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INTEGRATED FORCED-AIR HEATING AND VENTILATING SYSTEMS: EVALUATION AND DESIGN CONSIDERATIONS

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SUMMARY

Mechanical systems which use common ducts for combined heating and ventilating functions are becoming popular in the Pacific Northwest (U.S.). These systems range from simple fresh-air inlets ducted to the return side of a forced air heating system to more complex heat recovery ventilation systems utilizing the heating ducts for air distribution. Typical integrated systems do not have heat recovery capability.

Several approaches to integrating and controlling non-heat recovery ventilation and forced air heating systems were evaluated as part of the Residential Construction Demonstration Project (RCDP). The houses tested for this study were built under Bonneville Power Administration sponsored energy-efficiency programs. Fan pressurization tests were performed to assess the envelope leakage characteristics, and tracer gas decay tests were used to measure infiltration and mechanical ventilation rates.

Large variations in envelope tightness and mechanical ventilation rates were encountered. In most cases, the amount of accidental air leakage through ducts and air handlers exceeds the amount of fresh air intentionally supplied to the system. Systems which are properly designed, installed, and operated work well, but the potential for problems is large.

FRESH-AIR INLET CONTROL STRATEGIES

All of the fresh-air inlets examined for this study are connected by a duct to the return side of forced-air systems. Volume limiting strategies range from simple manual balancing dampers placed in the inlet duct to motorized dampers used in conjunction with pressure-bladder type airflow regulators.

The air handlers of most forced air heating systems typically move 500 l/s of conditioned air. The fresh-air portion would be about 38 l/s. The fan energy used to move the large volume of air is typically 600 watts. Relative to a ducted system that only moves ventilation air at the required rate, the energy consumption of the integrated systems is large.

Simple Dampers:

Simple manual or barometric dampers are inexpensive and easy to install, but they provide no control over when fresh air is introduced to the system. These dampers behave much like a leak of unknown size in the return side of the system. Whenever the air handler is activated, the negative pressure created in the return duct pulls air into the system. Unless the occupant or a timing mechanism intentionally activates the air handler, the only time fresh-air is introduced into the system is when the thermostat is calling for heating or cooling. This approach provides the greatest amount of ventilation when it is least needed, during periods when infiltration is at its greatest due to stack effects.

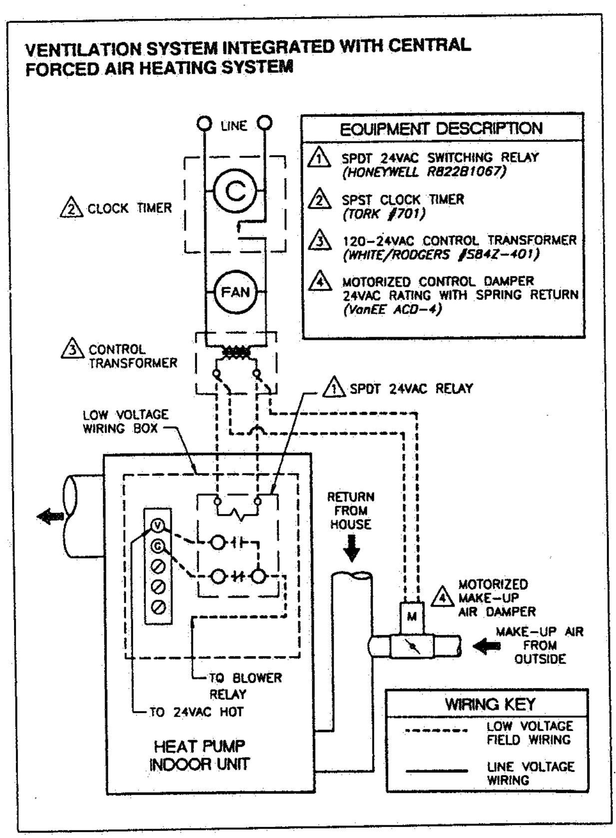
Motorized Dampers:

Motorized dampers provide a great deal of control over when fresh-air is introduced into the system. Typically, a time clock or dehumidistat opens the motorized damper and, if the system is not actively heating or cooling, activates the air handler. Since dehumidistats have proven to be an ineffective ventilation system controller in our generally leaky housing stock, time clocks have become common controllers. The major problem with using time clocks to open the damper and activate the air handler is that it assumes that the occupant knows how much mechanical ventilation is required and will set the clock according to need. We typically found the time clock set to 1 hour a day or disabled.

