ENERGY-SAVING STRATEGIES: SYSTEM SHUTDOWNS

Goal: To use risk-managed mechanical system shutdowns to achieve significant energy savings while minimizing the impact on the preservation environment.

Advantages	Disadvantages
Best possible energy savings	Potential for significant fluctuation in poorly insulated buildings
Often simple mechanical control	Potential for mechanical failure
Can have minimal impact on environmental conditions	Potential difficulty recovering to set point the next day

Description of Potential

Mechanical system shutdowns have been used for decades as a key strategy in energy-reduction initiatives in public and commercial buildings. Turning mechanical systems off during unoccupied hours (typically nighttime) takes advantage of the lack of need to condition for human comfort as well as the reality that the best potential energy savings on mechanical operation comes from not running the equipment at all.

This strategy has particularly strong potential in collection storage areas, where human occupancy is less of a concern. The potential viability of system shutdowns can be gauged by how well the system zone or physical space can hold its appropriate conditions without mechanical intervention. In well-insulated storage facilities, shutdowns may even be appropriate for periods during daytime hours, when summer heat loads are at their greatest. For institutions who pay peak rate charges on energy during those hours, daytime shutdowns may be a significant opportunity.

In the simplest definition, a system "shutdown" means turning off power to the fan units that circulate air through the AHU and the zone/spaces. Ideally, the various components that impact air conditions within the unit will also close or open appropriately. Outside air dampers should typically close in order to prevent unconditioned air from entering the building, a pre-heat coil may activate in cold seasons/climates (but not in warm seasons) to protect against frozen heating or cooling coils, primary heating or cooling coils may valve closed to avoid unnecessary circulation of steam/water, and other electrical components – heating coils, electrical filters, etc. – will also power down to save energy. All of this depends on the particular design and arrangement of your mechanical system. By using dataloggers or BMS data from an AHU, it is possible to examine data during a shutdown period and determine what components may remain running or open.

Potential energy savings from AHU shutdowns are often a factor of the percentage of a 24-hour period that a unit is turned off. If an institution is able to conduct an 8-hour nightly shutdown, then yearly savings of 33% may be possible; even a 3-hour shutdown can see 12% savings. A number of factors can influence actual realized savings, including time, peak rate charges, and type of equipment being used (constant volume vs. variable speed fans, direct expansion cooling vs. chilled water, etc.), and may reduce that total savings percentage. The energy impact of shutdowns in collections areas is often best quantified or compared as a percentage of energy used on the "air-side" (the air handler and the associated building zone) of the system. Impact on the "water-side" (boilers, chillers, etc.) is often minimal, especially when specific AHU(s) are a small customer on the overall building, district, or central plant steam, hot water, or chilled water system.

Although improvements in the preservation quality of the environment are theoretically possible during certain outdoor conditions (primarily cooler, drier weather), in practice they are rarely achieved due to the relatively short duration of most operational shutdown periods in occupied spaces.

Requirements

- Automated control of mechanical system is preferable
- Ability to schedule system operation
- Identified zones served by the AHU to be shut down
- Data logging within the mechanical system (if quantified energy savings are desired)
- Data logging in the collection space (to monitor the storage environment for any potential risk)

Critical Data Points

- Preservation
    - Space data from each space affected by the system that is shut down
    - Identification and monitoring of potential microclimate areas that may fluctuate differently than the rest of the space (especially near doors, windows, or anywhere that outside air may infiltrate)
- 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 fail closed upon shutdown
- Be wary of coils that may fail open, especially heating coils – while this control is fine, make sure that the heat cannot transfer downstream (i.e., via an open outside air damper)

System Notes – DX Cooling Systems

- There is a tendency to save less energy than with chilled water coil systems – the DX compressor and coil may run at increased rates on the day following a shutdown in order to catch up with any loss in space conditions, decreasing the total energy saved from the night before.

System Notes – Desiccant Dehumidification Systems

- In certain situations, the exhaust air from the regeneration side of a desiccant system can condense during a system shutdown. Factors that can cause this include:
    - If the desiccant system sits in a conditioned space with a temperature lower than the exhaust air dew point
    - If the exhaust air ductwork on the building interior is not insulated

In these situations it is possible for the condensed moisture on the interior of the ductwork to run back to the desiccant chamber and damage either the wheel or the wheel motor.

