New York State Energy Research and Development Authority

Improving Central Exhaust Systems for Multifamily Buildings

Final Report

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nyserda
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Improving Central Exhaust Systems for Multifamily Buildings

Final Report

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**New York State
Energy Research and
Development Authority**

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Notice

Introduction

Ventilation design has a major impact on the energy use and indoor air quality of multifamily buildings. Central exhaust roof fans connected to a riser shaft and exhaust grilles in individual apartments are the most commonly specified system in mid to high rise multifamily buildings. In practice, ventilation flows in these systems are inherently difficult to balance from floor to floor and from season to season. Tall multifamily can experience severe (and fluctuating) wind and stack effect driving forces that significantly impact apartment back pressure and airflow through exhaust grilles. The resulting over ventilation of some parts of a building is an unnecessary energy penalty while the corresponding under ventilation in other parts of a building can be detrimental to indoor air quality. Despite their greater complexity, multifamily ventilation systems have not been as well studied as single family ventilation systems.

This report documents the results of a research project to demonstrate the costs and benefits of a best practice systems approach to improving exhaust ventilation system performance in five New York State multifamily buildings. This approach incorporates the Carrier AEROSEAL technology to seal duct risers in-situ and ALDES Constant Airflow Regulator (CAR) Dampers to balance ventilation systems from floor to floor and from season to season.

Problem and Technical Solutions

Based upon Steven Winter Associates' observations and measurements of more than 20 multifamily buildings, there are two primary reasons why central exhaust ventilation systems do not work as designed:

1. Since construction oversight of exhaust ventilation duct air-tightness is unheard of, over 50% of the total airflow exhausted by roof fans is drawn by leaky ducts from random building cavities and not the bathroom and kitchen spaces that actually require ventilation. This reality means that roof fan exhaust flow (and total building ventilation rate) must be increased by over 50% to meet bathroom and kitchen ventilation requirements. In addition, duct leakage exacerbates static pressure loss in vertical exhaust shafts, contributing to balancing issues by making it more difficult to exhaust enough air from lower floor apartments.
2. High-rise multifamily buildings experience severe wind and stack effect driving forces for infiltration. These seasonally fluctuating driving forces significantly pressurize some apartments while significantly depressurizing other apartments, making system balancing challenging.

Since problems with central exhaust ventilation systems encompass design, installation and final commissioning, addressing this opportunity requires a systems approach. This report documents the results of a research project to demonstrate the costs and benefits of a best practice systems approach to improving exhaust ventilation system performance in five New York State multifamily buildings. This approach incorporates the Carrier AEROSEAL technology to seal duct risers in-situ and ALDES Constant Airflow Regulator (CAR) Dampers to balance ventilation systems from floor to floor and from season to season.

AEROSEAL works by sealing holes from the inside with a polymer based sealing agent that is injected into duct systems after exhaust grilles at each floor are removed and duct openings are temporarily blocked with friction fit foam blocks. The sealing agent does not coat the ducts, remains rubbery over time and can seal holes up to 3/8". An AEROSEAL set-up in a central exhaust application that illustrates the main components of the system is presented in Figure 1. The AEROSEAL equipment is easily connected to the exhaust ductwork by temporarily removing a roof fan.

