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The Lenox

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Results of Ventilation Retrofit by Remediation Specialists, Inc.

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Introduction

This report describes a ventilation system upgrade project at The Lenox Condominiums, a 300-unit apartment building located in Union City, New Jersey. The upgrade consisted of cleaning and sealing all exhaust ventilation ducts followed by the installation of automatic balancing dampers at all apartment registers. In this report, the work has been evaluated based on several criteria: balance, total airflow, static pressure, and duct tightness. The retrofit process itself was also evaluated for its efficiency and effectiveness, and lessons from the execution are shared near the end of this report. In addition, observations of the evaluation procedures themselves are made.

The ventilation work was performed by Remediation Specialists Inc (RSI), a remediation and ventilation system cleaning contractor that has developed a novel technology for sealing ductwork in existing buildings. Steven Winter Associates, Inc. (SWA), a building performance consulting company, provided third party testing and documentation. The building is owned and operated by Urban American Management Corp. Much of the project cost was paid by the local New Jersey utility, PSE&G, through a technology development grant, some portions were paid for by the owner.

This demonstration project was devised to address a number of problems that are typical in existing multifamily building, including poor balancing with over-ventilation of some units and under-ventilation of others, duct leakage resulting in indoor air quality issues, variable system performance as a result of changes in wind speed and outdoor temperature, and transfer of odors between apartments.

RSI and Steven Winter Associates have completed work on the Lenox ventilation systems for this demonstration project. This report summarizes the results of that work.

Executive Summary

The upgrade work consisted of cleaning and sealing all ventilation ducts followed by the installation of constant airflow register (CAR) dampers at all registers. The project resulted in dramatic reductions in duct leakage. 75% of shafts after the retrofit were found below the recommended maximum leakage rate, while those that did not reach this level of performance saw a reduction of at least 60%. By all measures, the project is a success. The reduction in the amount of air ventilated will reduce heating costs to the building by an estimated $27,000 annually in heating costs alone. In addition, the retrofit is expected to have a major positive effect on the operation of the systems, making them quieter, more efficient, and delivering better indoor air quality to all residents.

RSI was able to install balancing dampers on at least 90% of registers, and it is highly recommended that the building seek to change the remaining 10%. The proper functioning of the systems overall are dependent on ALL registers in a shaft being retrofitted with the dampers. The list of apartments that did not have the retrofit completed for various reasons is available from the building management.

Building and Ventilation System Description

The Lenox is a 17-story, 300 unit apartment building located in Union City, New Jersey. The building is rectangular, with the long axis running nearly north-south. The building is significantly taller the surrounding buildings, and is exposed to weather on all four sides. The building is in the process of converting to condominiums. There are no apartments located on the first floor of the building. The building is heated by a two-pipe steam system and cooled primarily by sleeve-mounted ACs.

Ventilation in the building is provided by 44 roof mounted fans. Apartment ventilation is provided by 40 of these, each fan is connected to a single riser which runs vertically through the building and serves all of the kitchens or bathrooms for a single line of apartments. In addition there are two fans serving the refuse rooms on every floor and two serving the hallways, one of each on either side of the building. The risers are constructed of steel sheet metal and connect to the apartment registers through short take-off pieces. The kitchen registers are quite large, approximately 16" x 8". Bathroom registers are approximately 6"x6". Prior to the cleaning, all risers and take offs were dirty as a result of continuous operation since the building's construction.

At the start of the project, 16 of the 44 roof fans, over one third, were not functioning. About ¼ of these had broken belts while the rest had more serious issues such as missing motors, missing fan parts, or wiring problems.

Roof exhaust fans. Note un-melted snow at non-working fans.

Kitchen riser before cleaning.

Background

There are a number of consistent issues with central ventilation systems in mid- and high-rise multi-family buildings, including poor balancing, excessive dirt, leakage, under- and over-ventilation. These issues lead to a number of problems.

- Poor balancing can lead to indoor air quality problems from excessive moisture and related mold growth when ventilation is not provided at necessary levels. It can also result in pollutants and undesirable smells accumulating or transferring between apartments.

- Dirt naturally builds up during the operation of any ventilation system. If it accumulates sufficiently it can interfere with the proper operation of fans and fire dampers, or begin to restrict and block flow through ductwork. Apartment registers may be completely blocked by accumulated dirt.
- Leakage in ductwork causes a drop in static pressure that impedes the proper operation of the system. It also allows systems to pull air from ceiling and wall cavities, ventilating spaces which have little direct impact on indoor air quality but still using energy.
- Under-ventilation can result in the same building durability and indoor air quality issues as poor balancing.
- Over-ventilation, ventilating at rates higher than needed for code compliance or indoor air quality, results in energy waste because conditioned air exhausted unnecessarily is replaced by outdoor air that must be conditioned. Combined with poor balancing, over-ventilation represents a worst-case scenario in which excessive exhaust air wastes energy but produces little benefit to indoor environmental quality.

In order to function correctly, ventilation systems must compete with the natural forces of wind and stack effect. Stack effect appears to be a significant issue at The Lenox. Stack effect is a result of the natural tendency of warm air to rise. In a conventional ventilation system with manual dampers (even a relatively tight one) the stack effect can have an enormous effect on how air moves through the system. Vertical exhaust risers are ideal for moving air, and serve as natural conduits for stack effect induced movement of air. This can result in air blowing out of the registers at the top of the building, transferring smells and moisture between apartments and failing to provide useful ventilation. The forces of stack effect and wind can be overcome only by maintaining sufficient static pressure.

