

Chapter 8

Duct Design and Sealing

Duct Materials

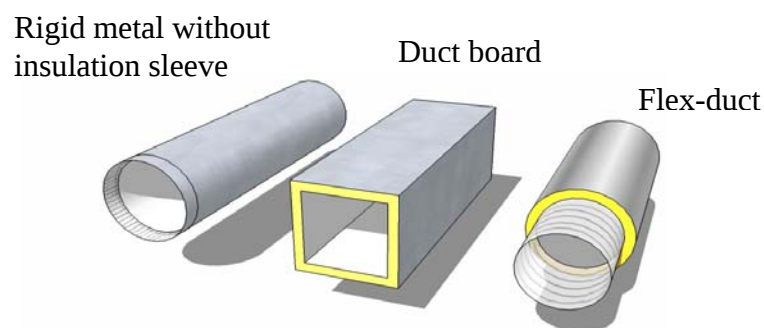
The three most common types of duct material used in home construction are *metal*, *rigid fiberglass duct board*, and *flex-duct*. Both metal and fiberglass duct board are rigid and installed in pieces, while flex-duct comes in long sections.

Flex-duct is usually installed in a single, continuous piece between the register and plenum box or plenum box and air handler. Be careful not to tear the soft lining material. The flex-duct must also not be pinched or constricted. Long flex-duct runs can restrict air flow, so they must be installed carefully. Flex-duct takeoffs, while often airtight in appearance, can have substantial leakage and should be sealed with mastic. Always select duct insulation with a shiny, metal foil exterior covering to reduce radiant heat gain and to act as a vapor barrier.

Round and rectangular metal duct must be sealed with mastic and insulated during installation. It is important to seal the seams and joints first, because the insulation does not stop air leaks.

Metal ducts often use fiberglass insulation having an attached metal foil vapor barrier. The duct insulation should be at least R-6, and the vapor barrier should be installed to the outside of the insulation - facing away from the duct. The seams in the insulation are usually stapled together around the duct and then taped. Duct insulation in homes at least two-years old provides visible clues about duct leakage – if the insulation is removed, lines of dirt in the fiberglass often show where air leakage has occurred. Sometimes, rectangular metal duct used for plenums and larger trunk duct runs is insulated internally with duct liner, a high density material that should be at least 1-inch thick. Many homeowners have concerns about the long term effects of the duct liner exposed to the air flowing through the system. They prefer to insulate the outside of the ductwork, rather than the inside. Internally insulated metal ducts cannot be cleaned as easily as externally insulated ducts. For acoustical dampening in transfer ducts (from room to room or hall) the internal lining is preferred.

Figure 8-1
Types of Ductwork



The Problem of Duct Leakage

Studies conducted throughout the country have found that poorly sealed ductwork is often the most prevalent yet easily solvable problem in new construction. Duct leakage contributes 10% to 30% of heating and cooling loads in many homes. In addition, duct leakage can decrease comfort and endanger health and safety.

Locating ducts in the conditioned space eliminates many problems with leakage. They are installed in vertical *chases* or *horizontal furred areas* (framed duct passageways situated below the ceiling). To be effective they must be completely sealed from unconditioned spaces.

Duct insulation does not provide an airtight seal. The heating and cooling contractor should use proper materials when sealing ductwork - in particular, duct sealing mastic with embedded reinforcing mesh tape. To ensure ducts are tight, a home energy rater will conduct a duct leakage test, which is necessary to qualify for possible tax credits.

The International Residential Code requires that HVAC contractors use mastic and mesh tape to seal leaks. This provision reflects the universal recognition that duct sealing is not only a cost effective energy efficiency measure, but it also improves comfort and, more importantly, makes our homes healthier places in which to live. Chapter 2 explains some of the health risks of leaky ductwork in detail.

Duct Leaks and Air Leakage

Forced-air heating and cooling systems should be *balanced* - the amount of air delivered through the supply ducts should be equal to that drawn through the return ducts. If the two volumes of air are unequal, the pressure inside the house can be affected. Pressure imbalances increase air leakage into and out of the home increasing air conditioning run-time to condition the infiltrated air. Pressure imbalances can also create air quality hazards in homes including:

