8.14 Ducted Air Distribution

SWS Detail: 5.01 Forced Air; 5.0101 Controls; 5.0104 Duct Installation; 5.0105 Duct Repair; 5.0106 Duct Sealing; 5.0107 Duct Insulation

The forced-air system consists of an air handler (furnace, heat pump, air conditioner) with its heat exchanger along with attached ducts. The annual system efficiency of forced-air heating and air-conditioning systems depends on the following issues.

- Duct leakage
- System airflow
- Blower operation
- Balance between supply and return air
- Duct insulation levels

8.14.1 Sequence of Duct Improvements

The evaluation and improvement of ducts has a logical sequence of steps.

√ Solve the airflow problems because a contractor might have to replace ducts or install additional ducts, which would possibly waste your efforts at retrofitting.

√ Determine whether the ducts are located inside the thermal boundary or outside it.

√ Evaluate the ducts' air leakage, and decide whether duct-sealing is important and if so, find and seal the duct leaks.

√ If supply ducts are outside the thermal boundary or if condensation is an air-conditioning problem, insulate the ducts.

8.14.2 Solving Airflow Problems

SWS Detail: 5.0104 Duct Installation; 5.0105 Duct Repair; 5.0106 Duct Sealing; 5.0107 Duct Insulation

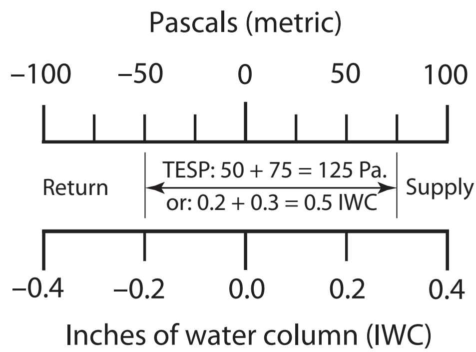
You don't need test instruments to discover dirty blowers or disconnected branch ducts. Find these problems before measuring duct airflow, troubleshooting the ducts, or sealing the ducts. These steps precede airflow measurements.

1. Ask the client about comfort problems and temperature differences in different rooms of the home.
2. Based on the clients comments, look for disconnected ducts, restricted ducts, and other obvious problems.
3. Inspect the filter(s), blower, and indoor coil for dirt. Clean them if necessary. If the indoor coil isn't easily visible, a dirty blower means that the coil is probably also dirty.
4. Look for dirty or damaged supply and return grilles that restrict airflow. Clean and repair them.
5. Look for closed registers or closed balancing dampers that could be restricting airflow to uncomfortable rooms.
6. Notice moisture problems like mold and mildew. Moisture sources, like a wet crawl space, can overpower air conditioners by introducing more moisture into the air than the air conditioner can remove.

Measuring Total External Static Pressure (TESP)

The blower creates the duct pressure, which is measured in inches of water column (IWC) or pascals. The return static pressure is negative and the supply static pressure is positive. Total external static pressure (TESP) is the sum of the absolute values of the supply and return static pressures. Absolute value means that you ignore the positive or negative signs when adding supply static pressure and return static pressure to get TESP. This addition represents the distance on a number line as shown in the illustration here.

TESP number line: the TESP represents the distance on a number line between the return and supply ducts.



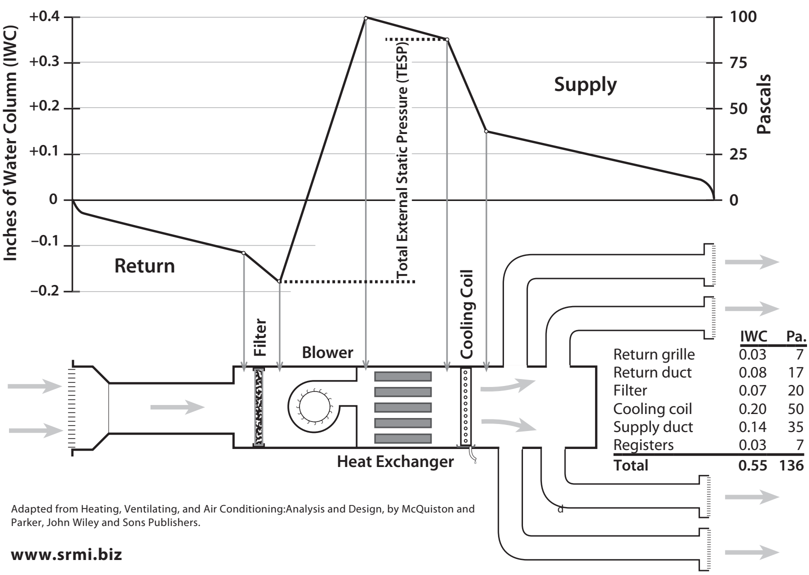
TESP gives a rough indicator of whether airflow is adequate. The greater the TESP, the less the airflow. The supply and return static pressures by themselves can indicate whether the supply or the return or both sides are restricted. For example, if the supply static pressure is 0.10 IWC (25 pascals) and the return static pressure is –0.5 IWC (-125 pascals), you can assume that most of the airflow problems are due to a restricted or undersized return. The TESP give a rough estimate of airflow if the manufacturer's graph or table for static pressure versus airflow is available.

1. Attach two static pressure probes to tubes leading to the two ports of the manometer. Attach the high-side port to the probe inserted downstream of the air handler in the supply duct. The other tube goes upstream of the air

handler in the return duct. The manometer adds the supply and return static pressures to measure TESP.

2. Consult manufacturer's literature for a table of TESP versus airflow for the blower or the air handler. Find airflow for the TESP measured in Step 1.

3. Measure pressure on each side of the air handler to obtain both supply and return static pressures separately. This test helps to locate the main problems as related to either the supply or the return.

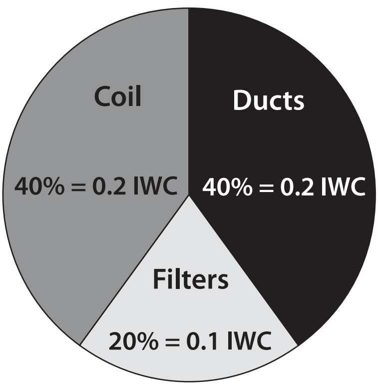


Visualizing TESP: The blower creates a suction at its inlet and a positive pressure at its outlet. As the distance between the measurement and blower increase, pressure decreases because of the system's lower resistance.

