Aerosol Ductwork Sealing in Laboratory Facilities

1 Overview

An aerosol-based sealing technology for HVAC ductwork was developed by Lawrence Berkeley National Laboratory (LBNL) in 1994. This commercially licensed technology seals ductwork leaks that are inaccessible to usual methods. It has been used effectively since 1997 in residences and light commercial buildings. Further research on commercial building applications was conducted at LBNL between 1997 and 2002. Application of aerosol duct sealing in laboratory facilities is just beginning to be explored. This technical bulletin: provides an overview of the technology; reviews the energy-saving benefits; describes the process for application in laboratory facilities; presents a case study with lessons-learned.

What is aerosol duct sealing?

The aerosol-based ductwork sealing (ADS) technology seals duct leaks from within the ductwork, by pressurizing the duct system with a fog of sealant-laden air. By temporarily blocking all outlet grilles and diffusers, the sealant particles are driven into the leaks with a small auxiliary fan. The sealant particles are gradually deposited in the leaks by the exiting air-stream as it bends and accelerates through the leaks (usually cracks and holes). As the process continues, the particles slowly begin to accumulate in the leaking cracks and holes until they are essentially sealed. Features of aerosol duct sealing include:

- Ability to seal holes up to 3/8" in diameter.
- Uses a safe vinyl polymer.
- Has no lingering odors or off-gassing.
- Does not coat ductwork.
- Does not require ductwork cleaning before sealing (unless very dirty).
- Lasts >10 years.

Fig. 1: A look inside sealed ductwork: note buildup of polymer sealant

How is sealing accomplished?

The sealant particles are "sized" by an injector so that they stay suspended in the air until they try to exit the duct system. The ADS injection process is monitored and controlled by a laptop computer that calculates the equivalent "hole area" of the leaks at the beginning of the sealing. It monitors the decreasing hole area and displays the remaining leakage in real time. The sealing is considered to complete when the initial leakage rate, in CFM, reaches a steady value, i.e., shows minimal reduction over time. When the sealing is finished, a complete minute-by-minute record of the process is provided.

Is my ductwork leaking?

Probably, but the real question is: "How much is my ductwork leaking?" The best way to know how much a laboratory's ductwork is leaking is to generate a Test, Adjust, and Balance (TAB) report of the ductwork system that compares the total flow through the outlet grilles with the total flow at the main air handler outlet. Ductwork leakage rates of 20 to 25 percent, and higher, have been encountered numerous times in commercial and laboratory buildings. Typically, ADS has been able to seal 85 to 90 percent of the leaks in these systems.

2 Benefits for laboratories

Aerosol sealing ductwork in a laboratory building saves energy, improves air and thermal distribution (comfort and ventilation), and can reduce cross contamination between different zones in the lab facility.

- **Decreases fan-power energy use**
  - Both supply and general exhaust.
  - Frees-up extra airflow capacity.
- **Reduces heating and cooling energy-waste**
- **Re-balances lab airflows**
  - Ensures safe and efficient fume hood operations.
  - Reduces offset air volume, saving energy.

Sealant Material

The sealant material consists of a 65%water-based solution prior to application. The dried sealant material primarily contains two chemicals, vinyl acetate polymer (VAP) and 2-ethyl-1 hexanol (2E1H). The vast majority of what is left in the duct system is VAP, which has been used in water-based paints, adhesives, and hair spray. VAP has been used in chewing gum, and has no OSHA Exposure Limit. 2E1H is a common industrial solvent and is not considered toxic by OSHA. A review of the literature showed no ill effects after long-term exposure to concentrations of 200 ppm. The largest concentration of 2E1H measured in test houses was 1 ppb (200,000 times smaller), during injection. The sealant is UL-listed for smoke generation and flame spread (UL 723 0,0), and additional testing by U.L. showed no signs of mold growth or erosion.

