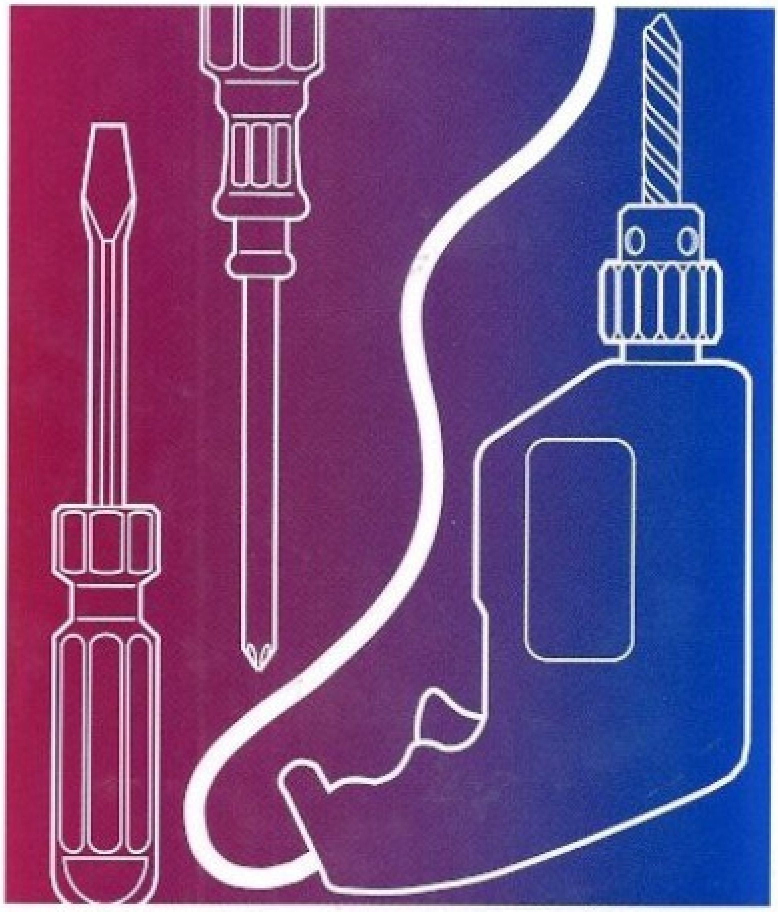
HVAC INSTALLATION PROCEDURES



- The Organized Installation
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- General Installation Considerations
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HVAC
Installation Procedures
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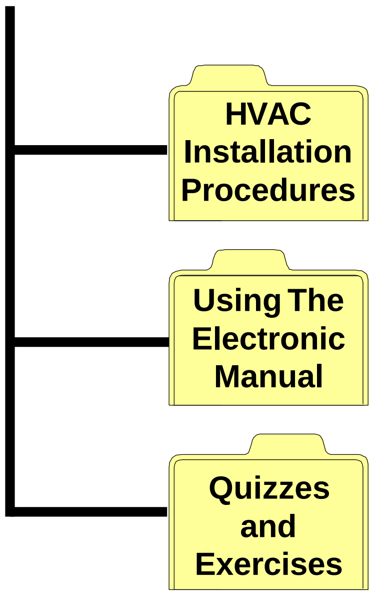


WELCOME

This CD-ROM contains an expanded version of the HVAC Installation Procedures Manual. The following information is included in addition to the material provided in the paper edition:

- A printable quiz for each section of the book
- Printable exercises that test and reinforce knowledge of the procedures contained in the book
- A list of tools referenced in the manual

Click on a folder at left to view that part of the
HVAC Installation Procedures CD-ROM.

Important Notes

1. Take the time to review the section on **Using the Electronic Manual**. This section contains an overview of the buttons, controls, and features of this particular electronic document. If you don't become familiar with the navigation tools, you will have difficulty in finding your way around.

2. When you click on a Help button/menu choice, you will see the Acrobat Reader Help information, which has information on using all of the features and navigation tools available in the Reader.

3. When you select an option other than **HVAC Installation Procedures** at the Main Menu, you open a Microsoft Windows folder. To return to the Main Menu and select another folder, you must close the open folder using the **Close** command in the **File** menu.

HVAC Installation Procedures Contents

SECTION 1
THE ORGANIZED INSTALLATIONN

INTRODUCTION

This section provides the basic information needed to plan and prepare for the installation of residential and light commercial air conditioning and heating systems. Planning the installation and an overview of the tasks and sequence for a typical installation are covered first, followed by a brief description of the tools used to perform common installation tasks. Also given in this section are guidelines for acquiring and maintaining good customer relations before, during, and after the installation.

INSTALLATION MENU

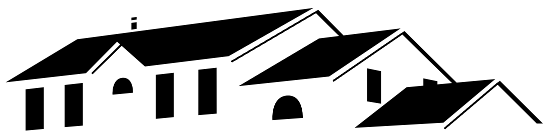
PLANNING THE INSTALLATION

Reliable system installations do not happen by accident; they require careful planning *(Figure 1-1)*. Local ordinances governing equipment placement, electrical hookup, materials, and the protection of the environment must be obeyed. This is necessary to avoid any inconvenience, increased cost, and bad reputation resulting from a failed inspection. Construction permits must be secured in some localities. The specific site for indoor and outdoor equipment, as well as any ductwork and piping, must be identified and prepared to receive the equipment.

The proper type of equipment for the job must be selected and ordered. Ducting, piping, and electrical materials must be selected and purchased by a qualified engineer or salesperson based on a survey of the job. For new construction, this survey may be done by consulting the builder and looking at the blueprints and specifications for the job.

For a replacement job, the survey is completed by visiting the job site and consulting with the customer to determine their needs. Heating and cooling load estimates for the building are made and the existing air distribution system, utilities, and electrical service are evaluated to determine their adequacy to support the new equipment.

▼ Figure 1-1.
Planning



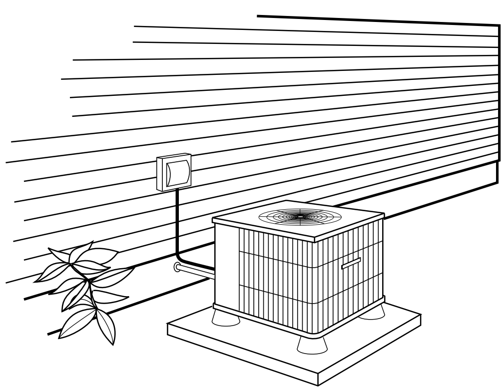
- EQUIPMENT
- MATERIALS
- PERMITS AND CODES
- SELECT EQUIPMENT LOCATION(S)
- PREPARE EQUIPMENT SITE(S)
- SCHEDULE JOB/COORDINATE WITH OTHER TRADES
- INSTALL/START UP/CHECK OUT

TYPICAL INSTALLATION TASKS AND SEQUENCE

The installation of any system or component should always be performed as recommended by the manufacturer's specific installation instructions. This is because the actual tasks and their sequence can vary widely based on the size and type of system being installed. A typical approach is to start by preparing the location and setting the equipment in place *(Figure 1-2)*. Electrical wiring is run to the equipment location or to a disconnect which feeds the equipment. Local codes may require that this be done by a licensed electrician. Ductwork and combustion vents are connected to the equipment as needed. This is followed by the installation and connection of the refrigerant, gas, and condensate piping to the equipment, as required. The final electrical hookup is made to the thermostat and to the unit's control circuits.

▼ Figure 1-2.
Installation Sequence

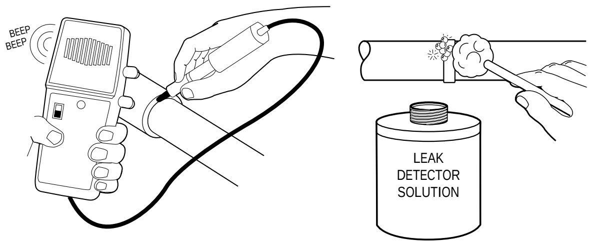
- EQUIPMENT PLACEMENT
- RUN WIRING (ROUGH IN)
- RUN DUCTING WITH FINAL CONNECTION
- RUN PIPING WITH FINAL CONNECTION
- ELECTRICAL HOOKUP



Following completion of the initial installation tasks, the system must be readied for service *(Figure 1-3)*. This often requires that the refrigerant and gas lines be leak-tested and, if necessary, repaired. If installing a field-piped cooling system, the system must be evacuated and the refrigerant charge checked. During this step, it is essential to follow all installation instructions and guidelines provided by the manufacturer. Next, the equipment start-up procedure is performed to check the operation of the equipment, make adjustments, and check out the operation of all safety controls.

The final step is a thorough cleanup of the equipment and the work area. You should also give the customer the owner's manual(s) along with simple, courteous instructions on how to operate and maintain the system.

▼ Figure 1-3.
Commissioning

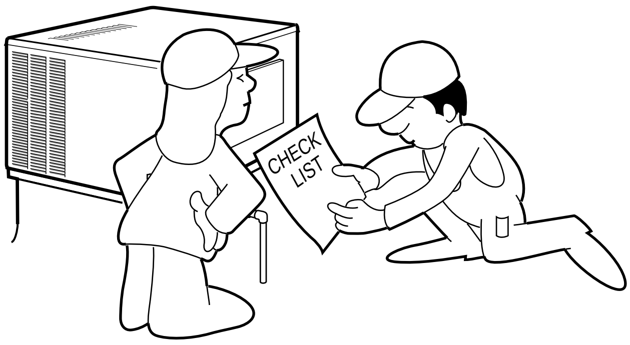


1. LEAK TEST AND REPAIR IF NEEDED
2. EVACUATE AND DEHYDRATE
3. CHARGE SYSTEM (REFRIGERANT AND ANY EXTRA OIL)
4. INSULATE REFRIGERANT LINES
5. FINAL INSPECTION
6. START UP AND CHECK OUT
7. CLEAN UP
8. CUSTOMER INFORMATION/INSTRUCTION

INSTALLATION AND START-UP CHECKLISTS

Most manufacturers provide installation and start-up checklists *(Figure 1-4)* in the literature supplied with their equipment. At appropriate points throughout the installation, these checklists should be used to confirm the completion of various installation tasks. During system checkout, the lists are used to record the unit's performance characteristics.

▼ Figure 1-4.
Confirm Correct Installation Using Installation and Start-Up Checklists



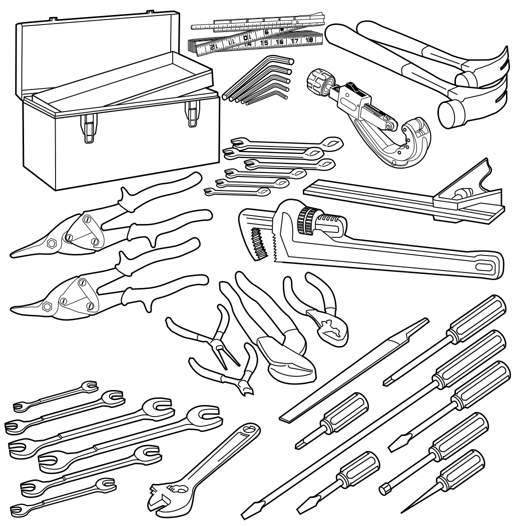
INSTALLATION TOOLS AND EQUIPMENT

A quality installation depends on using the right tools and equipment for the job. General-purpose tools and equipment are described here. Specialized tools and equipment are described, where relevant, later in this book.

Hand Tool Set

You should have a tool box equipped with a variety of quality hand tools *(Figure 1-5)*. Specialized tools needed to service refrigeration systems such as service valve adapters, etc. should also be included in this tool set.

▼ Figure 1-5.
Typical Hand Tool Set



Measuring and Layout Tools

Measuring and layout tools used to determine length, height, diameter, levelness, or plumb must be easy to use, accurate, and durable. Common measuring tools include:

- Measuring tapes and folding rules
- Squares
- Levels
- Plumb bobs and chalk lines

Measuring Tapes and Folding Rules – Measuring tapes and folding rules *(Figure 1-6)* are used for making most measurements. They are normally marked with both English and metric scales.

Folding rules come in 6- to 10-foot lengths, with hinges for folding. Some are equipped with a graduated sliding brass extension that is useful for making depth and inside measurements. Because of its stiffness, a folding rule is useful for making overhead and vertical measurements.

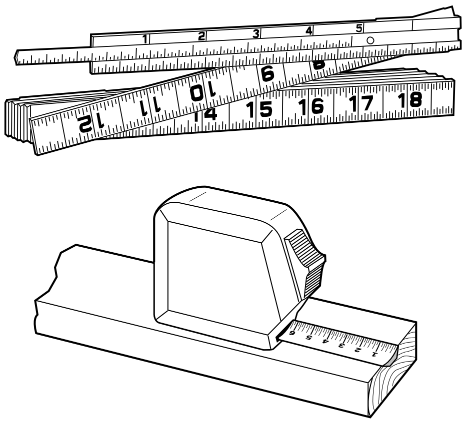
Self-rewinding measuring tapes are made of steel or fiberglass and usually come in 10- to 30-foot lengths. A hook on the end of the rule grabs onto the work piece, making it easier to use when making long measurements. A lock holds the tape in the open position and a rewind mechanism retracts the tape when not in use. Longer tapes are available for measuring longer lengths.

Squares – Squares are used for measuring, marking a line for cutting, checking squareness, and checking the flatness of materials. Two kinds of squares are commonly used: a combination square and a framing or carpenter's square.

The combination square *(Figure 1-7)* consists of a blade and a sliding adjustable head. The blade and head incorporate a 90° square and a 45° miter square that allow the tool to be used to check and/or mark out either 90° or 45° angles. Most combination squares have a built-in spirit level and a hardened scriber that can be used for marking metal.

Carpenter's squares *(Figure 1-8)* are used mainly as a straightedge and to mark out right-angle lines. They are also used to check the inside and outside squareness and flatness of materials. Both the body and tongue are stamped with graduations that are divided into inches, allowing the tool to be used as a ruler. Framing squares usually have tables and formulas marked on them to make calculations for area and volume.

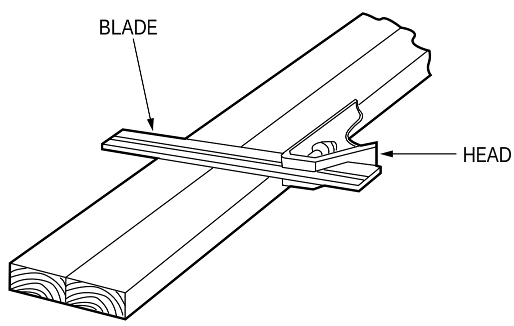
▼ Figure 1-6.
Folding Rule and Measuring Tape



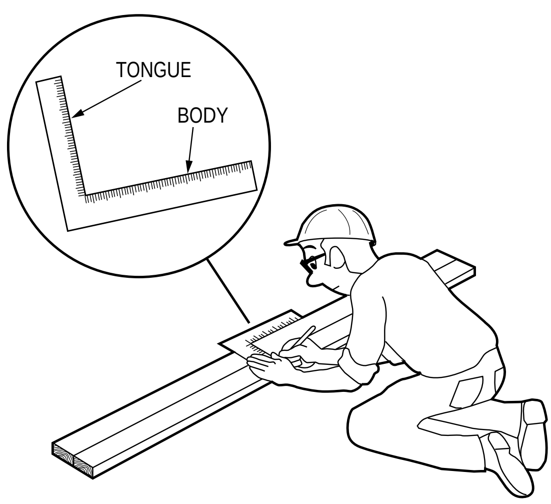
QUICK NOTE

- Folding rules require little maintenance, except for periodic lubrication of the joints.
- Avoid dropping a folding rule as the fall may loosen the joints enough to cause inaccuracies.
- To work properly, steel tapes must be kept clean, dry, and free of kinks.
- Keep water and mud out of the steel tape case as they can cause rust and other damage to the rewind mechanism.

▼ Figure 1-7.
Combination Square



▼ Figure 1-8.
Carpenter's Square



Levels – Levels are used to determine the horizontal (level) or vertical (plumb) alignment of structural members, piping, or mounted components. Levels are made in simple and electronic models and come in various lengths. A general-purpose spirit level *(Figure 1-9)* is normally adequate for use in HVAC installation work.

Common spirit levels have three vials. The two end vials are used to measure vertical plumb while the center vial is used to measure horizontal level. The item being checked is level or plumb when the air bubble within the appropriate vial is centered between the lines etched on the vial.

When not in use, levels should be stored in a manner that ensures they will not be twisted, bent out of shape, or have their vials broken.

Plumb Bobs and Chalk Lines – Plumb bobs *(Figure 1-10)* are balanced weights used to find plumb over long vertical distances. When suspended from a height by a string attached to its exact top center, and allowed to hang freely, the force of gravity causes the plumb bob string to settle in the plumb position.

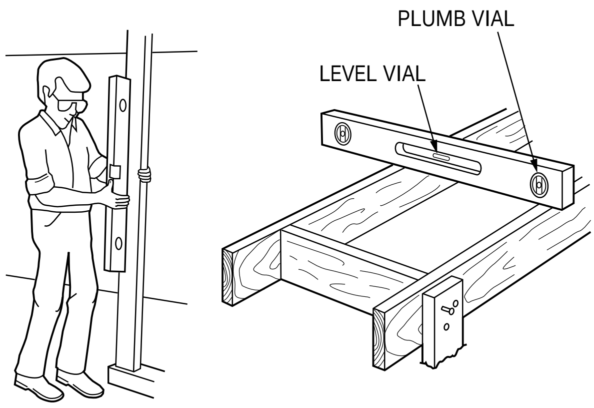
A chalk line *(Figure 1-11)* is used to mark a layout line between two points on long flat surfaces. It typically consists of a case filled with chalk and a length of line on a retractable reel. Each time the chalk line is pulled out of the box, it is automatically chalked. To use a chalk line, the line is pulled from the case, stretched taut between the two reference points to be connected, then snapped. This causes the chalk on the line to mark the surface underneath the string. The chalk line must always be kept in a dry place, or moisture may cause it to become clogged.

Portable Electric and Cordless Tools

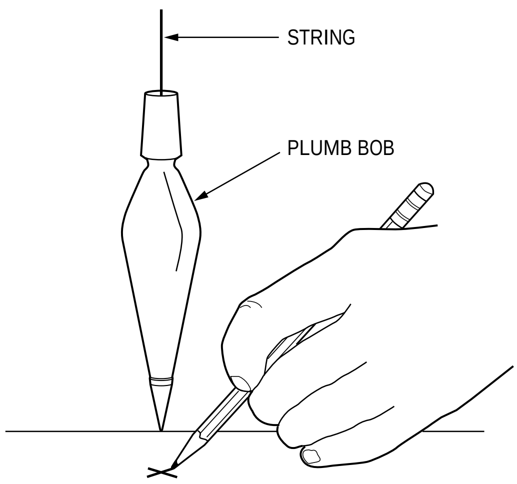
A variety of electric and/or cordless hand drills, saws, etc. are used regularly on installations. Electric tools normally operate on 110-120 volts AC, and are plugged into an outlet near the work location.

Cordless drills *(Figure 1-12)* and other cordless tools are useful for working where electrical outlets are not available. Cordless tools have a detachable and rechargeable battery pack that runs the motor. Generally, the higher the voltage rating of the battery pack, the higher the torque or capacity of the tool. Most quality tools have chargers that can quickly recharge the battery pack. However, an extra battery pack should be purchased so that the job is never halted while waiting for a battery to recharge.

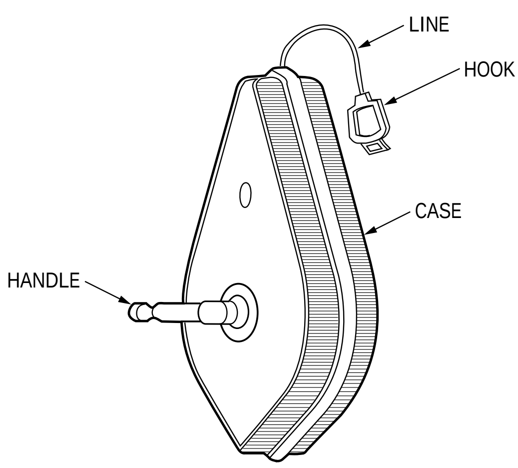
▼ Figure 1-9.
Spirit Level Used to Check Plumb and Level



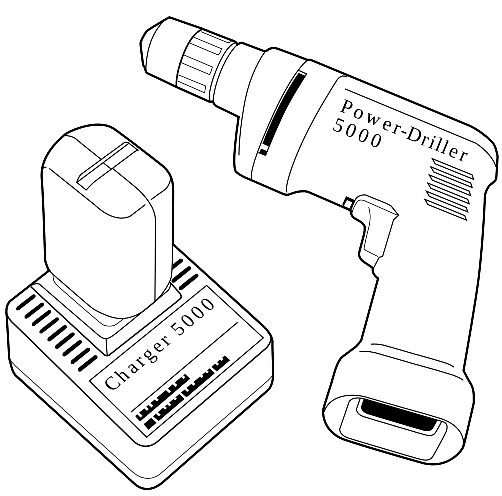
▼ Figure 1-10.
Finding True Vertical Plumb with a Plumb Bob



▼ Figure 1-11.
Mechanical Chalk Line



▼ Figure 1-12.
Cordless Driver-Drill and Charger



Electric and Cordless Drills – The specific drill used depends on the diameter, depth of the hole, and type of material to be drilled *(Figure 1-13)*. Drills are rated according to the maximum horsepower (hp) developed by the motor. Generally, the higher the hp, the more power or torque is available to the drill.

Drills are also rated by the largest drill bit *(Figure 1-14)* shank that the chuck will hold. Chuck size is a good indication of the largest size hole the drill can easily bore through hard metal. Drills can be fitted with 1/4-inch, 3/8-inch, or 1/2-inch chucks.

Drills with variable-speed and rotation-reversing features are desirable for installation work. Reversing the rotation of the drill makes it easier to release stuck and jammed bits and to remove screws, etc. Variable speed allows holes to be drilled at different speeds. Generally, the harder the material being drilled, the slower the drilling speed. Drilling iron or steel is best done at speeds in the range of 300 to 500 rotations per minute (rpm), while drilling in softer materials such as wood is better done at higher speeds up to about 1,200 rpm. The use of very slow speeds also makes it easier to start holes, run in screws, and perform other similar operations.

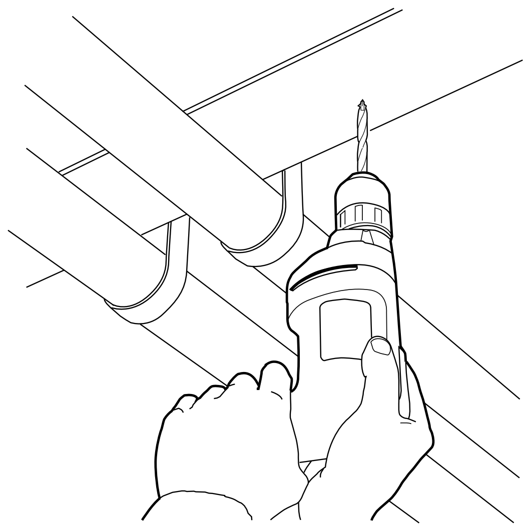
A hammer drill *(Figure 1-15)*, so named because of its hammering action, is commonly used to drill holes into masonry. It rotates and hammers at the same time and drills much faster than regular drills. Hammer drills have a depth gauge that can be set to control the depth of the hole being drilled.

Circular, Reciprocating, and Jig Saws – Installing HVAC equipment requires that holes be cut for pipes, ductwork, vents, etc. Wood and other materials must also be cut to build support structures for equipment and/or to mount electrical and other panels. These cutting jobs are normally done using circular, reciprocating, and/or jig saws.

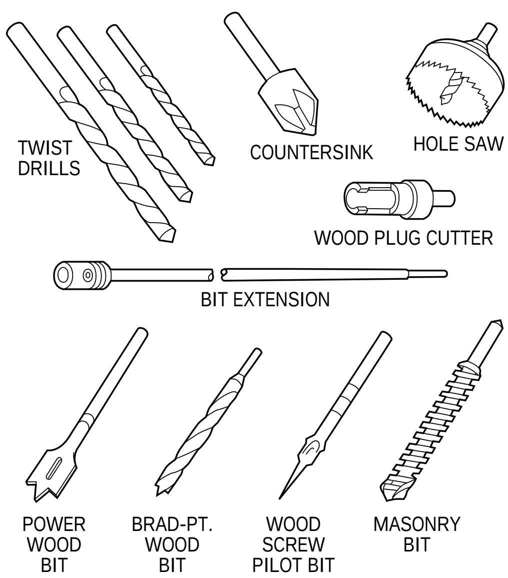
QUICK NOTE

Before drilling, make sure work is firmly supported and clamped. Make a starter hole with an appropriate punch to prevent the bit from wandering.

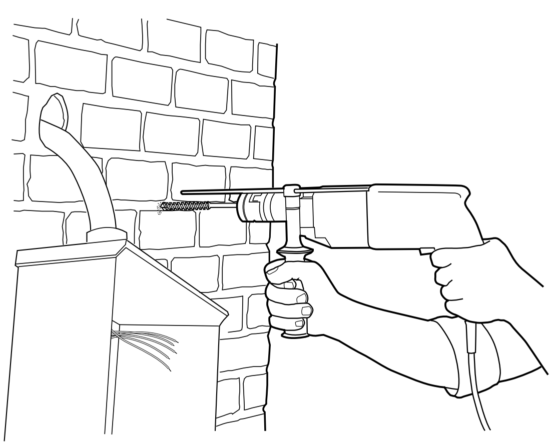
▼ Figure 1-13.
Electric Drill Used to Drill Hole in Metal I-Beam



▼ Figure 1-14.
Types of Drill Bits



▼ Figure 1-15.
Hammer Drill Used to Drill Holes in Masonry



QUICK NOTE

- A circular saw with a large diameter blade is of little value if the saw motor lacks the horsepower to drive it.
- If adequately powered, a saw with no-load blade speeds ranging between 4,000 and 5,800 rpm makes a faster, smoother cut than one that runs at a lower speed.
- Too much cutting blade depth increases the chance of saw kickback and can cause the cut to be rough. For standard steel blades, allow one whole tooth to project below the material to be cut. For carbide-tipped blades, allow 1/2 a tooth.

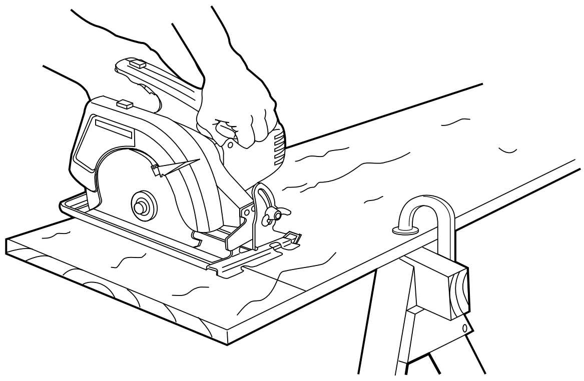
Circular saws *(Figure 1-16)* are used to make straight cuts in various materials. The size of a circular saw is determined by the diameter of the largest blade that can be used with the saw, which determines how thick a material can be cut. Saws using blades of 7-1/4 and 8-1/4 inches are the most popular. Circular saws have upper and lower guards that surround the blade. The upper guard is fixed; the lower guard is spring-loaded and retracts as the saw cuts into the work piece. The saw baseplate rests on the material being cut and can be adjusted to change the depth of the cut or to make bevel cuts ranging between 0° and 45°.

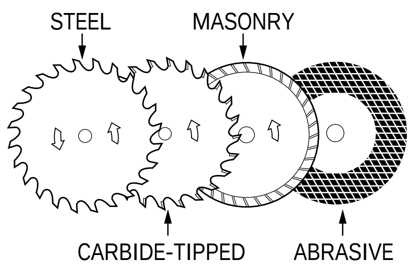
There are a wide variety of blades available, each designed to make an optimum cut in a different type and/or density of material. Generally, blades are standard steel or carbide-tipped. Carbide-tipped blades stay sharper longer, but they are more brittle and can be damaged if improperly handled. The number of teeth on a blade, the grind of each tooth, and the space between the teeth (gullet depth) determines the smoothness and speed of the cut. To select the right blade, use a blade recommended by the blade manufacturer for the type of material being cut. Make sure that the blade diameter, arbor hole size, and maximum rotation speed fit your saw.

Reciprocating saws *(Figure 1-17)* are heavy-duty saws with a back-and-forth blade motion. They can be used for cutting through floors and partitions including nails, wire mesh backed plaster, studs, and beams. Variable-speed models with speeds ranging from 0 to 2,400 strokes per minute (spm) are best. Higher horsepower and slower speeds are generally needed when cutting through metals or when cutting along a curved or angled line. The typical length of the horizontal sawing stroke is 1-1/8 inch. A good saw will have the capability of mounting the saw blade so cuts can be made upward as well as to the left and right.

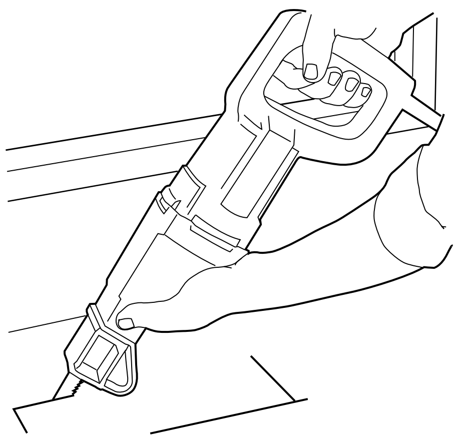
A jig or saber saw *(Figure 1-18)* is a lighter-duty saw than the reciprocating saw and is used to make straight or curved cuts. With the proper blade, it can cut wood, metal, plastic, and other materials. Variable-speed models with speeds ranging from 0 to 3,200 spm are best. The typical length of the vertical sawing stroke is one inch. Other features of a good saw include adjustable orbital action to clear away chips, a baseplate that can be tilted for bevel cuts, and a scrolling capability that makes it easier to cut along pattern lines.

▼ Figure 1-16.
Circular Saw

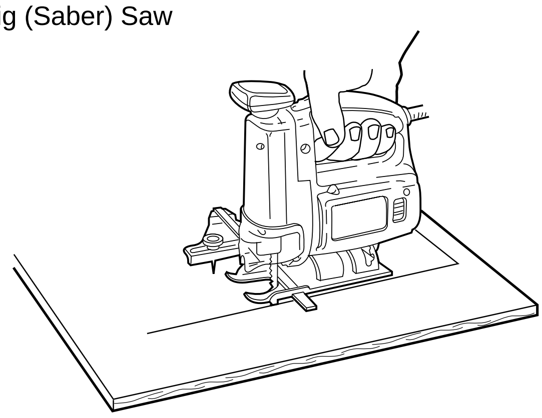




▼ Figure 1-17.
Reciprocating Saw Cutting through a Floor



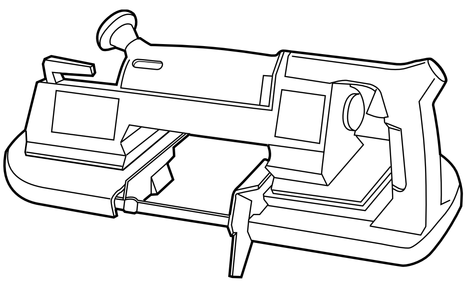
▼ Figure 1-18.
Jig (Saber) Saw



A wide variety of interchangeable blades are made for use with reciprocating and jig/saber saws. Each type of reciprocating or jig/saber saw blade is designed to make an optimum cut in a different kind of material. Always use the blade recommended by the blade manufacturer for the type of material being cut.

Portable Band Saw – The portable band saw *(Figure 1-19)* is useful for cutting heavy metals. Typical cutting capacities are up to 3-1/2 inches for round materials and 3-1/2 x 4-1/2 inches for rectangular materials. The band saw has a continuous one-piece blade that runs in one direction around guides located at either end of the saw. Two-speed and variable-speed models are both common. Band saw blades are made with standard pitch or variable pitch teeth. Blade materials and the number and pitch of the teeth are designed to make an optimum cut in different kinds of materials. Always use the blade recommended by the blade manufacturer for the type of material being cut.

▼ Figure 1-19.
Portable Band Saw



Extension Cords – An extension cord is frequently used to connect power to power tools. It should have a suitable wire size for the overall cord length and the proper amperage rating for the tools with which it will be used *(Table 1-1)*. This is necessary to prevent excessive voltage drop, power loss, and possible motor damage. When tools are used outdoors, only extension cords labeled for outdoor use should be used. For protection against potential shock from an electrically-shorted power tool, a ground fault circuit interrupter (GFCI)-protected extension cord should be used.

▼ Table 1-1.
Finding the Correct Extension Cord for the Job

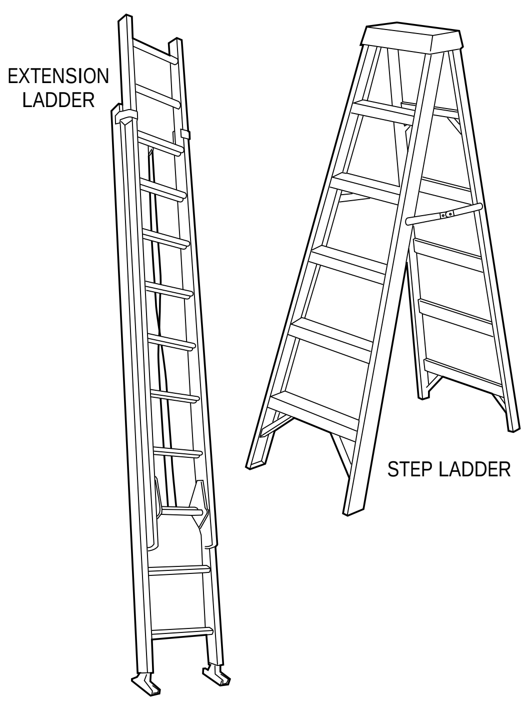
Cord Length (Feet)	Tool Ampere Rating			
	3.5 to 5	5.1 to 7	7.1 to 12	12.1 to 16
	Extension Cord Recommended Wire Size (AWG)			
25	18	18	16	14
50	18	16	14	12
75	16	14	12	10
100	14	12	10	–

Ladders

Extension and step ladders *(Figure 1-20)* are often needed to reach high places, such as rooftops. They can be made of fiberglass, aluminum, or wood. Fiberglass and wooden ladders are nonconductive, allowing them to be used when working around electricity. Aluminum ladders are lightweight and easy to move, but should not be used where contact with electricity is possible.

Ladders are rated by their total load capacity, which includes the combined weight of the user, tools, and any materials bearing down on the ladder rungs. Minimum load capacities used for installation work are 225 pounds (medium duty), 250 pounds (heavy duty), and 300 pounds (extra heavy duty).

▼ Figure 1-20.
Extension and Step Ladders



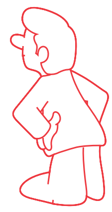
Common extension ladders range in size from 16 to 40 feet *(Table 1-2)*. Extension ladders are equipped with a rope and pulley system to help raise and lower the upper ladder section. Self-locking rung latches attached to one of the sections supports and secures the raised section in place.

Step ladders are self-supporting, non-adjustable ladders made in heights ranging from 4 to 20 feet. ***WHEN USING A STEP LADDER, NEVER STAND ON THE TOP TWO STEPS.***

WARNING

Wooden ladders require proper maintenance. Moisture can be a problem, so they should be stored in a dry place to prevent rot. ***Never paint a wooden ladder. The paint can hide cracks, splinters, and dry rot.*** Use of clear varnish or a preservative oil finish will protect the wood without hiding these defects. For additional information about ladders and ladder safety, refer to Section 2.

CAUTION



▼ Table 1-2.
Finding the Correct Extension Ladder for the Job

Ladder Size (Feet)	Maximum Extended Length (Feet)	Maximum Working Height (Feet)
16	13	9
20	17	13
24	21	17
28	25	21
32	29	25
36	32	28
40	35	31

CUSTOMER RELATIONS FOR INSTALLERS

Appearances Count – When people meet you for the first time, they form their critical first impression of you based to a large extent on how you look. Industry studies have consistently identified the appearance of installers as a factor that many customers consider important *(Figure 1-21)*.

▼ Figure 1-21.
How You Look on the Job is Very Important

Ask yourself these questions:

- Do you get enough sleep and look alert?
- Do you practice good personal hygiene?
- Do you wear a neat, clean uniform and clean shoes?
- Do you promptly identify yourself and show an appropriate ID?
- Do you smile, display confidence, and polite respect for the customer?

If your answer to each question is "Yes," congratulations! You are well on your way to consistently making the good first impression your company needs.

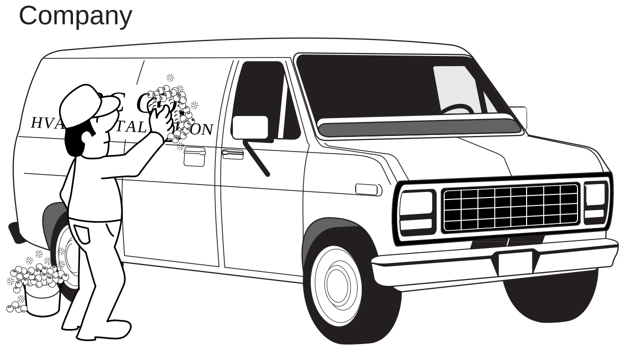
If you answered "No" to any of the questions, you have identified an area for improvement that can change how people feel about you and your company. Get to work on making that improvement. You will be glad you did.

Before you head out to a job, look in the mirror and ask: "Would someone's spouse or mother want me in the house?"

In addition, your vehicle is a traveling billboard for your company *(Figure 1-22)*. How it looks and how you drive it can greatly influence the public's impression of your company. Make that positive impression on the road.

- Is your truck clean and in good repair?
- Are your driving habits courteous?

▼ Figure 1-22.
Your Vehicle is a Traveling Billboard for Your Company

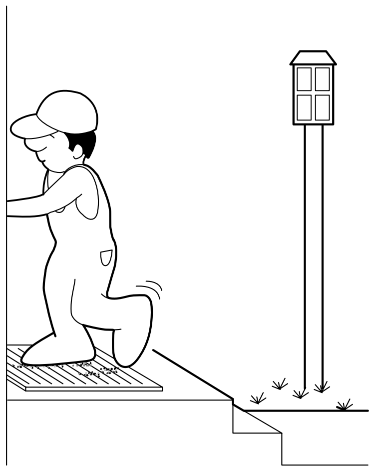


Treat Your Customers with Respect – In a way, admitting you into their home is a trusting gesture of faith by customers *(Figure 1-23)*. They have faith that you will do no harm, and that you will treat the premises and occupants with respect. Do you agree? Think about the people you invite into your home.

Ask yourself these questions:

- Do you refrain from smoking?
- Do you remember to protect the work area?
- Do you carry rags and carefully clean up after yourself?
- Do you have drop cloths to protect floors and carpets?
- Do you keep from tracking in dirt?
- Do you return the home to its original condition? (Replace covers, wipe off dirty fingerprints, clean up drop cloths, etc.)

▼Figure 1-23.
Treat Your Customers with Respect...Begin with Their Homes



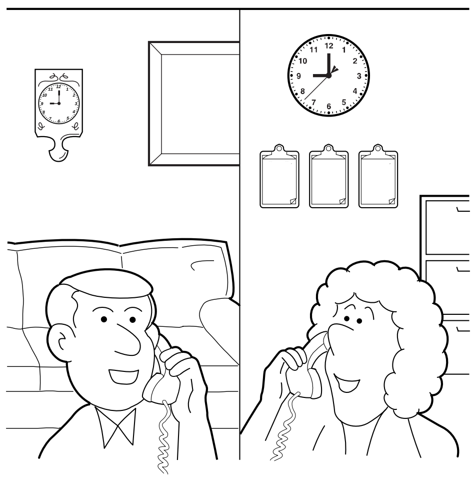
Good Work Habits Mark You as a Skilled Professional – As the number of homes with more than one income has increased, the need for installers to arrive on time has become more critical than ever, since in these cases someone may have to take time off from work to wait for the installer. Be on time. Call if you are going to be late *(Figure 1-24)*. Show the customer that you have consideration for their time.

It is a good idea to read the product installation instructions *before* going on the job. Using a wrong tool not only leaves behind poor results, it tells your customer that you are unprofessional. Customers notice if you arrive with a full set of tools, neatly packed. They notice your attitude, and whether it shows a good work ethic. They can see if you neatly repack your tools when you finish the installation, too. It is part of how they judge you and your company. It is also a large contributor to whether they call your company back for more work.

Review these questions. Any "No" answers indicate areas that need work.

- Are you on time?
- Do you arrive fully informed and prepared to do the job?
- Are your tools a full set, neatly packed?
- Do you tackle the installation promptly?
- Do you avoid general social conversation while working?

▼Figure 1-24.
Good Work Habits Mark You as a Skilled Professional



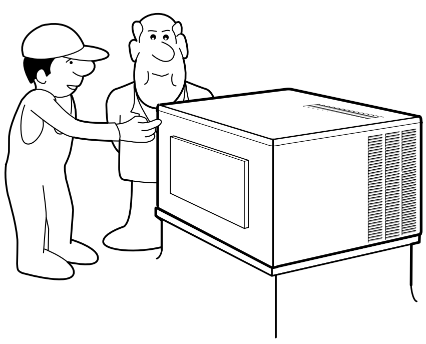
QUICK NOTE

No company wants its employees using alcohol, drugs, or profanity on the job, and no customer wants such people in their home. On the job, always show the customer the kind of positive, professional attitude and behavior you would expect if YOU were the customer.

Customer Satisfaction Depends on what You Say as Well as what You Do – Understanding your customer's needs is the first step in achieving customer satisfaction *(Figure 1-25)*. Imagine that you are the customer. What would you like to know about a new installation? Your answer is likely to include items your customer would also want to know. ***Helpful Hint:*** *Think of good communication with your customer as essential to understanding his/her needs.*

When installers do not explain how things work and fail to give the customer a good over-

▼Figure 1-25.
Customer Satisfaction Depends on what You Say as Well as what You Do

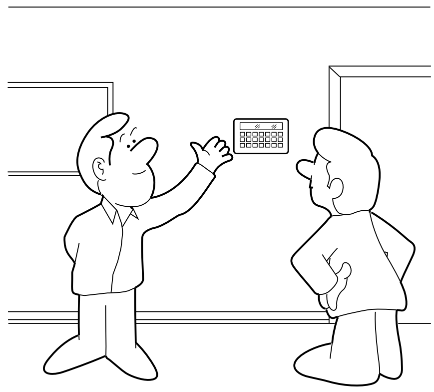


view of how to use and maintain the product, they leave customers with unanswered questions. Customers appreciate when you explain how to operate and care for the product/system *(Figure 1-26)*. Be brief, with no unnecessary conversation.

Sometimes, learning your customer's needs calls for using your powers of observation. For example, on a furnace job, a veteran installer noticed that his customer, a senior citizen, suffered from painful arthritis in her hands. He realized that the simple task of changing the filter would be difficult for her. So he suggested an optional, inexpensive, external filter rack. He explained how easily the filter slides in and out. Without hesitation, she purchased the optional rack. Weeks later, she was telling her friends about her "helpful furnace man."

Many customers incorrectly assume that a brand-new, just-installed product can go for years without maintenance attention. ***Suggestion:*** *Explain that today's high-tech systems, like today's cars, need regular maintenance.*

▼ Figure 1-26.
Customers Appreciate when You Explain how to Operate and Care for the Product/System



Many top installers show their customers simple, self-help maintenance techniques that prolong equipment life, such as how to change filters. In addition, they make sure the customer can set the thermostat, as well as explaining items unique to the product. For example, with heat pumps, the installer might explain how heat pumps work and tell why frost might form on the coil, and why the outdoor section must be kept clear of snow.

Top installers always leave the product literature packet with the customer because they know that with today's high-tech products, these instructions contain information that a servicing technician might need someday. The owner's manual also contains information that helps the owner to better understand equipment operation and helps to prevent needless service calls. It is a good idea to suggest to your customer that they keep the product literature, warranty, etc. in a safe place.

Dealers who do large amounts of repeat business have trained their installers to make things easy for the customer. They make it easy to contact the dealer. They check back to make sure the installation is satisfactory.

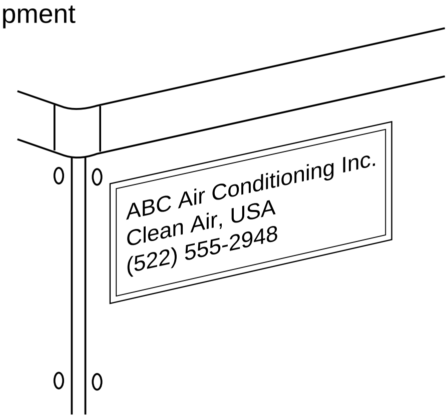
Consider these loyalty-building questions:

- Do you leave a business card or put a sticker with your company's phone number on the equipment *(Figure 1-27)* or leave a card with the customer to keep near the phone?
- Do you call the customer a day or two later to ask if your product/system is working properly?

If you answered "Yes," you are already making opportunities for repeat business based on satisfied customers. If you answered "No," perhaps you should consider trying one or all of these proven business-building techniques.

Finally, remember that your customers appreciate a positive attitude. For example, it is always best to be professional and avoid "bad mouthing" older or competitive products. Likewise, if for example, you are late—but it is not your fault—focus on the positive, getting the job done, rather than blaming someone else. Say something like: "I understand how you feel. I'm sorry. Please know that I will do my best to have your new furnace installed as quickly as I can."

▼ Figure 1-27.
Always Leave a Business Card or Put a Sticker with Your Company's Phone Number on the Equipment



SECTION 2
SAFETY

INTRODUCTION

This section summarizes general safety information for persons involved with the installation, operation, and maintenance of heating, ventilating, and air conditioning (HVAC) equipment. Working on HVAC systems means that you will encounter many potentially dangerous situations involving:

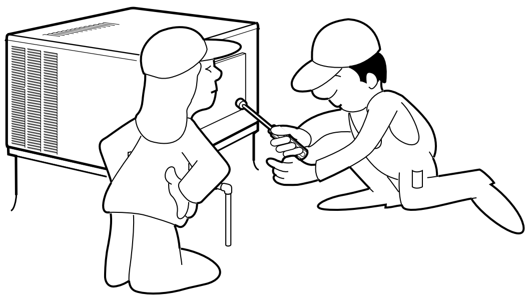
- Equipment containing liquids and gases under pressure
- Energized electrical equipment
- Contact with extremely hot and cold equipment surfaces
- Rotating machinery
- Contact with chemicals and hazardous materials
- Installation and repair work involving movement of heavy objects

SAFETY MENU

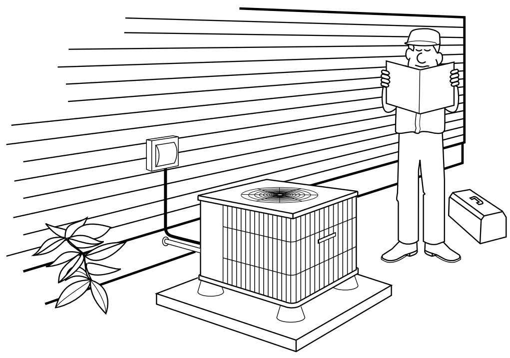
Only trained and qualified service personnel should install or service HVAC equipment *(Figure 2-1)*. Untrained personnel may perform basic maintenance tasks such as cleaning and replacing filters with little supervision. However, unfamiliar tasks must be performed by (or under the supervision of) an experienced technician.

The final responsibility for on-the-job safety rests with you. Job and construction sites can be hazardous places to work, but an awareness of the information provided in this section will help you to avoid injuring yourself or damaging equipment. The safety instructions given in this section and the remainder of this book are general in nature and are not to be used as a substitute for the manufacturer's instructions. No attempt should be made by anyone to install, operate, adjust, repair, or dismantle any equipment until the manufacturer's specific instructions have been read and are thoroughly understood *(Figure 2-2)*.

▼ Figure 2-1.
Always Learn New Skills Under the Supervision of a Qualified Technician



▼ Figure 2-2.
Read and Follow Specific Instructions in the Manufacturer's Literature

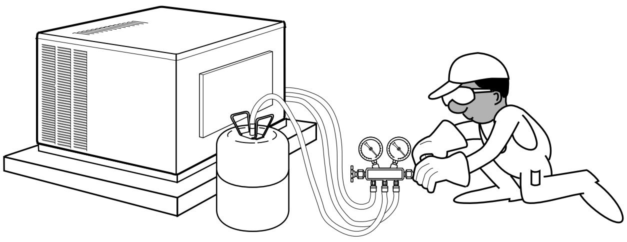


PERSONAL SAFETY

Personal Safety Equipment

Many on-the-job injuries occur because workers do not use personal protective equipment *(Figure 2-3)*. The exact type of personal safety equipment depends on the potential hazards involved and on the local and/or Occupational Safety and Health Administration (OSHA) rules that apply to the job site. The most common items of personal safety equipment you will use as an HVAC technician are:

▼ Figure 2-3.
HVAC Technician Wearing Safety Glasses and Gloves



- *Hard hat* – Protects head from hard blows and falling objects.
- *Safety glasses or goggles* – Protect eyes from flying objects or chemical splashes.
- *Gloves* – Protect hands from cuts, scrapes, burns, and chemical or refrigerant spills.
- *Safety shoes* – Protect feet from falling objects and prevent sharp objects from puncturing the foot.
- *Ear plugs/muffs* – Protect ears from exposure to high noise levels.
- *Respirator* – Protects against breathing hazards or suffocation that might occur in the presence of certain refrigerants or other gases.
- *Safety harness/lanyard* – Prevents falls when working more than six feet above the ground or near deep holes.

To ensure that safety and protective equipment provides the intended protection, it should:

- Be inspected regularly.
- Be cared for properly as directed by the manufacturer's instructions.
- Be used properly, when needed, as directed by the manufacturer's instructions.
- Never be altered or modified in any way.

Loose-Fitting Clothing and Jewelry Hazards

Rings or other jewelry, neckties, cloth gloves, or loose-fitting clothing must not be worn when working around equipment with rotating or moving components. Motors that drive fans, compressors, and pumps are an example. If jewelry or clothing becomes caught in a motor drive pulley or coupling, severe injury could occur. Rings or watches must not be worn when working around energized electrical equipment *(Figure 2-4)*. Contact between the jewelry and an energized circuit may result in electric shock, injury, or death.

Lifting

Lifting or moving heavy objects causes many injuries. Lift with your legs rather than your back, because your leg muscles are stronger. When lifting heavy objects, wear a back support belt or similar device for added protection from injury. Use the following procedure to lift heavy objects *(Figure 2-5)*.

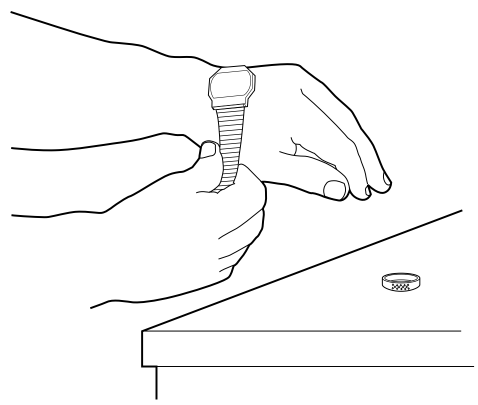
- Move close to the object to be lifted.
- Squat down. Keep your back straight and your chin tucked in. Position one foot behind the other with the forward foot at the side of the object.
- Grip the object from underneath using whole hands (not just fingertips), wrap your arms around it, or use lifting handles when provided.
- Draw the object close to your body.
- Lift the object by slowly straightening your legs. Keep the weight centered over your legs as much as possible. If possible, pick the object up in the direction of travel to avoid twisting your back or knees.

ELECTRICAL EQUIPMENT

When working on electrical equipment, always observe the precautions in the service literature, on tags, and on labels attached to or shipped with the unit. Perform all work to meet the local and national electrical codes. For additional guidance, refer to the current issue of the *National Electrical Code® (NEC®)*.

Electricity can be dangerous, but if you develop the proper safety attitude about working with it, you should have no problems. Working on HVAC equipment involves working near exposed electrical components and/or conductors. This can expose you to the potential hazards of electric shocks and burns.

▼ Figure 2-4.
Remove Watches and Other Jewelry Before Installing or Servicing Equipment



▼ Figure 2-5.
How to Lift Safely

QUICK NOTE

If an object is too heavy to lift comfortably, ask for assistance or use a hoist or other lifting device. Remember, it is a lot easier to ask for help than it is to nurse an injured back!

Electric Shock

Electric shock happens when electrical current flows through your body. It can damage your heart by causing it to beat erratically or it might even cause it to stop, resulting in death. High voltage levels, such as 120 volts AC or 240 volts AC, are always dangerous. However, even low voltages can be lethal *(Figure 2-6)*.

Many technicians think of DC voltages as low and relatively safe. In most cases, this is true. However, you can encounter high DC voltage in HVAC equipment that can be quite dangerous. Exercise caution in these situations.

Usually, the high resistance presented by the human body will prevent harm from low voltage. However, when skin is moist, or damaged as from a cut, the resistance of your body is greatly reduced. Under such conditions, even 40 volts or less can present a hazard. To prevent shocks, bodily contact between live (hot) circuits or a live circuit and ground must be avoided.

Circuit breakers with built-in ground fault circuit interrupters (GFCI) may be used to protect HVAC equipment. These circuit breakers protect the equipment from current overload. They also help to protect individuals against shock. The GFCI device in the circuit breaker can detect a small current leak to ground, causing the circuit breaker to trip and open the circuit. Such a leak may not be detected by a conventional circuit breaker.

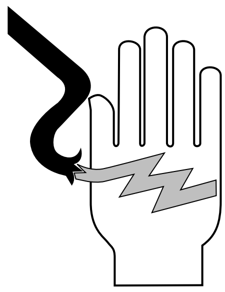
Portable, plug-in GFCI devices like the one shown in *Figure 2-7* are available that turn a standard utility outlet receptacle into a GFCI-protected circuit. GFCI-protected extension cords are also available. Use them for added protection against potential shock from an electrically-shorted power tool.

Electrical shock can result from using defective and/or improperly grounded power tools or from connecting power tools to improperly grounded utility circuits. Use only approved tools, equipment, and safety devices. Before use, always make sure that all tools, equipment, and safety devices are working properly and are in good condition.

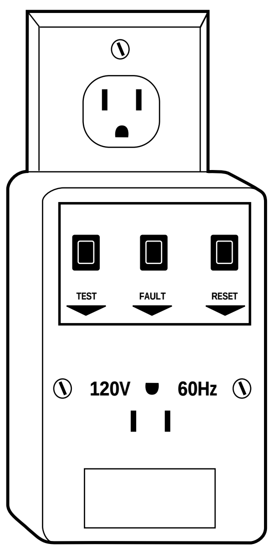
▼ Figure 2-6.
Both High and Low Voltages can be Dangerous

BE CAREFUL!

- **HIGH VOLTAGE IS ALWAYS DANGEROUS.**
- **EVEN 40 VOLTS CAN BE LETHAL IF SKIN IS WET OR DAMAGED.**



▼ Figure 2-7.
Portable Ground Fault Circuit Interrupter (GFCI) Module



When using tools or extension cords that have three-prong plugs, never remove or alter the grounding prong on the three-prong plug in order to insert it into a two-prong electrical utility outlet. If you must connect equipment to a two-prong outlet, always do so using an approved adapter with a green grounding lug. Make sure you connect the adapter grounding lug to a known ground such as a properly grounded outlet box. Since many outlet boxes are not properly grounded, always use a multimeter to verify that a good ground connection exists.

Electrical Burns

Electrical energy can pass for short distances through air. When it does, the arc and flash can cause burns, fires, and even explosions. Burns resulting from electrical arcs, such as in a short circuit to ground, can be extensive and deep. More serious burns can even result in amputation of the affected limb.

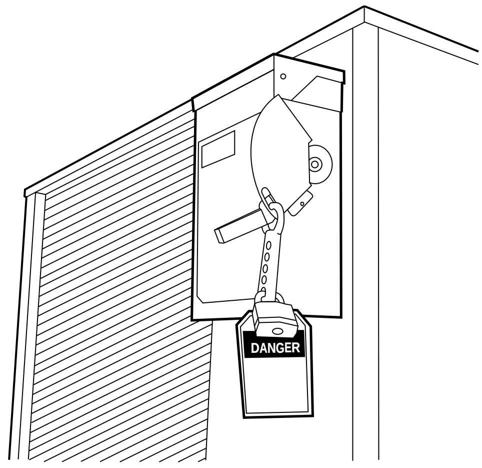
Lock Out/Tagout

Whenever possible, shut off electrical power at the disconnect or service entrance panel before working on HVAC equipment. As shown in *Figure 2-8*, the disconnect or panel should be locked in the off position with a padlock and tagged (lock out/tagout) to make others aware that service is in progress. Never assume that the equipment is "dead." Use a meter to verify it.

If you must perform a test with power applied, do not wear rings, watches, or other metal jewelry. Follow the safety guidelines listed below when you must work on equipment with the power on:

- Have only one hand in the unit.
- Avoid working in wet or damp conditions.
- Avoid working in poor light or when tired.
- Unless required by the manufacturer's service procedure, do not bypass safety devices such as door interlock switches.
- Make sure all grounds are connected properly.
- Use tools with insulated handles.

▼Figure 2-8.
Lock Out/Tagout Equipment Disconnect Switch



MECHANICAL EQUIPMENT

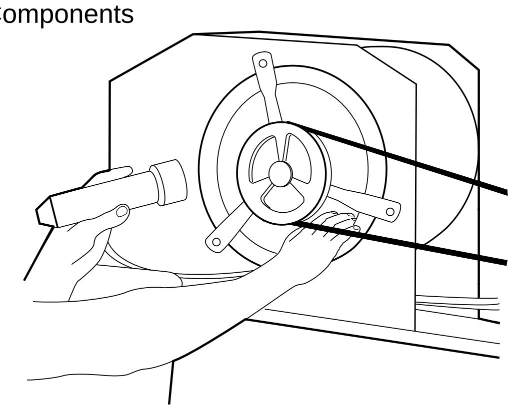
Rotating and Moving Parts

Equipment should not be operated without the coupling or belt guards installed, even if for only a short interval such as when checking motor rotation.

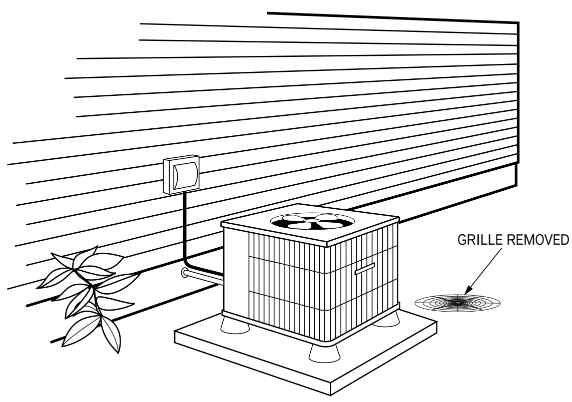
When servicing equipment, guards should not be removed from the equipment until it is deenergized, locked out, and tagged *(Figure 2-9)*. After removing electrical power from a unit, never attempt to service it until all rotating and moving parts have come to a complete stop *(Figure 2-10)*. Never try to stop a coasting motor or fan blade. If you grip the motor shaft, belt drive, pulley, or blades, the momentum can dismember or cut your hand severely or pull your hand into the rotating mechanism.

Loose hardware thrown from a rotating component can be deadly. All set screws and other attaching hardware must be tightened to specifications before starting a motor or other moving part. It is a good practice to tighten all coupling bolts twice to be sure that none have been overlooked.

▼Figure 2-9.
Deenergize, Lock Out, and Tag Equipment Before Removing Guards to Service Rotating Components



▼Figure 2-10.
Never Attempt Service Until all Rotating and Moving Parts have Stopped



Sharp Objects

Contact with sharp metal edges and other objects can cause injury. Be careful to avoid such contact when removing or replacing parts.

Hot and Cold Surfaces and Work Areas

Contact with hot surfaces can burn your skin and leave permanent scars. These surfaces include: furnace burners, heat exchangers, flues, electric heating elements, compressors, motors, and refrigerant lines.

QUICK NOTE

Even equipment that appears familiar may have special model differences from year to year. NEVER ASSUME ANYTHING! Always review and follow the manufacturer's instructions when installing or servicing any equipment.

Take care when soldering or brazing. High heat is present in the torch flame and the area surrounding the parts being soldered or brazed. When soldering or brazing, keep a fire extinguisher close by and know how to use it. Also, avoid wearing clothing made from manmade materials such as polyester because these materials can turn into molten plastic should a flame accidentally come in contact with the clothing.

Cold surfaces can be as harmful as hot ones. Contact with extremely cold metal surfaces can result in frostbite or other injury. Frostbite can also result from prolonged exposure to cold when working outdoors or inside a freezer or cold storage room.

REFRIGERANT AND OTHER PRESSURIZED GASES

Exposure to Refrigerants

Gloves and safety glasses must be worn when working with refrigerants. Avoid getting refrigerant on the skin or into your eyes. When accidentally released to the atmosphere, refrigerant can cause frostbite or burn the skin.

All refrigerants can cause suffocation if the concentration and time of exposure are great enough. Always provide adequate ventilation when working with refrigerants. Refrigerant vapor is invisible, usually has little or no odor, and is heavier than air. Therefore, be especially careful of low places where it might accumulate.

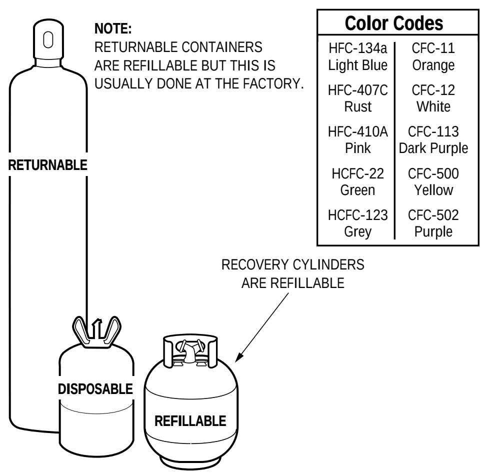
Equipment rooms or other areas with large machines holding large amounts of refrigerant must have alarm systems which detect small amounts of leakage and sound an alarm. Refrigerants increase dramatically in toxicity when exposed to an open flame or a hot surface. Self-contained breathing apparatus must be available outside the equipment room or other area containing large equipment in case leakage occurs and entry into the contaminated area becomes necessary. Some equipment rooms have a mechanical ventilation system to clear contaminated air from the room.

Refrigerant Containers

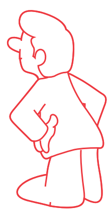
See *Figure 2-11*. Low-pressure refrigerants CFC-11, CFC-113, and HCFC-123 come in standard steel drums or cylinders. Their boiling point is close to, or slightly above, ambient temperature. The pressure they exert on the container is much less than that of medium and high-pressure refrigerants such as CFC-12, HCFC-22, HFC-134a, HFC-407C, HFC-410A, CFC-500, and CFC-502. These refrigerants are liquefied compressed gases. If improperly handled, the pressurized containers that hold these refrigerants can burst or leak, causing damage, injury, or even death.

Medium and high-pressure refrigerants come in either returnable or disposable metal containers which vary in shape and size. They range in capacity from about one pound of refrigerant to 1,000 pounds or more. ***Do not reuse disposable (nonreturnable) containers nor attempt to refill them.*** Disposable containers are made from common steel, which can rust. Rust weakens the container walls and seams so that they can no longer hold pressure and contain gases. Disposable cylinders should be stored in dry locations to prevent rusting, and transported carefully to prevent abrasion of their painted surfaces. Keep disposable containers in their original cartons as an added measure of protection.

▼Figure 2-11.
Refrigerant Containers



CAUTION



Refillable refrigerant containers must not be filled with more than 80% liquid. Never exceed their rated capacity in pounds as expressed by the net weight on the cylinder label. Be sure to take into account the container weight ("tare lbs.") when estimating the net weight of refrigerant in a cylinder. Excess liquid in a cylinder causes hydrostatic pressure that can result in an explosion. Hydrostatic pressure increases rapidly with even small changes in temperature.

NEVER HEAT A CYLINDER WITH AN OPEN FLAME OR PLACE AN ELECTRIC RESISTANCE HEATER IN DIRECT CONTACT WITH IT. If it is necessary to warm a cylinder, do it gradually and evenly with warm water *(Figure 2-12)*. Do not exceed 125° F on any part of the cylinder.

Always double check to be sure you are using the proper refrigerant. The containers are color-coded and are also labeled to identify their contents. Container labels also include product, safety, and warning information.

Technical bulletins and Material Safety Data Sheets (MSDSs) available from the manufacturers provide information important to your health and safety. They describe the flammability, toxicity, reactance, and health problems that could be caused by a particular refrigerant if spilled or incorrectly used.

In addition to the precautions described above, follow these rules when handling and using refrigerant containers *(Figure 2-13)*:

- Do not drop, dent, or abuse refrigerant containers. Do not tamper with safety devices.
- Always use a proper valve wrench to open and close the valve.
- Replace the valve cap and hood cap to protect the cylinder valve when not in use or empty.
- Secure containers in place to prevent them from becoming damaged from moving around, especially in a van or truck. Strap or chain cylinders in an upright position.
- Do not store containers where the temperature can exceed the cylinder relief valve settings.
- Do not mix refrigerants.

Other Pressurized Gas Hazards

Nitrogen, oxygen, acetylene, and LP gases are commonly used when installing or servicing HVAC equipment. These gases are compressed and shipped under medium to high pressures in cylinders. Because their use is so common, technicians often get careless about handling them.

Nitrogen – Nitrogen is supplied in cylinders at pressures of about 2,000 psi. These cylinders must not be moved unless the protective caps are in place. Dropping a cylinder without the cap installed may result in breaking the valve off the cylinder. This allows the pressure inside to escape, causing the cylinder to propel like a rocket *(Figure 2-14)*. Store nitrogen cylinders in an upright position and away from all flammable and combustible materials.

Because of the high pressure, a gauge-equipped pressure regulator must be used on the nitrogen tank *(Figure 2-15)*. In addition, a relief valve must be installed in the pressure feed line to limit the pressure to a safe level for use in the equipment being serviced.

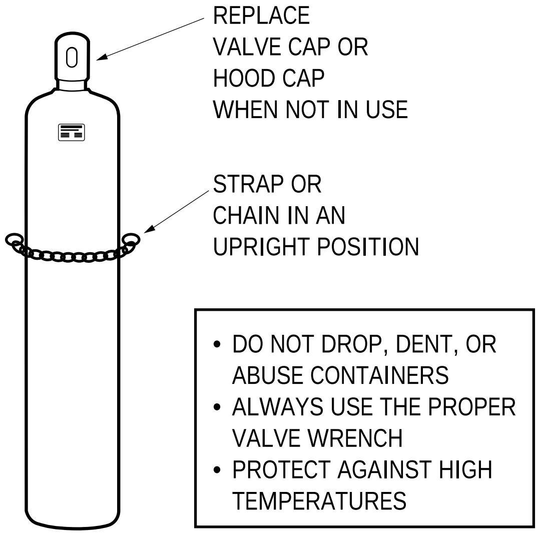
WARNING

NEVER CONNECT BOTH A REFRIGERANT CYLINDER AND A REGULATOR-EQUIPPED NITROGEN CYLINDER TO THE EQUIPMENT AT THE SAME TIME BECAUSE THE HIGHER PRESSURE NITROGEN CAN CAUSE THE REFRIGERANT CYLINDER TO EXPLODE.

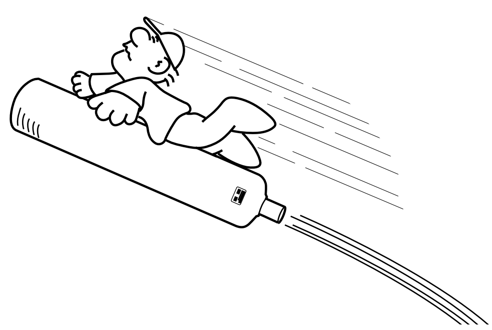
WARNING

▼ Figure 2-12.
Warming Cylinder with Warm Water

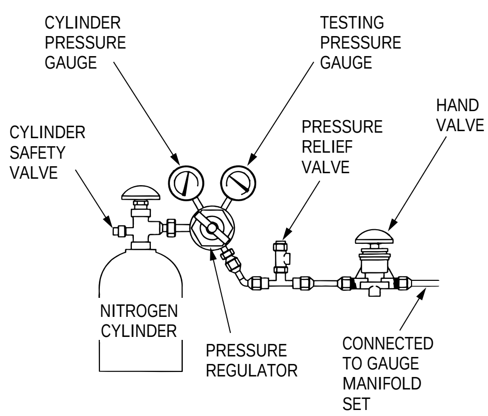
▼ Figure 2-13.
Refrigerant Container Safety



▼ Figure 2-14.
A Compressed Gas Cylinder Becomes a Dangerous Projectile if the Valve is Broken Off



▼ Figure 2-15.
Gauge-Equipped Pressure Regulator Used with Nitrogen

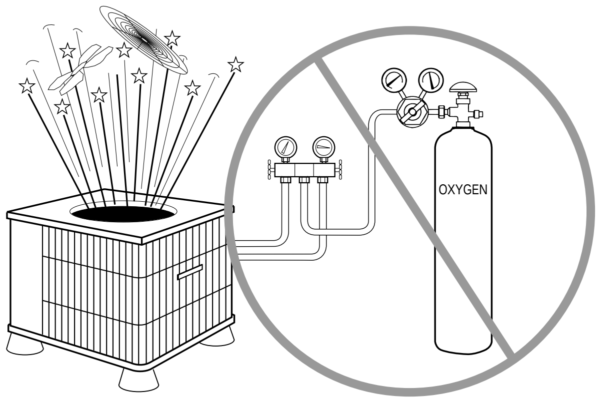


Oxygen – Like nitrogen, oxygen is supplied in cylinders at pressures of about 2,000 psi. When handling oxygen cylinders, follow the same precautions as for handling nitrogen cylinders.

Oxygen can cause ignition even when no flame or spark is present, especially when it comes into contact with oil or grease *(Figure 2-16)*. *OXYGEN MUST NEVER BE USED TO PRESSURIZE A SYSTEM SINCE AN EXPLOSION HAZARD EXISTS WHEN OIL AND OXYGEN ARE MIXED.* Never handle oxygen cylinders with oily hands or gloves. Keep oil and grease away from the cylinders and cylinder attachments or valves. Store oxygen in an upright position and away from all flammable and combustible materials, including gases like acetylene. There should be a minimum of 20 feet separating oxygen cylinders from fuel cylinders in storage, or they must be separated by a 1/2-hour minimum fire-rated wall that is at least five feet high. Never use an oxygen regulator for any other gas and never use a regulator for oxygen that has been used for other service.

WARNING

Figure 2-16.
Oxygen Mixed with Oil can Cause an Explosion



Acetylene – Acetylene cylinders are pressurized at about 250 psi. Even with its much lower pressure, acetylene should be handled with the same precautions as nitrogen and oxygen because acetylene is flammable. A pressure-reducing regulator must be used and set at a pressure of not more than 15 psig. ***ACETYLENE BECOMES UNSTABLE AND VOLATILE ABOVE 15 PSIG.*** The valve wrench should be left in position on open acetylene valves. This enables quick closing in an emergency. It is a good practice to open the acetylene valve as little as possible, but never more than 1-1/4 turns. Also, be sure not to use a torch tip that will exceed the flow capacity of the cylinder type (MC or B) being used. Use of too large a tip can result in excess flow from the cylinder, causing the tank absorbent (acetone) to be drawn from the cylinder and flow into the regulator, hose, and torch. This can occur when small multiple-flame (rosebud) tips are used with an MC cylinder or large rosebud tips are used with a B cylinder.

WARNING

Liquid Petroleum (LP) – LP gases such as propane and butane are usually pressurized at less than 300 psi and should be handled with the same precautions as nitrogen and oxygen. LP gas is heavier than air and explosive. It is normally used as a fuel gas in furnaces. As with the other gases discussed, a pressure-reducing regulator must be used. Gloves and safety glasses must be worn when working with LP gas. When accidentally released to the atmosphere, LP gas can cause frostbite or burn the skin. Do not use pure LP gas in a furnace set up for natural gas because an unsafe condition will be created. If using LP gas for soldering, be sure not to turn the cylinder upside down. This allows liquid fuel to flow into the torch and may cause an explosion.

Figure 2-17 summarizes the cylinder pressures of common gases.

Figure 2-17.
Cylinder Pressures of Common Gases

GAS	PRESSURE
NITROGEN	2,000 psi
OXYGEN	2,000 psi
ACETYLENE	250 psi
LIQUID PETROLEUM	<300 psi

GAS AND OIL HEATING EQUIPMENT

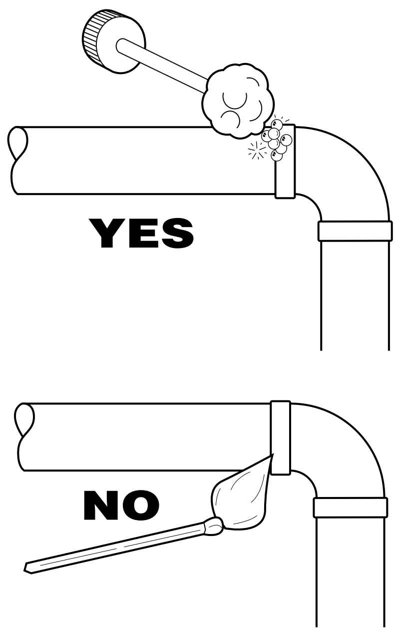
When working on heating equipment, always observe the precautions in the service literature, on tags, and on labels attached to or shipped with the unit. Perform all work to meet the local and national gas or oil codes. For additional guidance, refer to the current issues of the National Fuel Gas Code (NFPA No. 54/ANSI Z223.1) and/or the National Fire Protection Association Code.

Gas Leaks

Heating equipment can be hazardous due to the combustible fuels involved. Natural gas can be dangerous because it can displace oxygen in the air and, if it accumulates, can be explosive. LP gases are heavier than air and can collect in low places to form pockets of highly explosive gas. All fuel gases have odorants added to make leak detection easier. If a leak occurs that causes gas to collect inside a building, the following immediate actions must be taken:

- Clear the area of all occupants. Do not re-enter until it is known to be safe.
- Notify the local gas utility.
- Shut off the supply of gas.
- Use every reasonable means to eliminate sources of ignition. Do not operate electric switches. If lights are already turned on, do not turn them off. If turned off, leave them off.
- Ventilate the area by opening windows and doors.
- Never use matches, candles, a flame, or other sources of ignition to check for gas leaks. Use a soap and water solution *(Figure 2-18)*.
- Use only a battery-operated flashlight or approved safety lamp when searching for the leak.

▼Figure 2-18.
Never Use an Open Flame to Check for Leaks



Oil Leaks

Fuel oil on the floor or an accumulation in the furnace combustion chamber are usually signs of a leak. Leaking fuel oil in the presence of air and an ignition source can result in a fire. As a precaution to prevent leaks, compression fittings should not be used to pipe an oil-burning system. Absorb and clean any oil spilled on the floor with rags, absorbant, a suction pump, shop vacuum, etc. *(Figure 2-19)*.

Care should be taken not to start a furnace if any oil has accumulated in the combustion chamber. If oil has accumulated, shut off the oil valves and vent the chamber. Turn off the electrical power. Remove the oil with a suction pump.

If the puddle of accumulated oil is ignited, it will burn intensely. You may not be able to extinguish the fire; it will have to burn itself out. If this happens:

- Notify the fire department.
- Shut off the burner motor but allow the furnace fan to run to help dissipate the heat.
- Shut off the air shutter to reduce the air to the burner.
- Let the fire burn itself out with reduced air.

▼Figure 2-19.
Always Clean Up Oil Leaks Immediately

Standing Leak Test and Purging

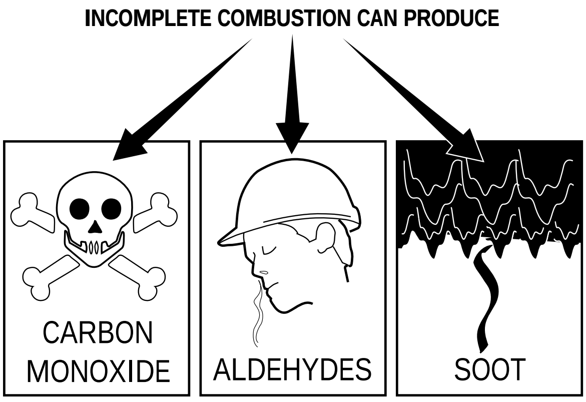
OXYGEN MUST NEVER BE USED TO LEAK TEST OR PURGE A GAS OR OIL FURNACE PIPING SYSTEM SINCE AN EXPLOSION HAZARD EXISTS WHEN OIL AND OXYGEN ARE MIXED.

After the leak test of a gas furnace is completed, the gas trapped in the system should be purged in a well-ventilated area to rid the system of air or other gases. When doing so, be careful not to purge the gas where it will collect in the furnace combustion chamber. After purging, but before operating the unit, it is a good practice to wait at least 5 minutes to allow any accumulated gas to dissipate. When lighting the furnace pilot, never stand in front of or look into the combustion chamber.

Incomplete Combustion

Only experienced technicians should make furnace combustion adjustments and then only as directed by the manufacturer's instructions. Fuel and combustion air must be mixed safely. Incorrect gas or oil pressure, wrong orifice type or size, or improper burner position or adjustment can result in incomplete combustion. This causes the furnace to produce aldehydes, soot, and carbon monoxide (CO) gas *(Figure 2-20)*. Carbon monoxide gas is deadly. Prolonged breathing of carbon monoxide can result in sickness or death. An inadequate supply of primary or secondary air to the burners caused by some restriction to airflow can cause flame rollout, possibly starting a fire.

Figure 2-20. Incomplete Combustion



Other Gas and Oil Heating Precautions

In addition to the safety precautions discussed above, observe the following guidelines when servicing gas and oil heating equipment:

- Gas, oil, and electricity should be turned on only when it is necessary to check the operation of a component or the furnace. At all other times during equipment maintenance, they should be turned off.
- Gas and oil furnaces should not be installed where flammable vapors or combustible materials exist.
- Never operate a furnace with a corroded, pitted, or cracked heat exchanger. Leaking combustion gases may cause sickness or death.
- Do not jumper limit switches or other safety devices. These devices protect the furnace, building, and occupants from fire or damage caused by malfunctions that result in overheating.
- Gas and oil furnaces must be properly vented to avoid leaking carbon monoxide in the heated area should the furnace combustion be incomplete. Also, any vent gases that leak into the heated area will reduce the oxygen level.
- Be extremely cautious when working around energized pilot lights, electronic spark igniters, and oil furnace ignition circuits. The control transformer secondary voltage and electrodes of some ignition devices operate in the range of about 10,000 to 20,000 volts.

INSTALLATION TOOL USE PRECAUTIONS

Installation work requires that you take precautions to work safely with power tools and other installation equipment while performing the various tasks.

Power Tools

The general safety procedures used when working with power tools are basically the same regardless of the tool being used. Safety begins by dressing properly and wearing safety glasses and face and/or dust masks, if appropriate. Loose clothing and jewelry must be removed because they can become caught in the moving parts of tools or equipment. Safety-type non-skid footwear must be worn. Protective hair coverings must be worn to prevent long hair from becoming caught in moving parts.

Before using a tool, inspect and check that the guards are properly attached and make sure that they operate properly and will work as intended *(Figure 2-21)*. Check for alignment and/or binding of moving parts, and any other condition that may affect operation. Always repair or replace any damaged guard or other damaged part before using a tool.

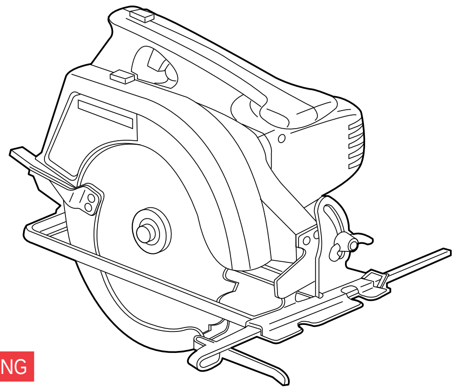
Use the right tool *(Figure 2-22)*. Do not use a light-duty tool to do the job of a heavy-duty tool, or use one for a purpose for which it was not intended. The right tool will do a better job and be safer to use.

NEVER OPERATE PORTABLE ELECTRIC TOOLS IN EXPLOSIVE ATMOSPHERES SINCE THE MOTORS IN THESE TOOLS NORMALLY GENERATE SPARKS WHICH CAN IGNITE ANY FUMES. Keep work areas clean because clutter invites injury. Customers and visitors should be prohibited from the immediate work area to prevent accidents. Also, dangerous practical jokes and horseplay must be avoided because they can result in accidents *(Figure 2-23)*.

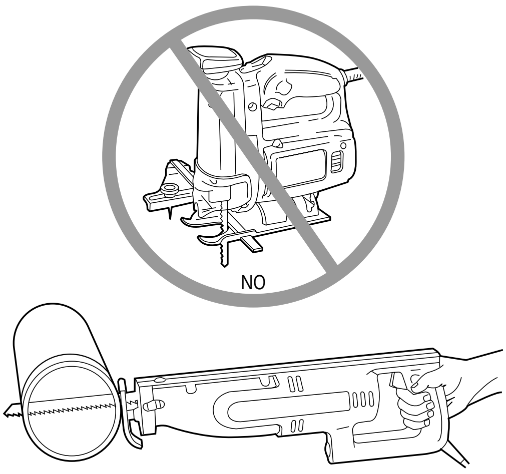
In addition to the precautions previously described, also follow these rules:

- Always operate the tool as directed in the manufacturer's instructions.
- Never carry a tool by its cord or yank the cord to disconnect it from a receptacle. Keep the cord away from heat, oil, and sharp edges.
- Stay alert. Watch what you are doing and use common sense. Do not operate a tool when you are tired.
- Use clamps or a vise to hold the work. It is safer and it frees both hands to operate the tool *(Figure 2-24)*.
- Make sure to remove adjusting keys and wrenches before turning the tool on.
- Disconnect tools when not in use, before servicing, and when changing blades, bits, and cutters.
- Prevent unintentional starting. Do not carry tools plugged into electrical outlets with your finger on the switch. Be sure the switch is set to the OFF position before plugging a tool into an outlet.
- Avoid overreaching by keeping proper footing and balance at all times while using the tool.
- When using an extension cord outdoors, always use one approved for outdoor use.

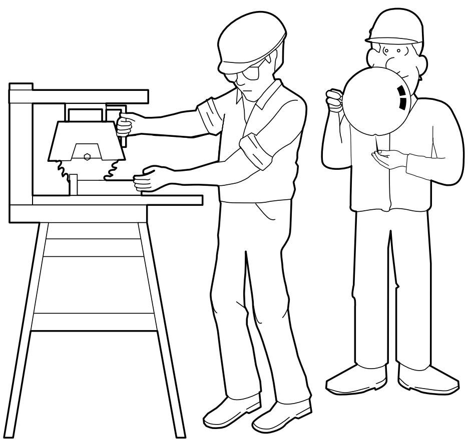
▼Figure 2-21.
Inspect Tools Before Using



▼Figure 2-22.
Use of the Right Tool is Safer



▼Figure 2-23.
Horseplay can be Dangerous



Air-powered tools are sometimes used instead of electrical-powered tools for drilling and cutting jobs. When using air-powered tools, follow the same general safety practices as would be used with the similar electrical tool. Before disconnecting the air supply hose from a tool, make sure to first shut off the air supply and use the tool trigger to bleed off and vent the air in the hose.

Powder-actuated tools that use a gunpowder cartridge are sometimes used to drive fasteners into steel or concrete. Because of the potential danger that the misuse of these tools may cause, only trained and certified employees are permitted to operate these tools. Refer to Section 3 for detailed information about powder-actuated tools, including any safety-related factors.

Ladders and Scaffolding

Before use, ladders should always be inspected to make sure the rails, rungs, safety latches, and feet are not missing, broken, damaged, or loose. It is important that both straight and extension ladders be raised and placed at the proper angle before climbing them *(Figure 2-25)*.

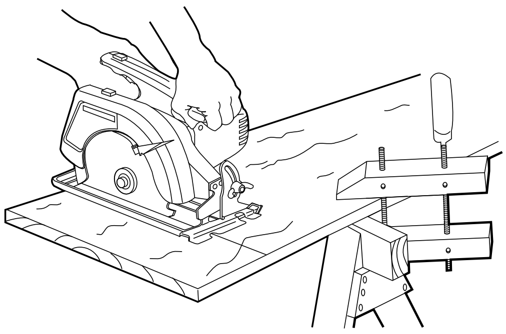
Once upright, raise the extended section to the desired height, making sure that the safety latches are engaged. Position the bottom of the ladder so that the horizontal distance between the ladder's feet and the wall is about 1/4 the ladder's vertical height or *working length*, which is the length of the ladder between the foot and the top support *(Figure 2-26)*. Both of the ladder's feet should be an equal distance from the wall, so the ladder does not rock. If you are going to step off the ladder onto a platform or roof, the top of the ladder should extend at least 3 feet beyond the support point.