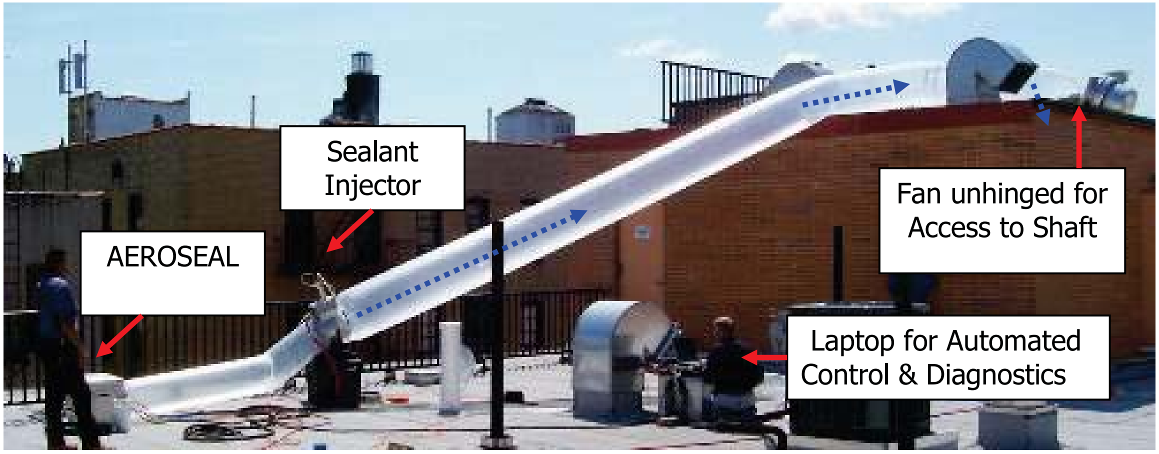

Figure 1. AEROSEAL installation set-up on roof a demonstration building.

CAR dampers are used to regulate airflow at each exhaust grille location. A silicon bladder mechanism (yellow component in Figure 2) expands as the pressure drop across the damper increases, which results in a constant airflow rate over a wide range of conditions. Another approach for accomplishing similar airflow regulation involves a pivoting wing with a torsional spring in place of the silicon bladder.

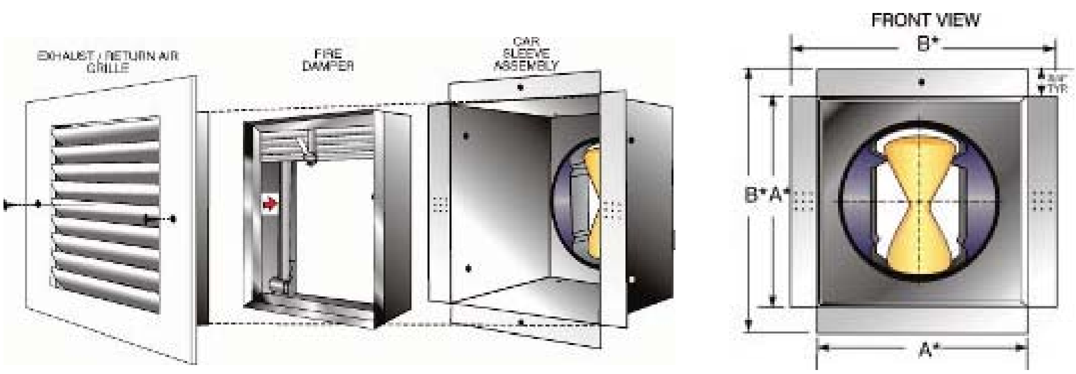

Figure 2. CAR damper shown in exhaust grill assembly

Combining CAR dampers with the AEROSEAL technology as part of a ventilation system Energy Conservation Measure (ECM) is a logical approach since:

1. Leakage area represents random unregulated openings in the duct system that result in unknown and fluctuating (due to stack & wind) ventilation loads. A sealed duct system with CAR dampers minimizes these unregulated openings and assures that all intentional openings are regulated.
2. With existing buildings, CAR dampers can be installed during the same site visit as AEROSEALING work is performed, resulting in the potential for cost savings.
3. AEROSEAL technicians are well suited to implement a multifamily ventilation ECM and can draw on their commercial and single family home experience performing duct leakage tests, measuring airflow and physically inspecting ductwork.

Field Measurements at Demonstration Sites

Survey results from new and existing buildings in this work indicate that leakage commonly occurs in three typical locations. In almost all of the demonstration buildings there was significant leakage where the shaft meets the roof curb. Since the roof curb encloses this penetration, a roof fan will pull additional air (leakage) from this gap if it is left unsealed. Leakage at transverse (horizontal) joints in vertical shafts was also found in many cases. In new construction buildings, the quality of mastic sealing was directly related to contractor training and expectations. Finally, significant leakage was consistently observed at the connection between exhaust ductwork and exhaust grilles in many buildings.