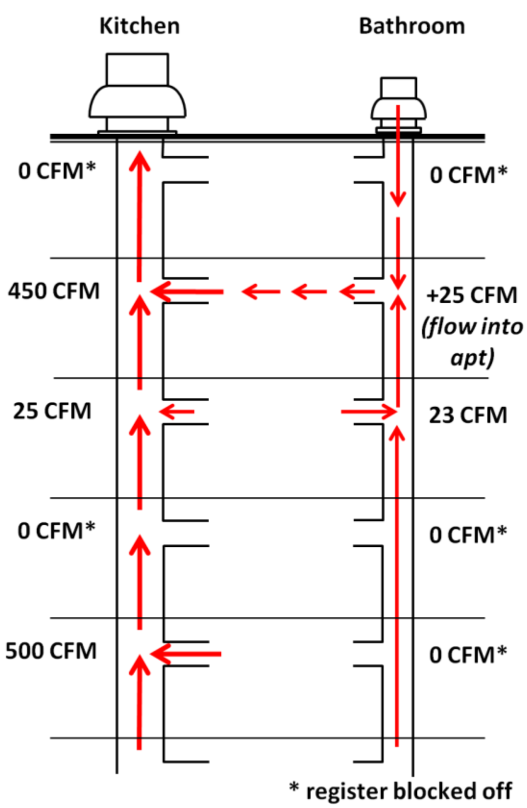
At the Lenox infiltration and the related stack effect appear to be extreme and are compromising the effectiveness of the ventilation system. The upper floors appear to be especially troubled by this, during a site visit on a windy day in March it was observed that nearly all apartment doors on the seventeenth floor have weather stripping on all four sides, as well as a wooden block installed across the threshold at the bottom of the door in order to block air infiltration. This is quite uncommon for a multi-family building. A strong draft could be felt around any apartment doors that were not tightly sealed, and wind was audible rushing under a single door. Meanwhile, on the ground floor the lobby doors (which are frameless glass doors on floor hinges) were constantly being held open by a powerful draft into the building. These infiltration and stack effect problems are being exacerbated by the significant number of openings at the top of the building, including open stairwell and elevator vents as well as a large number of broken exterior bulkhead doors.

Balancing issues are very difficult to address in a conventional ventilation system without adjustable dampers (such as at the Lenox), leading to a ventilation system that does not perform well. Often upper-floor apartments are significantly over-ventilated, leading to draft and noise complaints, while lower floors tend to have extremely low (or non-existent) exhaust flow which can lead to a host of moisture and indoor air quality problems. When combined with maintenance issues like those found at the Lenox the results can be significantly less than ideal. In order to be truly effective, ventilation retrofits must address all of these problems to some degree.

Ventilation System Conditions Pre-Retrofit

The state of ventilation systems at the Lenox before work began was poor. First, the majority of fans were either non-functional or turned off for one reason or another. Next, balance from floor to floor was astoundingly uneven, as indicated by massive flows at upper floors and zero or even reverse flows on other floors. Most tenants complained about noise, smoke, and smells from other apartments or from the fans themselves. A large number of residents had taken it upon themselves to block off the vents entirely.

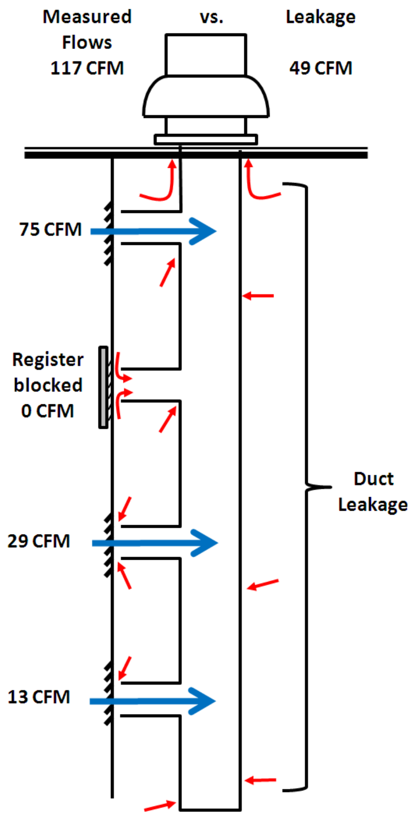
So extreme were the imbalances of this system that odd airflow patterns resulted. One bathroom exhaust fan was not working correctly, so its defunct shaft became a transfer pathway for airflow and smells from other apartments and even from the roof. Because the draw from the kitchen exhaust fans was so extreme, the broken roof fan serving the bathrooms had in effect become a supply fan, pulling air from outside. As a result of the noise and other objectionable operations of the exhaust systems in these apartments, most residents had blocked their ducts off completely. Those that hadn't experienced either low exhaust rates or even reversed airflow into their apartments.



Airflow Patterns in Malfunctioning Ventilation Systems at the Lenox

Part of the balance issue was that the exhaust registers in the kitchens were oversized even for their design airflow of 100 CFM, with register openings of 1.125 ft2 each. These large openings admit an estimated 450 CFM (at a static pressure of -145 Pa) on the 16th floor and 68 CFM (at -3 Pa) on the 4th floor. Certainly some of this drop in pressure and flow is due to duct leakage, but in this case the majority is caused by oversized grilles, which allow excess flow on upper floors that robs lower floors.

The figure to the left conceptually shows a common scenario in a poorly-sealed ventilation system at the Lenox. Though it is possible to precisely measure exhaust flows at registers in each apartment, a great portion of total building exhaust is missed. For example, when one encounters a register that a tenant has blocked for one reason or another, the measured flow is zero, while leaks behind



Leakage Points in a Poorly Sealed Duct System

the register may be a significant airflow. Added together, the leaks in an exhaust system may represent a significant portion of the total ventilation load and while this exhaust flow is practically useless to indoor air quality, it still uses energy.

Many of the Lenox's exhaust systems are therefore quite good at ventilating wall and ceiling cavities, but terrible at delivering exhaust where it is actually needed. Leaks in some are so bad as to be detectable within the apartment. In one apartment on the 2nd floor of the building, airflow being drawn from the wall cavity by a leaky duct was so great that 13 CFM exhaust was measured through a light switch, more than 100 feet from the fan.

