MULTIFAMILY PERFORMANCE PROGRAM
Technical Topic – Existing Buildings
Reducing Over-Ventilation in Existing Buildings

Reducing over-ventilation is a powerful way to help meet your energy target. Many multifamily buildings have higher ventilation rates than required by current codes. Building codes traditionally dictated high ventilation rates, but new building code requirements have lowered these.

Buildings with a high volume of existing ventilation can expend over 20% of their energy use on ventilation. This can readily be reduced to less than 10%.

Over-ventilation wastes energy and can have other adverse effects, such as lowering indoor humidity to very dry levels in the winter and increasing indoor humidity in summer. A variety of efficiency strategies can be considered to control ventilation quantities and timing.

Code Requirements for Ventilation

For new buildings, New York City and New York State have both adopted the International Building Code and its associated Mechanical Code. For New York State outside New York City, the same ventilation requirements apply to existing buildings. The Mechanical Code requires every occupied space to be ventilated, either naturally or mechanically, whenever the space is occupied, and allows operable windows to be used for natural ventilation.

The ventilation requirements pertinent to multifamily buildings are:

Kitchens	100 cfm if fan system operation is intermittent[1], 25 cfm if it is continuous.
Bathrooms	50 cfm if fan system operation is intermittent[1], 20 cfm if it is continuous
Living spaces	0.35 air changes per hour or 15 cfm per person, whichever is greater Assume 2 people for the first bedroom, one person for each additional bedroom
Garages	1.5 cfm exhaust per square foot. No recirculation.

Existing Buildings in New York City

Existing buildings in New York City must conform to either the New York City Housing Maintenance Code (HMC) or the Mechanical Code, whichever requires the higher ventilation rate.

The HMC requires bathrooms that do not have operable windows or operable skylights to be ventilated mechanically at the rate of four air changes per hour between six a.m. and midnight. Kitchens are required to have operable windows. Kitchenettes (kitchens no larger than 59 square feet in area) that do not have operable windows or operable skylights must have six air changes per hour of mechanical ventilation.

[1] For the purpose of this discussion, “intermittent” fans are fans whose operation is controlled by the occupant.

Working With the Codes

New York State outside New York City

The New York State Department of State responded to questions about ventilation requirements for multifamily buildings by citing from the Mechanical Code. Ventilation, either natural or mechanical, must be provided when rooms/spaces are occupied. Timers or other fan controls may be used to reduce or shut off mechanical ventilation during unoccupied periods, provided that minimum airflow requirements (either continuous or intermittent) are met when the space is occupied.

New York City

The codes regulating New York City buildings differ in significant ways. New York City Department of Buildings defines “continuous” in Table 403.3 of the Mechanical Code as meaning “24 hours per day,” but the HMC allows fans to be cycled off between midnight and six a.m. The Mechanical Code defines specific cfm requirements for bathrooms and kitchens, while the HMC bases its requirements on room volume.

According to the NYC Department of Buildings, when there is a difference between the requirements of the Building Code and the requirements of the HMC, “the most restrictive shall govern.” As a result, it appears that the code minimum ventilation rate within New York City is whichever requirement produces the higher result.

If the volume of a bathroom/toilet room in an apartment within an existing building is greater than 400 cubic feet (for example, 50 square feet if the ceiling is a typical 8 feet high) and the bathroom/toilet room has no operable window, it falls under the jurisdiction of the HMC and requires mechanical ventilation as described below:

Minimum continuous CFM = 4 x [room volume in cubic feet] x 18/(24 x 60) = [room volume]/20

Minimum CFM for 18 hours/day = 4 x [room volume in cubic feet]/60 = [room volume]/15

If the volume of a kitchenette in an existing building is greater than 250 cubic feet and the kitchenette has no operable window, it falls under the jurisdiction of the HMC and requires mechanical ventilation as described below:

Minimum continuous CFM = 6 x [room volume in cubic feet]/60 = [room volume]/10

Best Practices

Going Beyond the Mechanical Code: ASHRAE Standards 62.1 and 62.2

ASHRAE 62.1 and 62.2 are national standards that have historically served as a basis for codes such as the ventilation section of the NYS Mechanical Code. While they are not code requirements, both low- and high-rise buildings must conform to this standard in order to qualify for LEED certification.