Quantifying the impact that these leakage locations have on system performance requires an understanding of both the air leakage rates (in cubic feet per minute or CFM) and the operating pressure (in Pascals or Pa). SWA performed "duct blaster" pressurization tests on the exhaust ventilation shafts to determine their leakage rates at varying pressures. To conduct these tests, a calibrated fan is connected to the roof curb and all intentional openings in the system are blocked off so that fan flow is an indication of leakage. In order to provide a broader sample size, the results of this project have been leveraged with SWA field data from exhaust ventilation systems in approximately 20 other multifamily buildings. Fifty Pascals has been chosen as a universal reference pressure for all leakage tests since this is the minimum pressure required for the Constant Airflow Regulators (and arguably any other kind of balancing damper) to effectively regulate flow. Results of a normalized leakage comparison across different buildings indicate that there is not a significant difference between the leakage found in typical new construction buildings (with no oversight of duct sealing details) and typical existing buildings. Testing new construction buildings does allow for a better correlation of qualitative observations with quantitative results.

Combining the air leakage rates at 50 pascals (CFM50) per floor results with visual observations gives the following correlation between qualitative observations and quantitative test results:

- Great duct sealing --> 5 CFM50 per floor
- Good duct sealing --> 10 CFM50 per floor
- Some duct sealing --> 15 CFM50 per floor
- NO duct sealing --> 30 CFM50 per floor

Generally speaking, the existing buildings studied had no duct sealing present and exhibited air leakage rates of approximately 30 CFM50 per floor.

When combined with reasonably tight shafts, results generally indicate that CAR dampers are effective at "dialing into" a target ventilation rate and result in well balanced ventilation performance from season to season. A tight duct system is a prerequisite for optimal energy performance since total roof fan exhaust must compensate for any leakage in order to still achieve effective ventilation at all floors. This improvement is significant because while many buildings have sufficient ventilation on some floors, few buildings have sufficient ventilation ***on all floors***.

Energy Analysis

The energy saving opportunity from ventilation load reductions tightening duct systems, and using CAR dampers at any particular building depends on its preexisting condition or "baseline." From an energy standpoint, baseline performance is primarily characterized by the total exhaust airflow removed from the building enclosure by the roof fans. Baseline performance is dependent on both the original system design intent and O&M practices. Since the popularization of mechanical ventilation systems in the 1960s, the majority of mid and high-rise NYS multifamily buildings have not been constructed with windows to provide natural ventilation for kitchens and baths. In NYC, from 1968 up until the 2008 mechanical code change, bathrooms without windows required 50 CFM of mechanical ventilation. During this same time period, the mechanical ventilation rate required for kitchens was 2 CFM/ft2 (resulting in 100+ CFM per kitchen).

With existing buildings, O&M practices can have as large of an impact on baseline ventilation system performance/ energy saving potential as original design airflow targets. It is a very common practice for building owners to use time clocks to turn roof fans off for 8–12 hours per day, which correspondingly reduces any energy savings potential. This practice is inadvisable from an IAQ standpoint since when roof fans are off, shafts are turned into passive plenums for transferring contaminants between units. Regardless of baseline performance, a best practice upgrade must be designed to meet the NYS and NYC mechanical code requirements for continuous ventilation. In poorly maintained buildings, it is also not uncommon for a significant fraction of roof fans to be non operational, usually due to broken belts. Clearly if the baseline exhaust flow for a particular roof fan is zero than there will be an energy penalty associated with fixing it.