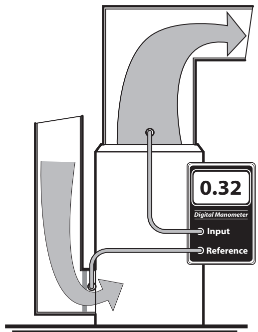
Static Pressure Guidelines

Air handlers deliver their airflow at TESPs ranging from 0.30 IWC (75 Pascals) to 1.0 IWC (250 Pascals) as found in the field. Manufacturer's recommended static pressure is usually a maximum 0.50 IWC (125 pascals) for standard air handlers. TESPs greater than 0.50 IWC indicate inadequate airflow in standard residential forced-air systems.

The popularity of pleated filters, electrostatic filters, and high-static high-efficiency evaporator coils, prompted manufacturers to introduce premium air handlers that can deliver adequate airflow at a TESPs of greater than 0.50 IWC (125 pascals). Premium residential air handlers can provide adequate airflow with TESPs of up to 0.90 IWC (225 pascals) because of their more powerful blowers and variable-speed blowers. TESPs greater than 0.90 IWC indicate the possibility of inadequate airflow in these premium residential forced-air systems.



Static pressure budget: Typical static pressures in IWC and % for a marginally effective duct system.



Total external static pressure (TESP): The positive and negative pressures created by the resistance of the supply and return ducts produces TESP. The measurement shown here simply adds the two static pressures without regard for their signs. As TESP increases, airflow decreases. Numbers shown below are for example only.

Table 8-14: Total External Static Pressure Versus System Airflow for a Particular System

TESP (IWC)	0.30	0.40	0.50	0.60	0.70	0.80
CFM	995	945	895	840	760	670

Example only

8.14.3 Unbalanced Supply-Return Airflow Test

Closing interior doors often separates supply registers from return registers in homes with central returns. A bedroom door with no return register and a closed door restricts the bedroom air from returning to the air handler. This restriction pressurizes bedrooms and depressurizes the central areas near return registers. These pressures can drive air leakage through the building envelope, create moisture problems, and bring pollutants in from the crawl space, garage, or CAZ.

The following test uses only the air handler and a digital manometer to evaluate whether the supply air can flow back to the return registers relatively unobstructed. Activate the air handler and close interior doors.

1. Measure the pressure difference between the home's central living area and the outdoors with a digital manometer.

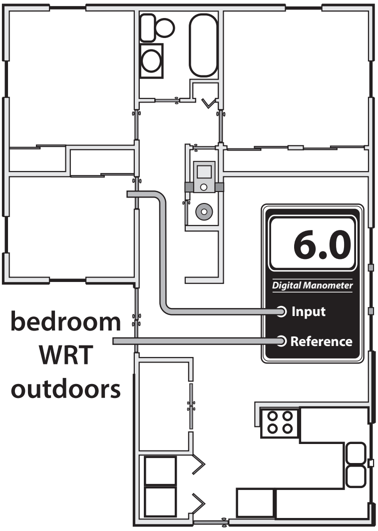
2. Measure the bedrooms' pressure difference with reference to outdoors.

If the sum of these two measurements is more than 3.0 pascals with the air handler operating, consider pressure relief.

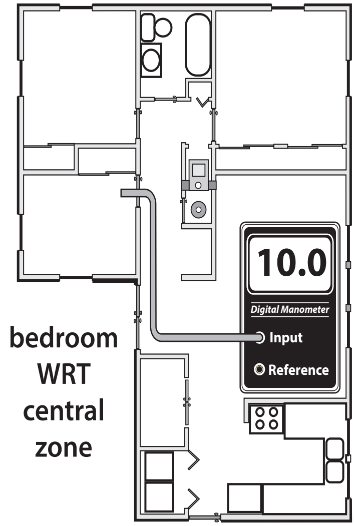
- Like TESP, disregard the positive or negative signs, and add the absolute values.
- Or instead, you can measure the pressure difference between the central zone and the bedroom as shown in the next illustration.

To estimate the amount of pressure relief needed, slowly open the bedroom door until the pressure difference drops below 1 pascal.

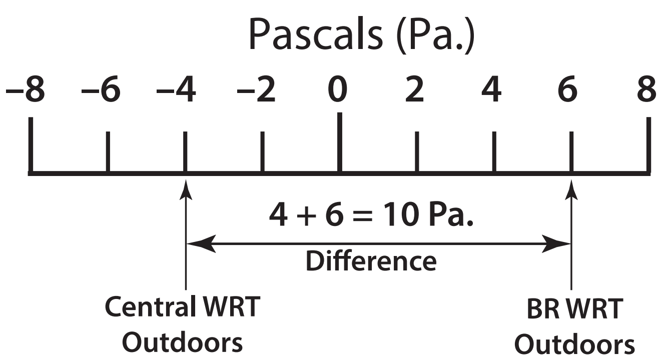
Estimate the surface area of that door opening. This is the area of the permanent opening required to provide pressure relief. Pressure relief may include undercutting the door, installing transfer grilles, or installing jumper ducts.



Pressurized bedrooms: Bedrooms with supply registers but no return register are pressurized when the air handler is on and the doors are closed. Pressures this high can double or triple air leakage through the building envelope.



Pressure difference bedroom to central zone: The air handler depressurizes the central zone and pressurizes the bedroom, when the bedroom doors are closed. This test measures the pressure difference.



Measuring unbalanced airflow: The distance on a number line represents the difference in pressure between the central zone and the bedroom.

8.14.4 Evaluating Furnace Performance

SWS Detail: 5.0108.4 Furnaces

The effectiveness of a furnace depends on its temperature rise, fan-control temperatures, and flue-gas temperature. For efficiency, you want a low temperature rise. However, you must maintain a minimum flue-gas temperature to prevent corrosion in the venting of 70+ and 80+ AFUE furnaces. Apply the following furnace-operation standards to maximize the heating system's seasonal efficiency and safety.

- ✓ Perform a combustion analysis.
- ✓ Check temperature rise after 5 minutes of operation. Refer to manufacturer's nameplate for acceptable temperature rise (supply temperature minus return temperature). The temperature rise should be the minimum and maximum temperature rise on the nameplate (usually 40°F and 70° F). Prefer the lower end of this range for energy efficiency.
- ✓ With temperature-activated controls, verify that the fan-on temperature is 120–140° F. The lower the better.
- ✓ With time-activated fan controls, verify that the fan is switched on with the shortest time delay available if it is adjustable. The appliance should be switched off with the time delay that achieves a fan off temperature of 20° to 30° above the measured return-air temperature.
- ✓ Verify that the high limit controller shuts the burner off before the furnace temperature reaches 200°F.