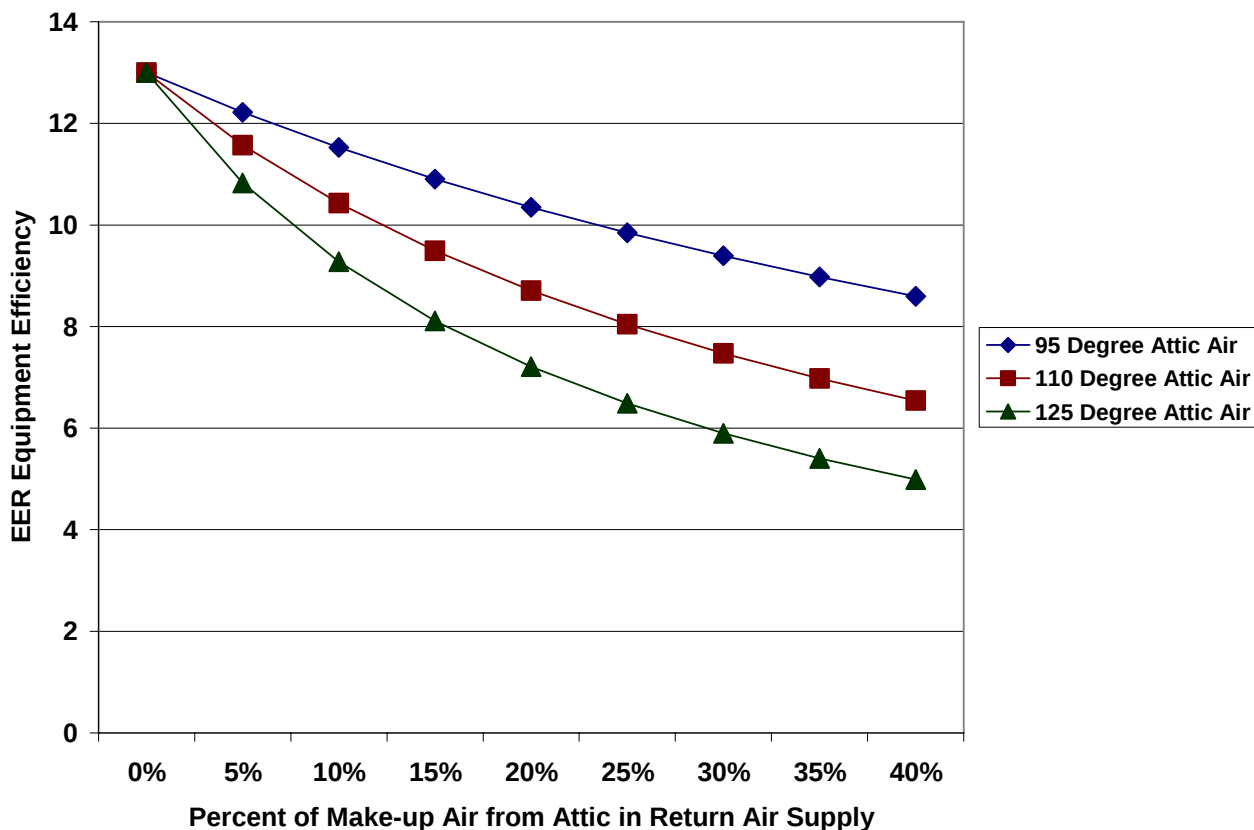
- Pulling pollutants into the air handling system via return leaks.
- Draws in dust, mold, and humidity from the crawlspace.
- Potential back drafting of combustion appliances such as fireplaces, wood stoves and gas burners.
- Homes with central (non ducted) returns can have pressure imbalances when the interior doors to individual rooms or suites are closed:
 - The rooms having supply registers and no returns become pressurized, while the areas with centralized returns become depressurized (negative pressure relative to other areas of the house).
 - If the returns are open to rooms with fireplaces or combustion appliances (gas water heaters, for instance), these spaces can become sufficiently depressurized to draw combustion products, including carbon monoxide, into the air stream.

Typical causes of and concerns about pressure imbalances are addressed more fully in Chapter 2.

Figure 8-2 shows the impact of return and supply leaks on HVAC equipment efficiency when the makeup air is drawn from a hot attic. For example, a HVAC system having 15% return leakage in a moderately hot attic (125°F) can suffer a 50% drop in efficiency - from SEER 10 to SEER 6. The

SEER (Seasonal Energy Efficiency Ratio) measures the number of Btu's per hour of cooling each watt of electricity provides.

Figure 8-2
Efficiency Losses Due to Attic Return Leaks
(15% Supply Leaks)



When HVAC supply ducts leak air to the outside, the return side of the system still requires the full amount of air back. In a home with 15% supply leaks, if 100% of the replacement air comes from the attic at 125 degrees, the efficiency of the system will drop from SEER 13 to about SEER 8.0, a 40% reduction in efficiency. Note that duct leakage of only 5% results in efficiency losses of 5% to 15%.

Leaky ducts can, therefore, be a significant cause for higher utility bills. They can also lower supply air temperatures in winter and increase them in summer, which may pose major comfort problems for the occupants.

Sealing Air Distribution Systems

Duct leakage should be minimized. Many duct seams and joints are poorly sealed with ineffective materials such as cloth “duct tape,” unrated aluminum tape, or similar products with low quality adhesives not designed to provide an airtight seal over the life of the home. Use only the following products and techniques for sealing the components of the air distribution system:

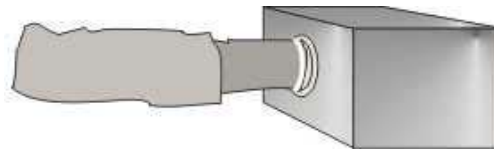
- Nontoxic duct sealing mastic (UL labeled 181A or B) with fiberglass mesh tape is highly preferred and provides a lifetime seal. It may add 1 to 2% to the cost of a system.

- Aluminum tape with a UL-181 A or B rating or "mastic" tapes with improved adhesives.
 - o The duct surface must be clean of oil and dirt, and the tape must fully adhere to the duct with no wrinkles.
 - o A squeegee must be used to remove air bubbles from beneath the taped surface.
 - o Costs only slightly more than "silver tape," which has an inferior adhesive.
- High quality caulking or foam sealant at register boots.

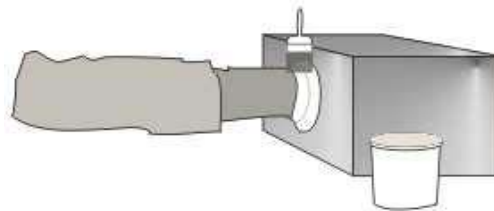
Proper sealing and insulation of the ductwork in unconditioned areas requires careful attention to detail and extra time on the part of the HVAC contractor. The cost of this extra time is well worth the substantial savings on energy costs, improved comfort, and better air quality that a properly designed, constructed, and sealed duct system offers.

