Revolutionizing Renovation – one building at a time

In the summer of 2013, Marc Zuluaga, vice president at Steven Winters Associates and John Boehm, director or operations for Legow Management partnered together on a building renovation project that would reverberate throughout the professional building industry. The project involved an innovative approach to improving the ventilation system in an older building. Its success has no less than sparked an entire rethinking of ventilation repair and management as more than 5,000 apartments in New York City alone have since undergone the retrofit.

It began with the Carlyle Towers, a 55-year-old multi-family apartment building in West Caldwell, New Jersey. The property owner, David Legow, was concerned about rising energy costs and was hoping to find practical solutions to improving the energy efficiency of the 100-unit building.

In fact, the majority of buildings constructed in the U.S. over the past 60 years are designed with mechanical ventilation systems for exhausting stale air from bathrooms and kitchens. Intrinsic with their design, these exhaust systems often prove to be inadequate for proper ventilation. As a result, energy costs for heating and cooling the building can be excessive. In addition, comfort levels are often found to be uneven with some units receiving too much heat while others feel cool. It is also typical to find uneven airflow with upper floor apartments receiving too much ventilation while bottom floor units remain under ventilated.

Like most mid- to high-rise multi-family buildings in the region, the Carlyle Towers was positively ventilated with roof fans. As is often the case, engineers designed the system to provide fan flow that is much higher than the International Mechanical Code requires. From the fans, several long vertical riser shafts were connected to additional ductwork leading to the individual bathrooms and kitchens within each apartment.

Also typical in older buildings such as this, the ductwork was not sealed externally. While the shafts retained their overall structural integrity, they exhibited cracks and gaps throughout the entire ductwork structure, particularly around the S and drive connections in the sheet metal shaft and at the connection of the return grill and shaft. As a consequence, pre-testing of the ventilation system showed an average leakage rate of about 30% to 40%; two to three times more than rates outlined by SMACNA specifications. According to industry insiders, leakage rates of 30% are typical in these types of buildings; rates of 50% to 95% or more are not uncommon.

These high leakage rates manifests in two common characteristics found in many buildings constructed over the past fifty years. First, it leads to enormous energy waste. Leaks in the shafts cause a reduction in pressure within the duct system requiring more energy to move the air. No matter how powerful the exhaust fans may be, they often remain insufficient to adequately vent the targets furthest from the fan. Like drawing liquid from a straw with holes in it, no amount of sucking will do the job.

In buildings where the exhaust shafts have not been sealed, the fan also draws air from both conditioned and unconditioned interstitial spaces around the shafts. The result is an unbalanced flow from each conditioned zone. In taller buildings, the downward pressure associated with seasonal stack effects can also overwhelm the exhaust airflow in the leaky shafts. In this situation, lower stories will typically experience minimal flow or even reverse exhaust airflow. To compensate for this imbalance, engineers often increase the power of the exhaust fan, leading to substantial energy consumption.

According to a 2003 report published by Lawrence Berkeley National Laboratory titled *Thermal Distribution Systems in Commercial Buildings*, even a low leakage rate can lead to a substantial increase in fan power consumption – and energy usage. As dictated by the fan affinity laws, an increase in fan power is proportional to the required increase in flow rate to overcome the shaft leakage, but the increase in fan power is proportional to the cube of the increased fan speed. Hence, just a 15% leakage rate leads to an increase in fan power consumption of 25% to 35%.

As the exhaust fan speeds are increased, the exhaust system also depressurizes the building, which increases infiltration flows. The unconditioned air infiltrating the building results in an additional thermal load that must be conditioned. And this leads again to additional energy consumption.

According to the U.S. Department of Energy, leaking building ventilation systems are costing Americans $5 billion in lost energy each year. The ACEEE (American Council For Energy-Efficient Economy) estimates that system upgrades in multifamily buildings could save owners an average of 15 to 30 percent on their monthly utility bills.

