

Supplement A

Improving Forced Air Heating Systems

The Challenge

Recent research and testing of new homes in the Pacific Northwest and across the United States shows the importance of a properly installed HVAC system. Interactions between system components, the house envelope, and other equipment can seriously affect:

- Occupant health and safety;
- Occupant comfort;
- Equipment and structural durability; and
- Energy efficiency.

The *Washington State Energy Code* (WSEC) provides specifications for duct sealing, duct insulation, equipment sizing, equipment efficiency, and controls that provide a basis for a safe, efficient system. In forced air heating and cooling systems, attention to detail in duct installation is very important. Ductwork that is undersized, unbalanced or leaky can cause serious problems. Understanding these problems helps you build a better, safer home for your client that meets the intent, as well as the letter, of the Code.

Health and Safety

Leaky ducts can compromise health and safety. Because the air handler fan drives air into the ductwork, even small leaks can have a large impact. When duct leaks are connected to areas outside of the conditioned space, the leakage induces pressure changes across the envelope of the house. Supply leaks depressurize the house. Return leaks pressurize the house (see Figure A-1). Depressurization can cause combustion appliances to backdraft. Backdrafting allows flue gases to enter the living space and can

Figure A-1
Supply and Return Leakage

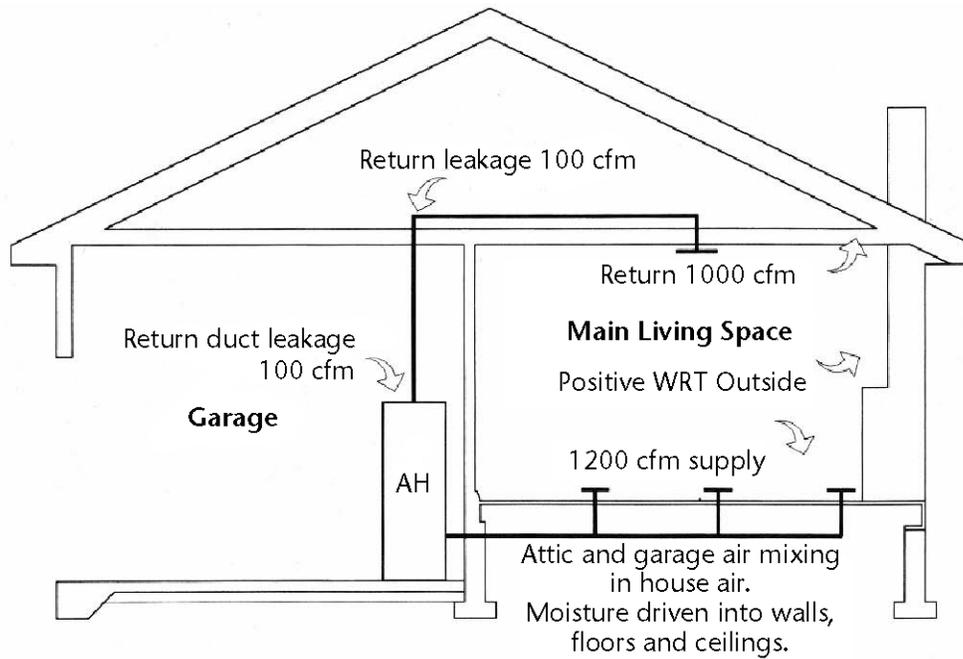
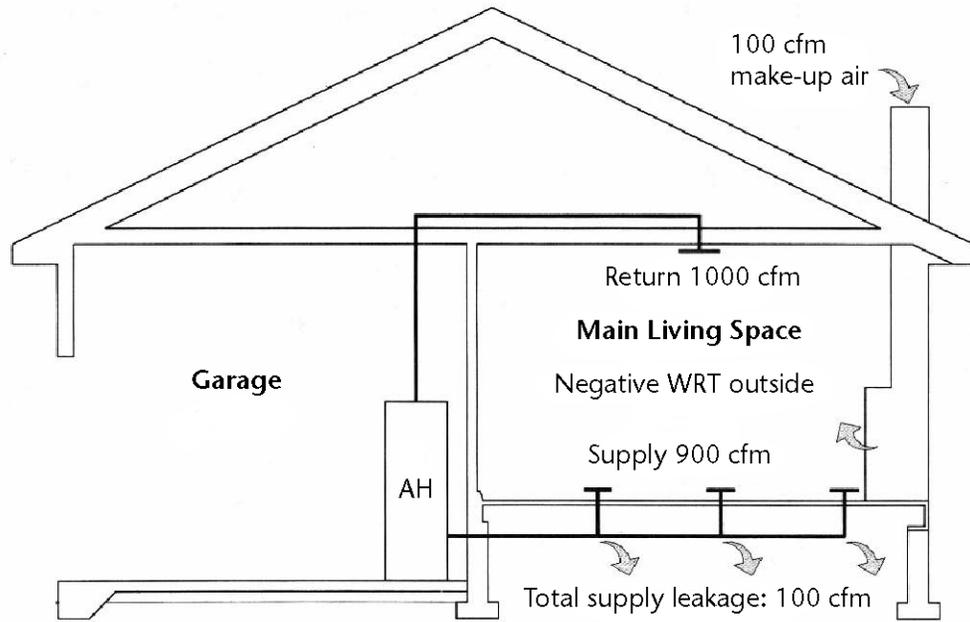
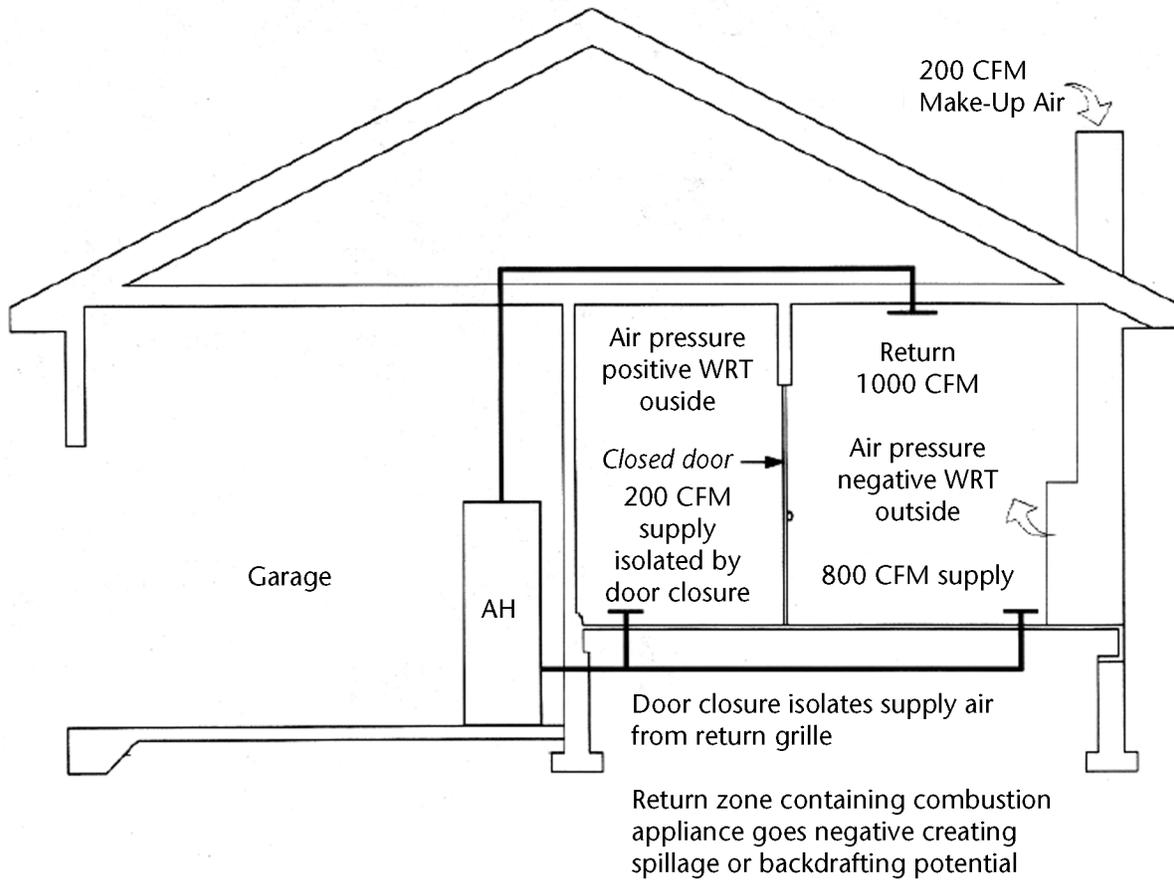


Figure A-2
Unbalanced Duct System



be very serious, potentially leading to death from carbon monoxide exposure. Return leaks in a confined area such as a utility room or basement can also induce depressurization. This can backdraft an adjacent gas-fired water heater, or suck soil gases (such as radon) into a basement. Return leaks in a garage, crawlspace, or attic can potentially introduce pollutants into a house, adversely affecting indoor air quality.

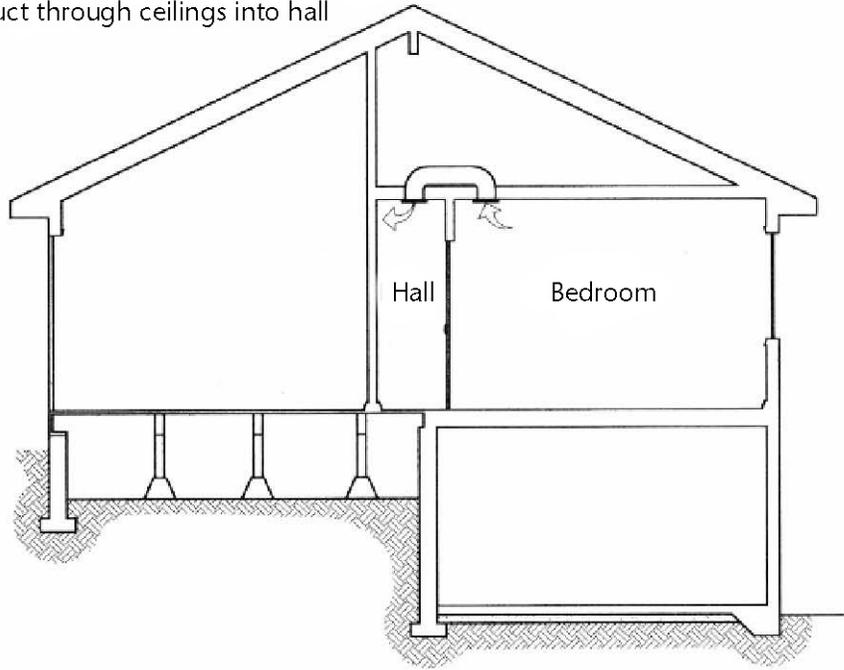
Unbalanced duct systems also cause pressure problems. In systems with central returns (very common in newer homes) supply registers and return grilles are often isolated when bedroom doors are closed. With the door closed, the zone with the return depressurizes, again creating potential backdrafts (see Figure A-2).

Testing in new homes shows that approximately 1 square inch of unobstructed return air pathway is required for each CFM of supply air delivered to a zone. This may be accomplished with ducted returns in each zone, undercut doors, transfer grilles or some combination of the above (see Figure A-3).

