A Systems Approach To Spot Ventilation

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The house is a system. The house is a system. The house is a system. It's becoming one of those phrases that is thrown about the construction world like overcooked pasta. But what does the phrase mean? Where does the system begin? Where does it end? What are the relationships between the components? And does it make any difference?

What is the system? Going beyond the ability to fully comprehend, everything is part of THE SYSTEM. The act of my creating this document has a ripple effect that is impacting an infinite array of other acts. This document may have an impact on the way you build your next house and so the document becomes a part of that system. (Then again, it may not.)

That's too much. The circle of reason is too big. We need to draw the physical circle smaller so that it takes into account the house and its occupants. We must also inscribe two other circles on the first: time and, of specific interest here, ventilation. For a single moment ventilation is not needed. The house is static. Nothing is changing. But if the clock begins to move, occupants come into the house, materials outgas, mold grows, air flows.

Ventilation is an active noun. It can be quantitatively defined for a moment, but it is constantly shifting and changing. The house is also constantly changing but at a slower rate. The goal is for the house to change extremely slowly, which would mean it would require painting less often, roofs would have to be replaced less frequently, and much less maintenance would have to be done. One of the byproducts of maintenance is material waste, and the most efficient use of any material is to leave it where it is.

The ventilation system in the house is one of the few components that can help to maintain the integrity of the structure, reducing maintenance, reducing waste. It accomplishes that by removing excessive moisture and by maintaining beneficial indoor air quality.

How much ventilation?

To be absolutely right, the ventilation rate should vary, balanced carefully on the edge between too much and too little. We can be begin to define the ventilation rate with establishing a comfortable range for humidity (approximately 35%RH in winter, 55%RH in summer).

But there are a number of other components to indoor air quality including odors and levels of CO_2 and all the other gases in the home. To be absolutely right a ventilation system should consider all of these components and increase and decrease in response to them. It should consider its source of "fresh" air to determine if the elements in that source are actually an improvement over the elements already in the home. It should consider if the negative pressure in the house will increase beyond which the furnace or water heater will back-draft.

What would be the result of too much ventilation?
- high energy cost
- excessive dryness
- potential backdrafting of natural combustion appliances

What would be the result of too little ventilation?
- high humidity
- increased maintenance cost
- poor indoor air quality

At the moment, unfortunately, such absolute balancing accuracy is not possible. We simply don't know enough nor do we have affordable sensors which can perform these tasks. And so we must compromise and work from rules of thumb.

ASHRAE says that we should change the air in the house .35 times each hour. This is about the amount of air necessary to remove the CO_2 created by the occupants. If all other factors are ignored,

(.35 x volume of the house)/60 minutes/hour

would calculate the required cfm. (Example: for a 2000 sq ft house (.35 x (2000x8))/60 = 93 cfm.)

An alternate acceptable approach is to figure on 15 cfm per person, two people in the master bedroom and one in each other bedroom. (For a three bedroom home the required cfm would therefore be 60 cfm.)

This is a constant flow of air through the house: 24 hours per day, 365 days per year. It makes no allowance for open windows or the removal of all occupants. But it is a generally safe approach for replacing the air in the home.

Systems

There's that word again: system. The ventilation component of the house-system is more than just the bathroom fan. It must include every means of moving air through the house including the range hood, the clothes drier, the fireplace, the warm air heating system, the recessed lights, the whole house fan, infiltration, exfiltration, etc.

In considering just the fan part of the ventilation system there are essentially bathroom fans, in-line or remote mount fans, "fan-in-a-box" fans (mult-port ventilators), and heat recovery ventilators.

Bathroom fans: most bathroom fans mount in the ceiling of the bathroom and push the exhaust air through a duct to a hood mounted on the outside of the building.

In-line fans: In-line fans are remotely mounted from the bathroom and are located in the middle of the duct between the bathroom and the outside.

Fan-in-a-box fans: These are fairly powerful blowers which are capable of drawing air from several rooms simultaneously and require only one exhaust point to the outside.

Heat (or Energy) Recovery Ventilators: These devices are connected to a variety of exhaust and supply points, and use the warmth of the outgoing airstream to pre-heat the cold incoming airstream.

Why you would choose one of these systems over another generally boils down to the configuration of the application, your personal preference, and, as an electrician I questioned stated, "The kind of car the customer drives!" All of these products will move the air. HRV's and ERV's have a considerably higher first cost than the basic bath fan. In terms of power consumption for their motors, some of the new, quiet, efficient bath fans require only 18 watts as opposed to 85 watts for an HRV.

The major energy savings with an HRV comes from the smaller amount of energy required to heat the incoming fresh air. Considering the natural heat load of the house, the infiltration component may be as great as 30%. Running a fan all the time may increase the air flow through the house by 20%. Thus if the house has an annual heating cost of $600, the fan will increase this cost by 20% x 30% or 6% or $36. If an HRV can save us 80% of that, its savings would be about $29 per year over a conventional fan. It would take more than 40 years to pay back the difference between the systems.

The best thing about the HRV's is really the fully distributed ventilation that they accomplish. Fresh air is supplied to bedrooms and living rooms and stale air is removed from the polluting sources such as bathrooms and the kitchen.

Some distribution can be accomplished by using fan-in-a-box fans and in-line fans connected to more than one bathroom. They are well suited to situations where single building skin penetrations are particularly helpful and the rooms to be ventilated are relatively close together. Their main limiting factor is that all the rooms are ventilated whenever any of the rooms are ventilated. This is an attribute of distributed ventilation.

Using a bath fan for single point ventilating system is the least expensive approach and can be quite effective if the fan is properly located and properly controlled. The biggest drawback is that distribution of the fresh air throughout the building relies on other dynamic factors such as infiltration and convective flows generally established by the warm air heating system.

Installation Details

Lengthy courses are offered concerning the installation of HRV's, so I won't touch on that topic here. Anectdotal evidence indicates that the majority of bath fans are incorrectly installed. They are ducted into the attic where the warm, moist air condenses on the cold surfaces and drips down onto the insulation. They are not ducted at all, blowing their warm, moist air into the joist cavity. They are ducted through uninsulated duct in a freezing cold attic, where they fill with water.

Correct installation is not, as they say, rocket science. The manufacturer's instructions are generally pretty descriptive on how to accomplish proper installation. And if the fans are installed correctly the air flow stated on the side of the carton can generally be achieved!

> What does the information on the side of the carton mean.
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> *XXcfm (air movement)* cubic feet per minute measured at .1 inwg. (In terms of a 75cfm fan, that would mean the ducting could be rigid duct, 20 feet long, with two 90° turns and a hood on the exterior of the building. For flex duct, you would have to cut the length in half.)
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> *X.X sones (sound level)* Sones are a linear scale of sound or noise. Two sones are twice as loud as one sone. One sone has been defined as "the sound that a quiet refrigerator makes in a quiet kitchen". Historically typical bath fans are in the four sone range. Fans used for continuous ventilation should be no louder than 1.5 sones.
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> *"For baths up to XX sq. ft."* The industry rule of thumb is that a bath fan should be able to change all the air in the bathroom 8 times per hour. To size the fan by this method, one would take the floor area and multiply it by 8 to get the volume and divide the result by 60 to convert to minutes.

Since the average bath fan only runs about seven minutes per day, this formula doesn't mean a whole lot.

Some general installation rules of thumb:

- Run the duct all the way to the outside of the building.
- Keep the duct runs as short and straight as possible.
- Use only insulated duct (well insulated) in an unconditioned attic space.
- Run the duct all the way to the outside of the building.
- Support flexible duct in an attic so that there are no sags where water can collect.
- If possible, slope the duct down hill to the outside so condensation runs out.
- Run the duct all the way to the outside of the building.
- If possible, use a duct size one inch larger in diameter than the fan nozzle.
- Using PVC pipe makes a very smooth, tight installation.
- Using a spring wire duct clamp to connect the duct to a plastic nozzle of the fan can exert unacceptable pressure on the nozzle. In high attic heat, these nozzles can deform and restrict the operation of the backdraft damper.
- Run the duct all the way to the outside of the building.

One bit of good news is that the back draft dampers in most of these attic fans are pretty good at keeping air from coming back down the duct. (They are not good at all at eliminating unwanted exhaust.)

Controls

So now we have sized and installed the fan, what turns it on and off? The trick of wiring the fan to the light switch is better than simply putting it on a basic on/off switch. At least when it is wired to the light it will be turned on some of the time. But it is obvious that all the humidity is not gone from the bathroom by the time it is vacated after a shower. Water continues to drip down the walls and evaporate from the towels.

A simple approach is to hard-wire it on. That way it runs all the time, 24 hours a day, 365 days a year. That's not a bad approach if the flow (cfm) and the sound level (sones) are low.

Controlling the fan with a timer is another positive approach. Pin timers or microprocessor timers can run the fan during the period of maximum use or occupancy.

Dehumidistats will control the fan whenever the relative humidity is high in the bathroom. (Even in summer when the natural relative humidity is high.) The fan will continue to run until the humidity drops below the set point. There are some fans and controls which are more sophisticated that will respond to spikes in humidity or humidity differentials so that the fan will respond to "wet events."

A motion controller will activate the fan whenever someone is in moving in the bathroom.

Again, the selection of the control at this point is as much dependent on personal and customer preference as anything else. Anything that will keep the fan running beyond the time when the bathroom is occupied is an improvement.

How do you know if it works

In most locations, there are code requirements that there be bathroom fans. There is no requirement that it will actually work and move air from the inside of the house to the outside. It is likely that this will change. But at the moment the fact is that there is no inexpensive instrument to test the real performance of the fan. There are flow hoods which are generally used for balancing heating systems that provide digital cfm readings. There are "duct blasters" which can be used with digital micromanometers. There is a strange Wheatstone bridge device that uses a motor to close a door to provide a calibrated opening. All of these devices cost in excess of $1000 and require some experience to operate accurately.

First of all, it must be understood that just because the fan is running, it doesn't mean that it is moving any air. The electric motor will spin the fan blade even if the outlet is completely blocked.

Putting your hand up to the fan will give you a sense of whether or not there is any air motion. The back of your hand, the side away from the fan, will feel cooler. Smoke from a candle or a cigarette will give you a more dynamic indication of air flow.

Then there is is the old toilet paper technique. Different weights of paper will offer different approximation of air flow. (Make sure that the grille opening is completely covered. Sometimes there are openings along the sides.) Two pieces of tape at one end of the paper will secure it to the grille. Three different weights of paper: a standard sized, single ply tissue (peal off from a double ply), a standard sized piece of single ply paper towel, and an eight and one half by eleven inch piece of "20 lb" copier paper.

Paper	Draws it up
Single Ply Tissue	> 30 cfm
Single Ply Paper Towel	> 60 cfm
"20lb" Copier Paper	> 110 cfm

When the flow rate is great enough, the paper is actually drawn up to the bottom of the fan and slaps into the grille. Once the paper has completely covered the opening, the flow rate will need to drop to less than 15 cfm before it will drop away.

Working with the customer

When a person is building a house or remodeling a bathroom, chances are very good that they are not even aware of the importance of the bathroom fan. In fact, one is likely to hear a throaty chuckle when one defines a bathroom fan as "important."

Clearly, a ventilation system protects the health of both the building and its occupants. Without it, maintenance costs for painting and allergy pills will go up. Eliminating this component of the house-system will have insidious but mostly hidden costs.

The homeowner must understand the importance of the system and not defeat it or turn it off permanently. And if it has been selected and installed carefully, there should be no reason for them to do so.

The house is a system, a system to shelter and protect its occupants. The ventilation equipment is as important a part of that system as the roof or the windows. And the more we learn about indoor air quality and building health, the more important it becomes.