The air flow rates recommended by ASHRAE Standard 62 are higher than the ventilation rates prescribed by the NYS or NYC Mechanical Code. Adopting the ASHRAE Standard 62 ventilation rate thus provides a design safety factor (except for buildings in which the NYC HMC ventilation rate apply). ASHRAE Standard 62.1-2007 recommends minimum exhaust quantities for bathrooms of 25 cfm if the system operates continuously during normal hours of use, 50 cfm if it operates intermittently. The recommendation for kitchen exhaust systems is a minimum of 50 cfm if the system is operating continuously, 100 cfm if operating intermittently.

Energy-Saving Exhaust Strategies

Existing central toilet and kitchen exhaust fans that operate continuously often produce airflow rates significantly higher than the 20 CFM per toilet and 25 CFM per kitchen prescribed by the new Mechanical code. Airflow rates can be reduced while still ensuring that the post-retrofit installation complies with code.

Before calculating savings from ventilation improvements, it is first necessary to measure or estimate the existing ventilation rate. The MPP Simulation Guidelines suggest various methods for accomplishing this task.

- Air flow can be measured at the exhaust grilles in a representative sample of apartments at the top, middle, and bottom floors served by each exhaust fan. This method can underestimate the flow of conditioned air, because it overlooks conditioned air that can leak into the ducts through gaps and cracks.
- Air flow can be measured at the exhaust fan; if there is substantial leakage around the fan curb, this method will overestimate the flow of conditioned air.
- Design air flow rates can be obtained from mechanical drawings but often are overestimates of current conditions.
- Air flow can be estimated from the rated fan horsepower shown on the nameplate; this yields a rough approximation, but again can underestimate flow of conditioned air if there is substantial leakage at the roof curb.

The most accurate approach might be to generate two independent estimates using the first two approaches (measurements at grilles and measurements at the fan) and then average the result.

Reducing Over-Ventilation in Existing Buildings

Reducing over-ventilation can reduce energy use for heating, cooling, and fan operation. Use the MPP Simulation Guidelines Section 9: AIR INFILTRATION AND MECHANICAL VENTILATION to assess the energy savings from reducing mechanical ventilation.

Because the new airflow rates are low, balancing is important. Duct leakage must be minimized to keep wind and stack effect from overpowering the exhaust fan. See *Minimizing Duct Leakage* in the discussion of "Elements of a Ventilation-Related Work Scope."

Savings

Heating and cooling energy use: As air is exhausted, the replacement air that is drawn into the building mixes with conditioned air and adds to the heating and cooling load. The amount of energy saved by reducing air flow rates is a function of heating or cooling plant efficiency.

Fan motor energy use: Fan power is a cube function of cfm, so if all other factors remained equal, reducing cfm by 50% would reduce kW (and therefore kWh) by 87.5%. However, as air flow reductions are implemented, other factors, such as fan efficiency and duct static pressure, also change. See the MPP Simulation Guidelines for guidance on calculating fan motor energy use.

Strategies

Strategies for reducing exhaust quantities include Approaches 1-6 listed below.

- Approach 1: Change or adjust fan pulleys (sheaves) and belts to reduce fan speed
    - Pros:
        - Least expensive approach to modifying airflow rate, depending on the characteristics of the existing fan.
        - Continuous ventilation eliminates concerns about contaminant migration.
        - Produces fan motor savings in addition to savings from reduced air movement, as shown in the fan power equation described above.
    - Cons:
        - Must confirm on a case-by-case basis that pulley replacement or adjustment is possible.
        - Cannot easily fine-tune ventilation rates.
        - Rebalancing is required.

- Approach 2: Install variable speed drives on fan motors to reduce fan speed
    - Pros:
        - Continuous ventilation eliminates concerns about contaminant migration.
        - Produces fan motor savings in addition to savings from reduced air movement, as shown in the fan power equation described above.
        - It is easy to readjust ventilation rates if necessary.