Figure A-3

Unobstructed Return Air Options

Duct through ceilings into hall



Through-wall transfer grille to hallway

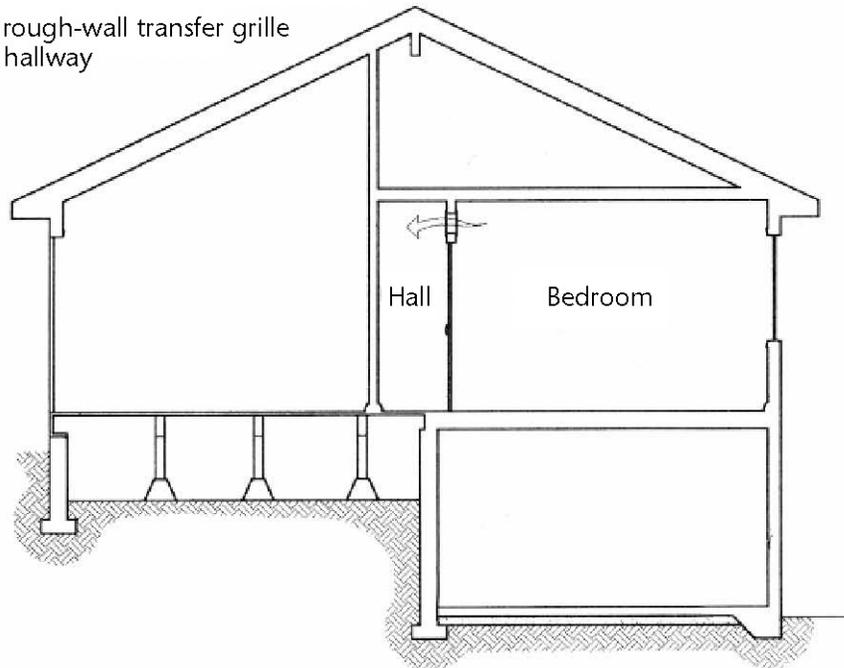


Figure A-4

Moisture Damage Resulting from Return Duct Leakage



Improper duct design and sizing can cause heating and cooling equipment to operate out of the manufacturer's specifications for temperature rise, pressure drop or air flow. This impacts efficiency and equipment lifetime. Airflow through the system is especially important for air conditioning and heat pump equipment. Inadequate airflow is a major cause of premature compressor failure. Follow the manufacturer's specifications, but generally look for 400-425 cfm of airflow per ton of installed capacity.

Comfort

Leaky ducts can also cause comfort problems. When supply ducts leak, the air delivery to different parts of the home may not match heating and cooling loads. If the ducts are well sealed, the register dampers can be adjusted to distribute conditioned air where it is needed. If the ducts leak, this control option is lost.

Return leaks connected to the outside can change the return air temperature, adversely impacting system performance.

Example: A large return leak in an attic in the summer time may draw 150°F air into the system rather than 75-80°F house air. The higher return temperature can overwhelm the system capacity and make it impossible to cool the home.

Duct leakage may also change the air infiltration rate of the home leading to excessive dryness during the heating season and high humidity levels during the cooling season. Both are common comfort complaints.

Improperly sized ductwork and poor register placement often contribute to comfort problems. Inadequate or excessive airflow may result from poor design. Heat pump systems with lower delivery temperatures are especially vulnerable to comfort complaints because of the higher volumes of air that must be moved.