Figure 8-3
Sealing Flex-duct Collar with Mastic

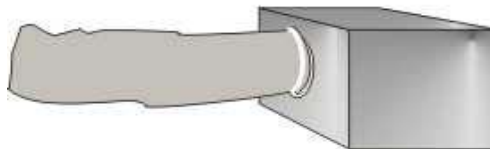
Attach flex-duct to take-off collar with strap.



Apply mastic to seal flex-duct to collar and collar to plenum.



Pull insulation and outer liner over sealed take-off; strap outer liner in place



The easiest answer to the question of where to seal air distribution systems is “everywhere.” A list of the key locations is as follows:

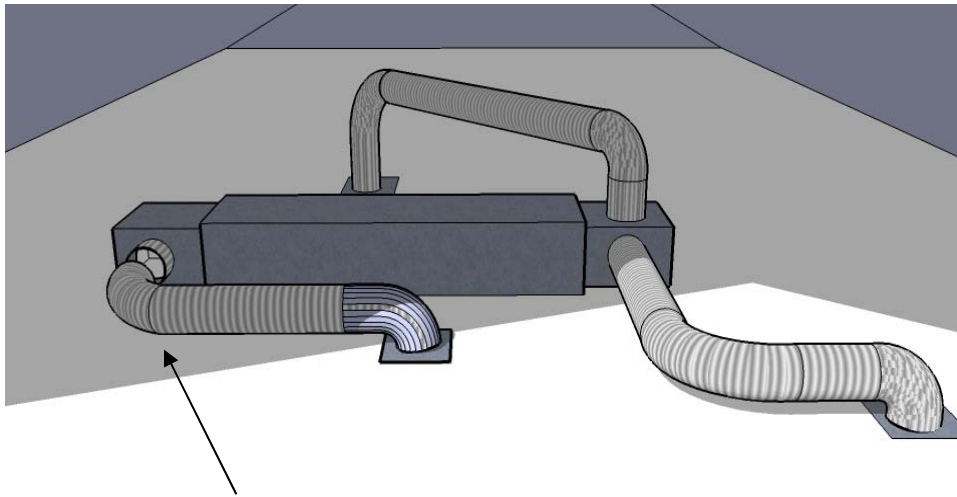
High priority leaks

- Disconnected components, including takeoffs that are not fully inserted, ducts that have been dislodged, tears in flex-duct, and strained connections between ductwork (visible where ducts are bent without a metal elbow).
- All of the seams in the air handling unit, the supply and return plenums, and rectangular ductwork - look particularly underneath components and in any other tight areas. Also, seal the holes for the refrigerant, thermostat, and condensate lines with non-hardening putty. Use tape rather than mastic to seal the seams in the panels of the air handling unit so they can be removed for servicing. After completing service and maintenance work, such as filter changing, make sure the seams are re-taped.
- The return takeoffs, elbows, boots, and other connections. If the return is built into a wall, all connections and seams must be sealed carefully.
- The takeoffs from the main supply plenum and branch lines.
- Any framing in the building used as ductwork, such as a “panned” joist in which sheet metal nailed to floor joists provides a space for conditioned air to flow. It is preferable to avoid using framing cavities as a part of the duct system.
- Between the branch ductwork and the boot, the boot and the register, the seams of any elbows, and other potential leaks in this area.

Low Priority Leaks

- Longitudinal seams in round metal ductwork.

Figure 8-4
Disconnected Ducts Are High Priorities



Disconnected duct. Also, regardless of the type of duct material, in order to maintain designed air flows to each register no bends greater than 45 degrees should ever be made in the duct run.

Ducts can become disconnected during initial installation, maintenance, or even normal operation. They should be checked periodically for problems.

Testing for Duct Leakage

The best method to ensure airtight ducts is to perform a pressure test on the entire duct system, including all boot connections, duct runs, plenums, and the air handler cabinet. Much like a pressure test required for plumbing, ductwork can be tested during construction so that problems can be more easily corrected.

In most test procedures, a technician temporarily seals the ducts by taping over the supply registers and return grille(s). Then, the ducts are pressurized to a low pressure, usually 25 Pascals, using a duct testing fan. This pressure is comparable to the average pressure the ducts experience when the air handler operates.

While ducts are pressurized, the technician can read the total duct leakage of the HVAC system. Some energy efficiency programs require that the cubic feet per minute of duct leakage measured at a 25 Pascal pressure (CFM25) be less than 3% of the floor area of the house. For example, a 2,000 square-foot house should have less than 60 (2,000 x 0.03) CFM25 of duct leakage.

Another test is to use a blower door (described in Chapter 3) and a duct testing fan together to measure duct leakage after construction is complete. This procedure gives the most accurate measurement of duct leakage to the outside of the home. A duct leakage test can usually be done in about one hour for an average-sized home.