Selection Criteria/Variables That Impact Potential

- Outdoor Climate
    - Shutdowns can be more difficult in hot/humid seasons and climates. Locations with outdoor temperatures that remain warmer than interior set points may need to initially test with shorter shutdown periods to mitigate risk.
- Building Envelope
    - The less exterior wall exposure in the collections space, the less likely it is that the space will see large fluctuations
    - The better the thermal and vapor barrier a building has, the less fluctuation will occur
    - Sub-grade spaces are often prime candidates for system shutdowns
- Occupancy
    - The best initial test period is during unoccupied hours
    - In an unoccupied storage area, the shutdown can take place at any time of day
    - If unoccupied hours are limited, aim to shut down no more than 1-2 hours before closing, and turn back on at least 1 hour before opening

    - Be careful of mixed-use zones – unoccupied storage is a plus, but a shared workspace may still need airflow
- Storage Density
    - Higher-density storage (library stacks, high-density storage modules) tends to fluctuate less than large air-volume spaces (such as galleries)
- Space Load
    - Using the method for calculating space loads described in the data analysis section, inspect your baseline data for the supply, return, and space air conditions. The smaller the load in the space, the more likely that a shutdown will be successful in terms of seeing minimal fluctuation. The greater the load, the more fluctuation will likely occur.

Shutdown Experimentation (Test) and Implementation

PREPARATION

- Complete documentation, data gathering, and analysis steps for the system/spaces being calculated.
- Use the selection criteria above to review whether the system/space is a good candidate for shutdown testing.
- Confirm that the system is capable of conducting programmed shutdowns.
- 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 all dataloggers (space and mechanical system locations) to inspect nighttime fluctuation
- Determine test parameters:
    - Night shutdown time
        - In hot/humid climates begin testing with 2-4 hours nightly shutdowns.
        - In temperate climates and seasons begin testing with 6-8 hours nightly. Daytime "peak" shutdowns can be tested in well-insulated buildings, but should be limited to 2-4 hours for initial testing.
        - In cool/cold climates and seasons begin testing with 8 hours nightly. If successful, consider extending the shutdown time to the full length of unoccupied hours.
    - Unoccupied shutdowns
        - Some institutions may want to test shutdowns during the entire time the building or space

is unoccupied, which may include weekends or other multiple day periods. In these situations, it is important to look at the total fluctuation in the space during the entire shutdown period, and the length of time and energy it takes for the system to recover to its original set point.

    - In some cases, systems may not recover to their set point during the "on" period, resulting in cumulative changes (steadily rising temperatures) in space conditions over a long period.

- Length of shutdown test:
    - Typically an initial test should be allowed to run for two weeks. Environments can respond differently based on outdoor weather conditions and two weeks is a reasonable compromise between gathering a representative sample set for a season and limiting any long-term risk.
    - If drastic or concerning fluctuations are experienced during the two week test period, the period of the shutdown should be reduced or the testing halted altogether.
    - Fully optimizing a shutdown will include initial seasonal tests in the extreme seasons to determine any variability in appropriate shutdown capability and lengths.
- Communicate the shutdown plan to collections and facilities staff responsible for managing the areas involved:
    - Discuss the potential impact on human comfort in the space.
    - If the shutdown will occur during work/occupied hours address the possibility of "still air".
    - Discuss how to schedule the restart to best recover to set point before the space is occupied.
    - Propose a start and end date for the test period and make sure that they fit with departmental needs.
    - Set up a communication structure during the test period for any environmental complaints or work-orders associated with the AHU being shut down.
- Finalize a start and end date for the test period

ON TEST START DATE

- Facilities staff should physically confirm that the system actually shuts down during the first shutdown 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 system starts back up at the scheduled time

DURING THE TEST PERIOD

- Collections staff should conduct daily walk-throughs of test 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 evidence of shutdowns in data from both the space and mechanical system dataloggers
    - If shutdowns are not occurring according to the planned schedule, work with facilities staff and/or controls technicians to find and resolve the problem
- Evaluate results of test shutdowns
- If the results of the initial test are acceptable, continue the shutdown 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 deviations from normal "on" set point conditions have been recorded, allow the shutdown procedure to continue through to the implementation phase
- Results of analysis will determine the next step:
    - If fluctuation in the space was minimal, consider testing with expanded shutdowns, either in duration or during different parts of the day
    - If test results were not favorable, consider altering the test in some manner (reducing length of shutdown, changing the time of day) to achieve more acceptable results
- 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 a shutdown procedure should be adopted, and settled on a schedule, 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 final shutdown schedule and operation to the normal sequence of operations for the AHU, both in programming and in any written documentation.
- If using a BMS for system control, note the appropriate operation of the unit while using the shutdown strategy – including confirmation of schedule, valve/damper positions when the unit is off, and any other factors that will help identify whether or not the AHU is functioning as it should for a shutdown.
- Repeat the test procedure seasonally if outdoor climate conditions vary widely (i.e., initial testing in summer may only yield a six-hour shutdown as appropriate, while a winter season may allow for a ten-hour shutdown).
- Collections staff should continue pulling and reviewing space data once a month. Any variation from documented 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 shutdown protocol remains in place, is of the appropriate length for the season, and that the space response to the shutdown is still appropriate for preservation.
    - 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
    - Discontinue shutdowns until the problem is resolved
    - Repeat testing procedure as necessary to determine the appropriate operation