Once the ladder is in position, fasten and/or block it securely at the top and bottom. Step ladders should always be opened and set level on all four feet, with the spreaders locked in place *(Figure 2-27)*. Never use a step ladder like a straight ladder or stand on the top two steps. For balance, lean your body into the ladder. When you can no longer reach your work comfortably, get down and move the ladder.

Falls account for most of the accidents that occur when working on ladders. To prevent falls and other accidents, follow these precautions:

- Never use a damaged ladder or one with broken or missing rungs or steps. Any such ladder should be removed from service.
- Barricade or put guards around a ladder that is erected in doorways, passageways, or any location where it can be jarred or knocked over by others.
- When climbing up a ladder, keep both hands on the rails and your body's weight centered between the rails.
- Face the ladder at all times when working from it. If it is necessary to work backwards, use a harness or safety belt with a lanyard.
- Do not carry tools or materials in your hands while climbing a ladder. Haul them up or have someone hand them to you.
- Never try to move a ladder while standing on it.
- Do not use metal ladders near electric lines or services.
- Never use a ladder as a scaffold by placing it horizontally and standing on it. Ladders are made for vertical use only.

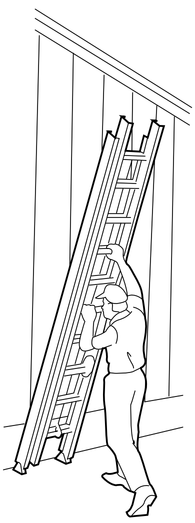
▼ Figure 2-24.
Clamp Work and Use a Two-Hand Grip



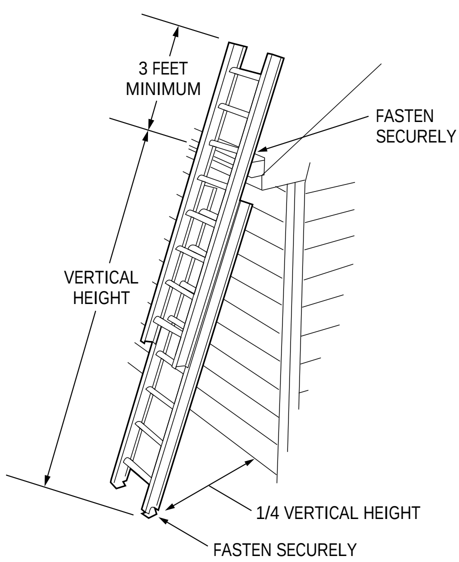
QUICK NOTE

Only trained and certified persons may operate explosive powder-activated tools. Certification is established by the possession of an accredited operator's card.

▼ Figure 2-25.
Raising the Extension Ladder



▼ Figure 2-26.
Proper Positioning of an Extension Ladder



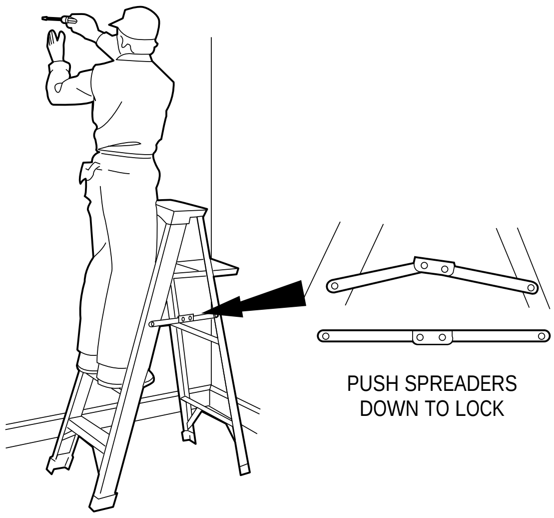
Metal scaffolds may sometimes be used instead of ladders. When erected level and plumb on a firm base, scaffolds provide a safe, secure elevated work platform. A green, red, or yellow tag should be attached to any scaffold that is assembled and erected to alert users of its current mechanical and/or safety condition *(Figure 2-28)*. Do not rely solely on the tag. Inspect all parts of a scaffold before each use. Handrails, toeboards, and decking must all be in place, all wheels must be locked on movable models, and all locking pins must be installed. Other precautions that must be taken when working on scaffolds are:

- Never exceed the weight limit of the scaffold. This stated weight limit includes the total weight of people, tools, equipment, and materials.
- Do not climb on or work from any scaffold railing or brace members. Use a ladder to get on the scaffold.
- Keep a minimum of 15 feet separation between the scaffold and any energized electrical lines or equipment.
- Remove or secure all tools and materials on a scaffold's deck before moving the scaffold. Do not ride on the scaffold when it is being moved. Watch overhead clearances when moving.
- If people can pass under the scaffold, screen the space between the toeboard and top rail to prevent tools and materials from falling off the work platform.
- Do not use scaffold railings or braces for rigging.

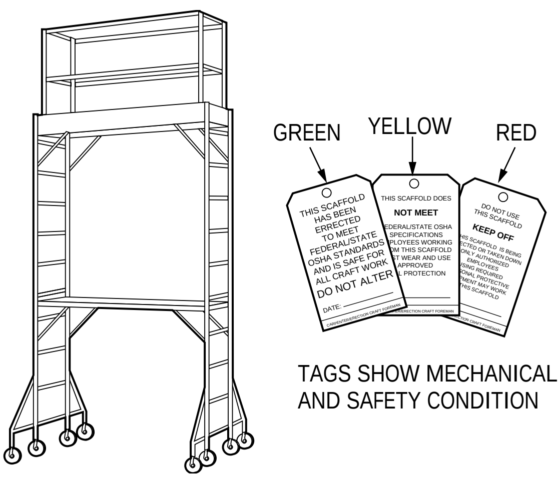
QUICK NOTE

To ensure extension ladder strength and your safety, keep a minimum overlap between extended sections of 3 feet for 16- to 36-foot ladders; 4 feet for 36- to 48-foot ladders; and 5 feet for 48- to 60-foot ladders.

▼ Figure 2-27.
Position Step Ladder so Feet are Level on Floor and Braces are Locked



▼ Figure 2-28.
Check Tags on Assembled Scaffolds



QUICK NOTE

SCAFFOLD TAGS

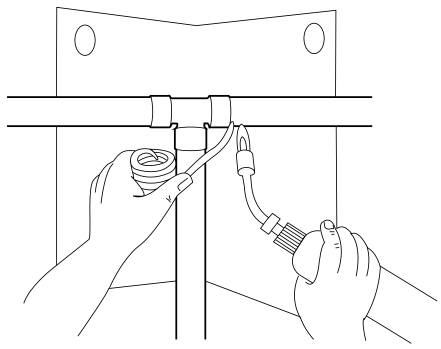
- Green Tag – Meets OSHA standards and is safe to use.
- Yellow Tag – Scaffold does not meet all OSHA standards. It can be used; however, it is mandatory that the person using it wear and properly use a safety harness and lanyard fall protection gear.
- Red Tag – Keep off, the scaffold is damaged and unsafe, or in the process of either being erected or taken down.

Soldering and Brazing Equipment

Soldering and brazing tasks normally involve the use of torches and accessories. The general safety precautions described earlier in this section about the use and handling of pressurized gases apply. The precautions given in *Figure 2-38* at the end of this section also apply. Procedures for soldering and brazing, including safety factors, are provided in Section 5. The material in both this section and Section 5 should be reviewed and understood before you attempt any soldering and/or brazing tasks. Other precautions to take when using soldering and brazing equipment are:

- To extinguish any fires, always keep a fire extinguisher within 25 feet of the work area.
- Use flame retardant shields to help protect adjacent areas from flame and spark damage *(Figure 2-29)*.
- Wear protective gloves and use proper tools to handle hot work. When brazing, wear goggles having an ANSI Z87.1 standard shade No. 4 or 5 lens.
- Do not point the torch flame towards your face or body or at other persons.
- Avoid getting flux on the skin or in the eyes. Avoid inhaling soldering or brazing fumes.

▼Figure 2-29.
Use a Fire Retardant Shield to Protect the Surrounding Area and Components from Flame and Spark Damage



Rigging Equipment

Rigging involves the movement of equipment and materials using ropes, slings, cables, rollers, hoists, and cranes. It is necessary that you be aware of rigging techniques and safety factors in order to prevent injury or damage to the equipment. For safe rigging, the tools and equipment used must be in good condition and of the required strength to handle the load *(Figure 2-30)*.

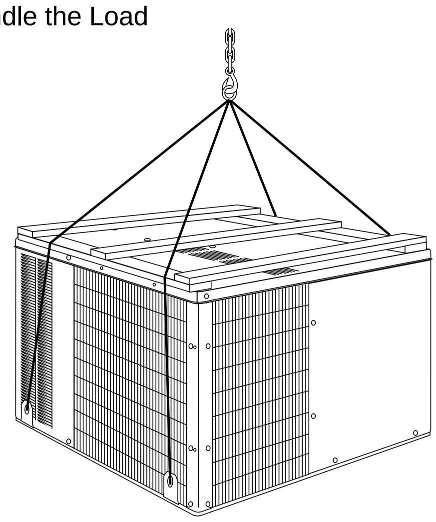
Always refer to the manufacturer's literature to find the maximum weight of the equipment. Always follow all warnings and cautions about rigging and mounting of the equipment given in the installation instructions and/or on instruction labels on the equipment.

General safety precautions for the use and handling of rigging equipment and loads are shown in *Figure 2-40* at the back of this section. The material in both this section and Section 4 should be reviewed and understood before attempting any rigging tasks.

QUICK NOTE

- On sunny days, it may be difficult to see the torch's flame.
- On windy days, the torch's heat may be carried towards you or to areas not intended to be heated.

▼Figure 2-30.
Rigging Tools and Equipment Must be in Good Condition and of the Strength Required to Handle the Load



EXTREME HOT AND COLD WEATHER PRECAUTIONS

Performing service or installation work outdoors in extreme heat or cold requires that appropriate precautions be taken to prevent bodily injury or illness.

Hot Weather Precautions

Heat stroke can result from heavy exertion in high temperature and/or high humidity conditions. When working in these conditions, dress in loose, cool cotton clothing and take periodic breaks to avoid overexerting yourself.

Heat stroke can be life-threatening because the body's heat-regulating mechanism stops working. This can cause convulsions, unconsciousness, and even death if the body is not cooled quickly. ***If heat stroke occurs, do not delay getting immediate medical attention for the affected person.*** To help reduce the body temperature, move the person to a cool place and remove as much clothing as possible. Douse the person with water or wrap him or her in a wet sheet.

Heat exhaustion and heat cramps happen when body fluids are lost through heavy sweating, but the sweat cannot evaporate fast enough to cool the body. To help reduce body temperature, the affected person should be moved to a cool place and clothing removed. Cramped muscles can also be gently stretched and massaged. Give sips of salt water and get immediate medical attention.

Cold Weather Precautions

Working in extremely cold weather requires that you dress adequately to protect against the cold. Dress in layers to allow you to adjust to changing temperature conditions. Cotton or lightweight wool should be worn next to the skin with wool layers over the undergarments. Outer garments should be waterproof and wind resistant. A hat with ear protection prevents heat loss from the head. Waterproof boots should be worn in wet or snowy weather.

The effects of hypothermia (low body temperature) are gradual, and often go unnoticed until it is too late. It is recommended that a buddy system be used when working in extreme cold. If working alone, let someone know where you will be and what time you expect to return. ***Get immediate medical attention for hypothermia.*** Move the person indoors and remove any wet clothing. If the person is conscious, give hot liquids and/or a hot bath to speed up the warming process.

The ears, nose, hands, and feet can be affected by frostbite. ***If affected by frostbite, cover the frostbitten area to protect it and get immediate medical attention.***

QUICK NOTE

SYMPTOMS OF HEAT STROKE

- Sudden onset
- Dry, hot, and flushed skin
- Dilated pupils
- Loss of consciousness
- Fast pulse
- Deep breathing at first, later shallow or almost absent
- Muscle twitching
- Body temperature 105° F or higher

CAUTION

SYMPTOMS OF HEAT EXHAUSTION/ HEAT CRAMPS

- Weak pulse
- Rapid and usually shallow breathing
- General weakness
- Pale, clammy skin
- Heavy sweating
- Dizziness, disorientation
- Slightly above normal body temperature
- Painful muscle cramps

QUICK NOTE

SYMPTOMS AND PROGRESSION OF HYPOTHERMIA

- Shivering
- Slurred speech
- Mental confusion
- Drowsiness and weakness
- Glassy stare
- Respiration and pulse rate become slower and slower
- Extremities freeze
- Death

CAUTION

SYMPTOMS AND PROGRESSION OF FROSTBITE

- Exposed skin reddens
- Skin takes on a gray or blotchy appearance, especially at the ear lobes, cheeks, and tip of the nose
- Exposed skin surface becomes numb
- All sensation is lost and the skin becomes white

CAUTION

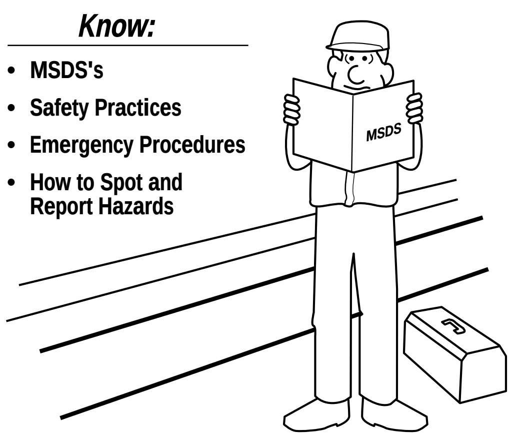
GENERAL SAFETY AWARENESS

Hazard Communication Standard

The work place contains many hazards that need to be recognized and respected *(Figure 2-31)*. The OSHA Hazard Communication Standard (HazCom), commonly called the “Right To Know” requirement, affects every worker. It addresses the worker’s right to know the specifics about any major environmental, chemical, biological, physical, or radiation hazards that may exist at the job site. It requires that a Material Safety Data Sheet (MSDS) accompany every shipment of a hazardous chemical or substance and be available to you on the job site. It is your responsibility to:

- Read the Material Safety Data Sheets that pertain to your work and work location to identify any physical and health hazards.
- Know and practice the actions necessary to protect yourself and others from any hazards. Know the actions to take in an emergency.
- Spot and report potential hazards on the job.

▼ Figure 2-31.
Safety Depends on Your Awareness

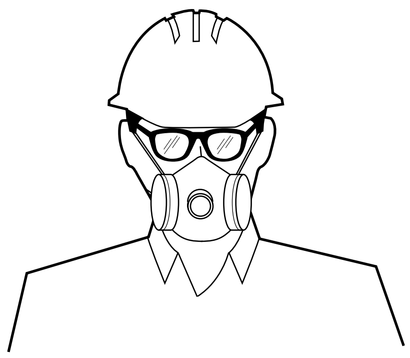


Confined Spaces

Installation and service work is not always done outside or in open areas. Much of it takes place in confined spaces. A confined space is any area that cannot be easily ventilated, such as a basement equipment room. Confined spaces can contain hazardous gases and/or fluids when the equipment is operating. Work you are doing, such as soldering and brazing, may introduce hazardous fumes into the space. To ensure safety, special precautions are needed before entering, and while working in, a confined space:

- Have one person inside and one outside the confined space. Voice or visual contact should be maintained to identify the need for aid in case of an emergency.
- Keep rescue equipment ready for an emergency.
- Use respiratory protection equipment when required *(Figure 2-32)*. If in doubt, have air sample readings taken to check for low levels of oxygen and/or explosive gases.
- Use only approved electrical tools, extension cords, etc.

▼ Figure 2-32.
Use Respiratory Equipment when Required



Hazardous Waste Management

Waste such as used oil or refrigerant, chlorinated solvents, chemical treatment solutions, acids, etc. may contain toxic components that require special handling and proper disposal at an EPA-approved waste management facility. When working with hazardous waste:

- Be knowledgeable about the use of chemicals from the Material Safety Data Sheets and follow the manufacturer’s instructions.
- Wear the proper protective equipment, such as safety goggles, rubber gloves, and aprons when handling or containing hazardous waste.
- Use only EPA/DOT-approved containers for storage, transport, and disposal of hazardous wastes. Make sure the content of the container is identified by the proper EPA/DOT label containing all the required information.

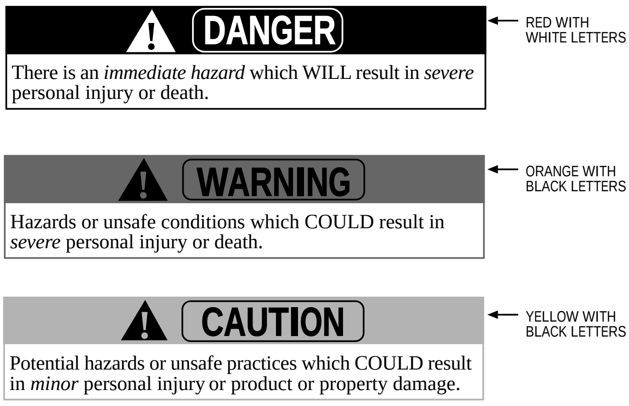
SUMMARY OF DANGERS, WARNINGS, CAUTIONS, AND SAFETY INSTRUCTIONS

The terms *DANGER, WARNING*, and *CAUTION* have specific meanings that have been designated by the American National Standards Institute (ANSI) to clearly identify the degree of hazard. The definitions and color coding shown in *Figure 2-33* are typical of those used in the HVAC industry to prioritize safety hazards.

Figures 2-34 through *2-41* shown in the remainder of this section are typical examples of safety precautions and information you will see both in equipment manufacturer's Installation, Start-Up, and Service literature and on equipment warning labels.

To avoid hazards and servicing mistakes, it is a good practice to always review a procedure before doing it. This review makes you aware of, and able to handle, all of the important safety conditions before you start.

▼ Figure 2-33.
Typical Terms Used to Prioritize Safety Hazards



▼ Figure 2-34.
Electrical Equipment Precautions

⚠ DANGER

DO NOT attempt to check voltage supplies until you know the proper procedures and have the proper equipment. SEVERE PERSONAL INJURY CAN RESULT. Consult your power company for specific instructions and obtain their services when necessary.

DO NOT attempt to take measurements on high-voltage systems (600 volts or over) with hand-held instruments. Always use current and potential transformers to take high-voltage measurements.

DO NOT take measurements or make continuity checks on a compressor until you are sure that ALL POWER IS TURNED OFF TO THE UNIT OR SYSTEM, INCLUDING THE CRANKCASE HEATERS. When taking voltage, current, or continuity measurements on a hermetic or semi-hermetic compressor in a pressurized system, always take measurements at terminal boards and test points away from the compressor, rather than at the compressor. If the compressor terminals are damaged and the system is pressurized, disturbing them to take measurements could cause them to blow out, causing injury. Once a system has been evacuated and is no longer under pressure, measurements can be taken at the compressor. Check the lockout and tagout of both electrical components and the compression system.

⚠ WARNING

DO NOT work on high-voltage equipment unless you are an experienced HVAC technician qualified to maintain electrical equipment or a qualified electrician.

GROUND all electrical equipment.

USE a ground fault circuit interrupter with power hand tools.

DO NOT work on electrical components, including control panels, switches, starters, or heaters until you are sure that ALL POWER IS OFF and *no residual voltage* can leak from capacitors or solid-state components.

LOCKOUT AND TAGOUT electrical circuits before working on them. IF WORK IS INTERRUPTED, confirm that the circuits are deenergized before resuming work.

DO NOT remove terminal box covers while machine or compressor is running.

DO NOT tighten any connection on a terminal board until the main disconnect switch is in the OFF position and locked out.

DO NOT attempt to stop a machine by opening an isolating knife switch. High intensity arcing can occur and cause serious injury.

NEVER USE an ohmmeter in any energized circuit. Destruction of the meter could result in personal injury.

NEVER apply voltage to or operate a compressor when there is a vacuum in the system. This can cause the compressor terminals to fail due to internal arcing which, in turn, can result in severe personal injury.

NEVER energize a compressor until the discharge service valve is open to the system. Failure to do so can result in excessive pressure buildup.

DO NOT exceed the manufacturer’s torque specifications when making electrical connections. Terminal bolts could snap and propel from the terminal block.

⚠ CAUTION

BE AWARE that certain automatic start arrangements *can engage the starter*. Open the disconnect and lock it out *ahead of* the starter in addition to shutting off the machine or pump.

DO NOT bypass, block interlocks, or remove a lockout/tagout that is in place unless it is yours.

MINOR SHOCKS can surprise you. While the shock itself would probably not be injurious, a resulting fall could be.

DO NOT check a circuit until you are sure that the power is off in any adjacent circuit.

▼ Figure 2-35.
Gas and Oil Heating Equipment Precautions

WARNING

Improper installation, adjustment, alteration, service, maintenance, or use of equipment can cause carbon monoxide poisoning, explosion, fire, electrical shock, or other conditions which may cause personal injury or property damage. Consult a qualified installer, service agency, local gas supplier, or your distributor or branch for information or assistance. The qualified installer or agency must use only factory-authorized and listed kits or accessories when modifying products. Failure to follow this warning could result in electric shock, fire, personal injury, or death.

When a furnace is installed in a residential garage, it must be installed so that burners and ignition sources are located a minimum of 18 in. above the floor. The furnace must be located or protected to avoid physical damage by vehicles. When a furnace is installed in a public garage, airplane hangar, or other building having a hazardous atmosphere, the unit must be installed in accordance with the requirements of the National Fire Protection Association Inc.

NEVER USE OXYGEN OR COMPRESSED AIR to leak test or purge gas or oil furnace piping systems since an EXPLOSION HAZARD exists when oil and oxygen are mixed. Follow the manufacturer's recommendations for leak testing or purging.

NEVER use matches, candles, flame, or other sources of ignition for the purpose of leak detection. Use a battery-operated flashlight or approved safety lamp when searching for the source of the leak. For gas leaks, use a soap-and-water solution to check for leakage. Failure to follow this warning could result in fire, explosion, personal injury, or death.

NEVER purge a gas line into a combustion chamber. Failure to follow this warning could result in fire, explosion, personal injury, or death.

Use the proper length of pipe to avoid stress on the gas control manifold. Failure to follow this warning could result in a gas leak resulting in fire, explosion, personal injury, or death.

▼ Figure 2-36.
Leak Testing and Pressure Testing Precautions

DANGER

NEVER USE OXYGEN to leak test, purge lines, or pressure test a machine. Nitrogen is recommended for these purposes. Always use a gauge-equipped regulator on the nitrogen cylinder and verify that the gauge has been recently checked and calibrated.

The full pressure of a nitrogen cylinder can cause a refrigerant cylinder to rupture violently. Therefore, when using nitrogen and a refrigerant trace for leak testing, *always put the refrigerant in first.* Then valve off and remove the refrigerant cylinder before connecting and adding the regulated nitrogen.

NEVER EXCEED the specified field leak test pressures. Verify the allowable *field test* pressure by checking the instruction literature.

Do not allow the full cylinder pressure to enter a pressurizing line. Valve off and *disconnect* the nitrogen cylinder when the recommended test pressure is attained. Do not rely on the shutoff valve or pressure regulator.

Do not pressure test any vessel at its design pressure (found on the equipment nameplate). Testing at these pressures must be done in a special enclosure or by using a hydraulic fluid under the direction of the manufacturer.

Do not confuse water (brine) side test pressures with refrigerant side test pressures.

HEAVY CONCENTRATIONS of nitrogen within a confined space or area can displace enough oxygen in the work area air to cause suffocation.

DO NOT enter any vessel or confined space immediately after the use of significant amounts of nitrogen without the protection of SCBA or first testing the oxygen level. Utilization of respiratory protection should not be needed if adequate ventilation of the space is allowed to occur prior to entry and the oxygen level has been tested and is above 19.5 percent.

▼ Figure 2-37.
Mechanical Equipment Precautions

DANGER

DO NOT remove coupling (or belt) guards to work on a machine until all rotating parts have come to a complete halt.

MACHINES MUST BE locked out and tagged out regardless of the type of energy powering the equipment.

NEVER ENTER an enclosed fan cabinet or reach into a unit while the fan is running.

NEVER use a torch to remove a compressor or component from the refrigerant circuit. The oil could ignite and cause a fire. Use a pipe cutter and follow correct procedures when cutting refrigerant lines.

WARNING

NEVER OPERATE an open-drive machine, pumpout unit, or other equipment without coupling (or belt) guards in place. This warning applies even to short runs such as a motor rotation check. Serious injury can result from contact with moving parts.

NEVER loosen any head or cover bolts when the compressor is open to the system or when it is under pressure. Make sure the internal pressure is at 0 to 2 psig *before* any bolts are loosened to prevent propulsion of compressor parts.

DO NOT attempt to remove fittings and covers or break lines while the machine is under pressure or while it is running.

USE CARE when working near or in line with a compressed spring. Sudden release of the spring can cause it and objects in its path to act as projectiles.

DO NOT syphon refrigerants or other chemicals by mouth. Check the manufacturer's instructions for correct syphoning procedures.

CAUTION

DOUBLE CHECK that coupling nut wrenches, dial indicators, or other items have been removed before rotating any shaft. Remember to wear safety glasses.

PERIODICALLY INSPECT couplings for proper lubrication and alignment to minimize the possibility of failure and resultant flying particles.

TIGHTEN all coupling bolts *twice* to be sure that none have been overlooked.

CHECK coupling locknuts for tightness and for insertion of setscrews.

DO NOT weld or flamecut any vessel or line until all refrigerant has been removed.

DO NOT loosen a packing gland nut before making sure that it has a positive thread engagement.

PERIODICALLY INSPECT all valves, fittings, and piping for corrosion, rust, leaks, or damage.

VALVE OFF AND TAG steam, water, and refrigerant lines before opening them.

DO NOT step on refrigerant lines. Broken lines can whip about and cause severe personal injury.

USE only repair or replacement parts that meet the code requirements of the original equipment.

▼ Figure 2-38.
Oxyacetylene Welding and Cutting Precautions

⚠ DANGER

DO NOT use oxygen as a substitute for compressed air, or for any purpose other than welding or flamecutting.

⚠ WARNING

DO NOT store oxygen cylinders near combustible material, especially oil and grease, nor handle oxygen cylinders or apparatus with oily hands or gloves.

Oxygen supports and accelerates combustion and will cause oil, grease, and plastic materials to burn with great intensity.

DO NOT weld or flamecut near combustible materials, nor in an atmosphere containing refrigerant, nor until pressure vessels and piping have been completely evacuated.

DO NOT weld or flamecut in a confined area unless the area is adequately ventilated. Where it is impossible to provide adequate ventilation, wear SCBA and have another person on standby immediately outside the confined area.

DO NOT carry a plastic liquid-fuel cigarette lighter or other flammable materials while welding, soldering, or brazing. Welding sparks, molten metal, and heat from a torch can ignite the contents of the lighter and cause it to explode.

⚠ CAUTION

DO NOT store oxygen and fuel gas cylinders near any heat source nor adjacent to each other.

STORE oxygen and fuel gas cylinders in an upright position and strap securely in place.

WEAR flame-retardant protective clothing and equipment when welding and flamecutting, and when in the vicinity of such operations.

DO NOT block passageways, ladders, and stairways with welding equipment.

Use effective safeguards when working on platforms, scaffolds, or runways including safety belts and safety lines when necessary.

SAFETY INSTRUCTIONS

Observe the color coding of pipelines, cylinder, and hoses. Double check the code by reading all labels.

Do not use defective hoses.

Do not tape more than 4 inches out of every 12 inches when taping parallel sections of fuel and oxygen hose.

Do not use connectors other than those made especially for acetylene welding and cutting equipment. Make sure all connections are tight.

Do not fail to crack the cylinder valve before attaching the regulator.

Release the regulator adjusting screw before opening a cylinder valve.

Stand to one side when opening a regulating valve.

Before each use, inspect torches for leaking shutoff valves and tip connection.

Do not use a defective torch.

Ignite torches by friction lighters only.

Customer requirements and construction work sites may or could specifically require utilization of safety equipment such as hard hats, gloves, goggles, safety glasses, safety shoes, respirators, etc. Be prepared by having these items safely stored in a clean and secure compartment of the service vehicle, readily available for use when necessary.

▼ Figure 2-39.
Personal Protection Precautions

WARNING

WEAR a hard hat wherever there is potential danger from falling or flying objects.

DO NOT touch electrical equipment if your hands are wet or if you are standing on a wet surface.

DO NOT look at arcs or other welding processes, regardless of distance, without appropriate eye protection.

DO NOT carry or use a plastic liquid-fuel cigarette lighter or other flammable materials when in the vicinity of welding operations. Sparks from a welding torch can ignite the lighter and cause it to explode.

Safety shoes, hard hats, and safety glasses are required at construction job sites.

CAUTION

DO NOT WEAR:
- Rings or other jewelry, long ties, gloves, or loose clothing when working around moving machinery.
- Rings or watches when working around electrical equipment.

WEAR:
- Safety glasses with side shields and safety shoes before entering construction sites or manufacturing areas.
- Goggles and gloves when handling chemicals; welding helmets when welding, cutting, brazing, or grinding; and when in the vicinity of these operations.
- Gloves before touching any part of a machine that is operating or one that has recently been shut down. Assume that the metal is hot!
- Gloves when handling machinery components after a major failure; e.g., after a motor burnout: not only the refrigerant but also the oil will be acidic.
- Gloves and coveralls when working with or around sheet metal.
- Hearing protection in areas where sound levels exceed 90 dBA.
- Safety shoes, or specially treated shoes when necessary to protect against corrosive chemicals.
- Flame-retardant protective clothing suitable for the type of welding being done.

▼ Figure 2-40.
Rigging Precautions

⚠ DANGER

DO NOT use cranes under power lines.

Obtain assistance from a utility company as necessary.

Damaged or defective equipment or equipment that does not have load capacity information shall be taken out of service.

Alloy 80 chain is the only type recommended for maintenance and servicing operations.

⚠ WARNING

CHECK the manufacturer's drawings and service instructions for assembly or component weights to be sure they can be handled safely by the rigging equipment.

CHECK the centers of gravity and note any specific rigging instructions.

DO NOT use other than OSHA-approved rigging equipment and methods.

INSPECT all rigging equipment *prior* to use to be sure it is in good condition and has load limit ratings on it.

DO NOT use eyebolt holes to rig an entire assembly, nor use eyebolts to rig a compressor.

DO NOT move a loaded crane, hoist, or chain fall until you are sure there is no obstruction or personnel in its path and have determined that the unit will remain stable and upright.

Safety shoes are recommended when working with rigging, gantries, and hoists.

⚠ CAUTION

USE MECHANICAL EQUIPMENT (chain fall, hoist, etc.) to lift or move the inspection covers or other heavy components. Even if the components are light, use such equipment when there is a risk of slipping, losing your balance, or injuring your back.

DO NOT climb over a machine or fan cabinet; use platforms, catwalks, or staging.

LOOK for objects on the floor or slippery areas that could cause falls.

SAFETY INSTRUCTIONS

FOLLOW safe practices when using OSHA-approved ladders.

Use lifting lugs, where provided, in accordance with each rigging instruction.

Be aware of the location of your fellow workers at all times.

▼ Figure 2-41.
Refrigerant Precautions

⚠ WARNING

NEVER APPLY an open flame or live steam to a refrigerant cylinder. When it is necessary to heat the refrigerant, use warm (110° F/43° C) water.

DO NOT STORE refrigerant cylinders where the surrounding temperature can exceed the relief valve setting. When this is not possible, use a water shower or similar type cooling.

SLOWLY OPEN charging and regulating valves to prevent overpressurizing.

ALWAYS USE the proper valve wrench to open and close valves. Loosen the packing nut before turning on the valve; retighten the nut after closing the valve.

NEVER FORCE connections.

DO NOT REUSE disposable (nonreturnable) cylinders nor attempt to refill them. IT IS DANGEROUS; it is also illegal. When a cylinder is emptied, bleed off the remaining gas pressure, loosen the collar, and unscrew and discard the valve stem. DO NOT INCINERATE.

ALWAYS leave room for expansion when filling a refrigerant cylinder. Hydrostatic pressure increases rapidly with even a small change in temperature.

DO NOT tamper with safety devices.

Use appropriate equipment to move refrigerant cylinders, such as hand trucks, dollies, etc.

⚠ CAUTION

ALWAYS REPLACE the valve and hood caps when a cylinder is not in use or is empty.

DO NOT alter cylinders.

DO NOT dent, drop, or abuse refrigerant cylinders.

SECURE all refrigerant cylinders, whether full or empty, in an upright position with a strap or chain.

AVOID pressure surges when transferring refrigerant. Use a pressure regulating valve to make gradual adjustments. The pressure relief valve device on a cylinder cannot protect against an instantaneous pressure surge.

NEVER charge a refrigerant cylinder beyond the weight marked on the cylinder.

DO NOT depend on the color of a cylinder for identification of the refrigerant; *read the label*.

INSPECT hoses, manifolds, and fittings regularly and keep them in good condition.

DO NOT USE damaged or defective equipment.

Figure 2-41.
Refrigerant Precautions (Cont.)

WARNING

DO NOT enter and perform work inside any vessel without proper respiratory protection and a second person on standby outside the vessel (the buddy system).

DO NOT enter any equipment room or space containing air conditioning or refrigeration machinery *after a known refrigerant spill* until you are using a self-contained breathing apparatus (SCBA) and are using the buddy system.

AVOID spilling liquid refrigerant on the skin or getting it into your eyes. USE SAFETY GOGGLES. Wash any spills from the skin with soap and water. If any refrigerant enters the eyes, IMMEDIATELY FLUSH EYES with water and consult a physician.

CAUTION

DO NOT weld or flamecut in an atmosphere containing refrigerant vapor until the area has been well ventilated.

DO NOT weld or flamecut any vessel or refrigerant line until the refrigerant has been removed.

AVOID breathing refrigerant fumes.

DO NOT smoke in an atmosphere containing refrigerant vapor.

Refrigerants are heavier than air and water and will settle in all low places.

RESPIRATORY PROTECTION such as SCBA may be necessary for entry into and work within areas where a spill has occurred.

SECTION 3

INSTALLING FASTENERS AND ANCHORSS

INTRODUCTION

A variety of mechanical fasteners such as nails, screws, and anchors are used when installing HVAC equipment. Use of the wrong fasteners or improper installation of fasteners can cause injury to people, damage to the equipment, or both. For these reasons, the HVAC installation technician must know the capabilities of fasteners, be able to select the correct kind for the job, and install them properly.

FASTENERS AND ANCHORS MENU

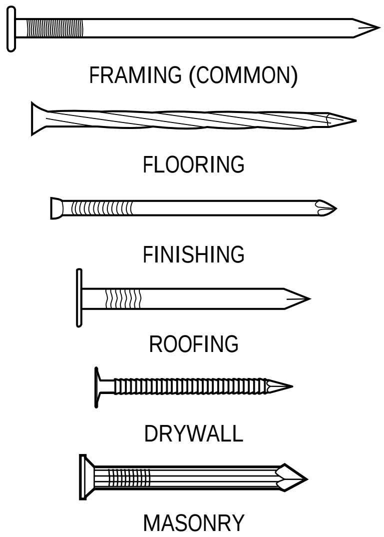
NAILS

A wide variety of nails *(Figure 3-1)* are made for fastening wood and other materials. Some nails are made specifically to be driven manually with a hammer. Other specialized nails are made to be driven by pneumatic or cordless nailer tools.

Nail manufacturers label their boxes of nails to identify their intended use. Refer to these labels to pick the right nail for the job. The length of a nail is stated by its *penny* size (d), where 8d identifies an 8 penny nail, 10d identifies a 10 penny nail, and so on. The larger the number, the larger the nail. Nailing rules of thumb are:

- Select a nail three times longer than the material being fastened.
- Drive nails at an angle to increase holding power.
- In hardwood or near the edges or ends of a board, drill a pilot hole to prevent splitting or the nail from bending.
- When fastening to metal, use nails made of the same metal to prevent galvanic corrosion.

▼ Figure 3-1.
Nails



QUICK NOTE

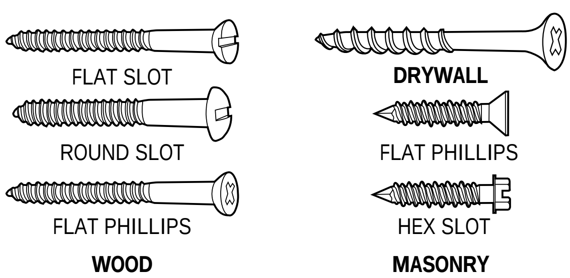
Pennyweight (d) is used to designate the length of a nail from tip to head. Nails are designated 2d (1 inch) through 16d (3-1/2 inches). Nails above 16d are called **spikes.** Spike sizes range from 20d (4 inches) to 60d (6 inches). The shank thickness or gauge of a nail increases with the length of the nail.

SCREWS

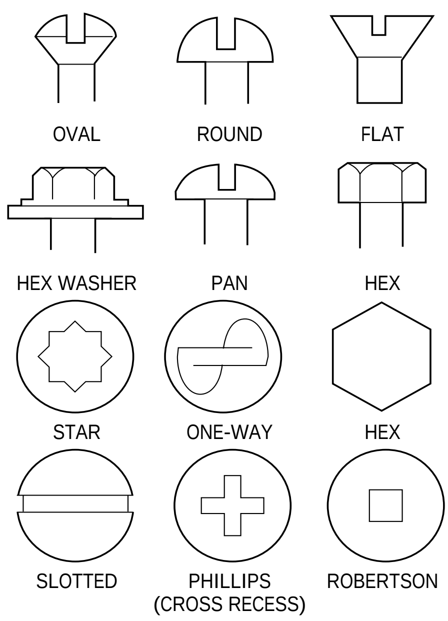
Screws *(Figure 3-2)* are made for fastening materials where greater holding power is needed than can be provided by nails, or where nails are not appropriate. They are also used to fasten materials that may need to be removed. Screws have heads with different shapes and slots made to fit various kinds of manual and power tool screw drives *(Figure 3-3)*. The size (diameter) of a screw's body or shank is given in gauge numbers ranging from No. 2 to No. 24, and in fractions of an inch for screws with diameters larger than 1/4 inch. The higher the gauge number, the larger the diameter of the shank. Screw lengths range from 1/4 to 6 inches. Some guidelines for installing screws are:

- Always use a driver tip with the proper size and shape to fit the screw.
- When possible, use screws long enough to allow 2/3 of the screw length to enter the piece that is being gripped.

▼ Figure 3-2.
Wood, Drywall, and Masonry Screws



▼ Figure 3-3.
Screwheads and Screw Drives



Lag screws (Figure 3-4) or lag bolts are heavy-duty wood screws that provide greater holding power. They typically are used to fasten heavy equipment to wood, but can also be used to fasten equipment to concrete if a lag shield is used. A lag shield or expansion shield is a lead insert that is placed in a pre-drilled hole in the concrete. When a lag screw is screwed into the lag shield, the shield expands in the hole, firmly securing the lag screw.

Sheet metal screws (Figure 3-5) are thread-forming or thread-cutting screws used to fasten light-gauge sheet metal. Sheet metal screw threads are deeper than those of wood screws and extend the full length of the screw, which allows the two pieces of metal being fastened to be drawn tightly together directly under the screw head. Because their deeper threads hold better, sheet metal screws are also recommended for use with softer materials like particleboard. Self-drilling sheet metal screws are also available that drill, tap, and fasten in one operation. Sheet metal screws are made in similar diameters and lengths as wood screws.

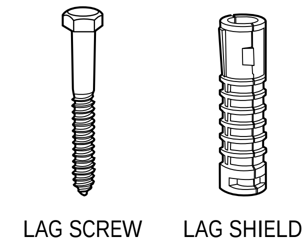
HAMMER-DRIVEN PINS AND STUDS

Hammer-driven pins and threaded studs can be used to fasten wood or steel to masonry without the need to pre-drill holes. The fastener is inserted into a hammer-driven tool (Figure 3-6). Then the tool's drive rod is struck using an engineer's hammer, causing the fastener to be driven into the masonry.

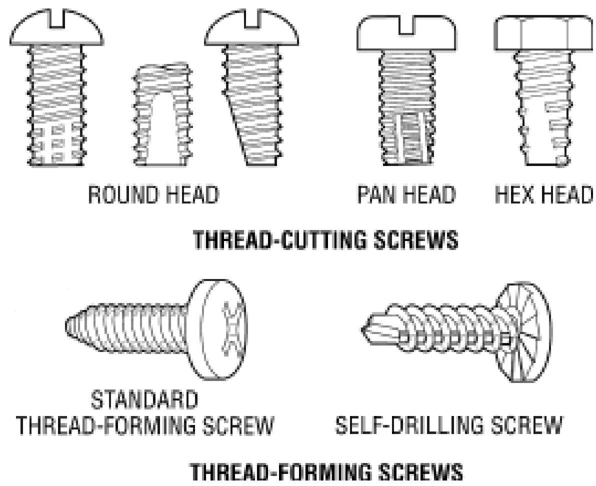
QUICK NOTE

- When drilling a clearance hole, use a drill that has the same diameter as the screw.
- When drilling a pilot hole, use a drill that is smaller in diameter than the screw.

▼ Figure 3-4.
Lag Screw and Lag Shield



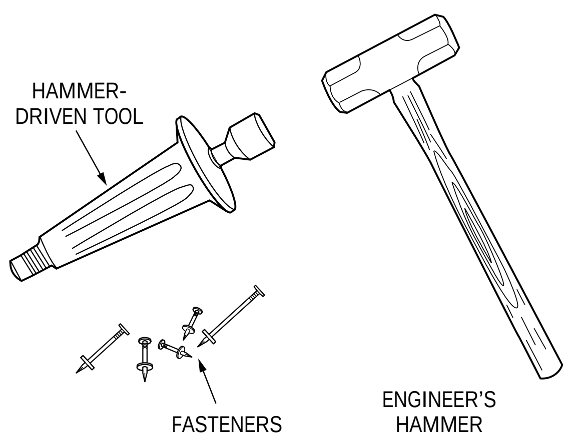
▼ Figure 3-5.
Sheet Metal Thread-Forming and Thread-Cutting Screws



QUICK NOTE

Make sure to use the proper size bit when drilling pilot holes for use with sheet metal screws. The correct drill size is usually marked on the box containing the screws.

▼ Figure 3-6.
Hammer-Driven Tool



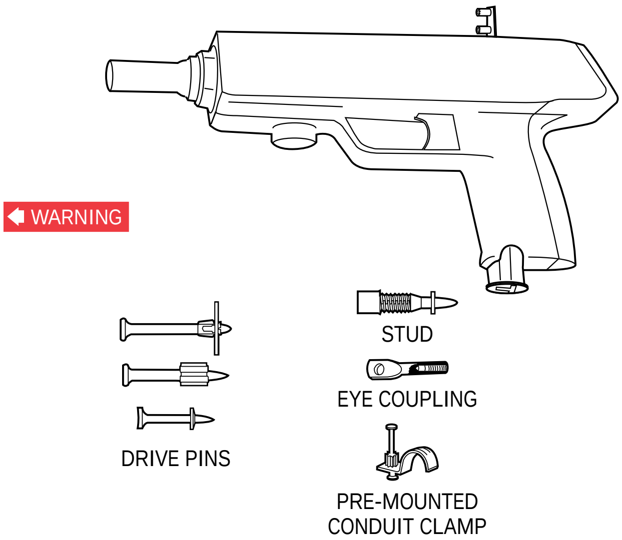
POWDER-ACTUATED DRIVERS AND FASTENERS

Powder-actuated drivers *(Figure 3-7)* can be used to drive specially designed fasteners into masonry and steel. These drivers are fired like a gun and use the force of a cartridge (typically 22, 25, or 27 caliber) to drive the fastener into the material. The gunpowder charges are made in different power or load levels to achieve the proper penetration.

POWDER-ACTUATED FASTENING TOOLS ARE TO BE USED ONLY BY TRAINED AND QUALIFIED OPERATORS AND IN ACCORDANCE WITH THE OPERATOR'S MANUAL. Certified operators must take precautions to protect both themselves and others when using powder-actuated tools:

- Operate the tool as directed by the manufacturer's instructions and use it only for the fastening jobs for which it was designed.
- To prevent injury or death, make sure that the drive pin cannot penetrate completely through and exit the material into which it is being driven.
- To prevent a ricochet hazard, make sure the recommended shield is in place on the nose of the tool.

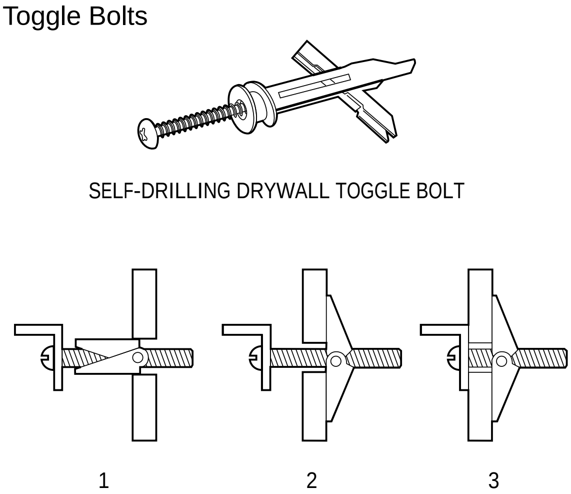
▼ Figure 3-7.
Powder-Actuated Driver



TOGGLE BOLTS

Toggle bolts *(Figure 3-8)* are used to fasten lighter equipment into hollow surfaces such as walls and ceilings. One type consists of a slotted round-head bolt and spring-loaded wings. When inserted through the item to be fastened, then through a hole in the wall or ceiling, the wings spring apart and provide a firm hold on the inside of the wall or ceiling as the bolt is tightened. Note that the hole drilled in the wall or ceiling should be just large enough for the compressed wing-head to pass through. *Once the toggle bolt is installed, be careful not to completely unscrew the bolt because the wings will fall off, making the fastener useless.* Another popular type of toggle bolt used for heavy-duty fastening in drywall is self drilling with a rotating clamp that flips out of the body and engages the wall as the bolt is screwed in.

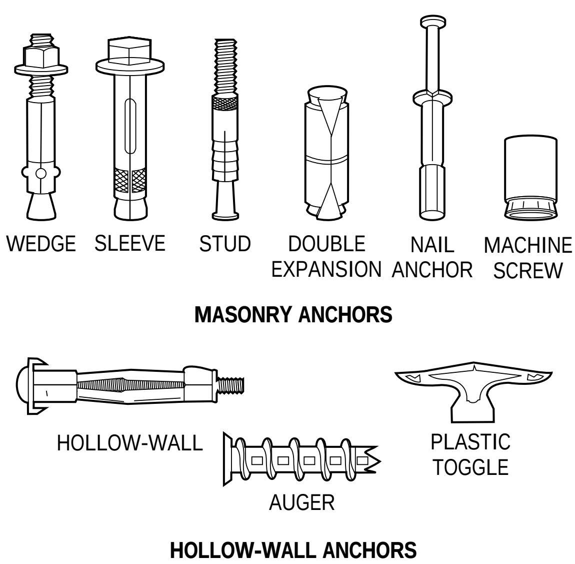
▼ Figure 3-8.
Toggle Bolts



MASONRY AND HOLLOW-WALL ANCHORS

Anchors are devices used to give fasteners a firm grip in a variety of materials where the fasteners by themselves would otherwise have a tendency to pull out. Anchors can be divided into two broad categories: those used in solid masonry and those used in hollow walls and ceilings made from masonry and other materials. *Figure 3-9* shows some common types of masonry and hollow-wall anchors. Installation instructions for anchors are normally given on the anchor box.

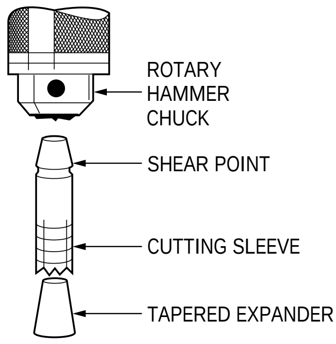
▼ Figure 3-9.
Common Masonry and Hollow-Wall Anchors



SELF-DRILLING, SNAP-OFF ANCHORS

Some expandable anchors made for use in masonry are self drilling. *Figure 3-10* is typical of those in common use. This fastener has a cutting sleeve that is first used as a drill bit and later becomes the expandable fastener itself. A rotary hammer is used to drill the hole in the concrete using the anchor sleeve as the drill bit. This is followed by inserting the anchor's expander plug into the cutting end of the sleeve. The anchor sleeve and expander plug are driven back into the hole with the rotary hammer until the sleeve shear point is flush with the surface of the concrete. As the fastener is hammered down, it hits the bottom, where the tapered expander causes the fastener to expand and lock into the hole. The anchor is then snapped off at the shear point. The component to be fastened can then be secured to the anchor using the proper size threaded bolt.

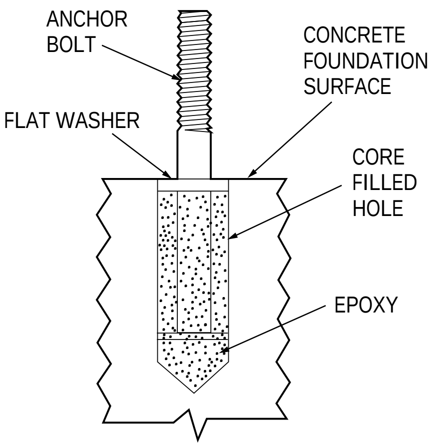
▼ Figure 3-10.
Self-Drilling, Snap-Off Anchor



EPOXY ANCHORING SYSTEMS

Epoxy resin compounds can also be used to anchor various fasteners *(Figure 3-11)*. Epoxy is installed in a drilled and cleaned hole of the proper diameter and depth. One type of epoxy system uses a tool similar to a caulking gun to fill the drilled hole about 1/2 full. The selected fastener is pushed into the hole with a slow twisting motion to make sure that the epoxy fills all voids and crevices, then is set to the required plumb (or level) position. After the epoxy is hardened, the fastener nut can be tightened to secure the component or fixture in place.

▼ Figure 3-11.
Fastener Anchored in Epoxy



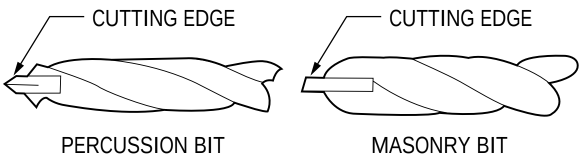
GUIDELINES FOR DRILLING ANCHOR HOLES IN MASONRY

When installing anchors and/or anchor bolts in concrete, make sure the area where the equipment is to be located is smooth so that it will have a solid and level footing.

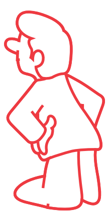
Before starting, carefully inspect the rotary hammer or hammer drill and the drill bits *(Figure 3-12)* to make sure they are the correct type and in good condition. Also, set the drill or hammer tool depth gauge to the correct depth.

DRILLING IN CONCRETE GENERATES NOISE, DUST, AND POSSIBLE FLYING OBJECTS. ALWAYS WEAR THE PROPER PROTECTIVE EQUIPMENT. The key to using masonry drill bits is not to force them into the material. Use a little pressure and let the drill do the work. For large holes, start with a smaller bit, then change to a larger bit.

▼ Figure 3-12.
Masonry and Percussion Drill Bits



WARNING



MACHINE BOLTS, SCREWS, AND RELATED HARDWARE

Various threaded machine bolts, screws, and studs *(Figure 3-13)* are used to assemble and hold together HVAC equipment.

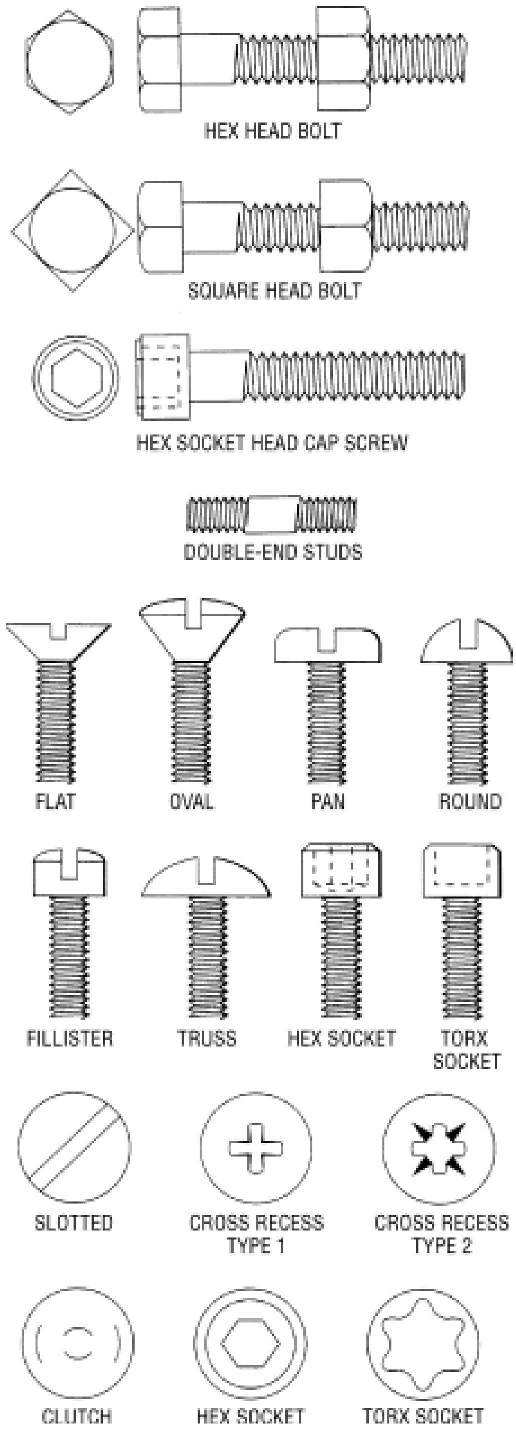
Machine Bolts, Screws, and Studs

Machine bolts are used for general assembly of parts that do not require close tolerances. When selecting a machine bolt, pick one that is long enough so that at least two or three of the bolt's threads protrude through the outside of the nut when assembled. Normally, a machine bolt is used with two or more washers and a nut. It is tightened and released by turning the nut. Cap screws, stud bolts, and machine screws are used for specialized fastening needs.

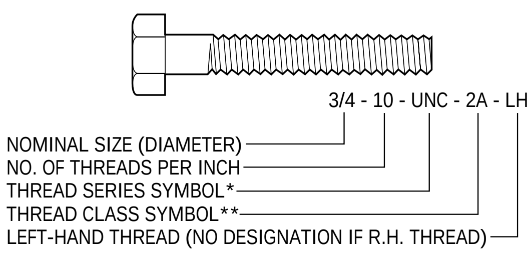
Thread Designations

Machine bolt, screw, and stud threads are made to different standards that determine their thread series and classes. The most common is the unified or *American National Standard*. There are three series of threads defined by this standard based on the number of threads per inch for a certain diameter fastener *(Figure 3-14)*. Metric screw threads based on the American National Standard are also in common use.

▼ Figure 3-13.
Machine Bolts, Screws, Cap Screws, and Stud Bolts



▼ Figure 3-14.
Machine Bolt and Screw Unified National Series Thread Designations

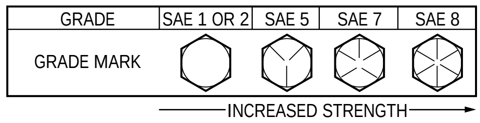


* UNC = UNIFIED NATIONAL COARSE THREAD
UNF = UNIFIED NATIONAL FINE THREAD
UNEF = UNIFIED NATIONAL EXTRA FINE THREAD
** 1A, 2A, 3A = CLASS OF FIT FOR EXTERNAL THREADS (BOLTS, SCREWS)
1B, 2B, 3B, = CLASS OF FIT FOR INTERNAL THREADS (NUT)

Fastener Grade Designations

The strength and quality of bolts can be determined by grade markings placed on the head of the bolt. These markings are standardized by the Society of Automotive Engineers (SAE) and the American Society for Testing of Materials (ASTM). *Good practice is to always use bolts that have grade markings, since bolts that do not may be inferior.* *Figure 3-15* shows the grade markings for commonly specified steel bolts.

▼ Figure 3-15.
Markings for Common Grades of Steel Bolts

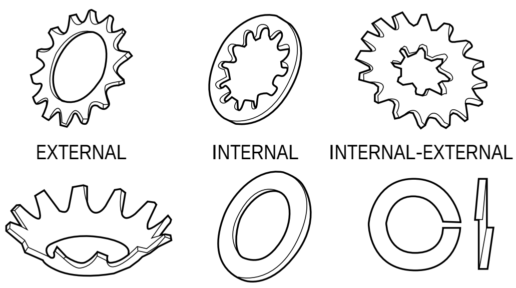


Flat and Lock Washers

Flat washers *(Figure 3-16)* provide an enlarged surface used to distribute pressure under the bolt head and the nut. Lock washers are used to keep bolts or nuts from working loose. They are placed between the flat washers and the bolts or nuts. Some common types of lock washers include:

- *Split ring* – Common type used with bolts and cap screws.
- *External* – Provides the greatest resistance.
- *Internal* – Used on small screws.
- *Internal-external* – Used for oversized mounting holes.
- *Countersunk* – Used with flat or oval-head screws.

▼ Figure 3-16.
Flat and Lock Washers

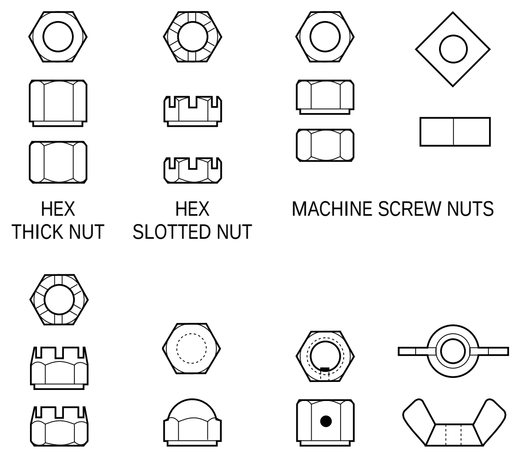


Nuts

Nuts used with most threaded fasteners have hex or square shapes and are normally used with bolts having the same head shape. *Figure 3-17* shows different types of nuts. Some special purpose nuts are:

- *Acorn nut* – Used when there are exposed, sharp threads on the fastener or when appearance is important.
- *Castellated,* or *castle,* and *slotted nuts* – After the nut is tightened, a cotter pin is fitted in one set of the nut slots and through a hole in the bolt to keep the nut from loosening.
- *Self-locking nut* – Has a nylon insert or is slightly deformed so it cannot work loose.
- *Wing nut* – Allows for frequent loosening and tightening of a fastener.

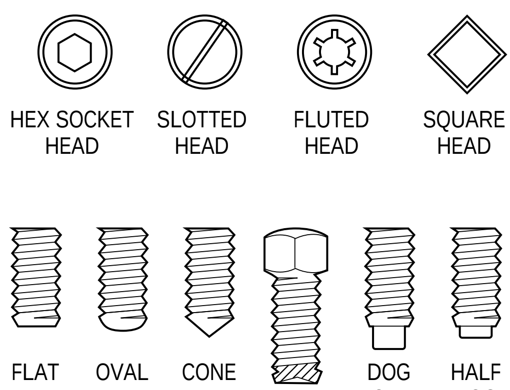
▼ Figure 3-17.
Nuts



Set Screws

Set screws *(Figure 3-18)* are commonly used to fasten pulleys and fan blades on shafts and to hold collars in place. Set screws are identified by their head and point styles.

▼ Figure 3-18.
Set Screws



QUICK NOTE

Once a self-locking nut has been used and removed, discard it and replace it with a new one.

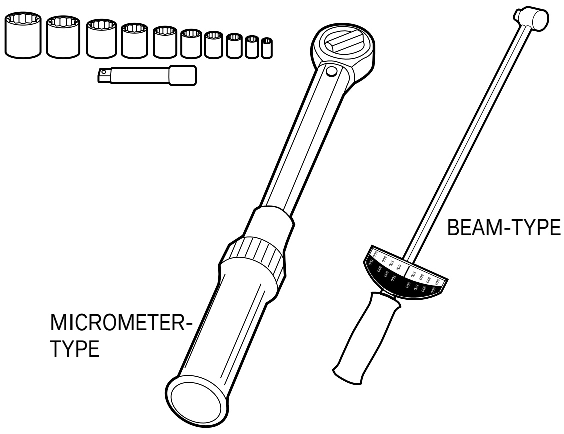
INSTALLING THREADED FASTENERS

To get the required clamping force and to avoid damage to parts, machine bolts, screws, and other threaded fasteners must be tightened correctly. Select the proper type and grade of fastener, then tighten (torque) it to specifications using a torque wrench.

Torque Wrenches

The torque wrench *(Figure 3-19)* is a combination wrench and measuring tool which measures the resistance to turning or twisting. The torque wrench consists of a handle and an attached indicator calibrated to measure torque in either foot-pounds or inch-pounds. It is normally attached to the nut or bolt to be fastened using the correct size socket.

▼ Figure 3-19.
Torque Wrenches



Tightening Sequence and Torquing Guidelines

Before assembling equipment, be sure that all the threaded fasteners are clean and undamaged in order to get accurate torque settings. Use a torque wrench that will provide the needed capacity and accuracy. This is generally one that will read near mid-scale when the specified torque is applied. Using a wrench with too large a torquing capacity normally makes it difficult to get an accurate reading because the scale divisions are too coarse. Using one with too small a capacity will not allow for the extra capacity needed in the event the bolt seizes or encounters run-down resistance.

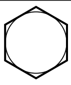
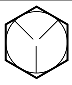
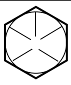
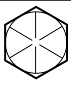
CAUTION

When installing fasteners in or on equipment, always refer to the equipment manufacturer's installation and service instructions for the recommended torque values. When no specifications are given, the guideline values shown in *Figure 3-20* can be used for the common graded steel bolts shown.

When installing bolts or screws on flanges or flat surfaces, they must be tightened in the proper sequence or pattern to prevent warping or damage. ***When installing fasteners in flanges and other surfaces in or on equipment, always refer to the equipment manufacturer's installation and service instructions for the recommended tightening pattern.***

CAUTION

▼ Figure 3-20.
Torque Values for Common Graded Steel Fasteners

GRADE		SAE 1 OR 2	SAE 5	SAE 7	SAE 8
GRADE MARK					
BOLT DIAMETER	THREADS PER INCH	FOOT-POUNDS TORQUE*			
1/4	20	5	8	10	12
5/16	18	11	17	19	24
3/8	16	18	31	34	44
7/16	14	28	49	55	70
1/2	13	39	75	85	105
9/16	12	51	110	120	155
5/8	11	63	150	167	210
3/4	10	105	270	280	375
7/8	9	160	395	440	605
1	8	235	590	660	910

* CLEAN, DRY THREADS

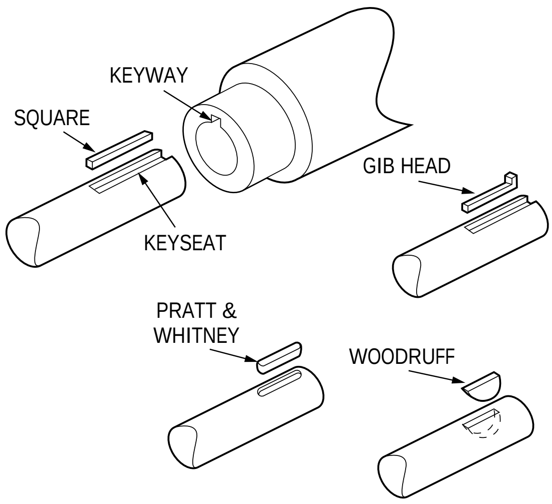
QUICK NOTE

- To convert inch-pounds to foot-pounds, divide the inch-pounds by 12. For example, 72 inch-pounds ÷ 12 = 6 foot-pounds.
- To convert foot-pounds to inch-pounds, multiply the foot-pounds by 12. For example, 6 foot-pounds x 12 = 72 inch-pounds.
- Tables of recommended torque values for use with most types and sizes of fasteners can be found in any one of several mechanical trade handbooks and/or manuals normally available at your parts distributor or local bookstore.
- Whenever possible, apply the force to the torque wrench by pulling rather than pushing. This reduces the chance of injury to the fingers or knuckles should some part fail unexpectedly.
- Check the calibration of a torque wrench regularly to maintain its accuracy.

KEYS

Keys *(Figure 3-21)* are metal parts used to prevent a gear or pulley from rotating on a shaft. Half of the key fits into a keyseat on the shaft, while the other half fits into a keyway in the hub of a gear or pulley.

▼ Figure 3-21.
Common Shaft Keys



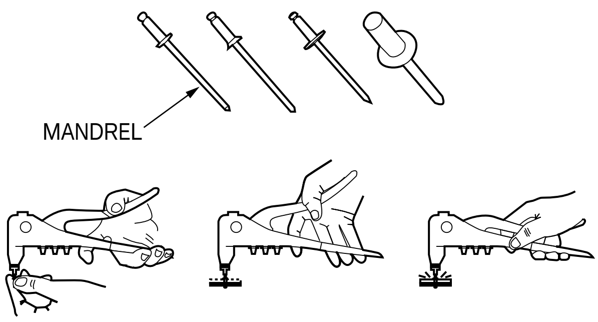
BLIND (POP) RIVET INSTALLATION

Blind (pop) rivets are used to permanently join sheet metal and/or other materials *(Figure 3-22)*. Blind rivets are installed from one side using a special riveting tool. The rivets are made of steel, aluminum, and copper and come in various lengths, diameters, and head styles. When using blind rivets, select those made of the same material as the metal being joined to prevent galvanic corrosion.

The general procedure for installing a blind rivet is outlined below.

1. Place the rivet's shaft or mandrel fully into the riveting tool's nosepiece.
2. Insert the rivet body into the correctly sized drilled hole until its flange is flush against the surface of the metal.
3. Squeeze the rivet tool's handles until the rivet mandrel breaks off at the flange.
4. Remove the broken mandrel from the rivet tool.

▼ Figure 3-22.
Blind (Pop) Riveting Tool and Rivets



SECTION 4
RIGGING, HOISTING, AND MOVING

INTRODUCTION

Installation jobs require the movement of heavy equipment, materials, and tools from one place to another. This task, called *rigging*, involves the use of special moving devices such as hand trucks, dollies, hoists, cranes, and related accessories. Rigging is a skilled profession and should always be performed by qualified riggers. However, the HVAC technician often is called on to assist riggers in their job. The focus of this section is on the basic knowledge and skills needed by the HVAC technician to assist the rigger. It is important that the technician recognize common items of rigging equipment, use correct rigging methods, and follow correct procedures to prevent personal injury.

RIGGING MENU

EQUIPMENT/MATERIAL MOVING DEVICES

Many special tools are made to help move heavy objects. They save time and manpower, and help prevent lifting injuries. Hand trucks *(Figure 4-1)*, portable dollies, pry bars, etc. are commonly used to manually move and position heavy equipment and materials on the job site.

Hand Trucks, Dollies, and Pry Bars

Hand trucks are used to move loads up to several hundred pounds. Good hand trucks are equipped with skid bars or glide plates to make their use on stairs and curbs easier. They also may have a load remover that allows foot pressure to remove the hand truck from under the load. Hand trucks built for moving appliances are equipped with rachet take-up belts that secure the appliance, preventing it from slipping or shifting. Some have continuous belted stair crawlers to make climbing and descending stairs easier.

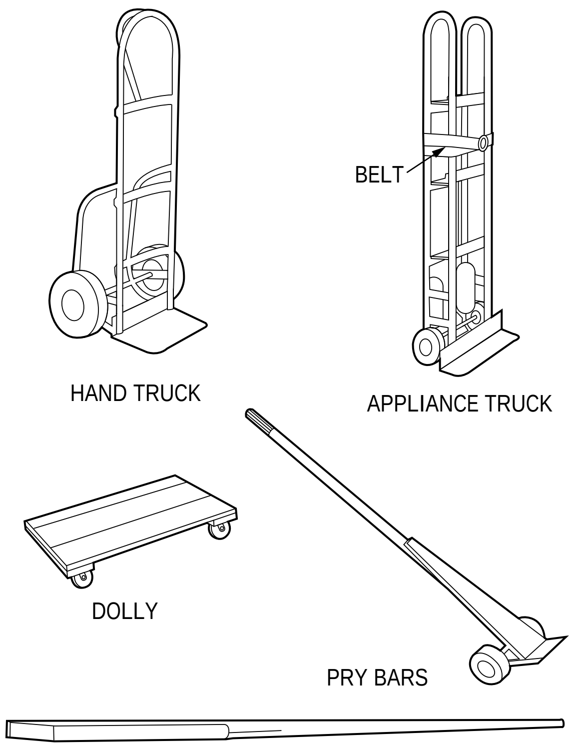
Dollies can be used to move bulky loads over floors and other flat, solid surfaces. When equipment has a flat bottom, several short lengths of pipe may also be used to move the equipment across a flat, solid surface *(Figure 4-2)*. Enough pipe sections should be available so that one is always free to be placed in front of the load as it is moved along.

Pry bars provide the leverage needed for moving heavy equipment on or off dollies.

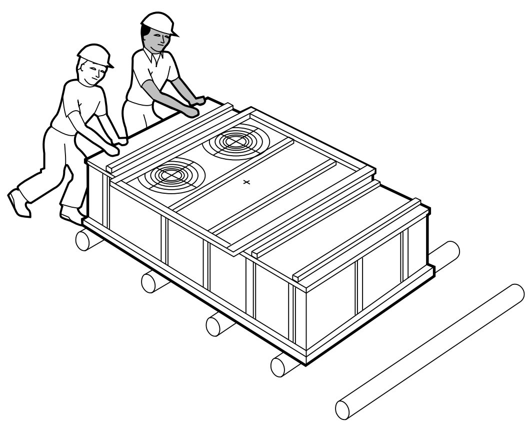
Ratchet Pullers

Ratchet pullers *(Figure 4-3)*, often called *come-alongs*, are typically used to position equipment. They are available in a wide range of load capacities. Some have a chain for pulling; others use wire ropes (cables). Some cable models have two lines and load hooks that can be used for double-line rigging. ***RATCHET PULLERS MUST NEVER BE USED TO LIFT OR SUPPORT ANY LOADS SUSPENDED OVER PEOPLE.***

▼ Figure 4-1.
Hand Tools and Equipment

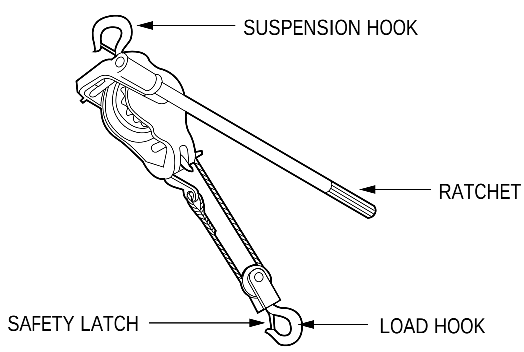


▼ Figure 4-2.
Pipe Sections Used to Move a Heavy Load

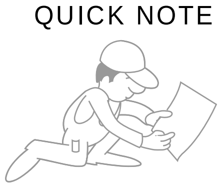


WARNING

▼ Figure 4-3.
Ratchet Cable Puller



QUICK NOTE



Plywood or similar paneling can be used to help move heavy equipment across rough or soft surfaces, such as a carpeted floor. Use two pieces, one under the load and one placed in front of the load as it is moved along.

RIGGING EQUIPMENT AND ATTACHMENT HARDWARE

Rigging equipment and attachment hardware are used to lift HVAC equipment. The truck-mounted crane is commonly used. Wire and fiber ropes, slings, and other rigging hardware are used attach the load to the crane.

Wire and Fiber Ropes

Wire rope or cable is strong and durable. It consists of wires, strands, and a central core *(Figure 4-4)*. Wire ropes are commonly made from galvanized steel.

Wire ropes use shackles, hooks, and other fasteners that allow for quick attachment to the load and crane. *Figure 4-5* shows some common fittings and fasteners. The thimbles shown are grooved metal rings that fit around or inside a wire rope loop to protect it from wear and over-bending.

U-bolt clips *(Figure 4-6)* are commonly used for fastening the end of a wire rope when forming a loop eye. A thimble should be used in the loop eye to prevent kinking. The diameter of the wire rope determines how many clips must be used and the spacing between them. *(See Table 4-1.)*

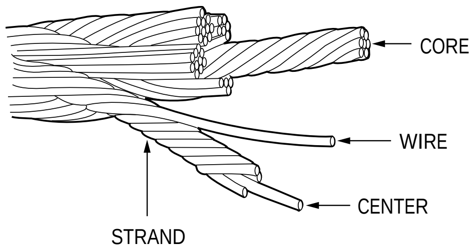
Fiber ropes are used for lifting lighter loads and as safety tag lines. For a given size, synthetic ropes are normally stronger and lighter in weight than ropes made of natural fibers. Only manila ropes made of No. 1 manila are acceptable for use in rigging. These are normally identified by rope manufacturers with some kind of marking, such as colored inlaid fibers. ***Manila ropes not marked as No. 1 grade should not be used, because they are made from an inferior fiber.***

CAUTION

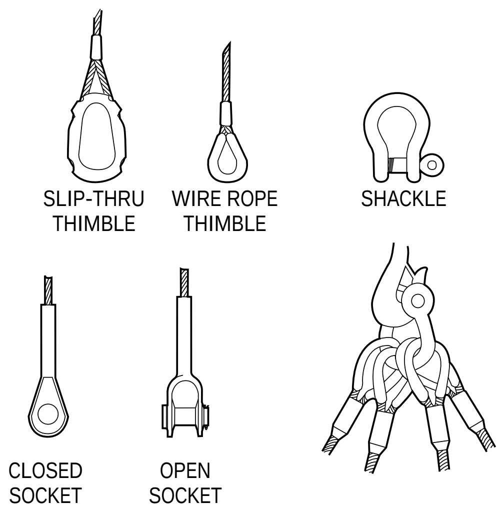
Ropes are generally rated by tensile or breaking strength and/or safe working load. Safe working load is the maximum load a rope can safely carry. Do not confuse the terms *tensile strength* and *safe working load*, because the safe working load is only a small percentage of the tensile strength. For example, a 3/8-inch diameter nylon rope may have a tensile strength of 3,700 pounds and a safe working load of only 308 pounds. Always be sure to refer to the manufacturer's data when selecting ropes for a lifting job.

When a crane starts to pick up a load, the attached ropes are subjected to sudden and extreme stress or shock loads called *dynamic loading*. The more rapid the acceleration when lifting the load, the greater the dynamic load. If the dynamic loading is large for a particular lifting job, make sure to select a rope that has an adequate safe working load capacity to compensate for the dynamic loading. When lifting a load that is close in weight to a rope's safe working load capacity, make sure to accelerate the load slowly when lifting it.

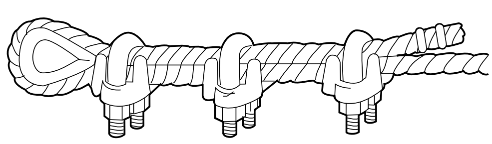
▼ Figure 4-4.
Wire Rope



▼ Figure 4-5.
Common Wire Rope Fittings and Fasteners



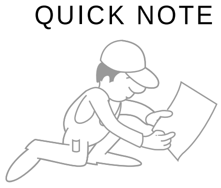
▼ Figure 4-6.
Correct Use of U-Bolts when Forming a Loop in Wire Rope



▼ Table 4-1.
Determining the Number of U-Bolt Clips Required

Wire Rope Size	Number of U-Bolts	Spacing
3/8	2	4
7/16	2	4-1/2
1/2	3	5
5/8	3	5-3/4
3/4	4	6-1/4
7/8	4	8
1	4	8-3/4

QUICK NOTE



The effects of dynamic loading are **not** included in a rope manufacturer's stated value for safe working load. Make sure to select a rope that has an adequate safe working load to compensate for any dynamic loading.

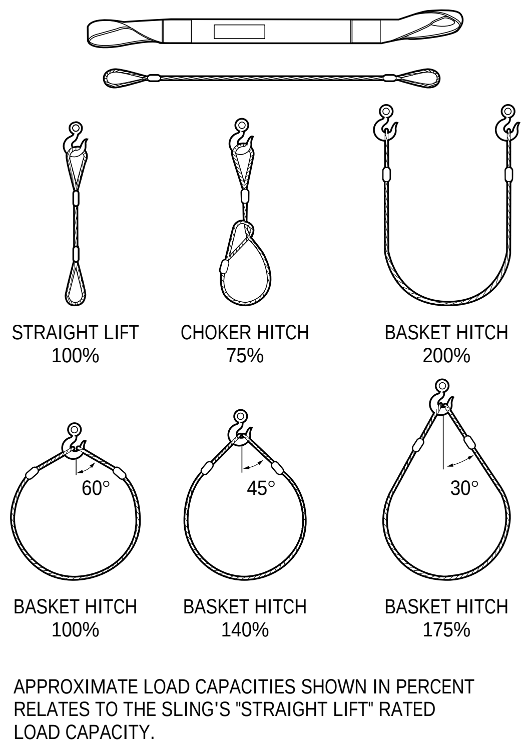
Lifting Slings

Lifting slings are used to attach a load to a crane's hook. They can be made of wire rope, chain, or synthetic materials, and in many general and specialized forms. Eye-and-eye wire rope and synthetic slings are versatile slings that can be used in vertical, choker, and basket hitch arrangements *(Figure 4-7)*. When used as a choker or basket hitch, care must be taken to balance the load so that it rides safely.

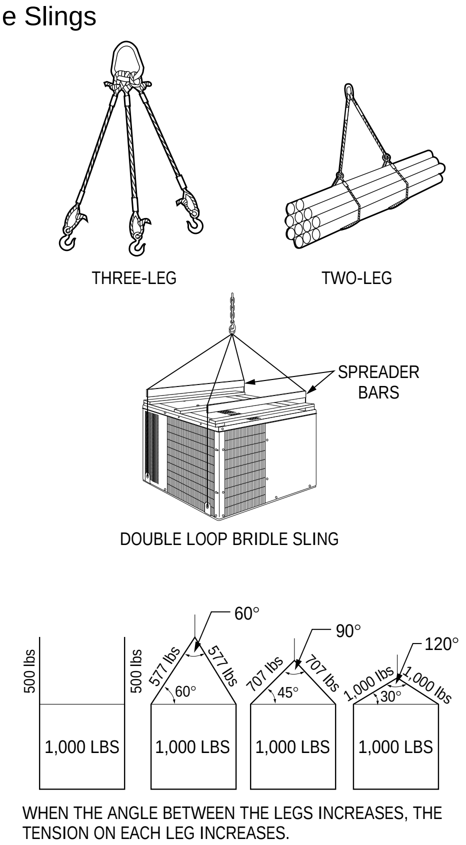
Sling manufacturers mark their slings with a tag that identifies the sling size, type, and safe load capacity. For example, an eye-and-eye sling rated at a capacity of 4,000 pounds will lift 4,000 pounds when used as a vertical hitch. When used as a choker or basket hitch, the sling's capacity is different. *Figure 4-7* shows the approximate load capacities in percent related to a sling's "vertical hitch or straight lift" rated load capacity. For example, a sling rated at 4,000 pounds has a load capacity of about 3,000 pounds when used as a choker hitch. When used as a basket hitch connected to a single hook at a vertical angle of 30°, its load capacity is about 7,000 pounds.

Bridle slings *(Figure 4-8)* are multi-legged slings equipped with a loop or ring that attaches to a crane hook. The ends of the legs can be equipped with a variety of fasteners. Bridle slings are made in three basic patterns: the two-leg, three-leg, and four-leg or *double loop*. The tension, and therefore the load, on each leg of a bridle sling increases as the *angle between the legs* is increased. For example, the tension and load are higher on the legs of a bridle sling when the legs are positioned at an angle of 30° relative to the horizontal (120° angle between the legs) than when the legs are at an angle of 60° relative to the horizontal (60° angle between the legs). This load capacity difference must be taken into consideration when selecting a bridle sling for a particular lifting job.

▼ Figure 4-7.
Eye-and-Eye Lifting Slings



▼ Figure 4-8.
Bridle Slings



GENERAL RIGGING PROCEDURES

Size, Weight, and Center of Gravity of Loads

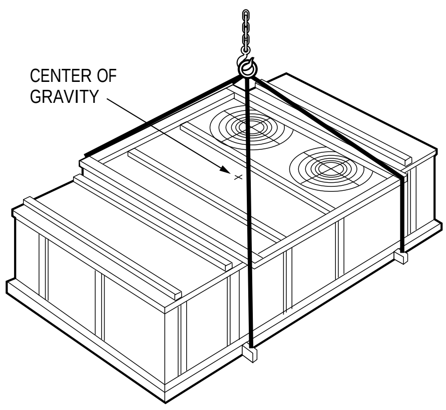
The correct size and weight of loads must be known in order to select the right type of rigging equipment. For the size and weight of HVAC equipment, always refer to the equipment manufacturer's installation instructions. Make sure to include any additional weight added by optional equipment. For example, a rooftop unit weighs a certain amount. When equipped with an optional economizer, the weight increases.

Safety demands reasonable accuracy when estimating the weight of an object. Professional riggers are trained to perform this task and should be the only persons on the jobsite trusted to do it. If the weight of a load is unknown and no accurate estimate can be made, contact the equipment supplier to find out the weight. ***NEVER ATTEMPT TO LIFT A LOAD WITHOUT KNOWING ITS WEIGHT.***

The center of gravity of an object is the exact point at which the object is balanced in all directions. If a load is unbalanced, it may twist, turn, or fall, causing possible injury or damage to the equipment.

To make a level lift, sling(s) of the proper length to balance the load must be used and the crane's hook must be directly above the load's center of gravity *(Figure 4-9)*. HVAC equipment normally comes with lifting lugs, eye bolts, or holes in the base rails located in the proper places to establish the center of gravity. For HVAC and other equipment, always refer to labels attached to the equipment or the equipment manufacturer's installation instructions for data on the use of such lifting points. Skill in estimating the center of gravity for odd-shaped and/or unbalanced loads comes with experience. When no specific rigging data is given, estimating the center of gravity for an unbalanced load should be performed by a professional rigger.

▼ Figure 4-9.
Crane's Hook Must be Centered Directly Over the Load's Center of Gravity



Inspecting Rigging Equipment

To ensure safe and proper operation, rigging equipment should always be inspected before use, and at regular intervals during periods of prolonged use. ***EQUIPMENT THAT IS WORN OR DAMAGED COULD RESULT IN DEATH OR INJURY AND/OR DAMAGE TO THE EQUIPMENT. IF IN DOUBT ABOUT THE CONDITION OF A PIECE OF EQUIPMENT, DO NOT USE IT.*** Guidelines for inspecting rigging equipment are given in *Table 4-2*.

▼ Table 4-2.
Guidelines for Inspecting Rigging Equipment

Equipment	Inspect for the Following Defects
Wire rope and slings	Broken wires in rope lay or strands. Abrasion that has caused a significant reduction (about 1/3) in the original diameter of the rope. Deterioration from corrosion. Shape is distorted as a result of kinking or crushing. Signs of heat damage. Unraveling of a splice. Inner core is showing or protruding.
Hooks, shackles, and sockets	Bent, broken, twisted, or otherwise damaged or loose shackle pins. Broken or missing cotter or clevis pin. Damaged or missing hook safety latch.
Synthetic slings	Colored inner yarn visible. Cuts, tears, or broken fibers. Worn or damaged end fittings. Signs of heat or chemical damage.
Equipment to be rigged	Damaged pad eyes. Eyebolts not threaded all the way in. Loose parts.

Rigging and Moving Loads

Safely lifting loads requires making decisions regarding the load to be moved and the lifting and rigging equipment that will be used. These decisions should be made by a professional rigger.

Some guidelines and precautions to be followed when assisting a rigger in preparation for and during the lift are:

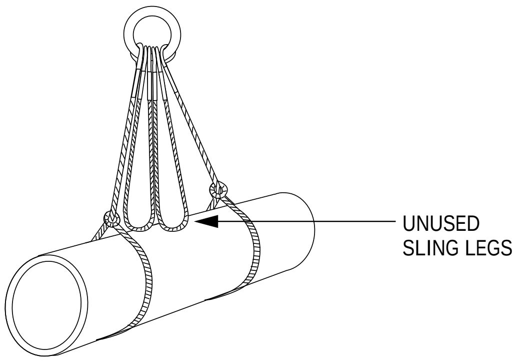
- Never attempt rigging or hoisting in bad weather.
- Rigging should always be performed under the supervision of a qualified rigger.
- All loose materials must be removed from the load before it is moved.
- Whenever two or more rope loops need to be placed over a hook, use a shackle *(shown earlier in Figure 4-5)*.
- Secure all unused sling legs *(Figure 4-10)*.
- Pad the corners of a sharp load to prevent cutting of the slings or rope. Do not bend wire ropes near splices or attached fittings *(Figure 4-11)*.
- Use tag lines on all lifts to control the load *(Figure 4-12)*. Do not hold onto the load with your hands. Keep hands, arms, feet, etc. away from and out of pinch points. Do not wrap tag lines around hands, waist, or any other part of your body.
- Before making a lift, make sure the rope or sling(s) have no kinks.
- While making a lift, have one authorized person use a radio or other device to give directions and maintain contact with the crane operator.
- When lifting loads with slings, lift slowly and uniformly.
- Never walk under the load during the lift.
- Never unhook a load until it is safely landed and properly secured.

