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To accelerate the development and wide application of energy efficiency measures, the Building Technologies Program:

- Conducts R&D on technologies and concepts for energy efficiency, working closely with the building industry and with manufacturers of materials, equipment, and appliances
- Promotes energy/money saving opportunities to both builders and buyers of homes and commercial buildings
- Works with state and local regulatory groups to improve building codes, appliance standards, and guidelines for efficient energy use



AIR DISTRIBUTION SYSTEM INSTALLATION AND SEALING

Proper Duct Installation Increases Efficiency

INTRODUCTION

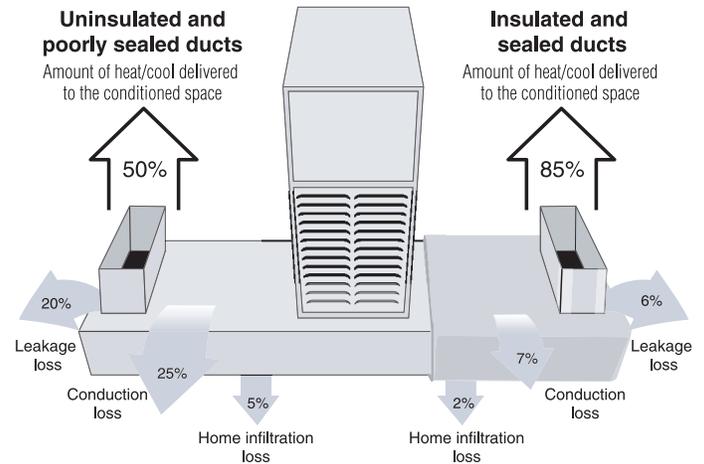
Central heating and cooling systems use an air distribution or duct system to circulate heated and/or cooled air to all the conditioned rooms in a house. Even when properly designed, duct systems must be installed correctly to be efficient, maintain uniform temperatures throughout the house, operate quietly, and not adversely impact comfort or indoor air quality.

WHY DUCT INSTALLATION AND SEALING ARE IMPORTANT

The efficiency of air distribution systems has been found to be 60-75% or less in many houses because of insufficient and/or poorly installed duct insulation and leaks in duct systems. Properly designed and installed duct systems can have efficiencies of 80% or more for little or no additional cost, potentially saving a homeowner \$50-200 or more per year in heating and cooling costs. Moreover, efficient duct system installations can reduce equipment size, further saving money for new or replacement equipment.

Duct systems that leak and/or do not distribute air properly throughout the house may make some rooms too hot and others too cold. Leaky and unbalanced duct systems force conditioned air outside and unconditioned air into the house. This increases heating and cooling costs and may also draw humidity, dust, mold spores, and other contaminants into a home from the attic, crawlspace, or garage and radon

BENEFITS OF INSULATING AND SEALING DUCTS



gas from the soil. In extreme cases, poorly installed duct systems can induce backdrafting—spillage of flue gases from combustion appliances (e.g., furnace, water heater, fireplace) into the living space—primarily when atmospheric or natural-draft flues are used rather than powered combustion systems.

Duct systems that are undersized for the heating and cooling equipment, have been pinched to fit around structural framing during installation, or have been installed with numerous bends and turns may lead to low air flow rates and high air velocities. Low air flow rates cause the heating and cooling equipment to operate inefficiently. High air velocities increase noise.

Unfortunately, researchers have found these types of duct problems repeatedly in new and existing homes because care was not taken initially in installing the air distribution system.

DUCT INSTALLATION PRINCIPLES

The objectives of a properly designed and installed duct system are occupant comfort, proper air distribution, economical heating and cooling system operation, and economical duct installation. Such a duct system is one that

- Provides conditioned air to meet all room heating and cooling loads.
- Ensures that the pressure drop across the air handler is within manufacturer and design specifications.
- Provides proper air flow.
- Prevents air from entering the house or duct system from polluted zones.
- Maintains a neutral pressure in the house by having balanced air flows between the supply and return systems.
- Minimizes duct air temperature gains or losses between the air handler and supply outlets, and between the return register and air handler.

