Integrated Heating and Ventilation: Double Duty for Ducts

by Mark A. Jackson

Northwest building codes require mechanical ventilation in new homes. Combining heating and ventilation can fit the bill if the builder considers the whole system carefully.

Building codes in Washington state and Bonneville Power Administration's specifications for new residential construction require mechanical ventilation systems. Since the majority of new houses built in the Northwest have forced-air heating systems, using the heating system ducts to supply fresh air as part of the ventilation system has become a popular option for home builders.

When properly designed, installed, tested, and operated, integrated heating and ventilating systems can be effective, and relatively inexpensive to install. However, there are inherent inefficiencies in these systems, and the overall cost for ventilation using an integrated system is higher than for any other ventilation system commonly used. Worse, poorly designed systems can function like a rather large uncontrolled leak in the heating system, with unacceptable energy consequences and little to offer in the way of effective ventilation.

The Basic System

Until recently, the typical approach to integrate the heating and ventilating systems required that mechanical components plus an electric control system be fabricated on site. In the last year or so, several manufacturers have responded to the need for an all-in-one mechanical and electrical control unit. There are still many possible variations using a diverse array of air inlet and exhaust strategies, but the essential elements are pretty straightforward (see Figure 1):

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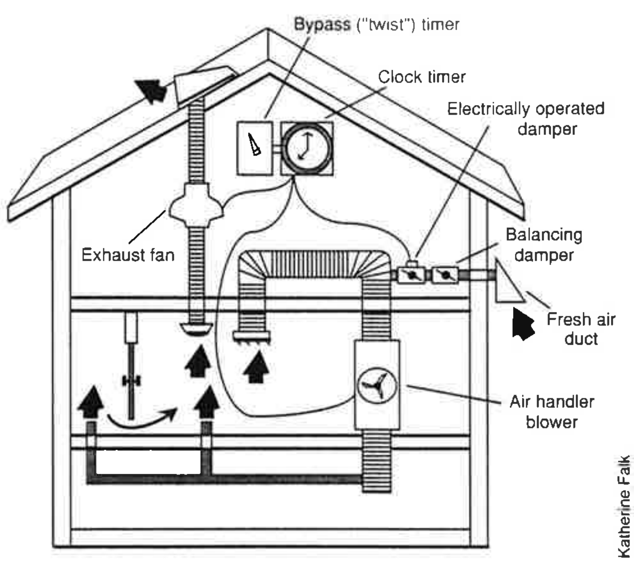
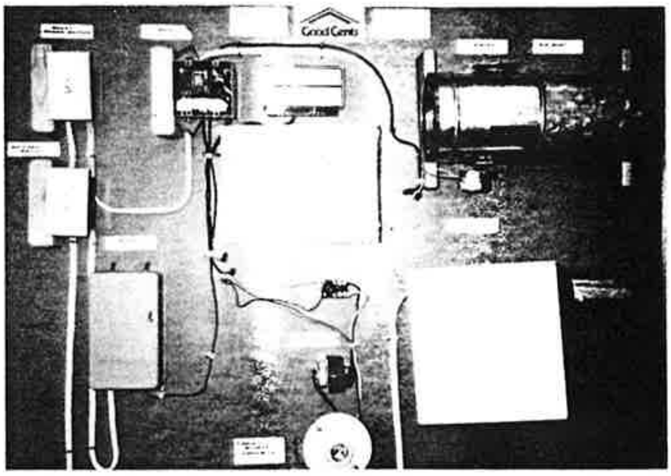


Figure 1. Integrating ventilation with a central forced-air heating system.

- A **fresh air duct** which brings outside air to the return side of the air handler of a forced air heating system (gas, electric resistance, or heat pump). The fresh air duct must be tight and well-sealed to the return plenum to prevent the introduction of unwanted combustion gasses from combustion appliances.
- A **balancing damper** or other device that limits the flow rate of fresh air into the system. The volume of fresh air required has to be calculated, and the damper needs to be set using an accurate air flow measuring instrument.
- An **electrically operated damper** controls the flow of air into the system to prevent fresh air flow when it is not needed or wanted.
- A **clock timer** is used to periodically cycle the system. A **bypass** or **"twist" timer** allows manual control to provide additional ventilation as needed. These controls open the electrically operated damper, and turn on the air handler and exhaust fan.