- Cons:
  - Rebalancing is generally required to ensure desired air flows.
  - Variable speed drives are more expensive than replacement pulleys, timers, or mechanical dampers.
  - Variable speed drives are not easy to find for small motors.

- Approach 3: Install new, lower capacity fans/motors.
  - Pros:
    - Low cost, especially for small systems.
    - Continuous ventilation eliminates concerns about contaminant migration.
    - Produces fan motor savings as well as reduced cfm.
    - For large capacity fans, may be additional savings potential from using premium efficiency motors.
  - Cons:
    - Rebalancing is generally required to ensure desired air flows.
    - Hard to adjust air flow rates back up if the resulting ventilation is too low.
    - Less energy savings than produced with Approaches 1 and 2.

- Approach 4: Use a damper to restrict the air flow at the fan.
  - Pros:
    - This mechanical approach does not rely on automatic controls
    - Can be less expensive than installing a new fan
    - Easy to re-adjust ventilation rates if necessary
  - Cons:
    - Rebalancing is generally required to ensure desired air flows.
    - Depending on the performance curve of the particular fan and the change in cfm, this strategy might produce oscillation and instability.

Mechanical balancing devices can be used to ensure balanced flow and reduce the need for balancing. Sealing leaks may be necessary for success with any of these approaches.

In addition to the previously described approaches to reducing exhaust quantities, it is possible to convert existing ganged exhaust systems to occupant-controlled systems. Fans that are directly controlled by occupants are assumed to operate intermittently. They are therefore required by code to produce higher airflows (e.g., 50 cfm for bathrooms, 100 cfm for kitchens). However, because the fans are used intermittently, the result is lower average ventilation rates.

Approach 5: Install switches in each apartment to control the rooftop fan
- Pros:
  - The rooftop operates only when an occupant decides it is needed.

- Cons
  - Higher exhaust air flows than with continuous operation, so if occupants forget to switch off the fan the cost of operation will be higher than with continuous operation at a lower air flow rate
  - Installation of wiring and switches adds to implementation cost
    - Wireless (e.g., X10 or A-10) switches could be less expensive to install than conventional switches and can be appropriate if the signal can reach the fan control from the farthest switch.

Approach 6: Install individual exhaust fans for each bathroom and kitchen. Connect fans to existing exhaust ductwork. The existing ganged exhaust fan can be a) removed, b) set to operate if any of the individual fans are switched on, or c) run continuously at a low speed to maintain a slight negative pressure in the exhaust ductwork.

- Pros:
  - The exhaust system operates at full volume only when an occupant decides it is needed.
- Cons
  - Higher exhaust air flows than with continuous operation, so if occupants forget to switch off the fan the cost of operation will be higher than with continuous operation at a lower air flow rate
  - Installation of wiring and switches adds to implementation cost

Note that the use of timers to cycle ganged exhaust fans is not included in this discussion of recommended approaches. NYS code officials contacted during the development of this guidance said they would approve cycling fans off during periods when kitchens and bathrooms are likely to be unoccupied. However, NYC officials said that because tenants may use bathrooms or kitchens at any time, ventilation must be uninterrupted. In addition, cycling ganged exhaust fans opens the possibility of cross-contamination between apartments. Even on-off cycles that would be allowable under ASHRAE Standard 62 could create problems; for example, a kitchen fan might be on while the bathroom fan was off and might pull bathroom odors and moisture into the apartment.

Energy-Saving Make-up Air Strategies

Mechanically supplied makeup air provides numerous opportunities to save energy. Compare airflows to current codes to evaluate the possibility of over-ventilation. Consider distribution effectiveness: if makeup air provided to corridors is leaking into stairwells or trash rooms or other non-residential areas, air sealing measures can increase the effectiveness of the delivered ventilation and may allow reductions in airflow rates.

Existing makeup air units typically include a large motor that can be evaluated for replacement with a premium-efficiency motor. Makeup air is also typically heated, and higher-cost fuels (for example, electric heat), can be replaced with lower-cost fuels. If makeup air is cooled, high-efficiency replacement for the air conditioning can be evaluated. Heat recovery ventilation is an option, recovering heat from exhaust to preheat makeup air[2]. Solar preheating can also be considered[3].