QUICK NOTE

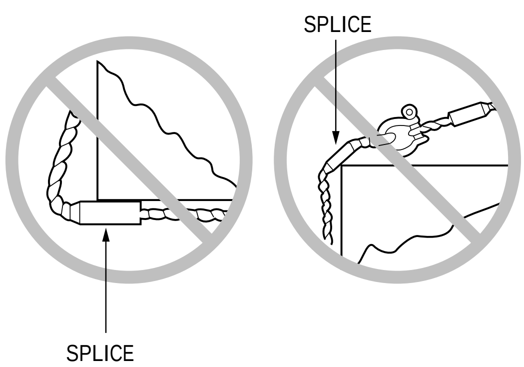
Inspect rigging equipment before using!

- Wire and fiber ropes and slings
- Hooks, shackles, and sockets
- Equipment or material to be rigged

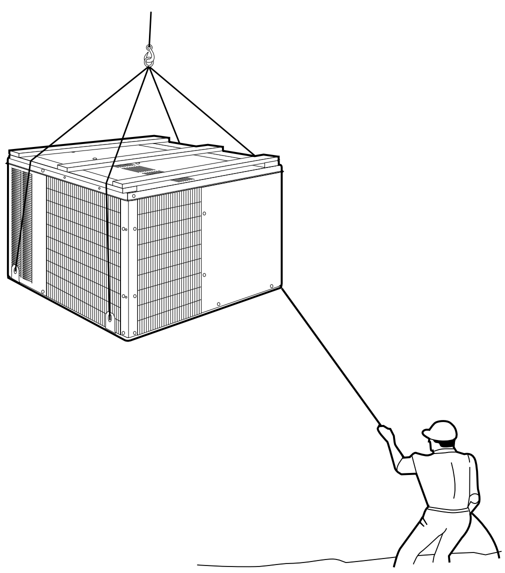
▼ Figure 4-10.
Secure all Unused Sling Legs



▼ Figure 4-11.
Do Not Bend Wire Ropes Near Splices or Fittings



▼ Figure 4-12.
Use Tag Line to Control the Load



SECTION 5

PIPING SYSTEMSS

INTRODUCTION

Installation jobs can require an HVAC technician to install refrigerant, gas, and condensate piping systems. This commonly involves installing copper pipe/tubing to carry refrigerant, steel or wrought iron pipe to carry natural gas in heating systems, and plastic pipe to vent combustion gases or drain condensate water in both cooling and heating systems. This section focuses on the general procedures for handling, cutting, and joining the various piping materials commonly used in HVAC systems. Specific information about installing different types of piping systems is provided in Sections 8 through 10.

PIPING MENU

REFRIGERANT COPPER PIPING/TUBING AND FITTINGS

Air conditioning and refrigeration (ACR) copper pipe and fittings are manufactured specifically for use in refrigeration systems. ACR pipe is thoroughly cleaned, dried, capped, and sometimes charged with nitrogen to help prevent contamination of the refrigeration system. ***Never use copper piping made for general plumbing use in a refrigeration system because it does not conform to the higher cleanliness standards required in refrigeration systems.*** Another important difference is that the size of ACR pipe is expressed by its outside diameter (O.D.), while copper pipe used for general plumbing is expressed in terms of its inside diameter (I.D.).

ACR copper tubing is made in both soft and hard forms. Both are classified by their wall thickness. Type L (medium wall) is used under normal conditions; Type K (heavy wall) is used where severe corrosion may occur. The O.D. of both types is the same. Refrigerant line sizing charts normally given in manufacturer's equipment installation literature are based on the use of Type L piping. Both soft and hard copper pipe may be used in the same system.

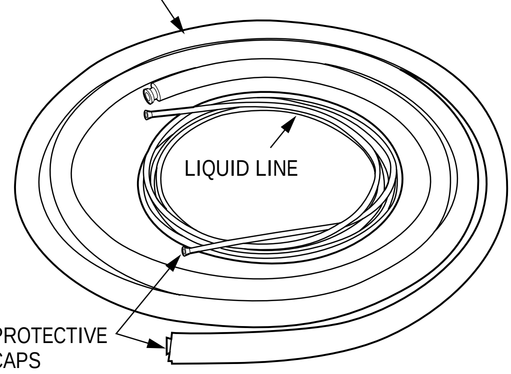
Soft ACR Copper Tubing

Soft ACR copper tubing made in sizes from 1/8-inch to 7/8-inch O.D. and supplied in 50-foot rolls is typically used in HVAC installation work. Because of its length, soft copper tubing needs fewer connections, reducing the chance of leaks. It is easily bent or shaped, but must be held in place by clamps or other hardware as it cannot support its own weight. Joints and connections can be made by soldering, brazing, or using flare fittings.

Line Sets

Manufacturers of HVAC equipment make soft ACR refrigerant line tubing kits, called *line sets* *(Figure 5-1)*. Line sets come in many lengths and tube sizes and may have fittings on each end that allow for quicker field installation. They may be pre-charged with refrigerant and sealed at both ends. The suction tubing is usually insulated. The installation of line sets is covered in detail in Section 9.

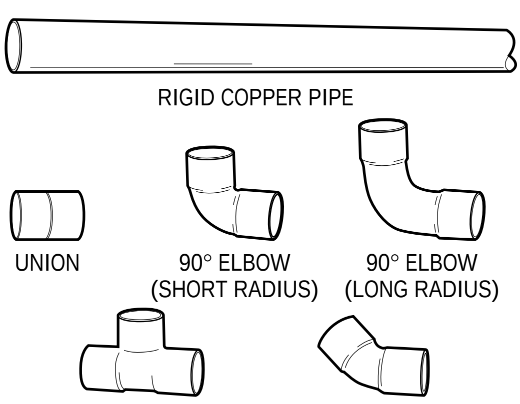
▼ Figure 5-1.
Soft Copper Line Set



Hard ACR Copper Piping

Hard copper ACR pipe comes in 20-foot lengths and similar sizes to soft copper tubing. It is designed to be used with fittings such as elbows and tees *(Figure 5-2)* to make necessary bends or changes in direction. Joints and connections are made by soldering or brazing.

▼ Figure 5-2.
Hard Copper Pipe and Fittings



Handling ACR Copper Tubing

ACR tubing and fittings must be kept clean and dry to prevent system contamination. Piping and fittings should remain capped and stored in a clean place until just before installation. When cutting lengths of pipe, cut only what is needed, then immediately recap any unused lengths. When unrolling soft copper tubing, good practice is to place the roll upright on a flat surface and unroll the tubing. Do not lay the coil flat and uncoil the tubing from the side of the roll. Also, do not bend or straighten the tubing more than necessary, because this will cause it to harden.

Cutting and Deburring Copper Tubing

Both soft and hard copper tubing should be cut using the proper size tubing cutter *(Figure 5-3)*. Do not confuse a tubing cutter with a pipe cutter. Tubing cutters are designed for clean, square cuts in soft, thin-wall materials such as copper. To use the cutter, place it over the tubing and tighten the adjusting knob until the cutting wheel is aligned with and touches the tubing at the point where it is to be cut. Rotate the cutter around the tubing, keeping a moderate pressure applied to the tubing by tightening the adjusting knob slightly on each rotation until the tubing is cut.

Deburr the tube by inserting the cutting tool deburring blade into the cut end and gently twisting it until the inside edge of the tube is smooth or use a dedicated deburring tool. Keep the end of the tubing pointed downward so that the metal chips fall out of (not into) the tubing.

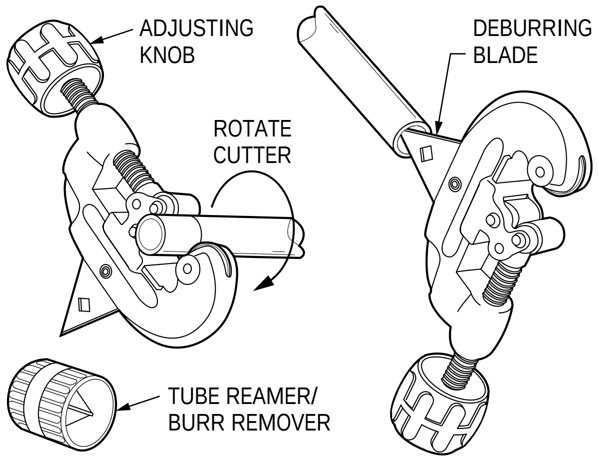
Bending Soft Copper Tubing

Soft copper tubing 5/8-inch in diameter and less is flexible enough to bend by hand. Use a spring-type bender *(Figure 5-4)* of the proper size slipped over the tubing to prevent kinking or flattening. Kinks restrict the flow of refrigerant through the tube. A mechanical tube bender is used for larger-diameter tubing and when an accurate bend is required. It can be used to get smooth bends at any angle up to 180°. These benders normally have a clip to hold the tubing while bending, and a calibrated degree scale.

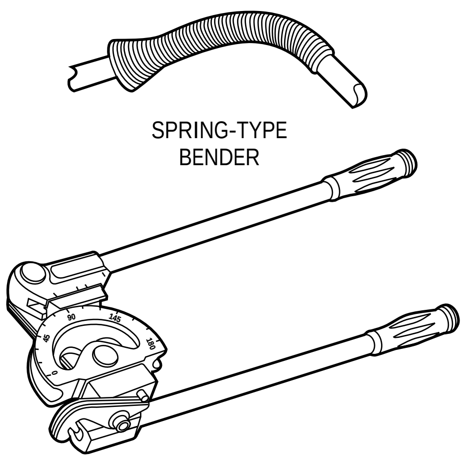
Flaring and Swaging Soft Copper Tubing

Soft copper tubing can be joined by soldering or with mechanical fittings. Soldering of copper tubing is described later in this section. Flare connections and fittings are the most common mechanical method used for joining soft copper tubing. A special flaring tool *(Figure 5-5)* is used to expand the end of the tubing into the shape of a 45° cone (flare) that mates with an equipment connector or flare fitting.

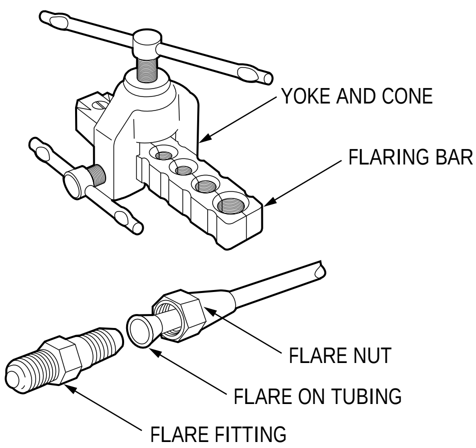
▼ Figure 5-3.
Using a Tubing Cutter



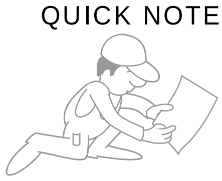
▼ Figure 5-4.
Soft Copper Tubing Benders



▼ Figure 5-5.
Flaring Tool and Flared Connection



QUICK NOTE



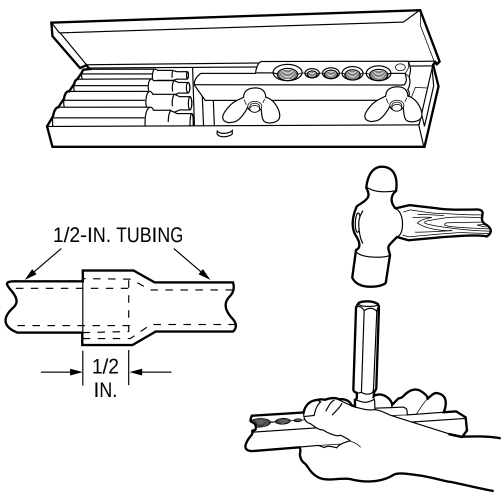
Always use a drop of oil on the flaring tool cone and feed screw to prevent binding during the flaring operation.

Flared connections must be made correctly or they will leak. For best results, always follow the flaring tool manufacturer's instructions. A general procedure is outlined below:

1. Use a tubing cutter to cut and deburr the tubing.
2. Slide a flare fitting nut over the tubing with its threads facing the end of the tubing being flared.
3. Place the tubing in the correct size die in the tool flaring bar. The tube must extend the correct distance above the bar (typically 1/3 the total height of the flare). If it extends too far, the end of the tube may split; if it is not far enough, the flare will be too small to seal tightly.
4. Place the tool yoke with attached tapered cone on the flaring bar with the cone positioned over the end of the tubing.
5. Make sure the tubing is clamped in the flaring bar, then screw the cone down into the tubing until the flare is completed.
6. Remove the tubing from the block and inspect the flare to make sure there are no defects.

Soft copper tubing of the same diameter can also be joined by making a swaged connection. This type of joint is made using a swaging tool *(Figure 5-6)* to expand the end of one pipe so that a same-diameter pipe can fit inside. Either a punch-type or lever (expander)-type tool can be used to make swaged joints. Good practice is to make the depth of the swaged joint equal to the outside diameter of the tubing. Once the swaged joint is formed, the joint is either soldered or brazed.

▼ Figure 5-6.
Making a Swaged Joint

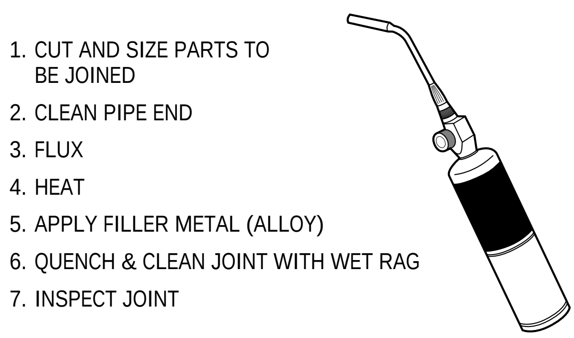


Soldering and Brazing Copper Tubing

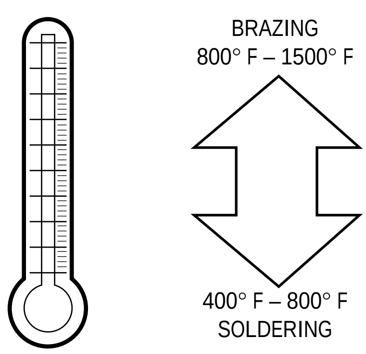
Soldering and brazing are two methods used to join soft and hard copper tubing. As a rule, soldered joints provide good sealing but are not as strong as brazed joints. Soldered joints typically are used to join copper water and drain pipes where temperatures do not exceed 250° F. Brazed joints provide the mechanically stronger joint needed to handle the higher pressures in refrigerant piping systems. Detailed procedures for performing soldering and brazing are described later in this section. *Figure 5-7* briefly shows the steps in the process.

The soldering and brazing processes use heat to melt solder or a brazing rod, respectively, to join the tubing. When heated, the alloy melts and is distributed between the surfaces being joined in a kind of soaking or spreading action, called *capillary action*. The difference between soldering and brazing is the temperature needed to melt the alloy *(Figure 5-8)*. Soldering is done at temperatures ranging between 400° F and 800 °F, with the heat commonly supplied by a propane torch. Brazing is done at temperatures above 800° F, usually with an oxyacetylene torch.

▼ Figure 5-7.
Steps of the Soldering or Brazing Process



▼ Figure 5-8.
Temperature Ranges for Soldering and Brazing



Soldering/Brazing Alloys and Fluxes – Alloys used to make soldered joints are different from those used to make brazed joints *(Figure 5-9)*. Alloys used for soldering in most HVAC work contain tin and varying amounts of either antimony or silver. For joining copper, an alloy made up of 95% tin and 5% antimony should always be used. Since this solder melts at about 465° F, an air-propane or air-acetylene torch can be used. Lead-free silver-bearing soft solders are also available. They can be used to join the same or dissimilar metals.

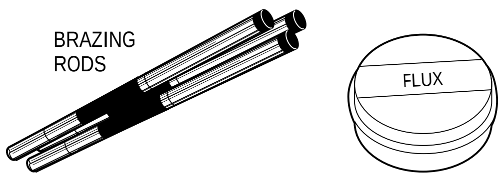
Two types of brazing alloys are commonly used in HVAC work: a silver-bearing alloy and a copper-phosphorus alloy *(Figure 5-10)*. Silver-bearing alloys, commonly called *silver solder*, can contain from 30 to 60 percent silver. Silver solder alloys are suitable for joining the same or dissimilar metals such as copper to copper, copper to steel, or copper to brass. They require the use of the proper flux. Copper-phosphorus alloys, commonly called *phosco*, *sil-fos*, or *phoson* are used only to join copper to copper. Copper-phosphorus alloys are self-fluxing so they do not require the use of flux. Both types of alloys require high temperatures to flow and typically require heating with an oxyacetylene torch.

Flux is a chemical substance that dissolves and removes traces of oxides from the surfaces being joined, protects the surfaces from re-oxidation during heating, and helps the melted alloy to flow into the joint. Flux does not clean the metal. It keeps the metal clean once it has been cleaned by other means. Some fluxes provide a relative temperature indication of the metal being heated by changing color or texture with increases in temperature.

▼ Figure 5-9.
Soldering Alloys

TYPE	FLOWPOINT (°F)
SILVER-BEARING SOFT SOLDER	400 - 550
95% TIN/5% ANTIMONY SOFT SOLDER (FOR JOINING COPPER-TO-COPPER ONLY)	465

▼ Figure 5-10.
Brazing Alloys



TYPE	FLOWPOINT (°F)
SILVER-BEARING BRAZING ALLOYS	1200 - 1300
PHOSPHORUS-BEARING BRAZING ALLOYS (FOR JOINING SIMILAR, NON-FERROUS METALS ONLY)	1500

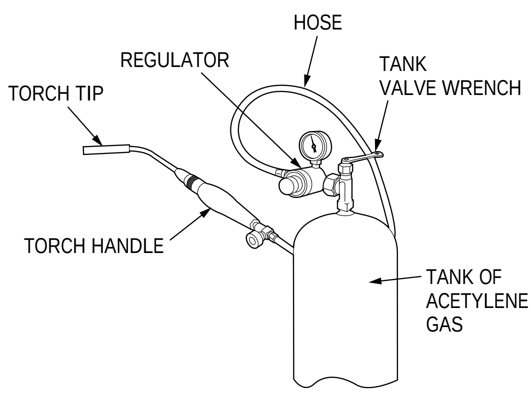
For best results when soldering or brazing, always use the flux recommended by the manufacturer of the solder or brazing alloy being used, or its equivalent. ***Do not interchange fluxes used for soldering and brazing copper joints because they are different in composition.***

Air-Acetylene and Oxyacetylene Torches – Soldering and brazing involves the use of torches and pressurized gases. General safety precautions pertaining to torches and pressurized gases are covered in Section 2. General procedures for setting up and operating air-acetylene and oxyacetylene torches are given here. The procedures for using these torches to solder or braze are given later in this section.

Acetylene Torch Set-Up – The air-acetylene torch *(Figure 5-11)* normally consists of a B or MC tank of acetylene gas, regulator, hose, torch handle, and a variety of torch tips. The air-acetylene torch is set up and ignited for use as follows:

1. Prior to connecting the regulator to the tank, stand to one side and "crack" open the tank valve slightly. Then close it. This will blow out any dirt or debris that has entered the valve.
2. Assemble the hose and torch with the required tip to the regulator, then attach the regulator to the tank. Make sure that all connections are tight.
3. Adjust the regulator valve to midrange. Stand to one side of the regulator and slowly open the tank valve about one-half turn.

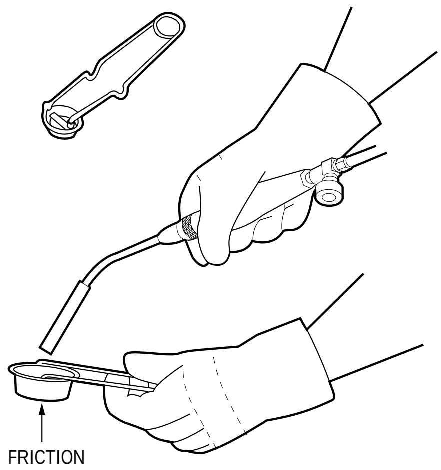
▼ Figure 5-11.
Air-Acetylene Equipment



4. Open the torch handle valve slightly and ignite the gas with a friction (spark) lighter *(Figure 5-12)*. If using a torch that has a built-in ignitor in the tip, push the button to ignite the gas. ***WHEN LIGHTING THE TORCH, POINT THE TORCH TIP AWAY FROM YOUR BODY AND ANY FLAMMABLE MATERIAL.***
5. Adjust the torch valve to get a sharp inner flame and a blue outer flame. The torch is now ready to solder.
6. When the soldering is done, shut off the torch by first closing the torch valve, then the tank valve. Bleed off any acetylene in the hose by opening the torch valve, bleeding the hose, then closing the torch valve.

▼ Figure 5-12.
Use Friction Lighter to Ignite the Torch

WARNING



QUICK NOTE

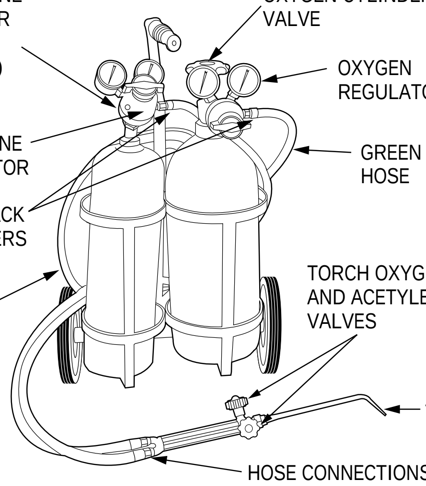
Follow these safety precautions when working with air-acetylene or oxyacetylene equipment:

- Keep a fire extinguisher handy.
- Wear safety glasses and gloves.
- Keep cylinders away from heat, sparks, or open flame.
- Store and transport the cylinders in a cart or in a secured upright position.
- Do not handle acetylene and oxygen cylinders with oily hands or gloves. Do not use any oil or grease on the tank or regulator threaded fittings. Oil or grease in contact with oxygen may ignite or explode spontaneously.
- Always stand to one side when adjusting regulators. A defective regulator can blow out, causing injury or death.

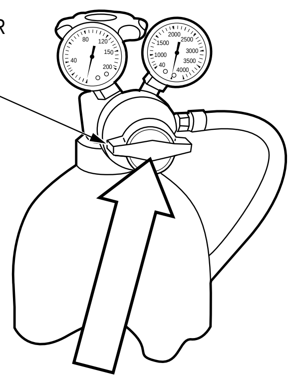
Oxyacetylene Torch Set-Up – The oxyacetylene torch *(Figure 5-13)* consists of acetylene gas and oxygen cylinders (tanks), related regulators, hoses, torch, and a variety of torch tips. The oxyacetylene torch is set up for use as described below.

1. Install the oxygen and acetylene regulators on the related tanks:
   a. Prior to connecting each of the regulators, stand to one side and “crack” open, then close the tank valve. This will blow out any dirt or debris that may have entered the valve.
   b. Before attaching the regulators to the tanks, back off (turn counterclockwise) the regulator knobs until no resistance is felt *(Figure 5-14)*. Install the oxygen and acetylene regulators on the tanks. Note that the oxygen regulator and tank fittings have right-hand threads and the acetylene regulator and tank have left-hand threads. This prevents you from putting the regulators on the wrong tanks.
2. Install and purge the hoses as follows:
   a. Install flashback arresters on the oxygen and acetylene regulators, then connect the green hose to the oxygen regulator and the red hose to the acetylene regulator. Install the torch on the ends of the hoses and open both torch valves.
   b. Purge (clean) the oxygen hose. Open the oxygen tank valve slowly until a small amount of pressure registers on the oxygen high pressure gauge, then open the valve completely.

▼ Figure 5-13.
Oxyacetylene Equipment



▼ Figure 5-14.
Typical Regulator



c. Turn the oxygen regulator knob clockwise until a small amount of pressure shows on the oxygen working pressure gauge. Allow this pressure to build up and purge the oxygen hose and torch. Then turn the oxygen regulator knob counterclockwise to decrease the pressure. Close the torch oxygen valve.

d. Purge the acetylene hose in the same way as was done for the oxygen hose. ***NEVER OPEN THE ACETYLENE TANK VALVE MORE THAN 1-1/2 TURNS. NEVER ADJUST THE ACETYLENE REGULATOR ABOVE 15 POUNDS PRESSURE (FIGURE 5-15) BECAUSE ACETYLENE BECOMES UNSTABLE AT EXCESSIVE PRESSURES.***

WARNING

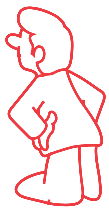
3. Check the equipment for leaks as follows:

a. Adjust the acetylene regulator knob for 10 psig on the working pressure gauge. Adjust the oxygen regulator knob for 40 psig on the working pressure gauge.

b. Close the oxygen and acetylene tank valves and check for leaks. If the gauges remain at 10 and 40 psig, there are no leaks. If one or both readings drop, look for and repair the leak.

DO NOT USE AN OIL-BASED SOAP OR OTHER SOLUTION FOR LEAK TESTING. THE MIXTURE OF OIL AND OXYGEN CAN CAUSE AN EXPLOSION.

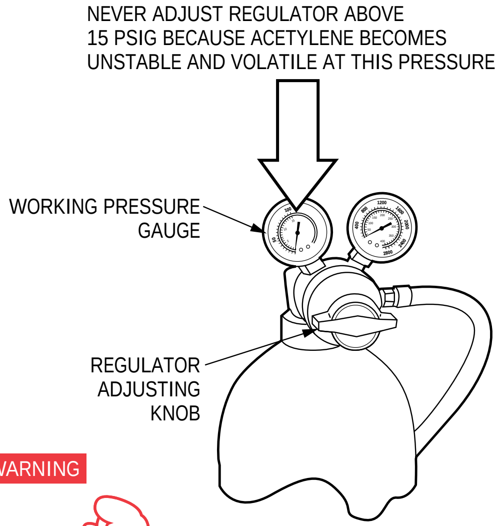
WARNING



c. Open both torch valves to release the pressure in the hoses, then close the valves on the torch.

d. Turn the oxygen and acetylene regulator knobs counterclockwise to release the pressure in the regulators. The torch is now ready to be ignited.

▼ Figure 5-15.
Never Adjust Acetylene Regulator Above 15 psig



Oxyacetylene Torch Ignition and Adjustment – Ignite and adjust the torch flame as follows:

1. Make sure that the following torch conditions exist:

a. Oxygen and acetylene regulators backed out (counterclockwise).

b. Oxygen and acetylene tank valves closed.

c. Oxygen and acetylene torch valves closed.

2. Adjust the torch oxygen system.

a. Open the torch oxygen valve to purge the regulator and hose.

b. Open the oxygen tank valve slowly to prevent damaging the regulator.

c. Adjust the oxygen regulator clockwise for a pressure of 10 pounds on the gauge. This pressure is more than adequate for air conditioning brazing.

d. Shut off the torch oxygen valve.

3. Adjust the torch acetylene system.

a. Open the torch acetylene valve to purge the regulator and hose.

b. Open the acetylene tank valve slowly. ***Never open this valve more than 1-1/2 turns.*** Be sure to leave the key on the acetylene cylinder valve so that the valve can be closed quickly in an emergency.

CAUTION

c. Adjust the acetylene regulator clockwise for a pressure of 5 pounds on the gauge. This pressure is adequate for air conditioning brazing. ***NEVER ADJUST THE ACETYLENE REGULATOR ABOVE 15 POUNDS PRESSURE.***

WARNING

d. Shut off the torch acetylene valve.

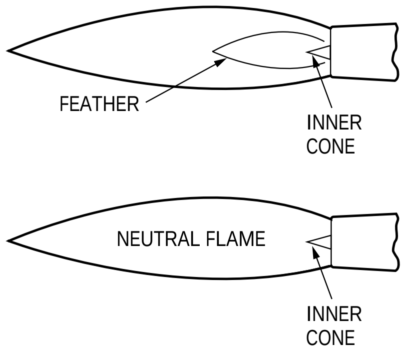
4. Light the oxyacetylene torch.
   a. Open the torch acetylene valve only and use a friction lighter to ignite the gas.
   b. Adjust the torch acetylene valve to get a standing flame about 3/4 inch from the torch tip.
   c. Open the torch oxygen valve and adjust the flame to get a slight feather edge on the inner cone, then reduce the oxygen until the feather edge just disappears *(Figure 5-16)*. This produces a neutral flame, which is the ideal flame for brazing. The torch is now ready for brazing.
5. Shut off the torch when finished brazing.
   a. On the torch, shut off both the oxygen and acetylene valves.
   b. Completely shut off both the oxygen and acetylene tank valves and back off both regulators.
   c. On the torch, open both valves to bleed off the regulators and hoses to zero pressure, then close the valves again.

General Brazing/Soldering Techniques – Soldering and brazing skills can be learned through practice under the supervision of an experienced technician *(Figure 5-17)*. Practice on scrap tubing. ***Do not practice on the customer's equipment.*** In this section, the procedure for brazing is described first, followed by a description of the differences in the procedure for soldering.

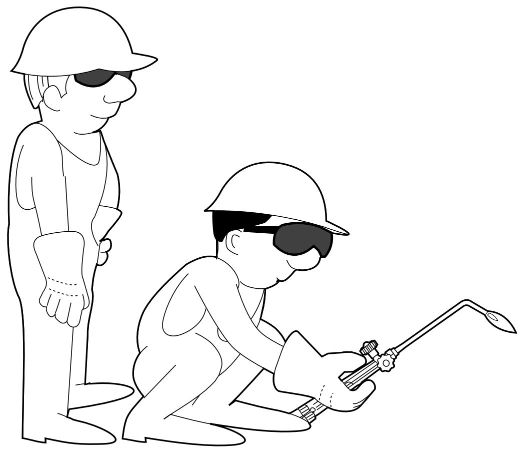
Brazing – To braze, follow the general procedure outlined below. ***Work in a well ventilated area. Some fumes generated when brazing can cause irritation.***

1. Measure, cut, and deburr the tubing. ***When measuring the tubing, make sure to take into account the extra length needed to insert the tubing into a fitting.***
2. Use a solvent to thoroughly clean any oil or grease from the surfaces to be joined. Clean the metal to a bright finish using sandcloth, being careful not to remove an excessive amount of metal *(Figure 5-18)*. ***Avoid touching the cleaned areas with your fingers because you may contaminate the clean metal.***
3. Using a clean brush, apply a minimum amount of the correct flux to the outside of the tubing ends only *(Figure 5-19)*, then assemble the tubing into the fittings. Be careful not to get flux into the inside of the tubing. If using a copper-phosphorus brazing alloy, the use of flux is not required. ***Flux can irritate the skin and eyes. Wash off any flux that gets on your skin or in your eyes.***

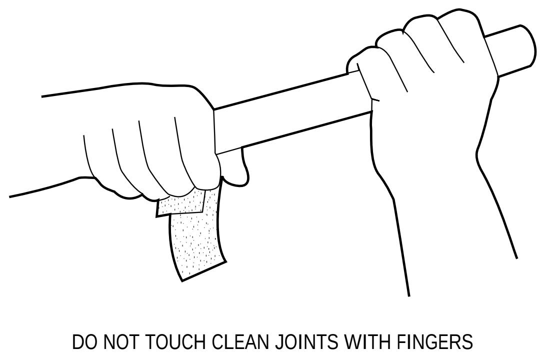
▼ Figure 5-16.
Reduce the Oxygen Until the Feather Edge Just Disappears, Resulting in a Neutral Flame



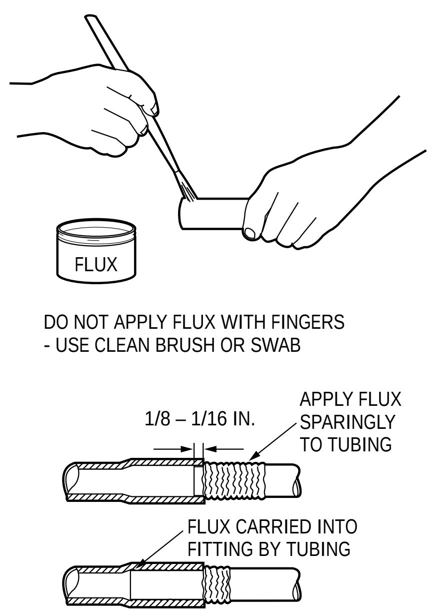
▼ Figure 5-17.
Learn Soldering and Brazing Skills Under the Supervision of an Experienced Technician



▼ Figure 5-18.
Clean the Outside of Tubing and the Inside of Couplings or Fittings with Sandcloth



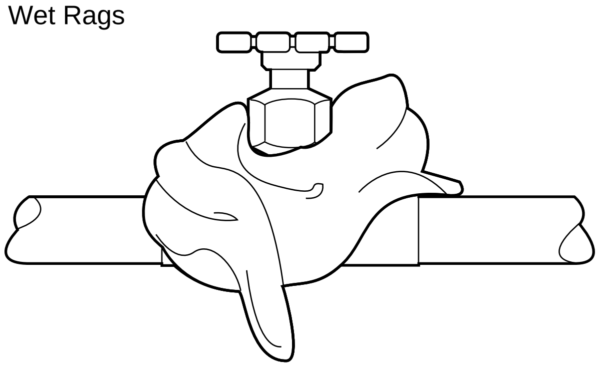
▼ Figure 5-19.
Apply Flux Properly



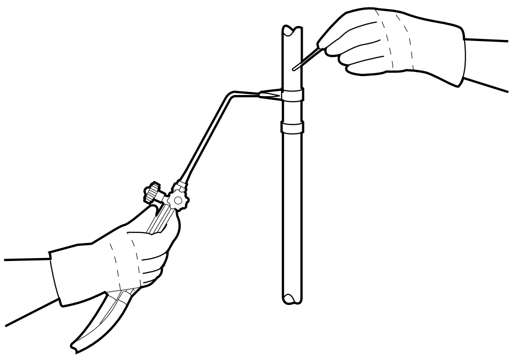
4. Support the assembled tubing and fittings to be joined so they do not come apart when heat is applied. ***If brazing near a service valve or similar component, wrap it with a wet rag to protect it from heat damage (Figure 5-20).***
5. Set up, ignite, and adjust the flame of the oxyacetylene torch per the instructions given earlier in this section.
6. Apply the torch flame to the joint. Do not allow the inner cone of the flame to touch the metal. Heat the male tube near the joint first. Make sure to keep the torch moving for uniform heating of the parts and to prevent overheating any one area.
7. If brazing with a silver alloy and flux, watch the flux. It will first bubble and turn white and puffy, then melt into a clear liquid. This is an indication that the metal is hot enough to melt and flow the filler alloy.

   If brazing using a fluxless copper-phosphorus alloy, the same basic process of heating the metal is used. However, a slightly higher temperature is normally required to flow the alloy since it does not flow as easily as the lower-temperature silver alloy.
8. When the flux becomes clear, shift the flame to the fitting or female tubing and touch the brazing rod to the joint to see if it flows (Figure 5-21). If the metal is hot enough, the alloy will flow. ***Do not heat the alloy rod directly.*** Move the rod around the circumference of the joint while still applying heat, allowing the alloy to be drawn into the joint by capillary action.
9. After the joint is made, quench it with water to cool the joint and to wash away any flux residue. Removal of the flux residue is important because it is slightly corrosive and can cause eventual failure or leakage at the joint. Inspect the joint for visual signs of defects.

▼ Figure 5-20.
Wrap Valves and Fixtures Near Joints with Wet Rags



▼ Figure 5-21.
When Flux Becomes Clear, the Metal is Hot Enough to Flow the Silver Alloy



WATCH THE FLUX:

- AT 212 ° F THE WATER BOILS OFF.
- AT 600 ° F THE FLUX BECOMES WHITE AND SLIGHTLY PUFFY AND STARTS TO WORK.
- AT 800 ° F IT LAYS AGAINST THE SURFACE AND HAS A MILKY APPEARANCE.
- AT 1100 ° F IT IS COMPLETELY CLEAR AND ACTIVE AND HAS THE APPEARANCE OF WATER.

Soldering – As stated previously, the techniques for soldering and brazing are similar. The difference is the torch used and how the heat and solder are applied to the joint. Solder a joint as follows:

1. Measure, cut, deburr, clean, and apply the proper flux to the tubing as previously described for brazing.
2. Set up, ignite, and adjust the flame of the air-acetylene torch per the instructions given earlier in this section.
3. Apply the flame to the joint. Hold the torch so that the inner cone of the flame just touches the metal. Heat the male tube near the joint first, then move to the fitting or female tubing. Make sure to keep the torch moving for uniform heating of the parts and to prevent overheating any one area.
4. Remove the flame from the joint, then touch the solder to the joint. If the solder does not melt on contact with the joint, remove it and continue to heat the joint, then try again. ***Do not melt the solder with the flame.***
5. When the joint temperature is hot enough to melt the solder, apply the heat to the base of the fitting to help draw the solder into the joint. Continue to feed solder into the joint until a ring of solder appears around the joint, then stop.
6. After the joint is made, quench it with water to help cool the joint and to wash away any flux residue. Inspect the joint for visual signs of defects.

QUICK NOTE

BRAZING AND SOLDERING TIPS

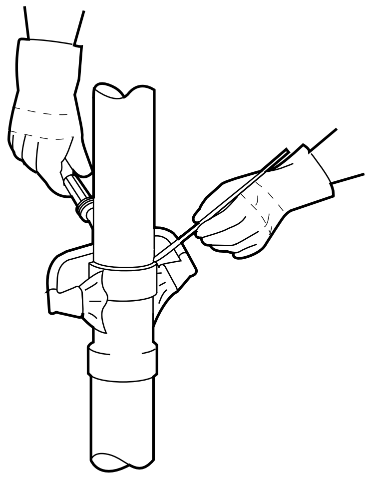
- When joining larger tubing, a double-tip torch *(Figure 5-22)* can supply the needed heat.
- If the filler alloy fails to flow or balls up, it can indicate oxidation of the metal surfaces, or insufficient heat on the parts to be joined.
- If work starts to oxidize during heating, it indicates the use of too little flux.
- If the alloy does not enter the joint but tends to flow over the outside of either part of the joint, it can indicate that one part is overheated, one part is underheated, or both. If this happens, stop brazing, disassemble the joints, and reclean and reflux the parts.

Purging while Brazing/Soldering – When copper tubing is heated, it reacts with the oxygen in the air to form copper oxide within the tubing. This copper oxide can contaminate the system *(Figure 5-23)*. To prevent this, all the air must be removed or purged from the tubing during the brazing process. Purging is best done using nitrogen. ***NEVER USE OXYGEN, REFRIGERANT, OR COMPRESSED AIR TO PURGE TUBING. AN EXPLOSION CAN RESULT WHEN OIL AND OXYGEN ARE MIXED.***

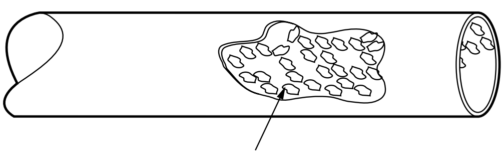
WARNING

When nitrogen is connected to and fed through the lines being brazed, no oxides will form. The nitrogen tank must be equipped with a proper flow regulator *(Figure 5-24)*. In addition, a pressure relief valve must be installed in the feed line to limit the pressure to a safe level for use in the equipment. The nitrogen regulator should be adjusted to the lowest pressure that allows just enough nitrogen to flow to keep air out of the tubing being brazed. As a rule of thumb, the flow is sufficient when it can be felt with the palm of your hand.

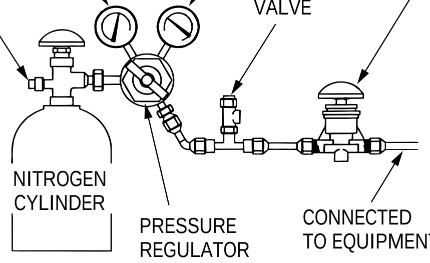
▼ Figure 5-22.
Double-Tip Torch



▼ Figure 5-23.
When Copper is Heated for Brazing, it Reacts with the Oxygen in the Air to Form Copper Oxide Inside the Tubing



▼ Figure 5-24.
Gauge-Equipped Pressure Regulator Used with Nitrogen



GAS PIPING AND FITTINGS

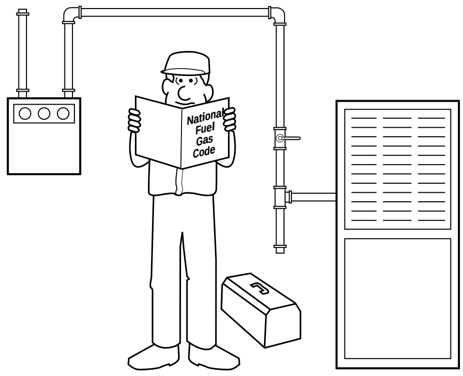
Schedule 40, steel and wrought iron pipe are commonly used for gas pipe. Stainless steel, copper, and aluminum tubing can also be used with gases that are not corrosive to them. When selecting and installing gas pipe, always follow all local codes *(Figure 5-25)*. If no local codes exist, follow the current issue of the National Fuel Gas Code. Some important precautions on pipe use are:

- Cast iron pipe cannot be used.
- Copper tubing cannot be used if the gas contains sulphur. To find out, check with the local gas utility.
- Aluminum tubing should not be used in wet locations, or in outdoor or underground locations. Aluminum tubing must be coated to protect against external corrosion in places where it is in contact with masonry, plaster, and insulation. When moisture is present in the gas, aluminum tubing should be used with caution.
- Plastic piping can be used in outside underground installations only.

Joints made in iron pipe may be threaded or welded, but in residential and light commercial work, they are normally threaded. Copper and steel tubing can be joined by brazing using an alloy containing not more than 0.05 percent phosphorus and having a melting point greater than 1,000° F. Flare fittings and compression fittings may also be used if permitted by local code, but are normally prohibited in concealed locations. The fittings must be made of compatible materials. For iron and steel, fittings may be made of steel, brass, bronze, or iron. For copper, they should be made of copper or brass, and for aluminum, they should be aluminum alloy.

The remainder of this section will focus on the procedures for joining iron and steel pipe.

▼ Figure 5-25.
Follow all Local Codes when Installing Gas Pipe—if None Exist, Follow the National Fuel Gas Code



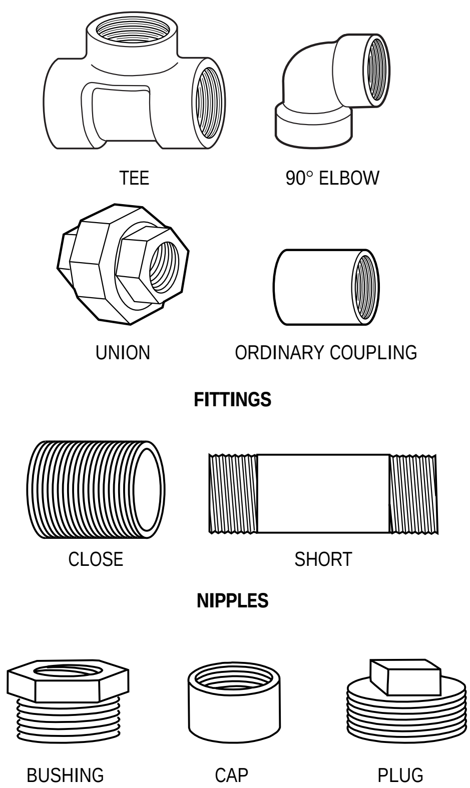
Black Iron/Galvanized Steel Pipe and Fittings

Black iron and galvanized steel pipe are similar. The difference between the two is that galvanized pipe is zinc coated to prevent rusting. Steel pipe comes in various lengths and sizes. In HVAC gas piping, threaded pipe ends and malleable iron fittings are normally used to make connections *(Figure 5-26)*.

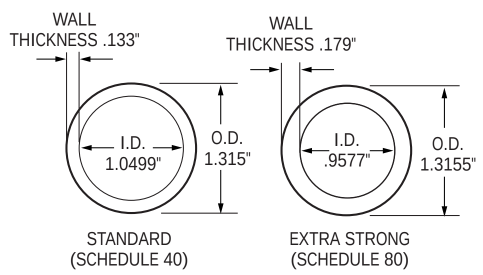
For pipe sizes below 12 inches, sizes are expressed by the *nominal* inside diameter (I.D.). Pipes with the same nominal size can have walls of different thicknesses. Wall thickness in HVAC applications is usually expressed by the term *Schedule*, such as Schedule 40 or Schedule 80, where the thickness and strength of the wall increase as the schedule number goes up *(Figure 5-27)*. For HVAC gas piping, Schedule 40 or standard weight pipe of the required size is normally used.

Pipe and fittings threaded for American National Standard tapered threads are always used for HVAC work because they produce a leak-tight and mechanically rigid piping system. Threads are expressed in terms of the nominal pipe size, number of threads per inch, and the thread series symbol. For example, the thread specification 3/4 - 14 NPT means:

▼ Figure 5-26.
Steel Pipe Fittings and Components



▼ Figure 5-27.
Comparison of 1" Pipe Wall Sizes



3/4 = 3/4-inch nominal thread diameter
14 = 14 threads per inch
NPT = American (National) Standard Taper Pipe Thread

Cutting and Reaming Steel Pipe

One common method for measuring pipe is called the *face-to-face method* *(Figure 5-28)*. As shown, the distance between the face of one fitting to the face of a second fitting is measured. To determine the length of pipe, add the depth of thread engagement needed for each of the fittings.

When cutting and threading pipe, secure the pipe in a vise *(Figure 5-29)*. A pipe cutter (not a tubing cutter) is used to cut the pipe. The cut is made by revolving the cutter around the pipe and tightening the cutting wheel about 1/4 revolution with each turn. Avoid overtightening the cutting wheel because this can cause a larger burr to form inside the pipe and excessive wear of the cutting tool wheel.

After the pipe is cut, remove any burrs with a tapered reamer. Failure to remove burrs can restrict the flow in a system.

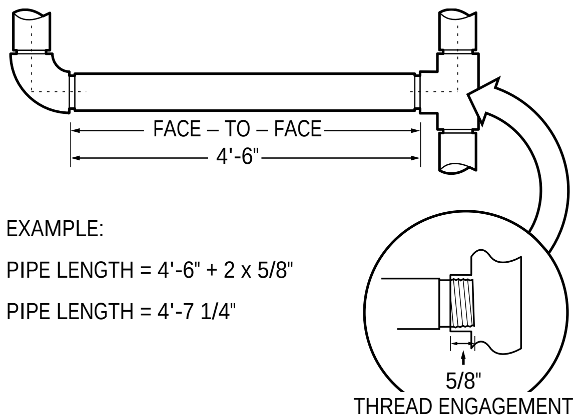
Threading Steel Pipe

Tapered threads can be cut with a hand threader *(Figure 5-30)* or electric pipe threader. The use of a hand threader is described here. If using an electric threader, operate it as directed by the manufacturer's instructions. Hand threaders are made up of two parts: the die and the stock. The stock serves as the tool handle and holds the die. The die cuts the threads. A different die must be used for each size pipe.

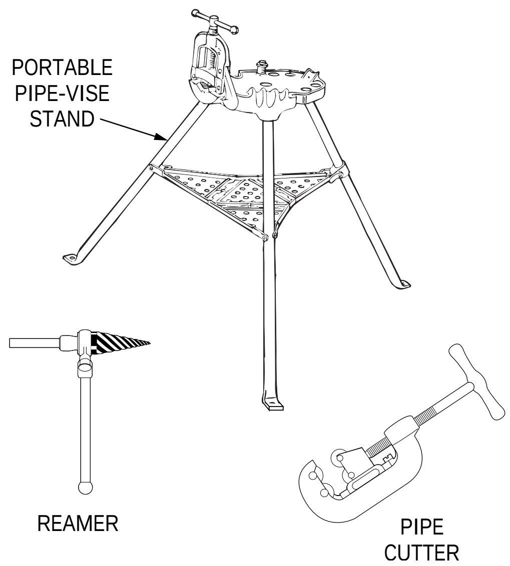
To thread pipe using a manual stock and die, proceed as follows:

1. Install the correct die for the size of pipe. Make sure the die cutters are free of nicks and wear.
2. Slide the die over the end of the pipe, guide end first.
3. Using the heel of your gloved hand, firmly push the die against the pipe, then slowly rotate the die clockwise until enough threads are cut to keep the die firmly on the pipe. At this point, apply some thread cutting oil.
4. The number of threads to cut depends on the size of the pipe. *(See Table 5-1.)* Make sure to oil the die often. Also, back off (turn counterclockwise) about 1/4 turn after each full turn forward to clear metal chips from the die.
5. When done cutting the threads, rotate the die counterclockwise to remove it, being careful not to damage the threads of the die or the pipe.
6. Wipe off excess oil and chips from the pipe threads with a rag to prevent cuts. Inspect the clean pipe for burrs, chips, and scale, and ensure that there are no damaged threads that might leak.

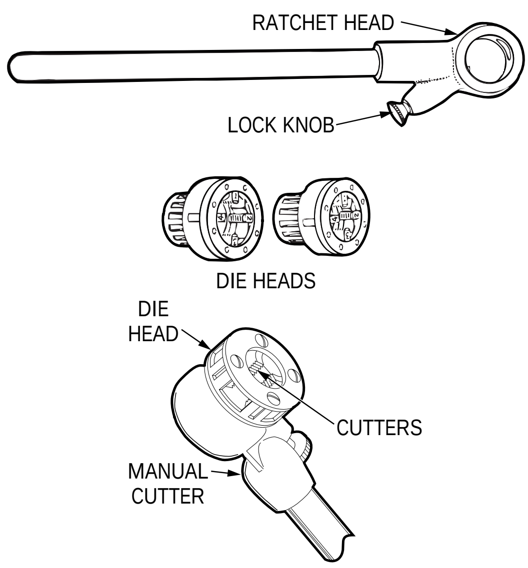
▼ Figure 5-28.
Face-to-Face Pipe Measurement



▼ Figure 5-29.
Pipe Vise and Cutting Tools



▼ Figure 5-30.
Manual Pipe Threading Tool



Assembling Steel Pipe and Fittings

When assembling joints in threaded pipe, a joint compound, such as pipe dope, must be used. If LP gases are being used, the compound must be resistant to LP gases. The compound should be applied sparingly to all male threads of all joints *(Figure 5-31)* to prevent excess compound from getting inside the pipe. ***To avoid contamination, do not apply the compound to the last two threads closest to the pipe opening. Do not apply compound to female fittings. Do not use teflon tape for joining pipes because particles of the tape may break loose as the joint is made, contaminating the system.***

CAUTION

Assemble the pipe joints in two phases; hand tighten first followed by wrench makeup. Tightening of the pipe should be done using two pipe wrenches, as shown in *Figure 5-31*. Generally, about three threads should remain showing after the pipe and fitting have been joined.

PLASTIC PIPING AND FITTINGS

Pipe Types and Sizes

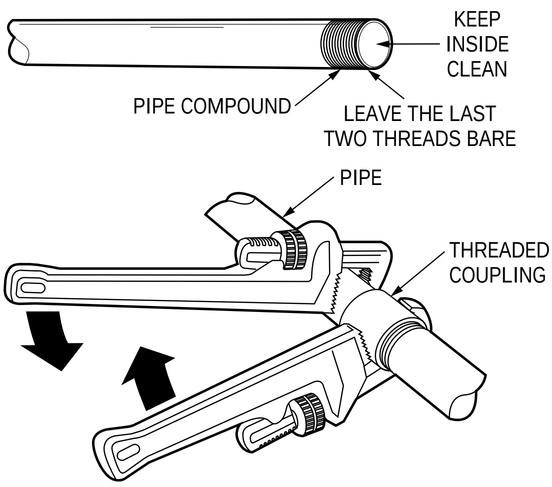
Plastic pipe is made in basically the same nominal sizes and schedules as metal pipe. The sockets of plastic fittings used to join the pipe are recessed to a depth of about 1/2 inch to 5/8 inch with shoulders at the end of the recess. When measuring pipe lengths, always make sure to take into account the depth of any fitting recesses up to the shoulder. Plastic pipe and fittings used in HVAC work are normally assembled using a special solvent-type cement. Plastic pipe can also be joined to steel or copper pipe using adapters made for this purpose *(Figure 5-32)*. Four types of plastic pipe are commonly used in HVAC work:

- *PVC (polyvinyl chloride)* – Rigid pipe with high strength used in HVAC applications to carry condensate water and flue gas.
- *CPVC (chlorinated polyvinyl chloride)* – Rigid pipe with high strength used to carry cold and hot water.
- *PB (polybutylene)* – Flexible pipe with good strength used to carry cold and hot water. It is commonly used in geothermal heat pump ground loops.
- *ABS (acrylonitrile-butadiene styrene)* – Rigid pipe with high strength used to carry water, waste, and sewage and also used in drain and vent applications.

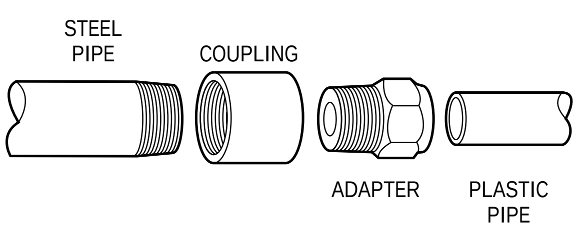
▼ Table 5-1.
Determining the Number of Threads to Cut

Pipe Size (In.)	Approximate Length of Threaded Portion (In.)	Approximate Number of Threads to Cut
1/2	3/4	10
3/4	3/4	10
1	7/8	10
1-1/4	1	11
1-1/2	1	11
2	1	11
2-1/2	1-1/2	12

▼ Figure 5-31.
Apply Thread Compound Sparingly and Use Two Wrenches when Tightening Pipe Joints



▼ Figure 5-32.
Adapter Used to Join Plastic and Steel Pipe



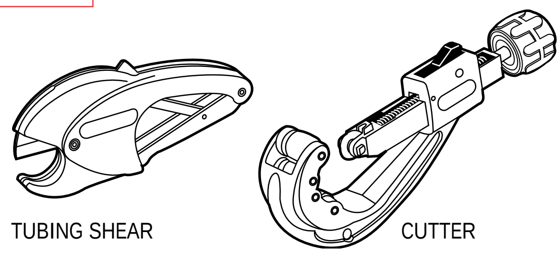
Cutting and Joining

To cut and join ABS, PVC, or CPVC pipe, proceed as follows:

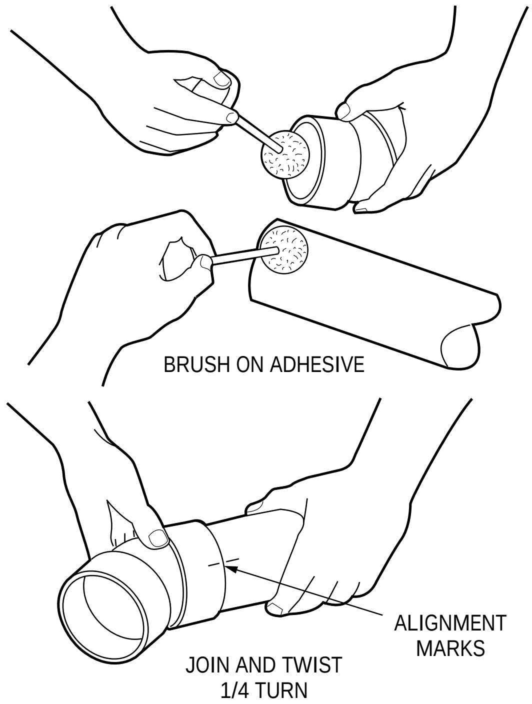
1. Use a plastic tubing cutter or a special cutter called a *plastic tubing shear* to cut the pipe *(Figure 5-33)*. Once cut, deburr using a knife or file. ***Do not use a cut-off saw to cut the pipe. It will leave particles inside the pipe which can cause clogs.***
2. Check the dry fit and alignment of the pipe and fitting. The pipe should easily go 1/3 of the way in.
3. Using a pipe cleaning solvent recommended for use with the cement, thoroughly clean the pipe end and the inside of the fitting socket.
4. Apply a thin coat of cement to the entire inside surface of the fitting socket *(Figure 5-34)* and to the end of the pipe equal to the depth of the socket.
5. ***Immediately*** after applying the cement to the parts, push the pipe completely into the fitting socket using a 1/4-turn twisting motion until the pipe bottoms in the socket and completely spreads the cement.

▼ Figure 5-33.
Plastic Pipe Cutting Tools

CAUTION



▼ Figure 5-34.
Cementing Plastic Pipe



QUICK NOTE

If the alignment of the plastic pipe and fitting being joined is critical, mark a line across both parts while the assembled joint is being dry-fitted. This line can be used later to properly align the pipe and fitting when they are permanently assembled with cement.

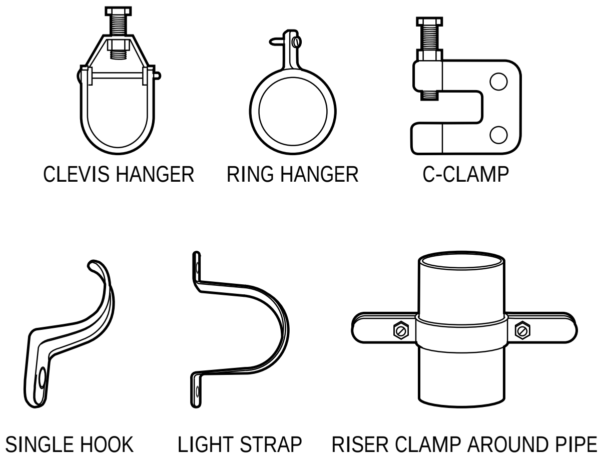
PIPE HANGERS AND SUPPORTS

Piping and tubing can be supported using a variety of hangers or supports *(Figure 5-35)*. Used at the necessary intervals, they keep the piping in alignment and prevent sagging or accidental movement. Hangers and supports must be installed in a manner that does not interfere with the free expansion and contraction of the piping between anchors. When installing pipes, always refer to local gas codes and other codes for specific requirements. ***Piping should never be supported by other piping in the building.***

Table 5-2 gives some guidelines for typical spacing of pipe hangers and supports used with steel pipe and copper tubing. For rigid plastic lines, support is generally provided about every three to five feet.

Hangers and wall brackets used to support refrigerant piping normally have a vibration-absorbing material between the support and the pipe. When piping must pass through a wall, roof, or ceiling, it must run through an adequately sized sleeve. There should be enough room within the sleeve for the pipe and for any pipe insulation. Any remaining open space in the sleeve should be stuffed with insulation. Where the sleeve meets the surface, caulk should be applied.

▼ Figure 5-35.
Common Hangers and Supports



▼ Table 5-2.
Typical Pipe/Copper Tubing Support/Hanger Spacing

Pipe Size	Spacing Between Hangers / Supports (Ft.)			
	Standard Steel Pipe		Copper Tubing	
	Water	Gas	Water	Gas
1/2	7	6	5	4
3/4	7	8	5	6
1	7	8	6	8
1-1/2	9	10	8	—
2	10	10	8	—
2-1/2	11	10	9	—

SECTION 6

FORCED-AIR DUCT SYSTEMSS

INTRODUCTION

Residential or light commercial cooling/heating installations often require that the HVAC technician install new duct systems or change existing ones. Proper installation of the air distribution system is critical to the correct performance of the related heating/cooling equipment. The focus of this section is on the techniques used for installing duct systems and components. Also covered are conditions in a duct system that can cause problems. This section is not intended to teach air system theory or duct design; it presumes that the proper type of equipment and ductwork have been selected and purchased for the job by a qualified engineer or salesperson based on a survey of the job.

FORCED-AIR DUCT SYSTEM MENU

THE BASIC AIR DISTRIBUTION SYSTEM

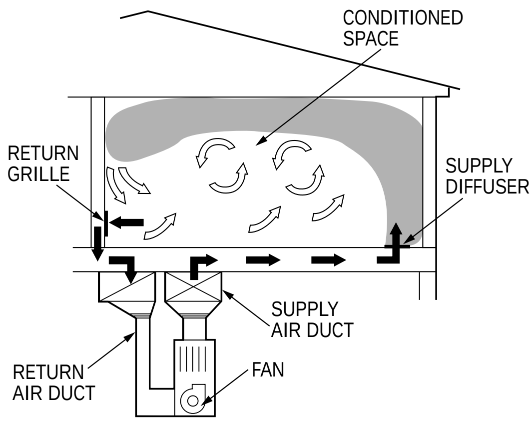
There is a great diversity in residential and light commercial forced-air distribution systems and equipment, but they all have the same basic components *(Figure 6-1)*. All systems, no matter how complex, can be divided into three functional areas:

- *Ductwork system* – Includes the supply and return trunk ducts and all the branch or runout ducts.
- *Air distribution system* – Includes the conditioned space supply diffusers and return air grilles.
- *Fan system* – Includes the blower and motor in the furnace or fan coil.

Depending on the climate and design of the building, duct systems can be installed in basements, crawl spaces, open areas, closets, attics, and imbedded in concrete floors (slabs). Ducts can be made from various materials, but galvanized sheet metal, fiberglass ductboard, and metallic or nonmetallic flexible ductwork are the most common.

Building codes pertaining to the installation of air distribution systems vary widely. The National Fire Protection Agency (NFPA) Standard 90B, Council of America Building Officials (CABO) *One- and Two-Family Dwelling Code*, or a local code are commonly used for duct systems in single-family dwellings. NFPA Standard 90A is used in most localities for multi-family homes. You must be aware of and follow all relevant codes.

▼ Figure 6-1.
Basic Air Distribution System

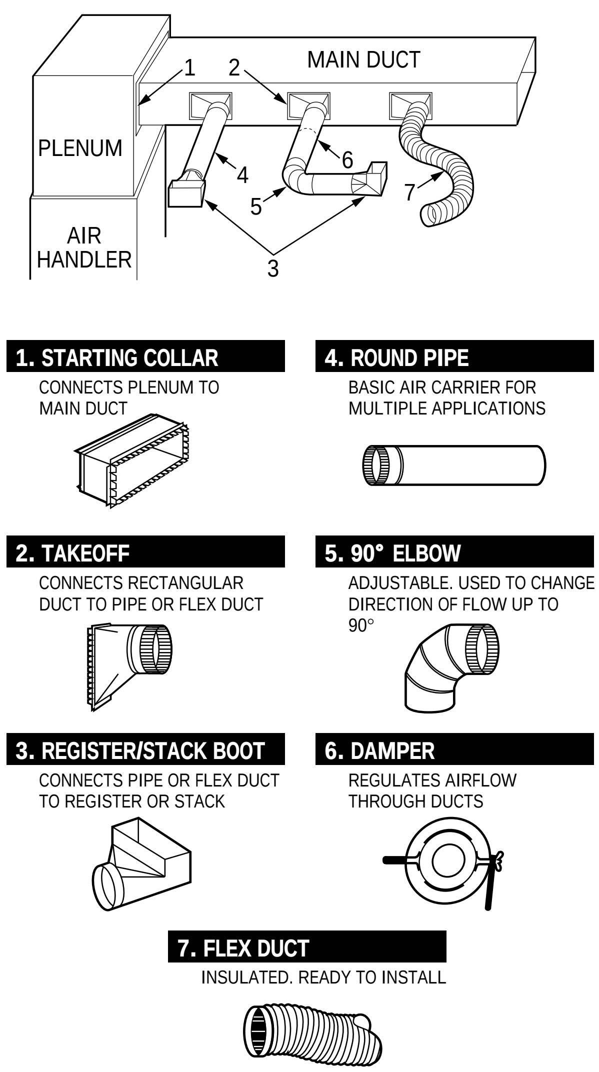


GALVANIZED STEEL DUCTWORK SYSTEMS

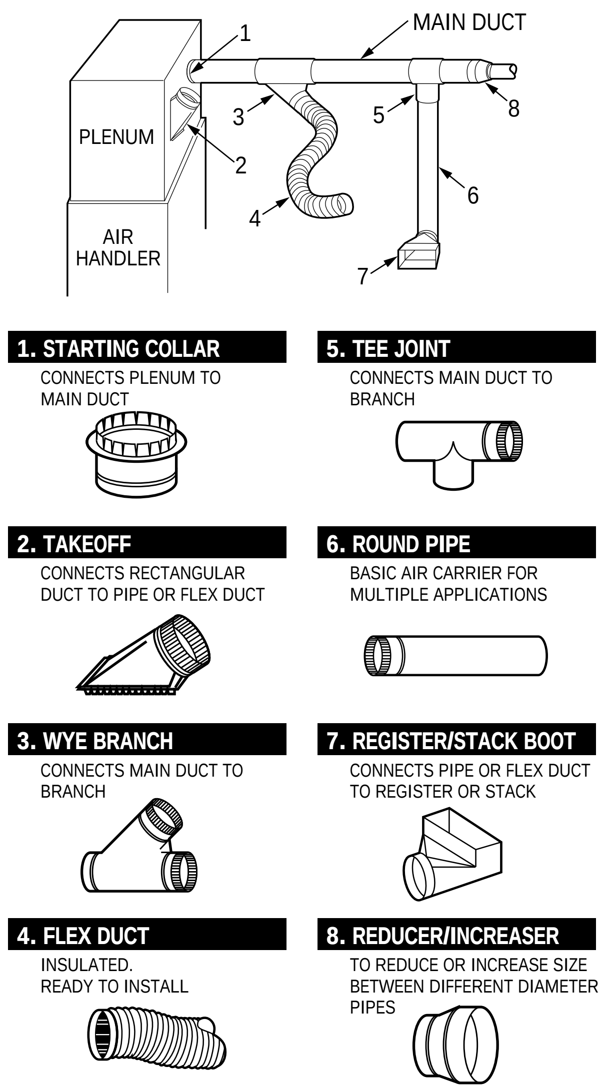
Trunk and Branch Ducts

Rectangular or round galvanized steel duct is commonly used in air distribution systems. Standard duct sizes are readily available. *Figures 6-2* and *6-3* show the components that are commonly used with rectangular and round duct systems. Standard lengths are available for both. The thickness of metal duct is expressed as its *gauge*. Rectangular and round ducts of 24 to 30 gauge are used for residential and light commercial installations. The larger size ducts have thicker, more rigid walls to prevent them from making popping-like noises when the system blower starts and stops. The sizes of the various ducts used in a system is determined by the maximum volume of air in CFM that must flow through each section of duct. Tables for sizing duct based on airflow in CFM are located on pages 156 and 157 of this book.

▼ Figure 6-2.
Typical Rectangular Duct System Components



▼ Figure 6-3.
Typical Round Duct System Components



Fittings and Transitions

Fittings such as elbows, angles, takeoffs, and boots change the direction of airflow or change its velocity. *Transitions* are typically used to change from one size or shape duct to another. Because each fitting or transition installed in a duct run adds friction and reduces the quantity of air the duct can carry, the use of unneeded fittings or fittings not suited for the job must be avoided. For the same reason, the path for all duct runs should be as direct as possible.

The pressure drop for each type of fitting is known and is expressed as an *equivalent length of straight duct* value. The assigned value is equal to the pressure drop of a specific number of feet of straight duct length of the same size. Duct designers use these values when calculating the external static pressure of a system. External static pressure is discussed later in this section.

Supply Outlets and Return Grilles

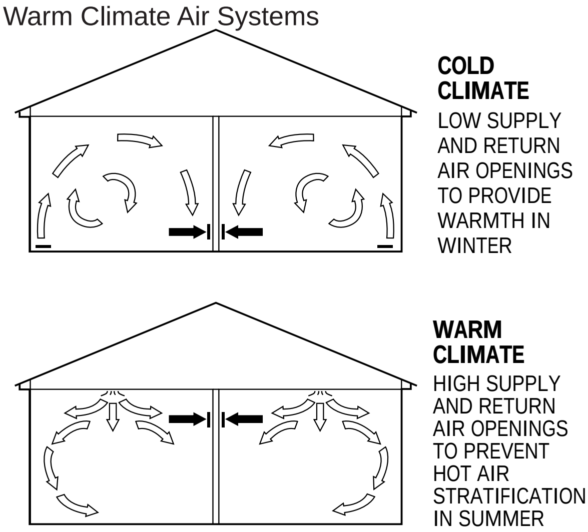
The locations and types of supply outlets and return grilles used in a system is determined by the climatic conditions for which the system is designed. Air distribution systems designed for cold climates will usually have supply and return air openings located low in the rooms to provide warmth at the walls and floors in the winter. This allows the heated air to rise into and heat the rooms *(Figure 6-4)*. Air systems designed for hot climates will usually have supply and return air openings located high in the rooms to allow the heavier cool air to fall into and cool the rooms. Systems designed for moderate climates may use either design, or a compromise between the two.

Supply air outlets (diffusers) provide the proper air motion in a room and blend the supply air with the room air so that the room is comfortable without excessive noise or drafts. The size of each diffuser is based on the volume of air in CFM that is supplied from the outlet. Tables for sizing diffusers and grilles based on airflow in CFM are located on page 156 of this book. Five types of supply diffusers are commonly used *(Figure 6-5)*. Baseboard, floor, and low sidewall diffusers are used mainly in heating systems; high sidewall and ceiling diffusers are used mainly in cooling systems.

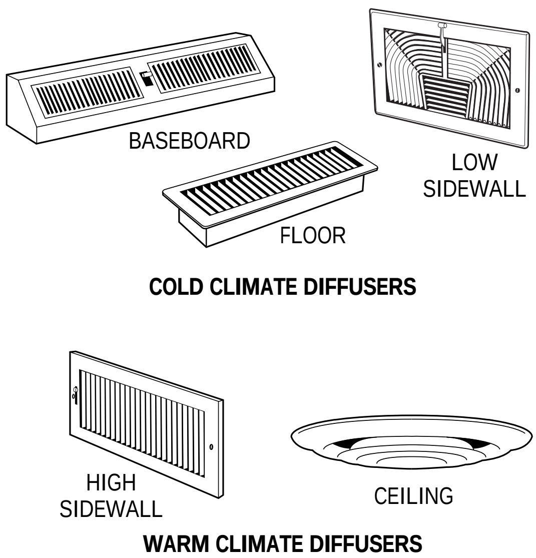
For proper operation, diffusers should be mounted at the ends of branch ducts. They should not be mounted directly on the main ductwork. Proper operation is based on each diffuser receiving a flow of non-turbulent air in a straight line. If attached directly to a main duct, the diffuser will shoot turbulent air out at an angle, causing it to be noisy. Also, the volume of air will be incorrect, making system balancing difficult. If it is necessary to install a diffuser in an extremely short branch run, turning vanes or a scoop should be installed in the run to straighten out the air before it enters the diffuser. Most diffusers are equipped with built-in dampers. These dampers should never be considered as a substitute for a branch volume damper. Diffuser dampers are intended only to apply or shut off airflow to a room.

Return grilles are similar to supply diffusers, except they normally do not have deflection or volume control devices. Return air grilles are mounted in locations that are compatible with the supply outlets and ductwork. In heating systems, return grilles are ideally installed where the coolest air in the area will be returned. Similarly, in cooling systems, they are installed where the warmest air will be returned. ***Never install return air openings in bathrooms or kitchens because they will spread odors throughout the building by way of the ductwork system (Figure 6-6)***.

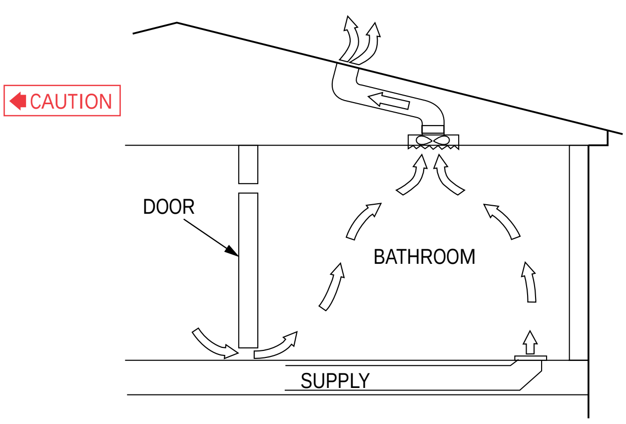
▼Figure 6-4.
Supply and Return Air Openings in Cold and Warm Climate Air Systems



▼Figure 6-5.
Supply Diffusers



▼Figure 6-6.
Avoid Odor Pollution



AVOID ODOR POLLUTION. DO NOT INSTALL RETURN IN BATHROOM. EXHAUST ODORS. PROVIDE UNDERCUT AT DOOR. SUPPLY AS USUAL.

Volume Dampers

Volume dampers are used to adjust the amount of airflow through the branch runs of an air distribution system. Without dampers, air cannot be properly distributed and balanced, causing some rooms to receive too much air while others do not receive enough. Dampers should be installed in an accessible place in each branch supply duct as close to the main duct or supply air plenum as possible *(Figure 6-7)*. Otherwise, significant turbulence and noise will be transmitted into a room via the room diffuser.

Simple butterfly dampers with manual adjustments are normally used in single-zone heating/cooling systems. Dampers used in multiple-zone systems are usually automatically controlled by a damper motor.

Installation Guidelines

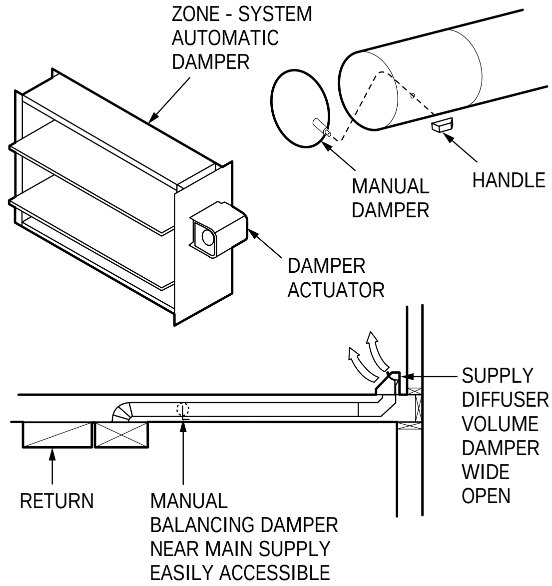
Before installing ductwork, study the system layout diagram and the building's construction to determine the best approach. Make sure to use all the ductwork parts exactly as specified by the system designer. Do not substitute different duct sizes, fittings, etc. as their use could alter the system design enough to prevent proper system operation. The methods used to install all metal duct systems are similar. Guidelines for the installation of a simplified extended plenum ductwork system *(Figure 6-8)* are given here. They involve the installation of the following components:

- Supply trunk starting collar on the plenum
- Supply and return main trunk ducts
- Branch supply ducts and room diffuser boots
- Branch return ducts and return grille boots
- Supply diffusers and return air grilles

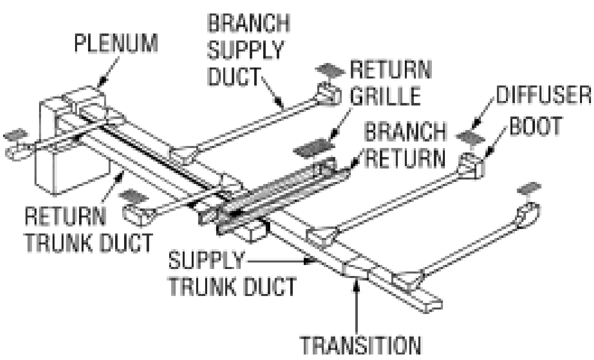
Installing the Plenum and Supply Trunk Starting Collar – When installing the plenum and supply trunk starting collar, follow these basic guidelines:

1. Temporarily place the prefabricated plenum in position on the furnace or air handler.
2. From the system layout diagram, determine where the supply trunk duct starting collar should attach to the plenum.
3. Using a template *(Figure 6-9)*, mark the location where the collar must be installed.
4. Cut the collar opening by first drilling or punching a hole inside the marked area to be cut, then use tin snips *(Figure 6-10)* to cut the opening. Follow around the marked outline. Use dividers or a hole cutting tool for making round takeoffs.
5. Place the collar in the opening of the plenum, then secure by bending the metal tabs flat against the inside of the plenum. If installing more than one starting collar on a plenum, they should all be mounted at the same height on the plenum.
6. Correctly position the plenum on the furnace or air handler and attach using sheet metal screws.

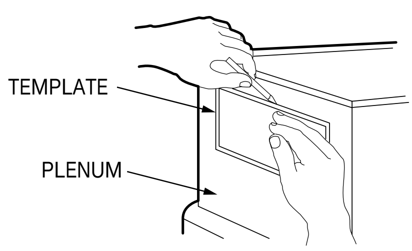
▼ Figure 6-7.
Dampers

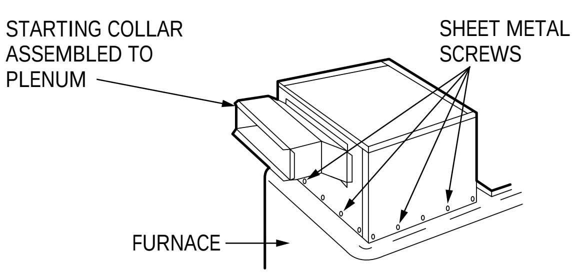


▼ Figure 6-8.
Simplified Extended Duct System



▼ Figure 6-9.
Using a Template to Outline Openings to be Cut in a Plenum



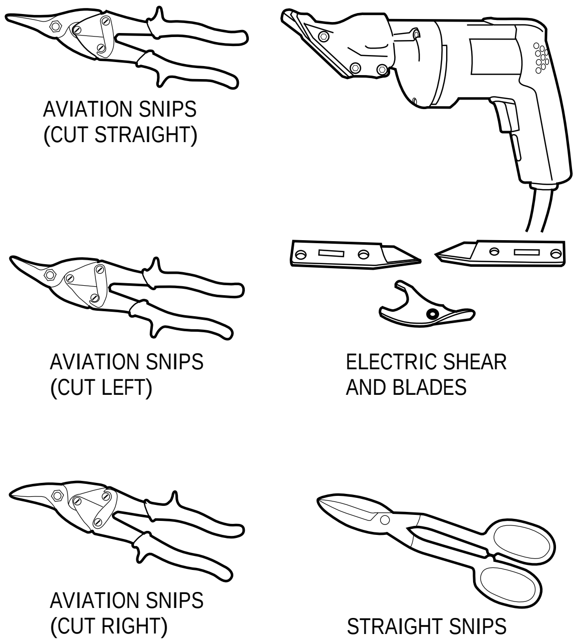


Installing the Main Supply and Return Air Trunks – Start at the furnace or air handler. Rectangular trunk ducts are usually run at right angles to the building's floor joists, allowing the branch ducts to run between the joists. The sections can be supported by strap, trapeze, or rod hangers. ***Be sure to leave a minimum clearance of at least one inch between the supply ductwork and the bottom of the joists. This is necessary for fire prevention.*** Joints in round duct trunk systems are normally fastened together with sheet metal screws. Rectangular ducts can be purchased with built-in snap joints *(Figure 6-11)* for quick assembly or can be fastened together using S-type connectors and drive clips as described below.

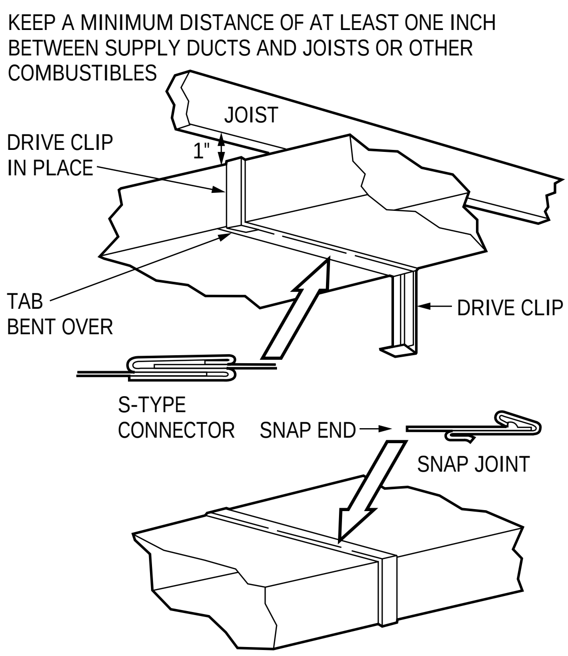
1. Put an S-type connector over both long (transverse) edges of the first duct section. Make sure the connector ends are flush with the sides of the duct.
2. Align the next section of duct with the preceding one so that its long edges are started into the S-type connector slots. Firmly push the duct so that it is completely seated in the slots of the S-type connector.
3. Use drive clips to fasten the two short sides of the joint. Bend the tab on one end of the clip inward 90°. Put the clip upward over the duct edges and tap it with a hammer to drive it in place, then bend the top tab down over the duct.
4. Duct fasteners make a nearly airtight connection. If further sealing is needed, tape the joint with approved duct tape.

Air that flows into a trunk duct elbow, takeoff, etc. becomes quite turbulent downstream from the device and requires a few feet of straight, uninterrupted airflow for the turbulence to diminish. When takeoffs and other parts are installed too close together, air turbulence can build up and cause the system to become noisy. To reduce turbulence and prevent noise in the extended plenum system, the first branch takeoff should be made at least 18 inches away from the beginning of the trunk duct *(Figure 6-12)*. Also, the end of the trunk should extend at least 12 inches beyond the takeoff for the last branch.

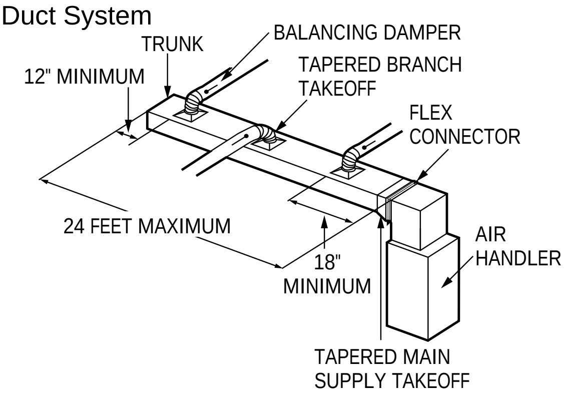
▼ Figure 6-10.
Sheet Metal Cutting Snips and Shears



▼ Figure 6-11.
Rectangular Duct Installation



▼ Figure 6-12.
Guidelines for Installing an Extended Plenum Duct System



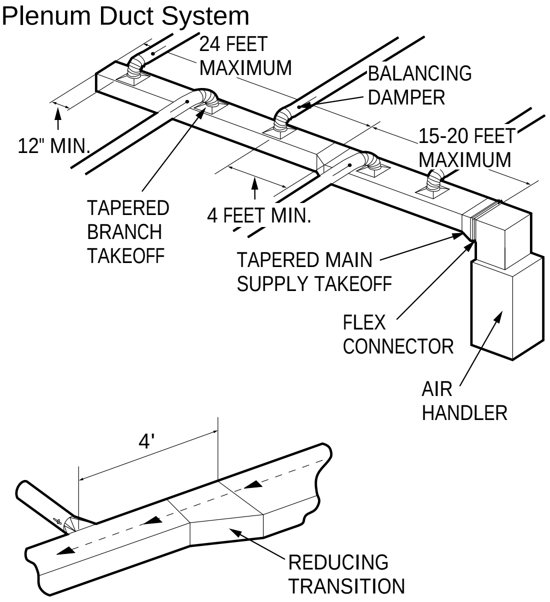
An extended plenum duct system works best when the length of its supply and/or return trunk ducts do not exceed 24 feet. When trunks longer than 24 feet are needed, a reducing extended plenum duct system *(Figure 6-13)* should be used. As shown, the length of the first trunk section should not be longer than 15 to 20 feet. The size of the duct used in each succeeding section becomes smaller because it carries less air. The length should not exceed 24 feet. Generally, a reduction in trunk duct size is made after every three branch duct connections. Single-taper transitions are used to reduce from the larger to smaller duct size. To allow the air turbulence resulting from the transition to diminish before the air enters the next branch duct, the first branch duct takeoff downstream of the transition should be located at least four feet away from the transition.

Installing the Branch Supply Ducts and Return Ducts – When the main trunk ducts are installed in the ceiling of a basement or crawl space, round branch ducts are normally run to the first floor supply air diffusers and return air grilles via the space between the floor joists *(Figure 6-14)*. In multi-story buildings, the upper floor supply and return branches are connected to the trunk ducts by combining round ducts within the floor joists with stack ducts installed in the interior walls.

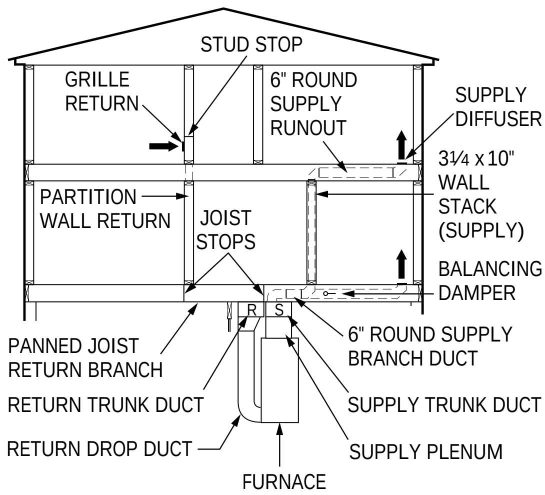
The size of the round duct used in each branch run is determined by the quantity of air it must carry. Depending on the system application, and for ease of installation, many duct designers will make compromises and choose to use a standard size round duct to feed all branches. Good practice requires that the smallest size round duct used for any branch duct to major rooms (all but bathrooms, foyers, etc.) be at least six inches. The duct used for partition wall stacks can be 2-1/4 or 3-1/4 inches thick with widths from 10 to 14 inches.