During the design of the duct system, the layout and locations of the ducts are identified, duct materials are chosen, the sizes of the ducts are calculated, insulation levels are identified, and registers are selected. Duct installation ensures that the duct design is achieved in practice by addressing three critical elements:

- **Mechanical integrity**—the system will remain as built for the life of the house, without developing leaks, obstructions, or insulation failure.
- **Freedom from leaks**—all the air moved by the air handler will be drawn from and delivered to the intended conditioned spaces.
- **Proper insulation**—conditioned air does not exchange heat with unconditioned spaces.

DUCT INSTALLATION STANDARDS

The installation guidance presented in this fact sheet should be followed insofar as it does not conflict with applicable building codes and the following standards:

Sheet Metal and Air Conditioning Contractors' National Association, Inc. (SMACNA) *Residential Comfort System Installation Standards Manual* (1998, seventh edition) and *Fibrous Glass Duct Construction Standards* (1992, sixth edition). SMACNA's *HVAC Duct Construction Standards—Metal and Flexible* (1995, second edition), although primarily for commercial and industrial projects, details good construction and installation practices that could improve residential applications.

Air Diffusion Council (ADC) *Flexible Duct Performance & Installation Standards* (1996, third edition).

North American Insulation Manufacturers Association (NAIMA) *Residential Fibrous Glass Duct Construction Standards* and *A Guide to Insulated Air Duct Systems*.

Underwriters Laboratory (UL) Standard for Factory-Made Air Ducts and Air Connectors (1996, ninth edition).

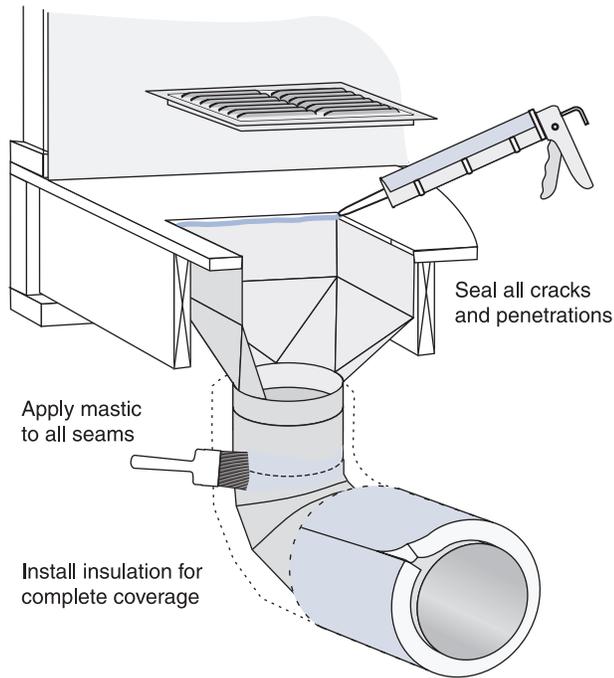
GENERAL DUCT INSTALLATION GUIDELINES

Air distribution ducts are commonly constructed from sheet metal, rigid fiberglass duct board, or flexible duct. General duct installation recommendations specific to these different materials are outlined below. In addition, the air handler, plenums, and duct boots form parts of the air distribution system. General installation guidelines for these components are also provided.

Duct systems should be installed inside the conditioned (living) and semi-conditioned spaces of the house to the greatest extent possible (but not in exterior wall cavities). Any air leakage in ducts located inside the house will not significantly affect the energy efficiency of the heating and cooling system because the conditioned air will remain inside the house. Also, ducts located inside the house need minimal insulation (in hot and humid climates), if any at all.