The second problem concerns indoor air quality (IAQ). With a leaky ventilation system, stale and odor-filled air in the affected areas remains ever present. Moisture from bathrooms and cooking continues to circulate, causing mold and other health-related concerns. Without an adequate supply of fresh air, the buildup of indoor pollutants is inevitable. The EPA has determined that leaky shafts are a main contributor to "Sick Building Syndrome," a combination of ailments directly associated with poor indoor air quality.

ASHRAE Standard 62 (Ventilation For Acceptable Indoor Air Quality) was specifically developed to address IAQ concerns, and while building codes in most states reference at least some of this standard as part of their own minimum ventilation requirements, indoor air quality and the illnesses associated with it, remain a significant problem. In 1984, the World Health Organization reported that up to 30% of new and remodeled buildings worldwide may be linked to symptoms of Sick Building Syndrome.

Though the size and scope of the problems associated with central ventilation systems are well known, fixing these problems has remained allusive at best. Short of tearing down walls to access and manually seal each of the individual leaks throughout the duct system, there has been no adequate fix. As a result, building owners and their residents have, for decades, simply persevered through these systemic problems.

Now, new technologies are offering up a viable solution. In the summer of 2008, Steven Winter & Associates, armed with new duct sealing technology out of Lawrence Berkeley National Laboratory and self-regulating dampers from American Aldes, engaged in the Carlyle Towers project, the first comprehensive ventilation retrofit for improving both energy and indoor air quality performance.

“I was aware of the aeroseal technology and its use in residential and commercial heating and cooling duct sealing projects,” said Zuluaga. “So when we were called in to solve the ventilation-related issues at the Carlyle Towers, I thought this would be a perfect time to try it for this application as well.”

Aeroseal is an aerosol-based sealant that works from the inside of the duct system. The process begins by blocking the wall registers so that air can only escape through the leaks in the ductwork. The duct system is slightly pressurized to 0.1 inWC, increasing to a maximum of 3 inWC during the sealing process. The sealant is than heated up and blown into the ventilation shaft through an existing access point or through a temporary entranceway cut into the system. The dry, 7-10 micron-sized adhesive particles remain suspended in air as they travel throughout the ductwork until they reach a leak. Here they begin to accumulate around the leak, bonding to other sealant particles until the entire hole is permanently filled.

Unlike some sealants such as those used for weatherization or material bonding, the aeroseal sealant is a vinyl acetate polymer with a rapid cure rate of approximately 2 hours. The sealant exhibits minimal VOC off gassing and its non-toxic properties afford it no OSHA maximum exposure limitations. Aeroseal has been used to seal leaks in school buildings, health clinics and hospital buildings. As is often the case, the Carlyle Tower project was successfully and safely conducted while the building was still occupied.

In August of 2008 Aeroseal was first used to seal leaks throughout the Carlyle Tower's 25 individual ventilation shafts. Each time, the process began and ended with a measurement of duct leakage. Before the duct sealing, average shaft leakage rates were well above 200 CFM. Post sealing tests showed leakage rates reduced to 15 CFM or less – in some cases into single digit range.

"Aeroseal sealed on average 90% of the duct leakage," said Zuluaga, "and that, along with the installation of CAR dampers at each register, had a significant impact on the ability to properly balance ventilation and reducing the use of both gas and electricity.

The American Aldes Constant Airflow Regulators (CAR) dampers regulate airflow over a wide range of pressure conditions. The dampers automatically adjust to compensate for changes in the pressure field due to wind and stack effect. This adjustment assures that the ventilation system remains balanced despite changing seasons and other environmental factors.

It took the engineers approximately 4 weeks to aeroseal the ductwork and install the dampers. With the leaks sealed and the pressure within the ventilation shafts balanced, SWA was able to recommend replacing the 25 300-watt roof exhaust fans with much smaller 140-watt fans. While the net overall ventilation for the building was much lower than before the retrofit, the system was now delivering the right amount at every location. The electricity savings from fan optimization alone resulted in an annual utility savings of $7,000.

In addition, by eliminating the heating and cooling air that was previously escaping through the air duct leaks, the building owners realized a dramatic decrease in gas use for space heating. Utility records examined over a three-year period after the retrofit completion show an approximate 30% reduction in gas usage – from an average of 57,500 therms (EC)/year to 41,000 therms (EC)/year.