Elements of a Ventilation-Related Work Scope

This technical tip includes references to numerous technologies, including both hard-wired and wireless switches, premium efficiency fans and variable speed drives. For any recommended improvement, the scope of work should include all relevant information about the ventilation strategy, device or technology that is being recommended:

- Location(s)
    - Where the existing system is to be modified
    - Where new equipment is to be installed
- Critical performance parameters
    - Size/capacity of fans and controls
    - Minimum acceptable efficiency: e.g. premium motors
    - Power for controls: Line voltage, low voltage, battery-powered, single or three-phase
    - Minimum acceptable static pressures (*see below*)
- Settings (e.g., hours of operation, minimum and maximum flow rates)
- Commissioning procedure(s) to ensure that the system is working as intended
- Test procedure(s) to confirm proper performance

Minimizing Duct Leakage

Ventilation system modifications typically require careful attention to air flows. Testing and balancing is often needed to ensure the desired air flow rates from all of the spaces served by the fan, but testing under a particular weather regime does not ensure appropriate air flows under other weather conditions. Pressure fluctuations caused by wind and stack effect can overpower the low negative pressure created by exhaust fan operation, especially when ventilation rates are reduced. To prevent this problem, it is necessary to minimize duct leakage.

To overcome wind and stack effects, the exhaust fan should be able to maintain a pressure differential of at least 20 pascals (preferably 40-50 pascals[4]) across the grille at the farthest end of the duct run. To achieve this goal, ventilation system ducts may require one or more of the steps described below:
- Seal gaps where the ductwork attaches to the fan curb.
- Seal holes where laterals come out of the riser and into the room, especially where the ductwork meets the drywall, to prevent bypass at the grille.
- Check bottoms of risers for missing end caps and repair as needed.

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[2] Taitem Engineering for NYSERDA Assisted Multifamily Program, “Recovery Ventilation in Multifamily Buildings: Energy Audit and Design Guide” February 2006
[3] NYSERDA Multifamily Performance Program Tech Tip, February 2009 – “Solar Ventilation Pre-Heater”
[4] Source: conversation with Terry Brennan, Camroden Associates, June 8, 2009.

- Clean the ducts, if necessary, to remove obstructions.
- Use an aerosol duct sealant to seal inaccessible leaks.

Sealing and testing pressure differentials is an iterative process. The pressure differential across a grille or other opening in the duct will tend to fall if air flow rates are lowered by slowing fan rotation, but will rise if openings in the ductwork are reduced by sealing leaks and restricting the size of air inlets. It may be helpful to use this rule of thumb[5]:

$$Q = SQRT(p) * A$$

Where

Q = airflow cfm

SQRT(p) = square root of the pressure difference across an opening (Pascals)

A = area of the opening in square inches

Thus, if the pressure differential is 25 pascals, a 3 square inch hole will allow 15 cfm of air to flow through the hole. [6]

[5] Source: conversation with Terry Brennan, Camroden Associates, June 8, 2009.

[6] The above formula is a rule of thumb. Flow is proportional to area and the square root of the pressure difference. The proportionality factor incorporates the flow coefficient and a constant to make the units consistent with each other. Coincidentally, the product of the flow coefficient and conversion factor is approximately one when the variables are used in this particular set of units. We are assuming that density doesn't matter and that the formula works over a range of velocities. The Bernoulli equation provides all of the factors that are being approximated away. For more information, see orifice plate" in Wikipedia. Thanks to Dan Clark of McQuay International for this explanation.