Figure 8-5
Duct Test on Return Grille

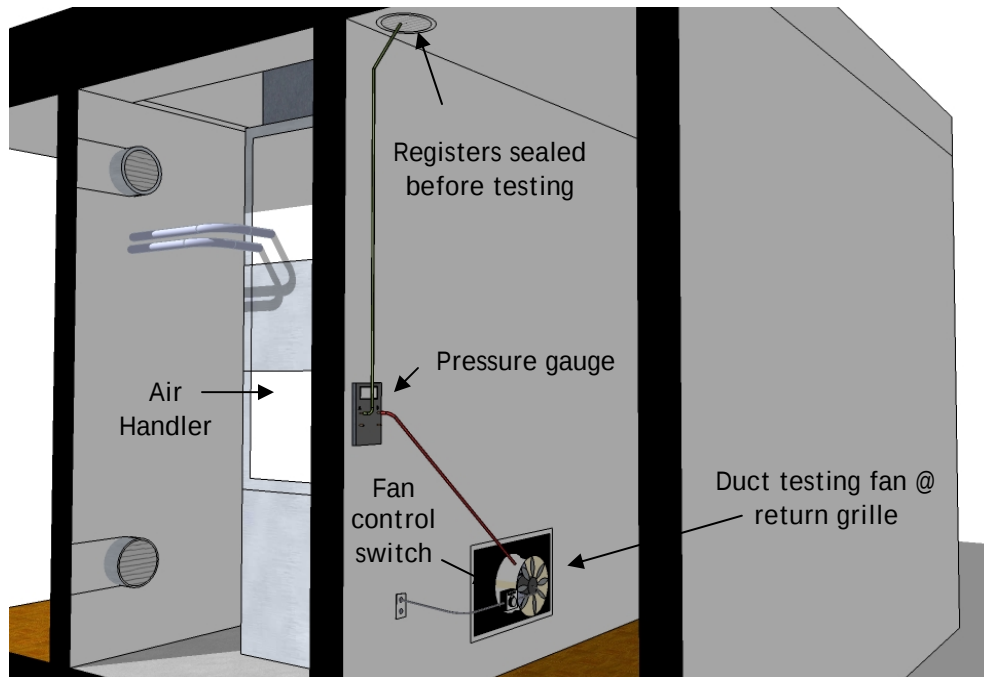


Figure 8-6
Duct Leaks in Inside Spaces

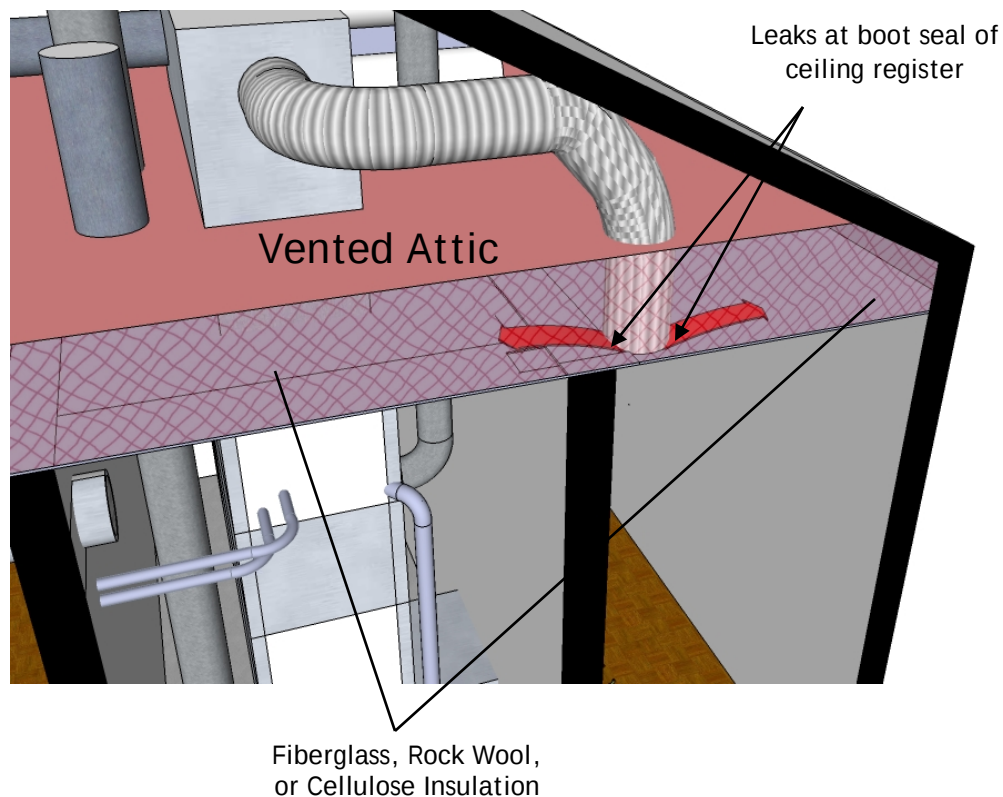
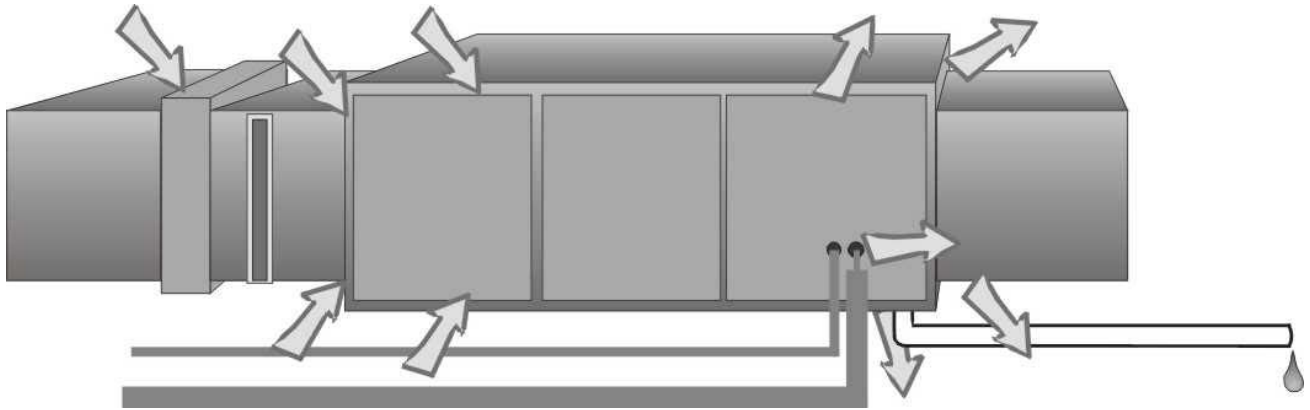
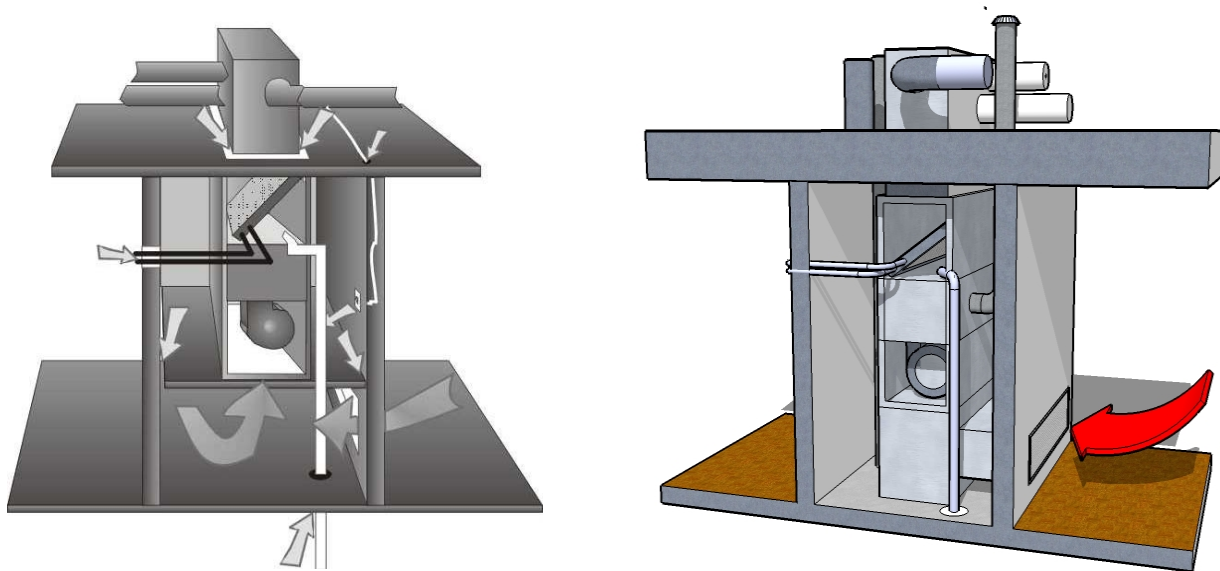