“Soon after the retrofit was completed, we heard from one tenant who thanked the building manager for fixing his heat,” said David Legow, president of Legow Management, owners of the property. “While we didn’t touch the heating system per-say, by sealing the shaft leaks and automating the damper adjustments, the furnace was noticeably more efficient and effective.”

The positive results from the Aeroseal / AA damper retrofit has gained industry attention. Lessons learned from the project were incorporated into the Green Code Task force recommendations to “ensure ventilation airflow in residences.” In addition, the National Center for Healthy Homes and a recent study funded by HUD both reference the project in guidelines for improving indoor air quality.

More importantly, since the completion of the Carlyle Towers retrofit project, hundreds of similar multifamily apartments with central ventilation have been retrofitted for higher energy performance. Today, there is an effective solution to fixing ventilation issues and the implications for energy savings is substantial.

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SUGGESTED SIDE BAR #1

Determining Ventilation Flow Rates

A proper exhaust ventilation flow rate will ensure adequate removal of pollutants and keep rooms at desired temperatures while minimizing energy usage. To determine the ideal flow rate, Steven Winter Associates recommends following the code minimum continuous exhaust requirements, plus a safety factor.

Example: 800 square foot two-bedroom apartment with one bath and a kitchen.

- ICC code minimum would require a flow rate of 45 CFM; the larger rate of 15 CFM per person or 0.35 (= 45 CFM for two bedrooms) Air Changes per Hour (= 38 CFM)

- Adding another 15 CFM (around 20%) increases the flow from 45 to 60 CFM, which provides a buffer to account for testing anomalies and changes in flow rate due to weather fluxuations.

Green building programs often require adherence to guidelines set by the American Society of Heating, Refrigeration and Air Conditioning Engineers' (ASHRAE) 62.2 standard. This includes:

- A minimum ventilation rate of 7.5 CFM per person plus 0.01 CFM per square foot of floor space. In the example cited above, this would equate to 22.5 CFM for the two bedrooms plus 8 CFM for floor space – a total of 30.5 CFM

Standard 62.2 also requires fan power for bathrooms and kitchens. For continuous exhaust 62.2 requires 20 CFM per bathroom and 5 air-changes-per-hour (ACH) for the kitchen. For a 59 square foot kitchen with an eight foot high ceiling, ASHRAE 62.2 would require:

- 59 CFM for the apartment minus 20 CFM for the bathroom plus 39 CFM (5 ACH x 472 ft^3/60 minutes per hour) for the kitchen.

59 CFM, which exceeds the minimum ventilation rate required by ASHRAE 62.2 and the minimum required by the ICC. Note: compliance with ICC standards for ventilation does not necessarily ensure compliance with ASHRAE 62.2. Often additional ventilation is needed above and beyond the code to satisfy 62.2.

SUGGESTED SIDE BAR #2 - Ventilation Tissue Test

How well is your building ventilated? In SWA's experience as a third party energy auditor, nearly every central exhaust ventilation system they've measured performed sub-optimally. The ACEEE supports that claim with their findings that energy efficiency upgrades in multifamily buildings alone could save building owners and residents up to $3.4 billion nationwide.

So what about that office building where you work? Or the luxury hotel where you stay, or the restaurant where you regularly go out to eat? Are their ventilation systems up to snuff? Are you getting clean fresh air or sharing old stale, potentially unhealthy air with others? You don't need fancy equipment to get a good idea – all it takes is a simple piece of tissue paper and a little tenacity on your part.

The next time you're in a public building, locate the exhaust vent (often on the ceiling or along the walls in bathrooms) and simply place a piece of tissue paper over the vent. If the tissue sticks – consider it a pass. But if the tissue falls to the floor, you can assume that the building is under ventilated. If the exhaust rate is too low to even hold up a piece of tissue, it is certainly too low to adequately replenish the air. It's a clear indication that the building's ductwork is leaking so much air that the exhaust fans cannot adequately do their job.

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