RSI Scope of Work

The scope of work intended to allow the installation of balancing dampers into a clean and well-sealed system that would provide enough static pressure for them to function well. The stages necessary to accomplish the goals of the project were balancing damper installation, duct cleaning, and duct sealing, each described below.
View from inside duct of sealed take off joint.
Balancing Damper Installation and takeoff sealing

The initial stage of the work was the installation of automatic balancing dampers at every apartment register. The constant airflow regulator (CAR) dampers are manufactured by American Aldes, they are mechanical dampers that self-adjust to provide consistent airflow rates over a range of static pressures. This is valuable because static pressures can be widely different between the top and bottom of a shaft. When installed at the top of a riser where static pressure is high, the dampers will close down to restrict flow, while further down the riser where the pressure is lower, the dampers will open up. In this way, CAR dampers can provide much more consistent ventilation over

View from inside duct of sealed take off joint.

a range of conditions. They serve the function of manually-balanced dampers but also respond to changes in static pressure due to the many forces acting on a building and its ventilation systems.

Since the existing register openings were so oversized for current ventilation code requirements, and since the CAR dampers are so much smaller than these openings, RSI manufactured metal inserts for every register and sealed them with metal tape or silicone caulk. As can be seen from the photograph below, the open area behind each register is vastly reduced.

Prior to installing dampers RSI also cleaned and sealed the joint between the short take-off duct and the main vertical riser. This joint is often a source of significant leakage and is relatively easy to seal. The joint was sealed using UL-181 rated tape.

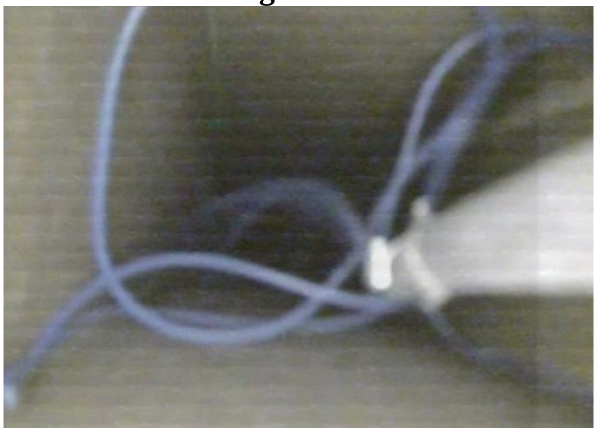
Cleaning

Cleaning of the risers involved visual inspections of all shafts using a camera to identify problems such as major debris that could impede the passage of cleaning and sealing equipment. Once all major debris had been removed, all registers were sealed with tape and a powerful vacuum was connected to the duct at the second floor. A cleaning nozzle was then lowered down the shaft. Compressed air flowing through the cleaning nozzle causes rubber tubing connected to it to whip around vigorously. As the nozzle is lowered down the duct these whips dislodge accumulated dirt which it is then collected by the vacuum at the bottom and top of the duct.

Sealing

Sealing of the joints in the ducts is accomplished by lowering a remote-controlled spray nozzle down the shaft. Liquid duct mastic is pumped through a hose to the spray head. The nozzle has an attached video camera so the operator at the top can use the remote controller to direct the spray at seams and holes in the duct work. For this project Hardcast SpraySeal spray mastic was used. At the Lenox a significant amount of the joints were sealed pre-cleaning during the installation of the balancing dampers in apartments.

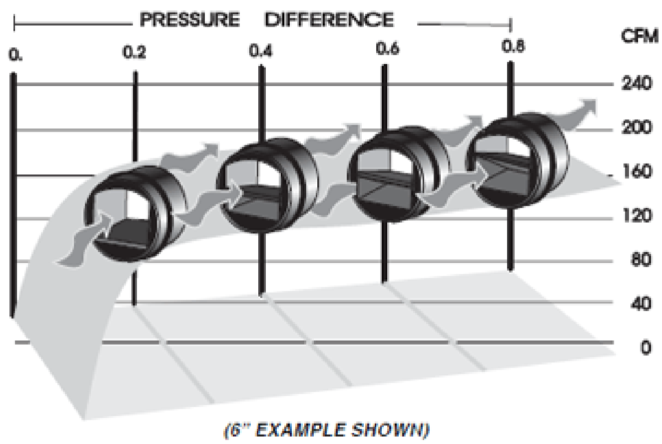
Cleaning Whips
Brushing Inside of Duct



Robot-Controlled
Spray Head Applying Mastic

CAR Damper

CAR Damper Operation



CAR damper images courtesy of American Aldes

CAR Damper Assembly
For Bathroom before Installation

CAR Damper Assembly
Installed and Sealed in Kitchen

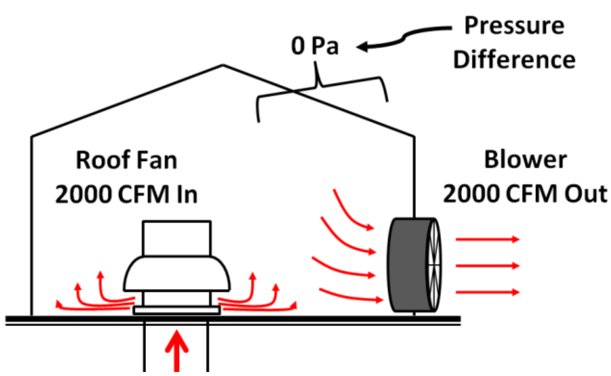
Pre-Retrofit Testing

In order to measure the performance of the existing ventilation system at the Lenox SWA conducted a number of tests, including tests to measure duct tightness, powered flow tent measurements of total flow for individual risers, and flow and pressure readings taken at individual registers in apartments.

Total Riser Flows

Flow measurements of all exhaust risers were taken before and after duct sealing and CAR installation in order to quantify all flow changes resulting from the RSI work. Measurements of the total airflow from the functioning roof fans were conducted using a powered flow hood device. The powered flow hood uses a capture hood to corral airflow and a fan to measure it. The concept is illustrated below. A large tent is placed over the roof fan and a calibrated blower is placed in its air-impermeable fabric. Obviously air blowing out of the roof fan will inflate this tent, so the blower is powered until the tent deflates and there is no pressure difference from inside to outside the tent. Without a pressure difference, we can presume 1) that the flow entering the tent equals the flow leaving the tent and 2) that leakage into and out of the tent is also minimized due to the lack of a pressure difference across its surface. In this way, the airflow coming out of a roof fan, which is extremely hard to directly measure due to its swirling, uneven pattern, is allowed to organize and enter the blower which takes a relatively accurate measurement.