Figure 8-7
Seal All Leaks in Air Handling Unit



Virtually all air handling cabinets come from the factory with leaks, which should be sealed with duct-sealing mastic. Removable panels should be sealed with tape.

Figure 8-8
Shelf-Mounted Systems without Returns



Non-ducted returns can severely depressurize mechanical room closets, not only sapping the system's efficiency, but also creating ideal conditions for back drafting and other air quality problems.

The return should be connected to the home via well-sealed ductwork. All holes to other spaces should be completely sealed.

Figure 8-9
Seal All Leaky Takeoffs

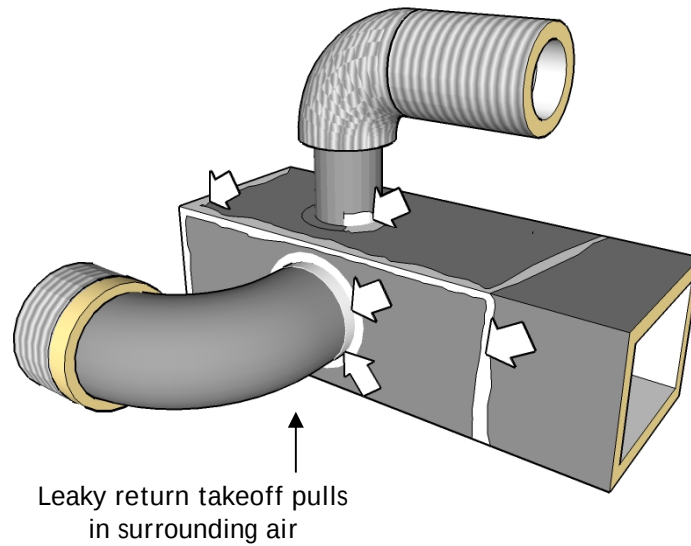


Figure 8-10
Sealing Leaky Boots



Use mastic to completely seal all leaky seams and holes. Use mesh tape with mastic to cover cracks over 1/8-inch wide.

