ENERGY-SAVING STRATEGIES: OUTSIDE AIR REDUCTIONS

Goal: To use only the amount of outside air necessary to prevent the build-up of gases that can pose risks for collections and human health, and keep spaces properly pressurized to reduce the load at the AHU for energy savings and potential increase in preservation quality.

Advantages	Disadvantages
Significant potential energy savings	Potential for indoor air quality issues
Often simple mechanical control	Potential air balancing/pressurization issues
Potential for improvement in preservation quality	

Description of Potential

Outside air is often the single largest source of energy load that AHUs, especially those serving primarily collections zones, have to contend with. In hot, humid climates or seasons, the majority of a dehumidification load is brought in on outside air, and in cool, dry climates or seasons, outside air increases the need for heating and humidification. Due to the specific environmental needs for collections preservation – cool temperatures at moderate RHs, which translate to a range of dew point conditions rarely provided outdoors in many climates – mechanical systems are nearly always working to overcome outside air conditions in order to provide the appropriate preservation conditions. Filtration load also becomes an issue in most buildings, as a large portion of the particulate and/or gaseous filtration load comes directly from the outdoors.

Outside air is typically introduced to buildings through AHUs for two primary purposes – as a means of providing fresh air for indoor air quality, and as a source of make-up air to provide for volume lost. Design outside air quantities for mechanical systems are typically based on a standardized formula in which the modeled maximum potential occupancy in the zone plays a large role. Local and state codes also play a significant role as many assign certain minimum percentages of outside air intake that must be met.

Typically, the minimum outside air quantities used in AHU control are based on the design criteria. Once initially programmed, the quantities often remain unchanged. The energy industry's recent increased use of CO_2 sensors in AHU control has shown that many systems can see significantly reduced outside air quantities even in normally occupied zones due to patterns of non-peak occupancy. Essentially, the sensors read the CO_2 ppm in the zone (either in the space or at the return air) and will modulate the outside air intake based on set point conditions. As a key indicator of human occupancy, low CO_2 levels in a space often mean that little or no outside air is required; high CO_2 levels will command the outside air damper to open and allow more fresh air in.

CO_2 monitoring and control capability means that even occupied spaces may be able to use reduced volumes of outside air during occupied hours. For systems that do not currently have CO_2 sensors as a control feature, reduced outside air tests can still be performed during unoccupied hours for public and work areas, and may be tested during daytime hours for zones that are primarily or entirely dedicated to collections storage. Experimentation and control are made significantly easier if the outside air damper is able to modulate automatically. Tests can still be performed with manual dampers, but the process requires more of a "trial and error" approach.

Economizer controls are a common energy reduction feature that allow increased volumes of outside air into the building as "free cooling" and are often seen on systems that serve human-occupied spaces. Unfortunately, these are not typically beneficial to collections preservation environments. Most economizers are based solely on a sensible temperature control, which may allow increased air volume at an inappropriate moisture content to enter the building.

Some economizers are controlled based on enthalpy, or the total energy content of the air (both sensible and latent). While this method takes moisture and its energy into account, it does not look specifically at dew point, or whether the air volume is at the actual appropriate condition for preservation. The result is that, even with the correct enthalpy condition, the unit may still have to perform moisture control work in order to achieve the correct dew point for the space. Generally speaking, economizer controls do not often work well for collections storage spaces – the amount of time that outdoor weather conditions provide the correct combination of moisture content (dew point) and cool temperatures is simply too small. From an energy and preservation perspective, reducing the total outside air volume to the absolute minimum necessary is far more beneficial.

Most collections storage zones receive far more outside air than they actually require – the result is increased energy expenditure working on loads that were not generated inside the zone, but that were brought in directly from outdoors. Expending energy and the unit's total capacity on outside air can also result in less-than-optimal preservation conditions; if that energy were focused on removing additional energy load from the AHU zone, many systems may have the potential to maintain better preservation environments, especially during extreme weather conditions.

If the AHU zone in question is primarily or entirely dedicated to collections storage, there is little need for outside air beyond two possible factors:

1. Original system design and balancing requirements
    - Be wary of potential balancing issues if testing outside air reduction strategies. Airflow design for many systems is based on a minimum quantity of outside air – if the return air is not capable of bringing back the necessary volume of air, the zone could experience pressurization or airflow issues.
    - State and local codes for minimum air may still apply and will take precedence.
2. Turnover of air to exhaust any off-gassing from collection materials (which CO_2 monitors will not address)
    - A wide range of materials off-gas, including nitrate and acetate film, rubber and plastic objects, and certain minerals and biological materials found in natural history collections. Even the cellulose of paper and books emits gaseous products as it degrades. Past treatments – for example, pesticides applied to specimens – can introduce pollutants to the air. Additionally, both indoor and outdoor air pollutants can accumulate in indoor air spaces. Mechanical systems will not take these pollutants

into account in their operation, so analysis of the off-gassing levels in collection spaces and establishment of acceptable levels might be performed independently.