Appendix – Additional Resources

NYS and NYC Mechanical Code Requirements for New Buildings

OCCUPANCY OR USE	ESTIMATED MAXIMUM OCCUPANT LOAD	OUTDOOR AIR (Cubic feet per minute (cfm) per person) UNLESS NOTED
Private dwellings, single and multiple		
Garages, common for multiple units[7]	—	1.5 cfm/SF
Kitchens[8]	—	100 cfm intermittent or 25 cfm continuous (exhaust)
Living areas[9]	Based upon number of bedrooms. first bedroom: 2; each additional bedroom: 1	0.35 air changes per hour[10] or 15 cfm per person, whichever is greater
Toilet rooms and bathrooms[8]	—	Mechanical exhaust capacity of 50 cfm intermittent or 20 cfm continuous

Excerpt from Table 403.3: Required Outdoor Ventilation Air

NYC Housing Maintenance Code Requirements for Existing Buildings

THE CITY OF NEW YORK
TITLE D
HOUSING MAINTENANCE CODE

ARTICLE 31: Sanitary Facilities
Sec. D26-31.05 Light and ventilation of water closet compartments

[7] Mechanical exhaust required and the recirculation of air from such spaces is prohibited
[8] Transfer air permitted. The amount of transfer air and exhaust air shall be sufficient to provide the flow rates as specified in Section 403.3 The required outdoor air rates specified in Table 403.3 shall be introduced directly into such spaces or into the occupied spaces from which air is transferred or a combination of both.
[9] Spaces that are unheated or maintained below 50 F are not covered by these requirements unless the occupancy is continuous
[10] Based upon net floor area

a. In every water closet compartment, bathroom and general toilet room one of the following requirements for light and ventilation shall be met:
{NOTE: 1) and 2) present operable windows or skylights as alternatives to mechanical ventilation.}
3) There shall be a system of mechanical ventilation, approved for construction and arrangement by the department. In a multiple dwelling such system of ventilation shall be maintained and operated continuously to provide at least four changes per hour of the air volume of each water closet, bathroom or general toilet room daily from six o'clock in the morning until midnight in all residential parts of a dwelling and from seven o'clock in the morning until seven o'clock at night in any non-residential parts of a dwelling. In a private dwelling the approved system of mechanical ventilation may be switch-operated.

ARTICLE 32: Kitchens and Kitchenettes
Sec. D26-32.03 Lighting and ventilation

The following requirements shall govern in multiple dwellings:

a. The lighting and ventilation of kitchens shall be governed by the provisions on lighting and ventilation in article 30 of this code. *{Note: Article 30 requires operable windows.}*

b. A kitchenette constructed after July 1, 1949, shall have a window opening upon a street, a yard, court, shaft, any partially enclosed balcony or space above a setback, as described in section D26-30.03(a)(3), or an offset or recess less than six feet in width. Such window shall be at least one foot wide, have a total area of at least three square feet and be at least ten percent of the floor area of such kitchenette. In lieu of such window, such kitchenette may have mechanical ventilation to provide at least six changes per hour of the air volume of such kitchenette, or, when such kitchenette is on the top story, may have a skylight of at least one foot wide with a total area of at least four square feet or one-eighth of the area of the kitchenette, whichever is greater, and shall have ventilating openings of at least one-half of the area of the skylight.

Fan Laws -

The following fan laws were used in this technical tip.

<u>Volume Capacity</u>

$$q_1 / q_2 = (n_1 / n_2)$$

<u>Power</u>

$$P_1 / P_2 = (n_1 / n_2)^3 (d_1 / d_2)^5$$

where

q_1 is the original flow rate (cfm)

q_2 is the new flow rate (cfm)

n_1 is the original motor speed (rpm)

n_2 is the new motor speed (rpm)

P_1 is the original power (W)

P_2 is the new power (W)

d_1 is the original fan diameter (inches or cm)

d_2 is the new fan diameter (inches or cm)

Additional Resources:

New York State Building codes, online at http://www.dos.state.ny.us/code/title19.htm
New York City building codes, online at
http://www.nyc.gov/html/dob/html/reference/code_internet.shtml

Diamond, R.C., Feustel, H.E., and Matson, N.E. **Energy-Efficient Ventilation for Apartment Buildings,** 1999 U.S. Department of Energy Rebuild America Guide Series. Available online at http://epb.lbl.gov/publications/energy_eff_ventilation.pdf

Taitem Engineering, "Recovery Ventilation in Multifamily Buildings: Energy Audit and Design Guide" February 2006 – prepared for NYSERDA Assisted Multifamily Program