Duct Design

Sizing and Layout

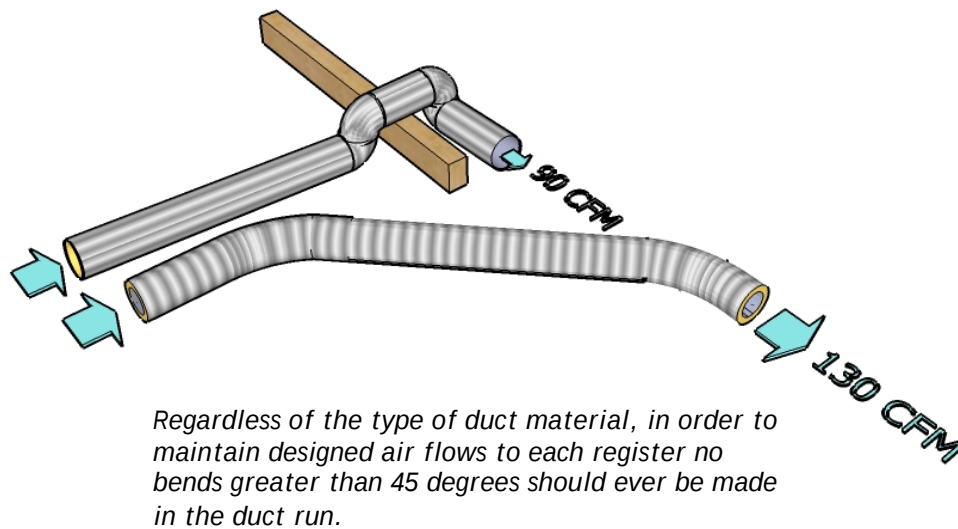
The size and layout of the ductwork affects the efficiency of the heating and cooling system and comfort levels in the home. The proper duct size depends on:

- The estimated heating and cooling load for each room in the house.
- The length, type, and shape of the duct.
- The operating characteristics of the HVAC system (such as the pressure, temperature, and air speed).

The lower temperature of the heated air delivered by a heat pump affects the placement of the registers. A heat pump usually supplies heated air between 90°F and 100°F. At these temperatures, air leaving registers may feel cool. They should be placed so as to avoid blowing air directly onto people. Fuel-fired furnaces typically deliver heated air at temperatures between 110°F and 120°F, 40°F to 50°F greater than room temperature, so placement of the supply registers is less important to maintain comfort.

HVAC contractors usually locate supply registers on room centerlines and place the return air grille(s) near the interior, typically in a central hallway. Most standard designs have only one return for each floor.

Figure 8-11
Comparison of Air Flow in Different 6-inch Ducts



Some contractors try to use one size duct through out the house. One size does not fit all situations. The standard approach of using all one size branch ducts with a single return works for some homes, but can create operating problems for others, including:

- Too much heating and cooling supplied to small rooms, such as bathrooms and bedrooms with only one exterior wall.
- Inadequate airflow, and thus, insufficient heating and cooling, in rooms located at the greatest distance from the air handler.

The heating and cooling industry has developed comprehensive methods to size supply and return ductwork properly. These procedures are described fully in *Manual D, Residential Duct Systems* published by the Air Conditioning Contractors of America. The advantage of proper design is that each room receives air flow proportionate to its heating and cooling load, thus increasing overall comfort and efficiency. The following thoughts, while no substitute for a *Manual D* calculation, should improve system performance:

- If two rooms have similar orientation, window area, and insulation characteristics, but one room is considerably farther from the air handling unit than the other, the ductwork going to the farthest room may need to be larger.

- Bonus rooms over garages often need larger supplies because of the extra heat passing through the roof, and the floor area over ambient air. Insulation installed to code requirements will reduce the need for extra cooling and heating capacity.
- Rooms with large window areas may warrant a larger supply duct, regardless of room size. Proper calculation of solar load will determine requirements. Double pane, low-e windows and shading can reduce the solar load.
- Likewise, large, well-insulated rooms with few windows, only one exterior wall, and with conditioned space above may need only one small duct.
- Ductwork air flow can be adjusted to meet each room's needs using manually controlled dampers and an air flow measurement device. However, velocity will increase for a given plenum pressure, and may increase noise at the register if the duct is oversized.

Return Air Flow Considerations

Air conditioning systems not only supply air flow to rooms, but they pull air out of the rooms, also. If the return flow is not free to exit the space, the pressure will build up in the room and it will look for the path of least resistance. This alternate path could be to either the outdoors or the attic. Window frames can be leak sites to the outdoors. Electrical outlets and switch boxes often communicate with the attic. Bathroom plumbing has vent pipes running up through the attic and is often closed off to limit moisture escape into the rest of the house.

Besides the loss of conditioned air, which you have paid for, the lost air must be replaced before reaching the fan or the remainder of the house would be at a lower pressure than the air outside the house. This causes infiltration, which can bring additional heat, humidity and other undesirable elements with it as described in Chapter 2. (Less than 3 Pascals pressure differential is acceptable for a well balanced system.)

Each space that has a door that is commonly closed, bedrooms, bathrooms, etc. should have adequate provision for air return flow. There are several ways this can be done. A complete return duct system could be used, but would add to the cost substantially. Since most house duct systems in Louisiana are located high on the wall or in the ceiling, floor level return is desirable to provide good ventilation, and to de-stratify the rising hot air in the winter. With under floor supply ducts, high mounted returns can be best.

The return openings will need to be 2 to 3 times the size of the supply duct depending on system design velocities. (Although not always a good basis for design, a “Rule of Thumb” to consider is 1 square inch of wall opening per cfm delivered to the room.) This can take the form of cutting off the bottom of the doors with a $\frac{3}{4}$ inch undercut of a 32” door (24 sq. in.) combined with a standard transfer grille having a width of 14 inches and 80% net free area whose height increases per the cfm delivered to the room divided by 25.