Table 8-14: Furnace Operating Parameters

20°–45°	45°–70°	70°–95°
Inadequate temperature rise: condensation and corrosion possible.	Temperature rise OK for both efficiency and avoidance of condensation.	Temperature is excessive: Check fan speed, heat exchanger and ducts.

Temperature Rise = Supply Temperature – ReturnTemperature

85°–100°	100°–115°	115°–130°
Excellent fan-off temperature if comfort is acceptable.	Bor derline acceptable: Consider replacing fan control.	Unacceptable range: Significant savings possible by adjusting or replacing fan control.

Fan-off Temperature

100°–120°	120°–140°	140°–160°
Ex cellent fan-on temperature range: No change needed.	Fair: Consider fan-control replacement if fan-off temperature is also borderline.	Poor: Adjust or replace fan control.

Fan-on Temperature

√ Verify that there is a strong noticeable airflow from all supply registers.

√ Adjust fan control to conform to these standards, or replace the fan control if adjustment fails. Some fan controls aren't adjustable.

√ Adjust the high limit control to conform to the above standards, or replace the high limit control.

√ All forced-air heating systems must deliver supply air and collect return air only from inside the intentionally heated portion of the house. Taking return air from an un-heated area of the house such as an unconditioned basement or a crawl space isn't acceptable.

8.14.5 Recommended Airflow for Air Handlers

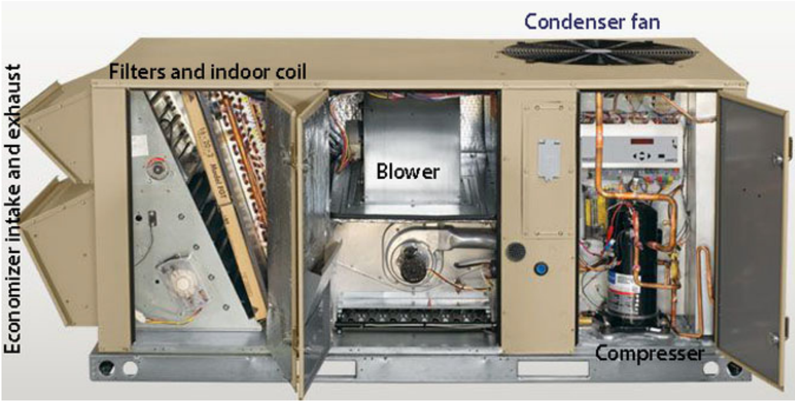
The air handler's recommended airflow depends on its heating or cooling capacity. For combustion furnaces, provide 11-to-15 cfm of airflow for each 1000 BTUH of output. Verify at least 2 square inches of cross-sectional area for each 1000 BTUH of furnace input in both the supply plenum and the return plenum in order to achieve this airflow.

Central air conditioners and heat pumps should deliver 400 cfm ±20% of airflow per ton of cooling capacity (one ton equals 12,000 BTUH). This airflow standard typically requires a duct system with at least 6 square inches of cross-sectional area of both supply plenum and return plenum, connected to the air handler, for each 1000 BTUH of air-conditioning or heat-pump capacity.

8.14.6 Rooftop Units (Air Handlers)

Rooftop units (RTUs) are air handlers located on roofs or on slabs or platforms outdoors. RTUs may contain one or more of the following.

- A combustion furnace
- All the components of an air conditioner (packaged or unitary air conditioner)
- All the components of an heat pump (packaged or unitary heat pump)
- Outdoor-air damper with another damper, called an economizer for ventilation and free cooling.



Rooftop Unit: HVAC manufacturers and dealers classify RTUs as unitary or packaged central HVAC systems. They may contain all the components for heating, cooling, and ventilation.

Economizers

A controller in the economizer measures the temperature (and humidity in humid climates) of the outdoor air. When the outdoor conditions are favorable, the control switches the air conditioning compressor off and cools the building with outdoor air instead. The economizer uses far less cooling energy compared to air conditioning.

Economizers typically operate at night when the outdoor air is cooler than the indoor air in a process known as "free cooling". Economizers mix enough outdoor air into the indoor air in order to meet the thermostat setpoint (which may be lower than the AC setpoint), without using the compressor.

Fresh air that economizers exchange with indoor air while they save cooling energy at night can also count as ventilation. Therefore the ventilation system can run for fewer hours and avoid operating during the day's peak electrical load.

RTU Maintenance and Improvement

Because RTUs are located outdoors, they are even more likely to be neglected compared to indoor air handlers. Fortunately though, the RTU's components are more accessible compared to indoor air handlers.

Consider the following maintenance and improvements for RTUs.

- ✓ Clean or change filters, provide extra filters, and educate the building owner on filter maintenance.
- ✓ Test the combustion furnace as you would an indoor furnace.
- ✓ Clean the evaporator and condenser coils as specified on *page 406*.
- ✓ Test the RTU and its ducts for air leakage because many RTUs systems have high duct leakage. *See "Evaluating Duct Air Leakage" on page 364.*
- ✓ Test and adjust the economizer to maximize its benefit for both free cooling and ventilation. **This requires an elite HVAC controls technician.**
- ✓ Educate the building owner or operator on economizer function and control. Replace the thermostat, if necessary to accommodate optimal economizer functioning. **Note: Economizers functioning isn't intuitive and therefore many, if not most, economizers function poorly.**

Troubleshooting Temperature Rise

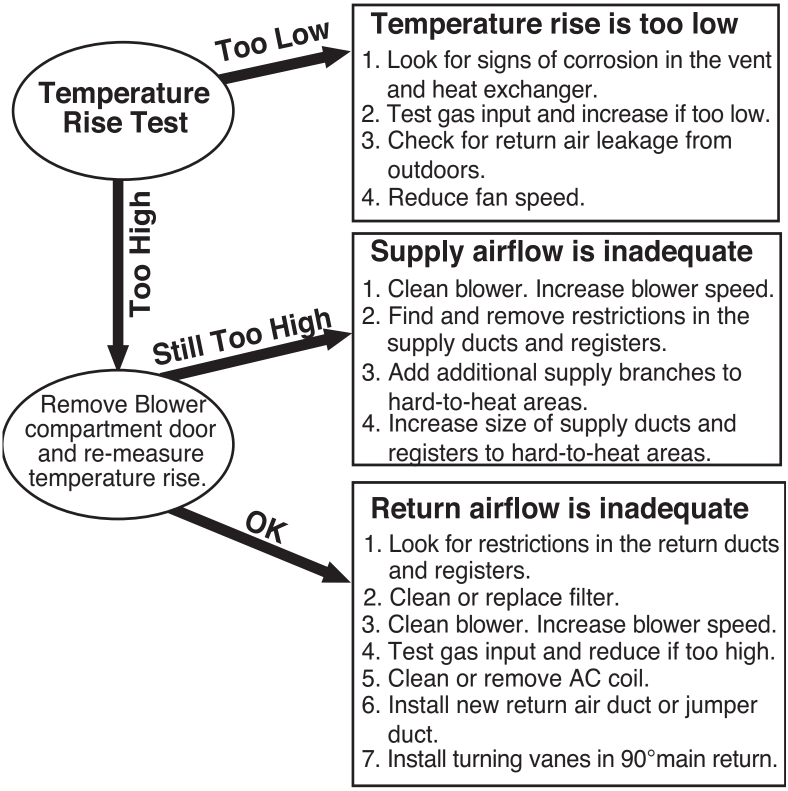


Table 8-15: Recommended Cross-Sectional Area of Metal Supply and Return Plenums at the Air Handler

Gas Furnaces		Heat Pumps & Air Conditioners		
BTUH Input	In^2 Area (Supp. & Ret.)	BTUH Capacity	In^2 Area (Supp. & Ret.)	Tons (capacity)
40,000	80	24,000	144	2
60,000	120	30,000	180	2.5
80,000	160	36,000	216	3
100,000	200	42,000	252	3.5
120,000	240	48,000	288	4
140,000	280	54,000	324	4.5
160,000	320	60,000	360	5

Each trunk, supply and return, should have the recommended cross-sectional area shown here. Courtesy: Bruce Manclark

8.14.7 Improving Forced-Air System Airflow

SWS Detail: 5.0104.1 New Duct Components

Inadequate airflow is a common cause of comfort complaints. When the air handler is on there should be a strong flow of air out of each supply register. Low register airflow may mean that a branch duct is blocked or separated, or that return air from the room to the air handler isn't sufficient. When low airflow is a problem, consider specifying the following improvements as appropriate from your inspection.

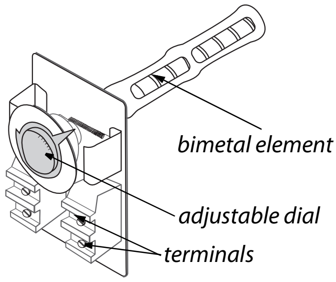
- √ Clean or change filter. Select a less restrictive filter if you need to reduce static pressure substantially.
- √ Clean air handler's blower.
- √ Clean the air-conditioning coil or heat pump coil. If the blower is dirty, the coil is probably also dirty.

√ On a condensing furnace, clean the secondary heat exchanger coil.

√ Increase blower speed.

√ Verify that balancing dampers to rooms that need more airflow are wide open.

√ Lubricate the blower motor, and check tension on drive belt.



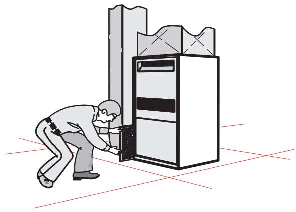
Fan/limit control: Turns the furnace blower on and off, according to temperature. Also turns the burner off if the heat exchanger gets too hot.

Duct Improvements to Increase Airflow

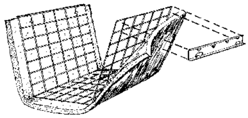
Consider specifying the following duct changes to increase system airflow and reduce the imbalance between supply airflow and return airflow.

√ Modify the filter installation to allow easier filter changing, if filter changing is currently difficult.

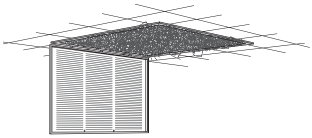
√ Install a slanted filter bracket assembly or an enlarged filter fitting to accommodate a larger filter with more surface area and less static-pressure drop compared to the existing filter.



Panel filter installed in filter slot
in return plenum



Washable filter installed on a rack
inside the blower compartment.



Panel filter installed in return register

Air-handler filter location: Filters are installed on the return-air side of forced air systems. Look for them in one or more of the above locations.

- √ Remove obstructions to registers and ducts such as rugs, furniture, and objects placed inside ducts (children's toys and water pans for humidification, for example).
- √ Remove kinks from flex duct, and replace collapsed flex duct and fiberglass duct board.
- √ Remove excessive lengths of slacking flex duct, and stretch the duct to enhance airflow.
- √ Perform a Manual D sizing evaluation to evaluate whether to replace branch ducts that are too small.
- √ Install additional supply ducts and return ducts as needed to provide heated air throughout the building, especially in additions to the building.
- √ Undercut bedroom doors, especially in homes without return registers in bedrooms.
- √ Repair or replace bent, damaged, or restricted registers. Install low-resistance registers and grilles.

8.15 Evaluating Duct Air Leakage

SWS Detail: 5.0104 Duct Installation; 5.0105 Duct Repair; 5.0106 Duct Sealing

Duct leakage is a major energy-waster in homes where the ducts are located outside the home's thermal boundary in a crawl space, attic, attached garage, or leaky unconditioned basement. When these intermediate zones remain outside the thermal boundary, duct sealing is usually cost-effective.

Duct leakage within the thermal boundary isn't usually a significant energy problem.

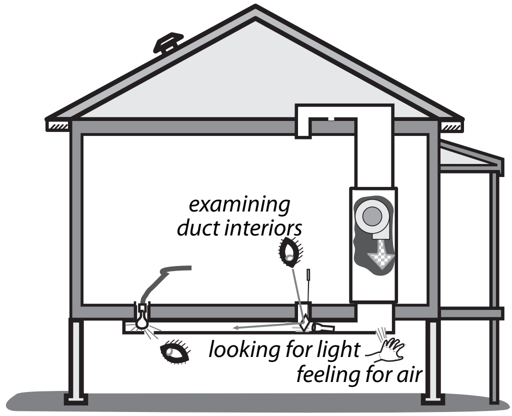
8.15.1 Troubleshooting Duct Leakage

There are several simple procedures for finding the locations of the duct leaks and evaluating their severity.