Evaluating Test Results

SPACE DATA

- **Temperature** – Look for day/night curves that match the shutdown schedule. Often spaces may fluctuate as little as 0.5°F and up to 4 or 5°F over an 8-hour period.
    - Shutdowns are considered successful if:
        - The fluctuations in temperature are not greater than those seen during normal operations,
        - do not result in relative humidity changes that exceed the safe range for collections,
        - do not rise significantly; and
        - there is no cumulative temperature gain after successive shutdowns.
    - Research shows that temperature equilibration in materials is fairly rapid, with full equilibration to a one-time change occurring within a matter of hours. Keep in mind that with shutdowns, the temperature changes gradually over the shutdown time period and therefore the full amount of change may only be felt for a small portion of the shutdown.

- **Relative Humidity** – Unless a serious moisture incursion significantly raises the dew point, the relative humidity typically does one of two things during a space shutdown – the RH either moves slightly in conjunction with temperature changes, or it remains steady as a result of the collection releasing or taking on moisture due to the ambient temperature change.
    - Research conducted by IPI has shown that the moisture equilibration rates (for full equilibration at the core of an object) for many hygroscopic materials found in libraries and archives are relatively slow, and may take weeks for materials to fully equilibrate to a one-time RH change in the ambient environment. Material surfaces will equilibrate faster and significant RH changes (again, typically due to dew point fluctuation) may cause mechanical change to sensitive media.

- **Dew Point** – Any fluctuations in dew point as a result of the shutdown typically indicate a moisture incursion in the space that is independent of any moisture brought in through outside air intake (assuming that the outside air intake successfully closed during the shutdown). If more than a 1-2°F variation in dew point is observed as part of shutdown testing, team members should inspect the space and building envelope for sources of moisture or outside moisture intrusion.

MECHANICAL SYSTEM DATA

- **Supply Air** – Use the datalogger in the supply air to provide the clearest "air" illustration for confirmation of the shutdown. During operation the system provides conditioned air to spaces downstream, while during the shutdown, the environment recorded inside the supply air duct often reverts to match the ambient condition of the space around it, whether it is the mechanical room or a supply diffuser in the space.
- **Fan Amps** – If an electrical datalogger is used on the power supply to the supply fan motor, the resulting amp usage graphs can also be used to confirm on/off times of the mechanical system, as well as to calculate the energy saved by shutting down the supply fan.

REMINDERS FOR MAXIMIZING EFFECTIVENESS

- In unoccupied spaces/zones, test shutdowns during daytime "peak" hours to reduce the peak load on the energy budget
- In cool/cold climates and seasons, explore expanding shutdowns beyond normal "unoccupied" hours, especially if the space is typically unoccupied

Shutdown Log Sheet for Zone/AHU#

[Organization Name]

Collection Staff:
Facilities Staff:

Is System Capable of Being Shut Down
YES NO
Shutdowns: Auto Manual

Pre Test:
Outside Air Damper Fail: Open Closed
Heating Coil Fail: Open Closed
Cooling Coil Fail: Open Closed
Logger Placement: Mech System Collection Space
Fan Amp Logger: Yes No

Mechanical System Logger Locations:
Outside Air/Preheated Air
Heated Air Supply Air
Cooled Air Downstream Reheat
Return Air Other__________
Mixed Air

2 Week Test

Date	System Stop	System Start	Duration	Recovery Time	Other Changes Made to the System	Notes

Daily Walk-through Log: Check if System and Space are Following Shutdown Schedule

Mon	Tues	Wed	Thurs	Fri	Sat/Sun

Daily Log: Upon Startup Verify That the Space and System Return to Normal Operation

Mon	Tues	Wed	Thurs	Fri	Sat/Sun

Daily Check of the BMS System:

Mon	Tues	Wed	Thurs	Fri	Sat/Sun

Weekly Data Pull

Post Tests:

Did System Shut Down Correctly: Yes No

Did System Start Back Up Properly: Yes No

Did Space Temperature Return to Normal: Yes No

Average Space Temperature Fluctuation: _______

NOTES: