

# Insight

## Top 10 Issues in Residential Ventilation Design

This *Insight* is excerpted from Armin Rudd's "**Ventilation Guide**." This publication can be ordered online at [www.buildingsciencepress.com](http://www.buildingsciencepress.com).

By Armin Rudd

Experience is a great teacher, but much bad experience can be avoided through education. That is the goal of this section. Following some basic, uncomplicated design guidelines can go a long way to avoiding most trouble spots.

# 1

**Ducts, Fittings, Grilles** A lot of time and effort can be spent following engineering procedures to design the ducts and fittings for a ventilation

system. The best known of these procedures is the Air Conditioning Contractors of America (ACCA) Manual D. However, that level of detail is usually not needed for residential ventilation systems. Following are a few simple, common sense rules that will serve you well for most situations:

- Make changes in airflow direction as infrequently and as smoothly as possible.
- Pull the inner liner of flex duct to its full extent to avoid the spiral "accordion" effect which causes a lot of flow resistance, or use smooth metal duct.
- Start with the size of the fan outlet/inlet connection. Use that size if the duct length is fairly short (less than 10 ft.) Increase the duct size 1 inch if the duct run is not long (less than 25 ft.) and there are few fittings (less than 3). Go up 2 inches in duct size if

the duct run is long or there are many fittings. Size the wall cap or roof jack to match the final duct size.

- Seal all joints with long-lasting material. Duct mastic is best. Some UL 181 listed tapes can also work well on clean surfaces, but do not use cloth-backed tape.

The outlet connection for standard bathroom exhaust fans is usually 3-inch diameter. The better fans are 4 inch. Remote fans usually have 4-, 6-, or 8-inch diameter inlet or outlet connections. Smooth increaser/reducer fittings to change duct sizes are commonly available and inexpensive. Don't ignore the odd sizes of 5-inch and 7-inch diameter duct. While they are less commonly stocked, they are available, and can make achieving the right air flow much easier.

If you are designing the duct system, when laying out duct runs and sizes, plan for air velocity of:

- 750 ft/min or less for exhaust ducts after the fan
- 350 ft/min or less for exhaust ducts before the fan (also called pickups)
- 500 ft/min or less for supply ducts

This will help keep static pressure and noise down, while keeping throw and efficiency up. Throw and efficiency have to do with how well the air is injected into the room so that it mixes well with room air.

General conventions for branching round ducts are:

- One 5" duct branches to two 4" ducts
- One 6" duct branches to two 5" ducts
- One 8" duct branches to two 6" ducts

Exhaust fans in the same dwelling can share a common discharge duct, but each fan must have a back-draft damper to prevent movement of air from one fan back through another.

Stamped metal grilles are the least expensive, but offer no adjustability and are the least efficient. Aluminum rather than steel should be used where moisture will be present. Grilles with adjustable curved blades to turn the flow to suit the situation are worth the investment. Grilles with a means to adjust the volume of air flow can help with balancing, but there are limitations. Inline balancing dampers do a better job of adjusting air flow.

Many good plastic grilles are available in sizes suitable for ventilation ducting. The best grilles have a means to close down the air flow and have curved diffuser-type surfaces to spread the air out evenly with little noise.

## 2

**Condensation and Mold In or On Ducts**

Condensation occurs when air is humid and surfaces are cold. To be more specific, the

temperature of the surface has to be at or below the dew point temperature of the air for condensation to occur.

A soda can that you take out of the refrigerator is about 36 °F. In summertime in air conditioned buildings, the room air dew point temperature is usually 55 °F or higher. Those conditions will cause condensation to form on the soda can. In wintertime, if room temperature is 68 °F and the room relative humidity is less than 30%, then the soda can temperature is slightly higher than the room dew point and condensation will not occur.

Think of the inside surface of your central air conditioning system supply ducts at the end of a cooling cycle like the surface of the soda can. Then think of humid ventilation air flowing through those ducts from a single-point supply ventilation fan or an HRV. The supply duct surfaces are about 50 to 55 °F, and the summertime ventilation air dew point is usually above 65 °F in humid climates. Those are conditions for condensation inside the central supply ducts. If that occurs over a sufficient length of time, mold will grow.

Therefore, it is not recommended to inject ventilation air from HRV/ERV's or other separate ventilation supply fans into the central supply ducts during humid outdoor conditions. Supplying ventilation air via HRV/ERV's or other separate supply fans into the return side of the central system ducts can also be risky because air can still flow through the central air handling unit is off. That scenario is unlikely if a MERV 8 or greater air filter is installed at the inlet to the air handling unit. In any case, if the central air handling unit is on along with the introduction of outside air, the high mixing ratio of recirculation air to outside air eliminates this condensation problem.

It is more feasible if a mixing ratio of at least 3 parts inside air is mixed with 1 part outside air and the air is injected upstream of the central system filter.

The following ventilation ducts need to be insulated to avoid condensation:

- Any exhaust ventilation duct going through wintertime cold spaces (avoids condensation on the inside of the duct)

- Any supply ventilation duct within the conditioned space (avoids condensation on the inside of the duct in summer and on the outside of the duct in winter).

## 3

**Short Circuiting**

Short circuiting of ventilation air occurs when ventilation air enters and leaves a space or duct before it has a chance to mix

well enough with room air to do the job it was intended to do—that is, to adequately dilute pollutants.

The most common occurrence of short circuiting is with HRV's and ERV's that are connected to the return side only, or connected to both the supply and return sides of a central air handling system. That configuration is common practice because it reduces the initial cost relative to an independent, fully ducted system. For that configuration to work, the central system fan must be operated whenever the HRV/ERV is on. Use of the thermostat fan-on selector must not be relied upon to solve this problem. If the central fan is not interlocked with the HRV/ERV, then the ventilation system will simply recirculate with the outdoors, having no positive effect on indoor air quality until there is a thermostat demand for central fan operation for heating or cooling. Constant operation of the central fan will result in high electric energy consumption and poor humidity control during the cooling season in humid climates. Energy consumption can be reduced through use of a timer to reduce the operational hours of the ventilation system and central fan, and through use of an ECM central fan.

Another example of short circuiting would be where an exhaust fan located in a utility room off the garage draws most of its air from the garage and exhausts it to outdoors. That will occur if the path of least resistance for air moved by the exhaust fan is through leakage in the enclosure separating the garage and the utility room. A similar short-circuit scenario could be true for any single-point exhaust fan located in a closed room.

Short circuiting of ventilation air can also occur for any system where air is supplied in close proximity to where air is returned. Where outlet or inlet placement does not allow for much separation, be sure to use a grille style that will throw the supply air away from the return inlet.

## 4

**Lack of Ventilation Air Distribution**

Lack of ventilation air distribution always occurs when short circuiting occurs. However, lack

of air distribution may also occur due to lack of ducting or whole-house mixing.

The best way to assure proper ventilation air distribution is to first avoid short circuiting, then duct ventilation air to each room or operate the central system fan periodically to achieve uniform mixing among all rooms.

## 5

### **Airflow for Comfort**

It is impossible to provide ventilation air exchange without moving air. Some people are more sensitive to air flow from ducts than others. An effective ventilation system will not cause uncomfortable air complaints. If a ventilation system annoys the occupants they will not use it. When the ventilation system is not used, problems related to building durability, occupant comfort, and occupant health may arise.

Exhaust air does not cause uncomfortable air complaints because the air flow where people could feel it is slow and diffuse.

Supply air, whether from a ventilation fan or a central HVAC system, can feel uncomfortable because of its temperature, humidity, speed, direction, and volume flow rate. Temperature and humidity should be addressed by tempering or conditioning the air before delivery. Speed, direction, and volume flow rate should be addressed by proper duct design, grille placement, and grille characteristics. Too much air, moving too fast over people feels uncomfortable even if it is at room temperature. If the air is colder than room conditions, and if the people are sedentary (such as in bed) even more care must be taken to avoid direct contact.

Uncomfortable direct contact is best avoided by:

- supplying smaller amounts of air to more locations;
- avoiding grille placement directly over locations where sedentary people will likely be; and
- using grilles that cause supply air to quickly mix with surrounding room air.

The following guidance is specific to ventilation systems that periodically operate the central air handler for ventilation air distribution and whole-house mixing:

- Educate the customer about the purpose of periodic air handler fan operation and its importance to whole-house ventilation air distribution, and its corollary benefits of more uniform comfort conditions.

- Do not feed a supply register with a duct larger than 8" diameter, except possibly for high ceilings in open areas.
- Do not feed a supply register in a bedroom with a duct larger than 6" and keep the duct air velocity below 500 ft/min, which will keep the volume flow below 100 cfm.
- Place registers so as to avoid blowing air directly on beds. Two-way and three-way registers will also help divert air evenly without concentrating the flow in one direction. This is especially important for master bedrooms. For example, use two supply registers in the master bedroom as opposed to one large register; always split an 8" duct into two 6" ducts for master bedrooms.

## 6

### **Where Does The Outside Air Come From?**

Since a basic assumption of whole-house ventilation is that the more contaminated inside air is diluted with less contaminated outside air, it is important that the intake of ventilation air be from a known fresh air location. This is a disadvantage of exhaust ventilation and a benefit of supply and balanced ventilation.

With exhaust ventilation, the source of outside air cannot be known because it simply enters through the building enclosure based on the path of least resistance, which is constantly changing due to environmental forces of wind and stack effect. The ventilation air may come through a variety of building enclosure penetrations connected to the garage, crawlspace, attic, or foundation gaps, all of which would likely add to the indoor pollutant level. As air comes inward through the building enclosure, whatever it comes in contact with can have an effect on its contaminant level. The building materials may release VOC's and particulates, or have surface mold, and foreign pollutants may exist within the walls.