Finding Duct Leaks Using Touch and Sight

One of the simplest ways of finding duct leaks is feeling with your hand for air leaking out of supply ducts, while the ducts are pressurized by the air handler's blower. Duct leaks can also be located using light. Use one of these 4 tests to locate air leaks.

Finding duct air leaks: Finding the exact location of duct leaks precedes duct air sealing.



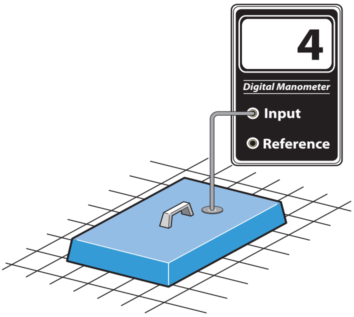
1. Use the air handler blower to pressurize supply ducts. Closing the dampers on supply registers temporarily or partially blocking the register with pieces of carpet, magazines, or any object that won't be blown off by the register's airflow increases the duct pressure and make duct leaks easier to find. Dampening your hand makes your hand more sensitive to airflow, helping you to find duct air leaks.
2. Place a trouble light, with a 100-watt bulb, inside the duct through a register. Look for light emanating from the exterior of duct joints and seams.
3. Determine which duct joints were difficult to fasten and seal during installation. These joints are likely duct-leakage locations.
4. Use a trouble light, flashlight, and mirror or a digital camera to help you to visually examine duct interiors.

Feeling air leaks establishes their exact location. Ducts must be pressurized in order to feel leaks. You can feel air leaking out of pressurized ducts, but you can't feel air leaking into depressurized return ducts. Pressurizing the home with a blower door forces air through duct leaks, located in intermediate zones, where you can feel the leakage coming out of both supply and return ducts.

Pressure Pan Testing

Pressure pan tests can identify leaky or disconnected ducts located in intermediate zones. With the house depressurized by the blower door to either –25 pascals or –50 pascals, make pressure pan readings at each supply and return register.

A pressure pan: Blocks a single register and measures the air pressure behind it, during a blower-door test. The magnitude of that pressure is an indicator of duct leakage.



If the ducts are in a basement and the basement is conditioned, pressure pan testing isn't necessary, although air sealing the return ducts for safety is still important.

If instead, the basement is unconditioned, close any openings between the basement and conditioned space. Measure and record the zone pressure of the basement with reference to the conditioned space before pressure pan testing.

1. Install blower door, and set-up house for winter conditions. Open all interior doors.
2. If the basement is conditioned living space, open the door between the basement and upstairs living spaces.
3. If the basement isn't conditioned living space, close the door between basement and upstairs. Then measure

and record the zone pressure of the basement with reference to the conditioned space.

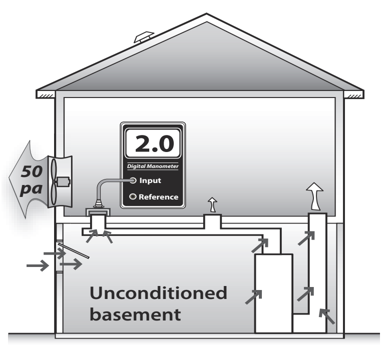
4. Turn furnace off at the thermostat or main switch. Remove furnace filter, and temporarily tape filter slot if one exists. Be sure that all grilles, registers, and dampers are fully open.
5. Temporarily seal any outside fresh-air intakes to the duct system.
6. Seal supply registers in unoccupied zones that aren't intended to be heated — an unconditioned basement or crawl space, for example.
7. Open attics, crawl spaces, and garages as much as possible to the outdoors so they don't create a secondary air barrier.
8. Connect hose between pressure pan and the input tap on the digital manometer. Leave the reference tap open.
9. With the blower door's manometer reading –25 or –50 pascals, place the pressure pan completely over each grille or register one by one to form a tight seal. Leave all other grilles and registers open when making a test. Record each reading, which should give a positive pressure.
10. If a grille is too large or a supply register is difficult to cover with the pressure pan (under a kitchen cabinet, for example), seal the grille or register with masking tape. Insert a pressure probe through the masking tape and record the reading. Remove the tape after the test.
11. Use either the pressure pan or tape to test each register and grille in a systematic way.

Pressure Pan Duct Standards

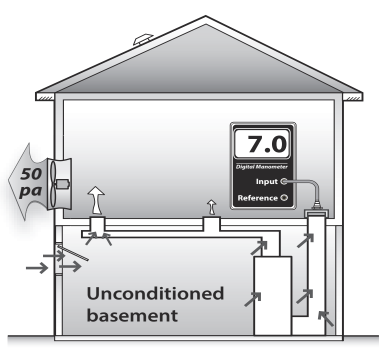
If the ducts are perfectly sealed with no leakage to the outdoors, you won't measure any pressure difference (0.0 pascals) during a pressure-pan test. The higher the measured pressure reading, the more connected the duct is to the outdoors.

- If the median pressure pan reading is 4 pascals or more and/or if one reading is more than 8 pascals, duct-sealing is usually cost-effective.
- Following duct-sealing work, no more than three registers should have pressure-pan readings greater than 2 pascals. No single reading should be greater than 4 pascals.
- The reduction you achieve depends on your ability to find the leaks and whether you can access the leaky ducts. The best weatherization agencies use 1 pascal or less as a general goal for all registers.

Examine the registers connected to ducts that are located in areas outside the conditioned living space. Unconditioned spaces containing ducts include attics, crawl spaces, garages, and unoccupied basements. Also evaluate registers attached to stud cavities or panned joists used as return ducts. Leaky ducts, located outside the conditioned living space, may lead to pressure-pan measurements more than 30 pascals if these ducts have large holes.



Pressure pan test: A pressure pan reading of 2 indicates moderate duct air leakage in the supply ducts.



Problem return register: A pressure reading of 7 pascals indicates major air leakage near the tested register.

8.15.2 Measuring Duct Air Leakage with a Duct Blower

Pressurizing the ducts with a duct blower measures total duct leakage. The duct blower is the most accurate common measuring device for duct air leakage. It consists of a fan, a digital manometer, and a set of reducer plates for measuring different leakage levels. If you use a blower door with a duct blower, you can measure duct leakage to outdoors.