BPA

An old approach: The parts laid out here represent discrete control components. Newer technologies package the control system in one integrated unit.

- An **exhaust fan** removes stale air from the house. A centrally located fan dedicated to the system or one of the bathroom fans can be used.
- The **air handler blower** provides the fan power to pull fresh air from outside into the system and to distribute the fresh air through the supply ducts. A two-speed blower is preferrable, so that the system can operate at low speed during ventilation mode. The fan-motor sets in residential forced air heating systems are typically inefficient, requiring 400–600W for shaded pole blower motors. Better motors are available, one of which is the permanent-split capacitor motor. New adjustable speed drives may be somewhat more efficient at low speeds, but these are not yet common in residential applications.

House-System Interactions

One of the first questions that arose when integrated systems became popular was: "What kind of damper do houses need to control fresh air entry into the system—are barometric dampers acceptable, or should electrically activated dampers be required?" To answer this question, several types of dampers were evaluated in 25 single-family homes as part of the Residential Standards Demonstration Project, sponsored by the Bonneville Power Administration. In addition to assessing the applicability of various dampers, we tested duct leakage, envelope tightness, and exhaust fan flows.

We found that not only is the type of damper important (see Table 1), but other aspects of the envelope, ducts, and heating and exhaust system have to be carefully addressed for an integrated system to work as planned, in particular:

- Tightness of the building envelope
- Pressure differentials within the house
- Leakage of ducts outside the heated space
- Control of and quantity of fresh air supply
- Exhaust fan flow rate

Tightness of Building Envelope

The number of air changes per hour (ACH) when a home is depressurized to 50 Pascals (50 Pa) is a common comparison for the relative tightness of houses. I would consider a house "leaky" if a blower door test showed more than 6 ACH at 50 Pa. Conversely, I would consider a house to be reasonably "tight" if it tested less than 3 ACH at 50 Pa. In a leaky house, there is no control over where or when ventilation, or more properly outside air infiltration, will occur. Keeping the envelope tight permits more control and predictability for ventilation systems in general. In the Northwest, we find that tightness is well correlated with climate. Houses built in colder areas are significantly tighter than houses built in milder areas.

Pressure Differentials

Pressure differences occur naturally between crawl space and main floor, and between ceiling and attic. They are caused by temperature differences (stack pressure) and wind effects. These pressure differences drive natural infiltration through the leaks in the house envelope. Over time, stack pressures seem to be dominant and are usually 1–2 Pa between floor and ceiling in single-story houses, relative to outside ambient pressure. In multi-story houses, stack pressures can become quite large between the lowest and highest points of the structure, relative to outside ambient pressure. We have measured stack pressures as

Table 1. Ten Houses, Ten Ventilation-Heating Performances

House	Damper Type	Leakage tests (House pressurized to 50 Pascals): Infiltration (air changes per hour)	Leakage tests (House pressurized to 50 Pascals): Duct leakage (cubic feet per minute)	Fresh Air Supply (cubic feet per miute)	Measured Exhaust Fan Air Flow (cubic feet per minute)
1	Electronically activated	2.8	66	65	45
2	Electronically activated	2.9	0	80	58
3	Electronically activated	3.6	66	187	94
4	Electronically activated	2.5	130	100	84
5	Barometric	6.1	115	80	80
6	Balancing damper only	6.7	136	53	90
7	Balancing damper only	4.9	65	70	75
8	Barometric	10.1	140	0	55
9	Electronically activated	4.9	154	40	75
10	Electronically activated	2.5	35	72	114

high as 11 Pa between the ground floor and the upper story of three-story multifamily structures.