In summary, to address the concerns of outside air reduction, environmental management teams may want to work with an institutional Environmental Health and Safety Officer during the experimental design and test period to ensure that human needs are met and in compliance with state and local regulations. Careful testing should be performed so that collection spaces do not go negative in pressure as a result of not enough air, encouraging the infiltration of unconditioned air from surrounding spaces and outside, as well as particulates. Also consider the potential build-up of off-gassing, the products of which can often accelerate degradation of collections materials without special monitoring to ensure they remain within safe limits.

Candidate systems for outside air reduction testing may include:

- Systems with a large percentage of outside air for a zone with little or no air loss due to exhaust fans or fume hoods
- Systems where data analysis shows that the majority of the energy work performed is due to the outside air intake quantities
- Collections storage zones with minimal daytime occupancy and low rates of off-gassing
- Occupied zones in which normal occupancy is significantly less than their maximum occupancy
- Occupied zones that have patterns of little or no occupancy, such as nights or weekends

Potential energy savings from outside air reduction will vary based on the initial quantity of outside air used, the total reduction of outside air quantities, and the schedule during which the reduction occurs.

Requirements

- Automated control of the outside air damper is preferable
- Ability to schedule system operation and damper positions
- Identified zone served by the air handling unit to be tested
- CO_2 monitoring or control is preferable
- Data logging within the mechanical system (if quantified energy savings are desired)
- Data logging in the collection space (to monitor the preservation environment for any potential risk)

Critical Data Points

- Preservation
    - Space data from each space affected by the system that is tested
    - Identification and monitoring of potential microclimate areas that may fluctuate differently than the rest of the space
- Energy

- Data from each location in the system where a component can mechanically work on the air:
    - Return air
    - Mixed air
    - Pre-heated air
    - Cooled air
    - Heated/supply air
    - Fan amps
    - Downstream reheats
    - Others (as needed)

Pre-Testing

- Be certain that outside air dampers modulate properly based on control commands – occasionally damper modulation is programmed backwards, where the actuator opens the dampers even though the control is to close them.
- CO_2 monitoring or sampling is helpful to get a baseline of fresh air requirements in AHU zones, from a human occupancy perspective.

System Notes – Code Requirements

- Municipalities or states may have strict requirements for minimum outside air percentages for a space. If these quantities are excessive for the specific zone in question, CO_2 monitoring and control can sometimes satisfy the code, or the team may have to work with local code enforcement to discuss permission for testing.

System Notes – 100% Outside Air Systems

- Some AHU designs are based on 100% outside air intake – no return air is provided to the unit at all. In these cases, outside air reduction strategies need to be based on necessary total air volume requirements for the zone.

Selection Criteria/Variables That Impact Potential

- Outdoor Climate
    - Climates with extreme conditions – those that are significantly different from the indoor set point conditions – can have the greatest energy savings for outside air reduction.
- Building Envelope

    - The less exterior wall exposure in the collections space, the more likely that outside air is the majority of the energy load, especially for collections storage zones.

- Occupancy
    - Zones with consistent, high occupancy rates may not be appropriate for experimentation.
    - Zones with sporadic high occupancy rates – galleries, event areas – may benefit from CO_2 control to only allow outside air into the building when necessary.
    - Collections storage zones, or zones with little occupancy on a regular basis or daily pattern may be excellent candidates for experimentation.
- Collections off-gassing
    - Some collections materials off-gas. If this is an issue in a collections zone, outside air may need to remain at a higher percentage to remove pollutants for either human health or collections preservation concerns.

Outside Air Reduction Experimentation (Test) and Implementation

PREPARATION

- Complete documentation, data gathering, and analysis steps for the system/spaces being evaluated.
- Use the selection criteria above to review whether the system/space is a good candidate for outside air testing.
- Confirm that the system is capable of controlling outside air intake quantities. If control is manual, experimentation will require greater involvement and attention from the facilities staff.
- Confirm that appropriate data gathering capabilities are deployed and determine who will pull and check data, and how often. The frequency of data pulls and analysis is up to the institution and is based on staff scheduling and the level of risk management desired for a particular collection space. Common approaches include:
    - A daily walk-through of the space to be sure that normal daytime set points are being held
    - Weekly data pulls from loggers to inspect nighttime fluctuation
- Determine test parameters
    - Outside air reduction during unoccupied hours
        - Outside air intake quantities should be returned to normal operation at least one hour before the zone/building is occupied.
    - Outside air reduction in occupied zones
        - Tests should be conducted incrementally based on estimated regular occupancy versus designed maximum occupancy. Systems running at 20% outside air may be tested with 10-15% outside air (depending on code requirements) to see how the zone responds.