3 Retro-commissioning (Retro-Cx) opportunity

Laboratory aerosol duct sealing can also be a part of a comprehensive laboratory airflow management effort that includes a full retro-commissioning of the laboratory. Combining an ADS project with a Retro-Cx project has a variety of benefits since each type of project has similar information needs, supportive process-steps, and compatible goals. Consider the fact that the following tasks need to be completed in preparation for proper execution of each project:

- Retrieve and review engineering drawings
- Gather equipment lists and evaluations
- Obtain current facility energy-use information
- Download EMCS historical information
- Review Facilities operational history and pending repairs/upgrades
- Meet with facility-user/client to identify problems
- Benchmark airflows
- Verify installation and operational status
- Spot-check individual equipment energy use
- Study EMCS control routines
- Identify additional sensors and hardware necessary to optimize system control

Once these tasks have been completed, flow benchmarking, installation verification, and operational status can commence for both ADS and Retro-Cx projects. After preliminary Retro-Cx tasks are finished, including spot-checks of particular equipment energy use, the ADS project can begin. While ADS is being performed, Retro-Cx the EMCS by analyzing control routines and identifying sensors and hardware necessary to optimize system control. ADS is usually completed in phases, or sections, of the entire HVAC system. As the sealing process evolves, Retro-Cx efforts can re-check control routines of completed phases, or sections, of the newly-sealed HVAC system. Rather than developing control routines for leaking, inefficient air distribution systems, tuning a "healthy" system will yield better energy-savings results. Otherwise, both time and energy will be wasted trying to correct an inherently inefficient HVAC system.

The U.S. Green Building Council (USGBC) Leadership in Energy and Environmental Design (*LEED*) Green Building Rating System™ references the American Society of Heating, Refrigeration, and Air-conditioning Engineer (ASHRAE) Standard 90.1 for duct seal performance. The 90.1 Standard prescribes minimum requirements for duct sealing, but does not explicitly reward duct sealing beyond the minimum requirements. There are two options to get credit for ADS under LEED: 1) under Energy & Atmosphere Credit 1, using the exceptional calculation method (ASHRAE 90.1 Section G2.5) to demonstrate above-standard performance; or 2) as an innovation credit.

4 Laboratory duct sealing process

The ADS process begins by meeting with facility users, EH&S representatives, and other stakeholders. Once these meetings have been completed, it will be necessary to coordinate the ADS with day-to-day facility operations. Some steps of the sealing process are usually performed after normal operating hours due to avoid interfering with normal facility operations.

Many laboratory facilities use variable air volume (VAV) systems to distribute conditioned air. It is very important to ensure that measured airflow into and out-of the ductwork is not skewed by any varying VAV damper. Leakage can only be determined when the system in a steadily-flowing condition. A process review is provided with the following eight project-steps:

4.1 Verify airflow requirements and system type

Review and, when necessary, re-establish laboratory air change rate, fume hood face velocity, and laboratory differential pressure criteria with the "authority having jurisdiction." Ensure that all stakeholders are interviewed and considered in accepting these criteria.

4.2 Benchmark fan airflow, power, and pressure

Pitot tube traversing at the outlet of the fans (both supply and general exhaust; not fume hood exhaust) is the most common method to quantify how much air is flowing into the ductwork system. Note that this procedure is fraught with potential misinterpretation of readings depending on instrumentation used. Retrieving main fan power consumption is relatively straightforward with clamp-on meters. Duct static pressure is usually available through the laboratory's DDC system or temporarily installed instrumentation.

4.3 Survey ductwork airflows

Survey airflows out of registers in offices, corridors, hallways, and other non-lab support spaces within the facility. In lab spaces, perform a survey to verify whether design criteria are being achieved or exceeded. Determine that each lab's air change rate per hour (ACH), differential pressure (ΔP) (usually to a hallway), and fume hood face velocity meet minimum requirements when all the lab's fume hood sashes are moved to each of three positions: minimum open, 18-inches open, and full open. For lab spaces with dedicated general exhaust systems (separate from fume hood exhaust), survey their inlet registers and main exhaust fan(s). Caution: ADS is not advised for any ductwork with fume hood exhaust due to potential corrosivity of the exhaust air stream.

4.4 Calculate ductwork leakage

Calculate airflow difference between: total main supply flow, at the AHU outlet, and the facility's supply outlets; and total dedicated general exhaust fan flow and exhaust inlets. Note that ductwork leakage can only be determined when the system in a steadily-flowing condition.

4.5 Determine life-cycle-cost effectiveness

If the calculated ductwork leakage is 10 percent, or more, then ADS is usually cost-effective. Perform additional life-cycle calculations that include climate, facility usage, and energy-cost factors to verify, as necessary.

4.6 Aerosol seal ductwork

As described above, ADS is accomplished by pressurizing the duct system with a fog of sealant particles sized that stay suspended in the air until they try to exit the duct system through leaks.