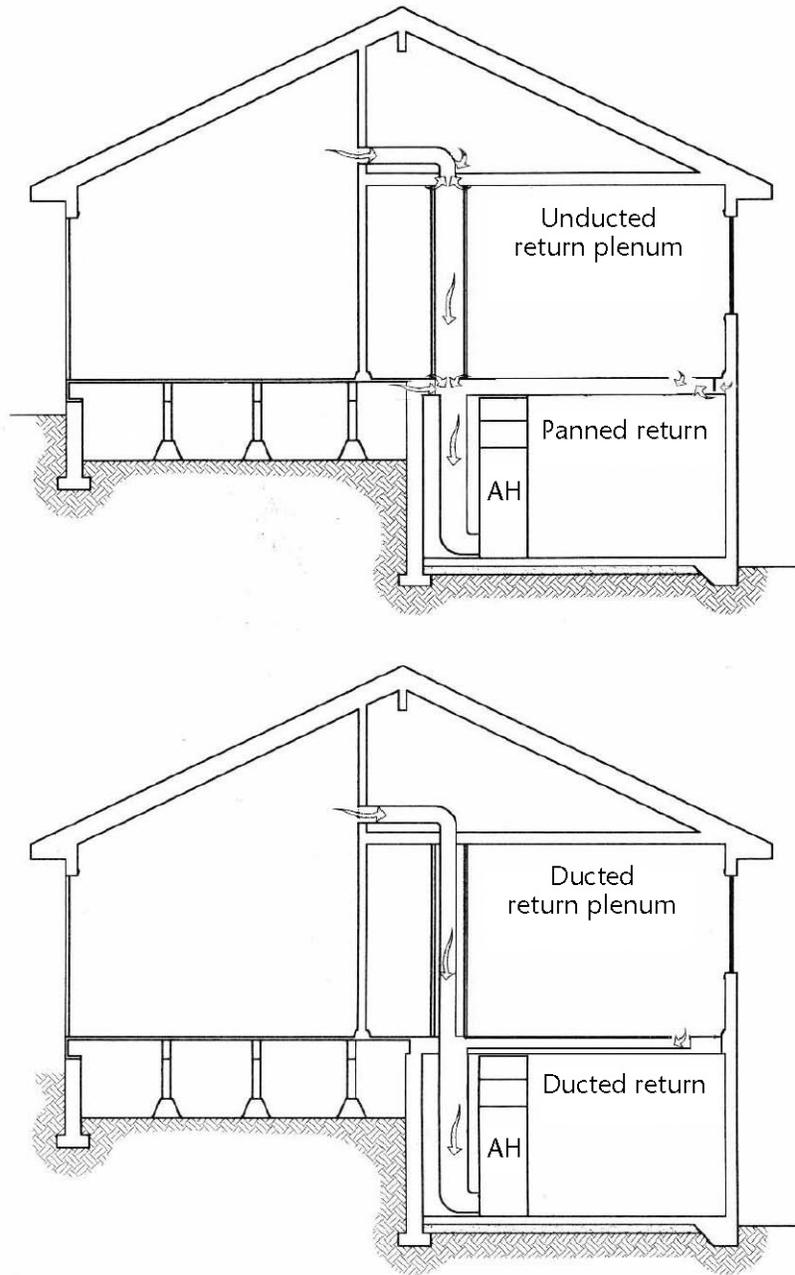
Durability

Leaky return ducts connected to the outside pressurize a home. Unbalanced systems also induce pressurization in zones where supply air does not have an adequate return pathway (see Figure A-1). Pressurized zones in homes in heating climates may adversely affect structural durability. During the heating season, positive pressure in the home causes warm moist air to flow into building cavities. As the air reaches colder exterior surfaces, the moisture condenses and wets the building materials.

Example: The photograph in Figure A-4 shows moisture damage to the exterior siding on a new home caused by a

Figure A-5

System with Fully Ducted Returns



return duct leak, which pressurized the house and drove moisture into the exterior wall. The area of most severe damage is the exterior wall for an upstairs bathroom. The use of air cleaning systems with continuous run times exaggerates this problem, making proper sealing and balancing even more important.

Energy Efficiency

The problems that impact health and safety, comfort and durability can also adversely affect energy efficiency. Leaky ducts can deliver conditioned air to unconditioned spaces. Pressure differentials created by leaky ducts or unbalanced systems increase whole house air leakage rates. To put this in perspective, studies have shown that, even in new homes, many systems perform below their expected efficiency (losses of 20-30 percent are not uncommon).

Ductwork and its interaction with the house has a significant impact on overall system effectiveness. When system components operate outside of the manufacturer's specifications for temperature rise, pressure drop, or air flow, efficiency is often lost.

The Solutions

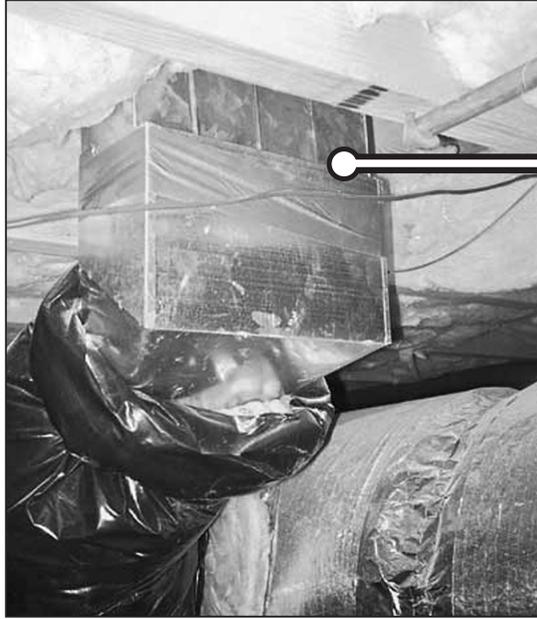
Duct Sealing

To achieve optimum duct sealing performance, the following practices are recommended:

- Do not use building cavities as ductwork. Testing in Northwest homes has shown that return ducts leak far more often than supply ducts. This is associated with the use of panned floor joists and building cavities used as part of the return system. Making a tight well-sealed duct out of a building cavity is often very difficult. For a quality system, it may be less expensive (in the long run) to install a fully ducted return (see Figure A-5).