EXHAUST SYSTEMS

In addition to manually controlled kitchen and bathroom exhaust systems, the houses tested have one or more "dedicated" exhaust fans which are automatically controlled by a time clock or dehumidistat. Sometimes the bathroom fan serves double duty as the dedicated exhaust fan. In less sophisticated systems, the exhaust fan serves as a stand alone system and no fresh air is intentionally introduced to make up for that which is exhausted. In more sophisticated systems, the dedicated exhaust fan and a motorized damper are interlocked with the air handler. When the controller calls for ventilation, the motorized damper opens and the air handler is activated, which pulls fresh air into the systems. Simultaneously, the exhaust fan comes on to remove air from the house.

Currently, there are no manufactured devices which will simultaneously control exhaust fans, motorized dampers, and air handlers. System installers must use relays and transformers to integrate the system. The schematic shows the elements required to integrate the components.



HOUSE CHARACTERISTICS AND SYSTEM INTERACTIONS

Several factors affect the effectiveness of integrated heating and ventilating systems, such as the tightness of the building envelope, differentials pressures within the house, duct location, and duct leakage and leak distribution. The following table lists selected data acquired during site visits.

Selected Data From Site Evaluations

ACH @50 Pa	DESIGNATED FAN FLOW (l/s)	DAMPER	DUCT LEAKAGE @50 P	FRESH AIR (l/s)
2.8	21.2	Motor	31.2	30.7
2.9	27.4	Motor	0	37.8
3.6	44.4	Motor	31.2	88.3
2.5	39.6	Motor	61.4	47.2
6.1	37.8	Barometric	54.3	37.8
6.7	42.5	Manual	64.2	25.0
4.9	35.4	Manual	30.7	33.0
10.1	25.9	Barometric	66.1	0
4.9	35.4	Motor	72.7	18.9
2.5	53.8	Motor	16.5	34.0

Envelope Leakage:

The tightness of the houses ranged from fairly tight to quite leaky. As is typically found in the Northwest, houses in colder areas are significantly tighter than those in warmer coastal areas. The tightness of the building envelope determines how duct leakage, intentional fresh air supply, and exhaust fans will interact. Palmiter has shown that when unbalanced air flows from exhaust fans or duct leakage are less than twice the natural infiltration rate, one half of the unbalanced flow is additional induced ventilation, and one half is displaced infiltration.

In houses with relatively tight envelopes, virtually all of the flow induced by exhaust fans and unbalanced duct leakage results in additional infiltration. To prevent overall positive pressurization of the house, which can force moisture laden air into wall cavities and into the attic space, the use of an exhaust device to balance the flows is suggested.

Duct and Air Handler Leakage:

Duct and air handler leakage can cause unbalanced air flows and introduces thermal problems when the air handler and ducts are outside the building envelope. In the Northwest U.S. it is typical to find supply ducts located in crawlspaces and return ducts in the attic. It is also common to find the air handler located in the garage. Most air handlers examined in this study seemed to be very leaky, but it was not possible to quantify air handler leakage. Leaks in the return side of air handlers located in garages will introduce air from the garage into the house.

Fresh-Air Supply Rate:

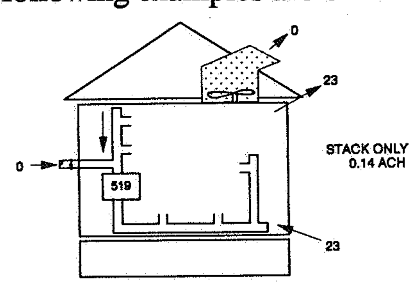
There is no way to reliably predict the quantity of fresh air that will be introduced into the system unless a pressure compensating airflow regulator is installed. it is common practice that when a simple balancing damper is installed, the damper is set to some random intake volume at the discretion of the installer. Actual airflow is rarely, if ever, measured.

Pressure compensating airflow regulators require a minimum operating pressure, typically 50 Pa. To make sure that this pressure is available, the intake duct should be kept short and should be located as close to the air handler fan as possible. In one instance, the intake duct exceeded 20 meters in length and was tied into the return grill just off the main living area. No flow was measured at the inlet.

