



National Center for
Healthy Housing

IMPROVING VENTILATION IN NEW AND EXISTING MULTI-FAMILY BUILDINGS WITH INDIVIDUAL UNIT VENTILATION SYSTEMS

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GREEN & HEALTHY HOUSING

IMPROVING VENTILATION IN NEW AND EXISTING MULTI-FAMILY BUILDINGS WITH INDIVIDUAL UNIT VENTILATION SYSTEMS

WHY VENTILATE?

Most of us spend the majority of our time in homes or apartments. Making sure the home living environment has enough clean, fresh air will help to improve occupant health. Many multi-family buildings do not consistently provide families with clean, fresh air. While all of our buildings have windows, these windows do not make a complete ventilation system in most U.S. climates. Nearly all buildings require mechanical ventilation and fans to perform the following functions:

- Exhaust pollutants generated inside the building, such as moisture from bathrooms and cooking, contaminants

generated during cooking, and chemicals from building materials and cleaners; and

- Provide enough clean, fresh air by pulling in and filtering outside air before it is heated, cooled, or circulated in the building to help reduce contaminants and allergens in homes.

Well-ventilated buildings are also less likely to experience odor or moisture/mold issues that are unhealthy and can trigger tenant complaints. Living in damp or moldy environments has been linked to increased risks of breathing problems, such as asthma.¹

DO YOU HAVE INDIVIDUAL VENTILATION?

With individual ventilation systems, each apartment is served by its own self-contained ventilation system. The ventilation may be provided by exhaust fans and related equipment or by outdoor air ducted to the return side of air handlers in each unit. In exhaust-only systems, the bath and/or kitchen exhaust ventilation systems are vented with a dedicated duct, directly outside. You know you have this system if there is a fan in each apartment vented directly to the outside. This fan could exhaust air from the kitchen and one/or one or more baths. Stale air is then ducted directly outdoors either horizontally with a through-wall vent termination or vertically with a rooftop termination for each fan. The fans exhaust air from the kitchens and baths. The walls, ceilings, and floors separating apartments must be air-sealed so less of the make-up air (i.e., air replacing the air exhausted

outside) will come from adjoining units, stairwells, and utility shafts. Air-sealing each apartment improves the performance of passive make-up air inlets. Supply air is as important as exhaust ventilation.

Individual fans in many different apartments that vent into a common shaft are NOT an example of individual ventilation systems. With a common shaft, exhaust performance of one apartment fan could be impacted by the operation of other fans in a building. With individual ventilation systems, each apartment has its own self-contained exhaust system, and exhaust performance is not impacted by other apartments. A ceiling-mounted

¹Institute of Medicine of the National Academies. 2004. *Damp Indoor Spaces and Health*. National Academies Press. ISBN 0-3-9-09246-9.



bath exhaust fan or kitchen range hood fan ducted directly to the outside are examples of individual ventilation systems. There are excellent resources for these two relatively simple applications since they are very common in single-family homes (www.hvi.org; www.aivc.org).

If each apartment has one or more air handlers, ventilation supply air can be provided by running a duct directly from an outdoor air intake to the return side of at least one air handler in each unit. The duct must be sized properly. Control systems must ensure the air handler runs frequently enough to provide enough ventilation (see ASHRAE 62.2 for details on ventilation systems that cycle on and off). In addition to the outdoor air supply duct, controls, and outdoor air intake, each

apartment must have exhaust for kitchens and baths. The air intake must be properly located so that it does not introduce outside air pollutants, such as gases from parking areas, into the living area.

This factsheet will focus on a less well-documented type of individual ventilation system that incorporates an exhaust fan in each apartment that continuously exhausts air from kitchen and bath(s). This design concept is appealing because the single fan and single outdoor vent termination minimizes cost and complexity. For more detailed information on providing ventilation through air handlers in each unit see the article in the reference section by Joseph Lstiburek, Building Science Corporation, Inc.

regarding minimum distances between exhaust vents and windows and fresh air intakes. Ductwork that ties kitchen and bath exhausts together can be run in a drop ceiling above these spaces. Inline fans can be located in this drop ceiling (with an access door). Alternatively, inline fans can be located at the top of closets either behind an access door or the fan grill can be left exposed. Leaving the fans exposed at the top of closets (Figure 1) reduces installed cost, improves serviceability, and can result in acceptable acoustic performance with proper fan specification and duct design. Some code jurisdictions require exhaust ductwork to be under negative pressure always. For this requirement to be satisfied, the inline fan must be located immediately adjacent to the outdoor vent termination so that all of the ductwork is under suction.