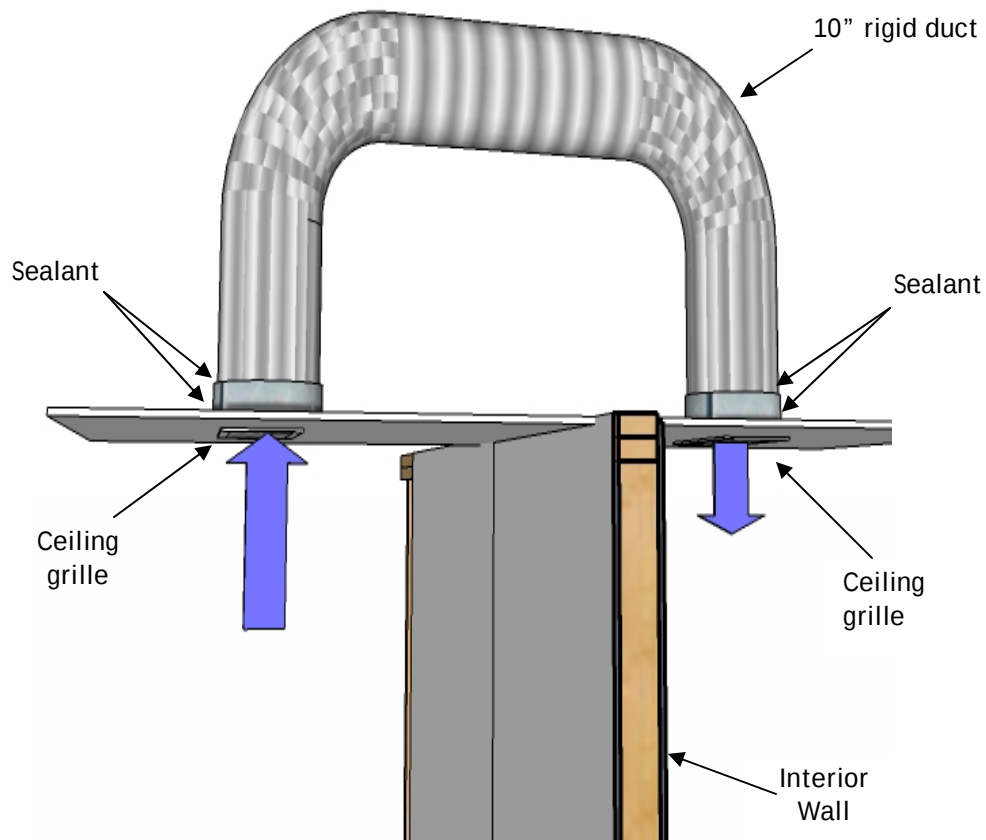
For typical bedroom having 70 cfm supplied and 24 square inches of return opening under a 2’8” door undercut $\frac{3}{4}$ inch and a nominal 14 inch wide transfer grille in the wall, the height of the transfer grille would need to be 4.1”, yielding approximately 70 square inches of total return opening from the bedroom to the air handler’s return grille.

$$32'' \times .75'' + [(14'' \times 4'') \times .80] = 68.8 \text{ square inches}$$

Other Alternatives

A “jump” duct can be installed over the door frame or some other convenient point such as an interior wall as long as it is insulated.

Figure 8-12
Jump Duct



A baffled (for sound) vent above the door may suit the situation if planned for in the framing.

