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

See *"NFPA Codes" on page 268* and *"ANSI/ACCA Manuals" on page 268*.

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

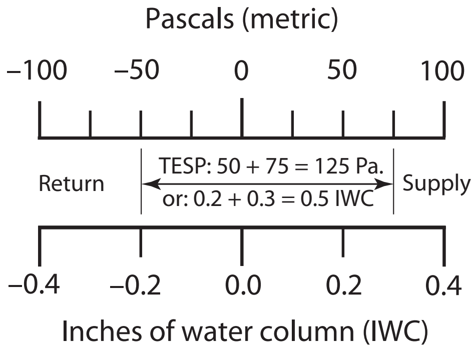
You don't need test instruments to discover dirty blowers or disconnected branch ducts. Find these problems before measuring duct airflow, troubleshooting the ducts, or sealing the ducts. These steps precede airflow measurements.

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.

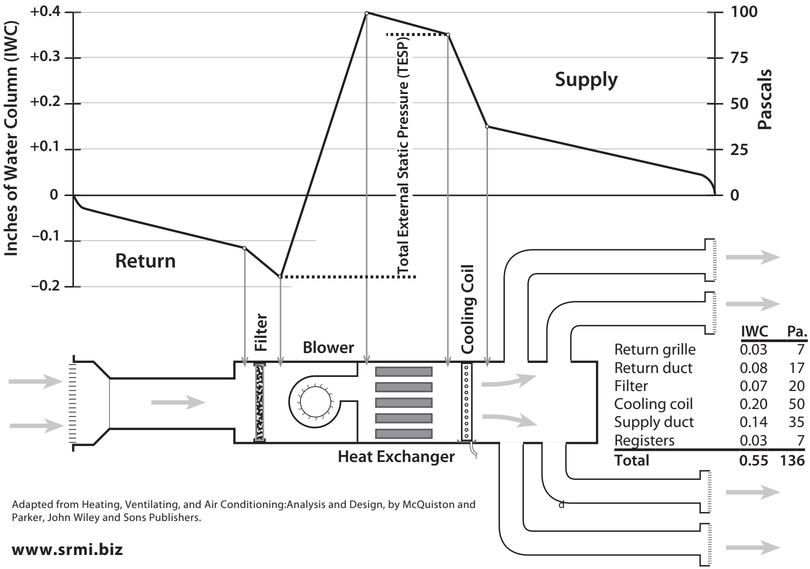
TESP number line: the TESP represents the distance on a number line between the return and supply ducts.



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 sepa-

rately. This test helps to locate the main problems as related to either the supply or the return.



Adapted from Heating, Ventilating, and Air Conditioning:Analysis and Design, by McQuiston and Parker, John Wiley and Sons Publishers.

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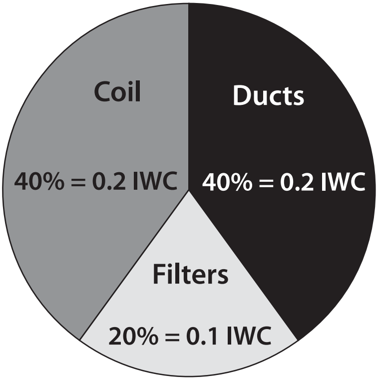
Visualizing TESP: The blower creates a suction at its inlet and a positive pressure at its outlet. As the distance between the measurement and blower increase, pressure decreases because of the system's lower resistance.

Video: Duct Energy Efficiency— An overview of the elements that make up and affect the energy efficiency of duct systems.

Static Pressure Guidelines

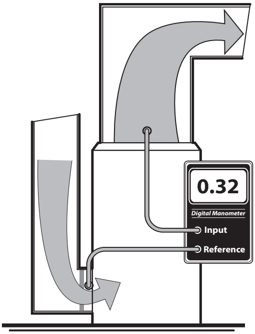
Air handlers deliver their airflow at TESPs ranging from 0.30 IWC (75 Pascals) to 1.0 IWC (250 Pascals) as found in the field. Manufacturer's recommended static pressure is usually a maximum 0.50 IWC (125 pascals) for standard air handlers. TESPs greater than 0.50 IWC indicate inadequate airflow in standard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

Video: Introduction to Duct Induced House Pressures— An introduction to duct induced house pressures.