STEP-BY-STEP DESIGN GUIDE

Although this system could be used in almost any multi-family building, it is most applicable to new construction or substantial gut rehabs when there is an opportunity to plan for and install the necessary ductwork, outdoor vent terminations, and passive air inlets. However, more severe stack and wind pressures, which are experienced by high-rise buildings, have an impact on design requirements and must be taken into account in fan specification.

A step-by-step guide to implementing an individual ventilation system properly in new construction or gut rehab applications is presented below.

Step 1. Determine the location of the outdoor vent termination, inline fan, and duct layout for the individual system in each apartment. If kitchens or baths have exterior walls, locating exterior vent terminations at these walls can minimize the required ductwork. In typical new multi-family buildings, baths and kitchens are located on the interior of the building with living space and bedrooms at the perimeter. In this case, outdoor vents can be located at perimeter walls with a duct run in a soffit to connect to interior kitchens and baths. Alternatively, with interior kitchens and baths, the shortest

duct run directly to the outdoors may extend to the roof. In buildings four stories or fewer, the average duct run to the roof can be less than the average duct run to the perimeter. In gut rehabs of historic buildings, penetrating certain (or all) façades may not be permitted.

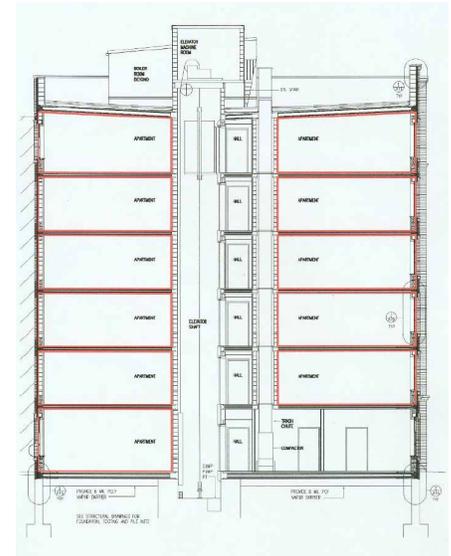
Vent termination locations must be coordinated with local code requirements

Step 2: Develop details to air seal each unit to an air tightness of 0.228 cfm per square foot of unit enclosure at 50 pascals pressure difference.² Identify the walls, ceilings, and floors that will be made into air barriers. Develop details to air seal the joints, intersections, and penetrations in them (Figure 2). Put the details and materials in the drawings and the specs. When renovating existing buildings, air-sealing the units is the most practical strategy. Complete air-sealing of units must sometimes be done to solve odor

Figure 1 | Inline Exhaust Fan Located above Closet Ceiling



Figure 2 | Air Barriers Compartmentalizing Each Unit



or tobacco smoke transfer between units. Some air sealing can be done when tenants change. In an existing building it may be hard to meet the air tightness level of 0.228 cfm (cubic feet per minute) per square foot. The 0.228 cfm per square foot of unit enclosure at 50 pascals pressure difference is a reasonable target when renovating. A reasonable target for other existing building situations is 50 percent of the beginning leakage rate.

Step 3: Develop details for exterior vent termination that do not compromise exterior air/weather barriers. Exchanging poor ventilation for a rainwater leak is not the goal. Rainwater drainage and air tightness must be maintained where the new ventilation system penetrates exterior walls, such as exhaust outlets, passive air inlets, or outdoor air intakes for unit air handlers. Ensure the drawings, specs, or the scope of work include these details and that field inspections ensure the details are followed.

Step 4: Determine the appropriate design exhaust ventilation flow rate for individual kitchens and baths to ensure adequate pollutant removal and an effective overall level of air change in the apartment, based on occupancy. For apartments with a kitchen and a bathroom exhaust, use the code minimum continuous exhaust requirements plus a safety factor. For example, to meet the ICC code minimum ventilation rate for continuous bathroom and kitchen exhaust in an 800 square foot two-bedroom apartment with one bath and a kitchen would require 45 cfm. The rate is the larger rate of 15 cfm per person (45 cfm for two bedrooms) or 0.35 Air Changes per Hour (38 cfm for an 800 square foot, eight-foot-tall apartment).

If continuous exhaust ventilation is used in the kitchen and bathroom, the ICC requires:

- 20 cfm continuous exhaust for the bathroom plus 25 cfm continuous exhaust in the kitchen = 45 cfm continuous exhaust flow.

²Air tightness standard specified in the LEED New Construction 2.2 Environmental Tobacco Smoke Air Sealing Prerequisite.

- By meeting the minimum exhaust rate for continuous bathroom and kitchen exhaust, we also meet the minimum requirement of 45 cfm.
- Adding another 15 cfm (around 20 percent) and increasing the flow from 45 cfm to 60 cfm provides a buffer to account for uncertainty in the test and balance and for changes in ventilation rates caused by varying weather conditions.