Duct systems should be hard-ducted as much as possible. Duct system installations that use the house structure or building framing (e.g., building cavities, closets, raised-floor air handler plenums, platform returns, wall stud spaces, panned floor joists) as supply or return ducts can be relatively

BOOT AND DUCT CONNECTION HIGHLIGHTS



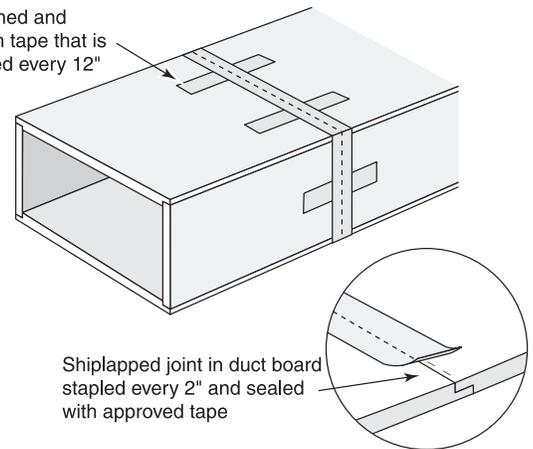
inexpensive to install. However, they should be avoided because they are difficult to seal and cannot always be insulated. In addition, because they tend to be rough and have many twists and turns, it is difficult to build them so as to ensure good air distribution. Even return plenums built under a stairway or in a closet, for example, should be avoided if a completely ducted system is possible.

✓ SHEET METAL DUCTS

Sheet metal is the most common duct material and can be used on most all supply and return duct applications (for plenums, trunks, branches, and runouts). Sheet metal ducts have a smooth interior surface that offers the least resistance to air flow. They must be carefully and completely sealed during construction/installation, using approved tapes or preferably mastic, because each connection, joint, and seam has potential leakage. Screws should be used to mechanically fasten all joints. When located in an unconditioned space, sheet metal ducts must be insulated with either an interior duct liner or exterior insulation.

DUCT BOARD

Joint fastened and sealed with tape that is crosstabbed every 12"



✓ FIBERGLASS DUCT BOARD DUCTS

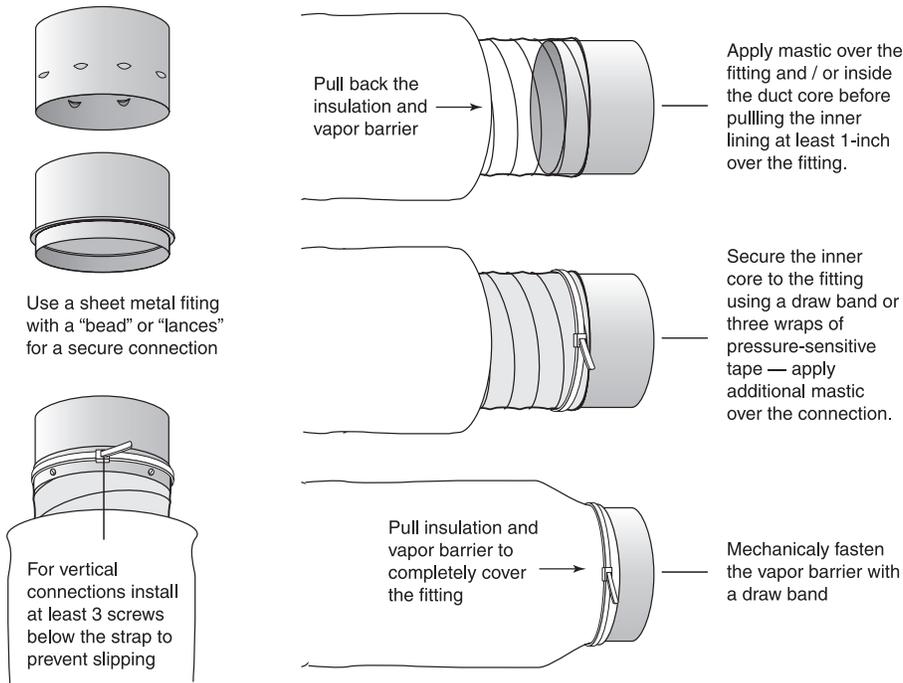
Fiberglass duct board is insulated and sealed as part of its construction. It is usually used to form rectangular supply and return trunks, branches, and plenums, although it can be used for runouts as well. Fiberglass duct board provides excellent sound attenuation, but its longevity is highly dependent on its closure and fastening systems. Connections should be mechanically fastened using shiplap or V-groove joints and stapling and sealed with approved pressure-sensitive tapes and mastic.

✓ FLEXIBLE NONMETALLIC DUCTS

Flexible nonmetallic duct (or flex duct) consists of a duct inner liner supported on the inside by a helix wire coil and covered by blanket insulation with a flexible vapor-barrier jacket on the outside. Flexible duct is often used for runouts, with metal collars used to connect the flexible duct to supply plenums, trunks, and branches constructed from sheet metal or duct board. Flexible duct is also commonly used as a return duct. Flexible duct is factory-insulated and has fewer duct connections and joints. However, flexible duct is easily torn, crushed, pinched, or damaged during installation. It has the highest resistance to air flow. Consequently, if used, it must be properly installed.

AIR DISTRIBUTION SYSTEM INSTALLATION AND SEALING

FLEX DUCT SEALING TIPS



Flexible nonmetallic ducts should not have an air-permeable core. Flexible ducts must be stretched to their full length and cut to fit (not compressed) using the minimum length required to make the connection. Flexible duct that is not fully stretched has high air-flow resistance and tends to sag between supports. Connections and joints must be mechanically fastened using drawstraps and sealed using mastic. Bends in flexible ducts should not exceed 90 degrees and should have a radius greater than one duct diameter.

✓ AIR HANDLER

Because system pressures are highest at the air handler, holes, cracks, and other openings at the air handler will cause more air leakage than elsewhere in the system. Air handlers located in the attic, garage, or crawlspace, or outside in single-packaged heat pumps or gas-packs, warrant special attention. Use mastic, cork rope or tape, or caulk to permanently seal unused holes, seams, wire penetrations, and refrigerant and condensate line penetrations in the air handler cabinet. Use approved pressure-sensitive tapes to seal access panels.

Connections between the air handler cabinet and the main supply and return plenums or ducts should be sealed with mastic or approved pressure-sensitive tapes. It is sometimes easier to remove service panels and seal these areas from the inside using mastic.

✓ PLENUMS

Fiberglass duct board is often used to build supply and return plenums. Mastics or approved tapes may be used to assemble butt joints on fiberglass duct board components such as plenum boxes. Although it is not recommended, closets, spaces under stairs, and other such areas of the house are often used as return plenums. Because these plenums are located inside the house, the need to

seal them is often overlooked. Unless they are well sealed, these plenums will frequently allow unconditioned air to be drawn into the system from the attic, crawl space, or outside. Be sure to seal all such plenums completely—all seams, gaps, and penetrations through the ceiling, floor, and walls. Seal the air handler unit to the shelf of a closet return system.

✓ DUCT BOOTS AND ELBOWS

Seal all joints between ducts, duct boots, and/or elbows with mastic or approved tapes. Seal any leaks in the boots or elbows with mastic, approved tape, or elastomeric caulk. Extend duct boots at the supply and return registers through the wall, ceiling, or floor material and make sure duct boots are sealed to the ceilings, walls, or floors. Sometimes boots may be most easily sealed from the inside, after installation; however, the sealing material must be installed so that it does not interfere with installation or removal of the register.

AIR DISTRIBUTION SYSTEM INSTALLATION AND SEALING

INSTALLATION MATERIALS

✓ FASTENERS

Mechanical fasteners—screws, staples, and draw bands—should be used to secure all joints between sections of duct. Materials intended to seal against air leaks—such as tapes, mastics, and other sealants—should not be used to hold sections of duct together except where mechanical fasteners are not feasible. Ducts should also be well supported so that joints are not pulled apart or the duct distorted (pinched) so that its air flow is reduced.