Powered Flow Hood Concept



Roof Fan Tent in Use

Results from pre-retrofit testing conducted on May 2nd, 2011 are summarized in the table below, showing the total volume exhausted from each riser. In this report, risers are called by the line of apartments that they serve and their function as either kitchen or bath ventilation. For example, riser B01 serves bathrooms in apartments 201, 301…1601, etc. Note that the building is 17 stories but there is no ventilation provided on the first floor since it contains no apartments.

The results are compared in the table to a recommended total flow based on the 2009 version of the International Mechanical Code (IMC), which New Jersey follows and which requires continuous ventilation rates of at least 25 CFM in kitchens and 20 CFM in bathrooms. In addition, since all duct systems leak, leakage should be included as a factor in ventilation rates. 10 CFM leakage at 50 Pascals per register is suggested as an acceptable standard of leakage for exhaust systems in existing buildings. Therefore, combined with 2009 International Mechanical Code, total airflows per register should be between 25 and 35 CFM per kitchen (or, 25 CFM plus 0-10 CFM50 leakage), and 20 and 30 CFM per bathroom (20 CFM plus 0-10 CFM50 leakage).

For the preliminary testing total measured flow 28,815 CFM, with an additional 16,540 CFM of flow estimated from fans which were not accessible or off for other testing. The estimate of flow from fans that were operating but not accessible to testing is the average of the tested functioning fans; that is, 820 CFM from baths and 2075 CFM from kitchens. There is also leakage from shafts which had no operating fan but are then in effect large leaks at the roof curb. This flow is difficult to quantify and has not been included in the calculations, but would push estimates of total flow higher.

Because the total actual flow is higher than the code requires, even with 17 fans not operating, it means that there is potential for significant energy savings once the retrofit is completed and even if all fans are repaired.

Lenox Roof Fan Flow Test Results

Fan #	Testing Notes	Measured Flow (CFM)	Estimated Flow for Inaccessible Fans (CFM)	Required Flow Rate (CFM)	% of Required Flow Rate***	Recommended Rate Change
B01		1025		450	195%	-575
B02		800		450	152%	-350
B03	No Motor - Not Tested	0		450	0	450
B04	Not working - Not Tested	0		450	0	450
B05		1180		450	225%	-730
B06	Belt Broken - Not Tested	0		450	0	450
B07	Not tested. No Access		830	450	0	-380
B08	Not tested. No Access		830	450	0	-380
B09	No Motor - Not Tested	0		450	0%	450
B10		1230		450	234%	-780
B11	No fan rotor - Not Tested	0		450	0	450
B12		770		450	147%	-320
B13	No Motor - Not Tested	0		450	0	450
B14		860		450	164%	-410
B15		1160		450	221%	-710
B16	Belt Broken - Not Tested	0		450	0	450
B17		800		450	152%	-350
B18	No Access - Not Tested		830	450	0%	-380
B19	Fan Supplying Air	-300		450	-57%	450
B20	Not Working - Not Tested	0		450	0%	450
K01	Operational - Not Tested		2075	525	0	525
K02	Not Working - Not Tested	0		525	0	525
K03		1950		525	371%	-3950
K04	Not tested. No Access		2075	525	0	-70
K05		2750		525	524%	-295
K06		3640		525	693%	525
K07	Belt Broken - Not tested	0		525	0	-1425
K08		1850		525	352%	-295
K09	Operational – Not Tested		1600	525	0%	-2225
K10	Not working - not tested	0		525	0	-3115
K11	Not tested. No Access		2075	525	0	525
K12		880		525	168%	-1325
K13	Not tested. No Access		2075	525	0	-295
K14	Belt Broken - Not tested	0		525	0	525
K15		4000		525	762%	-295
K16	Not working - not tested	0		525	0	-355
K17	very low flow - estimate	300		525	57%	-295
K18	No Access - Not tested		2075	525	0	525
K19		1220		525	232%	-3475
K20	Off because of noise - not	0		525	0%	525
Garbage	Not working - not tested	0		525	0	225
Garbage	Not working - not tested	0		525	0	-295
Hall north		4700		750	627%	-695
Hall South	Not tested. No Access		2075	750	0	525
	Total Flows	Measured Flow	Estimated Add'l Flow	Required Flow Rate		**Recommended Change**
		28,815	16,540	22,050		**-23,305**
		Total Building Exhaust	**45,355**			

Riser Floor by Floor Flow and Static Pressure Profiles

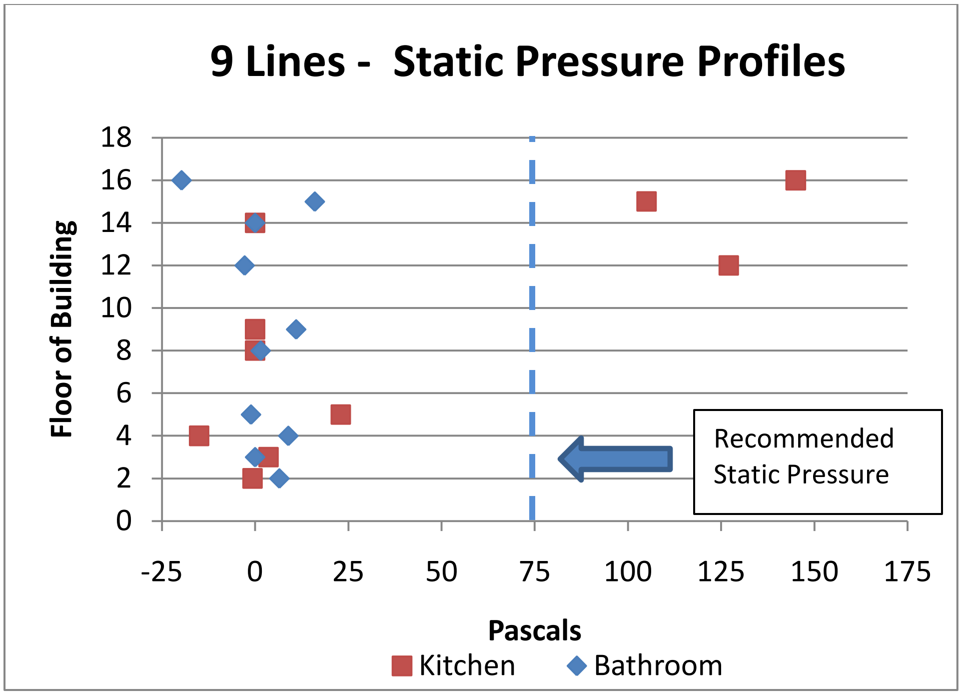
Static pressure and flow measurements were collected at a sampling of registers on five risers, K09, B09, K18, B18 and the hallway ventilation for the North half of the building. Tests were conducted using a pressure pan and flow box made by The Energy Conservatory, which measure static pressure and flow respectively and are used with a digital manometer. Although it was not possible to collect measurements at all registers because not all tenants were home, the sample that was collected indicated that the system was not well balanced, that flow and static pressure were variable and too low in a majority of apartments.