Although not recommended, it is sometimes necessary to run wall stacks up outside walls or in walls next to unconditioned spaces *(Figure 6-15)*. To avoid unacceptable losses in heating or cooling capacity, the thinner 2-1/4-inch stack duct typically is used to allow at least one inch of insulation to be installed between the duct and the outside wall. The disadvantage of using this smaller size stack is that it can only carry about 70% of the air that a 3-1/4-inch duct can carry.

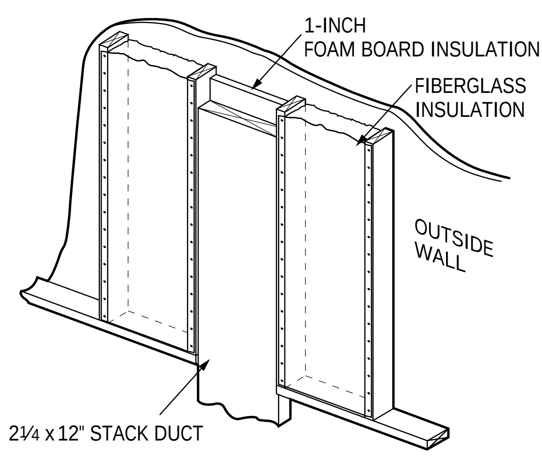
▼ Figure 6-13.
Guidelines for Installing a Reducing Extended Plenum Duct System



▼ Figure 6-14.
Typical Branch Duct Routing



▼ Figure 6-15.
Installation of Outside Wall Stack Duct



When local codes permit, framing spaces are often used as return ducts. As shown in *Figure 6-16*, the wall space between the studs can be used as a return stack duct for a high-wall return air grille or for a return stack connecting the first floor with an upper floor. Wooden or sheet metal stops must be installed to seal off the stud space from the rest of the area. In a like manner, the bottom of a floor joist space on any floor may be covered with sheet metal and its ends sealed to use the space as a return air duct. This is referred to as a *panned return duct.*

Branch duct installation involves cutting openings in the supply and return ducts to mount takeoffs and other fittings. The holes for these devices are marked and cut, and the devices mounted on the trunk ducts using the takeoff for a marking template.

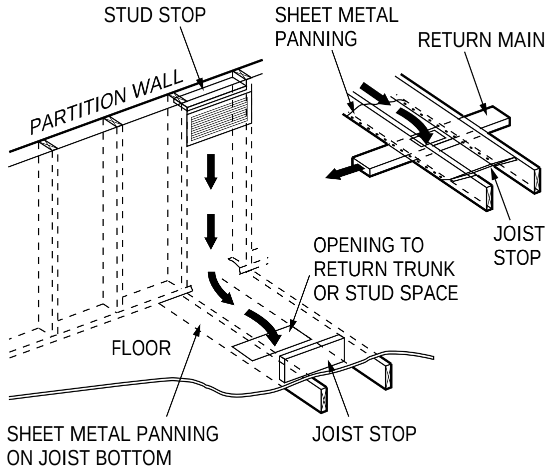
When assembling branch runs, the last section of duct usually must to be cut to fit. If using round duct crimped on one end, cut the excess length from the plain end. Make sure to add about two inches to the measured length to allow for insertion of the crimped end into the boot or elbow. Then swing the boot or elbow up or down to connect to the boot extension *(Figure 6-17)*. If it is not possible to swing a boot or elbow to make the connection, cut the round duct just long enough to fit with no overlap, and fasten the joint with a drawband. If cutting rectangular duct, add enough to the measured length at the transverse edges to slip into the S-type connector and enough on the sides to form drive tabs.

Running branch ducts to the various rooms can involve considerable cutting of access holes in the building's structure. In new construction, the process is easier because everything is open and visible. In renovation and remodeling jobs, it is much more difficult and mistakes can be costly.

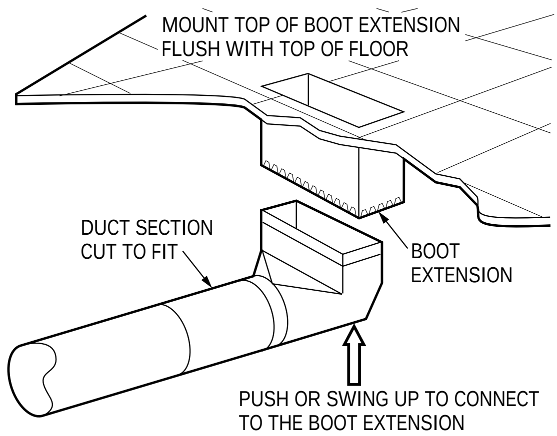
Installing Supply Diffusers and Return Grilles – Compromises are almost always made by system designers to gain a uniform appearance in a building when selecting diffusers and grilles. Diffusers and return grilles should be installed as recommended by the manufacturer.

A properly sized branch duct and diffuser reduces the velocity of the airflow in the branch. This results in quiet diffuser operation. Installation of an undersized diffuser will cause it to be noisy. For example, a diffuser rated at 110 CFM should not be connected to a duct supplying 150 CFM. An oversized diffuser can be used, but it is important to remember that the maximum amount of air it can supply is limited by the capacity of the branch duct feeding it. For example, a diffuser rated at 110 CFM can only supply 100 CFM of air when the branch duct feeding it has a maximum capacity of 100 CFM.

▼ Figure 6-16.
Stud and Joist Space Returns



▼ Figure 6-17.
Assembling the Last Section of a Branch Duct



QUICK NOTE

General guidelines to follow when cutting access holes:

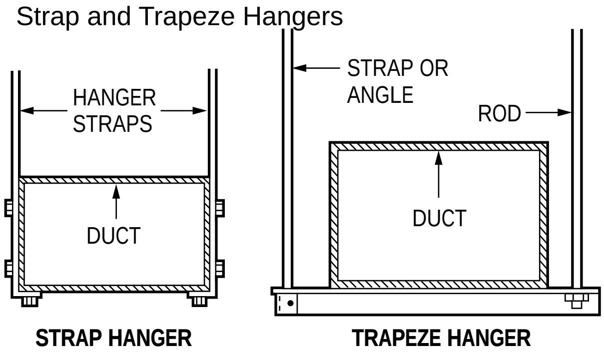
- Never assume that one building is constructed the same as a similar one.
- Always plan and measure carefully before attempting to cut any hole. Make a template to ensure that the opening will be of the correct size and shape.
- Make sure the hole will not weaken the structure. Provide temporary support for structural parts you will cut.
- When a portion of a joist or stud must be removed, always install a header of equal size to reinforce the area being cut.
- Use shallow blade settings or short blades to avoid cutting plumbing and/or electrical wires.
- Cut holes slightly larger than the duct or fitting to give enough room for adjusting and fastening.
- Be extra careful when cutting plaster to prevent leaving a ragged edge that the flange on a diffuser or grille cannot cover. Do not force the saw.

Noise and Vibration Control – A ductwork system must be supported so that it does not sag or move. Duct movement can occur when the fan starts as a result of the rush of air through the system. Metal ductwork also moves as a result of expansion and contraction. Strap or trapeze hangers *(Figure 6-18)* are commonly used to support ductwork at the joints in the duct, which are the weakest points. Your job as an installer is to hang the duct according to the designer's plans. If needed, specific requirements for supporting duct can be found in the *HVAC Duct Construction Standards* published by SMACNA.

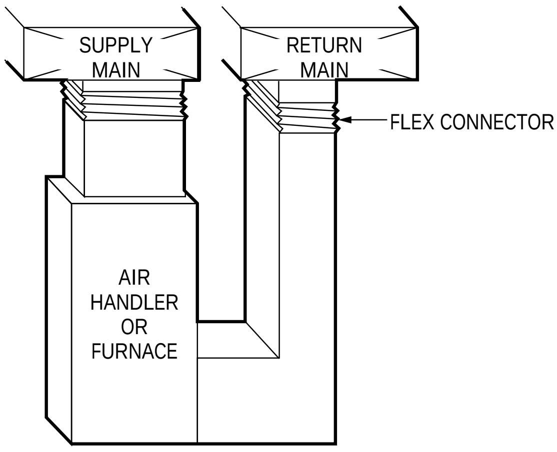
Metal duct with duct liner insulation on its interior, or fiberglass duct, can be used to absorb noise within the ducts. Duct liner is normally installed by the duct manufacturer or fabricator. It serves the purpose of providing both thermal and sound insulation. To carry the same volume of air, lined duct must be larger than unlined duct to account for the thickness of the liner. For example, when the thickness of the duct liner is one inch, a lined duct of 12 x 8 inches delivers the same amount of air as an unlined duct that is 10 x 6 inches.

Ductwork systems must not transmit machine vibrations into the conditioned space. To help prevent this, a flexible connector can be installed where the supply and return ductwork connects to the air handler unit *(Figure 6-19)*. Flex connectors should be installed so that they are not stretched so tight that they lose their flexibility nor so loose that they sag and block part of the airstream. Air handling equipment that is suspended from floor joists, roof rafters, etc. should use vibration-eliminating hangers. Without them, the unit vibration can be carried directly into the building and travel through the structure.

▼ Figure 6-18.
Strap and Trapeze Hangers

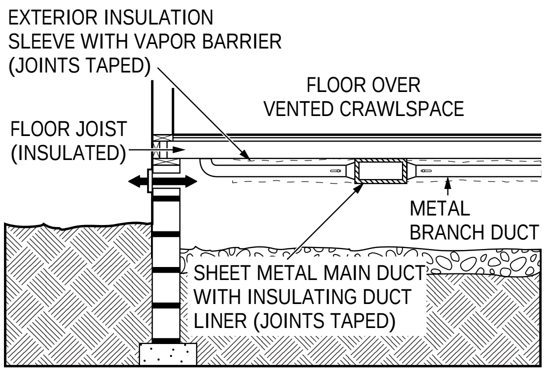


▼ Figure 6-19.
Ductwork Vibration Control



Installation of Insulation and Vapor Barriers – Any duct system that runs through an unconditioned space should be insulated if a temperature difference greater than 15° F can exist between the conditioned air in the duct and the ambient air outside the duct. This condition is common when ductwork passes through a ventilated crawlspace, attics, garages, or other unconditioned spaces *(Figure 6-20)*. Insulation is necessary to prevent the transfer of heat between the air in the duct and the air in the unconditioned space. The duct in systems with a cooling mode must also have a properly sealed vapor barrier to prevent the ductwork from sweating, causing corrosion of the duct, insulation degradation, and/or water damage to the structure.

▼ Figure 6-20.
Use of Duct Insulation and a Vapor Barrier in an Unconditioned Space



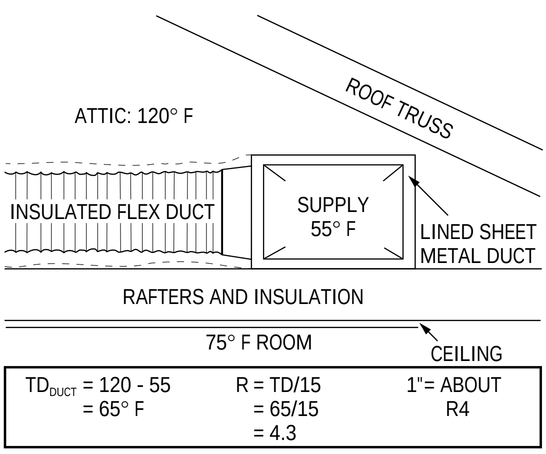
Where fiberglass ductboard is used, the insulation and vapor barrier is the duct itself. Fiberglass duct is covered in more detail later in this section. Metal ductwork can be insulated either externally, or on the inside with duct liner *(Table 6-1)*. Use of lined duct with taped joints eliminates the need for additional vapor sealing. For non-lined duct, the insulation/vapor barrier can be applied externally, after the ductwork has been installed. The insulation includes a foil or vinyl-backed vapor barrier and comes in several thicknesses. Branch ducts made of sheet metal are insulated using the same materials. It is important to seal all vapor barrier joints and holes with tape to prevent any moisture from condensing on the duct.

▼ Table 6-1.
Advantages and Disadvantages of Lined Versus Wrapped Metal Duct

	Advantages	Disadvantages
Lined	Easier to install Quieter Insulation damage unlikely	Higher cost Higher friction loss
Wrapped	Lower cost Lower friction loss	More difficult to install Insulation damage more likely Noisier

ASHRAE standards specify the minimum acceptable value (R-value) of insulation that must be used for insulating duct. *Figure 6-21* shows the formula used in the ASHRAE standard to determine the needed R-value and an example of its use. Normally, this value will be determined ahead of time for you. As a rule of thumb, the equivalent R-value for one inch of insulation is about R-4. Even though return duct systems have less difference in air temperature than supply ductwork, it is recommended that they also be insulated.

▼ Figure 6-21.
Example of a Method Used to Determine the Thickness of Duct Insulation



FLEXIBLE DUCTWORK

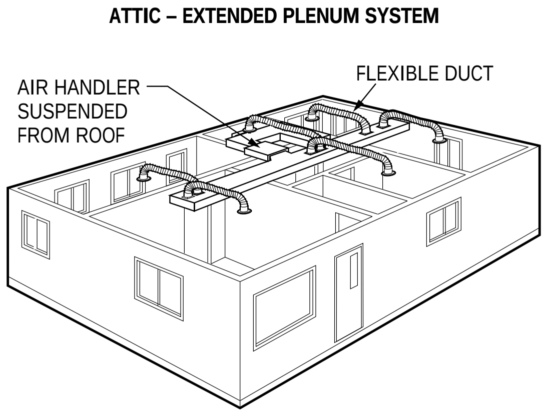
Flexible duct is commonly used as branch duct in unconditioned spaces such as attics *(Figure 6-22)* and in spaces where obstructions make the use of rigid duct difficult or impossible. Flexible duct is not recommended for use in the return side of a system. Both metallic and nonmetallic insulated and non-insulated forms of flexible round duct are manufactured in standard duct sizes and lengths and can be easily cut to the length needed.

Sections of flexible duct can be joined using coupling sleeves. Flexible duct is fastened to metal ducts or connectors using a drawband (duct strap) and a tightening tool to fasten it *(Figure 6-23)*. When making connections, collars, sleeves, etc. should be inserted into the flexible duct at least one inch before fastening. For insulated duct, the insulation is fitted over the connection and fastened with a duct strap or tape.

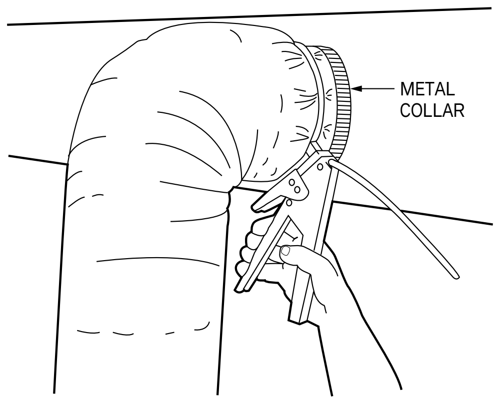
Long runs of flexible duct are not recommended. Even when properly installed, most flex duct causes at least two to four times as much resistance to airflow as the same diameter sheet metal duct. Duct runs should be kept as straight and short as possible *(Figure 6-24)*. Gradual bends should be used, because tight turns will greatly reduce the airflow and may even cause the duct to collapse. Flexible duct should be supported with one-inch or wider bands with a minimum of sag between the supports *(Figure 6-25)*. Some flexible duct comes with built-in eyelet holes for hanging the duct.

If a connection to a ceiling diffuser requires a bend, it is better to use an insulated metal elbow at the input to the diffuser than to bend flexible duct to form the connection. When using flexible duct to make very short duct runs between diffusers and takeoffs on a supply duct, the vertical alignment of the flexible duct run is critical and should be plumb. If not, diffuser noise will increase and air will shoot out to one side of the diffuser rather than being distributed evenly.

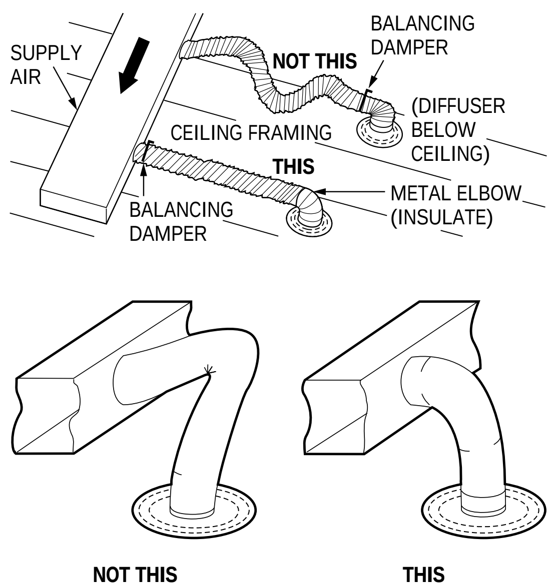
▼ Figure 6-22.
Typical Use of Flexible Duct



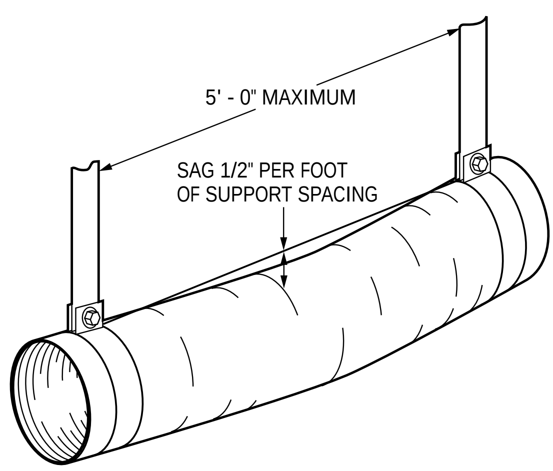
▼ Figure 6-23.
Connecting Flexible Insulated Duct to a Metal Collar



▼ Figure 6-24.
Make Straight Runs and Gradual Turns with Flexible Duct



▼ Figure 6-25.
Supporting Flexible Duct



FIBERGLASS DUCTWORK

Fiberglass duct can be used almost anywhere that metal duct can. It has more friction loss than metal duct, but has the advantage of being quieter and has a built-in vapor barrier. Fiberglass duct is available in flat sheets (ductboard) for fabricating rectangular duct and duct fittings. Some fittings such as elbows require the installation of metal accessories such as turning vanes to achieve proper airflow.

Fiberglass duct systems must be properly supported or they will sag. Hangers should not cut the outside cover of the ductboard. Follow the ductboard manufacturer's recommendations for supporting the ductwork. Guidelines are also given in SMACNA's standards for *Fibrous Glass Duct Construction*.

Aluminum-backed ductboard is made in different sizes; 1-inch thick, 4 x 10-foot boards are the most common. Ductboard manufactured with male and female shiplap joints along the 10-foot edge are normally used so that when formed into a rectangular duct section, the finished 4-foot duct has male and female joints at its ends to connect to other straight sections or fittings.

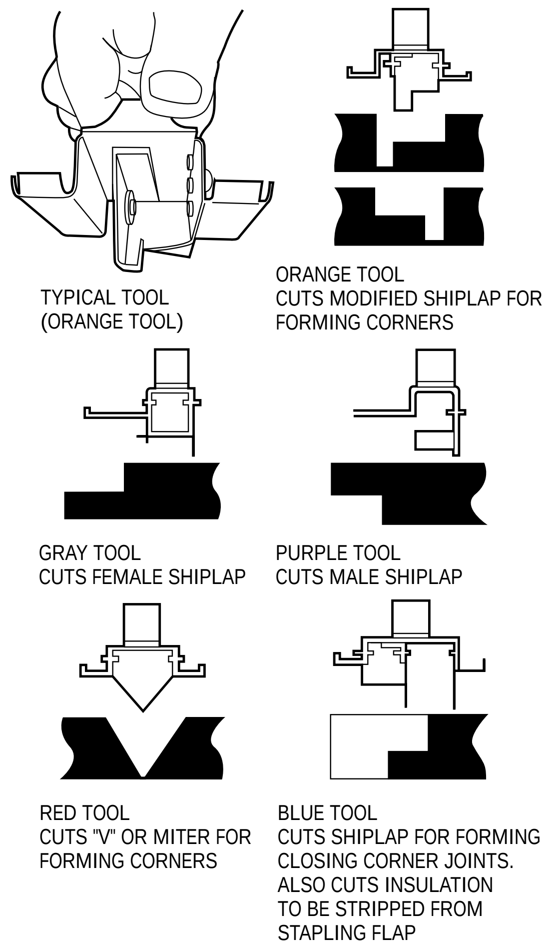
Fabrication of ductboard into straight sections and fittings is done with either special automatic grooving machines or manually with hand grooving tools. Hand tools are color coded to identify the kind of groove they cut *(Figure 6-26)*. Fabrication of straight duct sections and fittings can be done in several ways; always follow the ductboard manufacturer's instructions. Additional information can be found in SMACNA's standards for *Fibrous Glass Duct Construction*.

Figure 6-27 shows the various cuts needed to fabricate a rectangular duct section. *Figure 6-28* shows how a 90° elbow is fabricated using fiberglass ductboard. Connections are made with a combination of outward-clinch staples and special heat-activated tape.

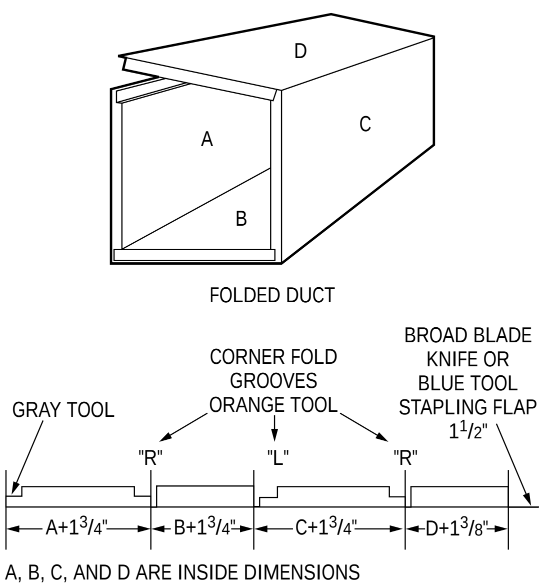
QUICK NOTE

Be careful when carrying 4 x 10-foot sheets of ductboard. Support the board overhead with hands spread lengthwise (not across the width).

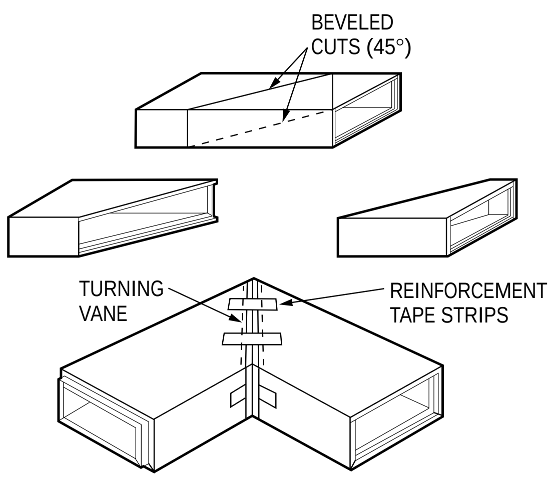
▼ Figure 6-26.
Ductboard Manual Fabrication Tools



▼ Figure 6-27.
Fabricating a Straight Duct Section



▼ Figure 6-28.
Mitered 90° Elbow

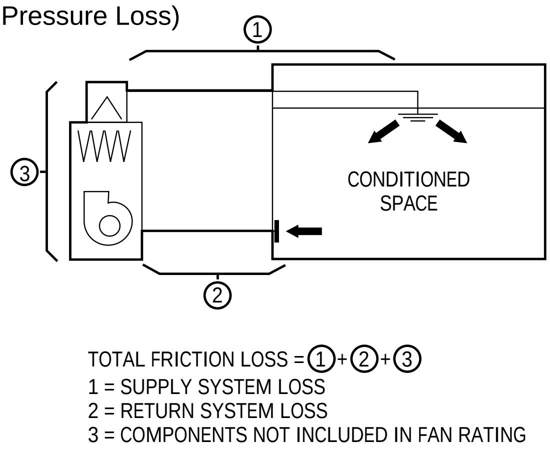


SYSTEM FANS

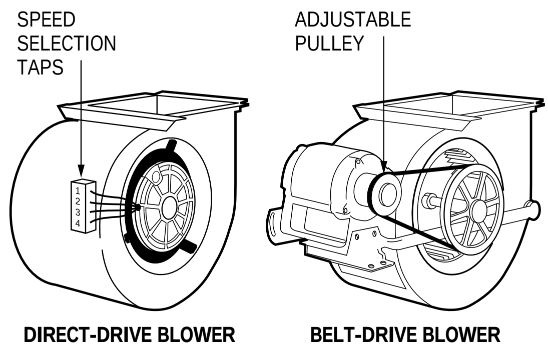
The system fan (blower) in the system's furnace, fan coil unit, etc. must provide the pressure needed to overcome the sum of the friction losses for the ductwork and other components such as evaporators, electronic air cleaners, etc. in the system that are not included in the fan rating *(Figure 6-29)*. The total pressure loss of the duct system components external to the fan assembly is called the *external static pressure* and is normally expressed in inches water gauge (in. w.g.) or inches water column (in. w.c.). Duct system designers use the friction loss to select equipment that has a fan capable of supplying the correct amount of air through the designed duct system.

Two types of fans are commonly used: direct-drive and belt-drive *(Figure 6-30)*. Most residential equipment uses multi-speed direct-drive fans. The fan speed can be selected to provide the proper amount of air needed for operating the system in the heating and cooling modes. Belt-drive fans are more likely to be encountered in light commercial packaged products. The fan speed can be changed by adjusting the pulley diameter.

▼ Figure 6-29.
Duct System Total Friction (External Static Pressure Loss)



▼ Figure 6-30.
Direct-Drive and Belt-Drive Fans



CHANGING FAN SPEED

Fan speed may need to be changed or adjusted at the time of installation to provide the required quantity of air.

If the system has a direct-drive motor, the speed can be adjusted by changing the speed taps on the blower motor.

If the system fan is belt-driven, the speed can be increased by narrowing the width of the pulley V-groove, or decreased by widening the width of the pulley V-groove. Typically, variable-pitch pulleys allow the speed of the driven fan to be varied by as much as 30 percent.

The manufacturer's installation literature should contain tables detailing the adjustable pulley settings required to achieve a certain CFM against a given external static pressure. The pulley settings and static pressure values should be predetermined by the system designer. *Figure 6-31* shows fan performance tables typical of those included in manufacturer's installation literature and an example of their use.

▼ Figure 6-31.
Example of How Fan Data is Used to Determine Required Fan RPM and Related Motor Pulley Setting

EXAMPLE:
DESIGNER SAYS THE SYSTEM FAN MUST PROVIDE AN AIRFLOW OF 1900 CFM AT AN EXTERNAL STATIC PRESSURE OF 0.4 IN. W.G. TABLE 1 SHOWS THAT THE FAN MUST ROTATE AT 928 RPM TO DELIVER 1900 CFM. TABLE 2 SHOWS THAT BY OPENING THE MOTOR PULLEY 3 TURNS, THE FAN WILL ROTATE AT 930 RPM.

TABLE 1 – FAN PERFORMANCE, MODEL 005 VERTICAL DISCHARGE UNITS; ALTERNATE MOTOR (BELT)

AIRFLOW (CFM)	EXTERNAL STATIC PRESSURE (IN. WG)																			
	0.1		0.2		0.4		0.6		0.8		1.0		1.2		1.4		1.6		1.8	
	RPM	BHP	RPM	BHP	RPM	BHP	RPM	BHP	RPM	BHP	RPM	BHP	RPM	BHP	RPM	BHP	RPM	BHP	RPM	BHP
1200	**542**	**0.16**	**616**	**0.21**	**739**	**0.32**	842	0.44	929	0.56	1008	0.67	1096	0.78	–	–	–	–	–	–
1300	**576**	**0.20**	**644**	**0.25**	**764**	**0.37**	867	0.50	952	0.62	1029	0.75	1101	0.86	**1184**	**0.99**	**1299**	**1.15**	–	–
1400	**610**	**0.24**	**673**	**0.30**	**791**	**0.42**	889	0.55	976	0.69	1052	0.83	1121	0.96	**1189**	**1.09**	**1265**	**1.22**	**1364**	**1.38**
1500	**646**	**0.28**	**704**	**0.35**	818	0.48	912	0.61	1001	0.76	1076	0.91	**1145**	**1.06**	**1208**	**1.20**	**1271**	**1.33**	**1341**	**1.47**
1600	**681**	**0.33**	**735**	**0.40**	845	0.54	938	0.68	1023	0.83	1100	1.00	**1168**	**1.15**	**1232**	**1.31**	**1291**	**1.46**	**1350**	**1.60**
1700	**718**	**0.39**	**768**	**0.46**	873	0.61	965	0.76	1045	0.91	1124	1.09	**1192**	**1.25**	**1255**	**1.42**	**1314**	**1.58**	**1370**	**1.74**
1800	**754**	**0.45**	801	0.53	900	0.69	992	0.84	1071	1.00	**1147**	**1.18**	**1217**	**1.36**	**1279**	**1.54**	**1338**	**1.71**	**1393**	**1.89**
1900	**791**	**0.52**	836	0.60	928	0.77	1019	0.93	1097	1.10	**1169**	**1.27**	**1240**	**1.47**	**1303**	**1.66**	**1361**	**1.85**	**1417**	**2.03**
2000	828	0.60	870	0.68	958	0.86	1046	1.03	1124	1.21	**1194**	**1.38**	**1262**	**1.58**	**1327**	**1.78**	**1385**	**1.98**	**1440**	**2.18**

Legend
Bhp – Brake Horsepower
NOTES:

1. **Boldface** indicates field-supplied drive required. (See Note 6)
2. **Shading** indicates field-supplied motor and drive required.
3. Maximum usable bhp is 1.3. Extensive motor and electrical testing on these units ensures that the full horsepower range of the motor can be utilized with confidence. Using your fan motors up to the horsepower ratings shown will not result in nuisance tripping or premature motor failure. Unit warranty will not be affected.
4. Values include losses for the filters, unit casing, and wet coils.
5. Use of a field-supplied motor may affect wire sizing. Contact your distributor to verify.
6. Alternate motor drive range: 800 to 1130 rpm. All other rpm's require field-supplied drive.

TABLE 2 – FAN RPM AT MOTOR PULLEY SETTINGS

MODEL	MOTOR/DRIVE	MOTOR PULLEY TURNS OPEN										
		0	1/2	1	1 1/2	2	2 1/2	3	3 1/2	4	4 1/2	5
005	ALT	1130	1095	1060	1030	995	960	930	900	860	830	800
006	STD	1190	1160	1130	1100	1065	1035	1005	970	940	910	875
	ALT	1260	1230	1195	1160	1130	1100	1065	1030	995	960	930
007	STD	1260	1230	1195	1160	1130	1100	1065	1030	995	960	930
	ALT	1460	1420	1380	1340	1300	1265	1230	1190	1150	1110	1070

QUICK NOTE

Remember, for a direct-drive motor, speed is adjusted by changing the speed taps.

For a belt-drive motor, speed is adjusted by adjusting the width of the pulley V-groove, which changes the pulley's diameter.

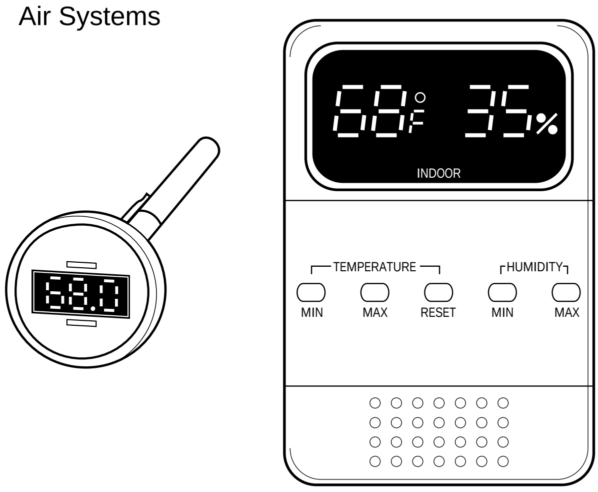
BALANCING THE AIR SYSTEM

Air balancing is necessary to make sure that the right amount of air at the right temperature is delivered to each room in the building. Air distribution systems can be balanced using several methods; some are complex and others relatively simple. Methods used for balancing air systems are described in several publications listed in the catalog referenced in the front of this manual. Information is also available in SMACNA's *HVAC Systems Testing, Adjusting, and Balancing* manual. A method often used for balancing single-zone residential systems using thermometers is given here. The procedure presumes that the heating and/or cooling equipment has been checked out and adjusted per the installation checklist and is operational.

Thermometer Balancing for Heating

1. Place a thermometer *(Figure 6-32)* at the center of each room, about four feet above the floor.
2. Fully open all the diffusers and return grilles. Set the diffuser vanes for optimum distribution.
3. Set the volume dampers in the branch ducts farthest from the fan to fully open and the others to the mid-position.
4. Adjust the room thermostat to call for heating (about 2° F above room temperature). Balancing is best done when the temperature in the room is within 5° F of the normal operating temperature.
5. Operate the system long enough for the room temperatures to stabilize, then read and record the temperature in each room.
6. Adjust the volume damper in the branch supplying the warmest room to reduce the airflow to that room. Do not reduce the airflow too much because the airflow and temperature in the remaining rooms will increase. Several adjustments to each damper are required.
7. Adjust the remaining dampers. Work from the warmer rooms to the cooler rooms.
8. Repeat the balancing process until the temperature in all rooms is as near to comfort conditions as possible.
9. After balancing is completed, recheck the temperature rise across the furnace heat exchanger or fan coil electric heating element per the manufacturer's instructions to make sure that it still meets specifications. If a blower speed adjustment is needed due to excess temperature rise, repeat the balancing procedure.

▼ Figure 6-32.
Typical Thermometers Used for Balancing Air Systems



Thermometer Balancing for Cooling

1. Place a thermometer *(Figure 6-32)* at the center of each room, about four feet above the floor.
2. Fully open all the diffusers and return grilles. Set the diffuser vanes for optimum distribution.
3. Set the volume dampers in all branch ducts to the mid-position.
4. Adjust the room thermostat to call for cooling and allow the system to operate until the room temperatures stabilize.
5. Make sure that the system fan is delivering the volume of air specified by the equipment manufacturer. Typically this is between 400 CFM to 450 CFM per ton of cooling. The temperature drop across the indoor coil should be between 15° F and 20° F.
6. Read and record the temperature in each room.
7. Slightly open the volume dampers in the branches to the rooms with temperatures higher than the thermostat setting. Slightly close the dampers in the branches to the rooms with temperatures below the design or thermostat setting.
8. Repeat Step 7 as often as necessary to provide even temperatures (±2° F) among the rooms.
9. After balancing is completed, recheck that the fan is delivering the proper volume of airflow per the manufacturer's specifications. If a blower speed adjustment is needed, repeat the balancing procedure.

SECTION 7
FIELD WIRINGG

INTRODUCTION

Electrical wiring needed to supply power and control signals to HVAC equipment must be installed at the job site and must meet national and local codes. In all cases, the *National Electrical Code® (NEC®)* is the primary code for installing wiring in the United States, but wiring must also meet any other local building code and/or electrical code standards. This section is not intended to teach circuit design; instead, it describes the various electrical components and wiring methods needed to field wire HVAC equipment. It presumes that the proper type of equipment has been selected and purchased for the job by a qualified engineer or salesperson based on a survey of the job. Even though the field wiring is normally installed by electricians, familiarity with the electrical equipment and wiring methods is important because the HVAC technician normally is responsible for evaluating the electrical installation to make sure that it complies with the HVAC equipment manufacturer's installation instructions.

FIELD WIRING MENU

TYPICAL BUILDING ELECTRICAL SERVICE

Power enters a building from the electric utility power lines through an electrical service. The most common service used for residential and light commercial buildings in North America is 120/240-volt single-phase service. Some light commercial buildings with higher power demands may have a three-phase service. The focus of this section is on the methods used to field wire equipment that requires a 120/240-volt, single-phase service. When relevant, methods used to field wire three-phase equipment are also described.

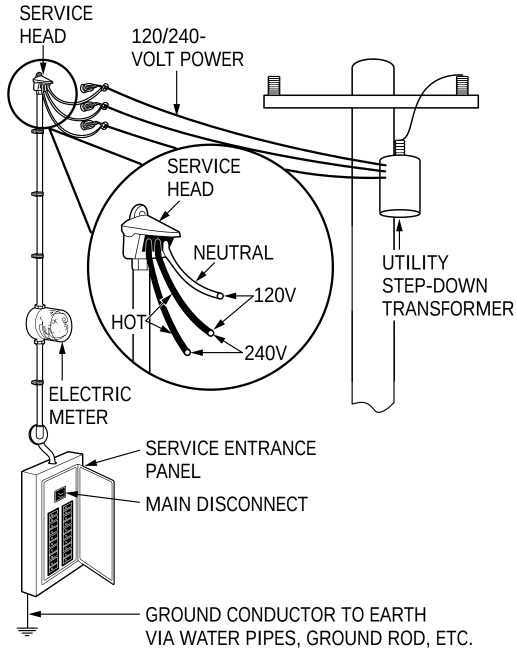
As shown in *Figure 7-1*, the 120/240-volt single-phase service applied from the utility pole transformer to the building has three wires. Two wires are hot while the third wire is neutral (N). The voltage across both hot wires is 240 volts; the voltage across either hot wire and the neutral is 120 volts. The neutral wire is electrically grounded at the pole power transformer and is connected to the building ground (earth) either through a grounding wire between the neutral bus bar in the service entrance panel and the building's cold water piping or a copper rod driven into the ground.

The entrance panels used in buildings all operate basically the same. They provide for the control and distribution of the 120/240-volt service input power to the individual branch circuits. Most panels use circuit breakers for this purpose with a main circuit breaker used to disconnect or turn off all power to the building *(Figure 7-2)*. Some panels may have a removable fuse block to disconnect all power. Some buildings have a separate disconnect switch placed ahead of the service entrance panel to turn off power.

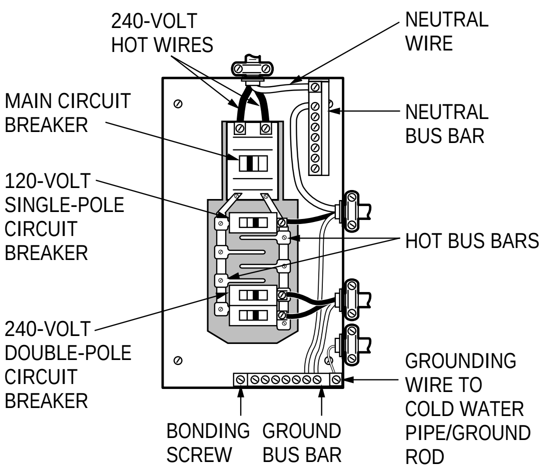
Figure 7-2 shows the components and wiring within a typical service panel. When the main circuit breaker is set to ON, 120-volt power is applied through the breaker to the two power bus bars that run through the panel. Power is then distributed from the two hot bus bars through circuit breakers that feed the branch circuits for the building's HVAC equipment and other loads.

The wiring and components used in a building's electrical service must have the electrical capacity (ampacity) to adequately carry all the electrical loads in the building, including the HVAC equipment. Normally, the adequacy of the electrical service has been determined ahead of time. If needed, Article 220 of the *NEC®* provides guidelines for determining the adequacy of a service.

▼ Figure 7-1.
Typical 120/240-Volt Service



▼ Figure 7-2.
Typical Service Entrance Panel



QUICK NOTE

Only qualified electricians may install service entrance equipment and connect the wiring for new branch circuits in existing panels. However, as part of the installation checkout, the HVAC technician must verify the correct wiring of branch circuits feeding the installed HVAC equipment. To accomplish this, the technician must understand how service panels are installed and how they operate in relation to the entire building electrical system.

HVAC EQUIPMENT BRANCH CIRCUIT COMPONENTS

Condensing units, furnaces, and packaged units are completely wired internally at the factory. Wiring referred to as *field wiring* in equipment installation instructions must be installed at the job site to connect the power supply voltages and control voltages to the equipment. This wiring must always be done in compliance with national and local codes. It also must be installed according to the manufacturer's installation instructions.

Electrical codes require that the input power to HVAC equipment be supplied by a separate branch circuit dedicated to the equipment. With most equipment, the codes also require that a safety/disconnect switch be installed on or within sight of the equipment. This provides the technician with a safe and convenient way of turning off power for servicing or repair.

Figure 7-3 shows the components used to field wire a typical residential split air conditioning system. The methods for field wiring the power supply voltages are covered here while thermostats and control wiring are covered later in this section. The components commonly used in HVAC equipment power supply wiring are:

- Circuit breakers and fuses
- Safety/disconnect switches
- Wiring

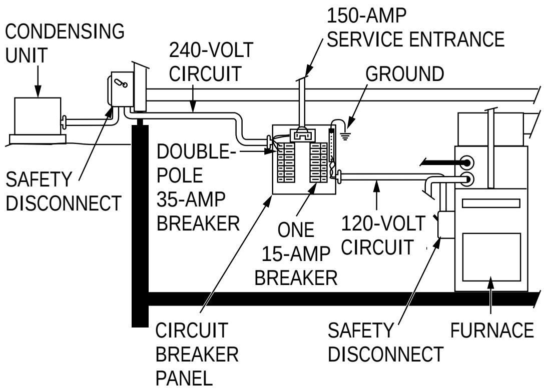
Circuit Breakers and Fuses

Circuit breakers are used in service entrance panels and subpanels to manually turn on or off power to a specified circuit. They also protect the circuit from current overloads or short circuits. In the event of an overload or short circuit, the breaker automatically "trips" and opens the circuit. Once tripped, and after the cause of the problem has been corrected, it can be reset to restore power to the circuit. This is normally done by first setting the breaker handle to the full OFF position, then switching back to the full ON position.

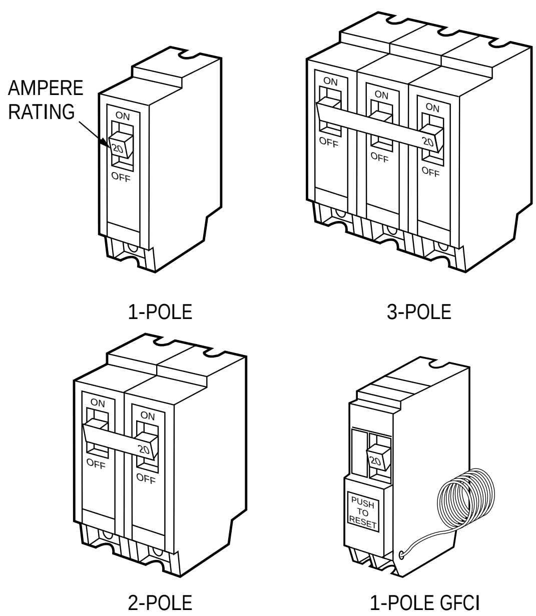
Breakers can be single-pole for 120-volt circuits or double-pole (two-pole) to protect 240-volt circuits *(Figure 7-4)*. Three-pole breakers are used in three-phase systems. The term *pole* refers to the number of conductors (wires) that the device will control. For example, a single-pole breaker will control one wire. The voltage and current rating of a circuit breaker must be matched to the electrical system in which it is used. The method used to size circuit breakers and the general procedure for installing them are covered later in this section.

HACR-type circuit breakers should be used in circuits connected to compressor units. HACR breakers have a built-in time delay that allows a higher current than its rating to momentarily flow in the circuit. This compensates for the large starting current drawn by a compressor motor.

▼ Figure 7-3.
Typical HVAC Equipment Field Wiring



▼ Figure 7-4.
Typical Circuit Breakers



Another type of special circuit breaker commonly used in entrance panels is the ground fault circuit interrupter (GFCI). It provides the normal overcurrent protection of a standard circuit breaker, but also protects people from electrical shock. Electrical codes define the areas where GFCI breakers or other devices are required.

Fuses are also used to protect a circuit from a current overload and are found in service entrance panels or in fused safety/disconnect switches. There are two main types of fuses: cartridge and plug *(Figure 7-5)*. Both types come in different styles and sizes and in instantaneous blow or time delay types.

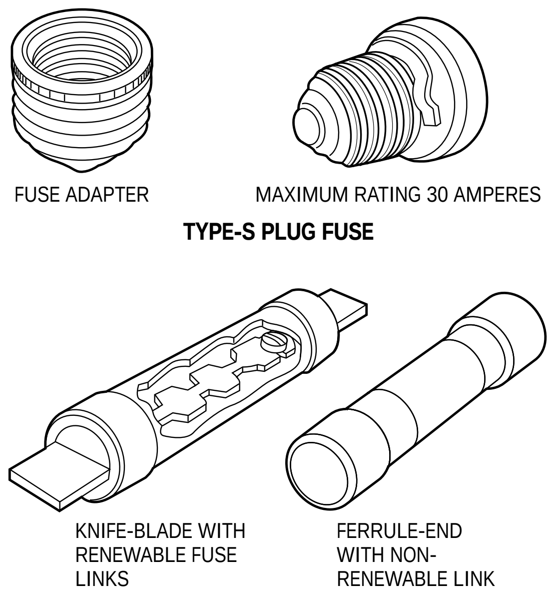
The ampere rating of each fuse must be matched to the circuit it protects. Fuses contain an element that melts or "blows" when its rated amperage is exceeded. Blown fuses must always be replaced with ones of the same rating and type. ***Never replace a fuse with one of a higher rating.***

Cartridge fuses are plugged into fuse blocks in service panels and disconnect/safety switches. Cartridge fuses can be non-renewable or renewable. Non-renewable fuses are disposable and must be replaced when blown. Renewable fuses have elements (links) that can be replaced.

To determine if a fuse is good or bad (blown), use a multi-meter to perform a continuity check or voltage check across the fuse.

Plug-type fuses are made with ratings up to 30 amperes. They are commonly used in field-wired utility-box disconnects for fossil fuel furnaces *(Figure 7-6)*. Only S-type plug fuses (*fusestats*) and adapter sockets are used. Plug fuses can be checked visually by looking into their "window" to see the condition of the fusible link. If the element is broken and/or the window is black or discolored, the fuse has blown and must be replaced.

▼ Figure 7-5.
Plug and Cartridge Fuses

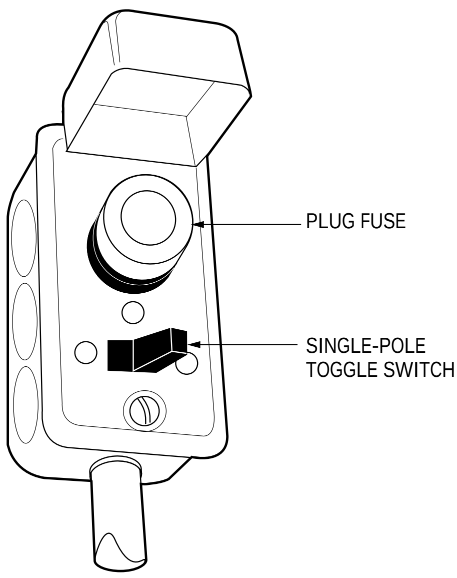


CAUTION

QUICK NOTE

- Before installing a circuit breaker, make sure it is physically compatible with the panel in which it will be installed.
- If there are no vacant slots available in a panel, additional room can be made by replacing existing standard-size breakers with slimline-style

▼ Figure 7-6.
Box Cover Unit for Plug Fuse Disconnect



Disconnect/Safety Switches

Per the electrical code, all fixed HVAC equipment must have a means of disconnecting the power from the equipment. Disconnect/safety switches *(Figure 7-7)* used for this purpose can be mounted in a metal or plastic indoor or outdoor (weatherproof) enclosure. Disconnect switches will have a current rating while switches for use in motor circuits have both current and horsepower ratings.

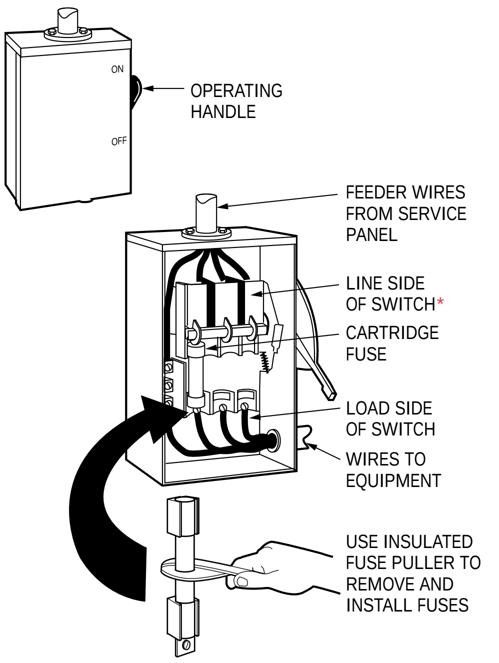
Disconnect switches are either non-fusible or fusible. If the only purpose served by the switch is to turn the power off and on to the equipment, a non-fusible switch is used. If the HVAC equipment manufacturer specifies it, a fusible disconnect (safety) switch with the proper size fuse is used.

Disconnects like those shown in *Figure 7-7* are operated using an ON-OFF handle. As shown, when the door is open, the switch blades and/or fuses are fully visible and accessible. After the disconnect has been turned off, the cartridge fuses can be removed or installed using an insulated fuse puller. ***EVEN THOUGH THE DISCONNECT SWITCH HANDLE IS IN THE OFF POSITION AND THE FUSES HAVE BEEN REMOVED, THE LINE-SIDE WIRES AND SWITCH CONTACTS MAY STILL BE HOT (ENERGIZED) IF THE INCOMING FEEDER POWER HAS NOT BEEN TURNED OFF.*** The type of disconnect shown in Figure 7-8 has a bracket that is used to padlock the switch in the OFF position while servicing the equipment.

A disconnect commonly called a *puller* is often used to remove power from HVAC equipment *(Figure 7-9)*. In this type, the switch contacts and/or fuses are enclosed in a removable block that fits into a socket within the disconnect. Power is disconnected by pulling out the block. Power is restored when the block is inserted back into the socket.

The size and type of disconnect needed for use with equipment normally is specified in the HVAC equipment manufacturer's installation instructions. This is covered in more detail later in this section.

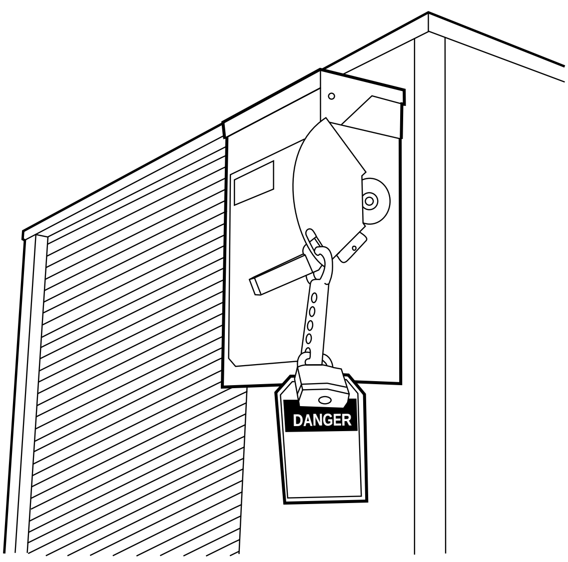
▼ Figure 7-7.
Typical General-Purpose Disconnect Switches



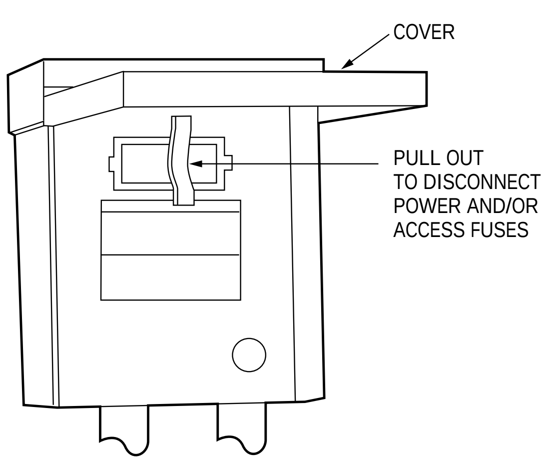
* THIS SIDE REMAINS "HOT" WHEN DISCONNECT IS TURNED OFF OR FUSES ARE PULLED.

WARNING

▼ Figure 7-8.
Disconnect Switch Locked in the OFF Position



▼ Figure 7-9.
Typical Air Conditioner Disconnect



Wires, Cables, and Connectors

Using the correct size wire ensures that it has the current capacity (ampacity) needed to safely carry the equipment load. It also prevents excessive voltage drop from occurring in the circuit that can result in poor operation or damage to the equipment. To ensure proper operation of their equipment, HVAC equipment manufacturers include recommendations in their product literature about the minimum size wire and maximum length of wire run to use with their equipment.

The American Wire Gauge (AWG) is the standard used to express wire size or gauge. The lower the AWG number, the bigger the wire diameter and ampacity. *(See Table 7-1.)* When wiring equipment, always use the type of wire recommended by the equipment manufacturer.

Nonmetallic Sheathed Cable – Nonmetallic sheathed cable, commonly called *Romex®* cable, is used for most of the wiring in residential and light commercial buildings. The outer sheath of the cable is marked to show the wire size, number of wires, cable type, and voltage rating *(Figure 7-10)*. NM-B or NMC-B cable is used for indoor wiring only, with NM-B cable being used only in dry areas and NMC-B cable used in both damp and dry areas. UF-B cable can be used anywhere that NM-B or NMC-B is used. It also can be used in wet locations, including underground.

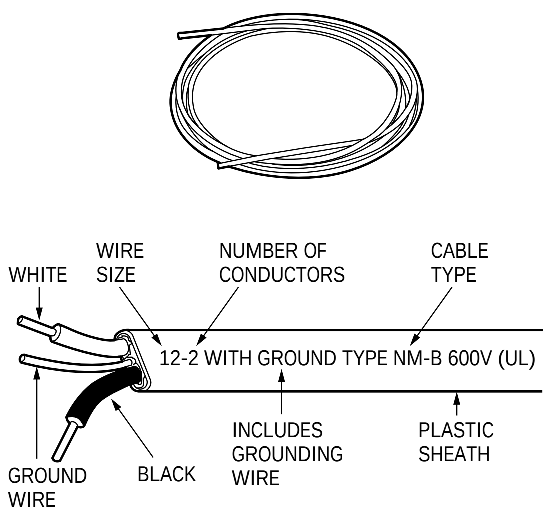
Cutting and Stripping Nonmetallic Cable – Lineman's pliers *(Figure 7-11)* are normally used to cut nonmetallic cable to length. Then, the outer sheath at the end is removed using a knife or a special cable stripper commonly called a *ripper* *(Figure 7-11)*. For connections in boxes, etc. enough sheath should be removed to allow the wires to extend about 8 inches from the front of the box with at least 1/4 to 1/2 inch of the sheathing showing in the box above the cable clamp. For connections in service panels, disconnects, etc. the exposed wires must be long enough to reach the farthest connection with enough slack to avoid sharp bends and provide for a neat installation. The individual wires within the cable can be stripped using a variety of stripping tools. A multi-purpose tool is shown in *Figure 7-11*.

▼ Table 7-1.
Maximum Allowable Ampacities of Common Copper Conductors Used in Residential Wiring (Maximum of Three Current-Carrying Wires in a Conduit or Cable)

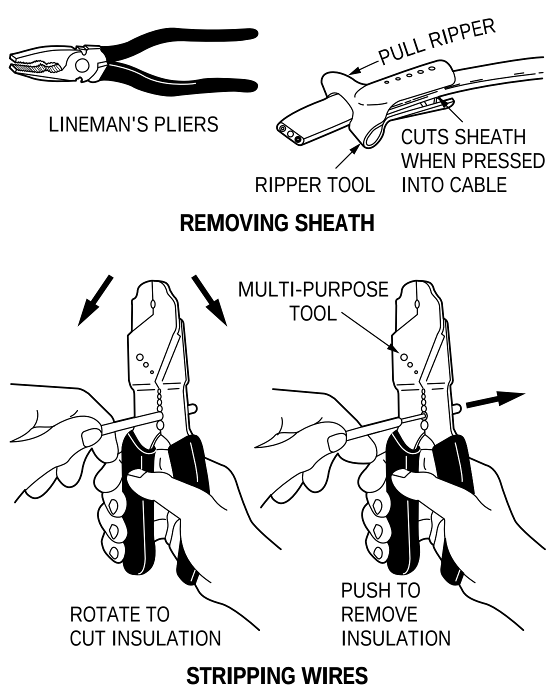
Wire Size	Type		
	TW, UF	THW, THWN	THHN
14	15*	15*	15*
12	20*	20*	20*
10	30	30*	30*
8	40	50	55
6	40	50	55

* Unless otherwise permitted by the code, the overcurrent protection for wire sizes marked with an (*) shall not exceed the amperage shown. The actual ampacities of the wires are greater. For detailed information pertaining to all conductors used for general wiring, refer to the applicable electrical code(s).

▼ Figure 7-10.
Nonmetallic Sheathed Cable



▼ Figure 7-11.
Cutting and Stripping Nonmetallic Cable



QUICK NOTE

The wire insulation in a cable or conduit is normally color coded to identify the wire's intended use:

- *Ungrounded "hot" conductors (recommended colors)* – Black, red, blue, and yellow. Be aware that the code permits hot conductors to be any color other than the colors required for use with neutral or ground wires.
- *Neutral (grounded conductors, AWG sizes No. 6 and above)* – Required to be white or gray. Note that white or gray wires can be used as a hot wire if permanently reidentified.
- *Grounding conductors* – Bare, green, or green with yellow stripe.

Fastening Nonmetallic Cable to Electrical Boxes – Nonmetallic cable is usually fastened to HVAC equipment or disconnects using cable connectors *(Figure 7-12)*. Cable connectors are installed in a round *knockout* hole in the HVAC equipment or disconnect. The knockout is removed by breaking and twisting it loose. After the knockout is removed, the connector is inserted and the locknut is screwed on and tightened. The cable is pulled through the connector into the box, then the screws on the connector are tightened to secure the cable.

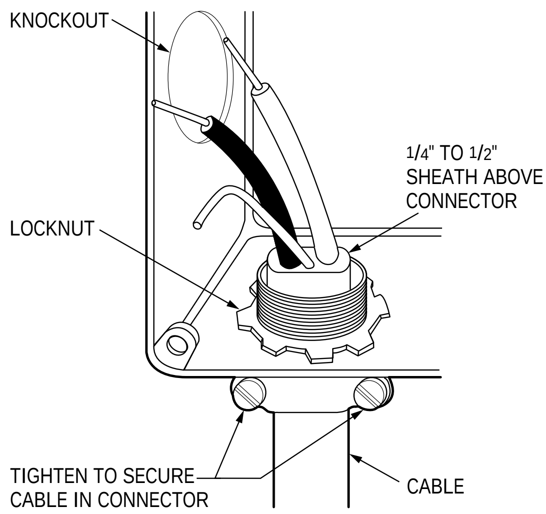
Connecting Nonmetallic Cable Grounding Wires – When fastening nonmetallic cable to metal boxes, all the cable ground wires must be connected to each other. Grounding lugs are provided in most HVAC equipment and disconnects *(Figure 7-13)*.

Armored Cable – Armored (AC) cable, also called *BX*, has a flexible steel metal (armor) sheath that encloses the insulated wires and a bonding strip and is always used with metal electrical boxes. It is used for indoor wiring only in dry locations where it is not subject to physical damage. Guidelines for preparing armored cable for use once the cable runs are installed are covered here.

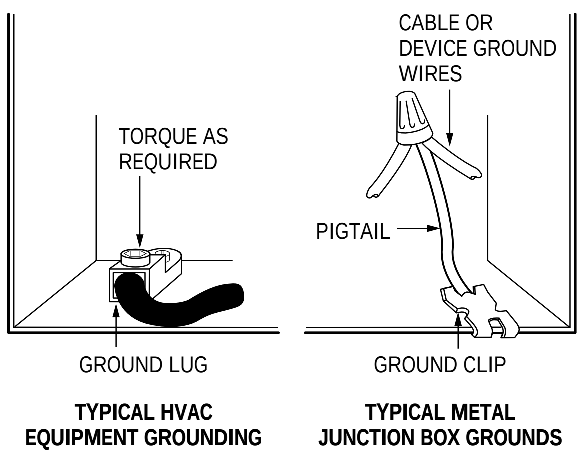
Cutting Armored Cable and Removing the Armor Sheath – Armored cable is usually cut to length using cable cutters or a hacksaw. The hacksaw method is described here.

1. Determine where the cable is to be cut.
2. Partially saw through the armor covering *(Figure 7-14)*, being careful not to cut completely through the armor because this can damage the conductors and cut the bonding strip.
3. Bend the cable back and forth at the cut until the armor breaks. Remove and cut off the paper that surrounds the wires.
4. ***Always*** install an anti-short bushing between the cut edge of the armor shield and the wires and bonding strip.

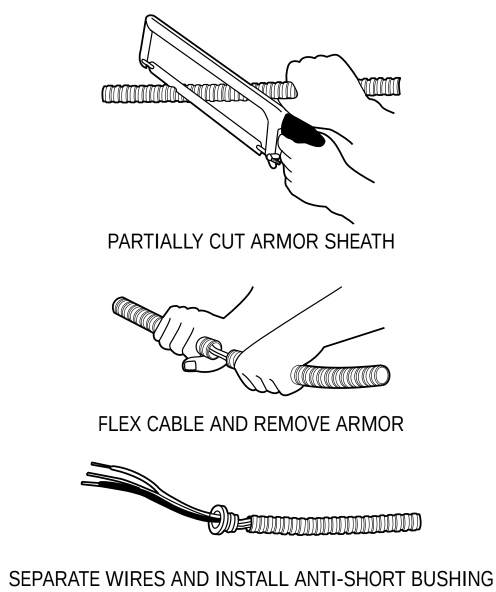
▼ Figure 7-12.
Fastening Nonmetallic Cable to Boxes



▼ Figure 7-13.
Method for Grounding Nonmetallic Cable to Metal Boxes



▼ Figure 7-14.
Removing Armor Sheath from Armored Cable



Fastening Armored Cable to Electrical Boxes – Armored cable is fastened to metal electrical boxes with either connectors or built-in clamps *(Figure 7-15)*. To use an armored cable connector, bend the bonding strip back over the armor and anti-short bushing. Loosen the connector screw, then slide the connector over the wires and onto the cable armor until fully seated. Wrap the bonding strip around the connector screw and tighten the screw to fasten the connector to the cable. Install the cable with connector in the box knockout hole and fasten with the connector locknut.

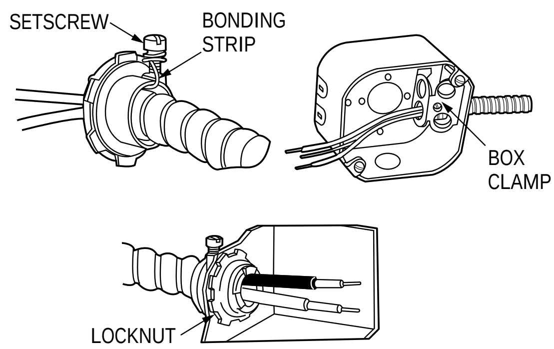
When fastening armored cable to boxes with built-in clamps, wrap the bonding strip around the cable armor and push the cable into the box pryout hole until the anti-short bushing contacts the face of the clamp, then tighten the clamp screw to fasten the cable.

Rigid Metallic Conduit – Electrical wires that run in exposed areas must be protected by rigid tubing called *conduit*. Conduit is made in a variety of sizes and the size used is determined by the number and size of the wire that the conduit must carry. Normally, the size of the conduit will already have been determined for you. If needed, refer to the national codes. Most HVAC installations involve the use of either intermediate metal conduit (IMC) or electrical metal tubing (EMT), so the remainder of this section will focus on these types of conduit.

Intermediate Metal Conduit/Electrical Metal Tubing – IMC conduit *(Figure 7-16)* can be used in exposed areas both indoors and outdoors. IMC is joined together and fastened to boxes with waterproof compression-type couplings and fittings. Waterproof L-body fittings with removable covers are used in IMC conduit runs where the wires must make abrupt bends and/or when needed to pull long lengths of wire.

EMT conduit *(Figure 7-17)*, commonly called *thin-wall conduit*, is used indoors only in areas where it cannot be damaged. EMT is normally joined together and fastened to boxes with setscrew-type couplings and fittings. Elbow fittings with removable covers are also used in EMT runs where the wires must make abrupt bends and/or when needed to pull long lengths of wire.

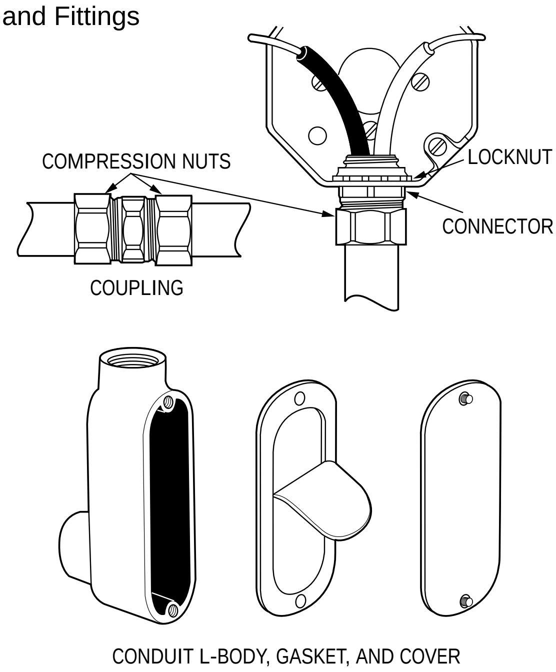
▼ Figure 7-15.
Fastening Armored Cable to Boxes



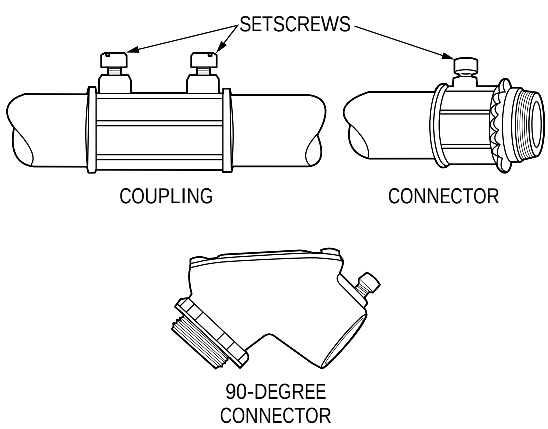
QUICK NOTE

An alternate method of cutting armored cable uses metal shears. Bend the cable sharply and twist until the armor buckles. Insert the shears through the open loop of the buckled sheath and cut. Trim off any sharp edges.

▼ Figure 7-16.
Intermediate Metal Conduit Coupling, Connector, and Fittings



▼ Figure 7-17.
Electrical Metal Tubing Coupling, Connector, and Fittings



Cutting, Joining, and Fastening IMC/EMT to Electrical Boxes and Fittings – Both IMC and EMT can be cut with a hacksaw. After making the cut, the inside edge of the conduit or tubing must be reamed to remove burrs which might damage the wires.

To join straight sections of IMC together, the ends are inserted into the coupling and the compression nuts are tightened. Connecting IMC to a box with a connector is done in a similar manner. After this, the locknut is removed and the connector with attached conduit is inserted into the knockout hole. The locknut is then used to secure the conduit to the box.

Joining sections of EMT and/or connecting it to electrical boxes is done in the same way as with IMC, except that the coupling or connector setscrews are used to tighten the coupling or connector to the tubing.

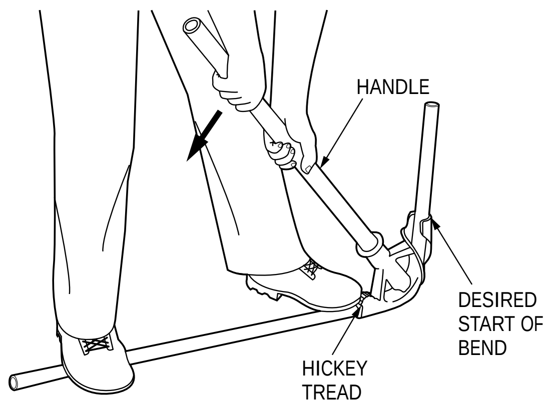
Bending IMC/EMT Conduit – Conduit can be bent *(Figure 7-18)* into angles using a bender called a *hickey*. This is done by placing the bender on the conduit so that its hook is where you want the bend to start. The conduit is bent by stepping on the bender tread to hold the conduit and bender in place, then pulling the bender handle back until the conduit is bent to the required angle. Some benders have a built-in bubble level or markings to indicate when 45° and 90° bends have been made. Because bending to precise measurements is difficult, it is recommended that the conduit be bent first and then cut to the exact length needed.

Rigid Nonmetallic (PVC) Conduit – Rigid nonmetallic (PVC) conduit and fittings are also available. They resemble those used with metal conduit. Conduit sections are assembled and joined to PVC electrical boxes using solvent-based cement.

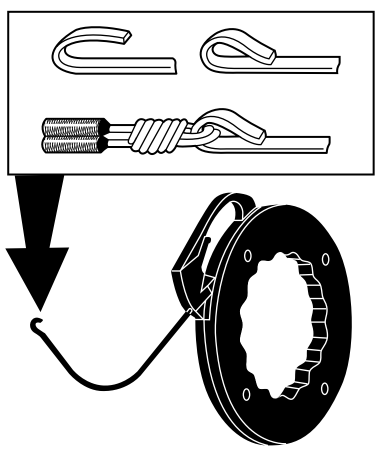
Pulling Wires/Cables through Conduit Runs – For other than very short runs, a flexible steel fish tape *(Figure 7-19)* is used to pull the wires through the conduit. The fish tape is pushed through the run first, then the ends of the wires are securely fastened to the end of the tape. The tape is then pulled back through, pulling the wires with it. The wires should be kept as straight as possible to prevent them from becoming tangled or crossed. To make pulling the wires easier, they can be coated with a special lubricant. Sometimes a second person is helpful when pulling wires.

Flexible Conduit – Flexible conduit is often used with outdoor wiring of air conditioning equipment. Liquidtight flexible metal conduit and liquidtight flexible nonmetallic conduit are more commonly used with HVAC equipment. The body of liquidtight flexible conduit is made with spiral metal turns which are covered with a weatherproof plastic. Special connectors and methods are used to install both the metal and nonmetallic types. For this reason, factory-wired assemblies called *air conditioner whips* *(Figure 7-20)*, available in various lengths, are often purchased and used to simplify an installation.

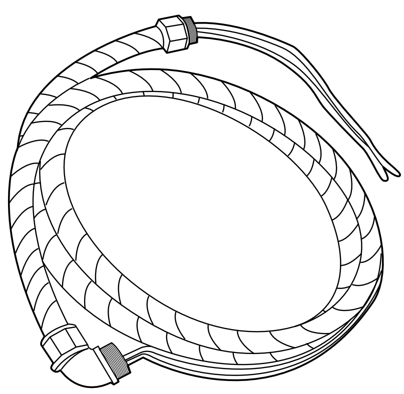
▼ Figure 7-18.
Bending Conduit



▼ Figure 7-19.
Connecting Wires to Fish Tape



▼ Figure 7-20.
Preassembled Liquidtight Air Conditioner Whip



Wire Connectors/Terminals – To complete the field wiring of a circuit, the wires must be joined together or connected to terminals. Unless otherwise marked on the equipment, aluminum wire cannot be used to supply power to HVAC equipment. Always refer to the equipment or component manufacturer's installation instructions for information concerning the types of wire that can be safely connected to the equipment.

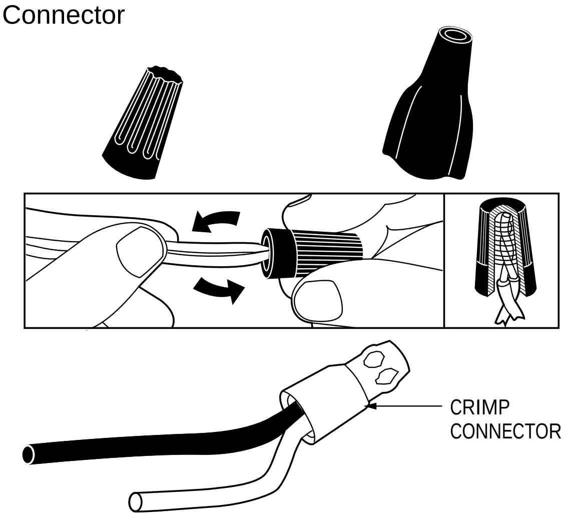
Splicing Wires – Splices made to join wires must be made inside an electrical box or enclosure using approved connectors. Most splices are made using connectors commonly called *wire nuts (Figure 7-21)*. Wire nut manufacturers color code the wire nuts and mark their packages to show the wire sizes and the maximum and minimum number of wires that can be connected by the wire nut. Note that green wire nuts are only used to splice grounding wires.

To splice wires with a wire nut, first strip off about 1/2 inch of the insulation. Place the wire nut over the wire ends, then turn or screw it onto the wires until the nut is tight. It is a good practice to twist the wires together before screwing on the wire nut. When the wire nut is fully tightened, no bare wires should be visible. Insulated crimp-type connectors may also be used to splice wires. The connector is slipped over the stripped wire ends, then crimped using a multi-purpose tool.

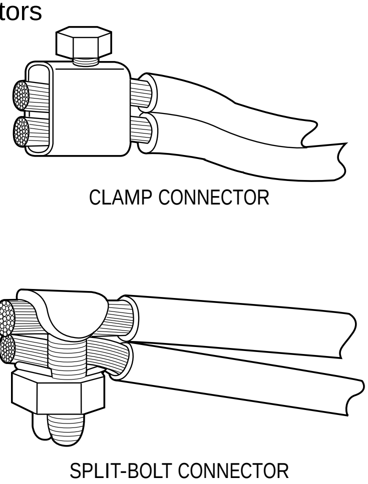
When No. 6 gauge and larger wires must be spliced, split-bolt or clamp connectors *(Figure 7-22)* are commonly used. With these connectors, the stripped wire ends are placed into the body of the connector and the screw or bolt is tightened to make the splice. The splice is then wrapped with electrical tape.

Connecting Wires to Terminals – Equipment connections are often made using compression-type lugs or terminals strips *(Figure 7-23)*. Normally, only one wire is permitted per terminal and the terminal screw must be torqued to specifications. For panels, disconnect switches, etc., the screw torque requirements and number of wires per terminal are normally marked on the inside of the door. For HVAC equipment, this information may be marked on the equipment and/or given in the installation instructions. It is important that the free end of any energized or deenergized wire not connected to a terminal be covered with insulating tape or a wire nut. To make connections to screw-type terminals, loop the wire around the screw post in a clockwise direction and then tighten the screw securely.

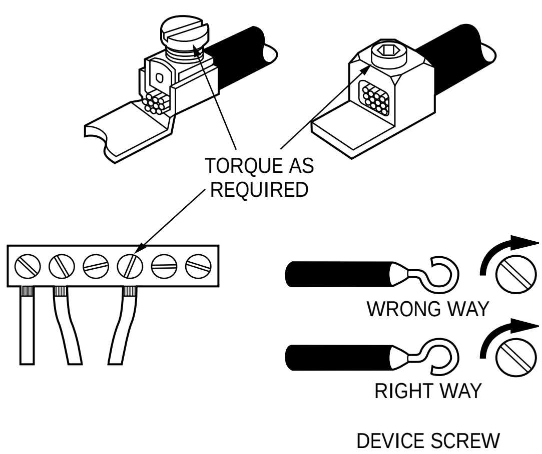
▼ Figure 7-21.
Splicing Wires Using a Wire Nut or Crimp Connector



▼ Figure 7-22.
Splicing Larger Wires Using Clamp and Split-Bolt Connectors



▼ Figure 7-23.
Connecting Wires to Compression Terminals



HVAC THERMOSTAT CONTROL CIRCUIT COMPONENTS

Control circuit wiring between the heating and/or cooling equipment and the room thermostat must be field wired *(Figure 7-24)*. Most control circuits operate on low voltage (24 volts AC) derived from a transformer normally located in the system furnace or fan coil unit.

Thermostats

Thermostats turn the applicable heating or cooling unit on or off as needed to maintain the desired room temperature. Thermostats are made that can control heating-only, cooling-only, or both heating and cooling *(Figure 7-25)*.

Installing Thermostats – Thermostat installation instructions should always be read carefully. This is especially important with electronic thermostats, because they require special handling. Some electronic thermostats may require the installation of an isolation relay. Some general guidelines for installing all thermostats are given here.

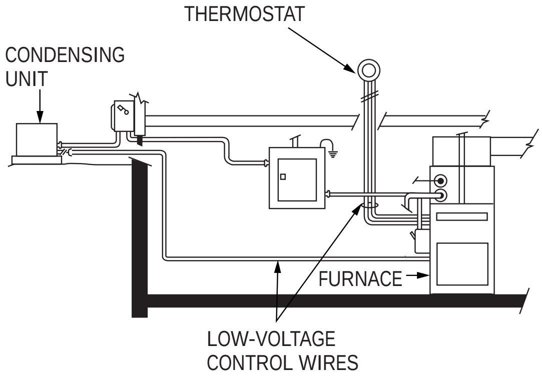
The thermostat must be installed in the area it is intended to control, on an inside wall that is free from any vibration and away from stairways. It should be mounted about 52 inches above the floor in an area with good air circulation at room temperature. All thermostats should be leveled for appearance and accurate operation. Locations with the following conditions should be avoided:

- Drafts or dead air spots
- Hot or cold air from ducts or diffusers
- Radiant heat from sunlight or a fireplace
- Concealed pipes or heating/cooling ducts
- Unheated areas behind the thermostat, such as an outside wall or garage

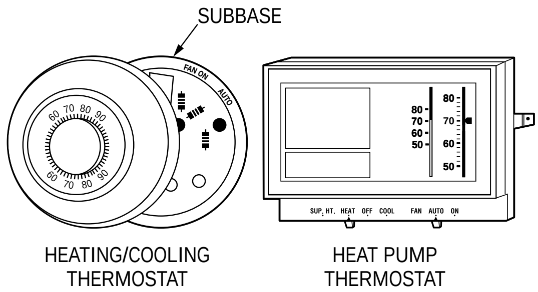
Thermostat Wire

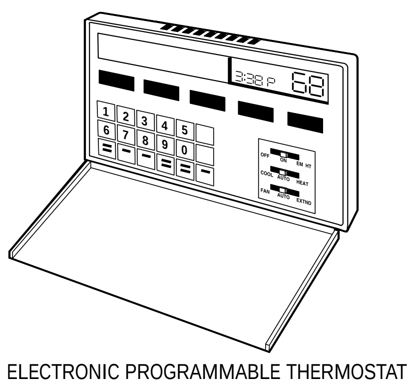
All thermostat and control circuit wiring must be done in accordance with electrical codes and the equipment installation instructions. This is covered in more detail later in this section. Most manufacturers mark their thermostat terminals using an HVAC industry standard that identifies the thermostat terminals by function and the related color of the wires that should be connected to them. *(See Table 7-2.)*

▼ Figure 7-24.
Typical Low-Voltage Control Wiring



▼ Figure 7-25.
Heating/Cooling System Thermostats





▼ Table 7-2.
Thermostat Wiring Codes

Terminal Marking	Wire Color	Function
R	Red	Power (24 volts)
G	Green	Fan control
Y	Yellow	Cooling control Y1 = Stage 1 Y2 = Stage 2
W	White	Heating control W1 = Stage 1 W2 = Stage 2
O	Orange	Heat pump reversing valve control

Thermostats located within 100 feet of the heating/cooling unit are normally connected with No. 18 gauge wire. No. 16 gauge wire should be used if the thermostat is located more than 100 feet from the unit. Multi-wire thermostat cable typically comes in 250- or 500-foot spools *(Figure 7-26)*.

To wire a thermostat, identify the terminals and color codes of the connecting wires as they relate to the equipment wiring diagram. Strip the wires with a wire stripper made specifically for small gauge wires. Make sure that all wires are connected properly and the connections are tight. Also, the wire access opening in the wall space behind the thermostat should be sealed so that the thermostat is not affected by drafts within the wall stud space.

The final step is to check the operation of the thermostat after power is applied. If required, the *heat anticipator* setting must also be adjusted per the thermostat's installation instructions to match the current draw of the primary control in the heating unit *(Figure 7-27)*. The current value used for the adjustment may be stamped on the furnace nameplate and/or primary control or may have to be measured. The method for measuring and adjusting the thermostat heat anticipator current is given in Section 8. The heat anticipator adjustment determines the duration of the burner-on cycle.

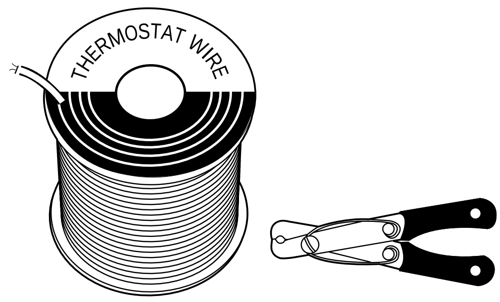
HVAC UNIT ELECTRICAL INSTALLATION GUIDELINES

Before starting the installation, the HVAC unit(s), electrical components, wire, and other materials to be installed should be checked to make sure that they are of the correct type and size.

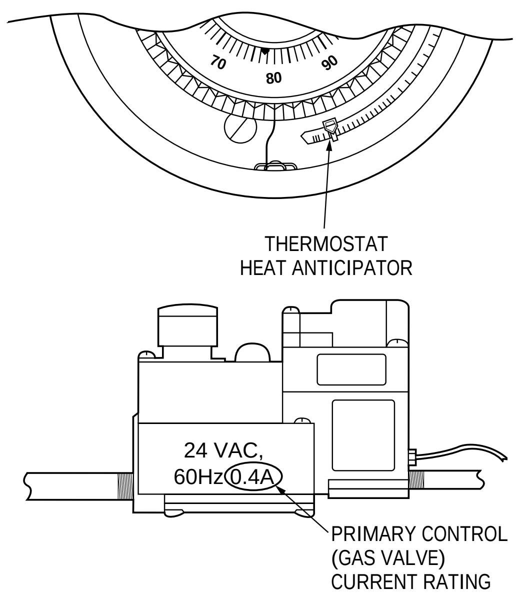
The rating plate *(Figure 7-28)* attached to each HVAC unit should be checked to make sure that the **POWER SUPPLY VOLTS** listed are compatible with the voltages supplied by the building's electrical service. Also check the **MAX OVERCURRENT PROTECTIVE DEVICE** information shown on the rating plate to make sure any circuit breakers/fuses and the disconnect are of the proper type and amperage rating. For air conditioner and heat pump units, the plate will state either **MAX SIZE FUSE** or both **MAX SIZE FUSE** and **MAX HACR CKT-BKR (CIRCUIT BREAKER)**.

When it only states **MAX SIZE FUSE**, fuses must be used to protect the unit. Assuming that a service panel with circuit breakers is being used to supply power to the unit, this means that a fused disconnect with the proper size fuses must be used with the unit. For example, if the maximum size fuse specified on the rating plate is 30 amps, then the service panel must use a 30-amp circuit breaker and a fused disconnect with 30-amp fuses. When the plate states **MAXIMUM SIZE HACR CKT-BKR,** an HACR-type circuit breaker normally is installed in the service panel and a non-fused disconnect is used with the unit.

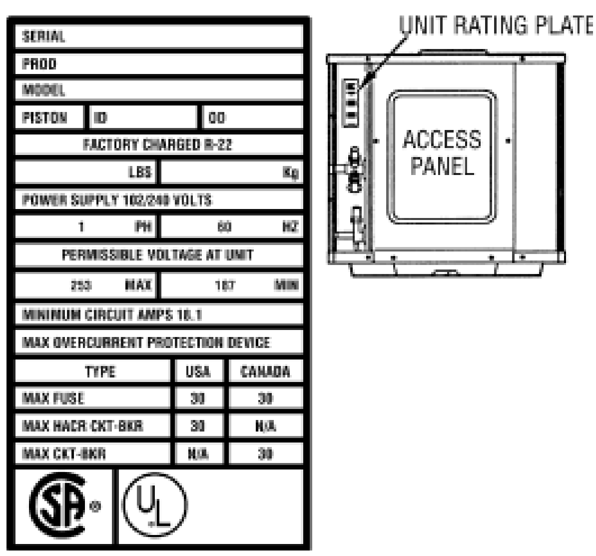
▼ Figure 7-26.
Thermostat Wire and Wire Stripper



▼ Figure 7-27.
Adjusting the Thermostat Heat Anticipator



▼ Figure 7-28.
Typical Air Conditioning Unit Rating Plate



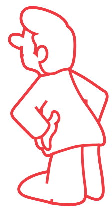
For the previous example, a 30-amp HACR circuit breaker should be used. ***The use of a standard circuit breaker instead of an HACR-type circuit breaker violates the electrical code.***

The value given for **MINIMUM CIRCUIT AMPS (MCA or MCC)** is used to determine wire size. For example, if the value listed is 18.1 amps, then the appropriate table in the electrical code is used to find the wire size needed. In the United States, *NEC®* Table 310-16 is normally used *(see Table 7-3)*. For this example, the table shows that No. 12 gauge wire must be used.

Note that the ampacity values given in the table are based on an ambient temperature of 86° F. To determine the correct wire size for locations with higher ambient temperatures, such as rooftops, attics, etc., the ampacity listed for a specific size and type of wire must be derated by multiplying the given ampere value by a correction factor. For example, when subjected to ambient temperatures ranging between 114° F and 122° F, the maximum ampacity of No. 12 TW wire is only 14.5 amps (25 x .58). To carry the 18.1 amps given for our example, No. 8 TW wire must be used. When No. 12 THHN wire is subjected to the same range of temperatures, its maximum ampacity is 24.6 amps (30 x .82), allowing it to be used.

Voltage drops exceeding 2% between the unit and service panel are considered excessive. When installing wiring runs that have one-way path lengths longer than about 80 feet, it is recommended that the next larger wire size be used to avoid possible voltage drop problems.

CAUTION



▼ Table 7-3.
Maximum Ampacities of Common Copper Conductors – Based on an Ambient Temperature of 86° F (30° C) and with No More than Three Current-Carrying Wires in a Conduit or Cable (Based on *NEC®* Table 310-16)

Wire Size	Type/Temperature Rating		
	140° F (60° C) TW, UF	140° F (75° C) THW, THWN	194° F (90° C) THHN
14	20*	20*	25*
12	25*	25*	30*
10	30	35*	40*
8	40	50	55
6	55	65	75
Ambient Temperature	Correction Factors For ambient temperatures above 86° F (30° C), multiply the ampacities shown above by the appropriate factor shown below.		
87° F - 90° F	.91	.94	.96
96° F - 104° F	.82	.88	.91
105° F - 113° F	.71	.82	.87
114° F - 122° F	.58	.75	.82

* The overcurrent protection for wire sizes marked with an (*) shall not exceed 15 amps for No. 14, 20 amps for No. 12, and 30 amps for No. 10 after any correction factors for ambient temperature have been applied.

Sequence and Use of Installation Instructions

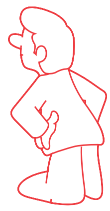
The general sequence for the electrical installation used with most HVAC units is outlined below.

1. Study the building's construction to determine the best routing for the branch and control circuit wiring.
2. Install the branch circuit components at their locations, then run the cable and/or conduit and wires between these components, the building's service panel, and the unit. Refer to the unit reference drawing in the installation instructions for the location of the unit's power wiring access hole.
3. With the exception of the wires in the service panel, connect all branch circuit wiring, including those in the unit.

For wiring details between the disconnect and the unit, refer to the wiring diagrams given in the installation instructions *(Figure 7-29)*. Also refer to the unit's component layout diagram for the location of electrical components within the unit. ***To avoid mistakes, always be sure to read all notes given on these diagrams.***

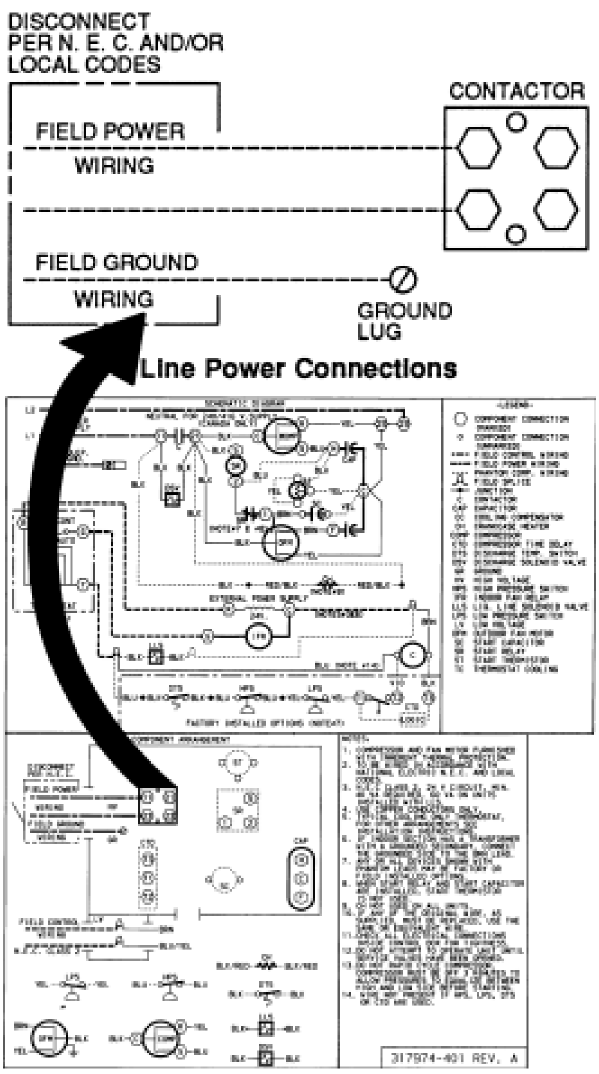
4. Install and connect the control wiring between the thermostat and the unit(s). Refer to the unit reference drawing for the location of the control wiring access hole.
   For wiring details between the thermostat and the unit(s), refer to the connection and wiring diagrams given in the installation instructions *(Figure 7-30)*.

CAUTION

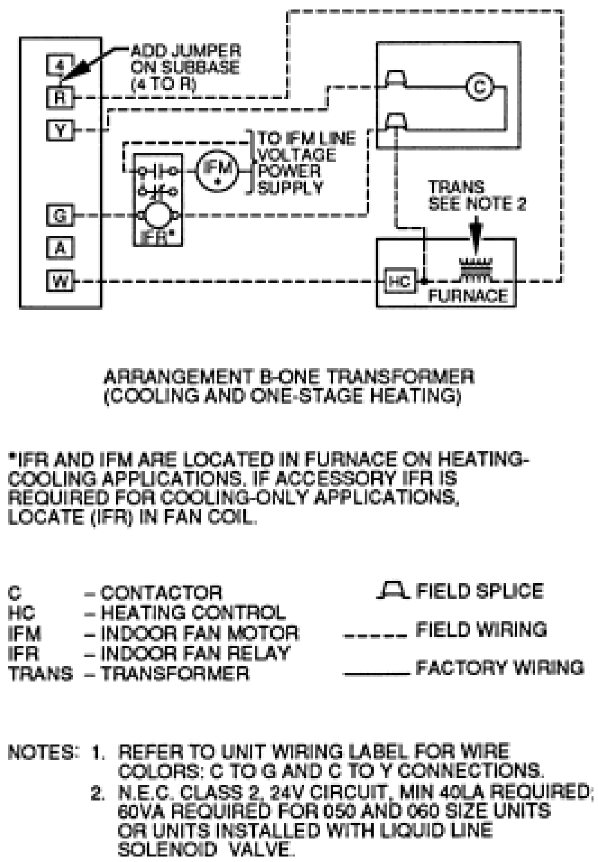


5. Have a qualified electrician install the circuit breaker(s) and connect the wires for the unit branch circuit in the service panel/subpanel. Be sure to label the new circuit breaker(s).
   For a 120-volt branch circuit, the black wire should be connected to the terminal of a single-pole circuit breaker, and the neutral and ground wires to the neutral and ground bus, respectively. This presumes the use of a two-wire cable.
   For a 240-volt branch circuit, the black and white wires should be connected to the terminals of a double-pole circuit breaker and the ground wire to the ground bus. This presumes the use of a two-wire cable. There is no neutral bus connection. The white wire should be marked with tape or paint to indicate that it is hot.
6. Check out the unit's electrical operation per the installation instructions and checklist(s).

▼ Figure 7-29.
Typical Electrical Wiring Data Contained in Manufacturer's Equipment Installation Instructions



▼ Figure 7-30.
Typical Control Wiring Data Contained in Manufacturer's Equipment Installation Instructions



Installing Cable Runs

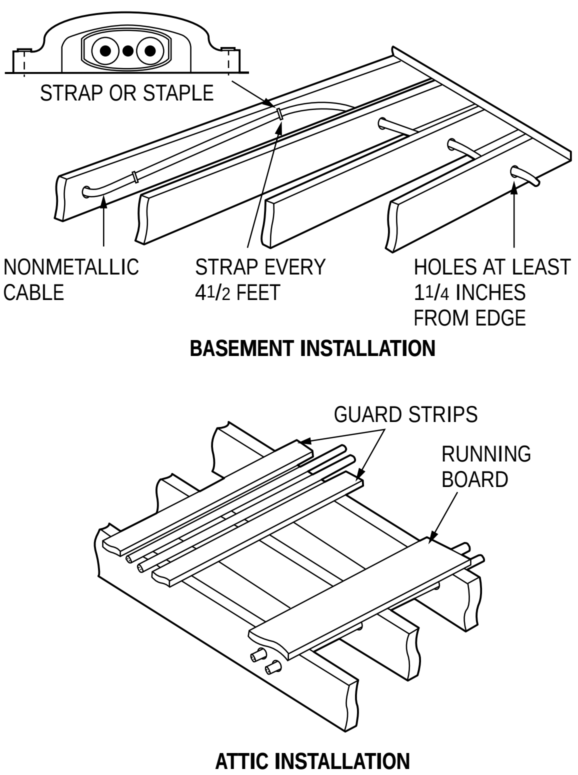
Nonmetallic Cable – Where nonmetallic cable runs are used in exposed areas such as basements and attics, they should be run along a joist or through drilled holes *(Figure 7-31)*. In attics, they should also be protected by a running board nailed across the joists over the cable runs. When run across the top of joists in attics, the cable should be protected on both sides by guard strips at least as high as the cable. Note that if exposed and passing through a floor, nonmetallic cable must be protected for at least six inches above the floor with metal conduit that has bushings at both ends. This protects the cables from abrasion.

Holes for cable runs should be drilled in the building framing after all boxes and equipment are mounted. Holes should be bored in the center of the framing member so that the edges of the holes are at least 1-1/4 inches from the edge. If this clearance cannot be maintained, the cable must be protected by a steel nail plate at least 1/16-inch thick. Nail plates must also be used if it is necessary to run cable in notches cut into studs.

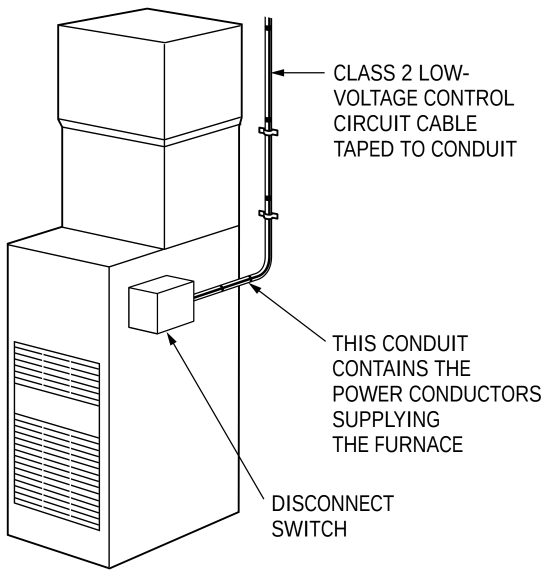
Cable must be fastened within 12 inches of metal boxes and, if not run through drilled holes, at least every 4-1/2 feet of length. The radius at the inside of any cable bends should not be less than five times the cable diameter. For example, with 1/2-inch cable, the radius of the bend must be at least 2-1/2 inches.

Low-Voltage Control Cable – Electrical codes prohibit the running of low-voltage control wiring inside the same conduit as power cables. This is why HVAC equipment normally has separate openings (knockouts) for the power and control wiring. Because control voltage is considered safe from fire hazard, it can be run exposed and need not be installed in conduit; however, it must be installed in a way that the cables will not be damaged by normal building use. It can be fastened using tape or wire ties to the outside of the conduit, etc. containing the power wires for the **same** equipment *(Figure 7-32)*. When run to outdoor units, the control wiring is frequently run along with and taped to the refrigerant lines.

▼ Figure 7-31.
Running Nonmetallic Cable



▼ Figure 7-32.
Typical Control Circuit Cable Installation



Installing Conduit Runs

The general methods for installing conduit were covered earlier in this section. The conduit must be supported with straps within three feet of every box and fastened in place at intervals not exceeding ten feet. Various fittings are available to make the transition from indoor nonmetallic cable to conduit needed for exposed outdoor wiring. *Figure 7-33* shows a typical method. It also shows a common use of liquidtight flexible conduit.

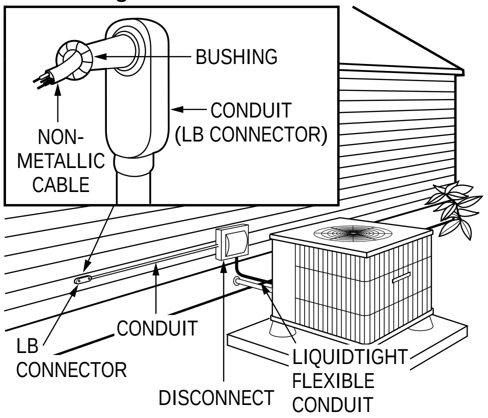
Installing Wires in Wall Partitions

When installing systems in existing buildings, thermostat wires (and sometimes power wiring) must be pulled between different floor levels and inside finished walls. For thermostat control wiring, this means that holes must be drilled through the building's framing to provide access for pulling the thermostat wires needed to connect the thermostat to the unit.

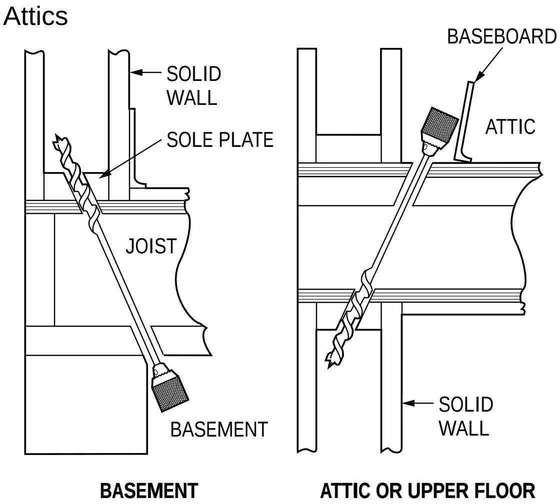
To go from a basement to a wall on the first floor, drill from the basement up *(Figure 7-34)*. If drilling from an attic to the floor below, the method is basically the same, except drill down. Then, an access hole for the wires is made in the first floor wall at the thermostat's mounting location *(Figure 7-35)*.

A fish tape is pushed up through the hole in the basement (or down from the attic) above or below the thermostat's wire hole in the wall. A hooked end wire is used to "snag" the fish tape through the hole in the wall. Once the fish tape is hooked, it can be pulled out of the thermostat wire hole with three or four feet sticking out into the room. The thermostat wires are securely fastened to the hook of the fish tape and pulled back through the two holes and into the basement (or attic), where the wires are run to the unit. Note that the actual method used to install the fish tape and pull the wires should be the easiest one that fits the situation. In some situations, it may be as easy as using an existing thermostat wire to pull the new wire.

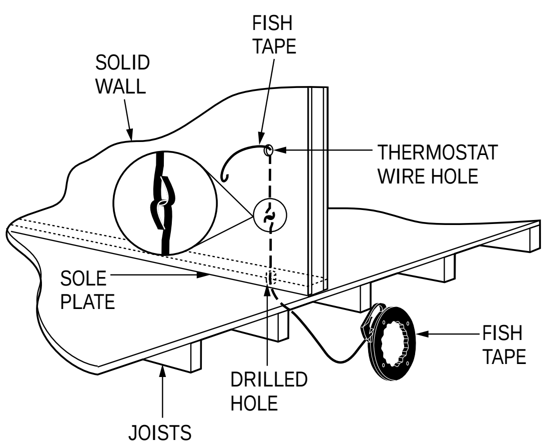
▼ Figure 7-33.
Typical Method Used to Transition from Indoor to Outdoor Wiring



▼ Figure 7-34.
Drilling Cable Access Holes from Basements and Attics



▼ Figure 7-35.
Example of Running a Fish Tape Between the Basement and the First Floor



SECTION 8
GAS FURNACE INSTALLATION

INTRODUCTION

This section provides guidelines for the installation of gas-fired, forced-air furnaces and their accessories. It is not intended to teach gas furnace or vent and combustion air theory; instead, it describes the different kinds of furnaces, the common accessories used with them, and the methods used to install them. This section presumes that the proper type of furnace and related accessories have been selected and purchased by a qualified engineer or salesperson based on a survey of the job.

GAS FURNACE MENU

TYPES OF GAS-FIRED FURNACES

A gas furnace is rated in terms of its *annual fuel utilization efficiency (AFUE)*. This rating, expressed as a percentage, represents the annual average efficiency of the furnace, taking into account the effect of on-off operation. All furnaces produced after 1992 must have an AFUE rating of at least 78%. There are three types of furnaces: natural draft, induced draft, and condensing.

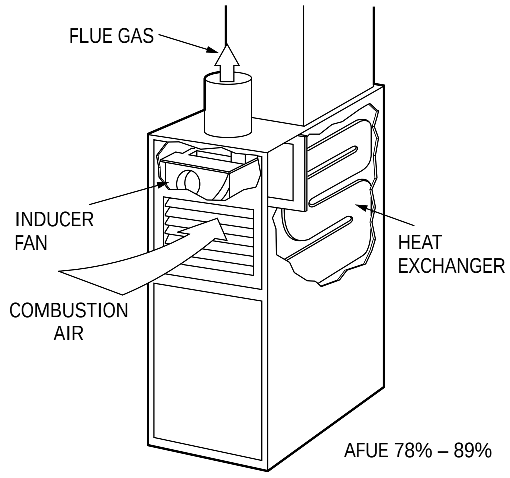
Natural-Draft Furnaces

Natural-draft furnaces rely on the buoyancy of the hot combustion products to create the draft needed to draw combustion products through the heat exchanger and out the vent system. Most manufacturers no longer produce this type of furnace because it is difficult to obtain a 78% AFUE with this technology.

Induced-Draft Furnaces

Non-condensing, induced-draft furnaces *(Figure 8-1)* typically have AFUE ratings of at least 78%. They achieve this increased efficiency by using an inducer fan to draw the combustion products through a more efficient heat exchanger which transfers more heat from the combustion products to the conditioned air passing over the heat exchanger, thus reducing the temperature at which the combustion products leave the furnace. The inducer fan also restricts the flow of warm air out of the vent during the off cycle. Venting of induced-draft, non-condensing furnaces is covered in more detail later in this section.

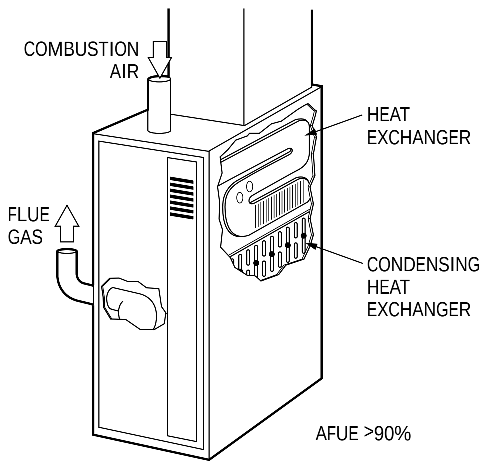
▼ Figure 8-1.
Induced-Draft Furnace



Condensing Furnaces

Condensing furnaces *(Figure 8-2)* have the highest efficiencies, with AFUE ratings above 90%. They achieve this by using an additional heat exchanger which removes latent heat from the flue gases by condensing the water vapor. Condensing furnaces use a more powerful inducer fan than induced-draft furnaces because of the added pressure drop of the condensing heat exchanger and the need to move combustion air and combustion products through long runs of pipe. Condensing furnaces do not exhaust flue gases into a vent system like those used with non-condensing furnaces. Instead, condensing furnaces may use 100% outdoor air for combustion. This air is obtained through a sealed combustion air/vent system powered by the inducer fan. The combustion products are discharged from the building through the exhaust vent by the inducer fan. The combustion air and venting systems used with condensing furnaces are covered in more detail later in this section. The condensate produced in the condensing heat exchanger must be disposed of properly.

▼ Figure 8-2.
Condensing Furnace



FURNACE CONFIGURATIONS

Depending on the building structure and application, four basic configurations of induced-draft or condensing furnaces are used to cover most applications: upflow, downflow, horizontal, and multi-poise.

Upflow Furnaces

The upflow furnace *(Figure 8-3)* is the most widely used, and is generally installed in basements, closets, or equipment rooms. Return air via the return duct system enters the lower side or bottom of the furnace through an air filter or electronic air cleaner (EAC), is pushed through the heat exchanger by the blower, then is discharged through the supply air duct system. When used with central air conditioning, the cooling coil is located in the supply air plenum.

Downflow Furnaces

The downflow or *counterflow* furnace *(Figure 8-4)* is the opposite of the upflow furnace. Return air enters the top of the furnace through the air filter or EAC and is pushed downward through the heat exchanger by the blower. It is then discharged into the supply air duct system located below the furnace. This type of furnace is often used in buildings that are built with a crawlspace or on a slab. When used with a central air conditioning system, the cooling coil is mounted under the furnace in the supply air plenum.

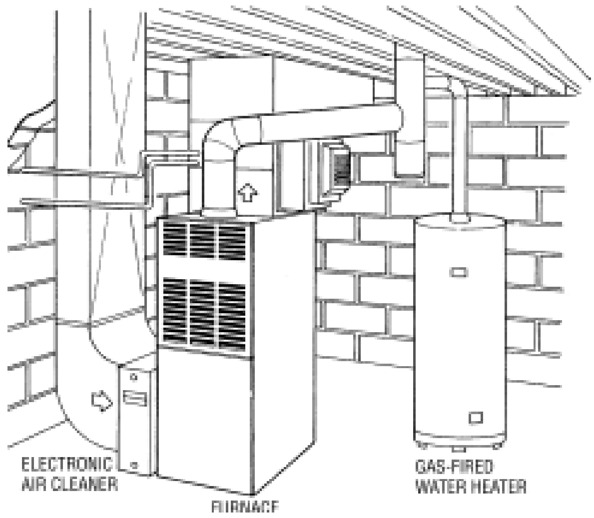
Horizontal Furnaces

The horizontal furnace can be installed on the floor of an attic *(Figure 8-5)*, suspended from an attic ceiling, or under the floor in a crawlspace. Return air is drawn into the blower and forced horizontally over the heat exchanger into the duct system. Special horizontal cooling coils are used if air conditioning is installed.

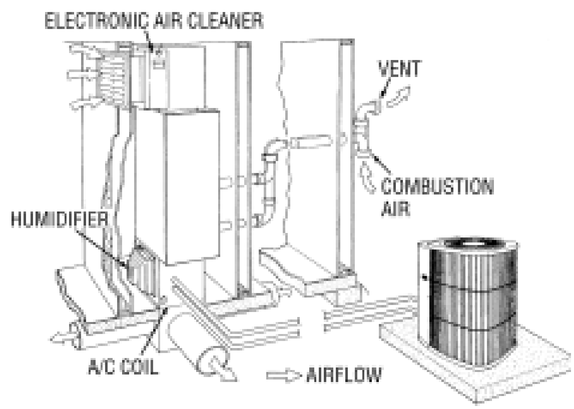
Multi-Poise Furnaces

Multi-poise (multi-position) furnaces *(Figure 8-6)* are versatile furnaces that can be installed in any position: upflow, downflow, horizontal left, or horizontal right. Usually, they come shipped from the factory configured for upflow use, but can be easily converted for other applications. Keep in mind that it is usually easier to make any conversion at the shop, instead of at the job site.

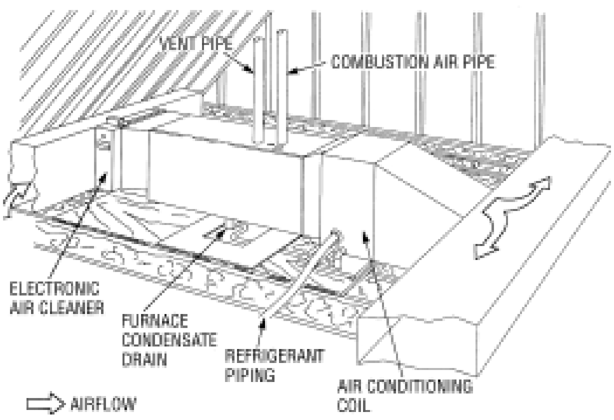
▼ Figure 8-3.
Typical Induced-Draft Furnace; Basement Upflow Installation



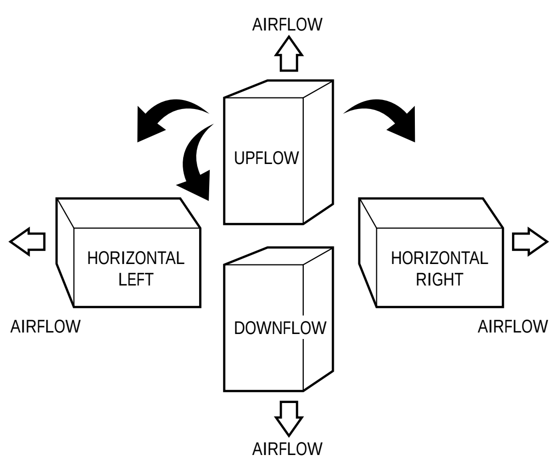
▼ Figure 8-4.
Typical Condensing Furnace; Closet Downflow Installation



▼ Figure 8-5.
Typical Condensing Furnace; Attic Horizontal Installation



▼ Figure 8-6.
Multi-Poise Furnace Orientations



Natural Gas and Propane Gas Furnaces

Gas furnaces are designed to burn natural gas or propane gas. Both gases are safe if the furnace is installed correctly and proper safety measures are used. However, both gases are explosive if allowed to leak or are mishandled.

Natural Gas – Most gas-fired furnaces use natural gas. Natural gas is lighter than air and will rise and diffuse into the surrounding air should a leak occur. It can displace the oxygen in the air and can be explosive. Natural gas has an odorant added to alert people to any leaks.

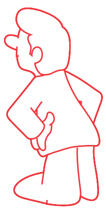
Propane Gas – Propane gas is typically used in rural areas and other places where natural gas is not available. Propane is a liquified petroleum gas (LPG) that has been compressed into its liquid form and stored under pressure in a tank. It can only be used as a fuel when it is in the vapor state. Refer to *Table 8-1* for a comparison of propane and natural gas characteristics. Propane gas is heavier than air and will collect and stay in low places if a leak occurs. Propane also has a distinct odor to alert people to any leaks.

Pressure regulators in the propane gas supply system reduce the pressure of the propane gas in the storage tank to 11 in. w.c. at the building input for use with furnaces and other appliances. ***Propane is an excellent solvent. Therefore, when assembling propane piping to a furnace always make sure to use a pipe joint compound that is resistant to LP gas.***

▼ Table 8-1.
Propane and Natural Gas Characteristics

Parameter	Natural Gas	Propane Gas
Ignition Temp. (°F)	1,170	932
Cu. ft. air needed to burn one cu. ft. gas	10	25
Heating value Btu's/cu. ft.	1,050	2,500
Specific gravity	0.4 - 0.8	1.5

CAUTION

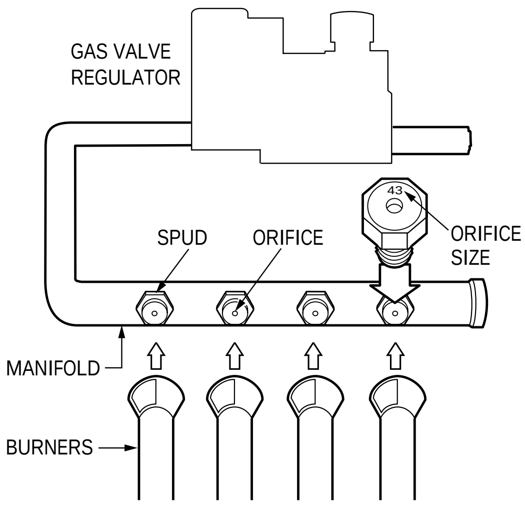


CAUTION

Furnace Conversion Kits – Gas furnaces are assembled at the factory to burn only one kind of gas. ***Do not use propane gas in a natural gas furnace or vice versa because an unsafe condition will be created.*** Most manufacturers make kits to convert the operation of a furnace from one fuel to the other. These conversion kits should be installed following the instructions supplied with the kits.

Conversion kits are necessary because the specific gravity of a gas affects its flow through pipes and a furnace's gas orifices. Orifices are located in the gas manifold *(Figure 8-7)* and determine how much gas is delivered to a burner. They are designed and sized for a specific furnace model operating with a specific gas. The conversion process involves changing the orifices as well as making changes to the gas valve regulator. Other components may need to be installed in the furnace electrical circuit to complete the conversion.

▼ Figure 8-7.
Gas Manifold



ACCESSORIES

Many furnace jobs require installing additional accessories such as a humidifier, electronic air cleaner, and/or a condensate pump.

Humidifiers

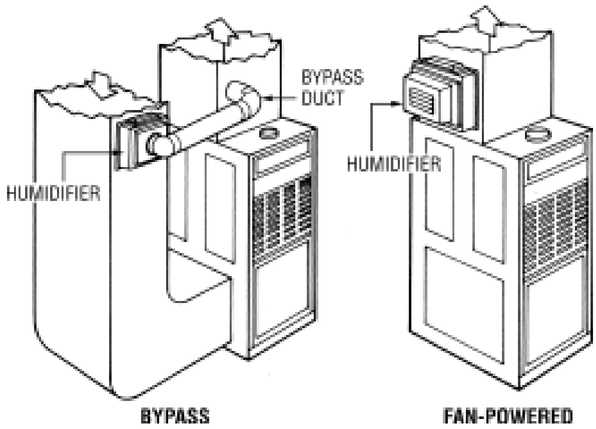
A humidifier *(Figure 8-8)* adds water vapor to a building's air supply in the winter to provide a comfortable humidity level. Humidifier operation is controlled by a humidistat which senses the relative humidity of the air in the home. Fan-powered and bypass humidifiers are the most commonly used humidifiers with gas furnaces. These humidifiers depend on the flow of warm air over a wet media pad to cause the evaporation of water into the airstream.

Fan-powered humidifiers are installed on the supply plenum. This allows warm air from the supply airstream to be drawn into the humidifier by the fan, passed through the humidifier's wet media pad, then returned to the supply airstream for distribution.

Bypass humidifiers can be installed either on the supply or return duct, allowing airflow in either direction through the unit. Bypass humidifiers work because of the air pressure difference that exists between the supply and return ductwork. Heated air passes out of the supply duct, through the humidifier, and then back into the return air duct via a field-supplied bypass duct installed between the supply and return ducts.

Many furnaces have built-in terminals to connect the humidifier to the furnace control circuit. Normally, the humidifier only operates when there is a call for heat and the furnace blower motor is energized.

▼Figure 8-8.
Fan-Powered and Bypass Humidifiers



QUICK NOTE

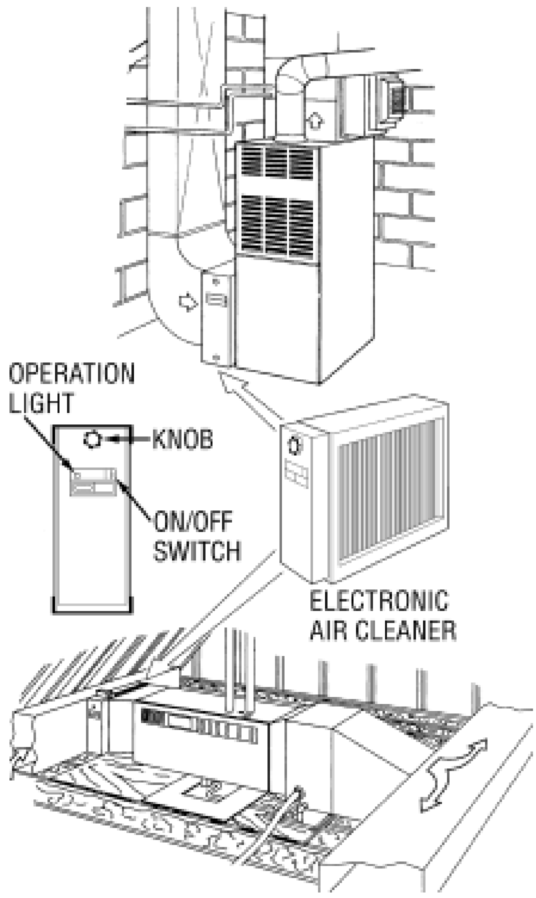
LOW HUMIDITY PROBLEMS

- Dry, itchy skin
- Static electricity shocks
- Sinus problems
- Chilly feeling
- Sickly pets
- Sickly plants
- Furniture joints loosen
- Clothing static cling

Electronic Air Cleaners

Electronic air cleaners or *EACs (Figure 8-9)* remove dust, pollen, and smoke from the air in the conditioned space. They have a high-voltage power supply used to charge (ionize), attract, and collect particles in the air that passes through the filter. EACs can be installed with all configurations of furnaces in the furnace return air connection. Many furnaces have terminals for connecting the EAC. They are wired into the furnace fan circuit so that they operate whenever the furnace blower motor is energized, regardless of the operating mode.

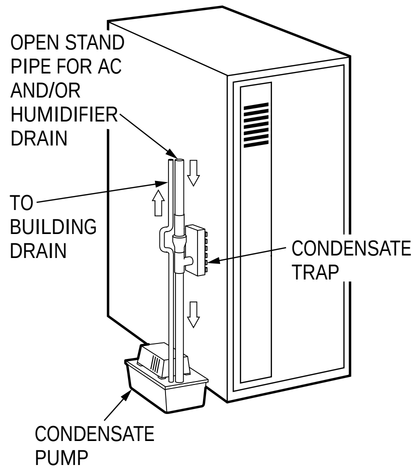
▼Figure 8-9.
Typical Electronic Air Cleaner



Condensate Pumps

When gravity drains are impractical, condensate pumps *(Figure 8-10)* are used to pump the condensate from condensing furnaces and/or cooling coils or excess water from humidifiers into a drain. Condensate pumps should be installed as near as possible to the unit being drained. Pump operation is controlled by a float-operated switch that senses the water level. Many pumps have a safety overflow switch to shut down the related heating or cooling equipment should the condensate pump fail. This stops the flow of condensate into the pump tank, where it could overflow and cause water damage.

▼ Figure 8-10.
Condensate Pump



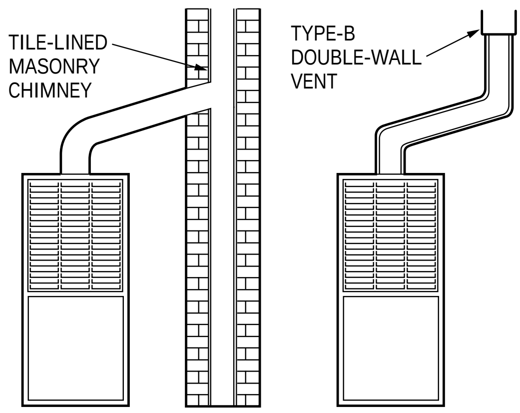
FURNACE VENT SYSTEMS

The furnace vent system carries the products of combustion from the furnace to the outdoors. The type and size of the vent system must be carefully matched to the furnace. Undersized or oversized vents will result in poor furnace performance and may cause an unsafe condition. The installation of vent systems must always comply with national and/or local codes and regulations that govern installations. Category I vents are used with induced-draft and natural-draft furnaces while Category IV vents are used with condensing furnaces.

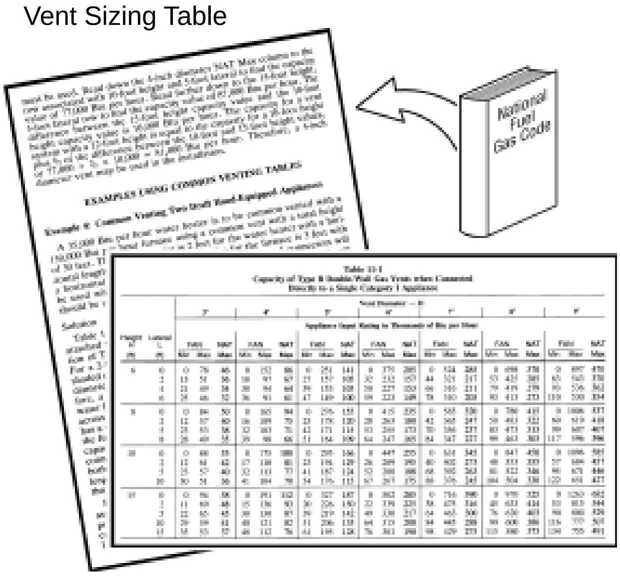
Induced-Draft Furnace Vent Systems (Category I Vents)

Category I vents *(Figure 8-11)* consist of a pitched horizontal run from the furnace, called the *vent connector*, and the vertical section of metal pipe or chimney, called the *vent*, that moves combustion products outdoors. Often the furnace is "common-vented" with another appliance, usually the water heater. Type-B double-wall metal vent pipe or a lined masonry chimney must be used as the vent with induced-draft and natural-draft furnaces. Existing metal vents and chimneys that are in good condition and properly constructed may be reusable if they meet the code and size requirements. They must be replaced or relined if they are undersized or oversized or not in good condition. Normally, the adequacy of an existing vent system, or the design of a new one, has been determined ahead of time. If needed, refer to the National Fuel Gas Code and the manufacturer's instructions for vent sizing tables *(Figure 8-12)* and examples of how to use them to find vent sizes.

▼ Figure 8-11.
Category I Vents Used with Induced-Draft Furnaces



▼ Figure 8-12.
Example of a Typical National Fuel Gas Code Vent Sizing Table



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General Guidelines for Installing Metal Vents and Vent Connectors – If installing a metal vent system, double-wall (Type-B) metal vent piping *(Figure 8-13)* ***must*** be used as the main vent with induced-draft or natural-draft furnaces. Good practice is to also use double-wall pipe for the vent connector because it has a much lower heat loss than single-wall pipe and it provides for greater installation flexibility. Single-wall pipe has a high heat loss that severely limits its use. It can sometimes be used as a vent connector, but never for the vent itself. The discussion in the remainder of this section presumes the use of double-wall pipe for both the vent and vent connector.

Main Vent – The diameter, height, and number of elbows determine the resistance the vent offers to the flow of flue gases. For this reason, a straight run to the roof is preferred. Should it be necessary to offset the upper portion in order to bypass an obstruction, good practice is to use 45° elbows instead of 90° elbows to keep restrictions to a minimum *(see Figure 8-13)*. Fire regulations require that a *firestop* made from non-combustible materials be installed where the vent passes through floors and ceilings.

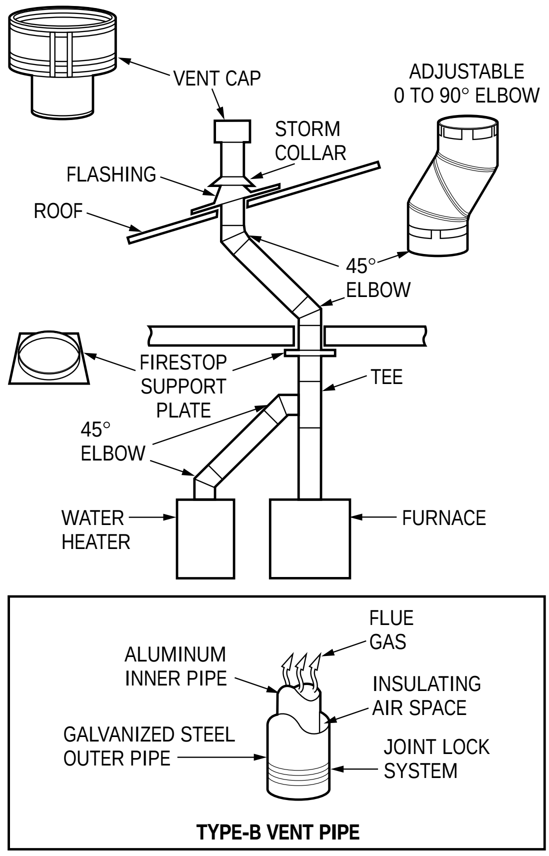
Always install the vent cap specified by the vent manufacturer. ***Use of the wrong cap or an unapproved cap can adversely affect venting action.*** Codes require that a vent (or chimney) termination project a minimum height above the roof to prevent wind forces from disturbing the venting action. Consult the applicable code for the required distances. Generally, the codes specify:

- For Type-B vents up to 12 inches in diameter with listed caps and located at least eight feet from a vertical wall, the height varies with the roof pitch *(Figure 8-14)*.
- For all other vents, the minimum height is two feet above the highest point where they pass through the roof and at least two feet higher than any portion of the building within ten feet *(Figure 8-15)*.

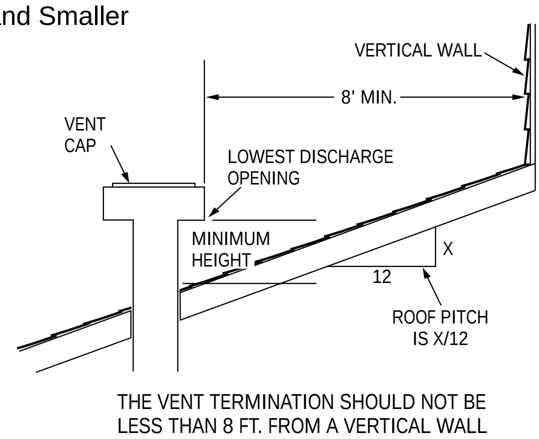
Vent Connectors – A vent connector directs flue gases from the furnace to the main vent. Type-B double-wall pipe must be kept one to three inches from combustible materials or as specified by the vent pipe manufacturer. Single-wall pipe, when used, must be kept six to nine inches away from combustibles.

In all cases, vent connectors should be made as short as possible and pitched upward toward the main vent at a slope of no less than 1/4 inch per foot. For example, a four-foot long vent connector should have an upward slope of at least one inch (1/4 x 4). Keep the number of elbows to a minimum and use 45° elbows instead of 90° elbows whenever possible.

▼ Figure 8-13.
Typical Type-B Metal Vent System

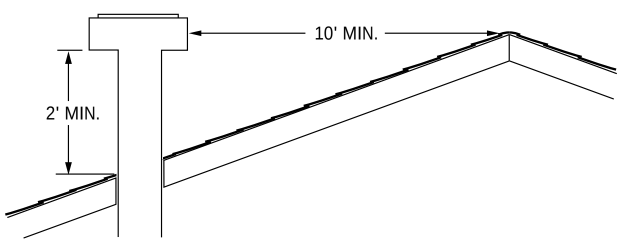


▼ Figure 8-14.
Vent Termination Heights for Vent Caps 12 Inches and Smaller



ROOF PITCH	MINIMUM HEIGHT
FLAT TO 6/12	1.0 FEET
6/12 TO 7/12	1.0 FEET
OVER 6/12 TO 7/12	1.25 FEET
OVER 7/12 TO 8/12	1.5 FEET
OVER 8/12 TO 9/12	2.0 FEET
OVER 9/12 TO 10/12	2.5 FEET
OVER 10/12 TO 11/12	3.25 FEET
OVER 11/12 TO 12/12	4.0 FEET
OVER 12/12 TO 14/12	5.0 FEET
OVER 14/12 TO 16/12	6.0 FEET
OVER 16/12 TO 18/12	7.0 FEET
OVER 18/12 TO 20/12	7.5 FEET
OVER 20/12 TO 21/12	8.0 FEET

▼ Figure 8-15.
Vent Termination Heights for Vent Caps Larger than 12 Inches



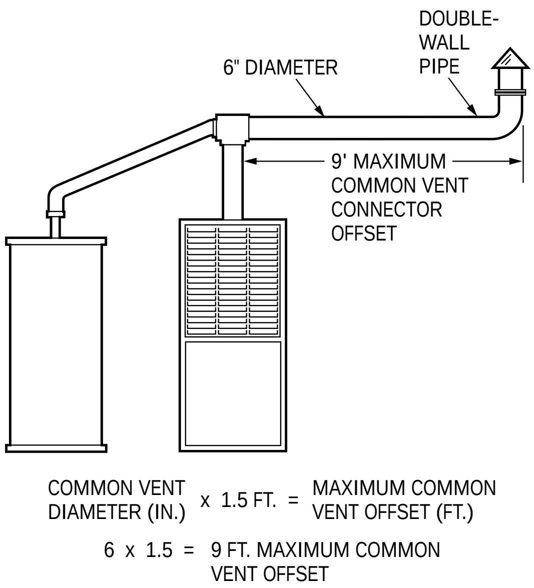
When an induced-draft furnace is common-vented with another gas appliance, the following rules apply:

- The vent connector from the smaller capacity appliance may have no more elbows than the vent from the larger appliance.
- The vent connector for the smaller appliance must connect to the common vent as high as possible above the connection from the larger appliance.
- The connecting tee fitting must always be the same size as the common vent to reduce turbulence at the connection. For example, if using a six-inch vent connector, the tee should also be six inches.
- For instances where two appliances are connected to a manifolded common vent connector *(Figure 8-16)*, the maximum length of the common vent connector is determined by allowing 1.5 feet in horizontal length for each inch of vent connector diameter. For example, a six-inch diameter common vent connector can have a maximum length of nine feet.

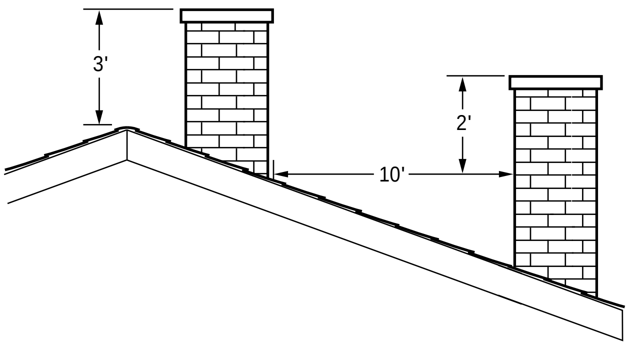
General Guidelines for Venting through a Masonry Chimney – All masonry chimneys must conform to NFPA Standard 211. Codes prohibit unlined chimneys from being used to vent furnaces. Tile-lined masonry chimneys can be used to vent an induced-draft furnace only if the furnace is common-vented with a draft hood-equipped gas appliance. If lined with a listed liner, a chimney can be used to vent an induced-draft furnace without the need to be common-vented with a draft hood-equipped appliance. A chimney must extend at least three feet above the highest point where it passes through the roof, and at least two feet higher than any portion of the building within a horizontal distance of ten feet *(Figure 8-17)*.

Gas code vent selection tables identify the chimney size (in inches) required to match the furnace capacity. Sometimes an existing chimney opening will be too big for the furnace and the proper size chimney liner ***must*** be installed. A double-wall Type-B vent or a flexible metal chimney liner can be used. Flexible liners *(Figure 8-18)* normally come in kits containing all parts and instructions needed to install the liner. Consult the furnace manufacturer and flexible vent manufacturer's installation literature to determine size, etc.

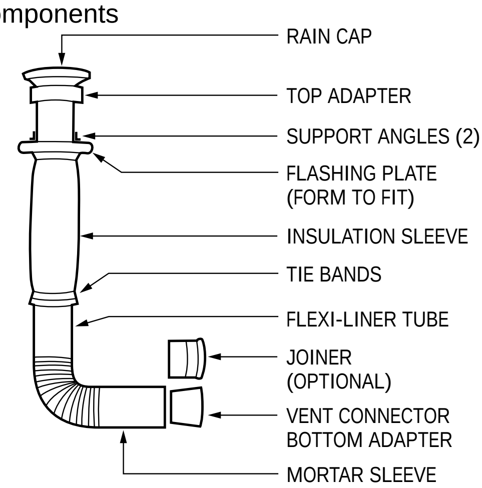
▼ Figure 8-16.
Manifolded Common Vent



▼ Figure 8-17.
Minimum Roof Projections for Chimneys



▼ Figure 8-18.
Typical Flexible Metal Chimney Liner Kit Components

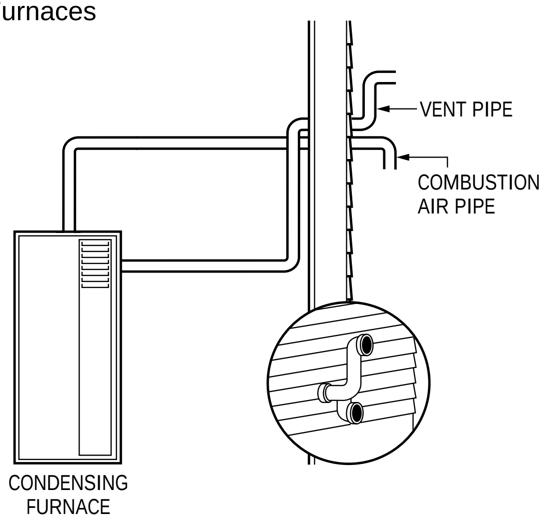


Condensing Furnace Vent Systems (Category IV Vents)

Condensing furnaces use a Category IV direct vent system *(Figure 8-19)* which operates under positive pressure with respect to the atmosphere and is powered by the furnace inducer assembly. In a direct vent system, all air for combustion is taken directly from the outdoors and all flue gases are discharged to the outdoors. A condensing furnace cannot be vented using an existing vent or chimney. It also cannot be common-vented with another appliance. Some condensing furnaces use indoor air for combustion but direct the flue gases to the outside under positive pressure.

Because condensing furnaces produce low-temperature flue gases, most can be vented using Schedule 40 PVC pipe. The same type of pipe is also used to supply the furnace with outdoor combustion air. The two pipes are the same diameter as determined by the furnace size, the length of the pipe run, the number of elbows needed, and the site altitude. *Figure 8-20* shows an example of how pipe sizing tables like those given in the manufacturer's installation instructions are used to find the correct size vent and combustion air pipe to use with a furnace.

▼ Figure 8-19.
Category IV Vent Used with Condensing Furnaces



▼ Figure 8-20.
Using a Manufacturer's Vent and Combustion Air Pipe Sizing Table to Determine Pipe Size

Table 5—Maximum Allowable Pipe Length (Ft)

ALTITUDE	UNIT SIZE	TERMINATION TYPE	PIPE DIAMETER (IN.)*	NUMBER OF 90° ELBOWS 1	2	3	4	5	6
0 to 2000	040-08 040-12	2 Pipe or 2-In. Concentric	1	5	NA	NA	NA	NA	NA
			1-1/2	70	70	65	60	60	55
			2	70	70	70	70	70	70
	→060-08 060-12 060-16	2 Pipe or 2-In. Concentric	1-1/2	20	15	10	5	NA	NA
			2	70	70	70	70	70	70
	080-12 080-16 080-20	2 Pipe or 2-In. Concentric	1-1/2	10	NA	NA	NA	NA	NA
			2	55	50	35	30	30	20
			2-1/2	70	70	70	70	70	70
	100-16 100-20	2 Pipe or 3-In. Concentric	2	5	NA	NA	NA	NA	NA
			2-1/2	40	30	20	20	10	NA
			3	70	70	70	70	70	70
	120-20	2 Pipe or 3-In. Concentric	2-1/2 one disk	10	NA	NA	NA	NA	NA
			3 one disk	35	30	15	NA	NA	NA
			3† one disk	35	35	35	30	30	30
			3† no disk	70	70	70	70	70	70
	040-08 040-12	2 Pipe or 2-In. Concentric	1-1/2	67	62	57	52	52	47
			2	70	70	70	70	70	70
	→060-08 060-12 06[illegible]	[illegible] 2-In.	1-1[illegible]	[illegible]	12	7	[illegible]	NA	NA

EXAMPLE:

AN 080-12 SIZE FURNACE BEING INSTALLED IN AN AREA AT AN ELEVATION OF 650 FEET ABOVE SEA LEVEL REQUIRES 3 ELBOWS AND 32 FEET OF VENT PIPE AND 5 ELBOWS AND 34 FEET OF COMBUSTION AIR PIPE. DETERMINE THE SIZE OF THE VENT AND COMBUSTION AIR PIPES INDEPENDENTLY, THEN USE THE LARGER SIZE FOR BOTH PIPES. THE TABLE SHOWS THAT THE VENT PIPE COULD BE 2 INCHES AND THE COMBUSTION AIR REQUIRES 2-1/2 INCH PIPE. THIS IS BECAUSE 2-INCH PIPE IS GOOD FOR 35 FEET WITH 3 ELBOWS, BUT ONLY 30 FEET WITH 5 ELBOWS. THEREFORE, 2-1/2 INCH PIPE MUST BE USED FOR BOTH PIPES.

General Guidelines for Installing PVC Vent and Combustion Air Pipes – Manufacturer's installation instructions provide detailed information for installing the vent and combustion air piping. Some general guidelines are given here.

Always slope (pitch) the vent pipe back toward the furnace with a slope of at least 1/4 inch per foot and secure it with straps at least every five feet to prevent sags. This is necessary to allow condensate to drain back to the furnace for proper disposal.

QUICK NOTE

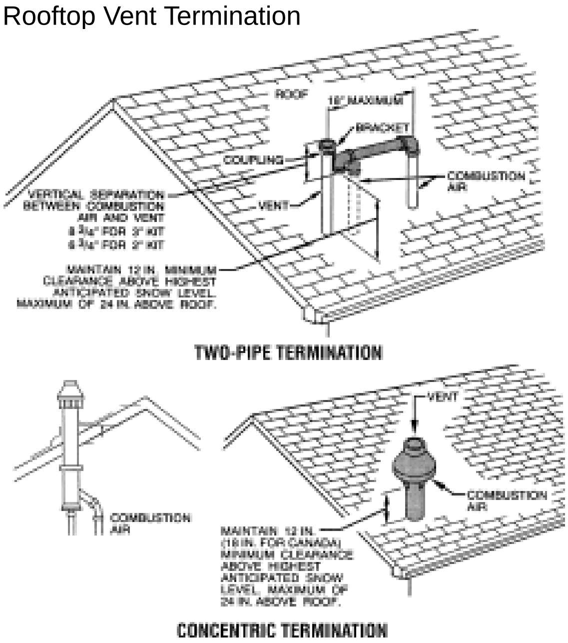
If a condensing furnace is replacing an existing gas furnace that was common-vented with another gas appliance such as a water heater, always check to be sure that the existing vent is not oversized when venting only the water heater. Most manufacturers provide detailed instructions for making this check in their installation instructions for the new condensing furnace.

The combustion air and vent pipes always terminate outside the building either above the roof *(Figure 8-21)* or through a sidewall. This termination can be done either with a two-pipe termination kit or a concentric single entry termination kit. Instructions for installing these kits are provided with the kits.

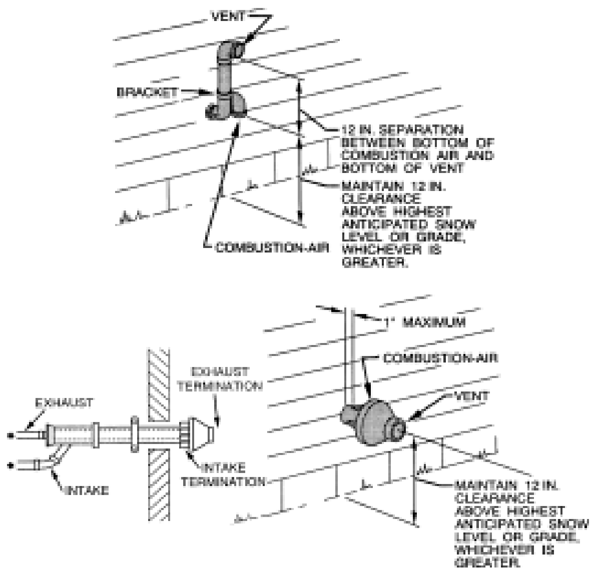
If venting is through a sidewall *(Figure 8-22)*, make sure the elbow for the combustion air intake points down and the vent points out. Also:

- Avoid terminating the furnace in a corner or in a confined area such as under a deck to prevent recirculation into the intake pipe, which may cause freeze-ups and/or poor combustion.
- Avoid terminating the furnace near trees or shrubs to prevent recirculation and plant damage.
- Avoid terminating the furnace near doors or windows. This keeps flue products from entering the building and prevents annoying steam clouds from obscuring vision.
- In areas of heavy snowfall, keep the termination at least 12 inches above the highest anticipated snow level. A termination too close to the ground can draw snow, dust, or leaves into the combustion pipe.
- Clearance dimensions for single-pipe condensing furnace vent terminations are different from two-pipe condensing furnace vent terminations.

▼ Figure 8-21.
Rooftop Vent Termination



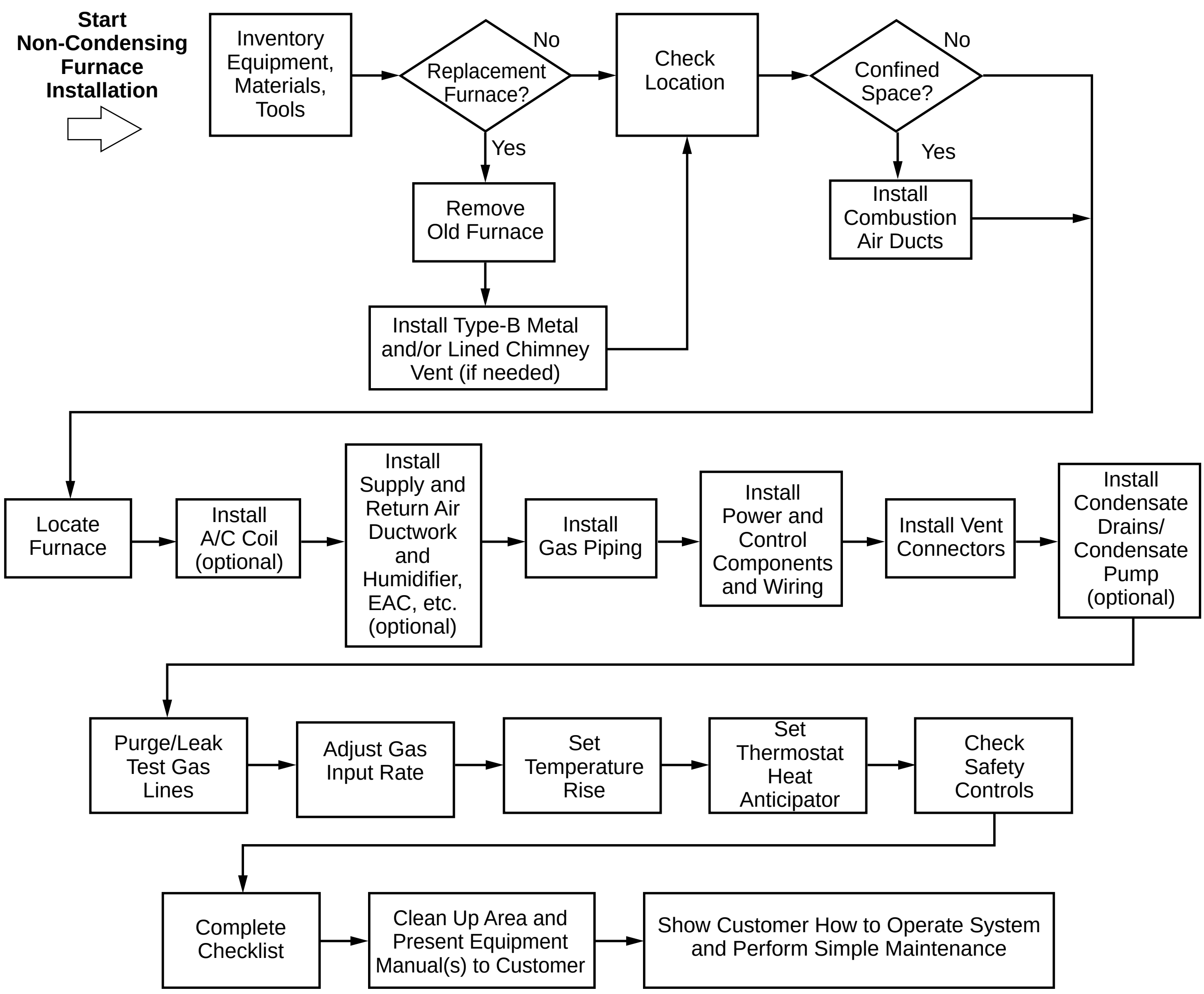
▼ Figure 8-22.
Sidewall Vent Termination



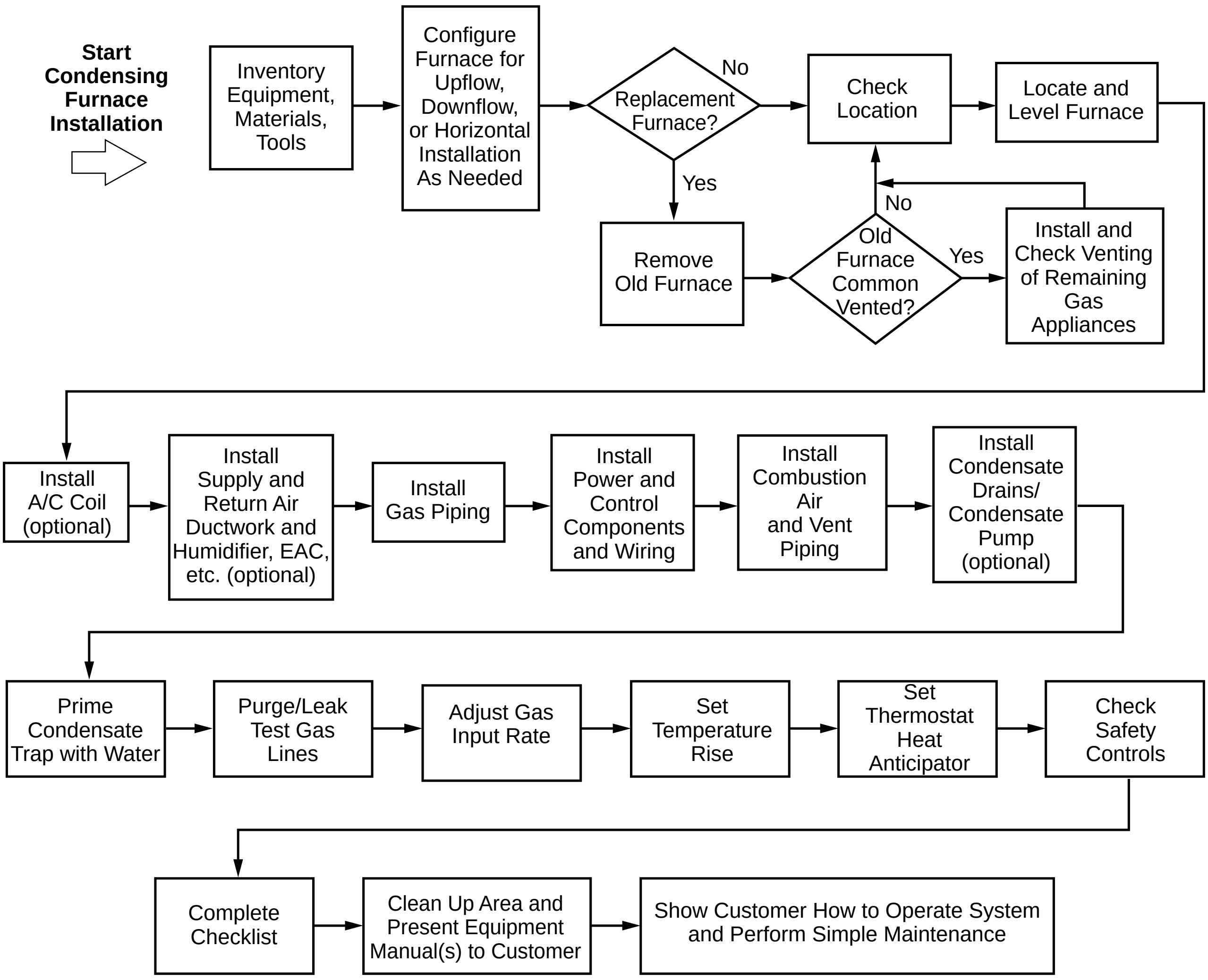
FURNACE INSTALLATION GUIDELINES

The methods for installing induced-draft and condensing furnaces are basically the same. The main area of difference is in the way they are supplied combustion air and the way they are vented. These guidelines apply to both new and replacement furnace installations. The installation of any furnace must always be done as directed in the manufacturer's installation instructions and must comply with any applicable codes and installation practices of the area where it is to be installed. The installation tasks for induced-draft and condensing furnaces and the general sequence in which they are performed are shown in *Figures 8-23* and *8-24*, respectively.

▼ Figure 8-23.
Non-Condensing Furnace Installation – Tasks and Sequence



▼ Figure 8-24.
Condensing Furnace Installation – Tasks and Sequence



QUICK NOTE

Always make sure all the required parts and tools are available before leaving for the job site.

QUICK NOTE – SAFETY REVIEW

- Only qualified technicians should install furnaces.
- Gas leaks are dangerous. Always check for leaks with soapy water solution prior to firing the burners.
- Whenever possible, shut off all power before working on furnaces. If you must work on a furnace with power on, remove your watch and other metal jewelry to reduce the shock hazard.
- Before installing or servicing any furnace, take the time to read the manufacturer's installation and service literature shipped with the product. Make sure to read and understand all **Warnings** and **Cautions** given in the literature.

Initial Preparation

A detailed list of required materials and a simple drawing showing the intended installation should be provided to the installer.

If installing a multi-poise furnace, reconfigure the furnace (if required) per the installation instructions before leaving the shop.

Removal of an Existing Furnace

Here are some guidelines for removing an existing furnace:

1. Shut off power to the furnace at the electrical service panel and attach a warning tag to the panel. Make sure there are no other appliances such as a refrigerator, etc., on the furnace circuit. Use a voltmeter to confirm that the power is off.
2. At the gas meter, shut off the main gas supply to the building. Disconnect all the gas piping at the furnace and temporarily plug or cap the gas line. Save the pipe and fittings, as they may be used for the replacement. For added safety, set the water heater control to OFF. If availability of the other gas appliances is not needed by the customer, wait until the furnace installation is complete before turning the gas back on.
3. Remove all power and thermostat wiring from the old furnace. Tape the power leads for added safety.
4. Disconnect the vent connector and supply and return air ductwork from the old furnace.

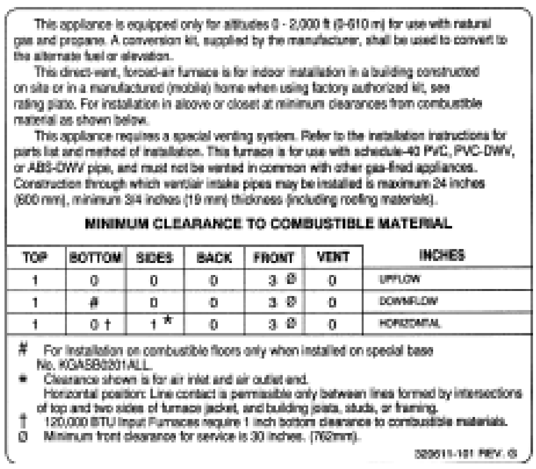
   If the new furnace is a condensing furnace, it cannot be common-vented with other gas appliances. If the old furnace was common-vented with a water heater or other gas appliance, the existing vent size must be checked per the gas code tables to make sure it is not oversized for venting the water heater.
5. Clean up the area in preparation for the new furnace.

Locating the Furnace

For all installations, the furnace location must always comply with the conditions specified in the manufacturer's instructions. Some important location considerations include:

- Install all furnaces so that electrical components are protected from water.
- Always maintain the minimum clearances as specified on the furnace rating plate and in the installation instructions *(Figure 8-25)*. Also, make sure that there is enough clearance in front of and around the furnace for servicing and cleaning.
- When installed in a hazardous location such as a residential garage, furnaces must be installed so that the burners are 18 inches above the floor and they must be protected from physical damage by vehicles *(Figure 8-26)*.
- Locate induced-draft furnaces as close to the vent/chimney as possible. Locate condensing furnaces so that the maximum allowable lengths of the combustion air and vent pipes are not exceeded.
- Locate the furnace as close to the center of the air distribution system as possible.

▼ Figure 8-25.
Typical Clearances to Combustibles Data Given in Manufacturer's Installation Instructions



This appliance is equipped only for altitudes 0 - 2,000 ft (0-610 m) for use with natural gas and propane. A conversion kit, supplied by the manufacturer, shall be used to convert to the alternate fuel or elevation.

This direct-vent, forced-air furnace is for indoor installation in a building constructed on site or in a manufactured (mobile) home when using factory authorized kit, see rating plate. For installation in alcove or closet at minimum clearances from combustible material as shown below.

This appliance requires a special venting system. Refer to the installation instructions for parts list and method of installation. This furnace is for use with schedule-40 PVC, PVC-DWV, or ABS-DWV pipe, and must not be vented in common with other gas-fired appliances. Construction through which vent/air intake pipes may be installed is maximum 24 inches (600 mm), minimum 3/4 inches (19 mm) thickness (including roofing materials).

MINIMUM CLEARANCE TO COMBUSTIBLE MATERIAL

TOP	BOTTOM	SIDES	BACK	FRONT	VENT	INCHES
1	0	0	0	3 Ø	0	UPFLOW
1	#	0	0	3 Ø	0	DOWNFLOW
1	0 †	1 *	0	3 Ø	0	HORIZONTAL

For installation on combustible floors only when installed on special base No. KGASB0201ALL.
* Clearance shown is for air inlet and air outlet end.
Horizontal position: Line contact is permissible only between lines formed by intersections of top and two sides of furnace jacket, and building joists, studs, or framing.
† 120,000 BTU Input Furnaces require 1 inch bottom clearance to combustible materials.
Ø Minimum front clearance for service is 30 inches. (762mm).

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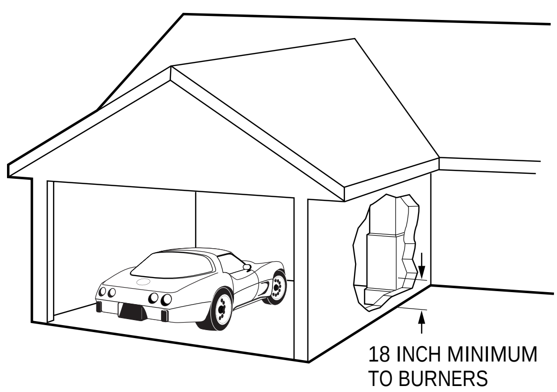
▼ Figure 8-26.
Installation in a Hazardous Location



- Avoid installing furnaces that use indoor air for combustion near sources of contamination such as those that can exist in laundry rooms *(Figure 8-27)*.
- Condensing furnaces installed in an unconditioned space where the ambient temperatures can drop below freezing must have adequate freeze protection. Freeze protection methods are described later in this section.
- The cooling coil (if used) must be installed on the supply side of the furnace to avoid condensation in the heat exchangers.

Induced-Draft Furnace Combustion and Ventilation

Adequate combustion and ventilation air for a furnace must be supplied from either inside or outside the building, depending on whether the furnace is installed in an unconfined or confined space. An unconfined space is one that has a volume of at least 50 cubic feet for each 1,000 Btuh of input for all appliances in the space *(Figure 8-28)*. For example, a 100,000 Btuh input furnace would require a volume greater than 5,000 cubic feet to be considered unconfined. The volume for any room can be calculated by multiplying the room's length by its width and height.

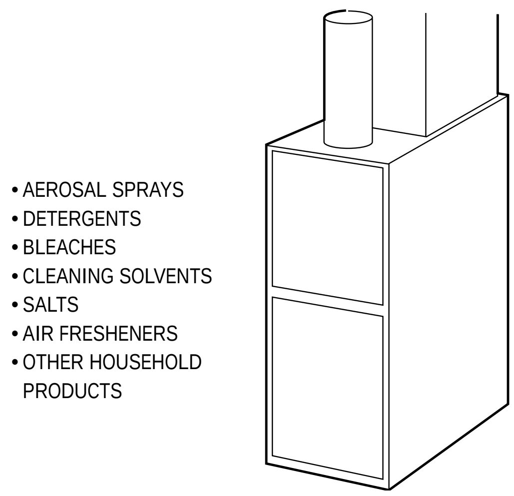
$$\text{Volume} = L \times W \times H$$

Confined spaces *(Figure 8-29)* are defined as those having less than 50 cubic feet per 1,000 Btuh of input. If the same 100,000 Btuh input furnace was installed in a room with a volume of less than 5,000 cubic feet, that installation would be considered in a confined space.

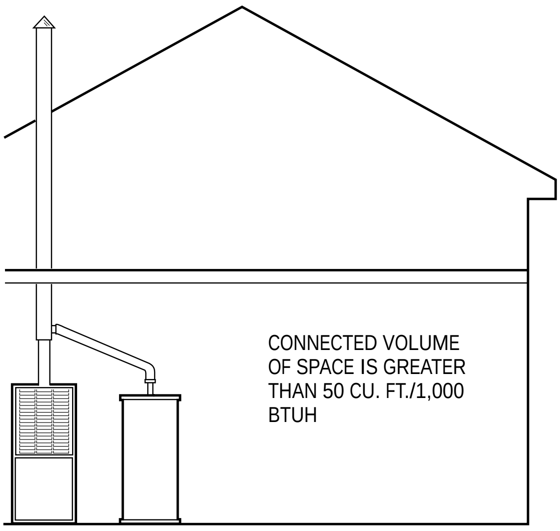
Whether the furnace is installed in a confined or unconfined space, adequate air must be made available for combustion. In older, loosely constructed homes, adequate air can be supplied by infiltration. If the home is newer and of tighter construction and/or infiltration cannot supply adequate air, the air must be brought in from outdoors.

By code, the combustion air requirements for all gas furnaces are the same. Only the sizes of the ducts, grille openings, etc. differ based on the specific model of furnace and its input in Btuh. A confined space must have two permanent openings, one within 12 inches of the ceiling and the other within 12 inches of the floor. Grilles or louvers installed over openings must be permanently open.

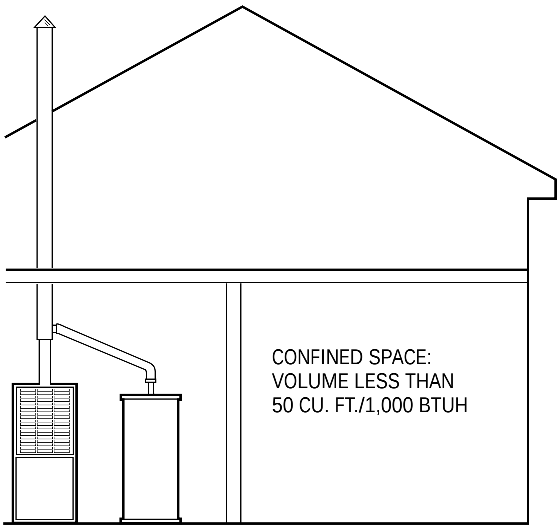
▼ Figure 8-27.
Avoid Contaminants in the Combustion Air



▼ Figure 8-28.
Furnace in an Unconfined Space



▼ Figure 8-29.
Furnace in a Confined Space



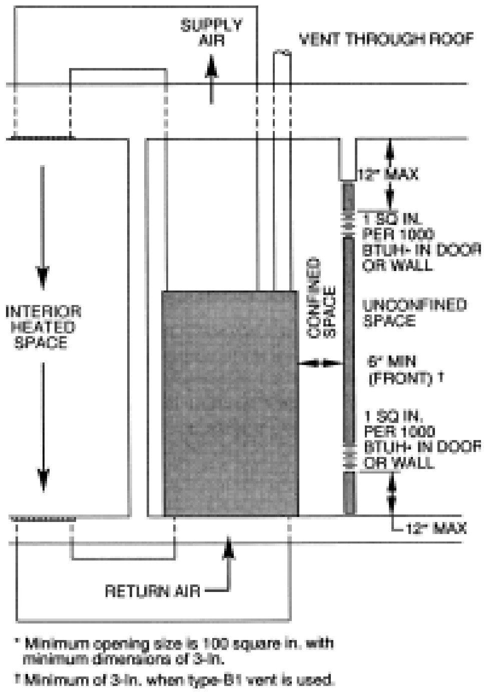
Supplying Inside Air to a Confined Space – *Figure 8-30* shows the requirements for bringing in combustion and ventilation air from an adjacent unconfined space into a confined space. These requirements are outlined here.

- Each opening must have at least one square inch of free area per 1,000 Btuh of the total input for all equipment in the confined space, but not less than 100 square inches per opening *(Table 8-2)*. The free area of grilles and louvers can be found in the manufacturer's literature. When used, screens must not be smaller than 1/4-inch mesh.
- If a furnace is installed on a raised platform to provide a return air plenum, and return air is taken directly from the hallway or space adjacent to the furnace, then all air for combustion must come from the outdoors.

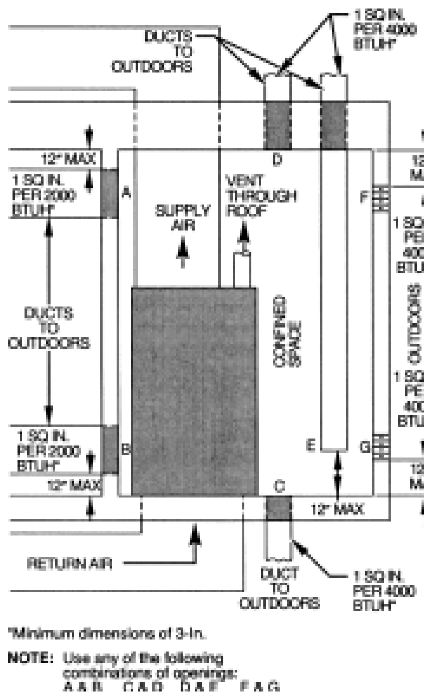
Supplying Outdoor (Outside) Air to a Confined Space – *Figure 8-31* shows the requirements for bringing outdoor combustion air into a confined space. These requirements are outlined here.

- If combustion air is brought in through vertical ducts, the openings and ducts must have at least one square inch of free area per 4,000 Btuh of the total input for all equipment within the confined space. *(See Table 8-3.)*
- If combustion air is brought in through horizontal ducts, the openings and ducts must have at least one square inch of free area per 2,000 Btuh of the total input for all equipment within the confined space. *(See Table 8-4.)*
- The cross-sectional area of any vertical or horizontal duct must be equal to or larger than the free area of the opening to which it connects. Rectangular duct must not be less than three inches wide or high.

▼ Figure 8-30.
Confined Space Requirements for Use of Inside Air for Combustion and Ventilation



▼ Figure 8-31.
Confined Space Requirements for Use of Outside Air for Combustion and Ventilation



▼ Table 8-2.
Sizing Air Openings into a Confined Space

Furnace Input (Btuh)	Free Area per Opening (Square Inches)
44,000	100
66,000	100
88,000	100
110,000	110
132,000	132
154,000	154

▼ Table 8-3.
Sizing Vertical Ducts into a Confined Space

Furnace Input (Btuh)	Free Area per Opening (Square Inches)	Round Pipe Diameter (Inches)
44,000	11.0	4
66,000	16.5	5
88,000	22.0	6
110,000	27.5	6
132,000	33.0	7
154,000	38.5	7

▼ Table 8-4.
Sizing Horizontal Ducts into a Confined Space

Furnace Input (Btuh)	Free Area per Opening (Square Inches)	Round Pipe Diameter (Inches)
44,000	22.0	6
66,000	33.5	7
88,000	44.0	8
110,000	55.0	9
132,000	66.0	10
154,000	77.0	10

Installing and Leveling the Furnace

Once a furnace is in position, it should be plumb and level within the specifications given in the installation instructions. Achieving the proper plumb and level is especially important with condensing furnaces because of the need for proper drainage of the condensate.

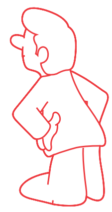
For a basement installation, it may be necessary to elevate the furnace on a pad or blocks to prevent corrosion. Seal the bottom opening of the furnace if it is not being used.

When installing a downflow furnace on a combustible floor, it must be mounted on a downflow subbase kit per the instructions provided with the kit.

Installing the Air Distribution System Ductwork

As part of the pre-installation survey, the correct sizes and dimensions of the ductwork should have been determined. Refer to Section 6 for guidelines pertaining to the installation of duct systems. Before installing any ductwork, the return air opening in the furnace should be cut or otherwise prepared. It is recommended that metal snips be used instead of a power tool. If power tools are used, cover the fan motor so metal chips do not get into the motor windings. ***BE CAREFUL WHEN WORKING AROUND SHARP METAL EDGES.***

CAUTION



If an evaporator (cooling coil) is being installed, the coil enclosure and coil should be mounted on the furnace. Following this, the plenum and supply ductwork can be installed. Before the return drop is hung and secured to the furnace, install any humidifier, electronic air cleaner, or external filter rack. After the ductwork is installed, make sure that the furnace is still level and plumb.

Installing Gas Piping

All gas piping must comply with local codes and the manufacturer's installation instructions. For information about cutting, threading, and assembling gas piping, refer to Section 5.

The size of the gas supply pipe for the furnace is determined by many factors *(Figure 8-32)*. For the purpose of sizing, a rule of thumb is to add about three equivalent feet of pipe for each fitting (elbow, tee, or valve) used in the run. The quantity of gas a furnace consumes, in cubic feet per hour (CFH), can be calculated by dividing the furnace's input capacity (Btuh) by the heating value of the gas as obtained from the local gas utility. The main gas supply pipe size is calculated by adding the flow of all gas-fired appliances in the building.

Once the quantity of gas and the length of the gas pipe run has been determined, find the pipe size using sizing tables in the gas code manual or installation instructions *(Figure 8-33)*. An example of its use for a furnace with an input of 132,000 Btuh is shown. Assume that the total piping length is 45 feet, including an allowance for fittings.

Figure 8-32.
Gas Piping Size

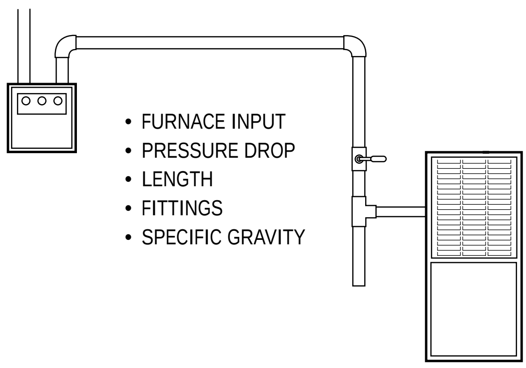


Figure 8-33.
Typical Gas Pipe Sizing Table Given in Manufacturer's Installation Instructions

Maximum Capacity of Pipe*

NOMINAL IRON PIPE SIZE (IN.)	INTERNAL DIAMETER (IN.)	LENGTH OF PIPE (FT)				
		10	20	30	40	50
1/2	0.622	175	120	97	82	73
3/4	0.824	360	250	200	170	151
1	1.049	680	465	375	320	285
1-1/4	1.380	1400	950	770	660	580
1-1/2	1.610	2100	1460	1180	990	900

* Cubic ft of gas per hr for gas pressures of 0.5 psig (14-in. wc) or less, and a pressure drop of 0.5-in. wc (based on a 0.60 specific gravity gas). Ref: Table 10-2 NFPA 54-1992.

First, the gas quantity in cubic feet per hour is calculated, assuming the heating value of the gas is 1,050 Btu/cu. ft. The gas quantity is:

CFH = 132,000 ÷ 1,050 = 125.7 cu. ft./hr.

Using the table, read across the top row for the pipe length. The 45-foot length would use the next higher length, 50 feet. Read down this column to the nearest gas quantity greater than 125.7 cu. ft./hr., which is 151 cu. ft./hr. In this example, the proper pipe size is 3/4 inch. The pipe size may vary, depending on the specific gravity and pressure drop in the pipe. Tables to allow for these factors are available in the code books.

The gas pipe should contain a manual shutoff valve, a drip leg to trap moisture and sediment, and a ground joint union *(Figure 8-34)*. The shutoff valve must be in a visible and accessible location so that it can be quickly and easily turned off in case of an emergency. The sediment trap prevents dirt or moisture from entering the gas controls. A bottom outlet cap allows for cleaning.

Support the gas piping at least every six feet. If propane is the fuel gas, use a joint compound (pipe dope) that is resistant to propane.

Once the gas piping is installed, turn the gas on and purge the line of air by loosening the union slightly until an odor of gas is noticed, then retighten it. Following this, check all joints for leaks with soapy water or a leak detecting solution.

Installing Power and Control Wiring

All wiring must comply with local codes and the manufacturer's installation instructions. For detailed guidelines on installing power and control circuit wiring, refer to Section 7.

Supply power to the furnace must use a ***dedicated*** line equipped with a correctly sized fuse or circuit breaker *(Figure 8-35)*, with a ***dedicated*** ground wire attached to the furnace ground and to the earth ground in the electrical panel. Establishing a good ground is essential to proper furnace operation. Failure to do so can result in several furnace operating problems. A disconnect switch should also be installed at the furnace. When the power wiring is completed, leave the power turned off until you are ready to start up and check out the furnace.

When installing the room thermostat and control wiring, always install at least four-conductor thermostat wire, even if installing the furnace in a heating-only system. Note that many thermostats use a 24V common wire, requiring that a five-conductor thermostat wire be installed. This will simplify the installation of air conditioning at a later date.

QUICK NOTE

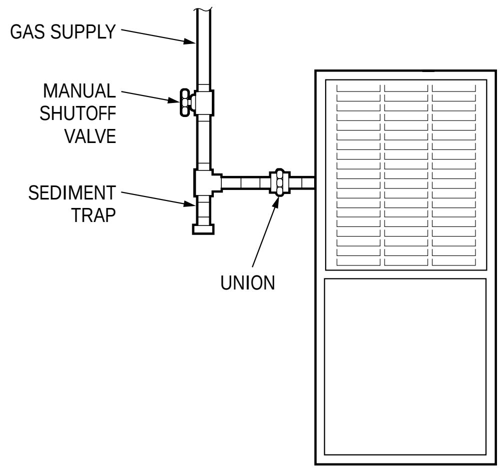
Calculating Gas Flow in Cubic Feet Per Hour (CFH):

$$CFH = \frac{Input\ (Btuh)}{Gas\ Heating\ Value\ (Btu/Cu.\ Ft.)}$$

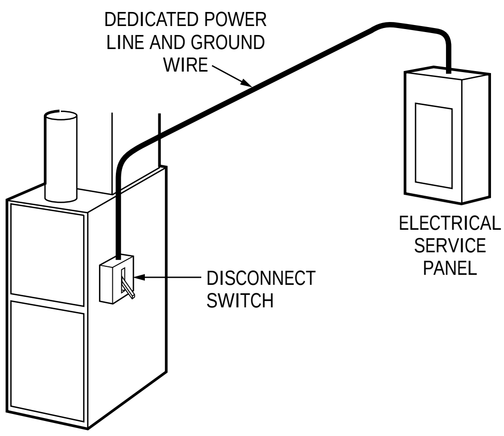
Where:

- Input (Btuh) = The furnace full-rated input heating capacity from its rating or nameplate.
- Gas Heating Value = Heating value of the gas as obtained from the local gas utility.

▼ Figure 8-34.
Typical Furnace Gas Piping



▼ Figure 8-35.
Installing Power to the Furnace



QUICK NOTE

When installing gas pipe:

- *Use the proper length of pipe and adequate support to avoid stress on the gas valve. Undue stress may cause a gas leak, resulting in a fire or personal injury.*
- If a flexible connector is required or allowed by code, black iron pipe must be installed at the gas valve and extend a minimum of two inches outside the furnace casing.
- Connect the gas pipe to the furnace using a backup wrench to avoid damaging the gas valve.

The installation of power and control wiring includes the wiring needed for accessories such as an electronic air cleaner or humidifier. These should be correctly wired per the instructions supplied with each accessory. They also must be wired to the correct terminals on the furnace's control board *(Figure 8-36)*.

Installing Venting

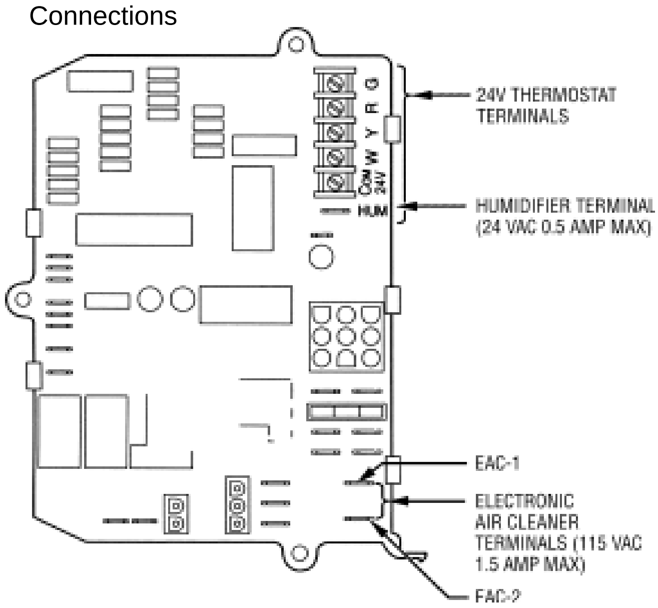
All venting must comply with local codes and the manufacturer's installation instructions. Furnace venting was covered in detail earlier in this section.

Installing Condensate Drains

The installation of a condensate drain is necessary for condensing furnaces, when a cooling coil is mounted on the furnace, or when a humidifier is installed *(Figure 8-37)*. All drain connections must be terminated into an open or vented drain. If that is impractical, a condensate pump and piping must be installed to pump the condensate into a suitable drain. Condensate pumps were covered earlier in this section. ***To ensure proper operation, the furnace condensate trap must be primed with water before operating the furnace.***

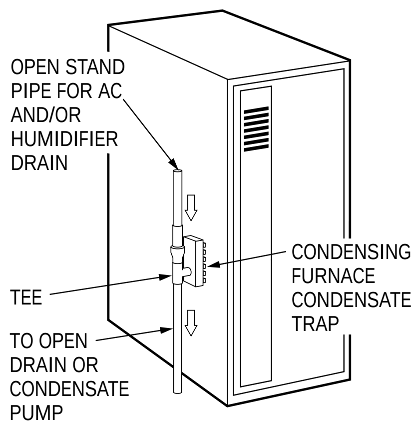
If a condensing furnace is installed in an attic, crawlspace, or other area where temperatures can drop below freezing, an accessory heat tape kit must be installed to prevent the condensate trap and drain line from freezing *(Figure 8-38)*. The heat tape kit is installed per the instructions supplied with the kit.

▼ Figure 8-36.
Typical Furnace Control Board Electrical Connections

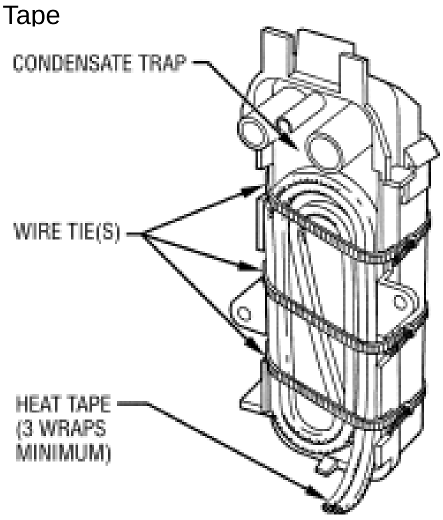


▼ Figure 8-37.
Typical Field Condensate Drain

CAUTION



▼ Figure 8-38.
Typical Condensate Trap Freeze Protection Using Heat Tape



Start-Up and Checkout

The furnace must always be started up and fully checked out per the installation instructions before the technician leaves the site.

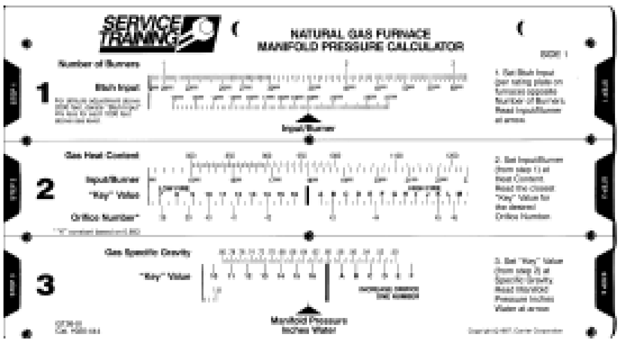
Normally, the start-up procedure begins by turning on power to the furnace and making general component and operational checks. If not previously accomplished, it also includes turning on the gas and purging the gas lines and priming the condensate trap with water (if applicable). While performing the various start-up tasks, the Gas Furnace Installation and Start-Up Checklist located on page 158 of this book should be used to check off each item when completed. Use of a checklist makes sure that an organized and consistent procedure is followed and that no area of the installation or checkout is overlooked.

After the initial start-up tasks have been performed, the gas input rate, temperature rise, and thermostat anticipator adjustments are made per the installation instructions. This is followed by a checkout of the safety controls. Guidelines for making the adjustments and safety checks are described here.

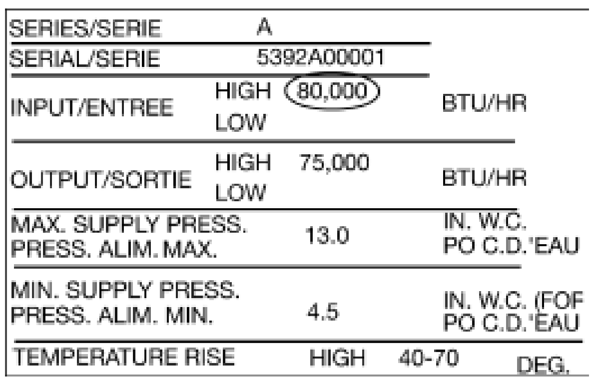
Adjusting Gas Input Rate – The burners must be fired at full input to prevent condensation in the primary heat exchanger and/or vent. The correct manifold pressure for full burner input can be found by following the procedure given in the installation instructions or by using a manifold pressure calculator *(Figure 8-39)*. Use of the manifold pressure calculator for installations below 2,000 feet above sea level greatly simplifies the procedure. For higher altitudes, follow the manufacturer's installation instructions. Instructions for using the manifold calculator are printed on the calculator. An example of its use follows.

1. From the local gas utility, get the yearly average heat content and specific gravity of the natural gas supplied in the area. In this example, assume a heat content of 1,120 Btu's per cubic foot and a specific gravity of .62.
2. Check the size of the orifices in the burner manifold and count the number of burners. In this example, #45 orifices are used with the four burners. Consult the furnace rating plate to find the total furnace input, which is 80,000 Btuh in this example *(Figure 8-40)*.
3. Using calculator Step 1, align the total furnace input of 80,000 with the four burners to obtain the input per burner of 20,000 *(Figure 8-41)*. Note that the calculator has two similar sides. Side 1 is used with furnaces having one to three burners. Side 2 is used with furnaces having four to eight burners.

▼ Figure 8-39.
Natural Gas Furnace Manifold Pressure Calculator

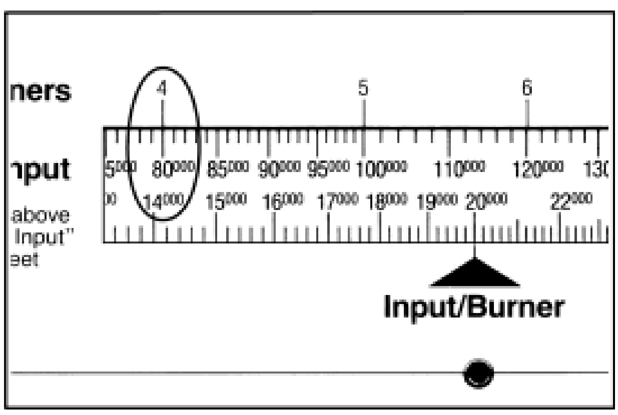


▼ Figure 8-40.
Find Total Input (Btuh) for Furnace on Rating Plate



SERIES/SERIE	A		
SERIAL/SERIE	5392A00001		
INPUT/ENTREE	HIGH	80,000	BTU/HR
	LOW		
OUTPUT/SORTIE	HIGH	75,000	BTU/HR
	LOW		
MAX. SUPPLY PRESS. PRESS. ALIM. MAX.		13.0	IN. W.C. PO C.D.'EAU
MIN. SUPPLY PRESS. PRESS. ALIM. MIN.		4.5	IN. W.C. (FOF PO C.D.'EAU
TEMPERATURE RISE	HIGH	40-70	DEG.

▼ Figure 8-41.
Example of Manifold Calculator, Step 1



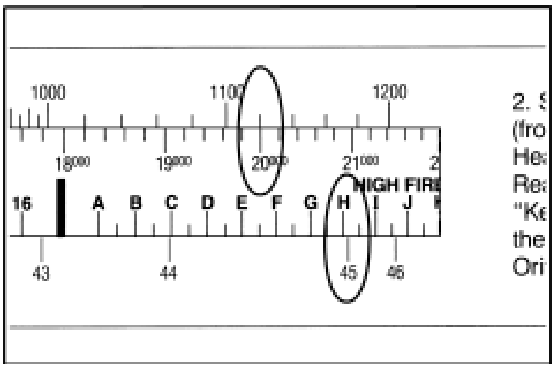
4. Using calculator Step 2, align the input per burner of 20,000 with the gas heat content of 1,120 *(Figure 8-42)*. Then find a key value that is nearest the #45 orifice. The key value in this example is H.
5. Using calculator Step 3, align the key value of H with the .62 specific gravity value *(Figure 8-43)*. This gives the correct manifold pressure, in inches of water, that will ensure that the burner is fired at its full input. In this example, the correct manifold pressure is 3.2 inches of water.

   If the calculator indicates a manifold pressure outside the range of 3.2 to 3.8 inches water column, the burner orifice size must be increased or decreased per the calculator. ***Do not redrill or peen burner orifices. Obtain the correct orifice from your distributer.***

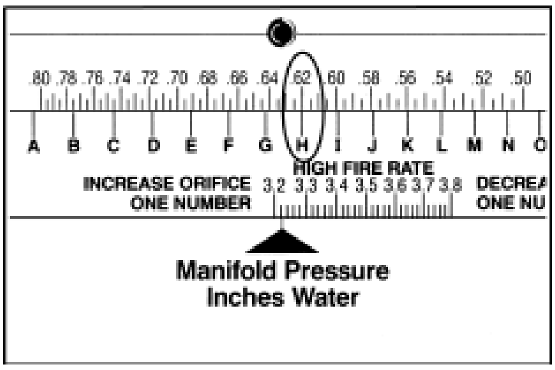
Once the required manifold pressure is calculated, the furnace manifold pressure must be adjusted to this value. This procedure involves connecting a manometer to the manifold pressure tap on the gas valve *(Figure 8-44)* or the manifold to measure the gas pressure. Following this, the furnace power is turned on and the burners fired. With the burners firing, the manifold pressure is measured and the gas valve regulator adjustment screw is set to obtain the required manifold pressure. ***Do not adjust for less than 3.2 in. w.c. or more than 3.8 in. w.c. for natural gas.***

Adjusting Temperature Rise – Temperature rise is the difference between the air temperature entering and leaving the furnace. The amount of temperature rise gives an indication of whether adequate air is flowing across the furnace heat exchanger. The correct temperature rise range for a furnace can be found on the furnace rating plate *(Figure 8-45)*. The correct amount of temperature rise is important in all furnaces. In condensing furnaces, if too much air passes over the heat exchangers, condensing can take place in the primary heat exchanger, causing corrosion and failure. In induced-draft furnaces, too much air can cause condensation in the heat exchanger and vent. If too little air passes over the heat exchangers, the resultant overheating may cause premature failure.

▼ Figure 8-42.
Example of Manifold Calculator, Step 2

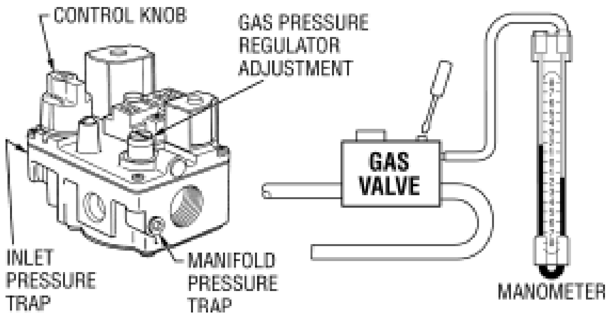


▼ Figure 8-43.
Example of Manifold Calculator, Step 3

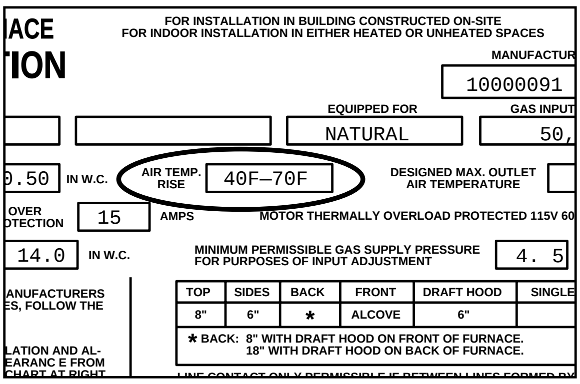


CAUTION

▼ Figure 8-44.
Measuring Manifold Pressure



▼ Figure 8-45.
Required Temperature Rise Range Shown on Furnace Rating Plate



QUICK NOTE

Before making temperature rise checks, make sure that the furnace is fired at its full input, the furnace air filter is clean, and all supply and return registers are open and unrestricted. If the furnace is equipped with a bypass humidifier, the damper in the bypass duct must be closed.

The procedure for measuring temperature rise is provided in the installation instructions. It is briefly outlined here and an example is shown in *Figure 8-46*.

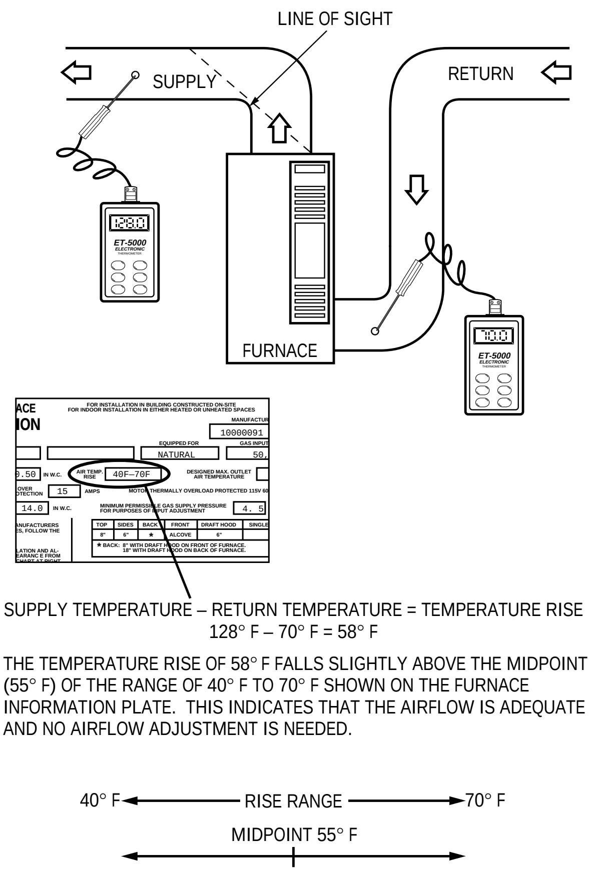
To measure temperature rise, drill a temperature measurement hole in the return duct near the furnace and another in the supply duct out of the line of sight of the heat exchangers. Then turn on the furnace and operate it for about ten minutes to allow the temperatures to stabilize.

Measure the supply and return air temperatures with an accurate thermometer, then calculate the temperature rise by subtracting the return air temperature from the supply air temperature. Ideally, the temperature should be slightly above the midpoint of the range shown on the furnace information plate. If the temperature rise is too low, decrease the blower speed to reduce the airflow; if too high, increase the blower speed to increase the airflow.

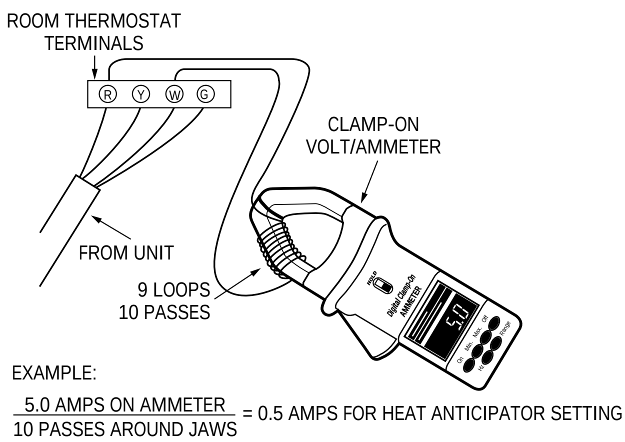
Adjusting the Thermostat Heat Anticipator – For all room thermostats, the heat anticipator or cycle rate setting must be adjusted correctly to prevent short cycling of the furnace. Short cycling prevents the furnace from coming up to operating temperature, causing condensation to occur in the heat exchanger and/or vent. Short cycling also contributes to poor indoor comfort. The procedure for anticipator adjustment is given in the installation instructions and briefly outlined here.

When properly adjusted, the thermostat heat anticipator is set to match the current draw of the primary control in the furnace. As shown in *Figure 8-47*, this is done by wrapping an insulated wire ten times around the jaws of a clamp-on ammeter, then connecting the leads to the thermostat R and W terminals. After furnace operation has stabilized, calculate the actual current draw by taking the meter reading (5 amps, *Figure 8-47*) and dividing it by ten for ten turns of wire. Based on this measurement, the heat anticipator adjustment would be set to 0.5 amps (5 amps ÷ 10 = 0.5 amps). If a microprocessor or electronic thermostat is being used, set the cycle rate at three per hour or per the thermostat manufacturer's instructions. Regardless of the type of thermostat used, at least two complete burner cycles should be witnessed to ensure proper operation before leaving the job.

▼ Figure 8-46.
Example of a Temperature Rise Measurement



▼ Figure 8-47.
Clamp-On Ammeter Connected for Thermostat Heat Anticipator Adjustment



Checking Safety Controls – Proper operation of the primary limit control, pressure switch, and any other safety controls must always be checked as directed in the installation instructions before leaving the job.

Primary Limit Switch – The main limit switch shuts off the burners if the furnace overheats because of a restricted air supply or blower motor failure. The operation of the limit switch can be checked with the furnace burners firing and blower operating by slowly restricting the return air *(Figure 8-48)* until the limit switch shuts off the burners. This confirms limit switch operation. As soon as the burners shut down, unblock the return air opening to permit normal operation.

Pressure Switch – The pressure switch "proves" the operation of the draft inducer fan. Its operation can easily be checked by disconnecting the sensor tube from the pressure switch *(Figure 8-49)* and setting the room thermostat to call for heat. There should be no burner operation.

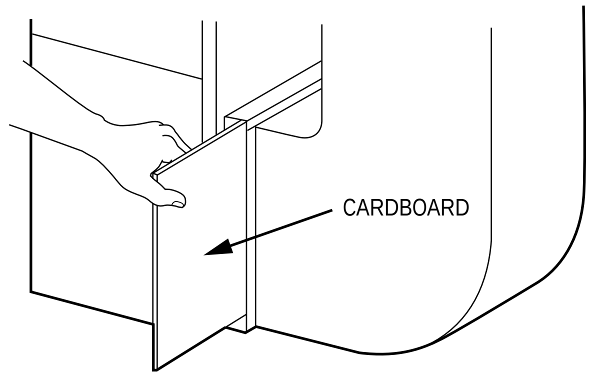
Final Checks, Adjustments, and Tasks

With the furnace operational, the following checks should be made to complete the installation.

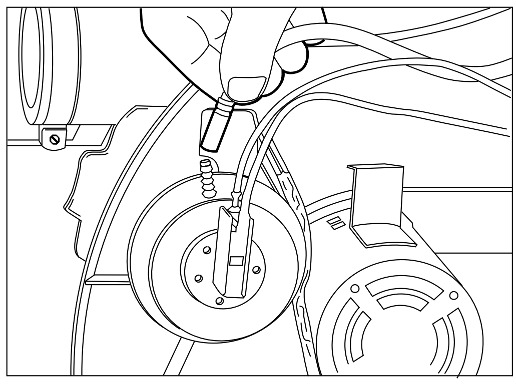
- Check all other functions of the room thermostat such as cooling operation and continuous blower operation.
- Check for correct operation of accessories such as an electronic air cleaner or humidifier, if installed.
- Check the furnace and ductwork for any unusual noises or vibration.
- Adjust the balancing dampers in each branch duct for correct operation.
- If applicable, light the pilot on the water heater and confirm that the water heater is operating. Confirm proper vent operation.
- Clean up the work area when done.

Before leaving the job, the installer should explain the operation of the complete comfort system to the customer *(Figure 8-50)*. Describe how the furnace operates and run the furnace through a complete cycle so the customer can see and hear the normally operating system. If installed, demonstrate air conditioning operation and operation of any accessories. After the demonstration, present the customer with the owner's operating and service manual(s). Fill out the warranty card and give it to the customer. Attach the dealer sticker to the furnace.

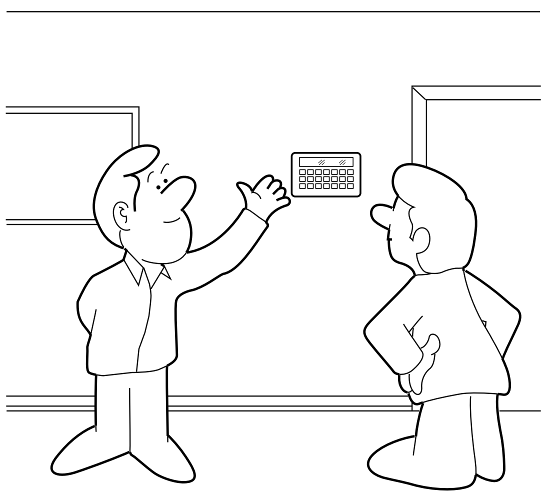
▼ Figure 8-48.
Slowly Restrict Return Air for Limit Switch Check



▼ Figure 8-49.
Disconnect Tube to Check Pressure Switch



▼ Figure 8-50.
Explain the Operation of the System to the Customer



SECTION 9
SPLIT SYSTEM INSTALLATION

INTRODUCTION

This section provides guidelines for the installation of split system air conditioning and/or heat pump systems and related accessories. It is not intended to teach refrigeration or air distribution theory; instead, it describes the different kinds of equipment used in split comfort systems and the methods used to install them. This section presumes that the proper type of equipment and related accessories have been selected and purchased by a qualified engineer or salesperson based on a survey of the job.

SPLIT SYSTEM MENU

SPLIT SYSTEMS AND COMPONENTS

Split systems are those in which the system's refrigeration components are housed in two or more separate and matched units, one located outdoors and the other indoors. There are two types of split systems: cooling systems and heat pumps.

Split Cooling Systems

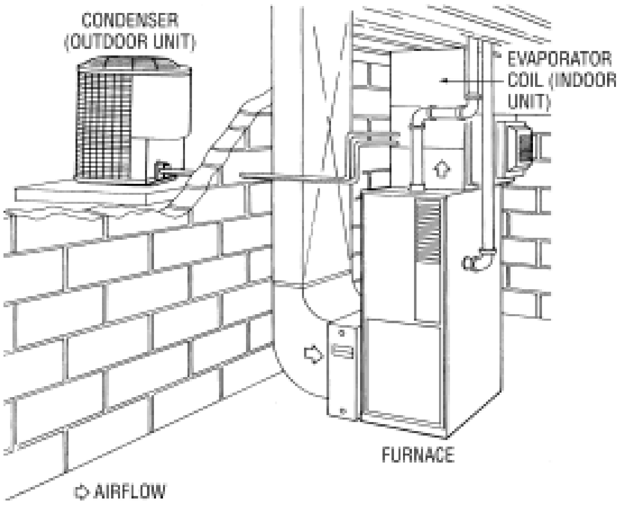
Split cooling systems provide cooling only. They consist of a condensing unit located outdoors and an evaporator coil located indoors. When functioning as part of a central air conditioning system where heating is provided by a furnace, the indoor evaporator coil is usually mounted in the furnace's supply air plenum *(Figure 9-1)*. The furnace's blower serves to circulate the cooled air through the system ductwork. In installations not involving a furnace, the evaporator coil is mounted within an air handler (fan coil) for the cooling system. Fan coil units are covered later in this section.

Figure 9-2 shows the basic components used in a split system air conditioner. The outdoor condensing unit consists of the compressor, condensing coil, fan, and controls. The compressor creates the pressure difference needed to make the refrigerant flow. The condensing coil is a heat exchanger that transfers the heat absorbed by the refrigerant flowing through the indoor evaporator coil to the cooler outdoor air.

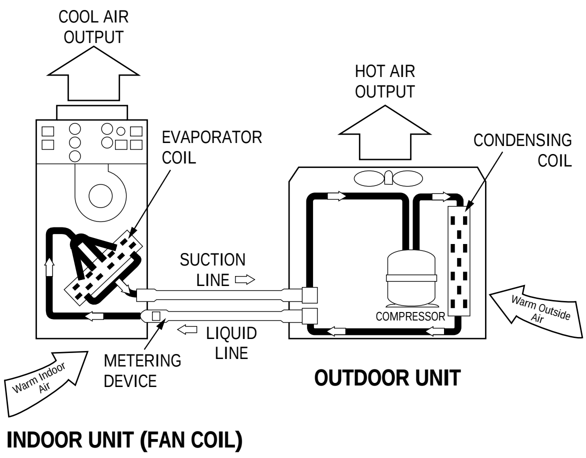
The indoor fan coil unit contains the evaporator coil and metering device. The evaporator coil is a heat exchanger in which the heat from the indoors is transferred to and absorbed by the refrigerant flowing through the coil. The metering device provides a pressure drop that lowers the boiling point of the refrigerant just before it enters the evaporator.

A line set consisting of suction and liquid refrigerant lines connects the outdoor unit to the indoor unit. The suction line carries heat-laden refrigerant gas flowing from the evaporator coil to the compressor in the outdoor unit. The liquid line carries liquid refrigerant, formed in the condenser of the outdoor unit, to the expansion device in the indoor unit.

▼ Figure 9-1.
Typical Split Cooling System with Indoor Evaporator Coil Mounted on a Furnace



▼ Figure 9-2.
Basic Split Cooling System



The size or capacity of a split cooling system is measured by the amount of cool air that it puts out in Btu's per hour (Btuh), often expressed in *tons*. The number of tons of capacity can be calculated by dividing the unit's Btuh rating by 12,000. For example, an output of 36,000 Btuh is equal to three tons (36,000 ÷ 12,000 = 3). The efficiency of a split system is rated in terms of its seasonal energy efficiency ratio (SEER). This rating is expressed as a number. The higher the number, the higher the efficiency. Capacity and efficiency information for the different units can be found in the manufacturer's product literature.

Split Heat Pump Systems

Split heat pump systems can provide both heating and cooling by reversing the flow of refrigerant in the system.

The outdoor and indoor units of a split heat pump system look similar to the units used with a split cooling system, but contain additional components because the system performs a dual role.

As shown in *Figure 9-3*, the split heat pump operates the same way in the cooling mode as a split cooling system. For cooling, the outdoor coil discharges heated air and the indoor coil discharges cooled and dehumidified air. In the heating mode, the direction of refrigerant flow and the functions of the coils in the indoor and outdoor units are reversed by the action of the reversing valve *(Figure 9-4)*. *Reverse cycle heat* is the term used for heat pump heating. The indoor coil becomes the condensing coil and the outdoor coil becomes the evaporator coil. This allows the outdoor coil to absorb heat from the outside air and transfer this heat via the indoor coil to the indoors.

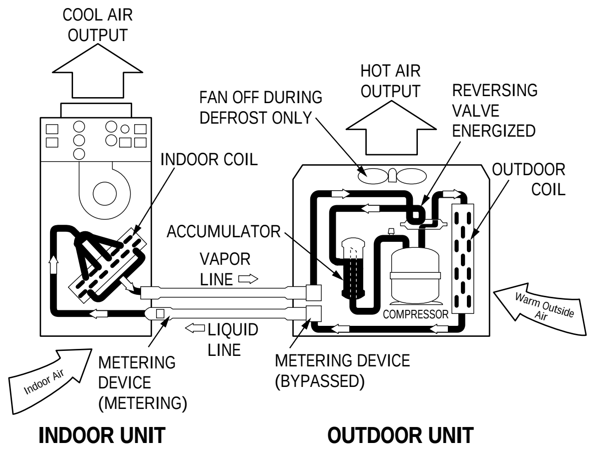
The line set consisting of vapor and liquid refrigerant lines connects the outdoor unit to the indoor unit. The vapor line carries superheated refrigerant gas from the indoor coil to the compressor during the cooling cycle and the hot gas discharged from the compressor to the indoor coil in the heating cycle. The liquid line carries liquid refrigerant between the units during both cycles of operation.

Indoor Evaporator Coil Units

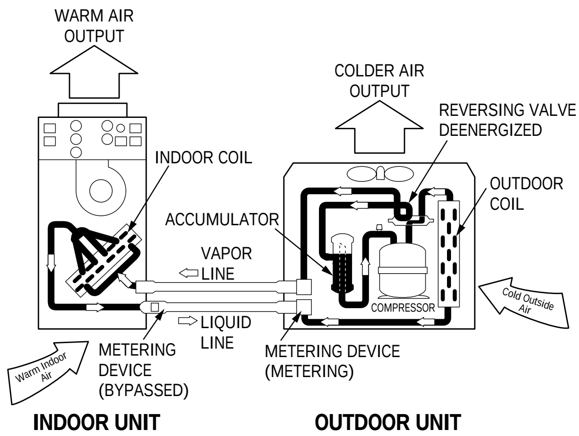
The indoor evaporator coil used in a split cooling system is typically mounted on a furnace in its own case or in the field-fabricated supply air plenum. If a cased coil is used, the plenum attaches directly to the discharge end of the cabinet. There are several types of coils. The "A" coil has two coil slabs connected together in a "A" arrangement *(Figure 9-5)* with a drip pan under each slab and a common condensate drain line. A variation of the "A" coil, called an *"N" coil*, provides more coil surface than is possible with an "A" coil. Slant coils are single coils mounted at an angle. Both the "A"-type and slant coils are commonly used in upflow or downflow applications. A horizontal coil is a vertical coil positioned for horizontal airflow applications. A condensate drain must be provided for all types of coils to remove the condensate water from the drip pan.

The indoor evaporator coil must match the outdoor condensing unit in order to produce the rated capacity and efficiency of the system. Also, the furnace blower or fan in the fan coil must be able to deliver the required CFM against the external static pressure of the coil, filter, and air distribution system. Depending on the type of coil and/or system, one of two types of metering devices can be used: a thermal expansion valve (TXV), or a fixed-orifice device *(Figure 9-6)*.

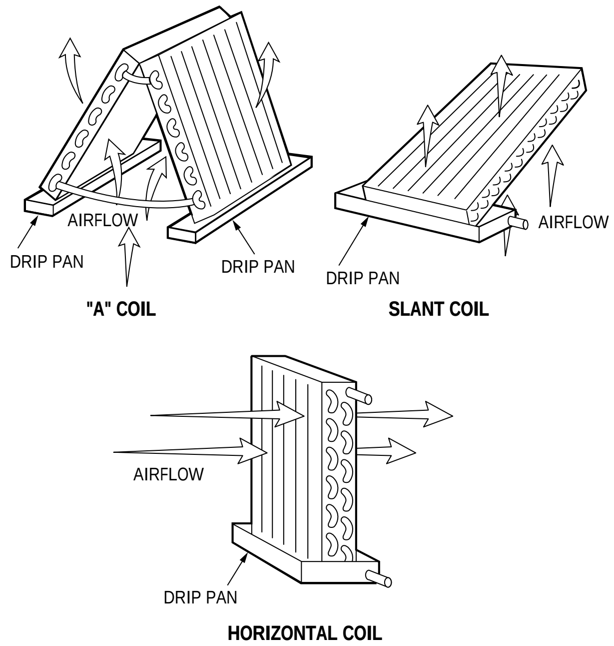
▼ Figure 9-3.
Basic Heat Pump Split System – Cooling Operation



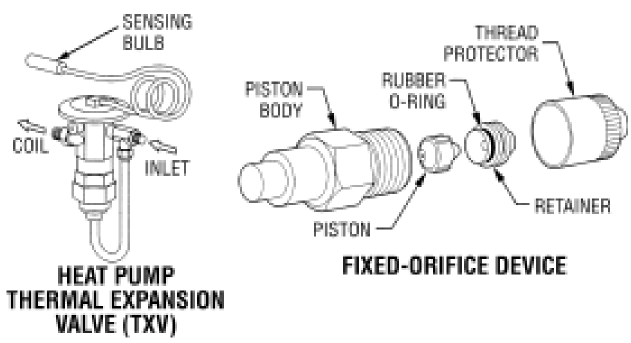
▼ Figure 9-4.
Basic Heat Pump Split System – Heating Mode Operation



▼ Figure 9-5.
Indoor Coil Units



▼ Figure 9-6.
Metering Devices



In a split heat pump system, the indoor coil can be mounted in a fan coil, or it can be mounted on a gas- or oil-fired furnace in the same manner as done in some split cooling systems. The indoor coil must have the capacity and physical size to function both as an evaporator and condensing coil, depending on the operating mode.

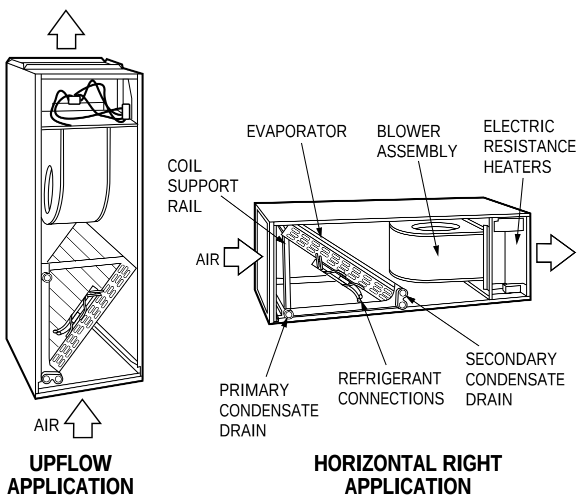
Fan Coil Units

A fan coil unit *(Figure 9-7)* can be used as the indoor unit in both split cooling and split heat pump systems. It consists of the indoor coil, metering device, blower, and may also include electric resistance heater elements used to supply supplemental heat. The blower draws the air from the return air duct system through the coil, then blows it through the electric resistance heaters, discharging the air into the supply duct system.

Fan coils can be used in upflow, downflow, or horizontal applications. Fan coils are selected to match the outdoor condensing or heat pump unit to produce the required capacity and efficiency. The fan coil blower must be able to deliver the required CFM against the external static pressure of the coil, filter, and air distribution system.

In hot, dry climates, an oversized evaporator is sometimes used in cooling systems. This is called *mix-matching*.

▼Figure 9-7.
Typical Fan Coil

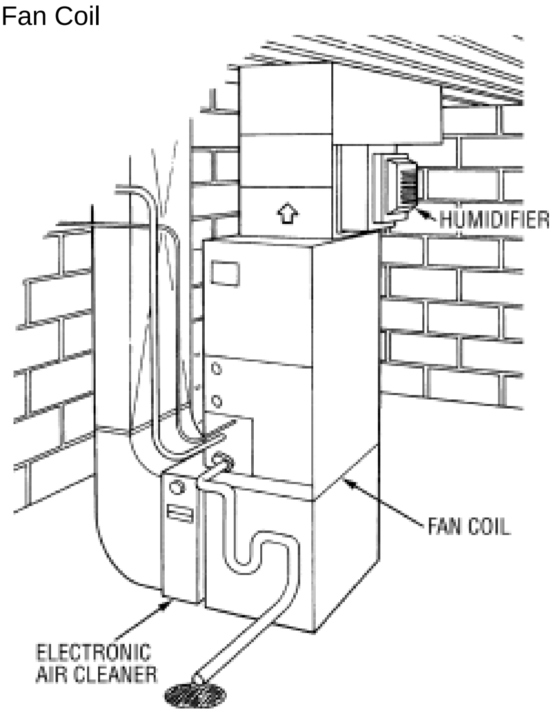


ACCESSORIES

There are many accessories that can be used to enhance the operation of split systems. Some of the more common ones are briefly described here. All such accessories should be installed per the manufacturer's installation instructions.

Humidifiers *(Figure 9-8)*, electronic air cleaners, and condensate pumps are commonly used with the indoor fan coil unit in both split cooling and heat pump systems. These accessories are described in detail in Section 8 of this book. Other accessories used with indoor units are described in the paragraphs that follow.

▼Figure 9-8.
Humidifier and Electronic Air Cleaner Used with a Fan Coil



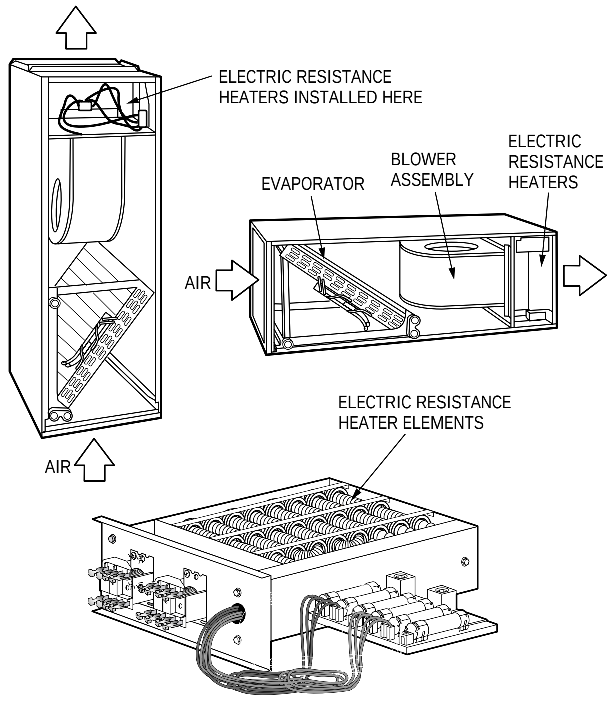
Accessories Used with Indoor Units

Electric Heaters – Accessory electric heaters *(Figure 9-9)* are used to provide additional stages of heat (supplemental heat) in split heat pump systems or to provide the primary source of heat in split cooling systems. They come in a range of sizes and are available with fuses or with circuit breaker protection. Normally, heater assemblies are fully wired and ready for installation in a fan coil unit.

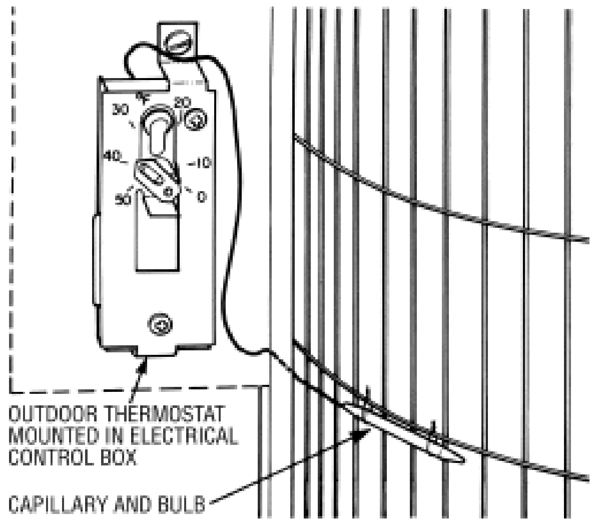
Most heat pump systems with supplemental heat use a one-stage cool, two-stage heat type of thermostat. When cooling is required, the single-stage cooling provides indoor space control. Heating operation is more complex. On a call for heat, the first stage allows the compressor to operate. If the building's heat loss is greater than the unit's capacity and compression heat cannot satisfy the demand, stage two will automatically energize the supplemental resistance heaters either directly or in accordance with outdoor thermostat settings.

The number of outdoor thermostats used to control successive stages of supplemental heat is determined by how the manufacturer has divided the heater element packages into controllable sections or stages. One stage should use one outdoor thermostat, two stages should use two thermostats, etc. The outdoor thermostat *(Figure 9-10)* opens on a rise in temperature. It has an extended bulb with a capillary tube to sense outdoor temperatures. The setting can be adjusted to any desired setpoint within the range of approximately 0° F to 50° F by turning a dial. Room thermostats used with heat pumps normally have a supplementary heat switch. In the event of a compressor failure, this switch can be used to bypass any outdoor thermostats, allowing the electric heaters to provide heat.

▼ Figure 9-9.
Electric Heating Elements Used in a Fan Coil Unit



▼ Figure 9-10.
Typical Outdoor Thermostat



Blower-Off Delay Relay – A blower-off delay relay allows the indoor blower motor to operate for a brief period after the compressor cycles off to capture the residual cooling capacity of the coil.

Accessories Used with Outdoor Units

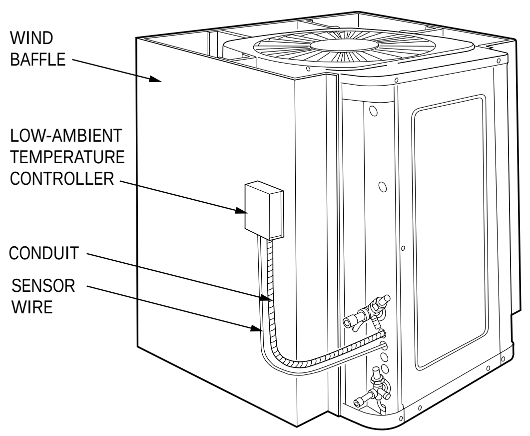
The accessories described below can be used with condensing units or heat pump outdoor units. These accessories can be either factory or field installed.

Low-Ambient Temperature Controller – A low-ambient temperature controller is a head pressure control device that is activated by a temperature sensor. It is typically used on light commercial cooling or heat pump systems that need to operate in the cooling mode at outdoor temperatures below 55° F. It controls the outdoor fan motor speed in response to the saturated condensing temperature to maintain the proper condensing temperature at any ambient temperature, typically down to -20° F.

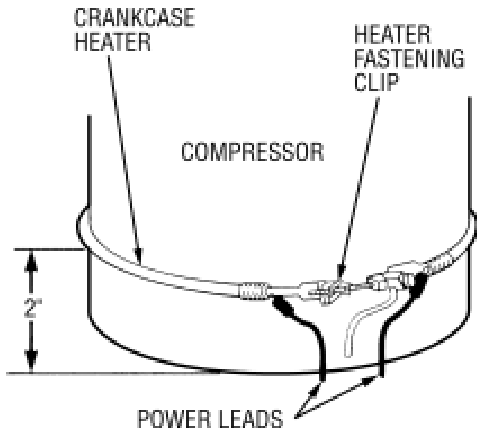
The control *(Figure 9-11)* is mounted on the outside of the unit and a sensor is mounted inside the unit on a return bend on the outdoor coil. The sensor is connected to the circuit board in the control box. In *Figure 9-11*, the control box is shown mounted on the outside of a wind baffle attached to the unit. Wind baffles are also an accessory that should be used in locations with high prevailing winds and where outdoor temperatures of less than 0° F can occur during unit operation. The wind baffle prevents cross currents from causing erratic controller operation. Wind baffles are also used on heat pumps to prevent the wind from retarding defrost.

Crankcase Heaters – Crankcase heaters *(Figure 9-12* and CH, *Figure 9-13)* warm the compressor crankcase during the off cycle to reduce refrigerant migration and ensure proper compressor lubrication.

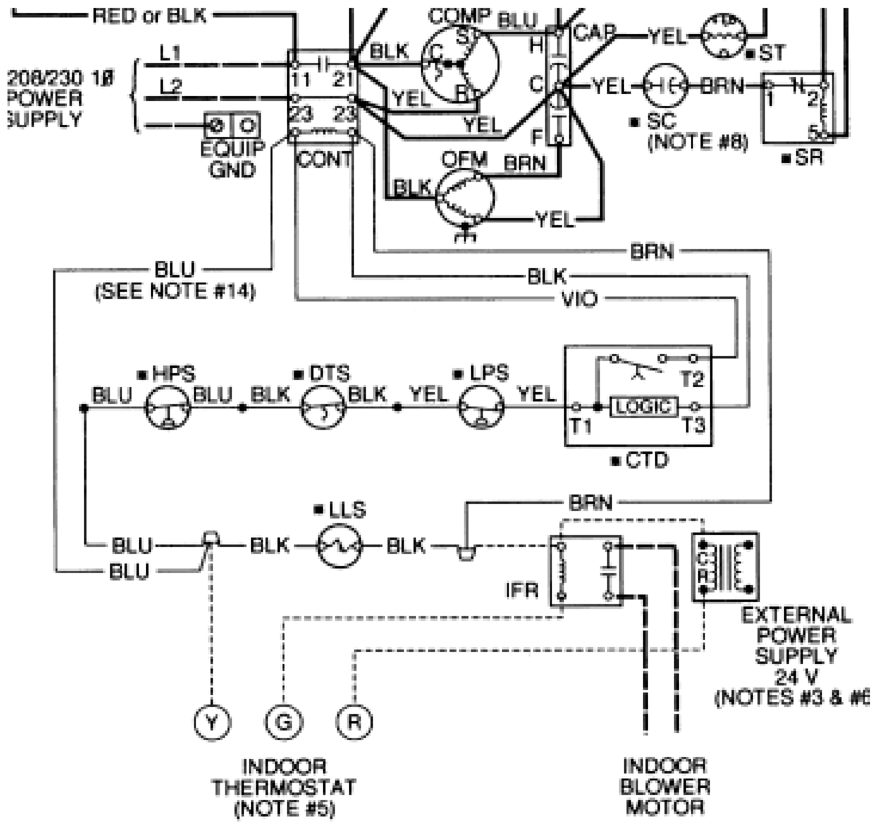
▼ Figure 9-11.
Low-Ambient Temperature Controller



▼ Figure 9-12.
Typical Crankcase Heater



▼ Figure 9-13.
Typical Air Conditioning (Condensing) Unit Wiring Diagram Showing Wiring of Accessories



- LEGEND -

——	FACTORY POWER WIRING
——	FACTORY CONTROL WIRING
-----	FIELD CONTROL WIRING
•——	FIELD POWER WIRING
o	COMPONENT CONNECTION
	FIELD SPLICE
	JUNCTION
ONT	CONTACTOR
AP	CAPACITOR (DUAL RUN)
CH	CRANKCASE HEATER
OMP	COMPRESSOR
CTD	COMPRESSOR TIME DELAY
DTS	DISCHARGE TEMP. SWITCH
HPS	HIGH PRESSURE SWITCH
IFR	INDOOR FAN RELAY
LLS	LIQ. LINE SOLENOID VALVE
LPS	LOW PRESSURE SWITCH
FM	OUTDOOR FAN MOTOR
▪SC	START CAPACITOR
▪SR	START RELAY
▪ST	START THERMISTOR

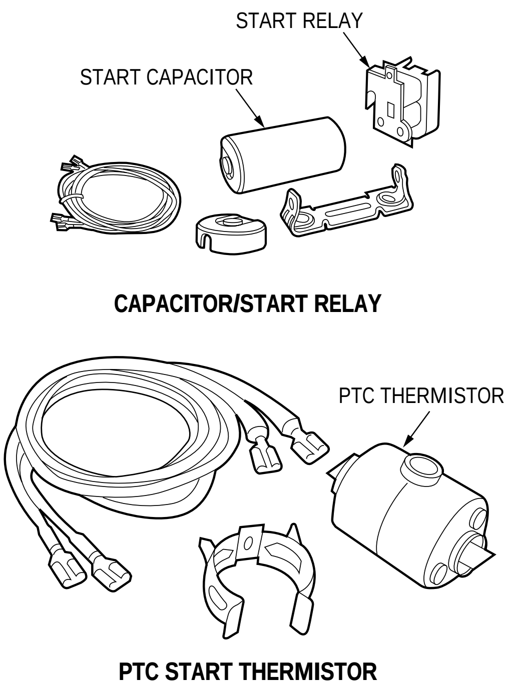
▪ MAY BE FACTORY OR FIELD INSTALLED

NOTES:

1. SYMBOLS ARE ELECTRICAL REPRESENTATIONS ONLY.
2. COMPRESSOR AND FAN MOTOR FURNISH WITH INHERENT THERMAL PROTECTION.
3. TO BE WIRED IN ACCORDANCE WITH NATIONAL ELECTRIC N.E.C. CODE AND LOCAL CODES.
4. N.E.C. CLASS 2, 24 V CIRCUIT, MIN. 40 VA REQUIRED, 60 VA ON UNITS INSTALLED WITH LLS.
5. USE COPPER CONDUCTORS ONLY.
6. CONNECTION FOR TYPICAL COOLING ON THERMOSTAT. FOR OTHER ARRANGEMEN SEE INSTALLATION INSTRUCTIONS.
7. IF INDOOR SECTION HAS A TRANSFORME WITH A GROUNDED SECONDARY, CONNE THE GROUNDED SIDE TO THE BRN LEAD.
8. WHEN START RELAY AND START CAPACITOR ARE INSTALLED, START THERMISTOR IS NOT USED.
9. CH NOT USED ON ALL UNITS.
10. IF ANY OF THE ORIGINAL WIRE, AS SUPPLIED, MUST BE REPLACED, USE THI SAME OR EQUIVALENT WIRE.
11. CHECK ALL ELECTRICAL CONNECTIONS INSIDE CONTROL BOX FOR TIGHTNESS.
12. DO NOT ATTEMPT TO OPERATE UNIT UN SERVICE VALVES HAVE BEEN OPENED.
13. DO NOT RAPID CYCLE COMPRESSOR. COMPRESSOR MUST BE OFF 3 MINUTES ALLOW PRESSURES TO EQUALIZE

Compressor Start Assist Kits – Compressor start assist kits *(Figure 9-14)* are used to give permanent split capacitor (PSC) reciprocating compressors a boost at start-up. There are two types of kits: a hard start kit, which consists of a start capacitor and a start relay (SC and SR, *Figure 9-13*) and a positive temperature coefficient (PTC) start thermistor (ST, *Figure 9-13*). One or the other device can be used but not both. Either device may be factory installed or can be field installed to correct a starting problem. The addition of certain field-installed accessories or certain installation applications may require that a start kit be field installed. Chronic low supply voltage conditions or unexplained compressor tripouts may indicate the need for a start kit.

▼ Figure 9-14.
Compressor Start Assist Kits



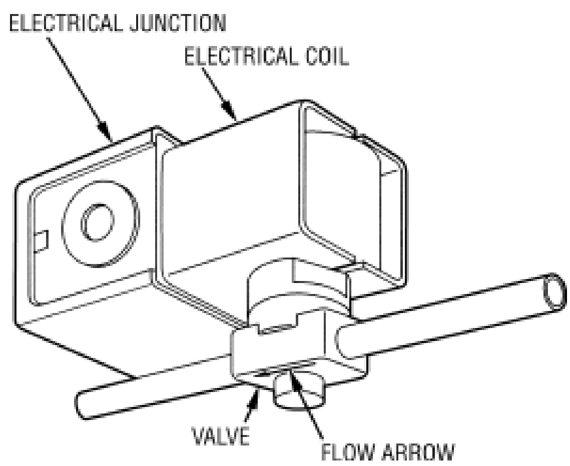
Compressor Short Cycle Protector – A compressor time delay (CTD, *Figure 9-13*) is used to prevent compressor short cycling. It provides an approximate five-minute delay after control power (24 volts) to the compressor contactor has been interrupted for any reason, including normal cycling. This device may be either field or factory wired.

Low-Pressure and High-Pressure Switches – Low-pressure and high-pressure switches prevent system operation if abnormal pressure conditions are present. The low-pressure switch (LPS, *Figure 9-13*) is an auto-reset switch activated by a drop in refrigerant pressure on the low side of the refrigerant circuit. If the pressure drops below the setpoint, it turns the compressor off.

The high-pressure switch (HPS, *Figure 9-13*) is an auto-reset switch activated by an increase in refrigerant pressure on the high side of the refrigerant circuit. If the pressure rises above the setpoint, it turns the compressor off.

Liquid Solenoid Valve – The liquid solenoid valve *(Figure 9-15* and LLS, *Figure 9-13)* is an electrically operated shutoff valve normally installed in long-line applications to increase efficiency. It controls liquid refrigerant flow when the compressor is turned off and on. It prevents liquid refrigerant migration and maintains a column of liquid refrigerant for the next compressor on cycle.

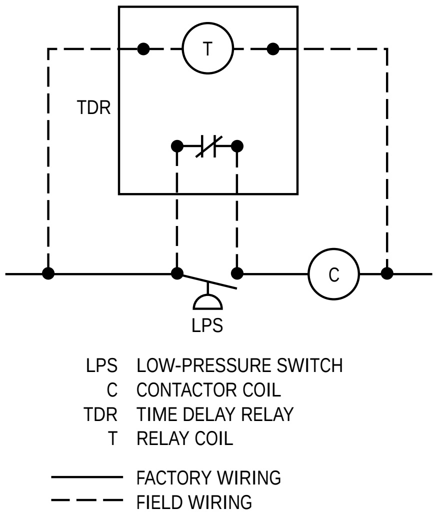
▼ Figure 9-15.
Typical Liquid Solenoid Valve



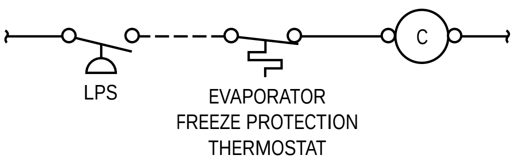
Winter Start Control and Time Delay Relay Kits – The winter start kit *(Figure 9-16)* is a time delay relay that bypasses the low-pressure switch in the outdoor unit for about three minutes to permit start-up and cooling operation under low load conditions. It should be used in all units that have a low-pressure switch and/or a low-ambient controller. The time delay relay is wired across the low-pressure switch.

Evaporator Freeze Protection Thermostat – The evaporator freeze protection thermostat stops unit operation if the evaporator or indoor coil temperature drops below a certain point. This prevents the coil from freezing up. The temperature sensing bulb is mounted on the suction/vapor line near the coil. Its contacts are wired in series with the contactor coil *(Figure 9-17)*.

▼ Figure 9-16.
Winter Start Kit Wiring



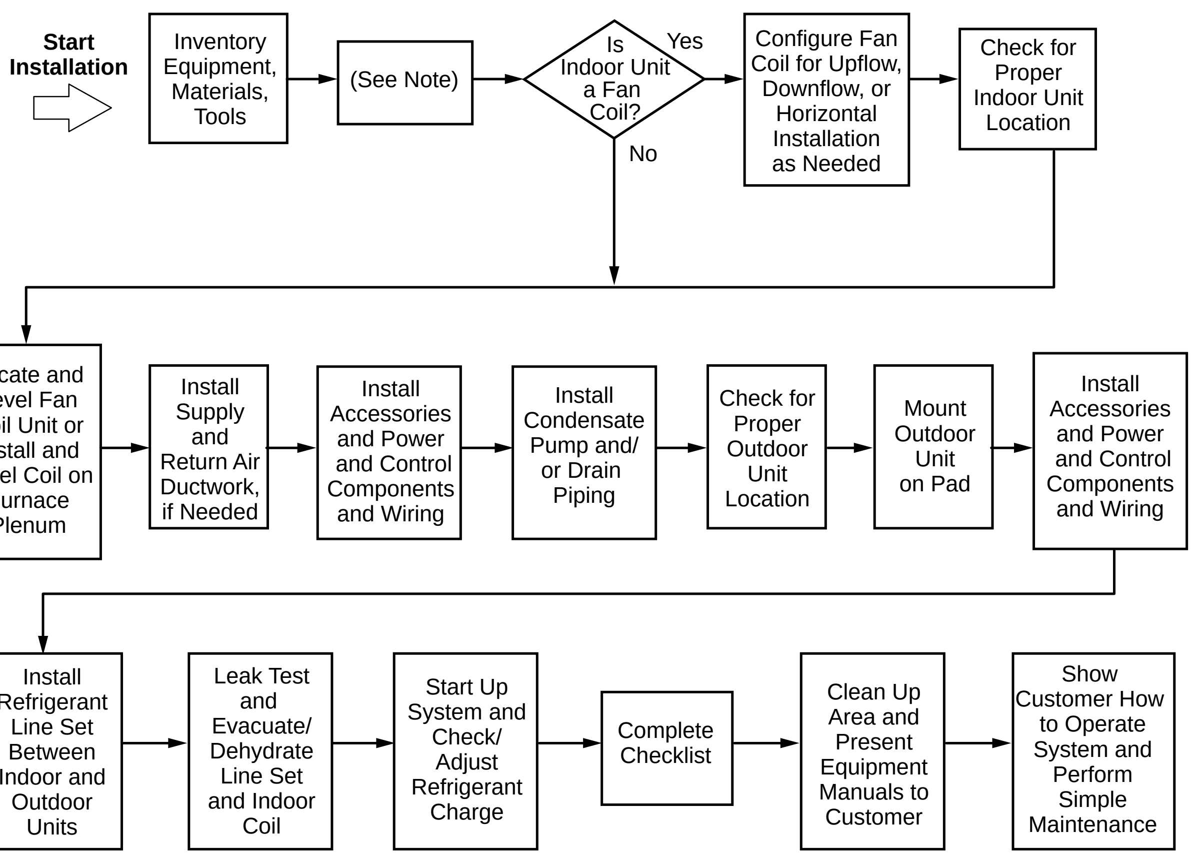
▼ Figure 9-17.
Evaporator Freeze Protection Thermostat Wiring



SPLIT SYSTEM INSTALLATION GUIDELINES

The methods for installing split cooling and split heat pump systems are basically the same. The installation of any system components must always be done as directed in the manufacturer's installation instructions and it must comply with the codes and installation practices of the area where it is to be installed. The installation tasks and the general sequence in which they are performed are shown in *Figure 9-18*. A detailed list of required materials and a simple drawing showing the intended installation should be provided to the installer. Make sure all the required parts and tools are available before leaving for the job site. If installing a convertible fan coil unit in a configuration other than that shipped from the factory, reconfigure the fan coil per the installation instructions.

▼ Figure 9-18.
Split System Installation – Tasks and Sequence



Note: This sequence installs the indoor unit first, followed by the installation of the outdoor unit. If desired, the sequence can be reversed.

Installing the Indoor Equipment

Installing Evaporator/Indoor Coils – Evaporator/indoor coils are made in both cased and uncased versions. Evaporator coils are normally installed on a fossil fuel heating furnace *(Figure 9-19)* as part of an add-on air conditioning or add-on heat pump installation. Add-on heat pumps are usually done to convert a conventional fossil fuel heating system into a dual-fuel heating system. Regardless of the use, the coil installation procedure is basically the same.

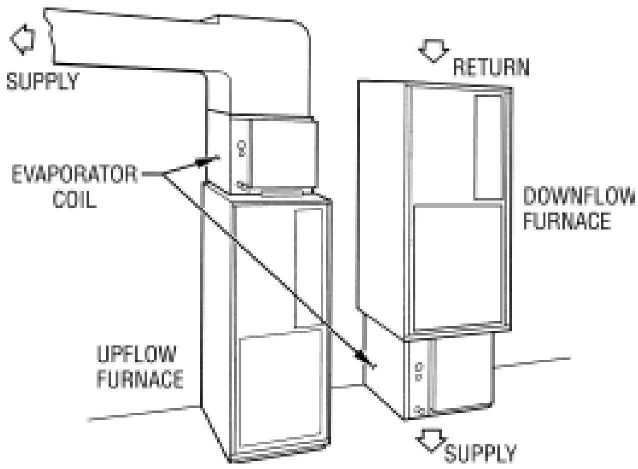
Installing Uncased Coils – Uncased coils are normally installed in the supply air plenum of an existing furnace. General guidelines for their installation are given here.

1. Shut off furnace power. Remove the vent connector pipe for better access to the furnace plenum, if required.
2. Lay out the pattern on the supply air plenum for the coil access opening *(Figure 9-20)*. Refer to the coil installation instructions for the specific width, height, and mounting dimension requirements.
3. Use aviation shears to cut the opening in the plenum. ***BE CAREFUL AROUND THE SHARP METAL EDGES.***

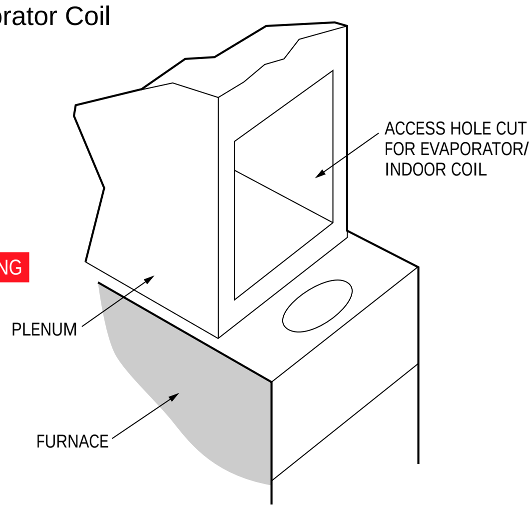
WARNING

4. Attach support rails or rods to the inside of the plenum to support the coil per the installation instructions. Fabricate sheet metal baffles *(Figure 9-21)* and install them inside the plenum against the sides. Configure the baffles and support rails so that when the coil is inserted, the piping connections are flush against the coil cover panel and all of the air will be forced through the coil.
5. Slide the coil through the hole in the plenum and onto the support rails until it is completely inside the supply air plenum. Make sure the coil is level for proper condensate drainage.
6. Carefully measure the location of the coil's refrigerant connections and condensate drain. Make a cover plate out of sheet metal with holes cut for the refrigerant and condensate lines *(Figure 9-22)*. Install the cover plate on the plenum and fasten it in place using sheet metal screws.
7. In high humidity areas, to prevent the possibility of the plenum "sweating" and water dripping onto the furnace, it may be necessary to wrap the outside of the plenum with insulation and a vapor barrier. Tape all joints.
8. The coil installation is complete except for installing the condensate drain piping and the refrigerant piping. These tasks are covered later in this section.

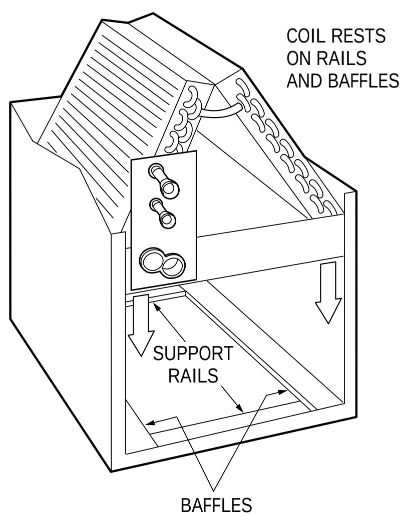
▼ Figure 9-19.
Evaporator Coil Installed on a Furnace



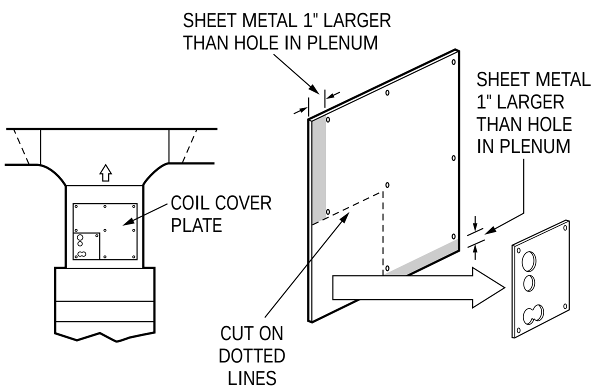
▼ Figure 9-20.
Access Hole Cut in Plenum for Uncased Evaporator Coil



▼ Figure 9-21.
Support Rails and Sheet Metal Baffles



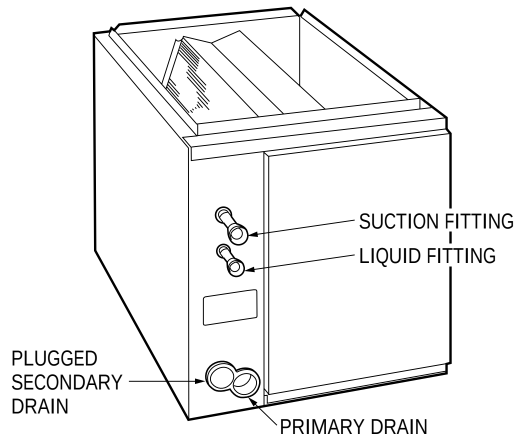
▼ Figure 9-22.
Coil Cover Plate



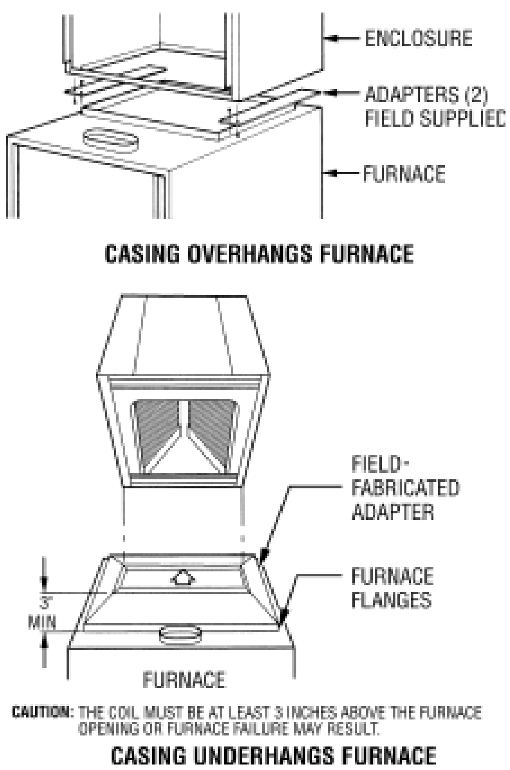
Installing Cased Coils – Cased coils *(Figure 9-23)* are often used when the coil is being installed along with a new furnace. General guidelines for the installation of a cased coil are given here.

1. Cased coils are designed to fit most furnaces. If the furnace width is such that the casing overhangs or underhangs the furnace opening, make and install sheet metal adapters *(Figure 9-24)* per the installation instructions to correctly fit the coil case to the furnace.
2. Set the cased coil in place on the furnace discharge air opening. Make sure it is level for proper condensate drainage. Normally, the coil does not need to be fastened to the furnace.
3. Install the supply air plenum and ductwork. Refer to Section 6 for guidelines pertaining to the installation of duct systems.
4. To prevent the possibility of the plenum "sweating" and water dripping onto the furnace, it may be necessary to wrap the outside of the plenum with insulation and a vapor barrier. Tape all joints.
5. Installing a cased coil on a downflow furnace is similar, except the furnace sits on top of the cased coil and air is discharged down through the coil *(Figure 9-25)*. In many downflow installations, a drip eliminator kit may be required. This kit ensures that the condensate is directed down and into the drip pan.
6. The coil installation is complete except for installing the condensate drain piping and refrigerant lines. These tasks are covered later in this section.

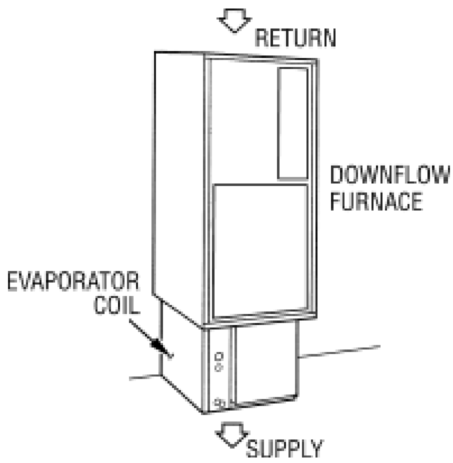
▼ Figure 9-23.
Typical Cased Coil



▼ Figure 9-24.
Adapters Used when Coil Casing Overhangs or Underhangs the Furnace



▼ Figure 9-25.
Cased Coil Installed on a Downflow Furnace



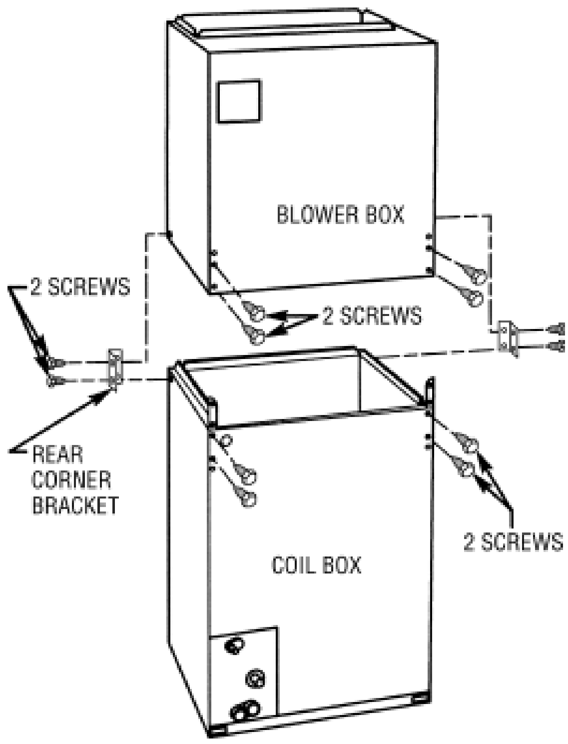
Installing a Fan Coil Unit – Fan coils can be used in upflow, downflow, or horizontal applications. Normally they are shipped from the factory set up for either upflow or horizontal-left installation, but can easily be modified for downflow or horizontal-right installations. For access into attics or crawlspaces, modular units can usually be disassembled into the coil box and blower box components *(Figure 9-26)*.

Locating the Fan Coil – When possible, centrally locate the fan coil in the building at a location that allows the air ducts and refrigerant lines to be as short as possible.

Avoid installation above, below, or next to a bedroom or other area where mechanical noise is unacceptable. Access for service, appearance, and risk of damage to the unit are other important considerations.

Installing and Leveling the Fan Coil – Suspended fan coil units should be mounted using proper rubber or spring vibration-eliminating hangers to prevent the transmission of noise through the building structure. The fan coil should be plumb and level for proper condensate drainage. For a basement installation, it may be necessary to elevate the fan coil on a pad or blocks to prevent corrosion. When a downflow unit with electric heaters is installed on a combustible floor, it may need to be mounted on a fireproof downflow base kit per the instructions provided with the kit.

▼ Figure 9-26.
Typical Modular Fan Coil Disassembled for Moving through Limited Openings



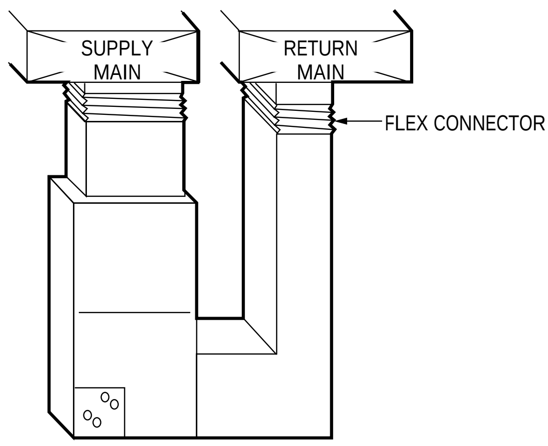
Installing Air Distribution System Ductwork to the Fan Coil – As part of the pre-installation survey, the correct sizes of the various pieces of ductwork should have been determined. Refer to Section 6 for general guidelines pertaining to the installation of duct systems.

If required, cut or otherwise prepare an opening on the appropriate side of the fan coil unit for the return air duct. Place the supply air duct over the flanges on the fan coil unit supply air opening and fasten with sheet metal screws. Before the return duct is hung and secured to the fan coil, install the humidifier, electronic air cleaner (EAC), and/or external filter rack, if used.

Use flexible, heat-resistant connectors between the ductwork and the unit to prevent transmission of unit vibration *(Figure 9-27)*. Make sure to maintain the distance between the discharge plenum/ductwork and combustible materials as specified in the installation instructions.

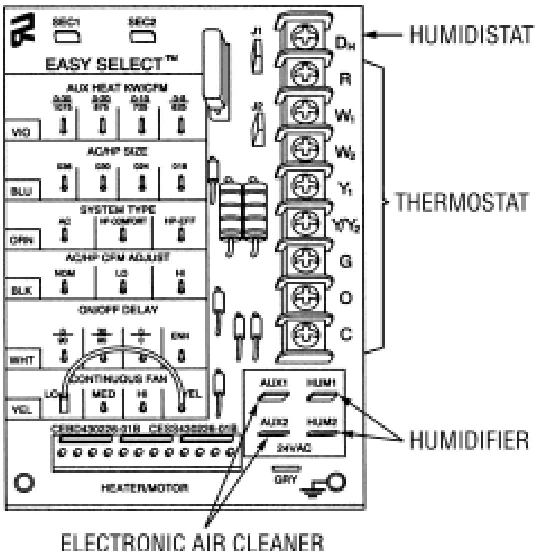
Installing the Fan Coil Power and Control Wiring – All wiring to the fan coil unit must comply with local codes and the manufacturer's installation instructions. Supply power to the fan coil unit must use a dedicated line equipped with a correctly sized fuse or circuit breaker, with an uninterrupted ground between the fan coil unit ground and the earth ground in the electrical panel. A disconnect switch should also be installed at the fan coil. When the power wiring is completed, leave the power turned off until you are ready to start up and check out the fan coil. Install the thermostat and control wiring. For detailed guidelines on installing power and control circuit wiring, refer to Section 7.

▼ Figure 9-27.
Flexible Connectors are Used Between the Ductwork and Fan Coil to Prevent Vibration Transmission



The installation of power and control wiring for accessories such as electric heaters, an electronic air cleaner, or a humidifier should be wired per the instructions supplied with each accessory. *Figure 9-28* shows the terminals used for connecting accessories on a typical fan coil unit control board.

▼ Figure 9-28.
Accessory Wiring Terminals on a Typical Fan Coil Unit Control Board

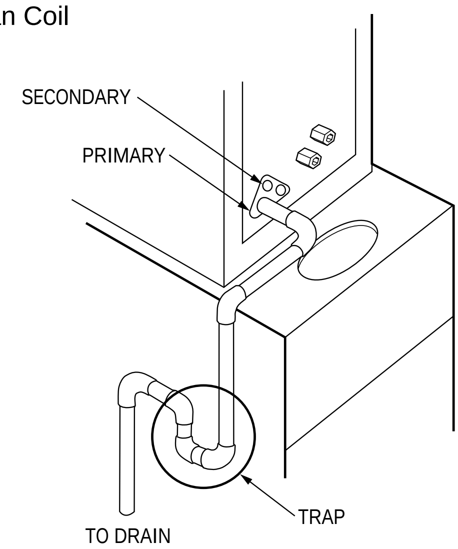


Installing Condensate Drain Piping – To dispose of condensate from the cooling coil, drain piping between the coil's condensate outlet and an open or vented drain must be installed. A laundry sink or basement floor drain is commonly used for this purpose.

Coils and fan coils normally have primary and secondary drain connections. The primary drain connection is the lower one and must have a trap installed as close to the unit as possible *(Figure 9-29)*. Traps must be used to ensure proper condensate drainage. The secondary drain is the upper connection and should remain plugged when use of a secondary drain is not required. Use of a secondary drain is covered later in this section. Normally, rigid plastic pipe is used for the condensate piping run, but clear flexible tubing can be used for some installations. Refer to Section 5 for the methods used to cut and connect rigid plastic pipe.

The diameter of the drain line and fittings should be the same as the primary (or secondary) outlet to which the pipe is being connected, typically 3/4 inch. The trap should be positioned flat against the unit and must have a minimum depth as specified in the installation instructions, typically two to three inches. The trap should be no higher than the bottom of the primary drain outlet. Once the trap has been made, the remainder of the condensate piping can be run to the drain.

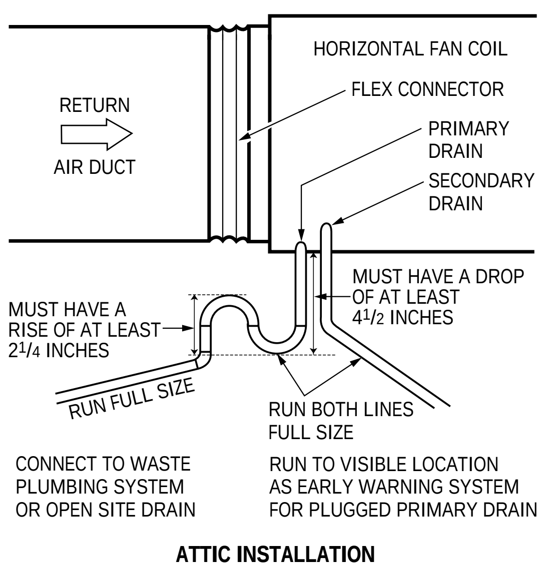
▼ Figure 9-29.
Condensate Drain Connections at the Furnace or Fan Coil



Ideally, a gravity drain should be used. If that is impractical, a condensate pump must be installed to pump the condensate into a suitable drain. Refer to Section 8 for more information about condensate pumps. Horizontal pipe runs should be pitched toward the drain. Pitch is not a requirement if the drain runs along a level basement floor. Rigid pipe should be supported at least every ten feet to prevent sagging or strain on the connections. To prevent noise transmission, vibration-absorbing hangers should be used where the piping contacts the framing of the building.

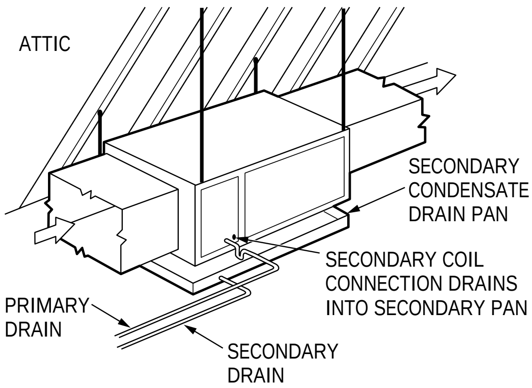
Figure 9-30 shows an attic installation of a horizontal fan coil where both the primary and secondary drain are connected. The primary drain is installed with a slight slope toward the termination. There should be a rise of at least 2-1/4 inches on the outlet side of the trap with a drop of at least 4-1/2 inches on the entering side of the trap. The secondary drain is piped without a trap to a visible location where any dripping water serves as an early warning to the customer that the primary drain is plugged. This is mandatory in an attic installation since a water leak in the ceiling can cause damage. A warning sticker should be attached to the secondary drain outlet and the customer encouraged to make a service call if water drains from it.

▼ Figure 9-30.
Double Condensate Drain Connection



When installing a coil or fan coil over a finished ceiling or living space, a secondary condensate pan *(Figure 9-31)* should be installed under the entire unit to protect against water damage either from a plugged primary drain or from water dripping off the outside of the unit as a result of condensation. Building codes for many areas mandate the use of a secondary condensate drain pan. Local codes should always be consulted for requirements. The secondary drain pan piping is run, without a trap, to a visible location. When a secondary drain pan is used, the coil's secondary drain can flow directly into the pan without being piped.

▼ Figure 9-31.
Use of a Secondary Condensate Drain Pan

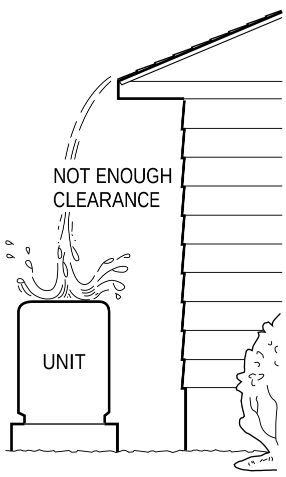


Installing the Outdoor Equipment

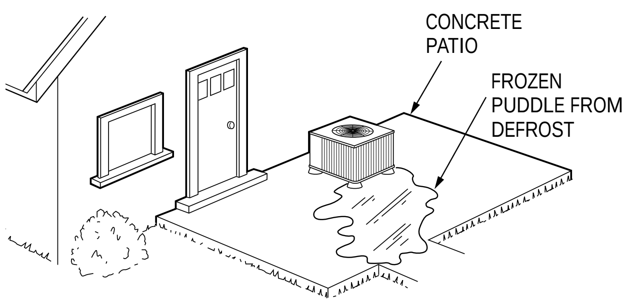
Locating the Unit – Several important factors must be considered when locating the outdoor condensing or heat pump unit. Local codes must be checked for special requirements. Many local codes prohibit locating units in the front yard and/or too close to property lines. The selected site should also leave the property attractive to the customer. Some guidelines for locating the outdoor unit are given below. The selected site should be one that achieves the best compromise among all the factors shown.

- Locate the unit where water, snow, or ice from the roof or eaves cannot fall directly on the unit *(Figure 9-32)*, or where the roof overhang cannot cause recirculation of the air exhausted from the unit. Do not install outdoor units under decks or porches unless the clearance dimensions specified by the manufacturer are met.
- Locate the unit near enough to the building to avoid long tubing runs which can be easily damaged.
- Locate the unit away from bedroom windows or rooms where the operating noise might be objectionable.
- Locate the unit so that there is enough clearance around the unit for service accessibility and air movement. Avoid areas where plants or shrubs can block air movement. Clearance dimensions are specified in the unit's installation instructions.
- Locate heat pumps so that prevailing winds are prevented from blowing directly across the outdoor coil.
- Locate heat pumps where defrost water from the coil cannot run onto sidewalks, patios, etc. and freeze *(Figure 9-33)*.