- **Screws**—On transverse joints in round sheet metal ducts that use sleeves or swedge or crimped fittings, use at least three metal screws equally spaced around the joint to ensure that the joint cannot become separated. For vertical connections made on flexible duct, install at least three screws below the drawband used to secure the inner lining to prevent slippage. Duct boots must be mechanically secured to the building using screws so that the boots do not rely on the ducts for support.
- **Staples and Tape**—Ducts constructed from fiberglass duct board should be fastened together using clinching staples on approximately 2-inch centers and approved pressure-sensitive tape. Where staples cannot be used, joints should be held together using approved pressure-sensitive tapes. The tape should be placed over the seam and 8-inch-long (minimum) crosstabs taped on each side of the duct with a distance of 12 inches or less between crosstabs.
- **Drawbands**—When joining flexible ducts to each other or to other types of duct, the flexible duct must be fitted over a beaded sleeve or collar and attached with drawbands (UV-resistant nylon duct ties or preferably metal worm-drive hose clamps, both with a temperature rating of 165°F)—one drawband to secure the inner lining and a second drawband to attach the outer insulation jacket.
- **Support Straps**—Round sheet metal ducts suspended in the air should be supported by hangers at least every 10 feet. Flexible ducts suspended in the air should be supported at least every 4 feet by straps that are at least 1½ to 1¾ inches wide, and they should not sag more than ½ inch for each foot of distance between the supports. Straps used on flexible ducts should not constrict the inner diameter of the duct or cut the outer jacket.

✓ SEALING MATERIALS

The two primary materials used to seal ducts during installation are mastic and tapes, although other sealants may also be used in special applications. Use all mastics, tapes, and other sealants according to manufacturer instructions. Clean and dry joints, seams, and openings of oil, grease, and dirt before applying sealants, especially when using tapes and non-mastic sealants. Duct insulation does *NOT* stop leakage and is *NOT* a sealing material; in fact, dirty insulation is a telltale sign of air leakage.

- **Mastics**—Mastics that meet UL Standards 181A or 181B may be used to seal duct joints. Use mastics labeled UL 181A-M for fiberglass ducts, UL 181B-M mastics for flexible ducts, and either for rigid metal ducts and components. Water-based mastics are preferable to petroleum-based mastics because they have shorter curing times, easier cleanup, and more “forgiving” application characteristics. Mastic must not be diluted. Mastic should be applied liberally over the entire joint between and over mated surfaces. When using over holes or gaps that are larger than 1/8 to 1/4 inch, apply a thick layer of mastic followed by at least one layer of fiberglass mesh tape, topped by a layer of mastic that fills the scrim pattern completely and covers the mesh.
- **Tapes**—Heat-activated and pressure-sensitive tapes that meet UL Standards 181A or 181B and are marked for use in the intended application can be used to construct ducts and, in some cases, seal ducts and other distribution system components. Heat-activated tape should be labeled UL 181A-H and used only on rigid fiberglass ducts. Use pressure-sensitive tapes labeled UL 181A-P for rigid fiberglass ducts, 181B-FX for flexible ducts, and either for rigid metal ducts and components. Pressure-sensitive tape used on rigid fiberglass ducts should be rubbed firmly until the pattern of the facing reinforcement shows through the surface of the tape. When taping traverse joints, wrap the tape three times.

Pressure-sensitive metallic tape with non-butyl adhesive is useful to temporarily seal air handler access panels that may need to be opened in the future. When sealing access panels, a card should be taped to the access panel that says “Please Replace Any Tape That is Removed” as a reminder to future repair personnel.

Cloth-backed rubber-adhesive (duct) tapes should not be used because they deteriorate with time and exposure to heat.

Pressure-sensitive metallic tape with butyl adhesive (not meeting UL Standard 181) can be used to seal metal-to-metal connections. Cork tape can be used to seal gaps where refrigerant lines penetrate the air handler unit cabinet.