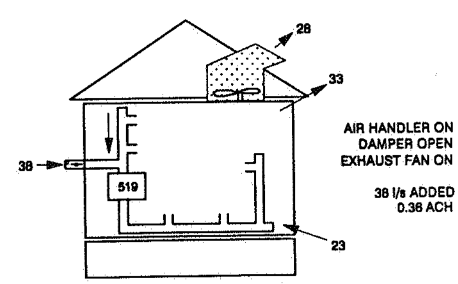
Differential Pressurization:

When the supplies and returns of a forced air heating system are separated by closable doors, large positive pressures can occur when doors are closed. The unbalanced pressures result in increased infiltration. These effects have been noted by several researchers (Cummings 1990, Palmiter 1991). In the Northwest, there are no code or programmatic requirements for pressure balancing systems or for locating both supply and return ducts in rooms with closable doors. To illustrate how the fresh-air inlet and the exhaust system interact with stack induced infiltration, the following examples are offered.

In the first example, a house with the ducts and air handler inside a fairly tight envelope (2.9 ACH @50 Pa). At a specific outside temperature (-5 C), the infiltration rate is 0.14 ACH. The combined fresh-air intake and the exhaust fan yield a total ventilation rate of 0.36 ACH. Intake and exhaust air flows were measured using a flow hood device, and overall infiltration and combined ventilation rates were measured using tracer gas decay.



All flow rates are in liters per second.



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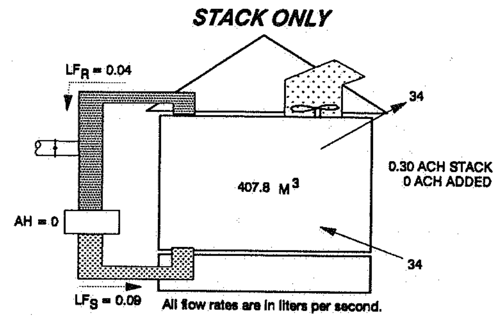
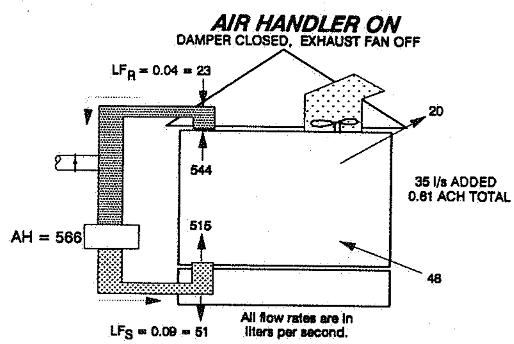
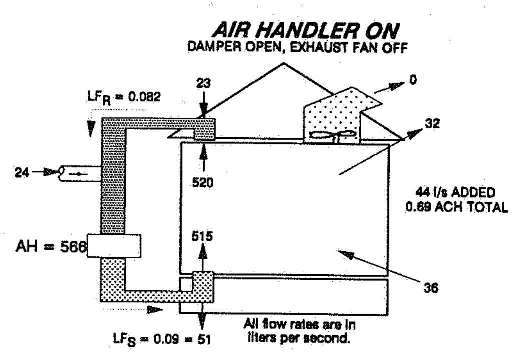
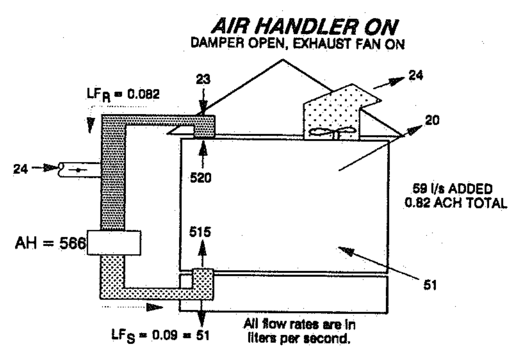
All flow rates are in liters per second.



In this example, the ducts and air handler are located outside a leaky (10.1 ACH @ 50 Pa) envelope. The infiltration component from stack effect is shown, and then the additional infiltration induced by the duct and air handler leakage is shown. The leakage fraction on the return (LFr) is 4 percent, and the supply leakage fraction (LFs) is 9 percent. When the fresh-air damper is opened, the return leakage fraction effectively becomes 8.2 percent. The impacts of the fresh-air supply and the exhaust fan on air flows are shown, assuming that one half of the unbalanced flows result in additional infiltration.







CONCLUSIONS

Fresh-air inlets can function as an effective supply method for introducing ventilation into forced-air heating system ducts. However, it is important that both the ducts and the air handlers be as tight as possible if they are located outside the building envelope. To prevent bulk overpressurization of the house, exhaust rates should equal supply rates. Suitable controls must be used to operate the system, and this currently requires electric relays and transformers. Finally, the energy cost associated with using a large air handler to move 500 l/s of air to supply 38 l/s of fresh air is large.

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