▼ Figure 9-32.
Carefully Select the Unit Location



▼ Figure 9-33.
Locate the Heat Pump where Defrost Water Cannot Run onto Walkways and Freeze

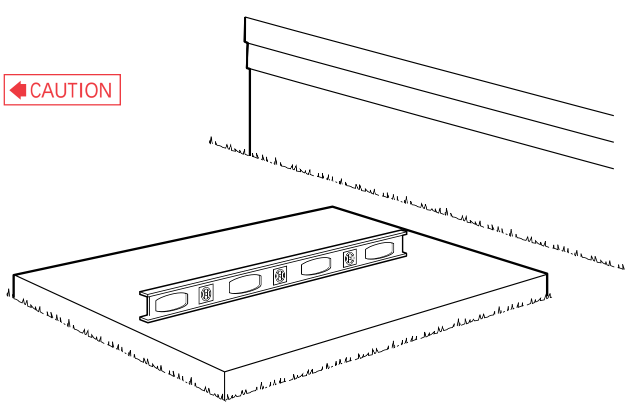


Mounting the Unit – Once the location for the outdoor unit has been selected, a pad is installed and leveled in preparation for mounting the unit *(Figure 9-34)*. Pads made of various materials are available and can be used providing they satisfy local codes. The minimum dimensions for the mounting pad are specified in the installation instructions for the unit. ***Never mount the outdoor unit on concrete blocks or wooden skids as they may settle or deteriorate over time.***

If installing a heat pump, a 12-inch to 18-inch bed of gravel or crushed stone extending out and away from the perimeter of the pad should be installed to provide for the absorption and drainage of the unit's defrost water.

▼ Figure 9-34.
Make Certain the Mounting Pad is Level

CAUTION



Before mounting the outdoor unit on the pad, appropriately-sized openings should be made through the outside wall for the refrigerant lines and for the power supply wiring to the disconnect.

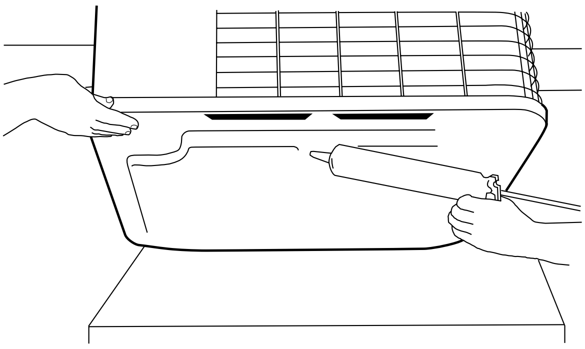
A condensing unit can be mounted and secured directly to the pad using construction adhesive *(Figure 9-35)*. When applying the adhesive, care must be taken not to block the drain holes in the unit's basepan. If conditions or local codes require that the unit be mechanically attached to the pad, tiedown bolts should be fastened through the unit basepan. When mounting the unit, make sure that all clearances are maintained as specified in the installation instructions.

When installing a heat pump in mild climates where there is little or no snowfall, the unit is normally installed directly on the pad or using short legs that raise it above the pad enough to provide for adequate drainage of defrost water *(Figure 9-36)*. In locations where the snowfall is heavy and defrost water will freeze and build up, the heat pump should be mounted on an accessory stand that raises the unit high enough to allow for adequate drainage of the defrost water and to prevent snow from blocking the coil.

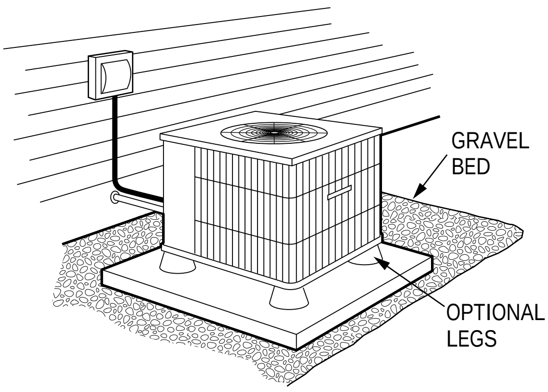
Power and Control Wiring – All wiring to the outdoor unit must comply with local codes and the manufacturer's installation instructions. Supply power to the outdoor unit must use a dedicated line equipped with the correct type and size disconnect and the correct size fuse or circuit breaker. It must have an uninterrupted ground between the unit ground lug and the earth ground in the electrical panel. When the power wiring is completed, leave the power turned off until you are ready to start up and check out the unit.

The control wiring between the indoor and outdoor units can be installed after the refrigerant lines are run. The control wires running between the units are commonly taped to the refrigerant lines and exit the building through the same hole as the refrigerant lines. For detailed guidelines on installing power and control circuit wiring, refer to Section 7.

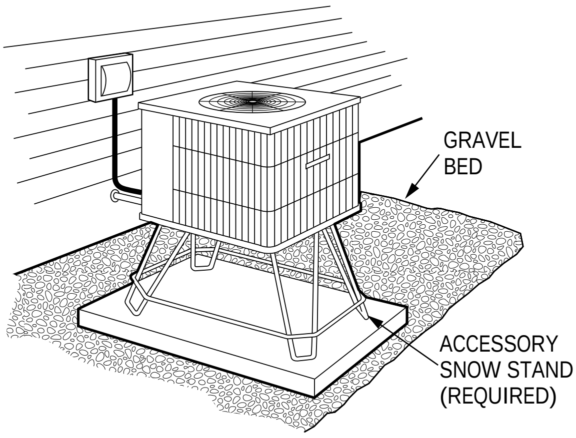
▼ Figure 9-35.
Construction Adhesive Being Used to Secure the Outdoor Unit to the Pad



▼ Figure 9-36.
Elevate Heat Pumps Enough to Allow for Adequate Drainage of Defrost Water



MILD CLIMATE – LIGHT OR NO SNOWFALL



SNOW-BELT AREA

Installing Refrigerant Tubing Lines

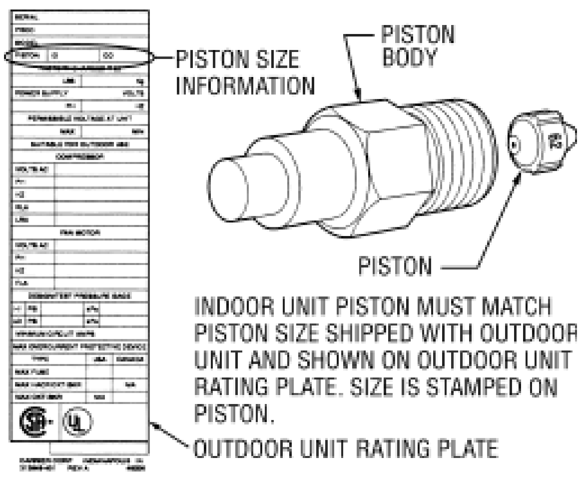
Installing the Correct Metering Device – Before connecting the refrigerant lines, it is important to make sure that the metering device for the indoor unit is the size and/or type specified in the installation instructions for the indoor unit. If the coil uses a piston-type metering device, check the size shown on the indoor unit rating plate to see if it is the same piston size shipped with the outdoor unit and as shown on the outdoor unit rating plate *(Figure 9-37)*. If it does not match, replace the indoor piston with one shipped with the outdoor unit.

Installing the Refrigerant Lines – The refrigerant lines used to connect the outdoor and indoor units can be a manufactured tubing kit (line set) or they can be field-supplied and assembled from refrigerant grade (ACR) tubing of the correct size. Line sets *(Figure 9-38)* come in various lengths and tubing diameters. Line sets may have no fittings on the ends, compression or flare fittings, or may come precharged with refrigerant and have quick connects on the ends. The procedures for working with line sets and/or ACR grade soft and hard copper tubing are described in detail in Section 4. If field-supplied tubing is used, the vapor line (suction line in cooling-only systems) must be adequately insulated. The remainder of this section will describe the installation of a line set. Field-supplied tubing should be installed in a similar manner. The sizes of the liquid and vapor line tubing used with a split system are specified in the installation instructions for the outdoor unit and apply to tubing runs up to 50 feet. Tubing runs greater than 50 feet are considered long-line applications. Before installing a long-line system, you should always follow the recommendations given in the manufacturer's *Guidelines for Split System Long-Line Applications* or similar document available from your distributer.

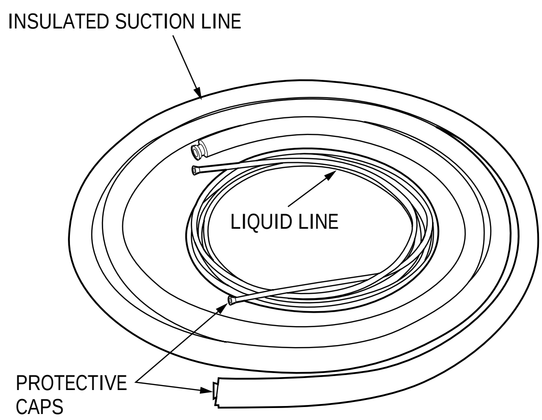
Running the refrigerant lines between units *(Figure 9-39)* is best done by two people and is accomplished as follows:

1. Remove the line set from the shipping carton. The liquid line is the smaller diameter uninsulated line; the vapor line is larger and is insulated with black foam rubber. ***Do not remove the rubber plugs from the tubing ends at this time.***
2. One at a time, unroll and straighten out both lines and tape the lines together at convenient intervals. One person can unroll while the other holds the tubing. Be careful not to collapse the tubing and avoid bends that can kink the tubing.
3. Being careful not to cut the insulation, feed the taped bundle of tubing through the hole in the outside wall until enough tubing is available to easily reach the refrigerant connections on the outdoor unit and indoor unit. Leave enough slack between the structure and the unit to absorb vibration. Seal the opening in the wall with caulk.

▼ Figure 9-37.
Indoor Coil Piston Size Should Match the Piston Size Listed on the Outdoor Unit Rating Plate

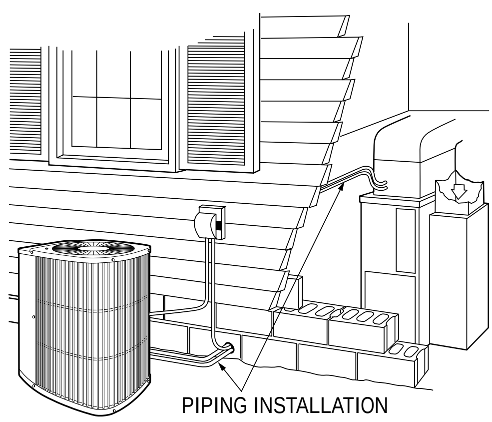


▼ Figure 9-38.
Typical Line Set



▼ Figure 9-39.
Installing Refrigerant Lines Between Units

CAUTION



QUICK NOTE

Many installers tape the multi-conductor control wire between the indoor and outdoor units to the refrigerant tubing.

QUICK NOTE

Do not bury more than 36 inches of refrigerant tubing in the ground. If more than 36 inches of tubing is buried, refrigerant can migrate to the cooler buried section during extended periods of unit shut-down, causing refrigerant slugging and possible compressor damage at start-up. If any tubing is buried, at least six inches of vertical rise should be provided at the service valve. Also, the buried line set should be run inside a chase or conduit. It is also recommended that a crankcase heater be installed in the unit.

4. Run the refrigerant lines between the units as directly as possible by avoiding unnecessary turns and bends. Use tubing benders to make any sharp bends or cut the line sets and use sweat elbows, if required.
   Support the lines every six to ten feet, and within two feet of bends. Avoid direct contact of the line set with water pipes and/or ductwork. Wire or straps used to support the tubing should contain foam rubber or similar insulation to isolate the tubing from the building structure *(Figure 9-40)*. This prevents unwanted noise transmission.

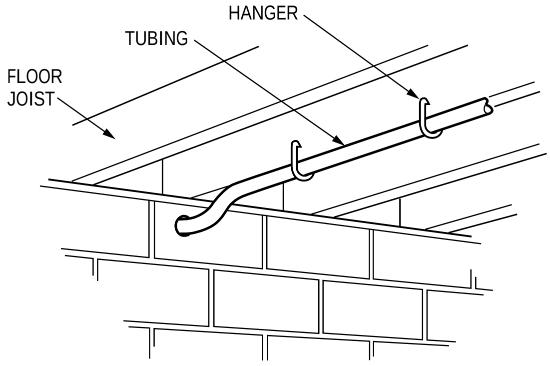
Vapor Line Considerations – The location of the indoor coil relative to the compressor in the outdoor unit must also be considered when running the refrigerant tubing. When the indoor coil is located above the compressor, the vapor line should loop up to the height of the indoor coil *(Figure 9-41)*. This helps to prevent liquid refrigerant from migrating to the compressor during the off cycle.

When the indoor coil and compressor are at the same level, the vapor line should pitch toward the compressor *(Figure 9-42)* with no sags or dips in straight runs.

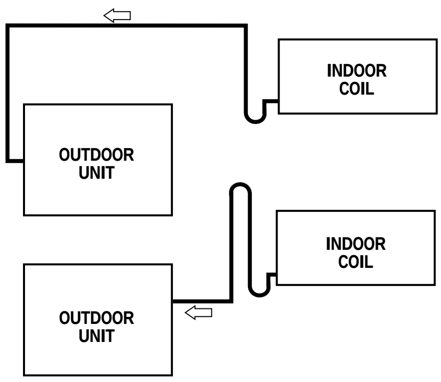
When the indoor coil is below the compressor, oil must be returned to the compressor via a vertical riser in the vapor line *(Figure 9-43)*. An oil trap should be provided at the entrance to the riser to collect and feed back small amounts of oil to the compressor to prevent compressor damage. The horizontal run to the compressor should also be pitched toward the compressor.

Connecting Refrigerant Lines to the Indoor and Outdoor Units – Brazing and mechanical fittings are two methods commonly used to connect refrigerant lines to split system components. To prevent contamination and moisture from entering the system, do not remove protective dust covers and/or plugs from the equipment or tubing until just before making the actual connection.

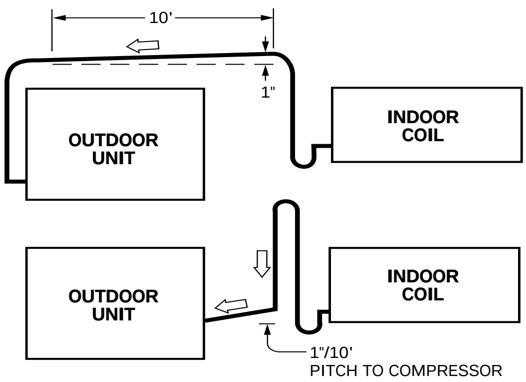
▼ Figure 9-40.
Typical Refrigerant Tubing Support



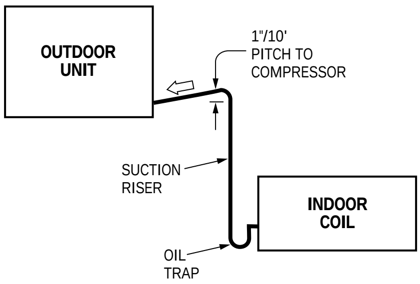
▼ Figure 9-41.
Vapor Line with Indoor Coil Above the Outdoor Unit



▼ Figure 9-42.
Vapor Line with Indoor Coil at the Same Level as the Outdoor Unit



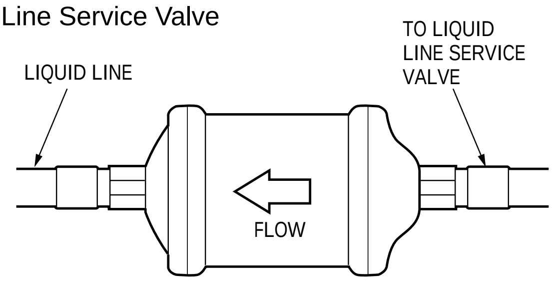
▼ Figure 9-43.
Vapor Line with Indoor Coil Below Outdoor Unit



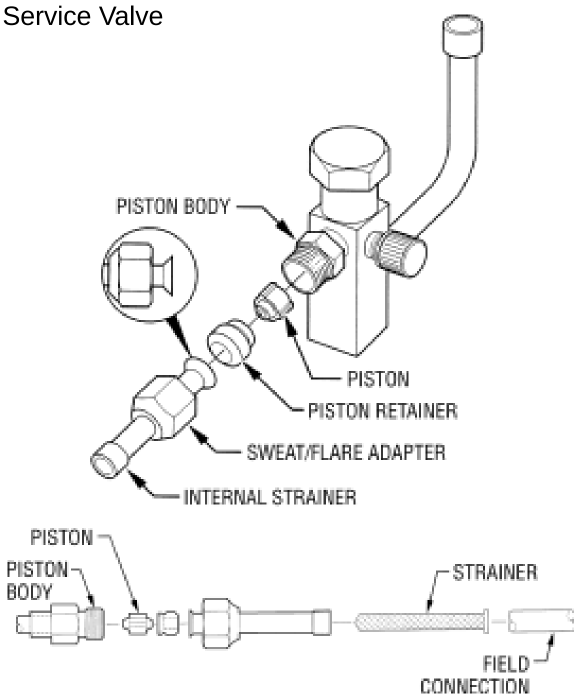
Brazing the Connections – The outdoor unit normally comes from the factory with the operating charge of refrigerant sealed in the outdoor unit by the service valves. Be sure to check local code requirements pertaining to the use of silver bearing or non-silver bearing brazing material. Brazing is covered in detail in Section 5. Connections are brazed at the outdoor and indoor units as follows:

1. At the outdoor unit, slide back the insulation and clean the exposed vapor tubing.
2. Remove the plugs from the end of the tubing and the vapor service valve port, then insert the end of the tubing into the port until it bottoms. Braze the joint.
   Make sure to wrap the service valve with a wet cloth to avoid damaging the valve while brazing. A brazing shield should also be used to prevent damage to any painted surface. Inspect the joint when done.
3. Good practice is to install a filter-drier in the liquid line. For heat pump split systems, make sure to use a bi-directional heat pump filter-drier. For cooling systems, make sure that the arrow on the filter-drier points away from the outdoor unit and toward the indoor evaporator coil *(Figure 9-44)*.
   Some heat pumps are shipped with a flare adapter and liquid line strainer *(Figure 9-45)*. They also include a flow direction sticker. These must be installed on the liquid service valve after which the liquid line is brazed to the flare adapter.
4. At the indoor coil or fan coil, remove the plugs when ready to make the connections, then braze the vapor and liquid lines to the coil. Inspect the joints when done. Some coils are also shipped with a flare adapter, liquid line strainer, and flow direction sticker as described above for heat pump units.
5. After the brazing is completed and the joints inspected, seal the openings around the coil access plate to prevent air leakage.

▼ Figure 9-44.
Install a Filter-Drier at the Outdoor Unit Liquid Line Service Valve



▼ Figure 9-45.
Flare Adapter Installed at Heat Pump Liquid Line Service Valve

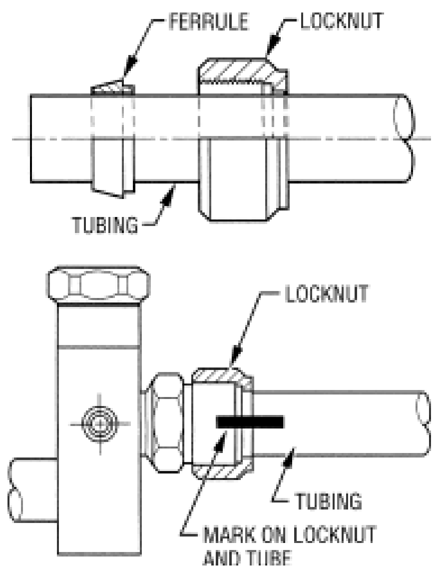


Making Mechanical Connections – Outdoor and indoor units can have several different kinds of mechanical connections. Connecting refrigerant lines with mechanical-type connectors should always be done as directed in the installation instructions. Compression fittings that use a ferrule and locknut are commonly used.

To make a connection using a ferrule and locknut-type compression fitting, proceed as follows:

1. Cut the tubing to the correct length, making sure the tube ends are square. The tubing should be clean, round, and free of nicks and/or burrs.
2. Slide the locknut onto the tubing, followed by the ferrule *(Figure 9-46)*.
3. Lubricate the ferrule and the threads of the mating valve or adapter threads with a few drops of refrigerant oil.
4. Insert the end of the tubing into the mating valve or adapter until it bottoms. Push the ferrule in place and tighten the locknut until an increase in torque is felt.

▼ Figure 9-46.
Ferrule and Locknut Compression Fittings



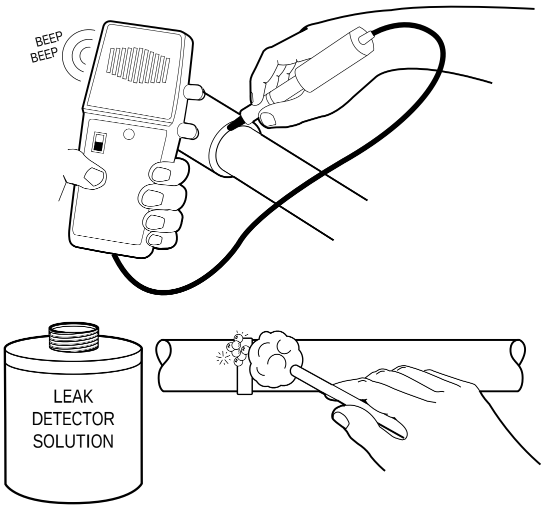
QUICK NOTE

For detailed information and procedures for methods of leak detection and evacuation, refer to Service Procedures SP-1 and SP-3, respectively, in the companion HVAC Servicing Procedures handbook.

5. Mark the nut and tubing, then tighten the nut 1-1/2 turns from the mark *(Figure 9-46)*. Be sure to keep the tubing bottomed in the valve or adapter while tightening the nut. A backup wrench should be used on the hex part of the valve or adapter while tightening.

Line sets precharged with refrigerant are made with specially-designed couplings at the ends of the tubing that must match the fittings provided on the indoor and outdoor units. Typically, the unit fitting contains a diaphragm that seals refrigerant within the line. As the fittings are connected, a knife blade in the fitting cuts through the diaphragm of both sets of fittings. When completely coupled, the diaphragm is cut through and pushed out of the way by the knife edge, allowing the refrigerant to flow freely. Precharged line sets do not have to be purged or evacuated before or after a connection is made. There are usually no service valves on units equipped with these types of fittings.

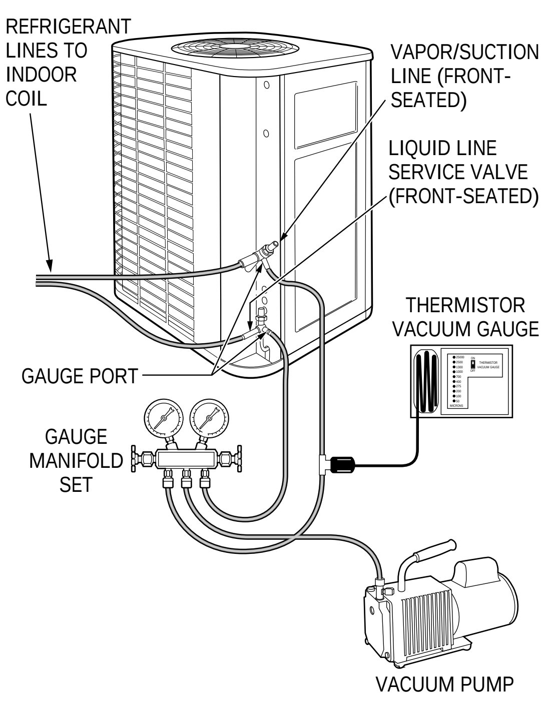
▼ Figure 9-47.
Electronic Leak Detector and Bubble Solution Used to Locate Leaks



Leak Testing and Evacuating the Refrigerant Lines – Once the refrigerant lines are connected between the indoor and outdoor units, they must be checked for leaks and evacuated. The outdoor unit is shipped from the factory with a complete charge and with its service valves closed (front-seated). ***Do not open (back-seat) the outdoor unit's service valves until after the refrigerant lines and indoor coil have been evacuated and leak tested.*** With the outdoor unit service valves back-seated, the refrigerant lines and indoor coil are isolated from the outdoor unit and can be accessed for leak testing and evacuation through the service ports on the service valves.

To perform a leak test, pressurize the lines and indoor coil with nitrogen and a trace of HCFC-22 (R-22) refrigerant. Then, use a bubble solution, electronic leak detector, or both to locate any leaks *(Figure 9-47)*. When leak testing is completed, the mixture of nitrogen and trace refrigerant can be vented to the atmosphere. Following this, the lines must be evacuated.

▼ Figure 9-48.
Vacuum Pump and Vacuum Gauge Used to Evacuate the Refrigerant Lines and Indoor Coil



Leak testing can also be performed as part of the refrigerant line evacuation process. Evacuate the refrigerant lines and indoor coil to 500 microns or less using a good vacuum pump and accurate vacuum gauge *(Figure 9-48)*. If the lines and coil are free of leaks, the reading on the vacuum gauge will not rise significantly when the vacuum pump is shut off.

If the vacuum gauge shows a pressure rise and the pressure continues to rise without leveling off, a leak exists and must be repaired. If it shows a pressure rise but levels off between 1,000 and 2,000 microns, this indicates that the lines and coil are leak tight, but are too wet. A constant reading on the vacuum gauge of between 500 and 1,000 microns indicates that the lines and coil are leak tight and dry.

When the evacuation is complete, remove the vacuum pump and vacuum gauge, but leave the gauge manifold connected to the service ports with both service valves front-seated in preparation for start-up and checkout.

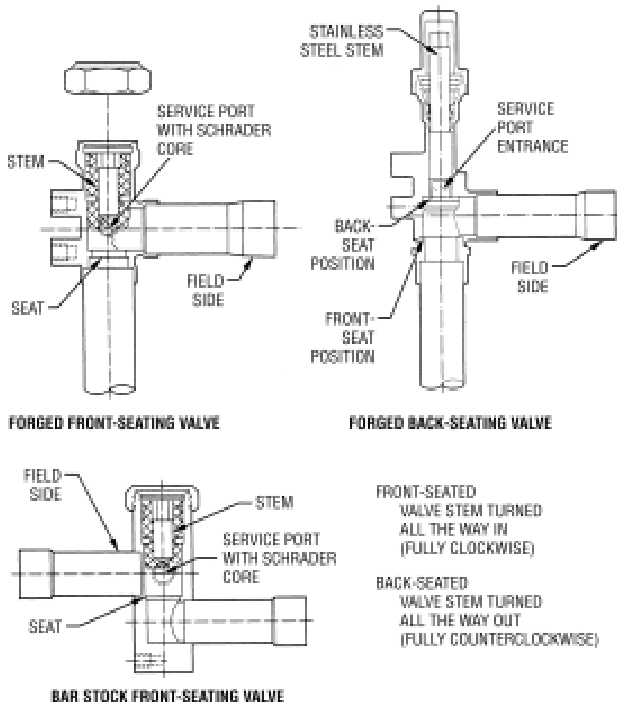
Start-Up and Checkout

The system must always be started up and fully checked out per the installation instructions before the technician leaves the site. Start up the cooling or heat pump system and check out the cooling mode as follows:

1. If equipped with a crankcase heater, energize the heater a minimum of 24 hours before starting the unit. To energize the heater only, set the thermostat to OFF and turn on the power to the outdoor unit.
2. Remove the valve stem caps from the service valves *(Figure 9-49)* and turn the valve stems fully counterclockwise to open the valves, allowing the refrigerant into the entire system.
3. Turn on the power to the indoor fan coil or furnace and the outdoor unit.
4. Set the room thermostat to COOL and the fan switch to ON or AUTO. Operate the system for 30 minutes to allow system pressures and temperatures to stabilize.

   During this time, make general component and operational checks and clean up the area. At the indoor unit, check the condensate drain. On a humid day, condensate water should run from the drain after a short period of time.

▼ Figure 9-49.
Typical Service Valves



QUICK NOTE

If installing a split cooling system and the outdoor temperature is below 55° F, wait for a warmer day before starting and checking out the system.

While performing the various start-up tasks, the Residential Split System Cooling Installation and Start-Up Checklist located on page 159 of this book should be used to check off each item when completed. Use of a checklist ensures that an organized and consistent procedure is followed and that no area of the installation or checkout is overlooked.

QUICK NOTE

For detailed information and procedures pertaining to charging refrigerants, refer to Service Procedure SP-4 in the companion HVAC Servicing Procedures handbook.

5. If necessary, check and/or adjust the system refrigerant charge. Use the superheat method for systems equipped with fixed-orifice metering devices and use the subcooling method for systems equipped with a thermostatic expansion valve (TXV) metering device. Note that factory-charged units often need a charge adjustment to compensate for longer-than-standard refrigerant line lengths and/or the use of a filter-drier or other accessory. ***BE CAREFUL WHEN CONNECTING THE GAUGE MANIFOLD SET TO SERVICE VALVES NOT EQUIPPED WITH SCHRADER VALVES AT THE GAUGE PORT. TO PREVENT INJURY AND REFRIGERANT LEAKS, MAKE SURE THAT THE VALVES ARE FULLY BACK-SEATED BEFORE REMOVING THE GAUGE PORT CAPS.***

   A charging aid called a *Required Superheat/Subcooling Calculator* *(Figure 9-50)* can be used to check the charge in systems that use HCFC-22 refrigerant. A similar calculator is available for HFC-410A. Complete instructions are printed on the calculator.

6. Check the airflow across the indoor coil in the cooling mode. For proper operation, the furnace or fan coil blower should be moving from 400 to 450 CFM of air across the coil for each ton of capacity. If required, adjust the furnace or fan coil blower speed per the manufacturer's instructions to obtain the proper airflow.

   A quick check of airflow can be made using the "Proper Airflow Range" section *(Figure 9-50)* of the *Required Superheat/Subcooling Calculator* previously described. Complete instructions are printed on the calculator.

WARNING

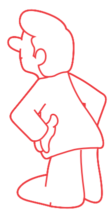
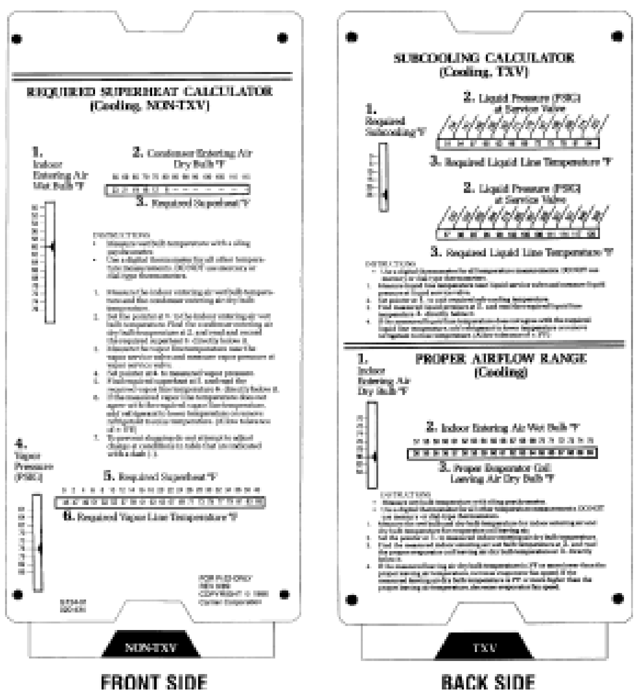
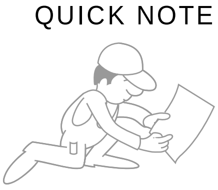


Figure 9-50.
Required Superheat/Subcooling Calculator



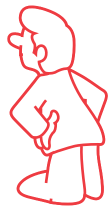
QUICK NOTE



For detailed information and procedures for measuring airflow, refer to Service Procedures SP-14 through SP-17 in the companion HVAC Servicing Procedures handbook.

7. If operating a split system with a furnace, set the thermostat to HEAT and check furnace operation and temperature rise as previously described in Section 8. If operating a split heat pump system, check the charge in the heating mode by following the procedure on the heating check chart located on the unit or check the charge in the cooling mode using the superheat or subcooling method. Also measure the temperature rise and airflow in the fan coil unit.
8. Disconnect the gauge manifold set and other test equipment from the outdoor and indoor units. ***BE CAREFUL WHEN DISCONNECTING THE GAUGE MANIFOLD SET FROM SERVICE VALVES NOT EQUIPPED WITH SCHRADER VALVES AT THE GAUGE PORT. TO PREVENT INJURY, MAKE SURE THAT THE VALVES ARE FULLY BACK-SEATED BEFORE DISCONNECTING THE MANIFOLD SET HOSES.*** Replace and tighten all valve stem and gauge port caps.

WARNING



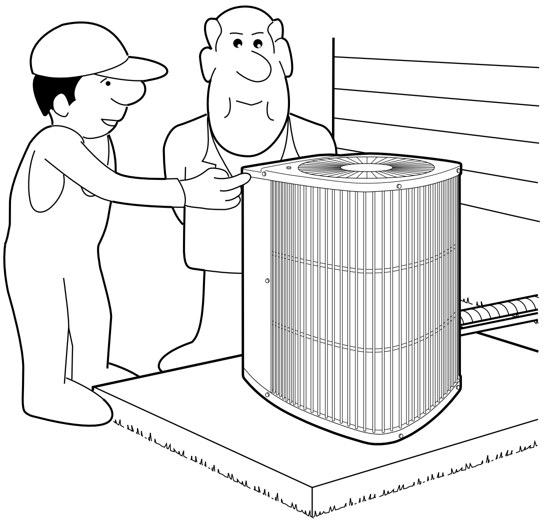
Final Checks, Adjustments, and Tasks

With the units operational, the following checks should be done to complete the installation.

- Check for correct operation of accessories such as an electronic air cleaner or humidifier, if installed.
- Check the outdoor unit, fan coil/furnace, and ductwork for any unusual noise or vibration.
- Adjust the balancing dampers in each branch run of duct for correct operation (refer to Section 6).
- Clean up the work area when done.

Before leaving the job, explain the operation of the complete system to the customer *(Figure 9-51)*. Describe how the system operates and run the system through a complete cycle so the customer can see and hear the normally operating system. If installed, demonstrate the operation of accessories. After the demonstration, present the customer with the owner's operating and service manuals and warranty.

Figure 9-51.
Explain the Operation of the System to the Customer



SECTION 10
PACKAGED UNIT INSTALLATIONN

INTRODUCTION

This section provides guidelines for the installation of packaged cooling/heating and heat pump systems and related accessories. It is not intended to teach refrigeration or air distribution system theory; instead, it describes the different kinds of packaged units and the methods used to install them. This section presumes that the proper type of equipment and related accessories have been selected and purchased by a qualified engineer or salesperson based on a survey of the job.

PACKAGED UNIT MENU

PACKAGED SYSTEMS

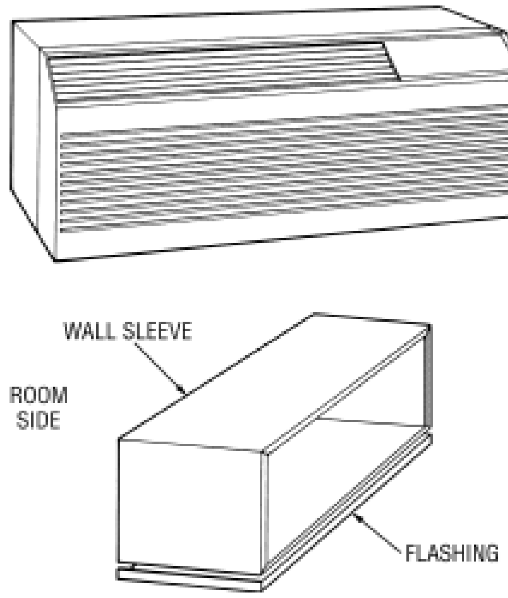
Packaged systems contain all the components for cooling, heating, or both in one factory-built package. For residential and light commercial applications, they fall into four categories:

- Packaged terminal air conditioners (PTACs)
- Packaged air conditioners (PACs)
- Year-round air conditioners (YACs)
- Heat pumps

PTAC Units

Packaged terminal air conditioners or *PTACs* *(Figure 10-1)* are typically used to cool one room such as a motel room. Both heat pumps and models with electric resistance heat are available. PTAC units slide into a wall sleeve that is built into the exterior wall of the building. Installation of the unit itself normally involves sliding it into its sleeve and plugging its power cord into an electrical outlet.

▼ Figure 10-1.
PTAC Unit and Wall Sleeve

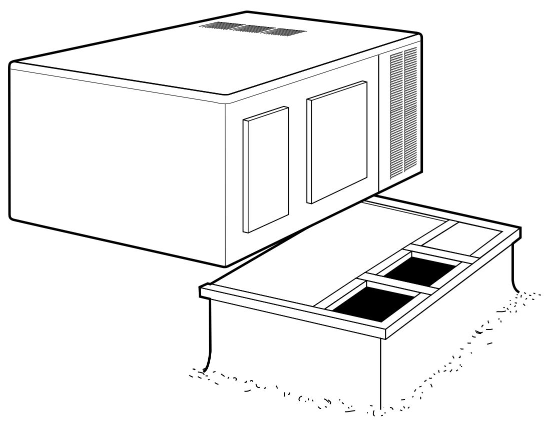


PAC Units

Packaged air conditioners or *PACs* *(Figure 10-2)* are commonly used for both residential and light commercial applications. PACs can provide cooling only or they can provide both cooling and heating when equipped with electric resistance heaters (electric cooling/electric heating units).

PACs are usually installed at ground level on a slab or on rooftops *(Figure 10-3)*. Factory-supplied roof curbs are used for installation on flat and pitched roofs. Stands are sometimes used where appropriate. When the unit is installed on a roof curb, gaskets are placed on the curb to seal out rain before the unit is rigged into place. The discharge airflow orientation (horizontal or vertical) will determine how the supply and return ductwork is connected. Round or rectangular supply and return duct flanges on the unit provide for connection to flexible or standard metal air ducts.

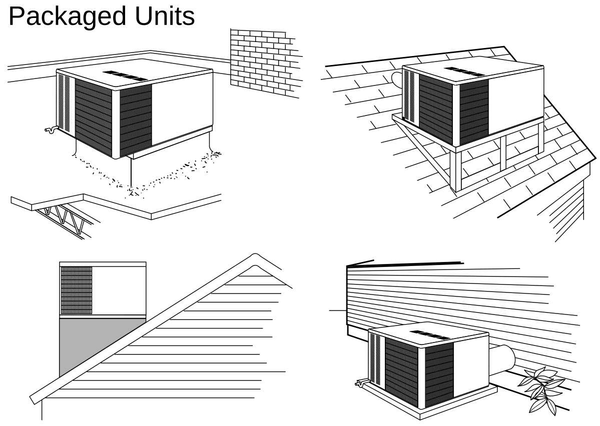
▼ Figure 10-2.
Typical Packaged Unit



YAC Units

The year-round air conditioner (YAC) unit provides both cooling and heating. It differs from a PAC in that its heating capability is provided by a natural or LP gas heating section (gas heating/electric cooling). All the other features described above for PACs also apply to YACs.

▼ Figure 10-3.
Ground Level and Rooftop Mounting of Packaged Units



Heat Pump Units

Heat pump packaged units provide both heating and cooling. As a heat pump, they extract heat from the outdoor air and move it into the conditioned space. This heat can be supplemented by electric resistance heat when necessary. For cooling operation, the heat pump works like a conventional air conditioner. All the other features described for PACs also apply to packaged heat pumps.

ACCESSORIES

Many of the accessories previously described in Sections 8 and 9 for use with furnaces or split system outdoor units are also used with packaged units. All such accessories should be installed as directed in the accessory installation instructions.

Depending on the application, the accessories can be either factory or field installed. These accessories include:

- Natural gas-to-propane conversion kit
- Low-ambient temperature controller
- Electric resistance heaters *(Figure 10-4)*
- Crankcase heater
- Compressor start assist kit
- Compressor short cycle protector
- High-pressure and low-pressure switches
- Outdoor air damper kits and economizers

This section focuses on outdoor air damper kits and economizers, both commonly used with packaged units.

Outdoor Air Damper Kits

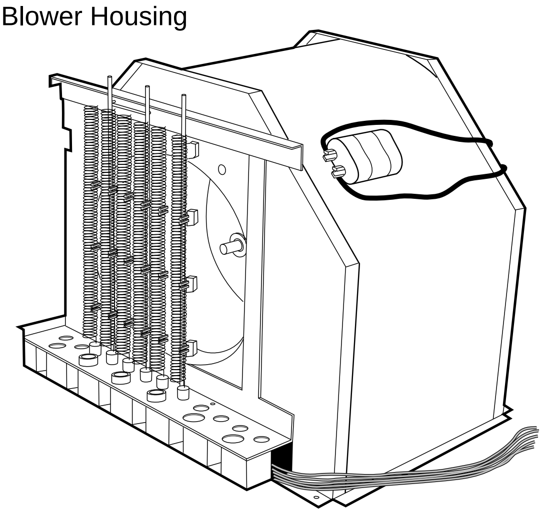
Manual and two-position outdoor air damper kits provide year-round ventilation *(Figure 10-5)*. The manual damper is adjusted to allow adequate outdoor ventilation airflow in the building to maintain good indoor air quality and negative pressure inside the unit. Typically, the outdoor air ventilation rate should be about 15 to 20 CFM per person. The two-position outdoor air damper kit is similar to a manual damper and is also adjusted to provide the airflow needed to maintain good indoor air quality and negative pressure. It allows fresh outside air to enter the building whenever the unit indoor fan is energized.

Economizer

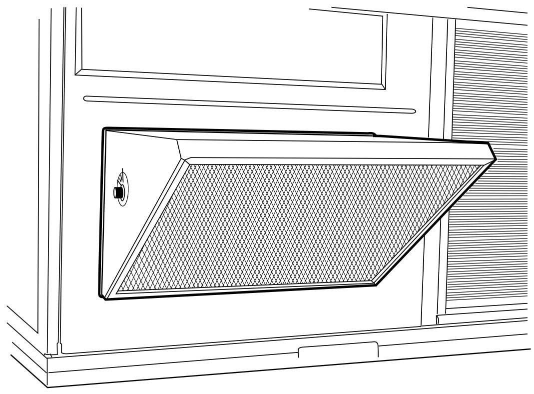
An economizer is an automatically-controlled damper system that reduces system operating cost for cooling operation and provides for adequate building ventilation air during all modes of operation. It uses cool outdoor air to satisfy the cooling load (free cooling) whenever the outside air temperature is low enough. If the outdoor air alone cannot satisfy the cooling requirements, economizer cooling can be used in conjunction with air conditioner (compressor) operation.

There are many variations of economizers. *Figure 10-6* shows a typical economizer. A basic economizer uses an outdoor air thermostat (OAT) to sense the outdoor dry bulb (sensible heat) air temperature. More efficient units use an enthalpy control (EC) instead of a thermostat to measure both the temperature and humidity (latent heat) of the outdoor air. The OAT or EC is normally installed on the inside of the ecomonizer hood assembly *(Figure 10-7)*. Some systems use a second enthalpy control called a *differential enthalphy control* mounted in the return air duct. These systems compare the temperatures and humidities of both the outdoor air and indoor return air.

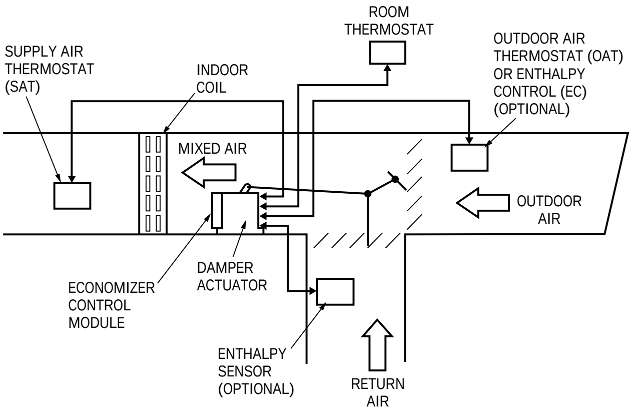
▼ Figure 10-4.
Electric Resistance Heaters Mounted on a Blower Housing



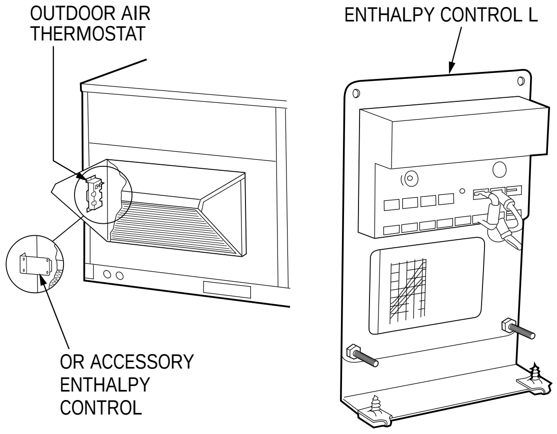
▼ Figure 10-5.
Typical Outdoor Air Damper Kit



▼ Figure 10-6.
Basic Economizer System



▼ Figure 10-7.
Typical Outdoor Thermostat/Enthalpy Control Installed Location

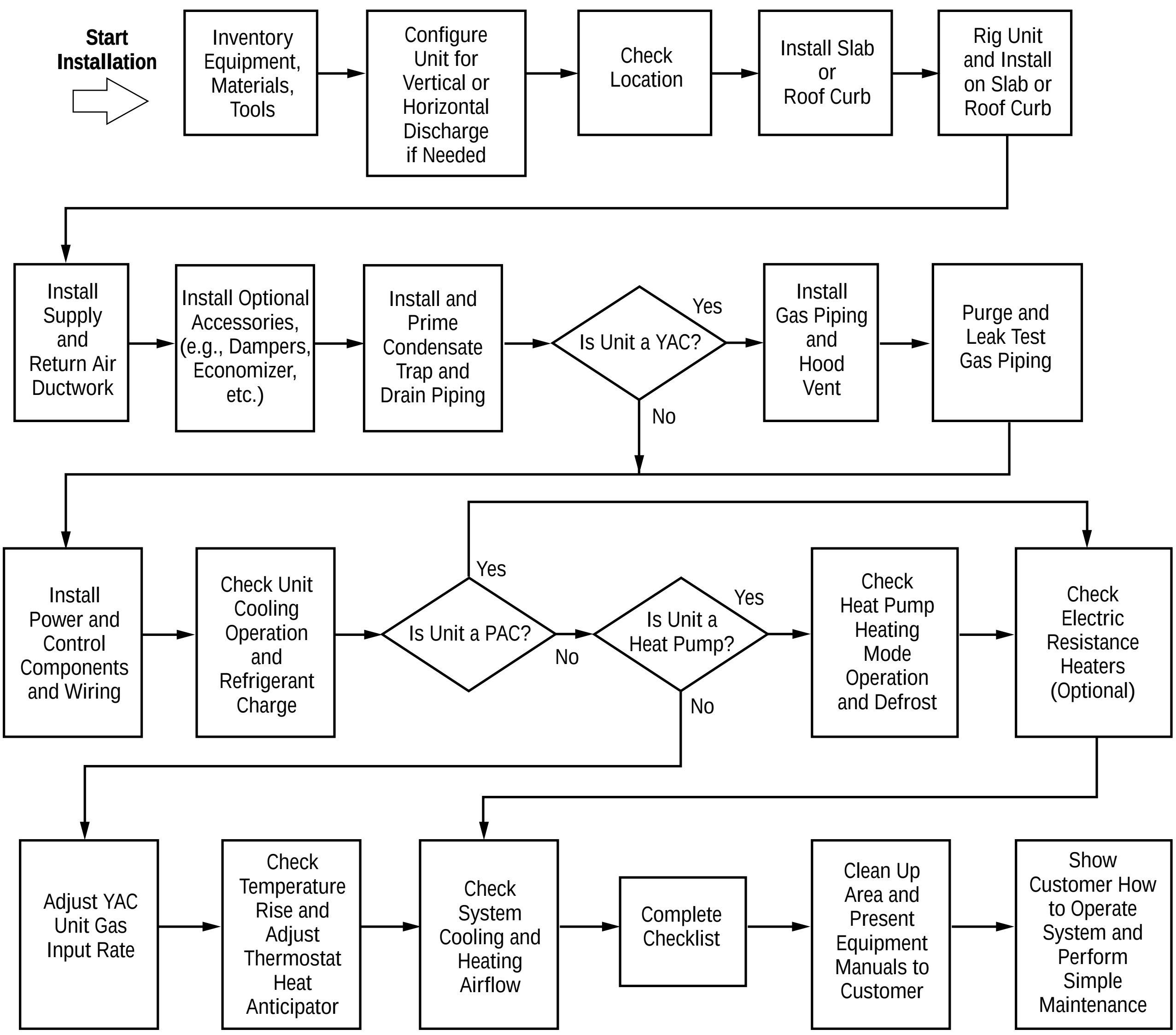


After sensing the outdoor and/or indoor temperatures and humidity, control voltages from the OAT or EC sensors, along with control voltages from the room thermostat and supply air thermostat *(Figure 10-6)* cause the economizer control unit to position the economizer damper to admit the required amount of air for mixing into the building's air distribution system. These control voltages also tell the damper to close if the outside air is getting too warm or humid for effective free cooling. The sequence of economizer operation and the procedure for setting the economizer controls are normally included in the installation instructions for the economizer.

*P*ACKAGED UNIT INSTALLATION GUIDELINES

The methods for installing PAC, YAC, and heat pump systems are basically the same. The installation of a packaged unit must always be done as directed in the manufacturer's installation instructions and must also comply with all codes and installation practices of the area where it is to be installed. The tasks for installing packaged units and the general sequence in which they are performed are shown in *Figure 10-8*.

▼ Figure 10-8.
Packaged Unit Installation – Tasks and Sequence



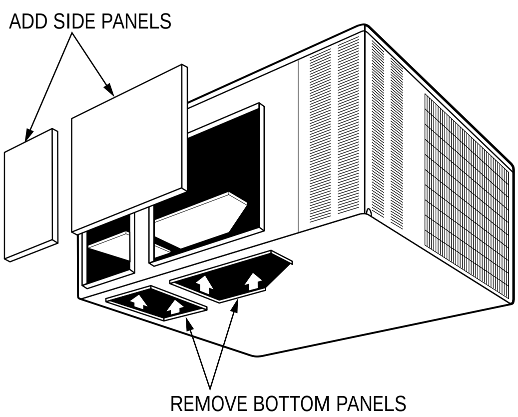
QUICK NOTE

Most packaged units have two sets of duct openings to allow for the option of either rooftop or ground-level installation. It is sometimes necessary to buy or fabricate covers for the unused openings (see Figure 10-9).

Initial Preparation

A detailed list of required materials and a simple drawing showing the intended installation should be provided to the installer. Always make sure all the required parts and tools are available before leaving for the job site. Configure the unit for proper supply and return airflow orientation (if required) per the installation instructions before leaving the shop *(Figure 10-9)*.

▼ Figure 10-9.
Reconfiguring a Unit for Downflow Orientation



Locating the Unit

Several important factors must be considered when locating the unit. Local codes must be checked for special requirements. Some guidelines for locating the unit are given below. The selected site should be one that achieves the best compromise among all the factors shown.

All Units –

- Locate the unit so that the required minimum clearances are maintained from combustible materials, air intakes, adjacent buildings or walkways, and for service accessibility and air movement. Clearance dimensions are specified in the unit's installation instructions.
- Locate heat pump units so that prevailing winds are prevented from blowing directly across the outdoor coil. Install a wind baffle, if necessary.
- Locate YACs where downdrafts or prevailing winds cannot affect venting of combustion byproducts.

Slab-Mounted Units –

- Locate the unit where water, snow, or ice from the roof or eaves cannot fall directly on the unit, or where the roof overhang cannot cause recirculation of the unit exhaust air.
- Locate the unit away from windows or rooms where sound or air discharge might be objectionable.
- Locate the unit so that the outdoor duct runs connecting to the unit are short.
- Locate heat pump units where defrost water from the coil cannot run onto sidewalks, patios, etc. and freeze.

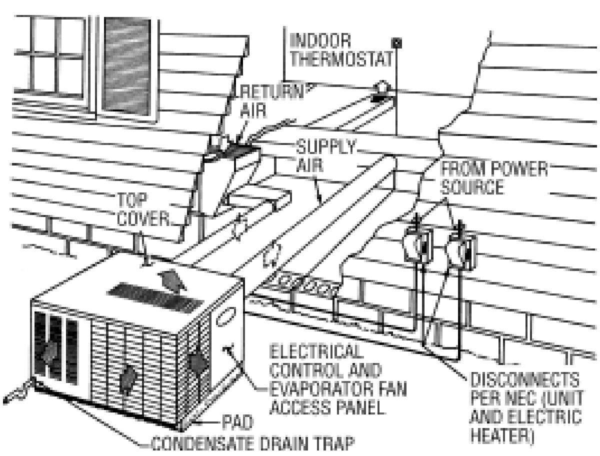
Roof-Mounted Units –

- If installed on a flat roof, be sure the unit is at least four inches above the highest water level expected.
- Locate the unit away from building exhaust vents or other sources of contaminated air.

Preparing Slab or Rooftop Sites for Installation

Slab Mount – A unit installed at ground level *(Figure 10-10)* should always be mounted on a slab or pad constructed as specified in the unit installation instructions. Typically, the slab is made of concrete, but pre-fabricated pads are also available. Position the unit to prevent grass or shrubs from obstructing airflow.

▼ Figure 10-10.
Slab-Mounted Unit



For a heat pump unit, install a bed of gravel or crushed stone extending out and away from the perimeter of the slab to provide for the absorption and drainage of defrost water. If installed in an area of heavy snowfall, a frame or snow stand should be used *(Figure 10-11)* to support the unit at a height of 12 to 24 inches above the slab.

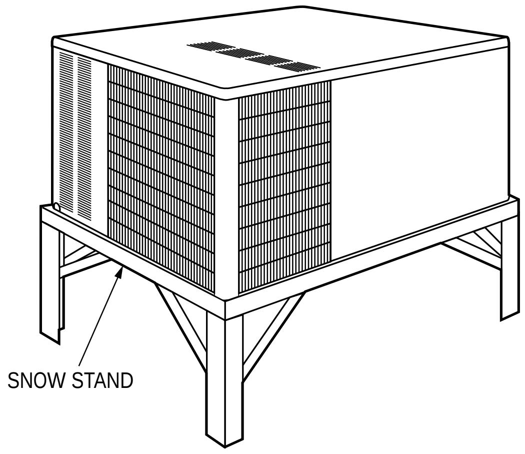
Roof Mount – A roof-mounted unit *(Figure 10-12)* is installed using a curb kit designed to mount the unit level, regardless of the pitch of the roof. The curb used is determined by the type and pitch of the roof and the model of equipment being installed.

For vertical (downflow) units, the building supply and return air ducts must be positioned to match the openings in the curb, which should line up with the supply and return openings in the unit. Curbs are usually installed by other trades during the building's construction and should conform to the standards in the unit's installation instructions *(Figure 10-13)*. The seal strip gasketing supplied with the curb must be placed on all horizontal surfaces of the curb, as directed in the instructions, to provide a watertight seal and prevent air leaks once the unit is installed. For many vertical applications, the supply and return air ducts are fastened to the roof curb rather than the unit.

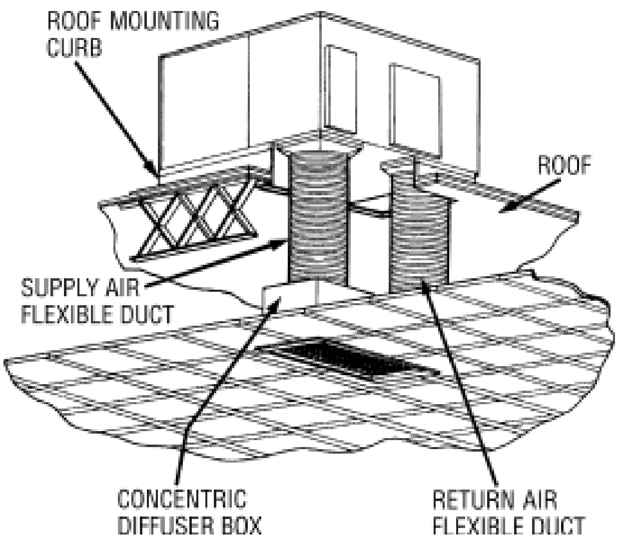
Rigging and Placing the Unit

Rigging should always be performed by qualified riggers and as directed in the unit installation instructions. Refer to Section 4 for detailed information on rigging procedures and equipment. Once the unit is mounted on the slab or curb, install accessories such as an economizer or damper kit, if used.

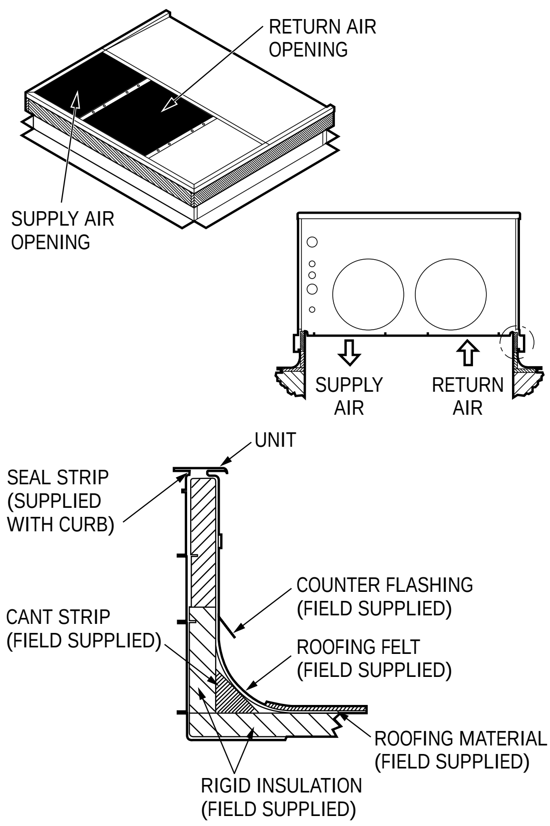
▼ Figure 10-11.
Heat Pump Snow Stand



▼ Figure 10-12.
Rooftop Unit – Vertical Application



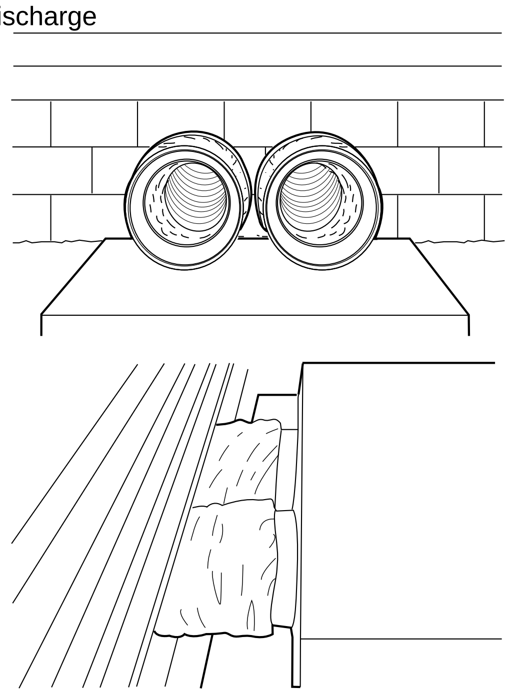
▼ Figure 10-13.
Typical Roof Curb Construction Details



Installing Air Distribution System Ductwork

The correct sizes and dimensions of the ductwork should have been determined during the pre-installation survey. Refer to Section 6 for guidelines pertaining to the installation of duct systems. All units should have field-supplied filters or an accessory filter rack installed in the return air side. For horizontal discharge units, the supply and return plenums can be connected to the unit with metal or flexible ducts *(Figure 10-14)*. For proper airflow, flexible ductwork must be positioned in a way that eliminates sharp bends or dips. For PAC/heat pump units with electric resistance heaters, make sure to observe the required minimum clearances from combustible materials. Insulate and weatherproof all exposed ductwork. Secure all ducts to the building structure. Flash, weatherproof, and vibration-isolate duct openings in the wall or roof according to good construction practices.

▼ Figure 10-14.
Flexible Air Ducts Connected for Horizontal Discharge

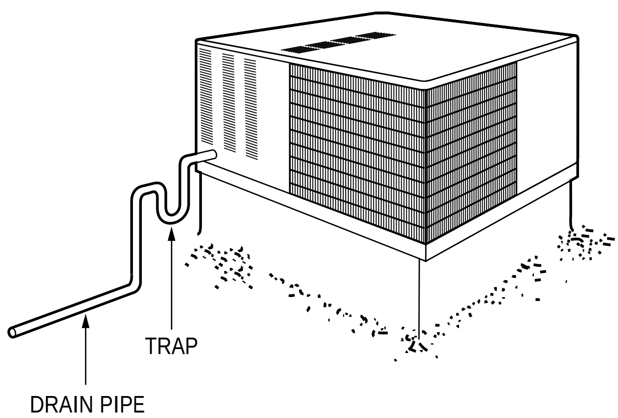


Condensate Drain Piping

Condensate piping must comply with local codes and restrictions and with the installation instructions. Slab-mounted units should be drained into a gravel apron. Where codes permit, the condensate water from rooftop units can be drained directly onto the roof. If not, the condensate must be piped to a suitable drain *(Figure 10-15)*. The pipe should be the same diameter as the unit's drain outlet throughout the length of the run. Pitch the drain pipe downward at least one inch per ten feet of horizontal run.

For both slab- and roof-mounted units, a condensate trap must be installed at the unit's condensate drain to ensure proper drainage. Make sure that the outlet of the trap is at least 4-1/4 inches lower than the unit condensate connection to prevent the condensate pan from overflowing. Once the trap is installed, prime it with water.

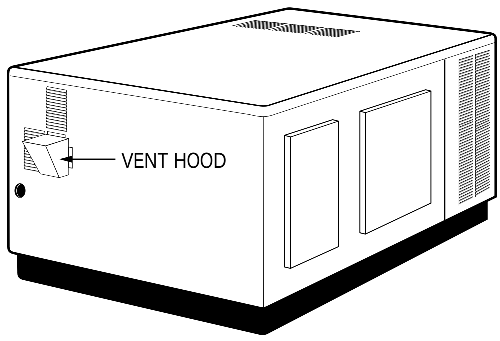
▼ Figure 10-15.
Rooftop Unit Condensate Drain Piping



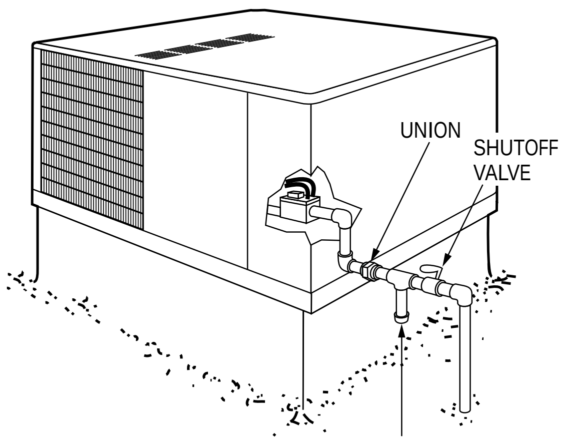
Installing Vent Hood and Gas Piping (YAC)

YAC units are shipped with a vent hood (flue hood) that must be installed over the unit's flue outlet per the installation instructions *(Figure 10-16)*. A gas supply line must be run to the heating section of the unit. All gas piping must comply with local codes and the manufacturer's installation instructions. To install the gas line, run a correctly-sized black iron pipe to the unit. Be sure that it is adequately supported and that it has a drip leg just outside the unit cabinet and a manual gas shutoff valve near the unit *(Figure 10-17)*. Install a ground joint union in the pipe to the main gas valve. Once the gas piping is installed, turn the gas on and purge the line of air by loosening the union slightly until an odor of gas is noticed, then re-tighten it. Following this, check all joints for leaks using a leak detecting solution. For detailed procedures used to correctly size gas pipe, refer to Section 8 and to the National Fuel Gas Code. For information about cutting, threading, and assembling gas pipe, refer to Section 5.

▼ Figure 10-16.
Vent Hood Installed on a YAC Unit



▼ Figure 10-17.
Gas Line Installation to a Rooftop YAC Unit



Power and Control Wiring

All wiring must comply with local codes and the manufacturer's installation instructions. For detailed guidelines for installing power and control circuit wiring, refer to Section 7.

Supply power to the unit must use a dedicated line equipped with a correctly-sized fuse or circuit breaker with a dedicated ground wire attached to the unit ground and to the earth ground in the electrical panel. A disconnect switch must also be installed at the unit. Note that codes in some areas may require that a separate disconnect be installed for electric heaters. When the power wiring is completed, leave the power turned off until you are ready to start up and check out the unit. Following this, install the room thermostat and control wiring.

Start-Up and Checkout

The unit must always be started up and fully checked out per the installation instructions before the technician leaves the site.

Cooling Checks - All Units – Start up and check out the cooling mode as follows:

1. If equipped with a crankcase heater, energize the heater for a minimum of 24 hours before starting the unit.
2. Prior to start-up, prime the condensate drain and trap. Turn on power to the unit.
3. Set the room thermostat to COOL, the fan switch to ON or AUTO, and the thermostat setpoint below room temperature. Operate the system for 30 minutes to allow system pressures and temperatures to stabilize.

QUICK NOTE

If the outdoor temperature is below 55° F, wait for a warmer day before operating the unit in the cooling mode.

QUICK NOTE

Packaged units come shipped from the factory fully charged and tested, and should require no charge adjustment. If the charge is incorrect, check the unit for leaks. Refer to Service Procedure SP-1 in the companion HVAC Servicing Procedures handbook for detailed information and procedures for leak detection. Refer to Service Procedure SP-4 for information and procedures pertaining to refrigerant charging.

During this time, make component and operational checks and clean up the area. Check the condensate drain operation.

While performing the various start-up tasks, the Packaged Unit Installation and Start-Up Checklist located on page 160 of this book should be used to check off each item when completed.

4. Check unit pressures and temperatures to determine if the charge is correct. If necessary, adjust the charge using the procedure shown on the unit charging label.

Heating Check - PAC with Electric Resistance Heating Elements – Check out the heating mode as follows:

1. Set the room thermostat to HEAT, the fan switch to ON or AUTO, and the thermostat setpoint above room temperature or jumper the thermostat R and W terminals.
2. Check that all heating elements are active, and make sure that the indoor fan motor starts when the call for heat is initiated.

Heating Check - Heat Pump – Check out the heating mode as follows:

1. Start with the unit operating in the cooling mode, then set the room thermostat to HEAT, the fan switch to ON or AUTO, and the thermostat setpoint above room temperature. Check that the indoor fan begins to blow warm air.
2. While the unit is running in the heating mode, "force" the unit into a defrost following the instructions in the manufacturer's service literature. ***To prevent compressor damage, do not operate a heat pump in the heating mode for extended periods if the outdoor temperature is above 65° F.***
3. If equipped with supplementary electric heaters, switch the room thermostat to supplemental heat and verify that the heaters are working.

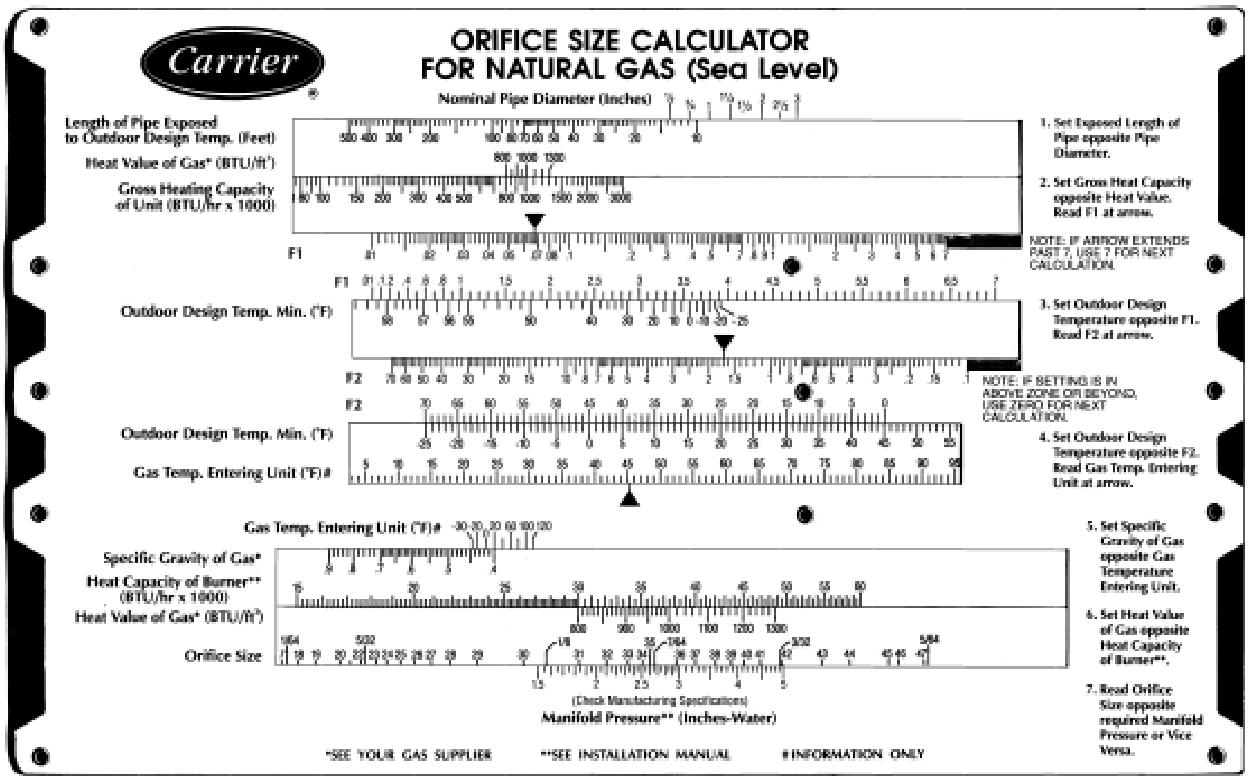
Heating Check - YAC – Check out the heating mode as follows:

1. If not done previously, turn the gas on and purge the line of air by loosening the ground joint union slightly until an odor of gas is noticed, then re-tighten it. ***NEVER PURGE GAS LINES IN A COMBUSTION CHAMBER.*** Check all joints for leaks using a leak detecting solution.
2. Check the unit's burner orifice size, gas input, and manifold pressure before unit start-up.
3. Set the room thermostat to HEAT, the fan switch to ON or AUTO, and the thermostat setpoint above room temperature.

Low outdoor temperatures can affect the heat content of the gas fed to the burners. A calculator *(Figure 10-18)* is available that helps determine the orifice size needed for correct burner operation. Orifice size is based on a number of factors including outdoor design temperature, the heat content and specific gravity of the gas supplied, and the length of exposed gas supply line pipe. Complete instructions are included on the calculator.

4. Adjust the room thermostat heat anticipator or cycle rate setting to prevent short cycling of the heating unit. Short cycling prevents the furnace from coming up to operating temperature, causing condensation to occur in the heat exchanger. Short cycling also contributes to poor indoor comfort. The procedure for anticipator adjustment is given in the installation instructions and in Section 8 of this book.

▼ Figure 10-18.
Orifice Size Calculator for Natural Gas



QUICK NOTE

For detailed information and the procedures for measuring airflow, refer to Service Procedures SP-14 through SP-17 in the companion HVAC Servicing Procedures handbook. Refer to Section 8 and/or Service Procedure SP-13 for the procedure used to measure temperature rise.

Airflow Check – For proper operation of the cooling system, the indoor blower should be moving 400 to 450 CFM of air across the coil for each ton of air conditioning. For heating operation, the airflow must produce a temperature rise that falls within the range stamped on the unit rating plate. Tables in the installation instructions give the required temperature rise at various airflow rates and heating and cooling airflows at various external static pressures. If required, adjust the indoor blower speed per the manufacturer's instructions to obtain the proper airflow for the unit.

Final Checks, Adjustments, and Tasks

With the unit operational, perform the following checks to complete the installation:

- Check for correct operation of accessories. If an outdoor air damper or economizer has been installed, adjust it in accordance with the installation instructions supplied with the damper or economizer. Check the economizer damper to be sure that the damper position is correct for the different modes of unit operation.
- Check the unit for any unusual noises or vibration.
- Adjust the balancing dampers in each branch duct for correct operation.
- Clean up the work area.

Before leaving the job site, explain the operation of the complete system to the customer. Describe how the system operates and run the system through a complete cycle so the customer can see and hear the normally operating system. If installed, demonstrate the operation of accessories. After the demonstration, present the customer with the owner's operating and service manual(s) and warranty.

APPENDIX

DUCTWORK CAPACITY TABLES

MAXIMUM RETURN AIR CFM
Panned Floor Joist & Wall Stud Spaces
(Framing on 16 in. centers)

NOMINAL JOIST SIZE	MAX. CFM
2 x 6	260
2 x 8	375
2 x 10	525
2 x 12	660
2 x 4 (wall)	130

MAXIMUM SUPPLY AIR CFM THROUGH DIFFUSERS

FLOOR (In.)	MAX. CFM
2 1/4 x 10	70
2 1/4 x 12	80
2 1/4 x 14	100
4 x 10	110
4 x 12	140
4 x 14	170
LOW SIDEWALL (In.)	**MAX. CFM**
10 x 6	80
12 x 6	100
14 x 6	120
HIGH SIDEWALL (In.)	**MAX. CFM**
10 x 4	100
10 x 6	150
12 x 6	200
14 x 6	225
BASEBOARD	**MAX. CFM**
2 Ft. Long	80
4 Ft. Long	140
6 Ft. Long	170
2 1/4 x 12 In.	80
2 1/4 x 14 In.	120
CEILING (In.) Round or Square Duct Connection Dia.	**MAX. CFM**
6	120
8	190
10	280

MAXIMUM RETURN AIR GRILLE CFM
Return grille velocities (FPM over total area)
Regular or Relief = 500 FPM (3.5 CFM/sq.in.)
Filter Grille = 300 FPM (2 CFM/sq.in.)
Undercut Door = 600 FPM (4 CFM/sq.in.)

SIZE (In.)	CFM*
10 x 6	130
12 x 6	160
12 x 8	220
14 x 6	190
14 x 8	240
24 x 6	320
24 x 8	420
30 x 6	400
30 x 8	500
12 x 12	340
12 x 18	530
18 x 18	810
18 x 24	1100
24 x 24	1490
24 X 30	1870

*Capacities do not deduct for a wall stud or floor joist blocking a grille which spans two framed spaces.

MAXIMUM CFM THROUGH RUNOUT DUCTWORK

RUNOUT SIZE (In.)	CFM	
	SUPPLY	RETURN
SHEET METAL OR DUCTBOARD		
5 Dia.	60	45
6 Dia.	100	75
7 Dia.	140	110
8 Dia.	210	160
3 1/4 x 8 Stack	70	55
3 1/4 x 10 Stack	100	75
3 1/4 x 14 Stack	140	110
2 1/4 x 12 Stack	70	55
2 1/4 x 14 Stack	90	70
FLEX DUCT*		
6 Dia.	55	40
8 Dia.	120	90
10 Dia.	200	160
12 Dia.	320	250
14 Dia.	480	375
16 Dia.	660	530
18 Dia.	880	680
20 Dia.	1200	900

*The maximum flex duct capacity fluctuates greatly depending upon length, bends, sags, etc. The numbers shown assume straight runs cut to proper length.

BALLPARK FIGURES

FRICTION LOSSES

ITEM	FRICTION LOSS (IN. W.C.)
WET EVAPORATOR	.25
ELECTRONIC AIR CLEANER	.10
SUPPLY DIFFUSER	.05
RETURN GRILLE	.05

RETURN OPENING SIZES

ITEM	VELOCITY TOTAL AREA (FPM)	CFM/SQ. IN. TOTAL AREA
Regular or Relief Grille	500	3.5
Filter-Grille	300	2
Undercut Doors	600	4

SHEET METAL DUCTWORK CAPACITIES (CFM)

CFM	DUCT SIZES (INCHES)						CFM
	SUPPLY			RETURN			
200	10 x 6	8 x 8		10 x 6	8 x 8		**200**
300	12 x 6	10 x 8		14 x 6	10 x 8		**300**
400	16 x 6	12 x 8	10 x 10	20 x 6	14 x 8	12 x 10	**400**
500	18 x 6	14 x 8	10 x 10	24 x 6	16 x 8	12 x 10	**500**
600	22 x 6	16 x 8	12 x 10	18 x 8	14 x 10	12 x 12	**600**
700	18 x 8	14 x 10	12 x 12	22 x 8	16 x 10	14 x 12	**700**
800	20 x 8	16 x 10	12 x 12	24 x 8	18 x 10	16 x 12	**800**
900	22 x 8	16 x 10	14 x 12	26 x 8	20 x 10	16 x 12	**900**
1000	24 x 8	18 x 10	14 x 12	28 x 8	22 x 10	18 x 12	**1000**
1200	28 x 8	22 x 10	18 x 12	34 x 8	26 x 10	20 x 12	**1200**
1400	32 x 8	24 x 10	20 x 12		30 x 10	24 x 12	**1400**
1600		26 x 10	22 x 12		32 x 10	26 x 12	**1600**
1800		30 x 10	24 x 12		36 x 10	28 x 12	**1800**
2000		32 x 10	26 x 12		38 x 10	30 x 12	**2000**

Supply duct sizes @ .08 in. w.g./100 ft. E.L./return @ .05 in. w.g./100 ft. E.L.

FIBERGLASS DUCTBOARD DUCTWORK CAPACITIES (CFM)

CFM	DUCT SIZES (INCHES)						CFM
	SUPPLY			RETURN			
200	10 x 6	8 x 8		12 x 6	8 x 8		**200**
300	14 x 6	10 x 8		16 x 6	12 x 8	10 x 10	**300**
400	18 x 6	12 x 8	10 x 10	20 x 6	14 x 8	12 x 10	**400**
500	20 x 6	14 x 8	12 x 10	26 x 6	18 x 8	14 x 10	**500**
600	24 x 6	16 x 8	14 x 10	20 x 8	16 x 10	12 x 12	**600**
700	20 x 8	14 x 10	12 x 12	22 x 8	18 x 10	14 x 12	**700**
800	22 x 8	16 x 10	14 x 12	26 x 8	20 x 10	16 x 12	**800**
900	24 x 8	18 x 10	14 x 12	28 x 8	22 x 10	18 x 12	**900**
1000	26 x 8	20 x 10	16 x 12	32 x 8	24 x 10	20 x 12	**1000**
1200	28 x 8	22 x 10	18 x 12		26 x 10	20 x 12	**1200**
1400	34 x 8	26 x 10	20 x 12		32 x 10	24 x 12	**1400**
1600		28 x 10	22 x 12		34 x 10	28 x 12	**1600**
1800		32 x 10	26 x 12	40 x 10	32 x 12	26 x 14	**1800**
2000		36 x 10	28 x 12		34 x 12	28 x 14	**2000**

Supply duct sizes @ .08 in. w.g./100 ft. E.L./return @ .05 in. w.g./100 ft. E.L.

APPROXIMATE CFM CAPACITY* OF EXISTING FURNACE FANS

FAN SCROLL SIZE (In.)		FAN MOTOR SIZE	COOLING COIL SIZE (TONS)						
Inlet Dia.	Scroll Width		1 1/2	2	2 1/2	3	3 1/2	4	5
8	9 1/2	1/6**	770	815	860				
8 1/2	11 1/2	1/4**	780	890	1000	1200			
8 1/2	11 1/2	1/3			1250	1330		1420	
8 1/2	11 1/2	1/2					1500	1600	1700
9	9 1/2	1/4**		1000	1160	1230			
9	9 1/2	1/3						1240	
10 1/2	10 1/2	1/3		1000	1220	1350	1400	1450	1500
10 1/2	10 1/2	1/2						1550	1640
10 1/2	10 1/2	3/4					1700	1800	1910
10 1/2	13 1/2	1/3				1500	1560	1620	
10 1/2	13 1/2	1/2						2000	2050
10 1/2	13 1/2	3/4							2300

* Ratings include static pressure loss (friction loss) of wet evaporator coil, clean filter and 0.2 in. w.g. allowance for air distribution system.

** Direct-drive motors smaller than 1/3 HP are usually not suitable for air conditioning.

GAS FURNACE INSTALLATION & START-UP CHECKLIST

LOAD CALCULATION AND EQUIPMENT SELECTION

- ☐ Heat loss ____________ Btuh @ ____________ °F design temperature
- ☐ Furnace selected Model # _______________
- ☐ Furnace input rate _______________ Btuh
- ☐ Supplied gas heat content _______________ Btu/ft.^{3}
- ☐ Supplied gas specific gravity _______________
- ☐ Burner orifice size _______________

FURNACE INSTALLATION

- ☐ Furnace level and plumb
- ☐ Supply/return ducts securely attached
- ☐ Gas supply pipe sized per installation instructions
  Diameter ________________ NPT
- ☐ Gas shut-off, sediment trap, and union installed in gas pipe
- ☐ Power and thermostat wire sized and installed per wiring diagram and code
- ☐ Branch circuit wire size ________________ AWG
- ☐ Circuit breaker size ________________ amps

CHIMNEY/VENT INSTALLATION

- ☐ Existing chimney/vent type noted
  ☐ Lined masonry ☐ Type-B double-wall
  ☐ Unlined masonry (must reline to use)
- ☐ Existing chimney/vent adequately sized per installation instructions
  Chimney _____ x _____ B vent _____ diameter
- ☐ New chimney/chimney liner/vent installed and sized per installation instructions
  Chimney _____ x _____ B vent/liner _____ diameter
- ☐ Vent connector size and type per installation instructions
  ☐ Single-wall pipe ☐ Double-wall pipe
  Vent connector length ________________ ft.
- ☐ Water heater common-vented with furnace
  Water heater input ________________ Btuh
  Vent connector ________________ diameter

CONDENSING FURNACES ONLY

- ☐ Combustion air/vent pipe sized per installation instructions
  Combustion air pipe ________ diameter
  Vent pipe ________ diameter
- ☐ Termination kit correctly installed
- ☐ Condensate piping installed per installation instructions

AIR DISTRIBUTION SYSTEM

- ☐ Ductwork sized to handle air delivery of furnace
- ☐ Branch runs at least 6" in diameter with balancing damper installed
- ☐ Ductwork insulated and equipped with vapor barrier (if applicable)
- ☐ Flexible connectors provided in return and supply ducts at furnace

FURNACE START-UP

- ☐ Gas piping checked for leaks
- ☐ Pilot lit (if applicable)
- ☐ Clean air filter in place
- ☐ All return and supply grilles open and unrestricted
- ☐ Burners fired and input rate checked/adjusted (use Manifold Pressure Calculator, Cat. #020-444)
- ☐ Temperature rise checked/adjusted and in correct range
  Measured rise ________________°F
- ☐ Thermostat heat anticipator setting checked/adjusted
  Anticipator setting ________________ amps
- ☐ Limit switch operation checked per installation instructions

GENERAL

- ☐ All thermostat functions operate correctly (heat, cool, fan)
- ☐ Optional and field-installed accessories, such as humidifiers, operate properly
- ☐ Furnace and ducts checked for noise/vibration
- ☐ Balancing dampers adjusted for correct airflow to each branch run
- ☐ All work areas cleaned up
- ☐ System operation reviewed with customer and Owner's Manual presented

RESIDENTIAL SPLIT SYSTEM COOLING INSTALLATION & START-UP CHECKLIST

LOAD CALCULATION AND EQUIPMENT SELECTION

- ☐ Heat gain ________ Btuh @ ________ °F design temp.
- ☐ Condensing unit selected Model # _______________
- ☐ Evaporator coil selected Model # _______________
- ☐ Refrigerant lines sized per installation instructions Liquid ________ Suction ________ Length ________
- ☐ HACR circuit breaker size ____________amps
- ☐ Branch circuit wire size ____________ AWG

OUTDOOR UNIT INSTALLATION

- ☐ Unit secured to pad with correct clearance for airflow and service
- ☐ Raintight disconnect installed within sight of unit
- ☐ Wiring done in accordance with wiring diagram and all applicable codes
- ☐ Refrigerant lines properly trapped, insulated, secured, and connected to service valves
- ☐ Shipping brackets/compressor bolts removed and/or loosened per instructions
- ☐ Optional and field-supplied accessories, such as filter drier, properly installed

INDOOR UNIT INSTALLATION

- ☐ "A" coil installed in furnace plenum for proper airflow and condensate drainage
- ☐ Fan coil securely mounted with provisions for vibration isolation
- ☐ Secondary drain pan installed under above-ceiling fan coils
- ☐ Correctly-sized metering device installed (TXV or metering piston)
- ☐ Refrigerant lines properly connected
- ☐ Condensate drain installed with trap
- ☐ All accessories/options correctly installed
- ☐ Air filters clean and in place

AIR DISTRIBUTION SYSTEM

- ☐ Ductwork sized to handle 400-500 CFM/ton of capacity
- ☐ Branch runs at least 6" in diameter with balancing damper installed
- ☐ Ductwork insulated and equipped with vapor barrier (if applicable)
- ☐ Flexible connectors provided in return and supply duct at furnace or air handler
- ☐ Air supply and return air grilles open and unrestricted

OUTDOOR UNIT START-UP

- ☐ Refrigerant lines and indoor coil evacuated to at least 500 microns
- ☐ Service valves opened
- ☐ All field-made refrigerant line connections checked for leaks
- ☐ Crankcase heater (if used) energized 24 hours prior to start-up
- ☐ Compressor and outdoor fan run on call for cooling
- ☐ Refrigerant charge correct (use superheat method for fixed restrictor metering devices or subcooling method for TXV-equipped cooling coils)

  ________ °F measured superheat

  ________ °F measured subcooling

INDOOR UNIT START-UP

- ☐ Condensate flows freely from drain
- ☐ No air leaks in system ductwork
- ☐ Air flows freely from all supply registers
- ☐ Airflow adequate (use airflow range calculator, Cat. #020-517)

GENERAL

- ☐ All thermostat functions operate correctly (heat, cool, fan)
- ☐ All accessory items operate correctly
- ☐ Outdoor unit/air handler/refrigerant lines checked for vibration
- ☐ Balancing dampers adjusted for correct airflow to each branch run
- ☐ All work areas cleaned up
- ☐ System operation reviewed with customer and Owner's Manual presented

PACKAGED UNIT INSTALLATION & START-UP CHECKLIST

Unless otherwise specified, checklist items apply to all units.