Measuring Total Duct Leakage

The total duct leakage test measures leakage to both indoors and outdoors. The house and intermediate zones should be open to the outdoors by way of windows, doors, or vents. Opening the intermediate zones to outdoors insures that the duct blower is measuring only the ducts' airtightness — not the airtightness of ducts combined with other air barriers like roofs, foundation walls, or garages.

Supply and return ducts can be tested separately, either before the air handler is installed in a new home or when an air handler is removed during replacement.

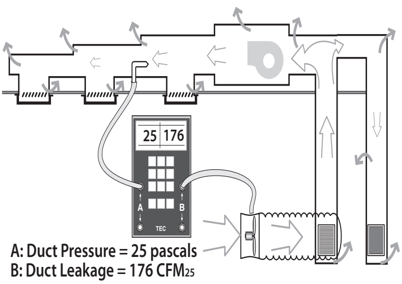
Follow these steps when performing a duct airtightness test.

1. Install the duct blower in the air handler or to a large return register, either using its connector duct or simply attaching the duct blower itself to the air handler or return register with cardboard and tape.
2. Remove the air filter(s) from the duct system.
3. Seal all supply and return registers with masking tape or other non-destructive sealant.
4. Open the house, basement or crawl space, containing ducts, to outdoors.
5. Drill a $^{1}/_{4}$ or $^{5}/_{16}$-inch hole into a supply duct a short distance away from the air handler and insert a manometer hose. Connect a manometer to this hose to

measure *duct with reference to (WRT) outdoors.* (Indoors, outdoors, and intermediate zones should ideally be opened to each other in this test).

6. Connect an airflow manometer to measure *fan WRT the area near the fan*.

Check manometer(s) for proper settings. Digital manometers require your choosing the correct mode, range, and fan-type settings.



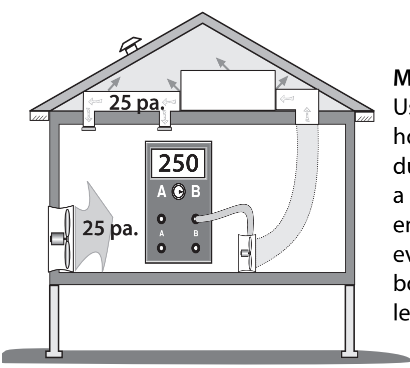
Total duct air leakage measured by the duct blower: All registers are sealed except the one connecting the duct blower to the system. Pressurize the ducts to 25 pascals and measure airflow.

1. Turn on the duct blower and pressurize the ducts to 25 pascals.
2. Record duct-blower airflow.
3. While the ducts are pressurized, start at the air handler and move outward feeling for leaks in the air handler, main ducts, and branches.
4. After testing and associated air-sealing are complete, restore filter(s), remove seals from registers, and check air handler.

Measuring Duct Leakage to Outdoors

Measuring duct leakage to outdoors gives you a duct-air-leakage value that is directly related to energy waste and the potential for energy savings.

1. Set up the home in its typical heating and cooling mode with windows and outside doors closed. Open all indoor conditioned areas to one another.
2. Install a blower door, configured to pressurize the home.
3. Connect the duct blower to the air handler or to a main return duct.
4. Pressurize the ducts to +25 pascals by increasing the duct blower's speed until this value is reached.
5. Pressurize the house until the pressure difference between the house and duct is 0 pascals (*house WRT ducts*). *See "Blower-Door and Zonal Pressure Diagnostic Test Procedures" on page 555.*
6. Read the airflow through the duct blower. This value is duct leakage to outdoors.



Measuring duct leakage to outdoors: Using a blower door to pressurize the house with a duct blower to pressurize the ducts measures leakage to the outdoors — a smaller number and a better predictor of energy savings. This test is preferred for evaluating duct leakage for specialists in both building air leakage and duct air leakage.

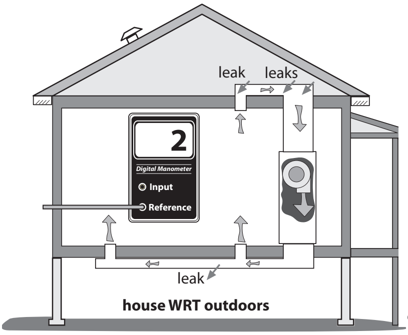
Video: Duct pressurization test setup

— How to pressurize duct to test air leakage.

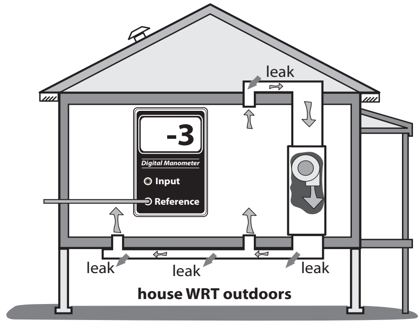
8.15.3 Measuring House Pressure Caused by Duct Leakage

The following test measures pressure differences between the house and outdoors, caused by duct leakage. Try to correct pressure differences greater than +2.0 pascals or more negative than –2.0 pascals because of the air leakage that the pressure differ-ences create.

1. Close all windows and exterior doors. Turn-off all exhaust fans.
2. Open all interior doors, including door to basement.
3. Measure the baseline house-to-outdoors pressure difference and zero it out using the baseline procedures Mode of the digital manometer.
4. Turn on air handler.
5. Measure the house-to-outdoors pressure difference. This test indicates dominant duct leakage as shown here.



Dominant return leaks: When return leaks are larger than supply leaks, the house shows a positive pressure with reference to the outdoors.



Dominant supply leaks: When supply leaks are larger than return leaks, the house shows a negative pressure with reference to the outdoors.

A positive pressure indicates that the return ducts (which pull air from leaky intermediate zones) are leakier than the supply ducts. A negative pressure indicates that the supply ducts (which push air into intermediate zones through their leaks) are leakier than return ducts. A pressure at or near zero indicates equal supply and return leakage or else little duct leakage.

8.16 Sealing Duct Leaks

SWS Detail: 5.0106 Duct Sealing; 5.0106.1 General Duct Sealing; 5.0106.2 Duct Sealing - Spray Polyurethane Foam (SPF);

Ducts located outside the thermal boundary or in an intermediate zone like a ventilated attic or crawl space should be sealed. The following is a list of duct leak locations in order of their relative importance. Leaks nearer to the air handler are exposed to higher pressure and are more important than leaks further away.