4.7 Re-balance systems

After sealing has been completed, airflow throughout the building's conditioned spaces will increase, since the ductwork is more effectively delivering and removing air. Consequently, to accommodate increased airflows, the systems will require "re-balancing" with a TAB-process. Re-balancing will include: changing supply and exhaust fan speeds; adjusting balancing dampers to lab spaces; verifying sufficient airflow "offset" in labs to provide required Δ-P; checking for proper functioning of lab room pressure control systems with fume hood sashes being operated. Fan motors with variable speed drives (VSDs) may simplify adjustments during the re-balancing process, but re-sheaving fans may still be necessary. This is an important step to not only realize energy savings, but to ensure user safety.

4.8 Calculate and validate energy savings

Calculate energy savings from reductions in fan power, and cooling and heating energy. Importantly, gathering real data, relating to fan power pre- and post-sealing, is necessary to validate energy savings. For VAV fume hood systems, energy savings calculations need to account for the influence of sash position on building airflow volume so that pre-sealing, post-sealing, and "usual" operational volumes are equivalent.

5 ADS Experience at LBNL: B70 Laboratory

ADS was applied at Lawrence Berkeley National Laboratory (LBNL) in a laboratory facility (B70) that was a noted high-consumer of energy. Due to the particular facility's age, changing missions, and continuous issues of re-balancing air flows, the integrity of air distribution system was in question.

Energy savings as a result of the duct sealing project were dramatic: electricity use dropped by 12 percent immediately following the ADS process. The was due entirely to a 30 percent reduction in required air flow to the building that, in turn, allowed in a 65 percent drop in main air handling unit fan-power from a slowing of the fans by their VSDs. Next steps are to re-balancing the air supply and exhaust systems that will yield additional savings reductions in fan energy and unaccounted heating energy.
Highlights and lessons-learned at B70 included:

- Immediate energy savings were realized from fan-power reductions because fans are operated with VSDs; they "self-adjusted" to static pressure set point achieved with lower airflow that resulted from ADS.
- Re-balancing system airflows will be necessary to capture all energy savings resulting from ADS.
- Lab general exhaust ductwork was leaking 22 percent.
- Aerosol injection was performed downstream of main AHU coils with a pressurizing fan upstream of heating coils; avoided "sealing" coils.
- Sealing was performed on a floor-by-floor basis (a section at a time).
- ADS injection step needed to be performed after-hours and on weekends.

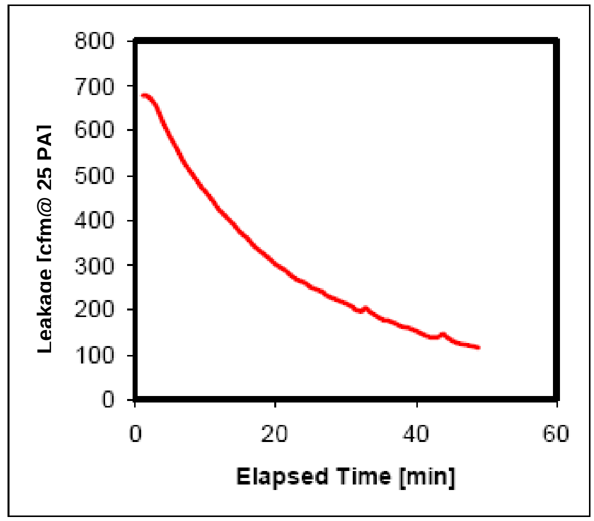

Figure 3: Example sealing profile (third floor northwest)

- Isolate (block) all downstream zone coils to prevent clogging with sealant. Under no circumstances should sealant material be blown through VAV boxes with coils.
- Avoid blowing sealant material through fire or smoke dampers.
- Flow-through air velocity sensors must be isolated from sealant fog.

6 Conclusion

ADS has a proven ability to save energy in a wide spectrum of building types. The application and use in laboratory facilities is especially appropriate due to inherently high airflow-volume associated with safety goals in these facilities. Improved thermal distribution and reduced cross contamination between lab spaces provided with correctly functioning ductwork distribution systems can contribute to overall energy-use reductions in a laboratory facility.

7 References

1. **Aerosol Duct Sealing B70 Energy, Environment, and Nuclear Science Laboratory;** presented at Laboratories for the 21st Century Annual Conference, San Antonio, Texas; October 2006.

8 Acknowledgements

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