Closed doors between supply and return ducts can generate large pressures. In some houses, we noted 12 Pa across closed bedroom doors. In leaky houses, this overpressurization causes increased exfiltration through the building envelope, and increases leakage from supply ducts for both heating and ventilating. And overall air flow into rooms with large pressure differentials is reduced.

Creating pathways to allow air to flow between supply ducts and return ducts when closed doors separate them may reduce pressure differentials. BPA is evaluating such "passive pressure reduction" measures as an 8 in. duct connecting registers in the ceilings between rooms with supplies and rooms with returns, using offset registers placed in the walls between rooms, and transoms over doors.

Duct Leakage

Ducts and air handlers of forced-air heating systems are typically exposed to large positive pressures in the supply ducts and negative pressures in the return ducts and plenum. Small leakage areas translate to large leakage volumes under pressure. Unintentional duct leakage carries a thermal penalty, and can promote indoor air quality problems if leaks are located in return plenums and air handlers are located in garages and crawl spaces.

We measured duct leakage to the outside of the air barrier by using a blower door and depressurizing the houses by 50 Pa. Flows from duct leaks were measured using a flow hood. Most of the houses we tested had significant duct leakage, in most cases exceeding the amount of fresh air intentionally supplied to the return plenum.

For an integrated system to work well, the ducts have to be within the air barrier of the home so that leaks have no thermal impact—or the ducts have to be very tight. Any house with over 30 cfm of duct leakage at 50 Pa is not a viable candidate for an integrated system.

Fresh Air Supply

Fresh air inlet flow rates in the houses we tested were 0–187 cfm. The negative static pressure, or suction, available in the return plenum to pull fresh air into the system can turn out to be very low, especially when the supply uses lots of flex duct. Keeping the outside fresh air supply duct short, making it at least 6 in. in diameter, building it out of smooth sheet metal, and tying it at or close to the air handler fan helps to ensure adequate fresh air flow. To measure flow, use a micro manometer with a pitot tube array, a pitot tube traverse, or use a hot wire anemometer. A flow hood can also be used.

A balancing damper is used to restrict air flow to a predetermined amount, or if sufficient pressure is available, a constant air flow regulator, available from American ALDES (4539 Northgate Ct. Sarasota, FL 34234-2124. Tel:(813)351-3441; Fax:(813)351-3442), can be installed. A reasonable flow rate would be 30 cfm for the first bedroom and 15 cfm for each additional bedroom, or alternately 0.35 ACH (according to ASHRAE standard 62-1989, for "Ventilation for Acceptable Indoor Air Quality").

Ceiling registers.

Dampers to Prevent Unwanted Air Flow

We evaluated several types of dampers, including barometric dampers and electrically operated or "automatic" dampers. To prevent unwanted or excess ventilation, an electrically operated damper is the best choice, installed in the fresh air duct. A balancing damper or air flow regulator must also be installed to control the volume of air drawn into the system.

If a simple balancing damper is used to control the flow rate of air into the system, but an electrically activated damper is *not* installed to control the duration of fresh air supply, the amount of ventilation will be in direct proportion to the operating time of the heating system. During the winter, when infiltration is at its greatest and the need for additional ventilation may be small, the system will have a large and probably excessive ventilation rate, and the energy costs can be large. During the spring and fall, when temperatures are mild and the driving forces for infiltration are low, the system may not provide adequate ventilation. It is essential that an electrically activated damper be used to provide uniform and adequate ventilation and minimize the energy penalties.

Exhaust Fan Flow Rate

To maintain balanced air flow, the exhaust flow rate should be equal to the fresh air supply flow rate. For instance, a three bedroom house with 60 cfm of fresh air supply, would need an exhaust fan capable of removing 60 cfm. Typically, fan flow ratings are measured at a pressure lower than that found in the exhaust duct run in most houses. To compensate for duct pressure loss, a fan rated at 80 cfm or greater is recommended. Installing the fan remotely, or use a quiet fan (1.5 sone, a measure of noise) to keep the noise to a minimum. Excessive fan noise is one of the reasons occupants disable ventilation systems.