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 8-1: 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.

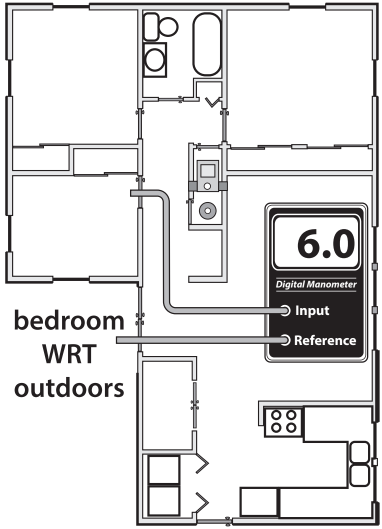
2. Measure the bedrooms' pressure difference with reference to outdoors.

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

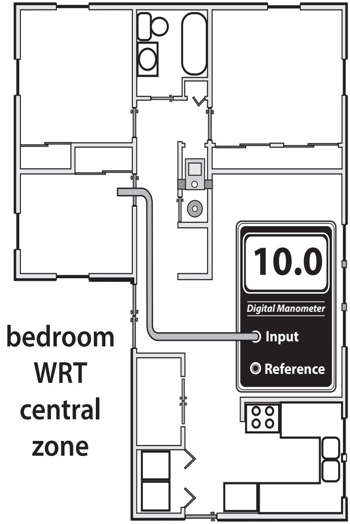
- Like TESP, disregard the positive or negative signs, and add the absolute values.
- Or instead, you can measure the pressure difference between the central zone and the bedroom as shown in the next illustration.

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

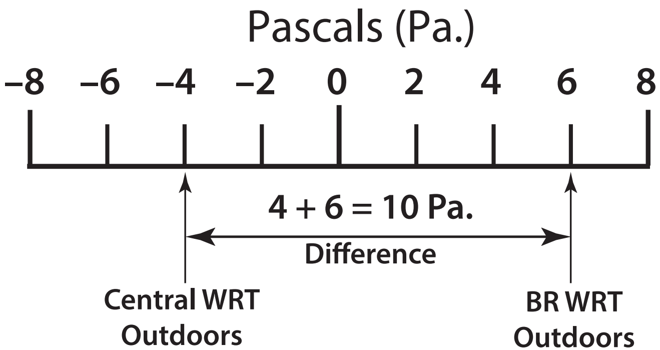
Estimate the surface area of that door opening. This is the area of the permanent opening required to provide pressure relief. Pressure relief may include undercutting the door, installing transfer grilles, or installing jumper ducts.



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 as described in *"Gas Burner Safety & Efficiency Service" on page 311*.
- √ 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 – Return Temperature

85°–100°	100°–115°	115°–130°
Excellent fan-off temperature if comfort is acceptable.	Borderline 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°
Excellent 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

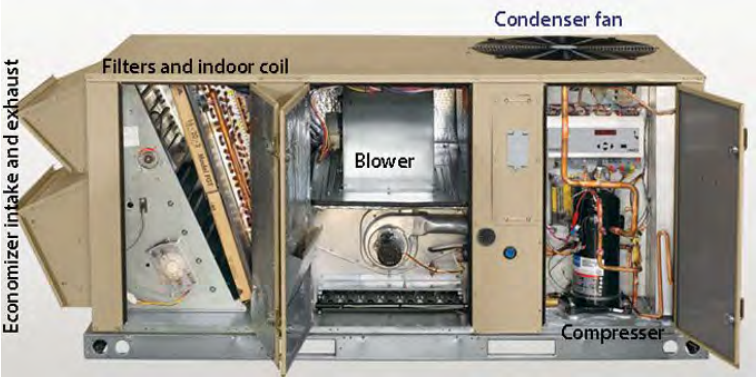
The air handler's recommended airflow depends on its heating or cooling capacity. For combustion furnaces, provide 11-to-15 cfm of airflow for each 1000 BTUH of output. Verify at least 2 square inches of cross-sectional area for each 1000 BTUH of furnace input in both the supply plenum and the return 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.*See "Electronic Combustion Analysis" on page 291.*
- √ Clean the evaporator and condenser coils as specified on *page 401*.
- √ Test the RTU and its ducts for air leakage because many RTUs systems have high duct leakage. *See "Evaluating Duct Air Leakage" on page 360.*
- √ 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