Static Pressure

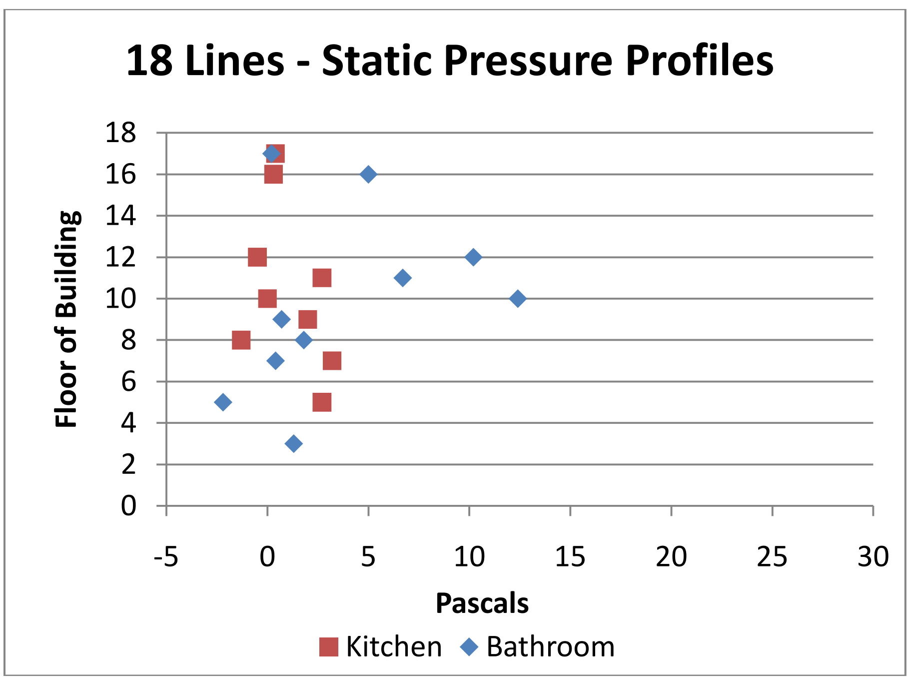
Developing adequate static pressure in a ventilation system is important for several reasons. It allows the system to resist the influence of wind and stack effect, providing more consistent ventilation regardless of weather. Combined with properly sized and balanced register openings, high static pressure also enables even ventilation at all floors.

In the ventilation scheme using CER dampers, a static pressure of 75 Pa or more is needed to properly operate the devices. Of the 48 registers at the Lenox where flow was measured only three had static pressure high enough to operate CER dampers.

Judging from the graphs below, one can see that the balance in single lines was very poor. A well-balanced and sealed ventilation system would have a more vertically-aligned profile of static pressures. The ideal (difficult to achieve in real practice) is indicated by the dotted line in the chart of pressures from 9 Kitchen and 9 Bath below. Obviously there were serious problems with balance in the kitchen lines, with some registers exhibiting very high static pressures while others showed very low or even negative pressures. The 18 Kitchen and 18 Bath lines are similarly imbalanced. One reason for these stark imbalances is modifications that tenants have made to the ventilation by taping and otherwise blocking off registers in their apartments, but the underlying cause of their modifications was frustration with the poor performance of the systems to begin with.