SYSTEM DESIGN

- ☐ Heating and cooling loads properly calculated
- ☐ Equipment (and electric heat, if applicable) sized in accordance with local utility and manufacturer directives
- ☐ Maximum thermal balance point in accordance with local utility standard
- ☐ Outdoor thermostats set at proper balance points
- ☐ Circuit breakers, disconnects, and wiring properly sized
- ☐ Properly designed and installed ductwork to handle 400-500 CFM/ton capacity
- ☐ Ductwork insulated and equipped with vapor barrier (if applicable)

UNIT INSTALLATION

- ☐ Unit elevated for snow clearance and defrost water drainage (if applicable)
- ☐ Unit placed on pad or curb with correct clearance for airflow and service
- ☐ Curb installed per instructions
- ☐ Raintight disconnect(s) installed within sight of unit
- ☐ Wiring done in accordance with wiring diagram and code
- ☐ Electrical connections and terminals tight
- ☐ Gas piping done in accordance with installation instructions, local and national codes (YAC)
- ☐ Gas supply line purged and checked for leaks (YAC)
- ☐ Burner orifices properly aligned (YAC)
- ☐ Vent hood installed per instructions (YAC)
- ☐ Optional and field-supplied accessories installed properly
- ☐ Fan(s) rotate freely without binding or hitting and properly located in housing/orifice
- ☐ Condensate drain installed per installation instructions
- ☐ Air filters clean and in place

OUTDOOR AIR DAMPER

- ☐ Outdoor air damper properly installed
- ☐ Outdoor air damper set per job specifications

UNIT START-UP

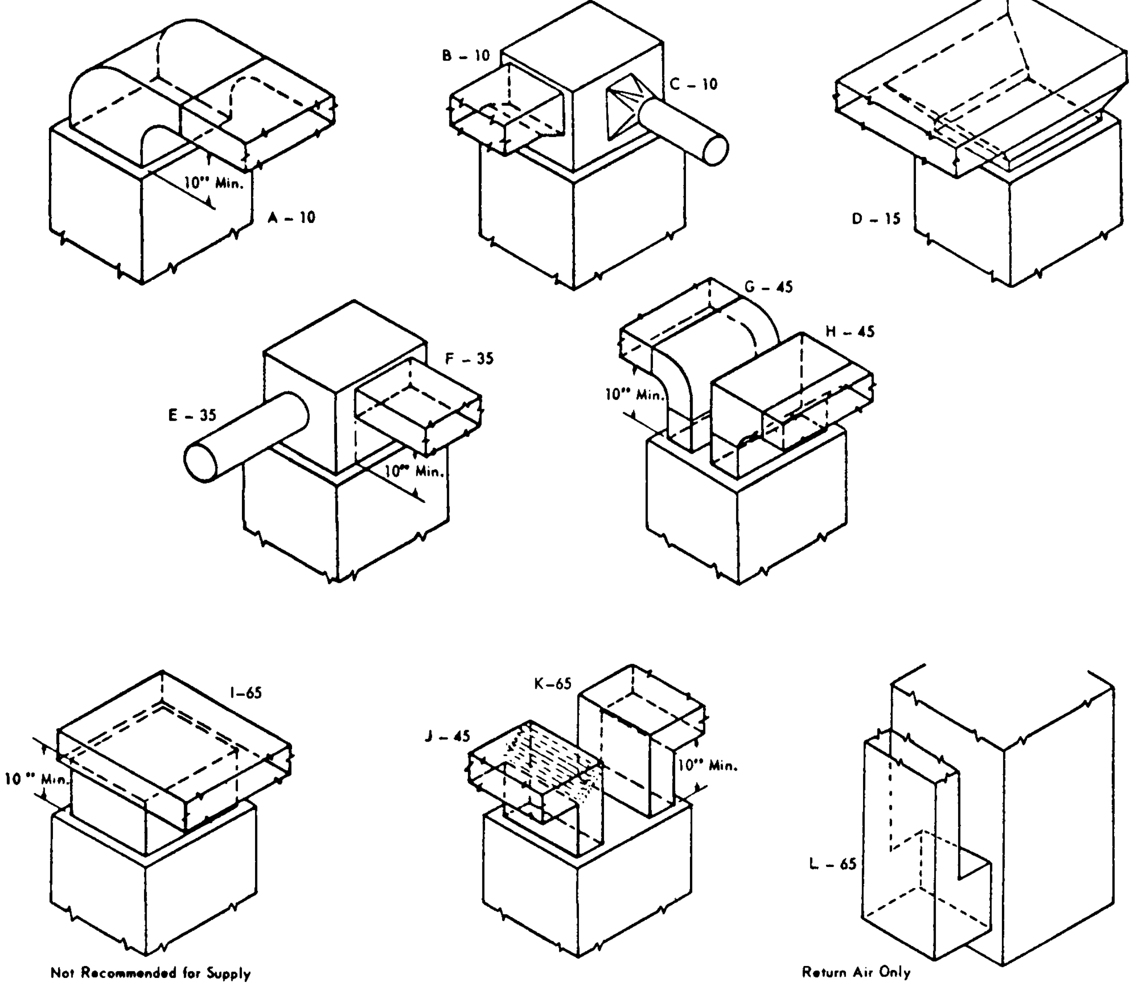
- ☐ Crankcase heater energized 24 hours prior to start-up
- ☐ Compressor and outdoor/indoor fans run on call for cooling
- ☐ Airflow adequate
- ☐ Refrigerant charge correct
- ☐ Condensate flows freely from drain
- ☐ Compressor and outdoor/indoor fans shut off on a satisfied call for cooling
- ☐ Compressor and outdoor/indoor fans run on a call for heating (Heat Pump)
- ☐ Verify defrost cycle operates properly (Heat Pump)
- ☐ Compressor and outdoor/indoor fans shut off on a satisfied call for heating (Heat Pump)
- ☐ Verify electric heater is working properly (PAC and Heat Pump)
- ☐ Burner(s) fired and indoor fan runs on a call for heating (YAC)
- ☐ Gas input and manifold pressure checked and adjusted (if required) per installation instructions (YAC)
- ☐ Indoor fan and burner(s) go out on a satisfied call for heating (YAC)
- ☐ Indoor fan rpm correct

GENERAL

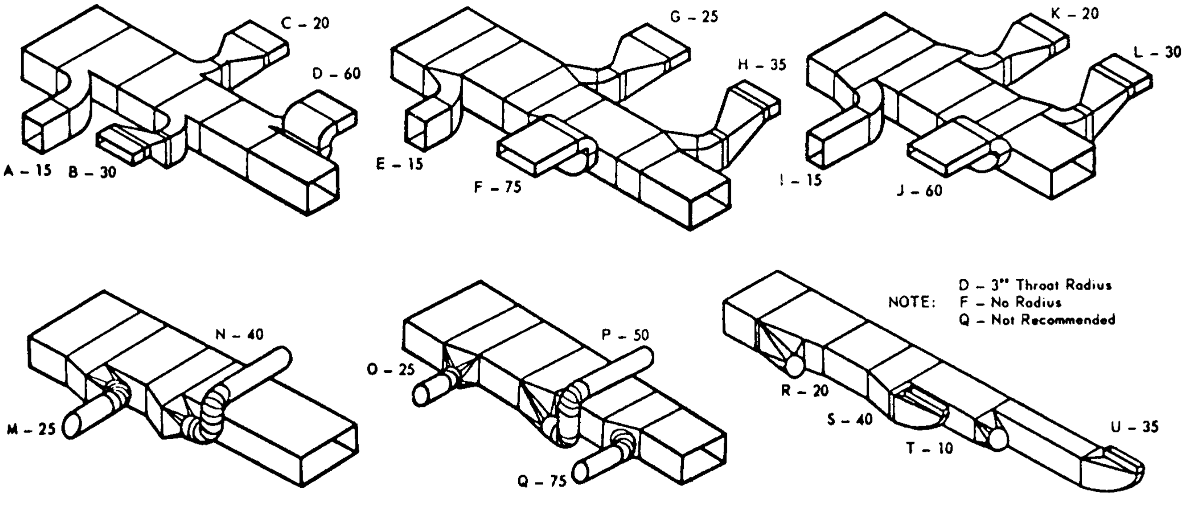
- ☐ Voltage and amperage imbalance for three-phase units are within accepted limits (2% voltage, 10% amperage)
- ☐ All thermostat functions operate correctly (fan, cool, and heat)
- ☐ All accessory items operating correctly
- ☐ All supply and return air grilles open and unrestricted
- ☐ Air flows freely from all supply registers. No air leaks in system ductwork
- ☐ Balancing dampers adjusted for correct airflow to each branch run
- ☐ All work areas cleaned up. All packing materials removed from equipment
- ☐ System operation reviewed with customer and Owner's Manual presented

DUCT FITTINGS AND EQUIVALENT LENGTHS

GROUP 1. SUPPLY AND RETURN AIR TAKE-OFF PLENUM FITTINGS
(These fittings may also be installed on plenums for counter flow units.)

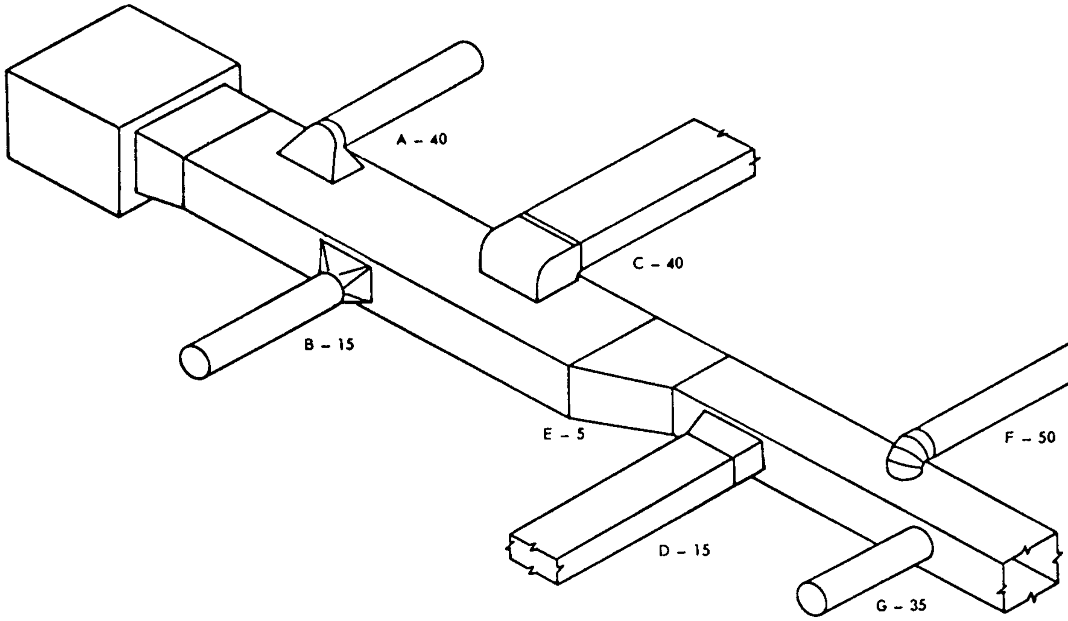


GROUP 2. REDUCING TRUNK DUCT FITTINGS



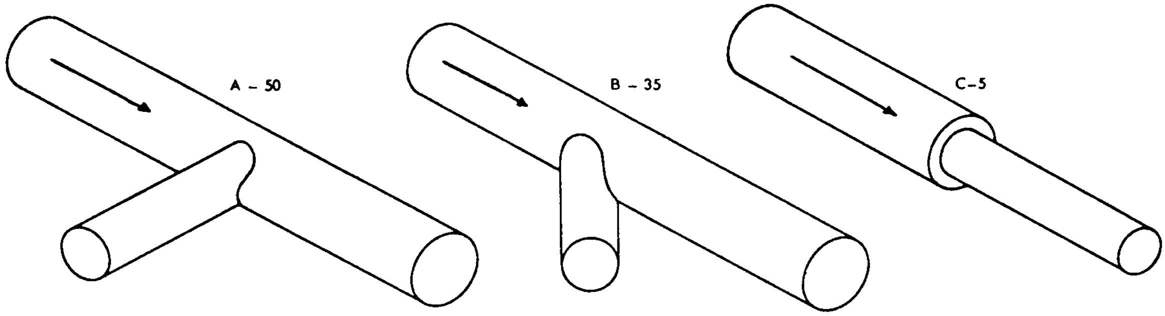
GROUP 3. EXTENDED PLENUM FITTINGS

(Add 25 equivalent feet to each of the 3 fittings nearest the unit in each Trunk Duct and after a reduction.)



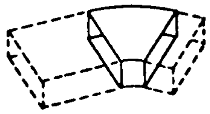
GROUP 4. ROUND TRUNK DUCT FITTINGS

(Add 25 equivalent feet to each of the 3 fittings nearest the unit in each Trunk Duct)



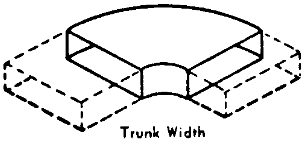
GROUP 5. ANGLES AND ELBOWS FOR TRUNK DUCTS

(Inside Radius = ½ Width of Duct)



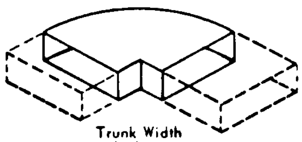
Trunk Width Inches

A – 4 to 15	5
A – 16 to 27	10
A – 28 to 41	15
A – 42 to 52	20
A – 53 to 64	25



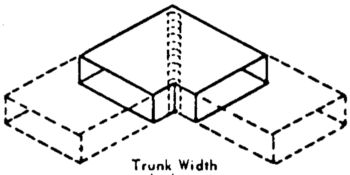
Trunk Width Inches

B – 4 to 11	10
B – 12 to 21	15
B – 22 to 27	20
B – 28 to 33	25
B – 34 to 42	30
B – 43 to 51	40
B – 52 to 64	50



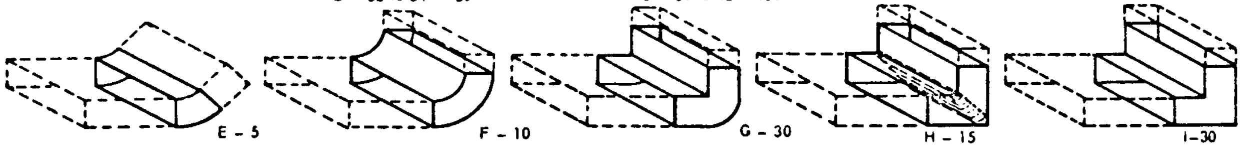
Trunk Width Inches

C – 4 to 6	20
C – 7 to 11	40
C – 12 to 15	55
C – 16 to 21	75
C – 22 to 27	100
C – 28 to 33	125
C – 34 to 42	150

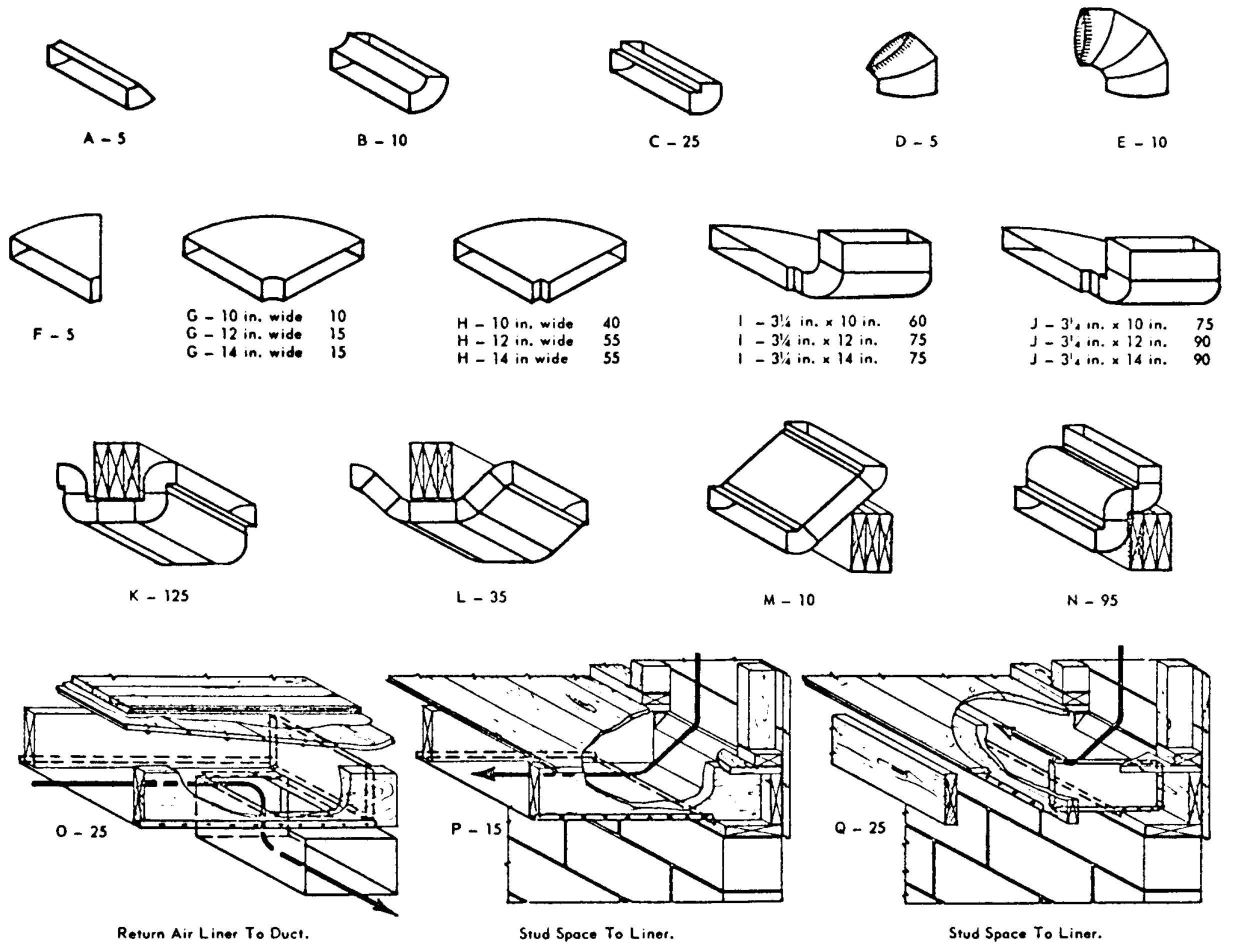


Trunk Width Inches

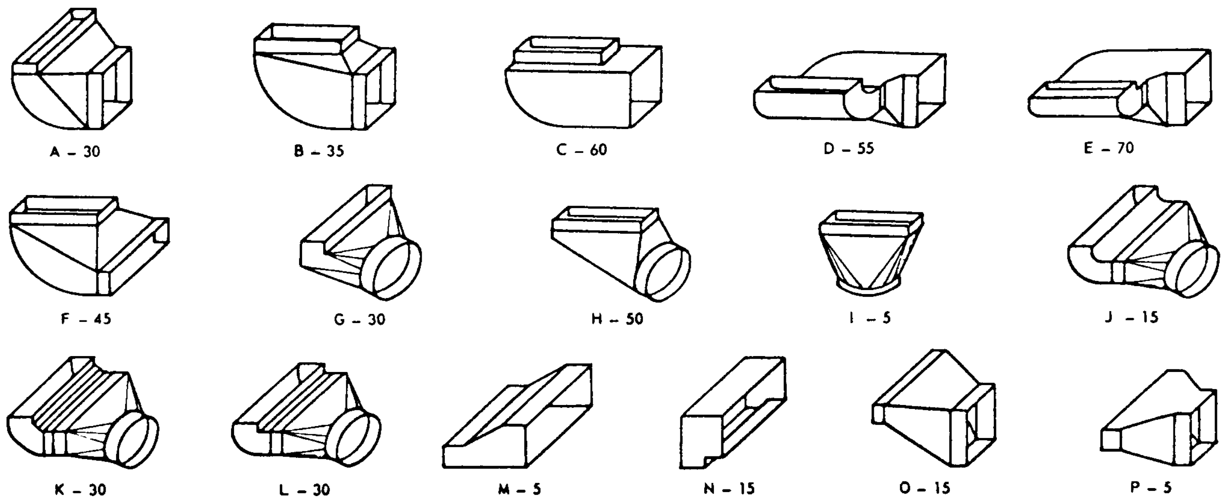
D – 4 to 11	15
D – 12 to 21	20
D – 22 to 27	25
D – 28 to 42	40



GROUP 6. ANGLES AND ELBOWS FOR INDIVIDUAL AND BRANCH DUCTS
(Inside Radius for "A" and "B" = 3 in. and for "F" and "G" = 5 in.)



GROUP 7. BOOT FITTINGS
(These values may also be used for floor Diffuser Boxes)



WEIGHTS AND MEASURES

LINEAR MEASURE

1 inch		=	2.54	centimeters
12 inches	= 1 foot	=	0.3048	meter
3 feet	= 1 yard	=	0.9144	meter
5½ yards or 16½ feet	= 1 rod (or pole or perch)	=	5.029	meters
40 rods	= 1 furlong	=	201.17	meters
8 furlongs or 1760 yards or 5280 feet	= 1 (statute) mile	=	1609.3	meters
3 miles	= 1 (land) league	=	4.83	kilometers

SQUARE MEASURE

1 square inch		=	6.452	square centimeters
144 square inches	= 1 square foot	=	929	square centimeters
9 square feet	= 1 square yard	=	0.8361	square meter
30¼ square yards	= 1 square rod (or square pole or square perch)	=	25.29	square meters
160 square rods or 4840 square yards or 43,560 square feet	= 1 acre	=	0.4047	hectare
640 acres	= 1 square mile	=	259	hectares or 2.59 square kilometers

CUBIC MEASURE

1 cubic inch		=	16.387	cubic centimeters
1728 cubic inches	= 1 cubic foot	=	0.0283	cubic meter
27 cubic feet	= 1 cubic yard	=	0.7646	cubic meter
	(in units for cordwood, etc.)			
16 cubic feet	= 1 cord foot			
8 cord feet	= 1 cord	=	3.625	cubic meters

DRY MEASURE

1 pint		= 33.60 cubic inches	=	0.5505 liter
2 pints	= 1 quart	= 67.20 cubic inches	=	1.1012 liters
8 quarts	= 1 peck	= 537.61 cubic inches	=	8.8096 liters
4 pecks	= 1 bushel	= 2150.42 cubic inches	=	35.2383 liters

1 British dry quart = 1.032 U.S. dry quarts

WEIGHTS AND MEASURES

LIQUID MEASURE

1 gill	=	4 fluid ounces	=	7.219 cubic inches	=	0.1183 liter
4 gills	=	1 pint	=	28.875 cubic inches	=	0.4732 liter
2 pints	=	1 quart	=	57.75 cubic inches	=	0.9463 liter
4 quarts	=	1 gallon	=	231 cubic inches	=	3.7853 liters

British imperial gallon (4 imperial quarts) = 277.42 cubic inches = 4.546 liters

TIME MEASURE

60 seconds	=	1 minute
60 minutes	=	1 hour
24 hours	=	1 day
7 days	=	1 week
4 weeks (28 to 31 days)	=	1 month
12 months (365 or 366 days)	=	1 year
100 years	=	1 century

ANGULAR AND CIRCULAR MEASURE

60 seconds	=	1 minute
60 minutes	=	1 degree
90 degrees	=	1 right angle
180 degrees	=	1 straight angle
360 degrees	=	1 circle

TROY WEIGHT

24 grains	=	1 pennyweight
20 pennyweights	=	1 ounce
12 ounces	=	1 pound

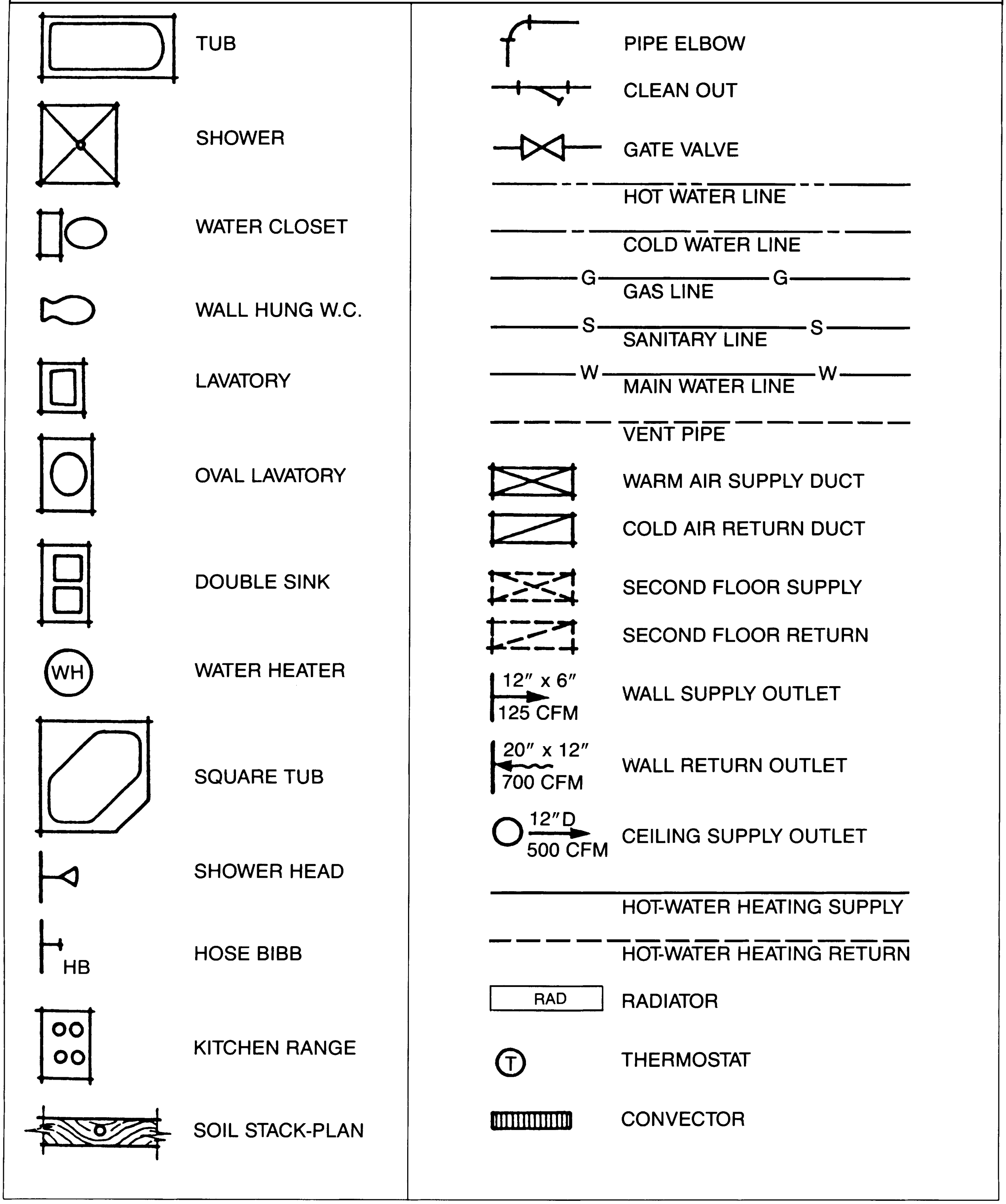
AVOIRDUPOIS WEIGHT

$27\frac{11}{32}$ grains	=	1 dram
16 drams	=	1 ounce
16 ounces	=	1 pound
100 pounds	=	1 short hundredweight
20 short hundredweight	=	1 short ton

LENGTH CONVERSIONS

Fractional inch	Millimeters	Decimal inch	Millimeters	Inch	Centimeters	Feet	Meters
1/32	.7938	0.001	.0254	1	2.54	1	.3048
1/16	1.588	0.002	.0508	1 1/4	3.175	1 1/2	.4572
3/32	2.381	0.003	.0762	1 1/2	3.81	2	.6096
1/8	3.175	0.004	.1016	1 3/4	4.445	2 1/2	.7620
5/32	3.969	0.005	.1270	2	5.08	3	.9144
3/16	4.763	0.006	.1524	2 1/4	5.715	3 1/2	1.067
7/32	5.556	0.007	.1778	2 1/2	6.35	4	1.219
1/4	6.350	0.008	.2032	2 3/4	6.985	4 1/2	1.372
9/32	7.144	0.009	.2286	3	7.62	5	1.524
5/16	7.938	0.010	0.254	3 1/4	8.225	5 1/2	1.676
11/32	8.731	0.020	0.508	3 1/2	8.89	6	1.829
3/8	9.525	0.030	0.762	3 3/4	9.525	6 1/2	1.981
13/32	10.32	0.040	1.016	4	10.16	7	2.133
7/16	11.11	0.050	1.270	4 1/4	10.80	7 1/2	2.286
15/32	11.91	0.060	1.524	4 1/2	11.43	8	2.438
1/2	12.70	0.070	1.778	4 3/4	12.07	8 1/2	2.591
17/32	13.49	0.080	2.032	5	12.70	9	2.743
9/16	14.29	0.090	2.286	5 1/4	13.34	9 1/2	2.896
19/32	15.08	0.100	2.540	5 1/2	13.97	10	3.048
5/8	15.88	0.200	5.080	5 3/4	14.61	10 1/2	3.200
21/32	16.67	0.300	7.620	6	15.24	11	3.353
11/16	17.46	0.400	10.16	6 1/2	16.51	11 1/2	3.505
23/32	18.26	0.500	12.70	7	17.78	12	3.658
3/4	19.05	0.600	15.24	7 1/2	19.05	15	4.572
25/32	19.84	0.700	17.78	8	20.32	20	6.096
13/16	20.64	0.800	20.32	8 1/2	21.59	25	7.620
27/32	21.43	0.900	22.86	9	22.86	50	15.24
7/8	22.23	1.000	25.40	9 1/2	24.13	100	30.48
29/32	23.02			10	25.40		
15/16	23.81			10 1/2	26.67		
31/32	24.61			11	27.94		
1	25.40			11 1/2	29.21		

PLUMBING AND HEATING SYMBOLS USED ON WORKING DRAWINGS



ELECTRICAL SYMBOLS USED ON WORKING DRAWINGS

GENERAL OUTLETS

- CEILING OUTLET
- WALL OUTLET
- FAN OUTLET
- LAMP & PULL SWITCH

SWITCH OUTLETS

- SINGLE-POLE SWITCH
- DOUBLE-POLE SWITCH
- THREE-WAY SWITCH
- FOUR-WAY SWITCH

CONVENIENCE OUTLETS

- DUPLEX OUTLET
- WATERPROOF OUTLET
- RANGE OUTLET
- SWITCH & DUPLEX OUTLET
- TRIPLEX OUTLET
- SPECIAL-PURPOSE OUTLET
- FLOOR OUTLET
- DUPLEX OUTLET FOR GROUND

AUXILIARY

- DOORBELL BUTTON
- BUZZER
- BELL
- TELEPHONE
- INTERCOM
- MOTOR OUTLET
- LIGHTING PANEL
- SPECIAL AUXILIARY OUTLET

DECIMAL SIZES OF NUMBERED DRILLS

No.	Size of Drill In Inches	No.	Size of Drill In Inches	No.	Size of Drill In Inches	No.	Size of Drill In Inches
1	.2280	21	.1590	41	.0960	61	.0390
2	.2210	22	.1570	42	.0935	62	.0380
3	.2130	23	.1540	43	.0890	63	.0370
4	.2090	24	.1520	44	.0860	64	.0360
5	.2055	25	.1495	45	.0820	65	.0350
6	.2040	26	.1470	46	.0810	66	.0330
7	.2010	27	.1440	47	.0785	67	.0320
8	.1990	28	.1405	48	.0760	68	.0310
9	.1960	29	.1360	49	.0730	69	.0292
10	.1935	30	.1285	50	.0700	70	.0280
11	.1910	31	.1200	51	.0670	71	.0260
12	.1890	32	.1160	52	.0635	72	.0250
13	.1850	33	.1130	53	.0595	73	.0240
14	.1820	34	.1110	54	.0550	74	.0225
15	.1800	35	.1100	55	.0520	75	.0210
16	.1770	36	.1065	56	.0465	76	.0200
17	.1730	37	.1040	57	.0430	77	.0180
18	.1695	38	.1015	58	.0420	78	.0160
19	.1660	39	.0995	59	.0410	79	.0145
20	.1610	40	.0980	60	.0400	80	.0135

DECIMAL SIZES OF LETTERED TWIST DRILLS

Letter	Dia. In.	Letter	Dia. In.	Letter	Dia. In.
A	0.234	J	0.277	S	0.348
B	0.238	K	0.281	T	0.358
C	0.242	L	0.290	U	0.368
D	0.246	M	0.295	V	0.377
E	0.250	N	0.302	W	0.386
F	0.257	O	0.316	X	0.397
G	0.261	P	0.323	Y	0.404
H	0.266	Q	0.332	Z	0.413
I	0.272	R	0.339		

Tap Drill Sizes For American Standard Threads

Diam. of Thread	Threads per Inch	Drill*	Decimal Equiv.
No. 0—.060	80 NF	3/64	.0469
1—.073	64 NC	1.5 MM	.0591
	72 NF	53	.0595
2—.086	56 NC	50	.0700
	64 NF	50	.0700
3—.099	48 NC	5/64	.0781
	56 NF	45	.0820
4—.112	40 NC	43	.0890
	48 NF	42	.0935
5—.125	40 NC	38	.1015
	44 NF	37	.1040
6—.138	32 NC	36	.1065
	40 NF	33	.1130
8—.164	32 NC	29	.1360
	36 NF	29	.1360
10—.190	24 NC	25	.1495
	32 NF	21	.1590
12—.216	24 NC	16	.1770
	28 NF	14	.1820
1/4	20 NC	7	.2010
	28 NF	3	.2130
	32 NEF	7/32	.2188
5/16	18 NC	F	.2570
	24 NF	I	.2720
	32 NEF	9/32	.2812
3/8	16 NC	5/16	.3125
	24 NF	Q	.3320
	32 NEF	11/32	.3438
7/16	14 NC	U	.3680
	20 NF	25/64	.3906
	28 NEF	Y	.4040
1/2	12 N	27/64	.4219
	13 NC	27/64	.4219
	20 NF	29/64	.4531
	28 NEF	15/32	.4687

Tap Drill Sizes For American Standard Threads (Cont'd)

Diam. of Thread	Threads per inch	Drill*	Decimal Equiv.
9/16	12 NC	31/64	.4844
	18 NF	33/64	.5156
	24 NEF	33/64	.5156
5/8	11 NC	17/32	.5312
	12 N	35/64	.5469
	18 NF	14.5 MM	.5709
	24 NEF	37/64	.5781
11/16	12 N	39/64	.6094
	24 NEF	16.5 MM	.6496
	10 NC	16.5 MM	.6496
3/4	12 N	17 MM	.6693
	16 NF	17.5 MM	.6890
	20 NEF	45/64	.7031
13/16	12 N	18.5 MM	.7283
	16 N	3/4	.7500
	20 NEF	49/64	.7656
7/8	9 NC	49/64	.7656
	12 N	20 MM	.7874
	14 NF	25.5 MM	.8071
	16 N	13/16	.8125
	20 NEF	21 MM	.8268
15/16	12 N	55/64	.8594
	16 N	7/8	.8750
	20 NEF	22.5 MM	.8858
1	8 NC	7/8	.8750
	12 N	59/64	.9219
	14 NF	23.5 MM	.9252
	16 N	15/16	.9375
	20 NEF	61/64	.9531
1½	6 NC	1 21/64	1.3281
	8 N	1 3/8	1.3750
	12 NF	36 MM	1.4173
	16 N	1 7/16	1.4375
	18 NEF	1 29/64	1.4531

Tap Drill Sizes For American Standard Threads (Cont'd)

Diam. of Thread	Threads per Inch	Drill*	Decimal Equiv.
2	4½ NC	1 25/32	1.7812
	8 N	1 7/8	1.8750
	12 N	1 59/64	1.9219
	16 NEF	1 15/16	1.9375
2½	4 NC	2¼	2.2500
	8 N	2⅜	2.3750
	12 N	61.5 MM	2.4213
	16 N	2 7/16	2.4375
3	4 NC	2¾	2.7500
	8 N	2⅞	2.8750
	12 N	74 MM	2.9134
	16 N	2 15/16	2.9375

*To produce approximately 75% full thread

GLOSSARY OF TERMS

ABS (Acrylonitrile Butadiene Styrene)
Plastic material used in the manufacture of pipe and fittings.

Absolute Pressure
Pressure measurements which are compared to absolutely no pressure at all, not even atmospheric pressure; e.g., psia and in. Hg abs.

ACR Tubing
Air conditioning and refrigeration tubing that is cleaned, dried, and sealed to keep contaminants from entering the tubing. It is often charged with dry nitrogen.

Adapter
Fitting that joins pipes of different materials or different sizes.

AFUE
Annual fuel utilization efficiency; the annualized average efficiency of a fuel-fired appliance, taking into account the effect of on-off operation.

AGA
American Gas Association.

Air Handler
The device that moves the air across the heat exchanger in a forced-air system. In a split system, it normally contains the blower fan, cooling coil, metering device, air filter, and related housing.

Alloy
Any substance made up of two or more metals.

Alternating Current (AC)
An electrical current that reverses (alternates) its direction of flow at regular intervals. AC is the primary source of energy for homes and businesses and is used when large amounts of energy are required. (See DC.)

Ambient Temperature
The temperature of the fluid (usually air) surrounding an object.

Ammeter
A device, calibrated in amperes, that is used to measure electric current.

Ampere or Amp (A)
A unit of electric current.

Anchor
A device used to fasten structural members in place.

Anemometer
An instrument used to measure the velocity of airflow.

Annealing
Heat treating to soften metal. Soft copper tubing is made by annealing hard copper.

Aquastat
A temperature-controlled sensory device. It can function both as an operating control and as a limit control. As an operating control, it can be used as the sensor to control the level of the water in a device reservoir based on the temperature of the water in the reservoir. As a limit control, it can be used to turn a device on or off based on the temperature of the water.

Armored Cable
A flexible, metallic-sheathed cable used for indoor wiring; commonly called *BX* or *Greenfield*.

Arrestor (Lightning Rod)
A device used to protect buildings, including electrical devices, from damage by lightning.

ASHRAE
American Society of Heating, Refrigerating, and Air-Conditioning Engineers.

Aspect Ratio
In air distribution outlets, this represents the ratio of the length of the core opening of a grille face or register to the width. In rectangular ducts, it is the ratio of the width to the depth.

Atmospheric Pressure
: The pressure exerted on all things on the Earth's surface that are a result of the weight of our atmosphere.

Automatic Changeover Thermostat
: A thermostat that automatically selects either heating or cooling, depending on room temperature and the heating and cooling setpoints.

Axial Load
: An external load that acts lengthwise along a shaft.

Back-Seated
The condition of a service valve in which the valve stem is turned fully counterclockwise and the valve is fully open.

Baffle
A sheet metal device that blocks or changes the direction of air, generally to make it turn a corner or distribute into a room.

Bonding
The permanent adhesion of metallic parts, forming an electrically-conductive path.

Boot
A fitting installed in the airstream at the termination of a branch duct to a room.

Box
A device used to contain wire terminations where they connect to other wires, switches, or receptacles.

Branch
The portion of the duct system connecting to a main duct.

Branch Circuit
Wiring between the last overcurrent device and the branch circuit outlets or load device.

Brazing
A method of joining metals using a nonferrous (no iron) filler at a temperature above 800° F.

Break-Away Torque
The torque required to loosen a fastener. This is usually less than the torque required to tighten the fastener.

Btu (British Thermal Unit)
The amount of heat required to raise the temperature of one pound of water 1° F.

Btuh (Btu's per hour)
The basic unit for measuring the rate of heat transfer.

Building Code
A set of rules governing the quality of construction in a community. The purpose of these rules is to protect the public health and safety.

Burr
A sharp, roughened, turned-in edge on a piece of pipe that has been cut but not reamed.

Bus Bar
A rigid conductor at the main power source to which three or more circuits are connected.

Bushing
(1) A pipe fitting with both male and female threads. Used in a fitting to reduce the size to connect pipes of different sizes. (2) A device used to mechanically protect and insulate electrical wires passing through abrasive openings.

Cable
A conductor consisting of two or more wires that are grouped together with an overall covering, such as a plastic sheath.

Capillary Action
Movement of a liquid (in soldering or brazing, nonferrous filler metal) along the surface of a solid in a kind of spreading action.

Capillary Tube
A long copper tube with a diameter of 1/16 to 1/8 inch.
Used as a refrigerant metering device in small systems where there are relatively constant loads.

Carbide-Tipped
Refers to cutting tools that have small, extremely hard pieces of carbide steel welded to the tips.

Caulking
Putty-like mastic used to seal cracks and crevices.

Center Punch
A tool used to make an indentation at the centerline of a hole to be cut.

CFM (Cubic Feet per Minute)
The unit of measure of the volume rate of airflow, as in a heating system.

Chase
A channel formed in buildings to run electrical, plumbing, or mechanical lines; spaces inside finished walls and between floors used for running ductwork or vent pipes.

Cheek
The flat side of an elbow or offset.

Circuit
An electron path that completes a loop. Circuits generally consist of a power source, conductors, a load, and a switch to control current flow.

Circuit Breaker
A protective device that opens an electrical circuit when an overload occurs. There are thermal and magnetic types.

Clamp-On Ammeter
A meter with jaws that are placed around a conductor to measure the current flow through the conductor.

Coefficient of Performance (COP)
The ratio of work performed in relation to energy used. A rating method for heat pumps.

Collar
A short section of duct that connects to another duct or piece of equipment.

Combustion
The rapid oxidation of fuel gas accompanied by the production of heat, or heat and light.

Combustion Efficiency
Producing the most heat with the fewest impurities.

Combustion Products
The gases that result from combustion; also called *flue gases*.

Common Ground Connection
Where two or more grounded wires terminate.

Complete Combustion
Burning in which there is enough oxygen to prevent the formation of carbon monoxide.

Compound Gauge
A service gauge that has both pressure and vacuum scales.

Compression Joint
A method of connection in which tightening a threaded nut compresses a compression ring to seal the joint.

Compressor
A pump in a refrigeration system that takes refrigerant vapor at a low temperature and pressure and raises it to a higher temperature and pressure.

Condensate
The liquid formed by condensation of a vapor. In air conditioning, water extracted from air, as by condensation on the cooling coil of a refrigeration unit.

Condensation
The process by which a gas is changed into a liquid at constant temperature by heat removal.

Condenser
A heat exchange coil within a mechanical refrigeration system used to reject heat from the system. The coil where condensation takes place.

Condensing Furnace
A high-efficiency, gas forced-air furnace that uses a second condensing heat exchanger to extract the latent heat in the flue gas.

Condensing Unit
The portion of a split air conditioning or refrigeration system that is mounted outside and contains the compressor, condenser, condenser fan motor, and controls for these components; most used today are air-cooled.

Conductor
A substance or body that allows electricity or heat to pass through it.

Conduit
Rigid or flexible metal or plastic tubing used to enclose electrical wiring.

Connector, Solderless
A device (typically insulated plastic) that uses mechanical pressure rather than solder to establish a connection between two or more conductors.

Contactor
A device consisting of a coil and one or more sets of contacts used to connect or disconnect a high-voltage circuit.

Continuity
A continuous current path. Absence of continuity indicates an open circuit.

Control Circuit
That portion of the total circuitry containing devices that apply power to or remove power from a load.

Cooling Capacity
The rate at which a device can remove heat from a substance, expressed in Btuh. For an air conditioner, it is the maximum rate at which it removes heat from a space.

Counterbore
Boring a larger hole partway through the stock so that the head of a fastener can be recessed.

Countersink
Making a flared depression around the top of a hole to receive the head of a flathead screw; also, the tool used to make the depression.

Coupling
A conduit or pipe fitting containing female threads on both ends. Couplings are used to join two or more lengths of conduit or pipe in a straight run to join to a fixture.

CPVC (Chlorinated Polyvinyl Chloride)
A type of plastic used to make pipe that will carry hot water and chemicals.

Crawl Space
The space between the floor framing and the ground in a building without a basement.

Crosscut
A cut made across the grain of lumber.

CU. FT. (cu. ft.)
Abbreviation for cubic foot or feet.

CU. IN. (cu. in.)
Abbreviation for cubic inch or inches.

Current
The rate of electron flow in a circuit. Current is measured in amperes.

Cycle
A complete positive and negative alteration of a current or voltage.

Damper
A bladed device used to vary the volume of air passing through an air outlet, air inlet, or duct.

Deadband
A temperature band, usually 3° F, that separates heating and cooling in an automatic changeover thermostat.

Defrost
In a heat pump, the process of cycling hot refrigerant through the outdoor coil to melt accumulated frost.

Dehumidification
The condensation of water vapor from air by cooling the air below the dewpoint or the removal of water vapor from air by chemical or physical methods.

Dehumidifier
A device used to remove moisture from the air.

Desiccant
Any absorbent or adsorbent, liquid or solid, that will remove water or water vapor from a material. In a refrigeration circuit, desiccant is contained in a filter-drier.

Device
A unit or component that carries but does not use current, such as a junction box or switch.

Dewpoint
The temperature of air at which the water vapor content is saturated.

Diffuser
An outlet that discharges supply air into a room in various directions and planes and is arranged to promote mixing of primary air with secondary room air.

Dilution Air
Air that enters the draft hood of a natural-draft, gas-fired furnace and mixes with the combustion products.

Direct Current (DC)
An electrical current in which the electron flow is in one direction. DC is used for low energy applications and allows for precise control.

Direct Vent System
A vent system for a fuel gas-fired appliance which is constructed so that all the air for combustion is drawn directly from the outside atmosphere and all the flue gases are discharged to the outside atmosphere.

Disconnect
A manual switching device used to remove power from a circuit. Usually mounted on or near air conditioning equipment.

Distribution Center
An electric panel used to distribute the electric supply to several branch circuits; can be of fusible or circuit breaker design.

Draft
The pressure difference that causes the flow of flue gases through a chimney or vent. See also Natural Draft and Induced Draft.

Draft Gauge
An instrument used to measure air movement by measuring very small air pressure differences.

Draft Hood
A device built into a natural-draft, gas-fired appliance to decouple the heat exchanger from the natural-draft vent so that updrafts, downdrafts, or blockages do not adversely affect the heat exchanger or combustion operation.

Drawband
Flat bar or metal strips with bolted ends; used to make airtight connections on round ductwork.

Drier
A manufactured device containing a desiccant placed in the refrigerant circuit. Its primary purpose is to collect and hold within the desiccant all water in the system in excess of the amount which can be tolerated in the circulating refrigerant.

Drop
The vertical distance that the lower edge of a horizontally projected airstream drops between the outlet and the end of its throw.

Dry Bulb Temperature
Temperature measured using a standard thermometer. A measure of the sensible heat of the air or surface being measured.

Dual-Fuel Heating System
A system in which a heat pump is combined with a furnace.

Duct
A passageway made of sheet metal or other suitable material; used for conveying air or other gas at lower pressures.

Dump Zone
An uncontrolled area in a zoned system that is used to avoid low airflow problems that can result when two or more of the individual system zone dampers are closed, blocking off airflow to the zones.

Dynamic Seal
A seal made where there is movement between two mating parts, or between one of the parts and the seal.

Economizer
An HVAC device that substitutes outdoor air for the cooled air produced by the air conditioning system when outdoor air conditions permit. It also controls the amount of outdoor air used to ventilate a building.

Effective Area
The net area of an outlet or inlet device through which air can pass, equal to the free area times the coefficient of discharge.

Elbow
A pipe, conduit, or duct fitting that is used to change the direction of fluid flow.

Electrical Metal Tubing (EMT)
Another name for thinwall conduit.

Electric Heater
A device constructed of high resistance wire or other material which produces heat when a current is passed through it.

Electrolysis
The decomposition of one of two unlike metals in contact with each other in the presence of water.

Energize
To apply voltage to an electric device.

Energy Efficiency Ratio (EER)
The ratio of the rated cooling capacity in Btu's per hour divided by the amount of electrical power used in watts at any given set of conditions.

Enthalpy
The total heat content (sensible and latent) expressed in Btu's per pound of the substance (Btu/lb.).

Equal Friction Method
A method of duct sizing wherein the selected duct friction loss value is used throughout the design of a low-pressure duct system.

Equivalent Length of Pipe
The resistance of a fitting, as compared to the resistance of straight pipe having the same cross-section.

Evacuation
The process of removing air, moisture, and other gases from the inside of a refrigeration system.

Evaporator
A heat exchange coil within a mechanical refrigeration system used to absorb heat into the system; the coil where evaporation takes place.

Excess Air
In gas combustion, the amount of air in excess of that needed for complete (stoichiometric) combustion.

External Static Pressure
The total pressure loss of the system ductwork and components external to the supply fan assembly.

Factory-Installed Wiring
The wiring installed in a piece of equipment at the factory; usually the connections between the components in the control panel and the system components in the unit itself.

Fahrenheit Scale (represented as °F)
The scale of temperature measurement most commonly used in the United States.

Fan Brake Power
The actual power required to drive a fan when delivering the required volume of air through a duct system. It is greater than the power needed to deliver the air because it includes losses due to turbulence and other inefficiencies of the fan, plus bearing losses.

Fault Isolation Diagram
A troubleshooting aid usually contained in the manufacturer's Installation, Start-Up, and Service Instructions for a particular product.

Feeder
The circuit conductors between the service equipment and the branch circuit overcurrent device.

Female Thread
Any internal thread.

Field Wiring
The wiring that must be installed in the field by the installation technician.

Filter
A device used to remove dust and contaminant particles from the air.

Filter-Drier
A device in refrigeration systems that removes foreign particles and moisture from refrigerant.

Fire Damper
A damper in a duct system normally held open by a fusible link which melts at a preset temperature, allowing the damper blades to close by gravity.

Firestop
Material used to fill air passages in a frame to prevent the spread of fire.

Fish Tape
Flat, steel spring wire with hooked ends; used to pull wires through conduits or walls.

Fittings
The parts of a duct, conduit, or piping system which serve to join lengths of duct, conduit, or pipe.

Fixed-Orifice Metering Device
A device in which the metering orifice is fixed; may be a piston or capillary tube.

Flame
The zone in which the combustion reaction between a fuel gas and oxygen takes place with the intense release of light and heat.

Flame Impingement
A condition which exists when the flame of a combustion reaction comes into contact with the cooler interior surface of the combustion chamber. It causes the reaction to stop in the impingement area.

Flame Rectification
The phenomenon by which an electrical current flows through a flame; used to prove the presence of a flame.

Flare Fitting
A fitting in which one end of each tube to be joined is flared outward using a special tool. The flared tube end mates with the threaded flare fitting and is secured to the fitting with flare nuts.

Flare Nut
Connects flared copper pipe to a threaded flare fitting.

Flashing
Rust-resistant materials such as copper or aluminum that are installed at joints between roofs and walls or roofs and chimneys to prevent water from entering.

Flexible Connection
: A connection using canvas, neoprene, or another soft material; used to dampen vibration and noise.

Flue Gas
: Products of combustion plus excess air plus dilution air (on natural-draft appliances) that pass through the vent.

Flue
: The passage that carries combustion gases from a heating system.

Flux
: A substance applied to surfaces that are to be joined by soldering or brazing. It prevents oxidation during the heating process.

Follower
: The sleeve on a pipe die that aligns the die with the pipe.

Forced-Air Furnace
: Any furnace that uses a fan to circulate heated air.

FPM
: Abbreviation for feet per minute.

Free Cooling
: A mode of economizer operation. It is the cooling provided by outside air rather than the compressor.

Frequency
: The number of complete cycles of an alternating current, sound wave, or vibrating object that occur in a certain period of time.

Friction
: The resistance found at the duct and piping walls. Resistance creates a static pressure loss in systems.

Fuse
: A safety device in which a metal link melts when it receives excessive current, thereby opening the circuit.

GA (ga)
Abbreviation for gage or gauge.

Galvanized
Protected from rusting by a coating of zinc.

Gas Valve
A device used to start, stop, or regulate the flow of gas.

Gasket
Any semihard material placed between two surfaces to make a watertight or airtight seal when the surfaces are drawn together by bolts or other fasteners.

Gauge Manifold
A device containing compound and high-pressure gauges, with a valve arrangement to control fluid flow. Used to measure pressures and perform other service procedures in a refrigeration system.

Gauge Port
An opening or connection used to attach a gauge during service procedures.

Gauge Pressure
The pressure measured on a gauge, expressed as psig or in. Hg vac.; pressure measurements which are compared to atmospheric pressure.

GPM
Abbreviation for gallons per minute.

Grille
A louvered covering for any opening through which air passes.

Ground Fault Circuit Interrupter (GFCI)
Overcurrent device that detects minute leaks of current and then quickly deenergizes the circuit.

Ground Fault
A situation in which electricity flows outside the conductors intended to carry power; e.g., when a hot wire at a bare point touches a grounded component, such as a conduit or grounding wire.

Grounding Conductor
The wire (green or bare) in a cable that carries no current; used as a safety measure to establish a ground.

Grounding
An electrical safety practice used to prevent a person from being shocked if a tool being used has an electrical short.

HACR Circuit Breaker
A circuit breaker with a built-in trip delay commonly used in air conditioning installations due to the power surge on start-up.

Hanger
Support for pipe, conduit, or duct runs.

Hard Start Kit
A kit consisting of a start capacitor and start relay used to provide high starting torque.

Heat Anticipator
A resistive heating element in a thermostat that shuts off the furnace before the space temperature reaches the setpoint. It prevents the system from overshooting the desired temperature.

Heat Exchanger
A device which provides a means for transferring heat between two fluid streams while keeping them physically separated.

Heat Gain
The heat transferred into a structure through its outside surfaces and cracks when the outside temperature is higher than the inside temperature.

Heat Loss
The heat that is transferred out of a structure through its outside surfaces and cracks when the outside temperature is lower than the inside temperature.

Heat Pump
A comfort system in which the refrigeration cycle is reversed by a four-way valve to supply heating as well as cooling.

Heat Recovery Ventilator (HRV)
HVAC equipment that saves energy by using a heat exchanger to transfer heat from the building exhaust air to the cold ventilation air entering the building.

Heater
An electric load that converts electric energy to heat.

Heating Capacity
The rate at which a device can add heat to a substance; it is expressed in Btuh.

Hermetic Compressor
A type of compressor in which the compressor and its drive motor are enclosed in a welded shell.

Hertz (Hz)
The unit of measure for the frequency of alternating current. One Hertz equals one cycle per second.

Hickey
A device used to bend conduit.

High Efficiency Particulate Air (HEPA) Filter
A dry-type filter in a rigid frame having a minimum particle-collection efficiency of 99.97% for 0.3 micron particles.

High-Side
The components of a refrigeration system that are under condensing pressure.

High-Voltage Circuit
The section of a wiring diagram showing distribution of primary AC power to the load devices.

Horsepower (HP)
A unit of power. One HP represents 33,000 ft. lb. of work per minute and is equal to 746 watts of electrical power.

Hot Surface Ignitor
A device that heats up when an electrical current flows through it; used to ignite gas in a gas furnace.

Hot Wires
The conductors of a circuit that are not grounded and are carrying power. Also called a *live wire*.

Humidifier
A device used to add moisture to the air.

Humidistat
An electrical control that is operated by a change in humidity.

Humidity
The moisture content of air.

HVAC
Heating, ventilating, and air conditioning.

Hydronics
Practice of heating and/or cooling with water.

Hygrometer
An instrument used to measure the degree of moisture in the air.

Hypothermia
A condition of lower-than-normal body temperature resulting from exposure to cold weather. It can result in death if left untreated.

Ignitor Pack (IGN)
A control device for gas heat that provides a voltage to operate the flame ignitor and a flame sensor to signal the gas valve to open or close.

IN. (in.)
Abbreviation for inch.

Inches Mercury Absolute (in. Hg abs.)
The scale used to measure absolute pressures equal to or below atmospheric pressure. Also used for weather reporting and forecasting.

Inches Mercury Vacuum (in. Hg vac.)
The scale used to measure gauge pressures equal to or less than atmospheric pressure.

Incomplete Combustion
Burning in which there is not enough oxygen to prevent the formation of carbon monoxide.

Indoor Coil
The designation given to the heat pump coil used to transfer heat to or from the conditioned space.

Indoor Fan Relay
An electric relay that starts and stops an indoor fan.

Induced Draft
The draft developed in the heat exchanger of a gas-fired furnace by a fan located at the outlet of the heat exchanger. May be used with a natural-draft vent, or with a direct vent system; also called *fan-assisted* or *mechanical draft*.

Induced-Draft Furnace
A furnace in which a motor-driven fan draws air from the surrounding area or from outdoors to support combustion.

Infiltration
The leakage of outside air into a structure through doors, cracks, windows, and other openings.

Inside Diameter (I.D.)
The distance between the inner walls of a pipe; used as the standard measure for tubing used in heating and plumbing applications.

Installation Diagram
A diagram that shows little internal wiring but gives specific information as to terminals, wire sizes, color coding, and breaker or circuit sizes.

Insulation (Electrical)
Nonconducting materials used to cover wires and in the construction of electrical devices.

Insulator
A device that inhibits the flow of current; opposite of a conductor.

Isolation Transformer
A transformer with a one-to-one turns ratio. It is used for safety and to prevent electrical interference.

Jig

Any type of fixture designed to hold pieces or guide tools while work is being performed.

Journal

The part of a shaft, axle, spindle, etc., which is supported by and revolves in a bearing.

Jumper

A length of wire used to connect a portion of an electrical circuit.

Junction Box

A box in which connections between circuit conductors are made. A junction box is not an outlet, since no load is fed from it directly.

K Grade Copper Pipe
: Copper pipe suitable for installation underground.

Knockout
: A die-cut impression in electrical boxes and enclosures designed so that it can readily be removed to provide an opening for access.

KW (kW)
: Abbreviation for kilowatt.

L Grade Copper Pipe
A type of copper pipe used to convey water above ground.

Label Diagram
A diagram usually placed in a convenient location inside HVAC equipment. It normally depicts a wiring diagram, a component arrangement diagram, a legend, and notes pertaining to the equipment.

Ladder Diagram
A simplified method for portraying an electrical diagram.

Lay Out
The act of measuring and marking the location of something.

Legend
An explanation of the component abbreviations on a diagram.

Light Emitting Diode (LED)
A semiconductor component that produces light when a current passes through it.

Limit Switch
A protective device used to open or close electrical circuits when temperature or pressure limits are reached.

Line Drop
The voltage drop due to resistance in an electrical conductor.

Line Duty Device
A protective device that opens the motor winding circuit under conditions of excess current or temperature.

Line Side
The side of a device electrically closest to the source of current.

Line Voltage
The voltage being supplied to the equipment at the power supply.

Liquid Sightglass
The glass-ported fitting in the liquid line used to indicate adequate refrigerant charge. When bubbles appear in the glass, there is insufficient refrigerant in the system.

Liquid Solenoid Valve
An electrically-operated automatic shutoff valve in the liquid piping that closes on system shutdown to prevent refrigerant migration.

Load Side
The side of a device electrically farthest from the current source.

Load
A device that converts electrical energy into another form of energy (heat, mechanical motion, light, etc.). Motors are the most common loads in HVAC systems.

Louver
An opening for ventilation consisting of horizontal slats installed at an angle to allow the passage of air, but exclude rain, light, and vision.

Low-Side
The components of a refrigeration system that are under evaporating pressure.

Low-Voltage Circuit
The control circuit portion of a wiring diagram, termed “low voltage” because it generally operates from a stepped-down voltage.

LPG (LP Gas)
An acronym for Liquified Petroleum Gas; refers to those fuel gases that remain a liquid under pressure, including propane and butane.

Lugs
Terminals on the ends of a wire or built into electrical devices for the purpose of making connections.

Magnetic Overload Device
A protective device that disconnects a circuit when excessive current creates a magnetic field sufficient to open the contact. Magnetic overload devices are not affected by the ambient temperature.

Main
The main circuit that supplies all other circuits; also called the *main disconnect*.

Male Thread
Threads on the outside of a pipe, fitting, or valve.

Malleable Iron
Cast iron that has been heat treated to reduce its brittleness. Pipe fittings are made from malleable iron.

Manometer
An instrument used to measure low positive, negative, or differential air and gas pressures.

Mastic
A thick adhesive.

Mechanical Cooling
A mode of economizer operation. It is the cooling provided in the conventional manner by the compressor.

Metering Device
A component of a refrigeration system that controls the flow of high-pressure liquid into the evaporator.

Microfarad (MFD)
One-millionth of a Farad; the standard unit of measurement for a capacitor.

Microprocessor
A micro-computer chip consisting of integrated circuits which accept, store, and process information and control output devices.

Milliamp
A unit of electric current equal to 1/1,000 of an ampere.

Motor
A device used to convert electrical energy into mechanical energy.

Multimeter
A combination meter used to measure voltage, current, and resistance.

National Electrical Code® (NEC®)

A nationally-recognized standard that establishes the minimum installation requirements for electrical systems in the United States. It is published by the National Fire Protection Association (NFPA).

Natural Draft

The draft developed in a chimney or vent of a gas-fired appliance by the difference in density of the hot flue gas and the outside atmosphere caused by their temperature difference.

Natural-Draft Furnace

A furnace in which the natural flow of air from around the furnace provides the air to support combustion. It also depends on the pressure created by the heat in the flue gases to force them out through the vent system.

Natural Gas

A naturally occurring fuel gas composed of about 95% methane gas with other gases, such as ethane, hydrogen, carbon dioxide, and nitrogen making up the remainder.

Negative Temperature Coefficient (NTC) Thermistor

A sensing element in which the resistance decreases as the temperature increases. NTC thermistors are used as temperature sensors and as protective devices in motors.

Neutral Wire

The conductor in a cable that is kept at zero voltage. All current that flows through the hot wire must also flow through the neutral wire.

NFPA

National Fire Protection Association.

Nipples

Short lengths of pipe (usually less than 12 inches) with male threads on both ends; used to join fittings.

Normally Closed Contacts

Contacts that close when a relay or contactor is deenergized.
Normally Open Contacts - Contacts that open when a relay or contactor is deenergized.

O-Ring
A rubber seal used around pipe flanges and stems of some valves to prevent water leakage.

OC (On Center)
The distance from the center of one structural member to the center of the next structural member.

Occupational Health and Safety Administration (OSHA)
A department of the U.S. government concerned with occupational safety.

Ohm
A unit of electrical resistance.

Oil (Refrigeration)
A specially-formulated compressor lubricating oil used in refrigeration systems.

One Hundred Percent Shutoff Valve
An automatic valve that shuts off all gas to the pilot and prevents gas valve operation if the pilot is extinguished.

Open Circuit
An electric circuit with a physical break in the path (caused by opening a switch, disconnecting a wire, burning out a fuse, etc.) through which no current can flow.

Orifice
A calibrated hole used to measure or control the flow of a fluid; e.g., a gas orifice is a precision-drilled hole in a spud that is used to control the flow of gas to a burner.

Outdoor Coil
The heat pump coil used to transfer heat to or from the outdoor air.

Outlet Box
A box used to terminate a cable or conduit. Connections are made in the box. A variety of covers and plates are available to close the box.

Outside Diameter (O.D.)
The distance between the outer walls of a pipe; used as the standard measure for ACR tubing.

Overcurrent Protection Device
A fuse or circuit breaker that is used to prevent an excessive flow of current.

Overload
Current demand exceeding that for which the circuit or equipment was designed.

Overload Protector
A device operated by current that shuts the system off when limits are exceeded.

Oxidation
The process by which the oxygen in the air combines with metal to produce tarnish and rust.

Packaged Unit
A self-contained heating and/or air conditioning system.

Packing
A loosely-packed waterproof material installed in the packing box of valves to prevent leaking around the stem.

Penny
Measure of nail length. Abbreviated as “d.”

Phillips Head
A type of screw head with a cross-slot.

Pilot
A small flame that is utilized to ignite the gas at the main burner(s) of a gas-fired device.

Pilot Duty Device
A protective device that opens the motor control circuit under conditions of excess current or temperature.

Pilot Hole
A small hole drilled to receive the threaded portion of a wood screw.

Pipe Joint Compound
Putty-like material used for sealing threaded pipe joints; commonly called *pipe dope*.

Piping
A generic term used to refer to all the pipes in a building.

Pitch
The degree of slope or grade given a horizontal run of pipe.

Pitot Tube
A tube used with manometers and differential pressure gauges to measure air velocities and static pressures.

Plenum
A sealed chamber at the inlet or outlet of an air handler. The duct attaches to the plenum.

Plug
A pipe fitting with external threads and head that is used for closing the opening in another fitting.

Plumb
Exactly vertical; at a right angle to the horizontal.

Plumb Bob
A pointed weight attached to a line for testing plumbness.

Pneumatic
Operated by air pressure.

Polarized Plug
A plug whose prongs are designed to enter a receptacle in only one orientation.

Polarizing
Using color to identify wires throughout a system to ensure that hot wires will be connected only to hot wires and that neutral wires will run back to the ground terminals in continuous circuits.

Pole
One set of electric contacts either in an automatic device or a manual switch. Electric devices such as relays, contactors, switches, and breakers can be purchased with one or many poles.

Polyethylene
Plastic used to make pipe and fittings primarily for gas piping. Also, a plastic sheet material used in the building trade as a vapor barrier and to protect building materials from poor weather during construction.

Positive Temperature Coefficient (PTC) Thermistor
A sensing element in which the resistance increases as the temperature increases. PTC thermistors are used as temperature sensors and as start assist devices for motors.

Pounds per Square Inch Absolute (psia)
The scale used to measure absolute pressures.

Pounds per Square Inch Gauge (psig)
The scale used to measure gauge pressures.

Power
The amount of energy consumed by a load in an electrical circuit.

Power Supply
The voltage and current source for an electrical circuit. A battery, utility device, and transformer are power supplies.

Pressure
Force per unit of area.

Pressure Drop
The pressure difference between two points.

Pressurestat
A pressure switch often used as a protective device for compressors. A bellows or diaphragm in the switch responds to pressure changes, breaking the circuit if the pressure goes beyond a set value.

Primary Air
Combustion air that is mixed with gas in a burner before leaving the port.

Printed Circuit Board
A support for electronic circuits that generally consists of electrical components linked by chemically etched (pre-printed) copper foil conductors.

Propane
A member of the methane family of hydrocarbons; used as a fuel gas.

Psychrometer
An instrument used to measure the relative humidity of the air.

Psychrometric Chart
A chart that displays the relationships of air temperature, pressure, and humidity.

Pull Box
A box inserted into a conduit run for the purpose of providing a cable pulling point. Cable may be spliced in these boxes.

Punch List
A list made by the builder or owner of a structure near the end of construction; it indicates what must be done before the structure is completely finished and ready for occupancy.

Purging
Releasing compressed gas to the atmosphere through some part or parts, such as a hose or pipeline, for the purpose of removing contaminants from that part or parts.

PVC (Polyvinyl Chloride)
A type of plastic used to make plumbing pipe and fittings for water distribution, irrigation, and natural gas distribution.

R-Value
The thermal resistance of a given thickness of insulating material.

Raceway
A protected runway or enclosure for holding conductors or cables; e.g., conduit, conduit bodies, or cable trays.

Radial Load
The side or radial force applied at right angles to a bearing and shaft.

Re-ignition Pilot
A pilot that is equipped with a device to re-light the pilot gas, either when the pilot is extinguished or, on furnaces with 100% shutoff valves, each time the furnace is turned on.

Reaming
Removing the burr from the inside of a pipe that has been cut with a pipe cutter.

Reducer
A pipe fitting having one opening smaller than the other. Reducers are used to change from a relatively large diameter pipe to a smaller one. In duct systems, it is a fitting larger on one end than on the other end used to change from one size duct to another.

Redundant Gas Valve
A gas control containing two gas valves in series. If one fails, the other is available to shut off the gas when needed.

Refrigerant
A fluid (liquid or gas) that picks up heat by evaporating at a low temperature and pressure. It gives up heat by condensing at a higher temperature and pressure.

Refrigerant Reclaim
The reprocessing of refrigerant to new refrigerant specifications. This requires chemical analysis and usually refers to the processes available at a reprocessing or manufacturing facility.

Refrigerant Recovery
The removal of refrigerant from a system and placement in a cylinder without testing.

Refrigerant Recycling
The cleaning of refrigerant for reuse by removing moisture, acids, and particulate matter. Usually applies to procedures performed at the job site or local service shop. The cleaned refrigerant does not meet new refrigerant specifications.

Register
An air grille equipped with a damper or control valve.

Relative Humidity
The ratio of the amount of vapor contained in the air to the greatest amount the air could hold at that temperature. Normally expressed as a percentage.

Relay
A magnetically operated device consisting of a coil and one or more sets of contacts used to connect or disconnect a load.

Resistance
The ability of a device or material to obstruct the current flow within a circuit.

Resistive Circuit
Any circuit that contains at least one resistive load.

Resistor
A device or material that impedes the current flow within a circuit.

Return Air
Air leaving the conditioned space and returning to the air conditioning equipment.

Reverse Cycle Heat
The heat produced by a heat pump when refrigerant flow is reversed from the cooling mode to the heating mode.

Reversing Valve
A valve that changes the direction of refrigerant flow in a heat pump.

Revolutions per Minute (RPM)
The speed at which a device is rotating.

Rigid Copper Tubing
Hard copper pipe used when installing refrigerant or water lines.

Rip
Sawing lumber in the direction of the grain.

Riser Diagram
A schematic depicting the layout, components, and connections of a piping system.

Riser
A vertical supply pipe extending from a horizontal supply pipe to a fixture or device.

Rollout Switch
A heat-sensitive protective device that opens the circuit if flame migrates away from the burner box.

Romex®
A trademark for one brand of NM cable (nonmetallic-sheathed cable) used for indoor wiring.

Rooftop Unit
A heating and/or cooling unit that conditions a structure; it is mounted on the roof after adequate reinforcement has been built into the roof.

Run
One or more lengths of pipe that continue in a straight line.

Run Capacitor
An electrical storage device that helps motors run more efficiently.

Run-Down Resistance
The torque required to overcome the resistance of associated hardware, such as lock-nuts and washers, when tightening a fastener.

Safety Pilot
A pilot light with a flame sensing element.

Saturation Temperature
The boiling point of a refrigerant. It is dependent upon pressure.

Schedules
Tables on construction drawings that describe and specify the types and sizes of items required for the construction of a building.

Schematic Diagram
A diagram that lays out the control system circuit by circuit and is composed of symbols representing components and lines representing their interconnecting wiring.

Schrader Valve
A spring-loaded device similar to a tire valve that allows refrigerant to be added to or removed from the system.

Seasonal Energy Efficiency Ratio (SEER)
The total cooling of an air conditioner or heat pump in Btu's during its normal annual usage period for cooling divided by the total electrical energy input in watt-hours during the same period.

Seasonal Performance Factor (SPF)
A heat pump performance rating that has been adjusted for seasonal operation.

Secondary Air
Combustion air that mixes with the burning gas-primary air mixture in the flame zone.

Semi-Hermetic Compressor
A hermetic (airtight) compressor that can be opened or disassembled by removing bolts and flanges. Also known as a *serviceable hermetic.*

Sequencer
A relay with a built-in time delay of a few seconds that allows electric heating elements to be gradually staged on.

Service Conductors
Electrical conductors that extend from the street main or transformer to the service equipment of the building being supplied with power.

Service Equipment
Electrical equipment located near the entrance of supply conductors that provides main control and enables cutoff (via fuses or circuit breakers) for the supply of current to the building.

Service Panel
The main panel through which electricity is brought from an outside source into a building and distributed to the branch circuits.

Set or Seizure
In the last stages of rotation in reaching the final torque of a nut or bolt, seizing or set of the fastener may occur. This is usually accompanied by a noticeable popping effect.

Setpoint
A preset temperature at which a temperature-sensitive switch will open or close.

Shank Hole
A hole drilled for the thicker portion of a wood screw.

Shim
A thin, wedge-shaped piece of material used behind pieces for the purpose of straightening them, or for bringing their surfaces flush at a joint.

Short Circuit
Conducting current, accidental or intentional, between any of the conductors of an electrical system. This connection may be from line to line or line to neutral (ground).

Short-Cycling
A condition in which a compressor or furnace is restarted immediately after it has been turned off.

SI (International System of Units)
Includes the common metric units of measure, such as meters, grams, Celsius, Kelvin, and pascals.

Sightglass
A glass tube or window in a liquid line. It shows the refrigerant or oil in the system and indicates the presence of gas bubbles in the liquid line.

Single-Phase Voltage
The potential difference produced by a single conductor output from a generating source. Single-phase voltage produces a single waveform.

Sleeve
A metal form providing a clear opening in concrete for duct or pipe.

Sling Psychrometer
A device with wet and dry bulb thermometers that is whirled rapidly in the air to measure sensible wet and dry bulb temperatures.

Slow Blow Fuse
A fuse with a built-in trip delay commonly used in HVAC installations due to the power surge on start-up.

SMACNA
Sheet Metal and Air Conditioning Contractors National Association, Inc.

Solder
A fusible alloy used to join metals.

Soldering
The process of joining two metals by using a third metal, a filler, with a melting temperature of less than 800° F.

Soldering Iron
A tool used to melt solder when joining pieces of metal.

Solenoid
A magnetic device that is used to convert electrical energy into mechanical energy. Many valves are solenoid-activated.

Specific Gravity
Of a gas, the ratio of the weight of a given volume of the gas to the weight of the same volume of standard air (i.e., air at standard temperature and pressure); for a liquid or solid, the ratio of the weight of a given volume of the substance to the weight of the same volume of water at 4° C.

Specific Heat
The amount of heat required to raise one pound of a substance 1° F; expressed in Btu/lb./°F.

Specification
A document that describes the quality of the materials and the work required. Specifications list the types of tubing, fixtures, hangers, etc. to be used on a project.

Splice
A connection made by joining two or more wires.

Split System
A refrigeration or air conditioning system in which the condenser and evaporator are in separate locations, joined by refrigerant piping.

Splitter
A hinged sheet of metal used to divert air into a branch duct.

Spread
The divergence of the airstream in a horizontal or vertical plane after it leaves the outlet.

Spud
A threaded metal device that screws into the gas manifold. It contains the orifice that meters gas to the burners.

SQ. (sq.)
Abbreviation for square.

SQ. FT. (sq. ft.)
Abbreviation for square foot or feet.

SQ. IN. (sq. in.)
Abbreviation for square inch or inches.

Staged System
A system that has more than one stage of heating or cooling operation.

Staging Thermostat
A thermostat that is designed to open and close more than one set of contacts to control several stages of heating or cooling operation.

Standing Pilot
A gas pilot that is on continuously.

Start Capacitor
An electric storage device that helps to overcome motor starting torque.

Static Pressure
The pressure exerted by a fluid at rest; for a flowing fluid, as air in a duct, it is the total pressure minus the velocity pressure.

Subbase
The portion of a two-part thermostat that contains the wiring terminals and control switches.

Subcooled Liquid
A liquid at a temperature below the saturation temperature of the substance.

Suction Side
The low-pressure side of a refrigeration system, extending from the metering device through the evaporator to the inlet valve of the compressor.

Superheated Gas
A gas at a temperature above the saturation temperature of the substance.

Supply Air
Air that has been treated at the conditioning device for distribution to the conditioned space.

Swaging
Enlarging one end of a tube using a special tool so that another tube of the same size can fit within it in preparation for making a solder or braze connection.

Sweating
A method of joining pipe in which solder is applied to the joint and heated until it flows into the joint.

Switch
A device used to connect and disconnect the flow of current or to divert current from one circuit to another.

T or T Fitting
A fitting shaped like the letter “T.” Each leg of the T can be joined to a pipe, duct, or another fitting.

Takeoff
(1) The process of surveying, measuring, itemizing, and counting all materials and equipment needed for a construction project, as indicated by the drawings. (2) A duct fitting used to make the transition between a main duct and a branch duct.

Temperature
The measure of the intensity of heat that a substance possesses.

Temperature Rise
The positive change in temperature of air passing through a heat exchanger as a result of heat transfer.

Tempered
Metal that is treated in a special way to be harder and stronger.

Template
A pattern or guide for cutting or drilling.

Terminal
A point on an electrical device where connections may be made.

Thermal Overload Device
A bimetal protective device that acts as a switch contact, disconnecting the circuit under conditions of excessive heat.

Thermocouple
A device comprised of two dissimilar metals that generates an electrical potential in the presence of heat.

Thermometer
A device used to measure temperature.

Thermostat
A device that connects or disconnects a circuit in response to a change in the ambient temperature.

Thermostat Body
The portion of a two-part thermostat that contains the heating and cooling thermostats.

Thermostatic Expansion Valve (TEV or TXV)
A valve used to control superheat in a refrigeration system by regulating the flow of liquid refrigerant to the evaporator.

Three-Phase Voltage
The potential difference produced by three conductors spaced 120° apart in a generating source. Three-phase voltage produces three waveforms, each out of sync with the others by one third of a cycle.

Throw
The horizontal or vertical axial distance an airstream travels after leaving an air outlet before the maximum stream velocity is reduced to a specific terminal level as specified by the outlet device manufacturer; e.g., 200, 150, 100, or 50 FPM.

Thrust
The force acting lengthwise along the axis of a shaft, either toward it or away from it.

Time Delay Relay
A relay in which there is a delay between the time the coil is energized or deenergized and when the contacts open or close. Often used to control fans for greater heating or cooling efficiency.

Tolerance
The amount of variation allowed from a standard.

Ton
The basic large unit for measuring the rate of heat transfer (12,000 Btuh).

Torque
The force that must be generated to turn a motor. Also, the resistance to turning or twisting.

Total Cooling Load (Expressed in Btuh or tons)
The rate at which total heat enters a space.

Total Pressure
The sum of the static pressure and the velocity pressure in an air duct. It is the pressure produced by the fan or blower.

Transformer
A device used to raise and lower AC voltage levels.

Transition
A duct fitting that changes from one geometric shape to another, as square to round.

Troubleshooting Table
A troubleshooting aid usually contained in the manufacturer's Installation, Start-Up, and Service Instructions for a particular product. Troubleshooting tables are intended to guide the technician to a corrective action based on observations of system operation.

Tubing
Thin-wall pipe that can be easily bent.

Turning Vanes
A series of small radius blades evenly spaced along the diagonal, parallel to the turn of a duct elbow.

Union

A fitting used to join two lengths of pipe. It permits disconnecting the two pieces of pipe without cutting.

Vacuum
Any pressure below atmospheric pressure.

Vacuum Pump
A pump used to remove air and moisture from a refrigeration system at a pressure below atmospheric pressure.

Vapor Barrier
A moisture-impervious layer applied to the surfaces enclosing a humid space to prevent moisture travel to a point where it may condense due to lower temperature.

Velocity
How fast air is moving; usually measured in feet per minute.

Velocity Pressure
The pressure in a duct due to the movement of the air. It is the difference between the total pressure and the static pressure.

Velometer
An instrument that measures the velocity of air or water.

Vent
A passageway used to convey flue gases from gas-burning equipment to the outside atmosphere.

Vent Connector
A pipe or duct which connects a gas-burning appliance to a vent or chimney.

Vent Damper
A device intended for installation in the venting system at the outlet or downstream of a gas-burning appliance to automatically open the vent when the appliance is in operation and to automatically close off the vent when the appliance is off.

Ventilation
The process of supplying or removing air, by natural or mechanical means, to or from any space. Such air may or may not have been conditioned.

Venturi
The flared-shape portion of a burner nearest the gas orifice that is designed to assist the gas jet in injecting air into the burner. Also a ring or panel surrounding the blades of a propeller fan used to improve fan performance.

Volt
A unit of electrical potential.

Voltage
An electrical measurement of the potential for electron flow within a circuit.

Voltage Drop
The amount of voltage required for a single load in a circuit.

Volume
The amount of air in cubic feet flowing past a given point in one minute (measured in CFM).

Watt

A unit of electrical power.

Wet Bulb

A device used to measure relative humidity. Evaporation of moisture lowers the temperature of the wet bulb compared to the dry bulb temperature of the same air sample.

Wet Bulb Temperature

A measure of humidity in the air.

Wetting

A process that reduces the surface tension so that molten (liquid) solder flows evenly throughout a joint.

Wire Gauge

A standard numerical method of specifying the physical size of a conductor. The American Wire Gauge (AWG) series is the most common.

Wire Nut

A solderless connector for joining wires.

Wiring Diagram

Also known as a *wiring schematic*, a wiring diagram is that portion of a label diagram which illustrates the internal wiring of the unit.

Zone Damper
A damper used to control airflow to a zone in a zoned comfort system.

Zone Valve
A thermostat-controlled valve used in hydronic heating and cooling systems to control the temperature in a certain area or zone.

Zoning
The practice of providing independent heating and/or cooling to different areas in a structure.

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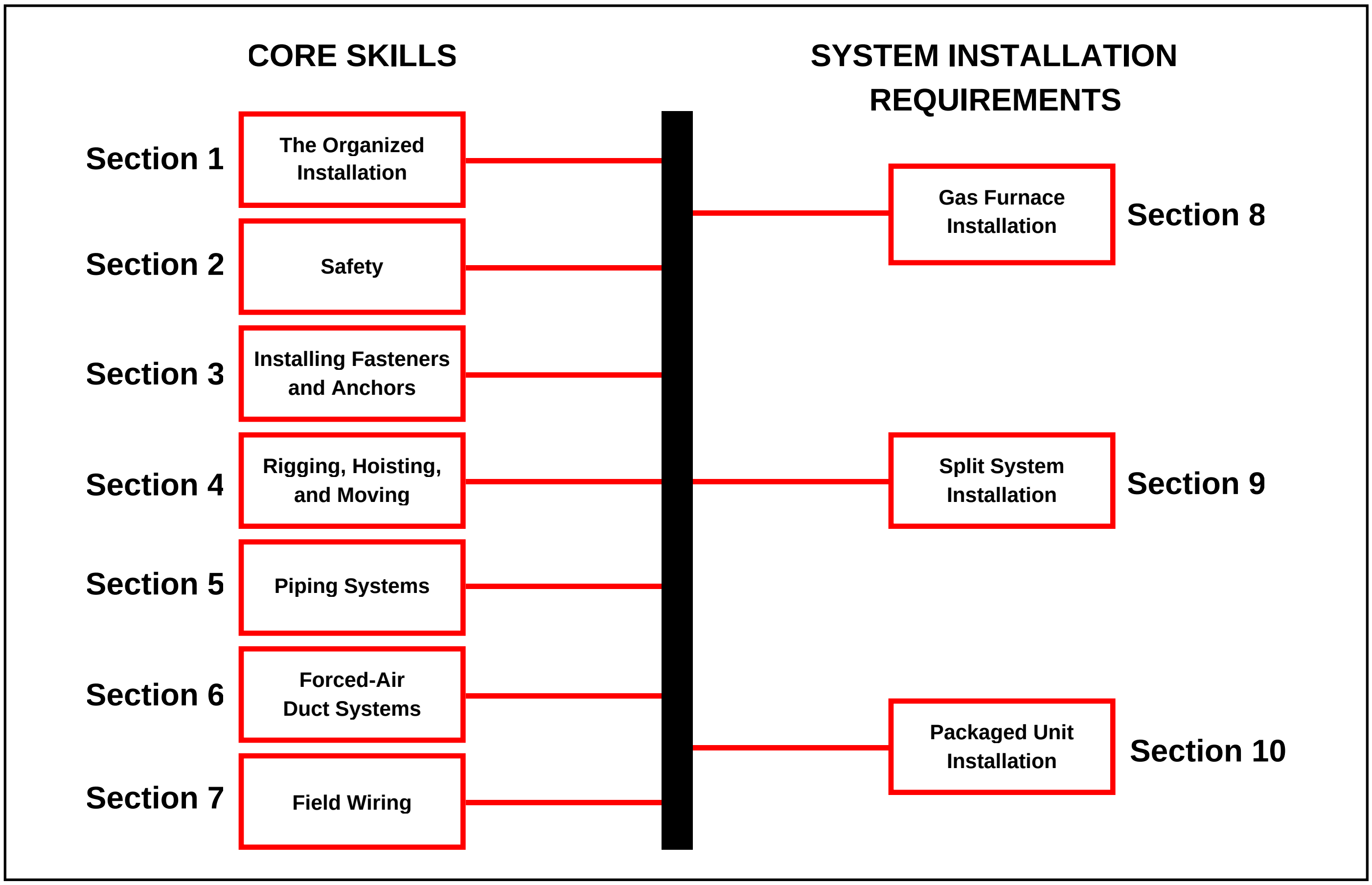
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