8.16.1 Duct Repair and Sealing Methods

SWS Detail: 5.0106 Duct Sealing; 5.0106.1 General Duct Sealing; 5.0106.2 Duct Sealing - Spray Polyurethane Foam (SPF)

Duct Repair and Fastening

Before you air seal ducts, make necessary repairs using these general guidelines.

- ✓ Attach flex duct to metal duct or duct board with a rigid metal coupling, using two tensioned tie bands per joint.
- ✓ Fasten round ducts to round ducts or fittings with a minimum of three equally spaced galvanized or stainless steel fasteners.
- ✓ Fasten duct board to duct board, using overlapping joints, UL 181 fiber mesh tape or aluminum tape, mastic, stitch staples, or other approved products.
- ✓ Fasten duct boots to wood using a minimum of 1 stainless steel or galvanized fastener per side.
- ✓ Fasten duct boots to drywall with mesh tape or a duct-boot hanger, if the boot is accessible.
- ✓ Support flexible and duct board ducts and plenums with 1-$^1/_2$-inch wide or greater material, installed every 4 feet or less. Don't pinch the duct or reduce its interior dimensions.
- ✓ Support metal ducts with $^1/_2$-inch-wide or greater eighteen-gauge metal straps, 12-gauge galvanized wire, or metal rods every 10 feet or less.

General Duct-Sealing Methods

Duct sealers install duct mastic and fiberglass mesh to seal duct leaks. When they need reinforcement or temporary closure, the duct sealers use tape or sheet metal. Observe these standards.

- ✓ Remove any substance that would prevent sealant adhesion (tape, oil, dirt) using appropriate methods and solvents.
- ✓ Seal seams, cracks, joints, and holes, less than ¼ inch using mastic and fiberglass mesh.
- ✓ Bridge seams, cracks, joints, holes, and penetrations, between ¼ and ¾ inch, with sheet metal or tape. Then cover the metal or tape completely with mastic reinforced by mesh at seams.
- ✓ Repair leaks larger than ¾ inch using a rigid duct patch. Mechanically fasten patch before applying mastic. Install mesh and mastic over seams, overlapping repair joint by at least one inch on all sides
- ✓ Overlap the mastic and mesh at least one inch beyond the seams, repairs, and reinforced areas of the ducts.

8.16.2 Sealing Return Ducts

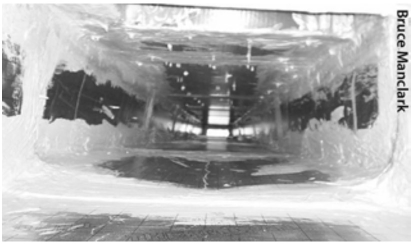
SWS Detail: 5.0106 Duct Sealing; 5.0106.1 General Duct Sealing; 5.0106.2 Duct Sealing - Spray Polyurethane Foam (SPF)

Return leaks are important for combustion safety and for efficiency. Use the following techniques to seal return ducts.

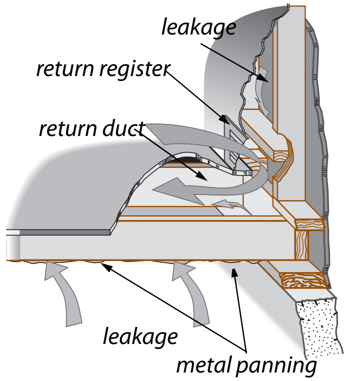
- ✓ First, seal all return leaks within the combustion zone to prevent this leakage from depressurizing the combustion zone and causing backdrafting.
- ✓ Seal all return ducts in crawl spaces for indoor air quality.
- ✓ Seal filter slots with a tight-fitting, durable, user-friendly filter-slot cover to allow easy removal for filter-changing.
- ✓ Seal the joint between the furnace and return plenum with a removable sealant such as foil tape.

Panned or Cavity Return Ducts

- √ Seal panned return ducts using mastic to seal all cracks and gaps within the return duct and register.
- √ Seal leaky joints between building materials composing cavity return ducts, like panned floor cavities and furnace return platforms. Remove the panning to seal cavities containing joints in building materials.
- √ Carefully examine and seal leaks at transitions between panned floor joists and metal trunks that change the direction of the return ducts. You may need a mirror to find some of the biggest return duct leaks in these areas.



Lining a panned cavity: Foil-faced foam board, designed for lining cavities is sealed with duct mastic to provide an airtight return.



Panned floor joists: These return ducts are often very leaky and may require removing the panning to seal the cavity.

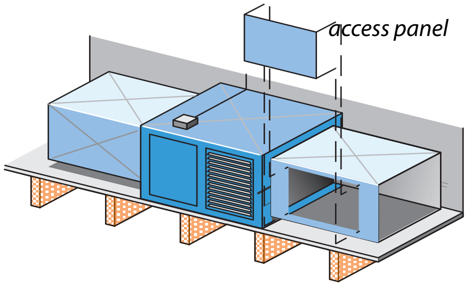
Pedestal return air: These return plenums are often very leaky and may require removing a panel to seal the leaks from inside.

8.16.3 Sealing Supply Ducts

SWS Detail: 5.0106 Duct Sealing; 5.0106.1 General Duct Sealing; 5.0106.2 Duct Sealing - Spray Polyurethane Foam (SPF); 5.0106.3 Duct Sealing - Proprietary Spray Application

Inspect these places in the duct system and seal them as needed.

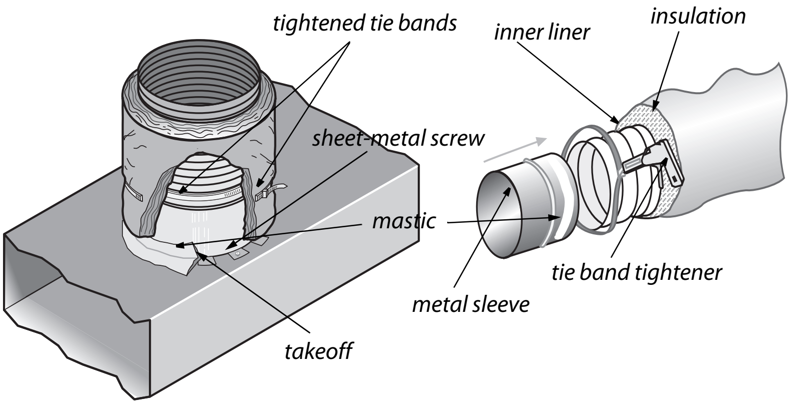
√ *Plenum joint at air handler:* Technicians might have had problems sealing these joints because of a lack of space. Seal these plenum connections thoroughly even if you must cut an access hole in the plenum. Use silicone caulking or foil tape instead of mastic and fabric mesh here for future access — furnace replacement, for example.