Some high-performance building programs mandate ventilation systems that meet the American Society of Heating, Refrigeration, and Air-Conditioning Engineers (ASHRAE) 62.2 Standard Ventilation and Acceptable Indoor Air Quality for Low-Rise Residential Buildings. 62.2 requires a minimum ventilation rate of 7.5 cfm per person plus 0.01 cfm per square foot of floor space, or 30.5 cfm total (22.5 cfm for the two bedrooms plus 8 cfm for the floor space).

If continuous exhaust is used in the bathroom and kitchen, 62.2 requires 20 cfm per bathroom and 5 ACH for the kitchen. Assuming the kitchen is 59 square feet, ASHRAE 62.2 would require:

- 59 cfm: 20 cfm for the bathroom plus 39 cfm (5 ACH x 472 ft²/60 minutes per hour) for the kitchen.
- This exceeds the minimum required by ASHRAE 62.2 and the minimum required by the ICC and meets the high performance program requirement.

ASHRAE 62.2 contains requirements in addition to the ventilation rates – e.g., maximum sound levels and ductloss.

Step 5: Specify a balancing device at each exhaust point, which (in combination with a sufficiently high system operating pressure) can ensure an appropriate and relatively constant continuous exhaust airflow that meets the design target over a wide range of conditions. For example, Constant Airflow Regulator (CAR) dampers manufactured by American ALDES incorporate an inflatable bulb or “airplane wing” mechanism that restricts free area for airflow at higher pressures, resulting in a relatively constant exhaust cfm for duct

Figure 3 | Constant Airflow Regulator Dampers



operating pressures between 0.2 and 0.9 inches water column (Figure 3). CAR dampers are essentially devices that choke down airflow to ensure that there is no over-ventilation, particularly in grills closest to the fan. And when there is no over-ventilation in any particular bath or kitchen, there is less likely to be under-ventilation in other baths or kitchens further from the fan. However, it is important to note that CAR dampers require a minimum operating pressure of 0.2 inches water column in order to regulate airflow. These dampers cannot boost airflow if there is insufficient pressure at a particular location in a shaft. Maintaining a sufficiently high pressure in shafts for CAR dampers to function properly requires (1) tight ducts and (2) adjustment of the roof fan.

Step 6: Specify an ENERGY STAR inline fan with a sufficient exhaust capacity for the application. For a typical apartment layout with 30 cfm kitchen and 30 cfm bath exhaust, an inline fan is required that can provide at least 70 cfm of airflow at an operating pressure of 0.4 in WC.

Step 7: Integrate performance-based specifications in the construction documents for duct air tightness and balancing. The following notes on the mechanical plans are critical:

- **Note 1.** Seal all ducts with mastic, including transverse ducts.

CASE STUDY: NYC THIRD STREET APARTMENTS

Design Team:

Chris Benedict, RA, and Henry Gifford

Design Goals:

Superior thermal comfort, low energy use, good IAQ, effective, low energy use ventilation, resistant to pest colonization, and good sound control were the goals of the project.

Ventilation system:

Individual ventilation systems in combination with air sealing each apartment provide good ventilation throughout the seasons.

Apartment Air Tightness Target:

0.228 cfm per square foot of enclosure at 50 pascals pressure difference.

Construction costs:

Costs averaged \$121 per square foot—the same as otherwise similar apartment buildings built at that time in NYC.

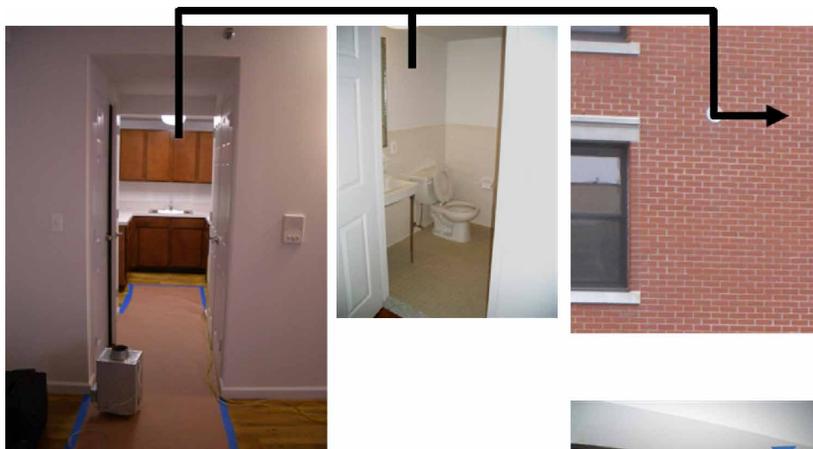
Results:

The ventilation systems work well and thermal comfort is uniform throughout the building; energy use is very low (5 BTU/ft²/HDD/year for heating and domestic hot water).