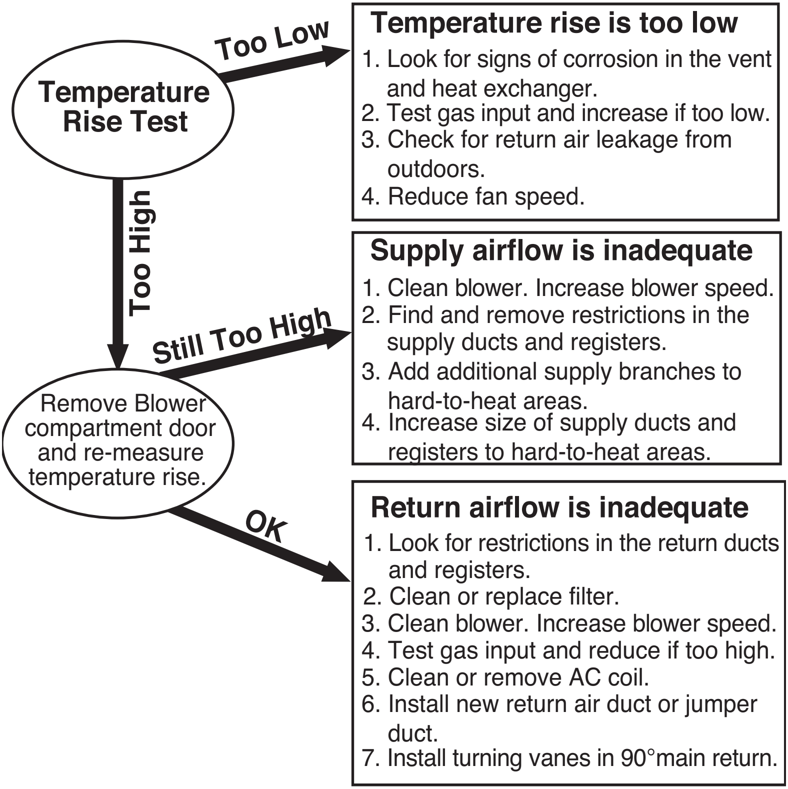


Table 8-15: Recommended Cross-Sectional Area of Metal Supply and Return Plenums at the Air Handler

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.

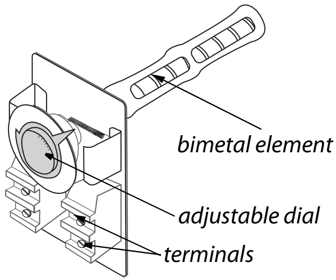
- √ Clean or change filter. Select a less restrictive filter if you need to reduce static pressure substantially.
- √ Clean air handler's blower.
- √ Clean the air-conditioning coil or heat pump coil. If the blower is dirty, the coil is probably also dirty.

√ 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.

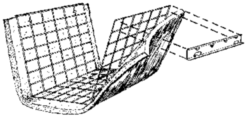
Duct Improvements to Increase Airflow

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

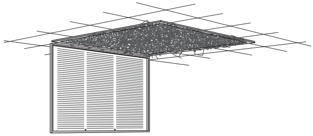
√ Modify the filter installation to allow easier filter changing, if filter changing is currently difficult.

√ 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 and other incorrectly sized ducts. Perform a Manual D whenever replacing a significant amount of ductwork.

√ 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.