Supply or balanced ventilation on the other hand allows the point of outside air intake to be planned. The International Residential Code prohibits sources of outside air as follows:

**Outside or return air for a forced-air heating or cooling system shall not be taken from the following locations:**

1. **Closer than 10 feet from an appliance vent outlet, a vent opening from a plumbing drainage system or the discharge outlet of an exhaust fan, unless the outlet is 3 feet above the outside air inlet.**
2. **Where there is the presence of flammable vapors; or where located less than 10 feet above the**

**surface of any abutting public way or driveway; or where located at grade level by a sidewalk, street, alley or driveway.**

That covers a lot of the potential for problems, but it is best to simply avoid locating an outside air intake on the roof for the following reasons:

- Air from exhausts, vents, and chimneys can too easily be re-entrained in outside air intakes due to the potential for mistakes in locating air intakes far enough away from outlets, as well as due to wind effects.
- Air intakes on shingle roofs can draw in asphalt fumes or odors.
- In summer, air taken from roofs is usually hotter than air taken from sidewalls.
- The additional roof penetration is another potential water leak.

Therefore, it is not recommended to take ventilation air from the roof. Taking ventilation air from a sidewall, gable end or soffit area is better. For 2-story homes, going out the band joist often works well. For 1-story homes that have no gable, a small 45-degree fur-down in a closet on an outside wall, or in the back corner of the garage works well to get to the sidewall below the cornice.

While a back porch ceiling/soffit can be a convenient place to locate an outside air intake, care should be taken so that outdoor cooking smoke is not likely to be drawn in.

Running ventilation ducts through the eave soffit is not recommended. If the outside air intake or exhaust outlet are run through the eave soffit instead of through the sidewall, specific care must be taken to:

- 1) not crush the ventilation ducts between the wall top plate and the roof sheathing;
- 2) leave the full depth of ceiling insulation in place; and
- 3) fully terminate the ducts through the finished soffit to outdoors so that air flow is not restricted and air leakage to/from the attic will not occur.

## 7

### Fan Flow Ratings

Manufacturers usually give a rated air flow based on duct system static pressure. The higher the static pressure, the lower the air flow. The two rating points are 0.1 inch water column (w.c.) and 0.25 inch w.c. In Pascals (Pa), those points are 25 Pa and 62.5 Pa.

Properly designed and installed systems should be able to keep the static pressure below 0.25 inch w.c. However, it is not uncommon to find systems in the field at 0.4 to 0.6 inch w.c. (100 to 150 Pa). Depending on the specific fan and its ability to handle high static pressure, such systems may have insufficient air flow.

## 8

**Fan Flow Verification** After installation, actual air flow should be verified by testing and compared to the design air flow. The most common

test instrument for measuring volumetric flow (cfm) is a flow hood. The flow hood is placed over the supply or return grille and a calibrated velocity grid inside the hood measures the air flow.

A calibrated fan that is commonly used to test ducts for air leakage can be used to provide the most accurate ventilation air flow measurements. A box connected to the calibrated fan is placed over the supply or return grille and the pressure differential between the box and the room is taken to zero by increasing the fan speed. When the pressure difference is zero, the measured air flow through the calibrated fan is representative of the air flow due to the ventilation fan.

Flow grids, also called flow stations, can be used inline with ducts. By measuring the pressure differential across the flow station, the air flow can be calculated using a chart or equation given by the manufacturer. These devices usually require some straight duct distance upstream and downstream to give reliable results.

Other handheld devices can measure air velocity in a duct or at the face of a grille, but obtaining the average velocity over the entire cross section is difficult and more uncertain.

## 9

**Noise** Sound levels for ventilation fans are measured in sones. HVI literature states that the sound level of 1

sones is about the same as a quiet refrigerator running in a quiet room. Fans used for ventilation should be 1 sone or less, unless they are remotely mounted, or part of the central air distribution system. Fans that are too noisy cause complaints or get shut off.

Even a low-sones fan will become noisy if ducted improperly. Improper ducting results in excessive air turbulence and/or high static pressure. Several simple rules for reducing fan and air flow noise are:

- Keep the duct system static pressure below 0.3 inch w.c.
- Don't change the air flow direction on the discharge side of the fan for at least 18 inches after the fan.
- Where ducting for remote fans is short (less than 8 ft), use flex duct.
- Hang remote fans with metal straps or clips where possible. Otherwise, use sound/vibration dampening material underneath mounting points if fastened to or resting on framing.

# 10

**Maintenance** Maintenance must be easy or it won't get done. Clogged air filters are probably the most common maintenance failure. Air filters

must be easy to access. They should be either washable or readily available to purchase, preferably at the common home center stores. Outside air intakes that go through the first floor band joist are items that require annual cleaning. Avoid placing outside air intakes less than 12 inches or so off the ground. Parts that are expected to wear out and need replacement, like drive belts or moisture transfer cores, often don't get noticed when broken, or replaced when needed. Homeowners are usually less aware of maintenance needs for ventilation systems that are not part of the central space conditioning system. If the central space conditioning system fan stops, the system will surely receive the needed attention. Education through verbal and written information is important to make sure that ventilation system maintenance is not ignored.