AIR DISTRIBUTION SYSTEM INSTALLATION AND SEALING

For more information, contact:

Energy Efficiency and Renewable Energy Clearinghouse (EREC)
1-800-DOE-3732
www.eere.energy.gov

Or visit the Building Technologies Program Web site at
www.buildings.gov

Or refer to the Duct Installation and Sealing Standards, Specification of Energy-Efficient Installation Consortium for Energy Efficiency
617-589-3949
www.cee1.org/resid/rsac/hvac.php3

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www.ornl.gov/btc

SMACNA's manuals may be obtained from 4201 Lafayette Center Drive, Chantilly, Virginia 20151-1209
703-803-2980, www.smacna.org

ADC's standards can be obtained from 1000 East Woodfield Rd, Ste. 102, Schaumburg, Illinois 60173
847-706-6750, www.flexibleduct.org

NAIMA standards and guidelines can be obtained from Canal Center Plaza, Ste. 310, Alexandria, Virginia 22314
703-684-0084, www.naima.org

UL's standards may be obtained from
www.ul.com

The International Energy Conservation Code can be obtained from the International Code Council
703-931-4533, www.intlcode.org

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DUCT LEAKAGE TESTING

Once ducts have been installed and sealed, the only way to really know how leaky they are is to conduct a duct airtightness test. Such tests can be performed using a special fan called a blower door or, better, with a special duct blower. Often, energy efficiency incentive programs, such as the DOE/EPA Energy Star® Program, require duct leakage testing (usually performed in less than an hour) to confirm the airtightness of the ducts. A typical requirement is that duct leakage measured when the ducts are pressurized to 25 Pascals should not exceed 5% of the system air flow rate.

DUCT INSULATION

Insulate all portions of duct systems located outside of the conditioned space (including boots and plenums), typically using flexible or rigid fiberglass insulation. Metal ducts located in the conditioned space may be insulated to prevent condensation. Adhere to the following guidelines when selecting and installing the insulation.

- Select the insulation levels for the duct system in accordance with the 2000 International Energy Conservation Code. Use higher duct insulation levels in ducts located outside the conditioned space than those specified by this Code, especially when variable-speed air handling equipment is being used. Lower air flows provided by variable-speed heating and cooling systems to improve operating efficiency increase the resident time of air within the air distribution system, which in turn increases thermal losses in the winter and thermal gains in the summer. Attic insulation placed over ducts helps where it is possible.

- Insulation must be continuous, especially at plenums, boots, elbows, and connections (i.e., no gaps or voids in the insulation).
- Wraps of spirally-wrapped unfaced insulation should overlap at least 2 inches.
- Permanently secure insulation to the duct with draw bands, non-corrosive wire, rust-resistant staples or nails, or pressure-sensitive tape wrapped at least three times around the circumference. Parallel-wrapped faced insulation is usually secured with pressure-sensitive tape. Secure unfaced parallel-wrapped insulation at least every 18 inches along its length using non-taping methods. Attachments should not compress the insulation more than 20% along straight duct lengths and no more than 50% in bends.
- When flexible ducts are joined, the insulation jackets must overlap at least 2 inches. The overlap must be secured and sealed with a draw band or with three staggered wraps of pressure-sensitive tape.
- Install a continuous vapor barrier outside the insulation (e.g., foil-faced fiberglass insulation sealed with pressure-sensitive metallic tape) on metal ducts that are used for space cooling, except in dry climates where condensation on the duct surface will not occur. Tears in the insulation facing (especially the outer lining of flexible duct) must be avoided to prevent moisture accumulation in the insulation, which significantly reduces its effectiveness.
- At duct terminations (e.g., boots, collars), the insulation jackets of flexible ducts should be pulled over the insulation and secured and sealed to the fitting with a draw band, mastic and fiberglass mesh tape, or three wraps of pressure-sensitive tape.



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