Figure A-6

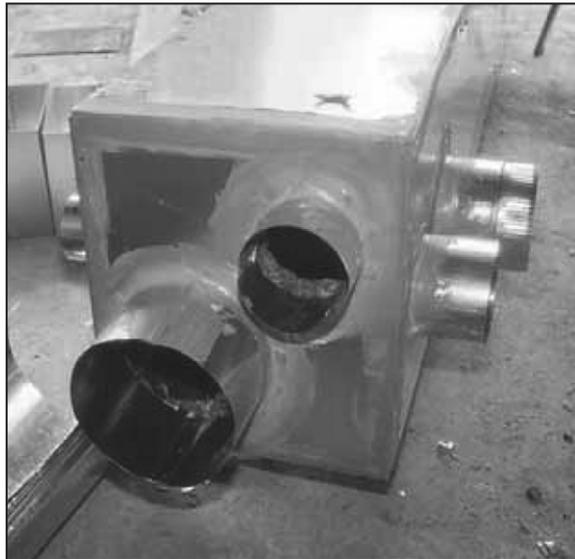
Poor Duct Fittings Can Not be Well Sealed



Tight fittings and assembly are required to control duct leaks over the long term.

Figure A-7

Tight fittings and Mastic Make the Best Seal



- Select fittings that do not leave large gaps in the system. Many ducts are assembled with large gaps between fittings. Even if they are well sealed when first installed, this practice will eventually lead to sealing failure. Duct sealing materials simply are not designed to seal large holes for long periods of time. Tight fittings and assembly are required to control duct leaks over the long term (see Figure A-6).
- Do not use “duct tape” – instead, use durable sealing materials. Advanced aging tests conducted on commonly used duct sealing materials by Lawrence Berkeley National Laboratory concluded that duct tape is a poor performer. Cloth or vinyl backed duct tapes with rubber adhesives failed very quickly and are not recommended for duct sealing. The metal-backed tapes with acrylic adhesive worked better. Mastics were by far the most durable (see Figure A-7).
- Select sealing materials that are compatible with duct system components. Duct sealing materials need to be installed according to the manufacturer's instructions. Many tapes require that the ducts be clean and oil free before installation. Using sealants rated under the UL 181 standard assures compatibility with duct board and flexible duct systems.
- Use performance testing methods to assure a tight seal. Contractors should consider duct tightness testing. While this may not be practical on every job, it is a valuable learning experience. Duct tightness testing will provide feedback on problem areas and sharpen a crew's ability to provide quality installations. Testing can also alert contractors to potential liabilities associated with combustion

appliance back-drafting, as well as durability issues. Tests are required to obtain Energy Efficient Mortgages and the Energy Star® Homes five star rating. Make sure the ducts are fully insulated. The code requires R-8 insulation for ducts outside the conditioned space (R-5 in slabs or the ground). The Super Good Cents® energy efficiency standard suggests that insulating ducts up to R-11 is cost-effective in electrically heated homes. See Chapter 7 of the *Builder's Field Guide* for more detail.

Move the Ductwork Inside

Rather than placing the air handler and duct work in the garage, crawlspace or attic, consider moving it inside. By bringing the components inside the insulation and air barrier of the home, significant energy savings can be achieved. By keeping the system completely indoors, the chance of bringing poor quality air in from the garage or attic space is eliminated. An additional benefit is that ducts installed in the heated space do not require insulation.

Studies conducted in the Northwest indicate that forced air heating systems located completely indoors will reduce energy use by about 30 percent. This can be accomplished at no additional cost. When the builder provides a space indoors for the equipment and ducts, it reduces the HVAC contractor's cost. The HVAC contractor will use less ductwork, will not need to insulate the ducts and will be able to work in better conditions. The HVAC contractor will also be able to specify smaller equipment, reducing cost further. The builder will need to provide an indoor space for the ducts. This may add to the cost of framing and drywall. Per project, the HVAC contractor and builder cost will usually offset each other.

Moving the heating system indoors is most easily accomplished in two-story homes. The duct work can be placed in the space between the floors. Much of the system can be placed in existing floor cavities (see Figure A-8).

Where transitions must be made between floor cavities,

Figure A-8
Ducts Placed Within the Floor Joists



Figure A-9
Drop Soffit Conceals Ducts

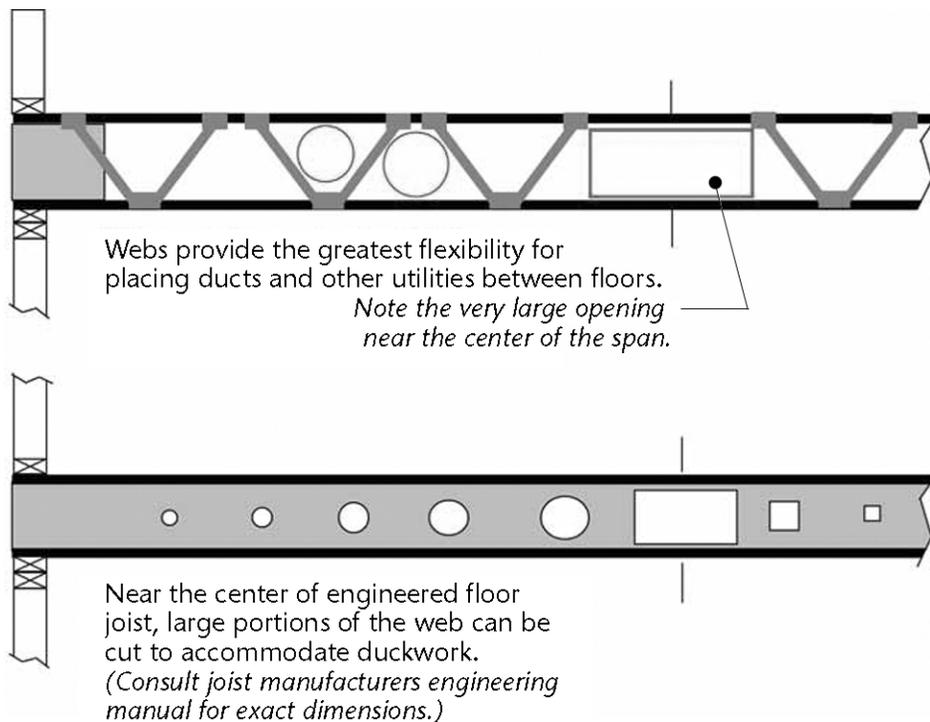


drop soffits are traditionally used (see Figure A-9).

The increasing use of engineered floor trusses provide additional opportunities for moving ducts easily between floors. Most composite wood trusses can be cut to accommodate large transitions across the floor joist. Web trusses provide the greatest opportunity. Steel webs with wood cords provide areas large enough to incorporate substantial

Figure A-10

Engineers Trusses Provide Space for Ducts Between Floors



duct systems (see Figure A-10).

Bringing combustion furnaces inside the envelope requires care in meeting combustion air and venting requirements. Direct vent and sealed vent equipment are likely the best solutions.

Heating System Design and Installation

Heating systems do not perform to promised specifications when the ducts are not the correct size. Ducts supplying air to individual rooms need to be sized to provide air flow that matches the heating requirement of the room. The entire system must be designed so that it allows the correct air flow through the heating and cooling equipment. In many cases, these two criteria are not met. This leads to comfort problems, and loss of equipment efficiency.

To correctly size duct systems, use recognized engineering principles and calculated loads. The most widely used methods are *ACCA * Manual J* heat loss method and *ACCA Manual D* duct sizing method.

The home designer needs to provide space for the ductwork. Forced air heating systems need to be included in the home planning process. Too often systems fail because the home designer has not provided space for equipment and ductwork. Home designers should consult the HVAC contractor early in the design process.

* Air Conditioning Contractors of America Association, Inc.

Recommended Practice

Follow these suggestions to build quality HVAC systems:

- Meet or exceed Code requirements. Codes affecting HVAC installations are set up to establish minimum safety and efficiency standards. It is a good place to start.
- Size and design duct systems using recognized engineering principles and calculated loads.
Examples: *ACCA Manual D* and *ACCA Manual J*.
- Install equipment according to the manufacturer's instructions.
- Test and adjust the equipment and the distribution system.
- When combustion appliances are present, provide for combustion safety. Vent properly, provide combustion air, minimize negative pressures, test for CO (carbon monoxide) production and backdrafting, install CO alarms and educate the homeowner about combustion safety.
- Where possible, install ducts in the heated space.
- Seal ducts.
- Insulate ducts not installed in the heated space.
- Use a systems approach to assure health, safety, comfort, durability and energy efficiency.