Plenums, poorly sealed to air handler: When air handlers are installed in tight spaces, plenums may be poorly fastened and sealed. Cutting a hole in the duct may be the only way to seal this important joint.

Sectioned elbows: Joints in sectioned elbows, known as gores, are usually leaky and require sealing with duct mastic.

- √ *Joints at branch takeoffs:* Seal these important joints with a thick layer of mastic. Fabric mesh tape should cover gaps and reinforce the seal at gaps.
- √ *Joints in sectioned elbows:* Known as gores, these are usually leaky and require sealing with duct mastic.
- √ *Tabbed sleeves:* Attach the sleeve to the main duct with 3-to-5 screws and apply mastic plentifully. Or better, remove the tabbed sleeve and replace it with a manufactured takeoff.
- √ *Flexduct-to-metal joints:* Apply a 2-inch band of mastic to the end of the metal connector. Attach the flexduct's inner liner with a UL-181-approved tie band, tightening it with a tie-band tensioner. Attach the insulation and outer liner with another tie band.
- √ *Damaged flex duct:* Replace flex duct when it is punctured, deteriorated, or otherwise damaged.
- √ *Deteriorating ductboard facing:* Replace ductboard, preferably with metal ducting, when the facing deteriorates because this deterioration leads to a lot of air leakage.



Flexduct joints: Flexduct itself is usually fairly airtight, but joints, sealed improperly with tape, can be very leaky. Use methods shown here to make flexduct joints airtight.

- √ Consider closing supply and return registers in unoccupied basements or crawl spaces.
- √ Seal penetrations made by wires or pipes traveling through ducts.
- √ Seal the joint between the boot and the ceiling, wall, or floor between conditioned and unconditioned areas.

Duct Support

- √ Support rigid ducts and duct joints with duct hangers at least every 5 feet or as necessary to prevent sagging of more than one-half inch.
- √ Support flexible ducts and duct board every 4 feet using a minimum of 1 ½" wide support material.

Sealing register boots: Seal between the boot and floor. Seal joints inside the boot.

8.16.4 Materials for Duct Sealing

Duct mastic is the best duct-sealing material because of its superior durability and adhesion. Apply mastic at least $^{1}/_{16}$-inch thick, and use reinforcing mesh for all joints wider than $^{1}/_{8}$-inch or joints that may move. Install screws to prevent joint movement or separation.

Aluminum foil or cloth duct tape aren't good materials for duct sealing because their adhesive often fails. Consider covering tape with mastic to prevent tape's adhesive from drying out and failing.

8.17 Duct Insulation

SWS Detail: 5.0107 Duct Insulation; 5.0107.1 General Duct Insulation; 5.0107.2 Duct Insulation - Spray Polyurethane Foam (SPF)

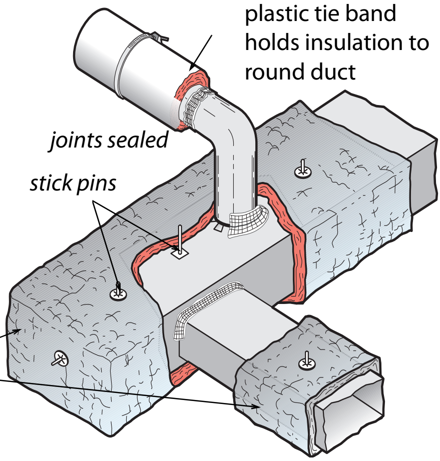
Insulate supply ducts, located in unconditioned areas outside the thermal boundary, such as crawl spaces, attics, and attached garages. Use vinyl- or foil-faced duct insulation or SPF. Don't insulate ducts that run through conditioned areas unless they cause overheating in winter or condensation in summer. Use these best practices for installing insulation.

- √ Always perform necessary duct sealing before insulating ducts.

√ Duct-insulation R-value must be ≥R-8 indoors and ≥R-12 outdoors.

√ Select insulation with a flame spread and smoke developed index listed at 25/50.

√ Insulation should cover all exposed supply ducts, with no significant areas of bare duct left uninsulated.



√ Insulation's compressed thickness must be more than 75% of its uncompressed thickness. Don't compress duct insulation excessively at corner bends.

√ Fasten insulation using mechanical means such as stick pins, twine, staples, or plastic tie bands.

√ Cover the insulation's joints with UL 181 tape to seal all gaps.

√ Install the duct insulation 3 inches away from heat-producing devices such as recessed light fixtures.

√ Post a dated receipt, signed by the installer, that includes: Installed insulation type, coverage area, installed thickness, and installed R-value.

Caution: Burying ducts in attic insulation is common in some regions and it reduces energy losses from ducts. However, condensation on ducts in humid climates is common during the air-conditioning season, so don't allow cellulose to touch metal ducts to avoid corrosion from cellulose's Borate fire retardant.

Important Note: Tape can be effective for covering joints in the insulation to prevent air convection, but the tape fails when expected to resist the force of the insulation's compression or weight. Outward-clinch staples or plastic tie bands can help hold the insulation facing and tape together.

8.17.1 Spray Foam (SPF) Duct Insulation

SWS Details: 5.0107.2 Duct Insulation - Spray Polyurethane Foam (SPF)

High-density spray foam insulation is also a good duct-insulation option, assuming it is listed as ASTM E-84 or UL 723. Spray foam is effective in areas where the foam can seal seams and insulate in one application. However, the spray foam application is limited by the available space around the duct compared to wrapping ducts with fiberglass blankets because the installer needs room to spray.

- ✓ Select foam insulation with a flame spread and smoke developed index listed at 25/450.
- ✓ Prepare surfaces to satisfy manufacturer's specifications for cleanliness, moisture content, and temperature.
- ✓ Cover all holes, cracks, and gaps where SPF may enter the duct with a backing material, such as foil tape.
- ✓ Separate foam insulation from living spaces with a thermal barrier or ignition barrier as required by local codes.
- ✓ Post a dated receipt, signed by the installer, that includes: Installed insulation type, coverage area, installed thickness, and installed R-value.