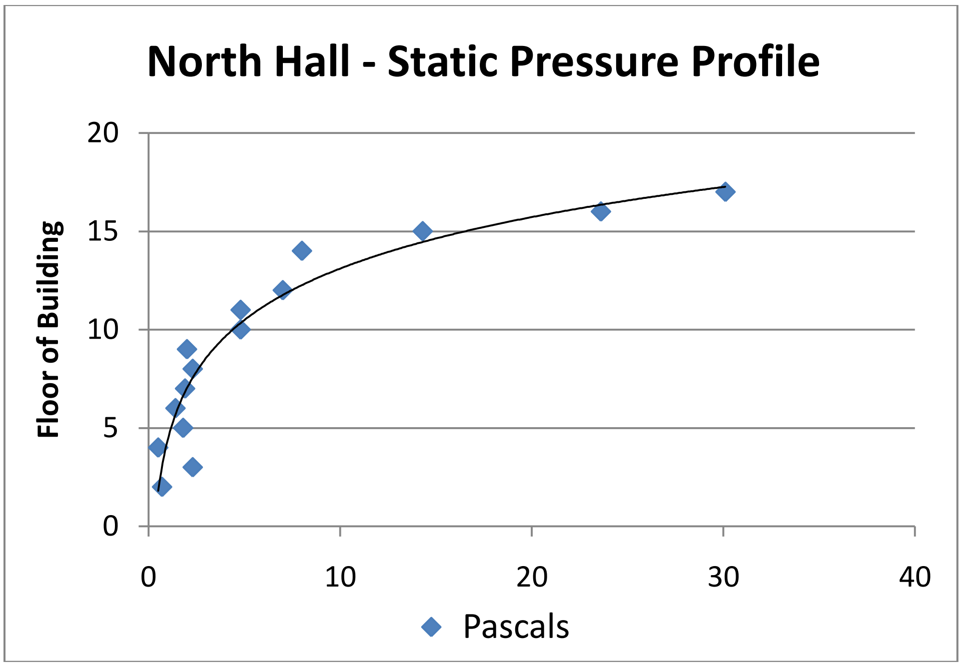


Average: 17 Pascals



Average: 2.1 Pascals

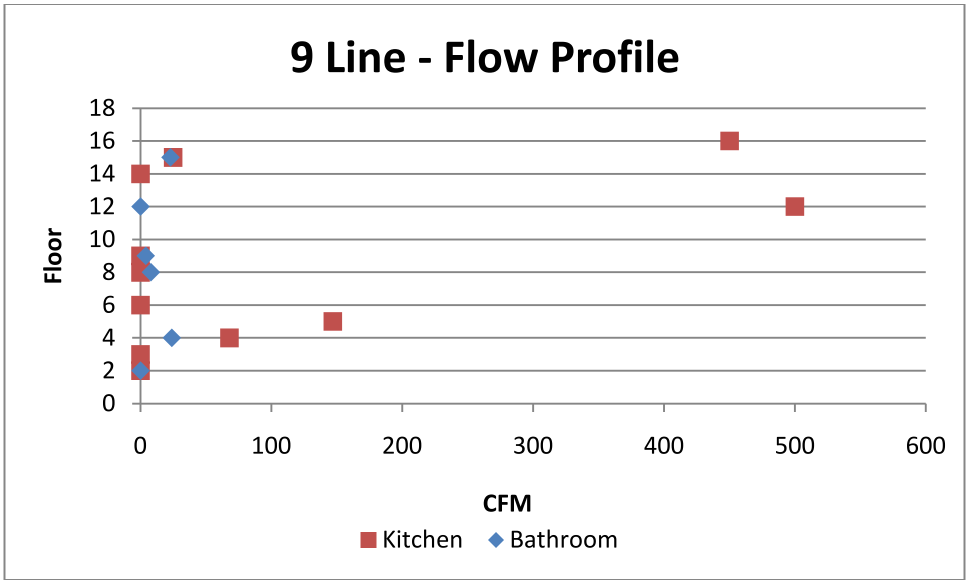
Though it was not included in the retrofit, static pressure and flow was measured at the North Hallway exhaust registers, mostly because the data from these systems would be easy to obtain and analyze. The static pressure profile for the hallway exhaust line follows a pattern that is very much expected for a ventilation system in a high rise building which is unaltered from its original design. The pressures fit a logarithmic curve essentially as expected, with much higher static pressure at the top of the riser decreasing at regularly smaller intervals on lower floors. The hallway systems were designed much like the kitchen risers, with large ducts and large register openings. The open areas of the registers are too large to allow the system to ever develop sufficient static pressure for proper operation; the result is extremely high flows on upper floors and very poor flows on lower floors.



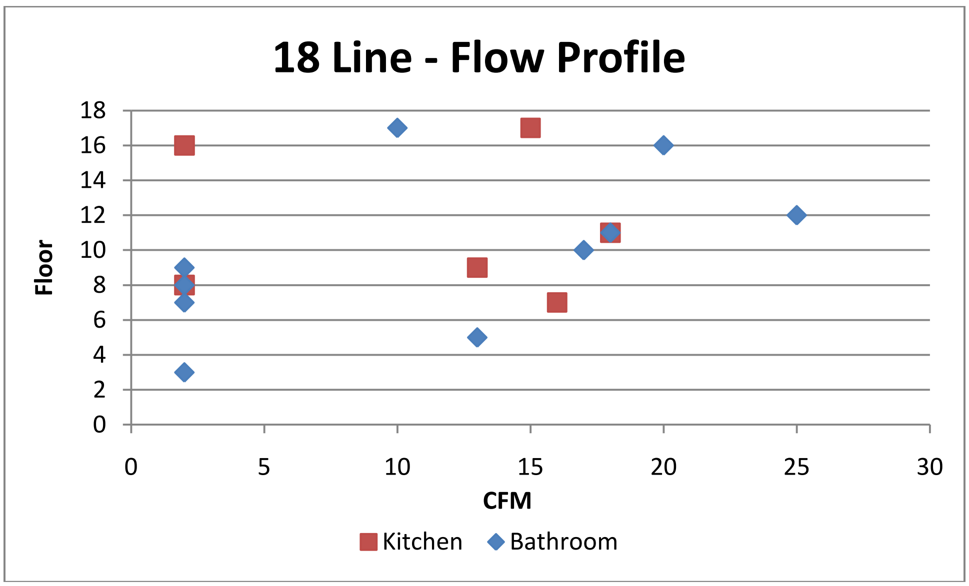
Average: 7 Pascals

Flow Profiles

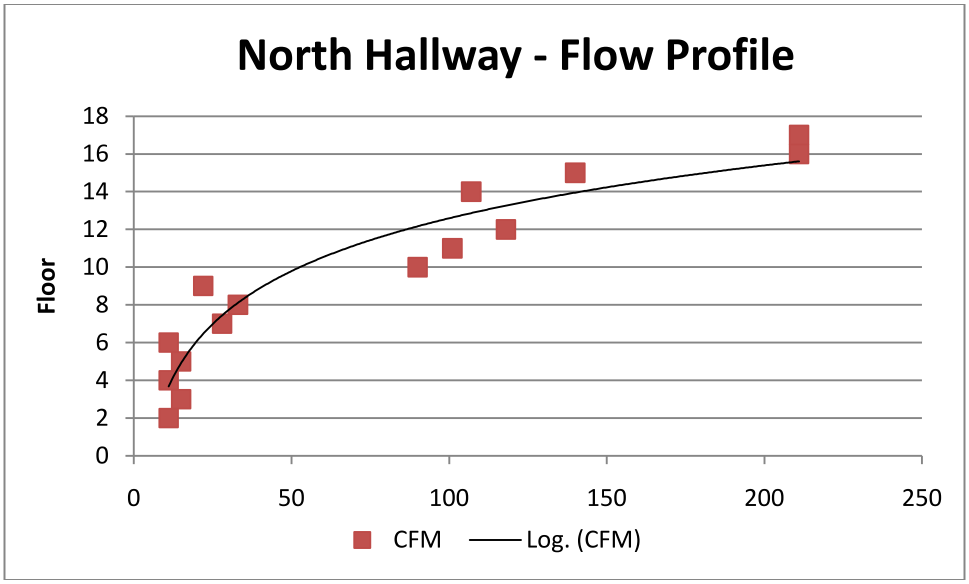
Flow is obviously a very important metric for evaluating a ventilation system. As expected from measurements of static pressure, the measured flows were inconsistent and generally very low. The apartment risers had much more irregular flows. The 9 Kitchen riser had two registers with over 400 CFM of flow and several with no measurable flows because they were blocked off. The 18 Kitchen riser had much lower flows overall, with none of the measured registers above 15 CFM. The North hallway had a flow profile more typical of a lengthy vertical duct run, with high flows at the top that gradually decrease to essentially zero flow at the bottom. This is essentially how most of the risers in the building would look if they had not been altered from their original designs.