- CO_2 monitoring/control
    - For systems that have CO_2 monitoring, review the CO_2 ppm set point (the threshold where the sensor tells the system to allow more outside air in) and determine if it is appropriate based on trended CO_2 conditions.
    - Review control to see whether no call for outside air means that the outside air intake is closed, or simply set to a minimum percentage.
- Length of test
    - Typically an initial test should be allowed to run for two weeks. Interior environments can respond differently based on outdoor weather conditions and interior energy loads.

- Communicate the outside air reduction plan to collections and facilities staff responsible for managing the areas involved
  - Discuss the potential impact on human comfort in the space
    - Set up a communication structure during the test period for any environmental complaints concerns
  - Finalize a start and end date for the test period and make sure that this fits with departmental needs

ON TEST START DATE

- Facilities staff should physically confirm that the outside air damper modulates or is closed appropriately during the first test period
- Facilities staff should notify team members and building facilities staff that the testing has begun
- Collections staff should notify other staff members that testing has begun
- Facilities staff should physically confirm that the outside air dampers open automatically, or are manually opened, at the scheduled time

DURING THE TEST PERIOD

- Collections staff should conduct daily walk-throughs of tested space and check space dataloggers for deviation from set point range
- Follow schedule for data retrieval from space and mechanical systems
- Facilities staff should conduct regular checks of BMS for alterations in system operation
- First data retrieval as per test schedule
  - Look for any evidence of environmental issues in both the space and mechanical system dataloggers
    - Reduction in energy load from outside air may result in different patterns within the

mechanical data, including lower dew points during dehumidification seasons or higher dew points during humidification seasons.

        - Review data to ensure that the system and space are adjusting to to the different energy loads appropriately.

    - Initial evaluation of outside air reduction tests

- If the results of the initial test are acceptable, continue the outside air reduction test protocol until the end date

AT THE END OF THE TEST PERIOD

- Conduct a final walk-through of systems and spaces
- Retrieve and upload data from space and mechanical system dataloggers
- Conduct final analysis of the test data as a team
- Meet with collections and facilities staff that manage the area to discuss any observations on their part during the test period and communicate the results of the final data analysis to them
- If no issues due to outside air reduction have been recorded or reported, allow the procedure to continue through to the implementation phase
- Results of analysis will determine the next step:
    - If test results showed challenges with maintaining space set points due to airflow issues, or if there were any human health or comfort issues, consider altering the test in some manner (smaller reduction quantities, shorter test periods during unoccupied hours) to achieve more acceptable results, or discontinue the strategy.
- If testing of all strategies for that AHU is complete, remove mechanical system dataloggers and reset them to be used in experimentation for other systems
- Compile, quantify, and report test results to appropriate administrative staff

Once a team has determined an outside air reduction procedure should be adopted, and settled on a schedule based on zone occupancy, the process enters the implementation/maintenance phase. At this point, the team should be satisfied that they have tested the potential variants of operations and schedules, and have chosen the best operation for the needs of both preservation and energy savings.

Implementation/Maintenance

- Add the outside air intake quantities and schedules, and the CO_2 control parameters, if any, to the normal sequence of operations for the AHU, both in programming and in any written documentation
- Repeat the test procedure seasonally or as necessary
- Collections staff should continue pulling and reviewing space data once a month. Any variation from

documented expected space conditions should be watched and reviewed with the team

- Review and analyze space data (via dataloggers) and mechanical system operation (via BMS) every 4 to 6 months to ensure that the outside air reduction strategy is in place, and is using appropriate quantities at the specified times
- If the operation deviates from the intended sequence of control, use the system and space documentation and compare those to the current operation and environmental behavior to try and diagnose the problem
    - Revert to original design outside air quantities until the problem is resolved
- Repeat testing procedure as necessary to determine the appropriate operation

Evaluating Test Results:

MECHANICAL SYSTEM DATA

- Mixed air conditions should more closely match return air conditions after outside air use has been reduced.
- Cooling coils or desiccant units should see reduced work during dehumidification seasons
- Heating coils and humidifiers should see less work during cool or dry seasons

COLLECTIONS SPACE DATA

- Spaces still operate at positive or neutral pressure. This can be tested by holding a lightweight object such as tissue paper up to a door; open the door slightly, and ensure the paper does not blow towards the collection space.
- Monitoring levels of off-gassing can be difficult. Coupons and A-D Strips may be useful to gauge approximate levels. Spot measurements can also be performed for likely pollutants using instruments for air sampling.