METHODOLOGY:
EXPERIMENTATION & IMPLEMENTATION

The selection of which optimization strategies to test and experiment with requires input from every member of the environmental management team. The strategies are not a one-size-fits-all technique. The ability to successfully perform a strategy will vary from one facility to another. While some institutions can utilize all of the strategies, other institutions may only be able to employ one or two. The team should select strategies that will work for their institution.

The environmental management team can customize the selected strategies for their institution as well, and set their own limits for tests, be it using longer or shorter periods of shutdowns, different fan speeds, or different set point conditions. Institutions should test the combination of strategies that seem to work best for them, and adjust to match collections and building needs.

An experimentation phase of approximately two weeks for each individual adjustment is recommended for most of the strategies; this allows the team to record and measure the impact of the change over a period of time that will hopefully include a variety of weather conditions during the season in question. Certain operational adjustments, such as shutdowns and set point changes, may require several days of experimentation before potential impacts to the storage environment can be seen. Shutdowns may cause cumulative temperature gains in spaces, and a system may work for several days to achieve a set point change before the team realizes that it does not have the capacity to do so. During the assessment phase, the team can review the AHU's performance during the test, and decide whether to repeat the experiment with different parameters. The final results of the test will determine which strategies are implemented and which are abandoned.

The strategies provided in the *Energy-Saving Strategies* section of this methodology are suggestions of common tests and improvements that may work for institutions. Individual organizations may find that specific corrections in sub-optimal operation are necessary, but are not covered in this guide. We encourage you to use the included strategies, evaluation considerations, and testing processes as a template for your own work.

There is no order in which the strategies should be tested. Your team should work together to determine which strategies your equipment and facilities are capable of. After you determine this you should work as a team to decide which strategy to test first. The order of what is tested is completely up to the team.

Evaluation

The final decisions on which strategies to employ will largely be based on the results of the data analysis and the team's review of different strategies. Each potential strategy should be evaluated to determine the appropriateness for the institutional need, chances for success, possible outcomes or issues, and feasibility of implementation. This will help determine which strategies make the most sense to attempt, and in what order of priority they should be tested.

To begin the selection every member of the environmental management team should review the data analysis, focusing on shortcomings in preservation or excessive energy consumption, and consider how different strategies could impact these issues. Team members should comment on the strategies specifically citing any possible concerns they may have or issues they may perceive. Those concerns should then be discussed within the team.

At this stage, the environmental management team should also consider equipment or control limitations, and whether these may eliminate certain strategies.

When analyzing data, the environmental management team may find that there are some optimization strategies already in place; if this occurs, the team should evaluate whether the existing operation is the best possible, or whether additional experimentation may be beneficial. A common example is when facilities are currently employing nightly shutdowns – data analysis should reveal whether the existing shutdown protocol is putting the collections at risk or whether it may be possible to employ longer shutdowns than currently used.

Remember, strategies should not be tested or adopted if they place the collection at risk.

Identifying Potential Risks

Every strategy poses potential risks either to the collection, facility, or the air handling system. In many cases these risks are minor and with some foresight can be avoided or mitigated. It is important to identify and recognize the potential risks of the selected strategies. With careful planning and attention, the team may be able to eliminate risks entirely or at least establish a response plan of action in the event they occur.

Begin by determining the severity of the potential risks, and categorizing them as major, minor, or inconsequential risk. If the consensus is that a risk situation is too great, the test may need to be abandoned or postponed until maintenance or repairs can be performed. For minor risks, establishing a plan of action should a problem occur may be enough to allow the team to continue. The key is to attempt to predict what might go wrong, and be prepared to address and resolve the situation as quickly and orderly as possible. Some teams may choose to put these plans in writing; others may be comfortable with an unwritten team understanding. In either case, the plan of action should be discussed and acknowledged among the entire environmental management team and any additional staff that may need to be involved.

In the event of a critical unseen issue occurring, work to revert to the original operation or control, cease any active experimentation or testing completely, and refrain from further testing until the cause is identified and the issue is resolved.

Know What Areas Are Impacted

It is important to have a holistic view of the entire collection and facility when considering which strategies to experiment with. The team's suggested changes or adjustments are intended to optimize the collection environment, but they may also impact other areas of the facility unexpectedly, whether an office on the same zone or an adjacent exhibition space on a different AHU zone.

Completing the documentation process will provide this insight into much of the facility. By using the documentation to know how your building is connected and how the systems operate, the team can determine what zones or areas of the facility will be directly impacted by an experiment, and what additional spaces or rooms could be affected.

Know the Collection

Before any experimentation is conducted, collections staff should be sure to review among the team any particular environmental concerns or risks for the materials housed in the testing zone, and testing parameters should be defined accordingly. IPI's Dew Point Calculator (www.dpcalc.org) can help plan environmental changes for experimentation by showing the potential preservation impact of altered conditions. Remember to always check dew point conditions – cooler temperatures may be achievable, but without adequate dehumidification, they may cause RH conditions to rise and place certain materials at increased risk for degradation.

Risks to the Collection

There is a common tendency to think about risks as specifically environmental issues – spikes in or loss of control of temperature or relative humidity. However, other physical risks exist that are primarily a function of making an improvement or conducting an experiment. The environmental management team should work to consider the broad range of potential risk during any experimentation or implementation of optimization strategies.

Lighting upgrades is one example. If your facility is working on the replacement of fluorescent lights with LEDs, consider:

- To change the bulbs, the maintenance staff will need to access the collections space. This may involve collections staff having to move collection materials to access lights and having maintenance staff working in the space for extended periods. Be sure to plan accordingly for access and security, and to give proper notice to collection managers in the area in case there are special handling or protection considerations.
- The change from the older style light bulbs (fluorescent, halogen, incandescent), to LEDs may have a potential impact of the temperature in a space depending on the number of fixtures adjusted, style of bulbs, and typical operation. Watch environmental data carefully – depending on how the system is controlled, spaces may become cooler quickly due to the reduction in energy load.

In some cases, risks may not be as significant as initially perceived. Shutting the air handling system down for periods of time (ranging from a matter of hours to unoccupied weekends) will likely lead to some degree of fluctuation in temperature and relative humidity in the space. If managed properly, these fluctuations should be small and only last as long as the shutdown period. Sometimes, however, greater fluctuation may be seen in hot weather or with experimental complications (such as an outside air duct remaining open rather than closing during the shutdown schedule).

The impact of fluctuation on individual objects will vary based on their housing and the amount of surface area exposed. Individual photographs or pieces of paper will equilibrate to environmental changes more quickly than bound volumes or boxed archival collections. Before responding to or correcting for brief environmental changes, consider how long the collection was exposed to the most extreme condition, and whether the material will have felt the full effect of the change. Before abandoning optimization testing, consider whether the risk could be mitigated with different housing or physical control for unprotected materials.

Risks to the Facility

Whenever adjustments are being made to the environment inside a building, it is also important to assess the risks that may be posed to the facility overall. Just as with collection risks, the likelihood for some of these incidents to occur is small, but thinking about them ahead of time and preparing and planning for them can have a major impact in limiting the effects. Every facility is different; it is nearly impossible to predict what to expect with each strategy in every space. However, it is important for the team to consider impacts to staff comfort in addition to the impacts on collections.

One common issue that can occur during the testing of overnight shutdowns – depending on when the system is restarted – is spaces may not return to normal temperature conditions before staff arrive. Conditions that are warmer or cooler than normal may lead to comfort complaints and poor reactions to the testing protocol. Not only is it critical to ensure that all staff are informed of the testing protocol, but another consideration may be making sure that the system will start back up early enough in the morning to recover whatever temperature change occurred. If part of the experimentation is altered set points, be sure to review the purpose of the test with the staff and encourage them to dress accordingly for the new set point conditions.

If the facility is employing fan speed reductions, staff may notice slower air velocity or comment on the "still" air. As with the above example, it is important to inform staff of the purpose of testing and make sure that they understand that the adjustments do not affect the quality of the air.

In both examples, encourage staff to serve as an initial response mechanism, notifying the team if a space has not recovered its set point by mid-morning, or if there is no air coming from a diffuser. Simple tools such as a bit of tissue or lightweight paper taped to a supply air diffuser can help both the team and the staff watch for changes in supply air delivery.

Stakeholders

Once you have identified the area or zone that the experiments will focus on, the team should identify the key stakeholders, if any, for those locations. These may be collections or facilities staff, or other individuals in some way responsible for the collection, zone, AHU, or building in question. In some cases they may already be part of the environmental management team, and will need to inform their own staff of the experimentation process.

It is critical, as much as is possible, to have staff be your allies in the optimization process. This may necessitate a larger group meeting or presentation to explain the process to the larger staff, ask for their assistance in keeping an eye on conditions during the tests, and work with them to find appropriate solutions to any problems that changing environmental conditions may cause, whether comfort related or otherwise. Hopefully, informing the staff and seeking their assistance will help eliminate potential environmental complaints. Another helpful step is to identify a point person to contact – this may be the environmental management team leader, or another staff member – if there are any issues with comfort as a result of the experimentation. Likewise, it is important to keep any technicians who may service the system informed as well – these individuals may not be based in the collections building or zone, but may be housed in other departments across the institution. Again, it is helpful to establish a clear line of communication to ensure that environmental complaints are not immediately acted on, ruining the experiment, without communication with the environmental management team. Certain tests or experiments could cause alarms in a BMS that alert technicians to automatically work to correct, so work to ensure that appropriate staff across the organization are aware of the testing process.

Know Your Equipment

Once inefficiencies or sub-optimal operation have been identified through data analysis, revisit the documentation (building drawings, zone maps, etc.) to confirm which AHU the team is working with. Most optimization strategies pertain in some way to the AHU; it is critical to know as much as possible about its capacity and operation before considering experimentation. The question to consider when evaluating any potential optimization strategy is what the AHU is capable of and whether you have the appropriate equipment and control to conduct the experiment. For example, shutdowns will be difficult to test without a BMS that automatically controls the operating schedule, and fan slowdowns and air-volume adjustments are difficult to perform without a Variable Frequency Drive (VFD).

Risks to the Mechanical Equipment

Whenever adjustments are being made to the air handling equipment there is a risk of potential malfunction or loss of control, some of which can be prepared for, and some of which may just be normal mechanical failure. Considering potential issues ahead of time – have there been control issues in the past, or is a particular piece of equipment near failure already – can help determine whether an experiment should be conducted or if there is a way to minimize any potential issues.

Again, every facility and system is different; it is nearly impossible to predict every potential issue that may arise from individual tests and experiments. Problems may range from control issues of incorrect programming, complete shutdowns or lockouts, or mechanical or control failure of individual components. All these issues that are common enough in normal practice, but that may be exacerbated by purposeful testing.

As mentioned above, the key is clear communication with collections and facilities staff who normally work in the spaces or with the unit. If staff are aware of an experimental shutdown schedule and realize that no air is moving, or the system is still shut off outside of the proposed test schedule, they may be able to catch an issue that may not otherwise show up until the team pulls data a week later. Control issues may be fairly easy to correct, whereas equipment problems may require repair or replacement and necessitate the postponement of the test. Make sure that as experiments are begun, members of the environmental management team or other staff are observing the space and the system to catch any problems as quickly as possible.

The BMS is often another ally in risk management for a system and equipment. Appropriate alarms for unscheduled shutdowns, inappropriate pressure readings or temperature conditions outside of the reasonable set point range can all alert staff and the team to issues that may not be caught downstream until the data pull. Again, be sure that controls staff and contractors are clear on the experimental protocols – which may include providing a written description of what the test is, and what it hopes to accomplish – so that they understand what operational variation is expected and what may indicate a problem. Another potential risk for the system may not occur at the unit at all, but at the BMS system.

It is critical to note that experimentation does not automatically put the AHU or the building at risk – many institutions will never experience issues beyond normal repair, equipment replacement, or preventive maintenance. If the capability is there to slow down the fan speed, modulate a damper, conduct a soft start or stop on a motor, or adjust a valve or water flow, do not be afraid to use it. These are all moving parts that are meant to be controlled – just because they have been performing the same operation without any alteration for years does not mean that they are not capable of safe adjustment. Numerous shutdown tests and schedules have been implemented by IPI and other institutions with no additional equipment attrition (belts, bearings, motors) beyond normal issues or replacement schedules. More often, data analysis and experimentation tend to reveal which components are already malfunctioning, have lost some of their capacity or capability, or may be due for replacement.

Potential Gains

Many of the gains or improvements that can be made by employing optimization strategies can be estimated beforehand through preservation and operational data analysis. The best strategies will yield an improvement in the preservation environment while also providing significant energy savings. Reducing set point temperatures during cool seasons employs passive strategies utilizing cool temperatures on the exterior or surrounding environment to reduce energy consumption while providing a better preservation environment. The cooler temperatures, especially when accompanied by low exterior dew points, can help improve the preservation environment while the reduced heating operation saves energy. If the space would normally be humidifying during the same season, dropping temperature can also help keep the RH higher, reducing energy consumption at the humidifier. Changing lights in a collection space may not only save energy but, depending on the bulbs being replaced, will expose the collection to less UV light, reducing the risk of light damage to exposed materials in the environment.

By utilizing the degrees of work method described in the data analysis section, the environmental management team can also estimate which optimization experiments may be the most beneficial to energy savings. The key is to not become so focused on trying to save energy that strategies that may achieve the larger goal – an optimal preservation environment – are set aside.

When evaluating the potential of various opportunities or strategies, be sure to consider the relative merits of each approach. Lighting upgrades may seem like an obvious option for sustainable operation, but that upgrade takes an initial investment, and the savings and preservation benefit may be relatively small (although it will grow over time) depending on the time of operation and the amount of collection that is exposed. Compare that to a reduction in air volume (fan speed adjustment). If the appropriate equipment – a VFD – is already in place, then the investment in experimentation is very small, simply the labor of making a straightforward control change. If the experiment is successful (safe for the collection and achieves the goal), the benefit may be immediate and at minimal to no initial investment.

These two strategies are both excellent ways to save energy but they only provide small gains to preservation. Other options, such as shutdowns in cool environments or seasons, may yield significant energy savings while also improving the preservation environment, either to a small extent as temperature drops during the shutdown period, or to a larger extent if the shutdown is combined with a cooler temperature set point than initially held.

The environmental management team should be pursuing experimentation that achieves the best combination of:

- Addressing preservation risks identified in the data analysis phase;
- improving on sub-optimal or inefficient operation; and
- feasibility with the existing mechanical system.

Design Experiment

When testing any of the strategies included in this methodology it is important to follow the guidelines. Most of the strategies included follow a similar testing and execution plan. If data analysis shows opportunities for improved operation that are not covered here, use the included strategies as templates for process and design. Below are a few additional guidelines for how to approach your own experiment:

1. Have your data software established. If you are using an eCNB account, be sure that the account is activated, set up, and that you have some experience using it. To perform proper data analysis, it is important to have the appropriate software and the ability to use it with the team.

2. Install enough dataloggers to monitor the experiment in both the space and the system.

    a. During an experiment, data from the dataloggers should be pulled at least once a week. The management team should meet to analyze the data to assess and evaluate the test.

3. Have a response plan for any major issues that might arise.

4. For strategies that require implementing an operation schedule, be sure that the schedule has been agreed upon by all members of the environmental management team and has been communicated to appropriate collections and facilities staff.
5. For strategies that employ any set point changes to the temperature or RH within a space be sure to review the proposed conditions with the Dew Point Calculator website. This is the best way to compare the temperature, RH, and dew point for the space with the potential value or risk to the collection that these set point changes may pose.
6. A testing period should be a minimum of two weeks. If the experiment shows successful results after the initial test, the team can consider whether to adopt it as part of a long-term operational strategy.
    a. Due to seasonal effects on the environment, strategies like shutdowns and setbacks should have separate winter and summer tests performed to establish the desired operation for those seasons.
7. Within your environmental management team identify the point people for the experiment.
    a. Who will any complaints, issues, or emergencies be directed to?
    b. Who will perform the data pulls?
    c. Who will check on the equipment and controls?
    d. Who will inspect the spaces?
    e. Who will be responsible for documenting the experimental process and data?
8. Properly inform all who may be affected by the experiment – what the test is, why it is being performed, what they may expect, and if they have any issues, who to contact.
9. The first day or night of the test assign an individual to verify that the experiment actually started (and/or stopped if on a schedule).
10. Walk the spaces daily during and after the test to ensure there are no issues.
11. Check the controls, and ideally the equipment, daily during the test to ensure everything is working properly.
12. Pull and analyze data weekly during the testing period.
13. At the end of the test, inform all parties that the test has concluded.
14. Update the BMS to new settings or return to the former programming.
15. If no further data gathering or experimentation is required, remove all dataloggers from the mechanical system.

Strategies deemed successful after experimentation and assessment may be worth exploring in other parts of the building, with similar systems, or elsewhere in the facility or campus.