The ventilation system exhausts continuously from the kitchen area (not the range hood) and the bathroom. An inline fan in above the closet ceiling exhausts a total of total of 70 cfm. The exhaust air exits the unit through a round grill in the exterior wall of each apartment. The units have been air sealed and passive air inlets provide make-up air from outside.



228 E 3rd Street features round metal plates visible on the exterior, which are air louvers for the individual ventilation systems in each apartment.



- Each unit airsealed to 0.1 cfm at 50 pascals per ft² enclosure
- No transfer to neighbors when system's on
- 4% transfer when one unit turned off
- 1-3% exhaust re-enters through trickle vents worst case



- **Note 2.** Ductwork shall be smooth metal. No flex duct permitted.
- **Note 3.** All connections between gypsum board and ductwork must be sealed (duct mastic, sealants, or weather stripping).
- **Note 4.** Contractor shall provide a balancing report for 20 percent of the units. Airflow at kitchen and bath exhaust grills shall be measured with a capture hood that fully encloses the exhaust grills and is able to measure as low as 20 cfm \pm 5 cfm.

Step 8: Meet with mechanical contractors onsite prior to installation of ductwork in order to clarify expectations regarding duct sealing.

Step 9: Visually inspect and conduct air tightness testing of the ductwork in 20 percent of the units prior to the installation of sheetrock. After the installation of sheetrock, an owner's representative or other third party should visually inspect the connection between sheetrock and ductwork to verify an airtight seal in this location.

Step 10: The owner or owner's representative should coordinate with the mechanical contractor to be present during the system balancing. A good rule of thumb is to verify exhaust airflow for all exhaust grills in at least 20 percent of the units, or at least five units, whichever is greater. With the installation of CAR dampers, it is not necessary for the contractor to manually balance and then measure cfm at every exhaust grill in the building. Instead, the final system balancing measurements are intended to confirm performance in a representative sample of the exhaust grilles. Typically, balancing reports are not inspected closely. Since cfm is required to be measured in only 20 percent of exhaust grilles, these measurements must be made accurately with the appropriate equipment and with the owner or owner's representative present. The owner or owner's representative should review the balancing report carefully to ensure the system is functioning as intended.

Step 11: The owner should implement a preventive maintenance program to inspect exhaust grills in all apartments once a year. Exhaust grilles should be removed and CAR dampers inspected for blockages. CAR dampers and grilles should be cleaned.

It is important to note that many owners in many markets do not provide any mechanical ventilation in multi-family buildings as a standard practice. With an individual ventilation system, the extra ductwork required to add an exhaust vent for multiple baths and kitchens tied to the same inline fan is relatively insignificant. With a central exhaust ventilation system, an owner who usually only provides mechanical ventilation in baths will have to install nearly twice as many central exhaust systems (at twice the cost) in order to ventilate both kitchens and baths. From an efficiency standpoint, ENERGY STAR inline fans exist that use approximately 50 percent of the electricity (if specified correctly) as typical rooftop “mushroom” fans. It is also important to note that these apartment fans are usually tied to the meters in individual apartments, while mushroom roof fans are tied to a common building electricity meter.

RESOURCES

Energy-Efficient Ventilation for Apartment Buildings—Lawrence Berkeley Laboratories. epb.lbl.gov/publications/energy_eff_ventilation.pdf. This is a fairly large overview of ventilation systems in multi-family buildings.

“Multifamily Ventilation” by Joe Lstiburek, Building Science Corporation. www.buildingscienceconsulting.com/resources/mechanical/ventilation/Multifamily_Ventilation.pdf. This article covers important and often overlooked fundamentals and includes a case study that uses air handlers in each unit to provide ventilation.

“Constant Airflow Regulators (CAR) in Multi-Family Multi-Story Central Ventilation Systems: New York, NY & Caldwell, NJ.” National Association of Homebuilders Research Center. www.toolbase.org/Building-Systems/HVAC/constant-airflow-regulators. This website documents a

case study that uses central exhaust systems and flow-limiting dampers to provide exhaust only ventilation for an apartment building. A link to the final report for the project is included.

“Reduction of Environmental Tobacco Smoke Transfer in Minnesota Multifamily Buildings Using Air Sealing and Ventilation Treatments by the Center for Energy and Environment.” www.mncee.org/research/environmental_tobacco/multifamily_bldgs/index.php. This report covers efforts made to stop tobacco smoke migration from one unit to another. It highlights the importance of controlling airflow between units, regardless of whether it is a smoking or non-smoking building.

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