Figure 8- 13
Transfer Grilles – Over Doors

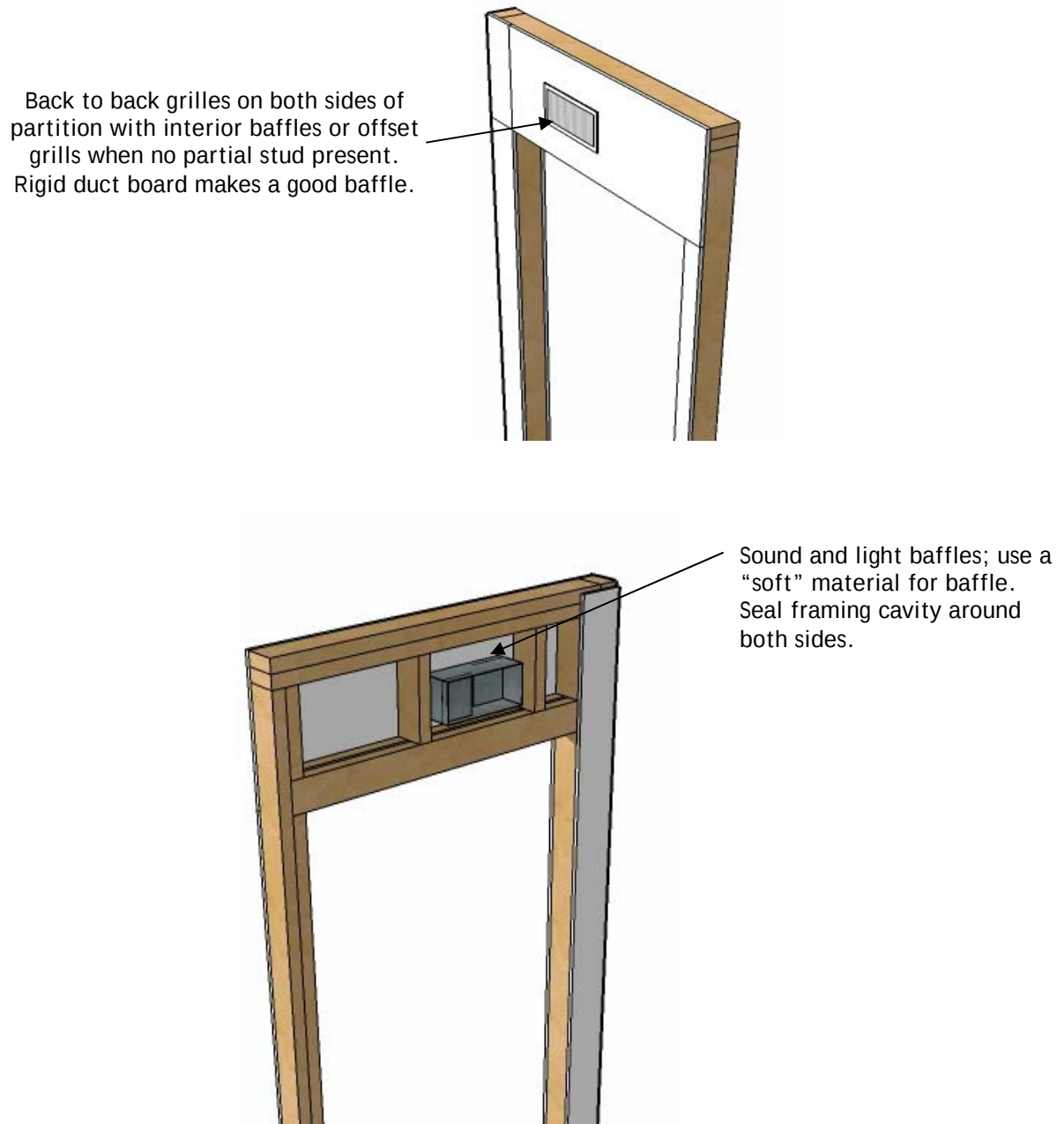
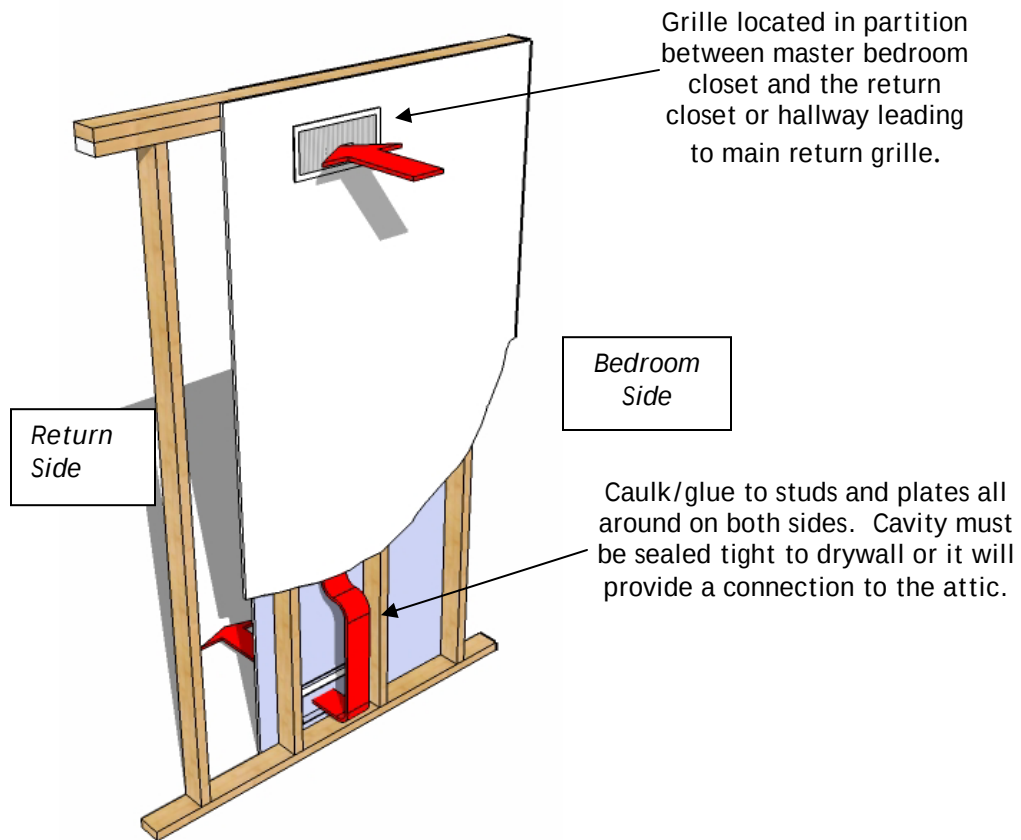
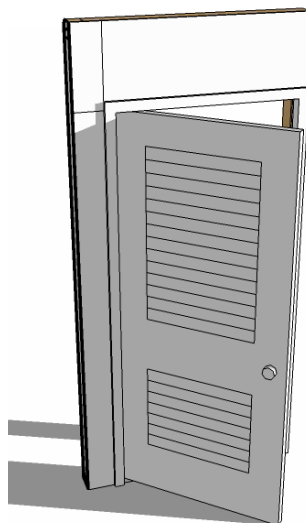


Figure 8-14
Transfer Grilles – In Wall



Louvered passage doors are also a good solution if sound or moisture is not a problem.

Figure 8-15
Louvered Passage Doors



Conclusion

Proper air flow provides comfort and temperature control in the house. Good duct design moves the right amount of air to each space with little sound. Although simple in appearance, the duct system is just as critical to a comfortable and economical home as a high seer air conditioner or abundant insulation. In fact, a leaky, inadequate duct system can undo all the effort put into these other systems.

Insist on a properly sized and designed duct system to compliment the other equipment you are buying. This is no place to save a few dollars as you will be paying for it on every utility bill for the life of the house. If the house will have high ceilings in some parts, investigate keeping equipment and all duct work inside the envelope. By doing this leaks don't hurt performance nearly as much. If duct work must be located in the attic, make certain that it is well sealed permanently and well insulated. It may cost a little more but it will save you money every month.

Notes: