achieving desired conditions: temperature, humidity, air quality, sound	
Taking temperature and humidity measurements: physical measurements—temperature and heat, thermometers	
Installation: fabricating copper tubing, duct installation, installing accessories, field wiring, refrigerant circuit tools, installing gas furnaces	
Service: introduction to systems, planned maintenance	
Applied knowledge—design considerations: design considerations—comfort, design considerations—external components	
Safety: personal safety and work practices, personal safety around moving machinery, electrical safety, safe brazing and soldering practices, safe handling of containers, understanding HAZMAT	

3. Now you need to make a schedule. Begin by choosing the date you plan to take the test. You have up to 180 days from the time you registered. You should not wait until the last possible minute because unexpected delays could occur. If you are confident with most of the topics (have a lot of 1s and 2s), then it may take you much less time to prepare for and take the test. If the information is new (3s and 4s), take more time to study.

4. Look at your calendar between today's date and the date when you plan to take the test. For each week, identify all of your important commitments such as work, appointments, and vacation. To be successful, you have to balance studying with the rest of your life, so also include times for relaxing, eating, and sleeping. You should now see some free time that you can use for studying. Some people like to study for half an hour each day, while others might prefer bigger blocks of time on the weekend. Whatever you prefer and your schedule permits, make sure to include breaks for study times that are more than two hours. Write the dates of each week you plan to study in the schedule below. Then add the days and hours you have free to study for each week.

5. Decide how many days or weeks you think you will need for studying each content area. Some people like to start with the hardest material first, while others might like to start with the easiest ones to build up their confidence. Others like to mix it up. Add the content to the schedule in a way that works best for you.

Table 2			
WEEK	**DAYS AND HOURS FOR STUDYING**	**CONTENT TO STUDY**	**COMPLETED**
		TAKE THE EXAM	

Make sure to check the completed column when you have finished a week of studying because it helps to recognize your success and to keep you motivated for the rest of your studying. You can adjust your schedule if things change but stick with studying regularly. Remind yourself of your goal to get this certification and how it will be worth the effort you put into it.