Average: 73 CFM



Average: 11 CFM



Average: 75 CFM

Duct Tightness

SWA evaluated the air-tightness of the same four ventilation risers where flow and static pressure were measured, kitchen and baths for the 9 and 18 lines, using "duct blaster" testing equipment and industry accepted protocols. To conduct this test, all of the exhaust registers were sealed and a calibrated duct blaster fan was used to pressurize the system. With the registers sealed, all of the air forced into the duct system to maintain the test pressure represents air leakage through unintentional holes. Leakiness results are given in CFM50, meaning cubic feet of air movement per minute when the duct is pressurized to 50 Pascals.


Duct Leakage Test in Progress

As mentioned before, SWA typically recommends that measured shaft leakage be less than 10 CFM 50 per register in the system in an existing building. The ducts in the Lenox were very leaky, with the 9 Kitchen riser the only one which (barely) passed. During testing of the 9

Kitchen line, it was discovered that the end cap at the bottom of the shaft had come partially disconnected and was hanging. This created a large gap effectively including the wall cavity in the duct system. This was sealed temporarily and the shaft was retested, with results given below as well. Sealing this missing end cap did not have the dramatic effect that might have been expected from a 1 ft^2 hole in a duct, mainly because the wall cavity in which this duct was buried was small and relatively well-sealed.

Riser	CFM50	Leakage/ Register
Kitchen 09	214	14.2
Bath 09	453	30.2
Kitchen 18	1499	99.9
Bath 18	470	31.3
Kitchen 09 (retest)	194	12.9

Pre-Retrofit Testing Conclusions

Before the retrofit the ventilation system at The Lenox was not operating well, partially as a result of the system design and partially as a result of poor maintenance. Approximately 1/3rd of the rooftop exhaust fans were not operational when work began. Total exhaust flows were extremely variable in different risers, with extreme over-ventilation in some lines while others had a slight negative flow (into the building). Measured flow and pressure at individual registers was also extremely variable, ranging from zero or even positive flow upward to several hundred CFM. Ducts were fairly leaky, with only one of four tested risers barely meeting SWA tightness recommendations; another had seven times the recommended permissible leakage.

The total pre-retrofit exhaust flow is less than the recommended flow, which means that after shafts are cleaned, sealed and have CAR dampers installed there will be significant reductions in flow for the over-ventilated lines, and even after all the broken fans are fixed there should be a net reduction in total flow for the building. Because heated exhaust air is a significant fuel cost there is a significant opportunity to reduce heating fuel costs at the Lenox by reducing ventilation rates. SWA calculations indicate that the retrofit scope of work will save approximately $27,200 in annual gas heating costs alone.

Although difficult to quantify, it seems likely that the functioning of the ventilation system is being further compromised by the extreme infiltration and stack effect problems that were observed at the Lenox.

Post-Retrofit Testing

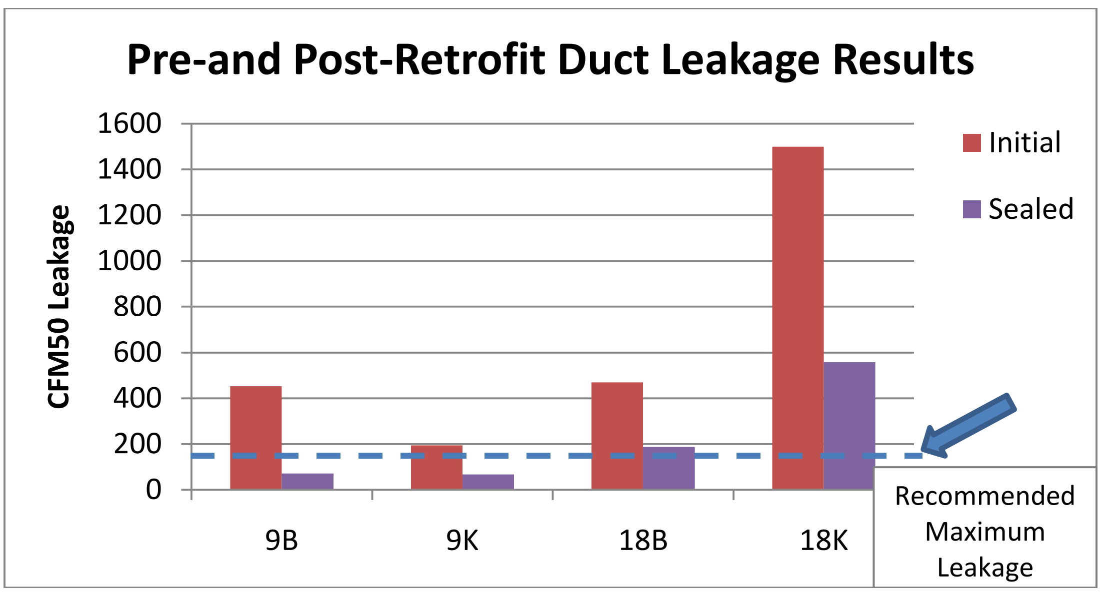
Post-retrofit testing at the Lenox was limited to several duct tightness tests at various stages of completion. Measurement of total flows is not possible or meaningful until tape installed by RSI is removed and new roof fans are installed. Results of the testing from 8 shafts are shown below.