As a hypothetical example, consider the energy savings potential to be taken as the difference between base line performance for the 1968 code and the improved performance after dialing exhaust grille performance to the low level continuous ventilation rates permitted by the current code requirements. For a ten-story shaft serving one bath exhaust grille per floor having an originally design of 50 CFM per bath, the exhaust air flow from the shaft will be 500 CFM. If in practice, this roof fan is exhausting 500 CFM from the building, from an *energy* standpoint, it does not matter what percentage of total roof fan airflow is due to leakage. Whether it is drawn from random cavities or the bathrooms actually requiring ventilation, 500 CFM of conditioned air is exhausted from the building and represents the effective ventilation load on the heating and cooling equipment. If this building is retrofitted with CAR dampers factory calibrated for 25 CFM and any leakage is reduced to 5 CFM50 per floor, than total roof fan airflow would be 300 CFM—a 200 CFM reduction in ventilation load from the base case. Note that if the baseline was a 10-story shaft serving one kitchen exhaust grille per floor at 120 CFM per kitchen then total baseline exhaust ventilation rate would be 1,200 CFM but it would still be code permissible to reduce total roof fan flow to 300 CFM. Based on these examples it is apparent that the original design airflow targets for kitchens and baths are a major driver for the total ventilation load reduction and energy savings possible with a best practice retrofit. As a result, new buildings being designed and constructed to current mechanical code requirements are more likely to result in lower baseline ventilation rates and less potential for savings.

In addition to heating/cooling savings, if total roof fan airflow is reduced, there is also the potential for roof fan electricity savings. Roof fan electricity savings potential is generally driven by the same above described design and O&M factors that drive heating/cooling load energy savings potential. An over-ventilated base case building will have the most potential for both thermal and fan electricity savings.

Thermal energy and fan energy savings associated with sealing and balancing exhaust ventilation systems were estimated for two of the existing construction demonstration buildings. The results are presented in the following table.

	Pre retrofit Exhaust flow rate	**Post retrofit Exhaust flow rate**	**Annual Heating Savings**	**Annual Fan Electricity Savings**	**Fan Demand Reduction**
Building 1- Six Story Kitchen Exhaust Shaft	384 cfm	192 cfm	268 therms	1,113 kWh	127 W (45%)
Building 2 - Nine Story Kitchen Exhaust Shaft	486 cfm	290 cfm	330 therms	1,463 kWh	163 W (55%)

Assuming energy prices of $1.50/therm, $0.20/kWh, $20/kW per month, the annual economic savings for one kitchen exhaust shaft in Buildings 1 and 2 were $655 and $826, respectively. Omitted are any potential savings for air conditioning.

Costs associated with these retrofits have also been estimated based on the results of the demonstration projects. For existing buildings, the cost for air sealing the ducts and installing CAR dampers was estimated to be more than $300/exhaust grill. For new construction this cost was estimated to be approximately $150/exhaust grill. This project has demonstrated that the energy savings associated with sealing and balancing exhaust ventilation systems can represent an attractive Energy Conservation Measure (ECM) from a cost benefit standpoint compared to other commonly evaluated and implemented ECMs in NYS multifamily buildings. Assuming measure costs of $1,900 and $2,800 per kitchen exhaust shaft for buildings 1 and 2 above, their respective paybacks would be 2.9 years and 3.4 years, respectively.

Closing Remarks

An important outcome of this project has been the lessons learned for the screening, implementation and commissioning of this type of retrofit in occupied buildings. These lessons learned have been incorporated into a ten page brochure distributed by the National Center for Healthy Housing on "Improving Ventilation in Existing or New Multifamily Buildings with Central Roof Exhaust." The results of this project have also directly informed the development of a proposal to further improve the quality assurance provisions relating to central exhaust ventilation systems in the NYC Mechanical Code in coordination with "Greening the Code" efforts by the U.S. Green Building Council.

Document templates have been developed to support implementation of the discussed ventilation measures. These include new construction sealing guides, a sample letter to tenants in an existing building preparing for these retrofits, and a retrofit sequence for existing building conducting the work. While not rigorously validated, these documents still provide useful information to serve as a starting point for others wishing to develop similar materials. Electronic copies of these documents can be obtained from Robert Carver at NYSERDA.

NYSERDA, a public benefit corporation, offers objective information and analysis, innovative programs, technical expertise and funding to help New Yorkers increase energy efficiency, save money, use renewable energy, and reduce their reliance on fossil fuels. NYSERDA professionals work to protect our environment and create clean-energy jobs. NYSERDA has been developing partnerships to advance innovative energy solutions in New York since 1975.

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