Duct Leakage

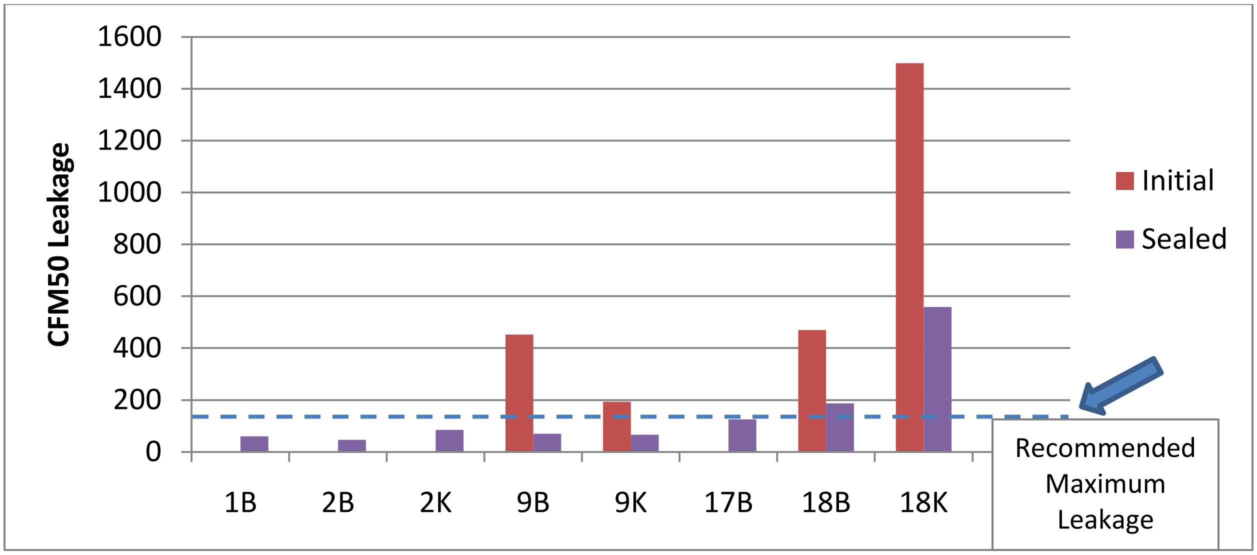
Duct leakage tests were conducted throughout the retrofit process to determine the effectiveness of the air sealing regimen. Results on the whole were outstanding. Leakage in every shaft that was tested before and after dropped dramatically, with the greatest absolute reduction in the 18 Kitchen shaft and the greatest relative reduction in the 9 Bathroom shaft.

	Pre-Retrofit		Post-Retrofit		
Riser	CFM50	Leakage/ Register	CFM50	Leakage/ Register	Percentage Reduction
Kitchen 09	214	14.2	66.7	4.4	66%
Bath 09	453	30.2	70.5	4.7	84%
Kitchen 18	1499	99.9	558.0	37.2	63%
Bath 18	470	31.3	187.0	12.5	60%

Before the retrofit, 4 of 4 shafts were above the maximum leakage level recommended for good ventilation operation, while after the retrofit, 2 of 4 of the shafts were. Though the obvious goal is to get every shaft below the maximum recommended level, one must consider the starting point for each of these shafts. The 18 Kitchen shaft, for example, has more than 3 times the recommended maximum leakage after the retrofit, but before, it had almost 10 times the recommended level.



RSI chose these four shafts for the improvement potential they expected to realize, and given the post-retrofit results, one should say that they were each a success. Put in the context of other shafts tested after the completion of the project, these "trouble" shafts are standouts among many other well-performing examples. The chart below shows post-retrofit results from four other shafts, and all these were below the recommended maximum leakage level.



Shaft 18 Kitchen was found to have major ductwork issues at every floor. RSI constructed special takeoffs and ductwork for each unit in this line, and these efforts were likely largely responsible for the massive reduction in leakage.

Conclusions

The ventilation upgrade work at the Lenox was very successful. Duct leakage from the tested shafts was reduced dramatically. 75% of shafts tested post-retrofit were found to be below the recommended maximum, which is good considering that those that did not make the cut were 3-10 times over the limit to begin with and each saw at least a 60% reduction. These shafts were also chosen for their poor state to begin with.

The installation of the CAR dampers and the significant reduction in overall free area at each register should be greatly beneficial to the balance of the systems as well. They should increase static pressure in the shafts and improve distribution as a result. This should decrease the impact of the stack effect on the ventilation system and also decrease the transfer of smells between apartments.

The post-retrofit tightness of shafts overall in the building is very good. Apart from the one shaft which had major ductwork problems, the average air-tightness of the ducts was 92 CFM50, or 6.1 CFM50 per register, well below the recommended maximum.

The Lenox is poised to reap major benefits from this ventilation retrofit. As described before, the good performance of the ducts post-retrofit will allow the building to replace its aged, broken, oversized, and inappropriate fans with high-efficiency models set to deliver code-compliant levels of ventilation.

The estimated exhaust flow from the building currently costs over $50,000 per year in gas heating alone. By reducing ventilation to 2009 International Mechanical Code levels, the building can cut 23,000 CFM of ventilation, at a savings of $27,000 per year in gas costs.

	CFM	**Operating Cost**
Pre-Retrofit Estimate	45,355	$52,900
Post-Retrofit Recommendation	22,050	$25,700
Potential Savings	23,305	$27,200

Savings from fan electricity can also be factored into this once new fans are chosen for replacements. Each 1/4 HP fan uses approximately $200 per year in electricity, but there are more than 20 fans operating on the building and many are 3/4 HP and greater. New high-efficiency fans use mere fractions of this electricity. The savings from smaller, more efficient fans should raise estimates of savings from this ventilation retrofit to greater than $30,000 per year. In addition, new direct-drive fans will require much less maintenance for several years than the current fans which are largely in poor condition, and these savings can also be attributed to the retrofit.