

Ongoing Commissioning (OCx) with BAS and Data Loggers

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Synopsis

Bryan Welsh's presentation will discuss how a Building Automation System (BAS) can be configured as a tool to automatically perform a series of functional tests on the building HVAC system. These functional tests will allow the building operator to quickly identify typical abnormalities that affect system performance. Data loggers can also be useful additions to the building operator's tool box. Welsh will explore the pros and cons of data loggers and how they can help commission the DDC system. Success strategies will be discussed along with lessons learned. The presentation will also discuss using alarms, trending and the automated tools together to create a simple but effective OCx strategy.

There are a range of Fault Detection and Diagnostic (FDD) systems available. These systems are typically add-ons to the BAS or stand-alone systems. FDDs are generally fairly sophisticated, including statistical analysis and regression, making them of limited use to the average operator. Further, new construction typically does not include them as part of the work scope. By using the native BAS system and defining special sequences of operations and graphical interfaces, a relatively inexpensive and user friendly system can be developed. This presentation will examine an actual example of how this concept was applied to a building that was commissioned by Welsh.

The presentation will be based on the presenter's extensive practical experience in facilities related work, building commissioning, working with O&M staff and various pilot projects to automate functional testing. The audience should leave the presentation with a general understanding of OCx, the elements of an integrated OCx plan, how various BAS tools fit into the OCx plan and key concepts/lessons learned for setting up the various BAS tools within the OCx plan.

About the Author

Bryan Welsh has a mechanical engineering degree from Washington State University and is a licensed professional mechanical engineer in the States of Washington and Idaho. He has an MBA from the University of Washington. He is a member of the U.S. Green Building Council and is a LEED Accredited Professional. He is a member of the Building Commissioning Association and is a BCA Certified Commissioning Professional. He is also an AABC Commissioning Group Certified Commissioning Authority.

Bryan has over 25 years experience in facilities management, project management and utility management. For the first six years of his professional career, Bryan worked as a Mechanical

Engineer for Chevron Oil Company, then Boeing Aerospace. In these roles he acquired extensive experience with sophisticated maintenance management programs, computerized data acquisition & controls and test procedure development. He then served 10 years as Project Engineer and Director of Maintenance and Operations for the South Kitsap and Auburn School Districts.

Bryan has extensive experience in the fields of computerized building management systems, utility/energy management systems, maintenance management systems, test procedure development, and facilities operations. He has been involved with building commissioning since 1989 and a full time commissioning provider since 1999.

Bryan has presented on commissioning to a variety of audiences including ASHRAE, CSI, CEFPI, the 2000 National Workshop on State Building Energy Codes and the 2001, 2002, 2003, 2004 and 2006 National Conference on Building Commissioning. He is the chairperson for the BCA Certification Committee and now leads the Building Commissioning Certification Board responsible for review and approval of BCA Certified Commissioning Professionals.

The Case for Ongoing Commissioning (OCx)

When a building is properly designed, constructed, commissioned and turned over to the owner, it is theoretically operating at its peak efficiency. To use an automobile analogy, it gets good gas mileage. As with any system, with normal use the efficiency of the building goes down. The gas mileage drops. As a tune-up will improve the gas mileage in the automobile, so will retro-commissioning bring the building back up to near peak operating efficiency. But during the time between tune-ups, there is lost opportunity in the increased operating cost of the system. OCx is a process that helps ensure that the systems are monitored to optimize the point at which the systems are tuned up, keeping the systems operating at near peak efficiency and avoiding hidden energy consumption.

True sustainability cannot be achieved without maintainability. There are a variety of types of maintenance listed here in relative order of sophistication from low to high: reactive, preventive, proactive and predictive. Reactive maintenance is simply responding to issues as they are reported. Preventive maintenance includes such things as filters, belts and lubrication – equivalent to changing the oil in your car. Proactive maintenance includes an ongoing program that looks for issues before they become a bigger problem or to find hidden energy consuming systems. OCx is really just proactive maintenance. Predictive maintenance includes equipment and process that measure critical system parameters and attempts to predict the point at which a system will fail. That system would then be shut down just prior to failure for repair. OCx can include some predictive elements, but typically this is a more advanced strategy intended for industrial applications.

Many maintenance departments do not get any farther than reacting to maintenance calls and performing a modest level of preventive activities. Maintenance of facilities for most organizations is considered a “necessary evil.” It is a cost center, a liability. Maintenance departments are typically not noticed unless there is a problem. So getting a maintenance department to buy in to an OCx program can be a challenge.

A Building Automation System (BAS) can be configured as a tool to automatically perform a series of functional tests on the building HVAC system. These functional tests will allow the building operator to quickly identify typical abnormalities that affect system performance. Data loggers can also be useful additions to the building operator’s tool box. A combination of BAS alarms, trending, data logging and automated functional testing tools can be a simple but effective on-going commissioning strategy as part of a fully integrated OCx plan.

Ongoing Commissioning Defined

OCx is sometimes referred to as continuous commissioning. There is another type of commissioning, monitoring based commissioning, that relies on extensive metering systems that can be considered a subset of a good OCx program. Regardless of the name, OCx can be thought of as a very good maintenance program.

ASHRAE Guideline 0 defines OCx as follows:

Ongoing Commissioning Process: A continuation of the commissioning process well into the occupancy and operations phase to verify that a project continues to meet current and evolving owner's project requirements. Ongoing commissioning process activities occur throughout the life of the facility; some of these will be close to continuous in implementation, and others will be either scheduled or unscheduled (as needed). Also see continuous commissioning process.

The USGBC has a certification for existing buildings called LEED Existing Buildings Operations and Maintenance (EBOM) which also makes reference to OCx. The Energy and Atmosphere section has a Credit 2 that includes OCx as part of the EBOM credit system.

EA Credit 2.1: Existing Building Commissioning: Investigation and Analysis

EA Credit 2.2: Existing Building Commissioning: Implementation

EA Credit 2.3: Existing Building Commissioning: Ongoing Commissioning

LEED EBOM also has two credit points for measurement and verification which can also be a valuable element of the OCx Plan.

EA Credit 3.1: Performance Measurement: Building Automation System

EA Credits 3.2 and 3.3: Performance Measurement: System-Level Metering

EA Credit 2.3 for OCx includes the following requirements. Note that the requirements include important elements of a good OCx plan such as equipment list, frequency of activities and steps to respond to deviations.

Requirements

Implement an ongoing commissioning program that includes elements of planning, system testing, performance verification, corrective action response, ongoing measurement and documentation to proactively address operating problems.

Create a written plan that summarizes the overall commissioning cycle for the building by equipment or building system group. The ongoing commissioning cycle must not exceed 24 months. This plan must include a building equipment list, performance measurement frequency for each equipment item and steps to respond to deviation from expected performance parameters.

Complete at least half of the scope of work in the first commissioning cycle (as indicated by the percentage of the plan's total budget) prior to the date of application for LEED for Existing Buildings: O&M certification. Only work completed within two years prior to application may be included to show progress in the ongoing commissioning cycle.

Update the building operating plan and/or systems narrative as necessary to reflect any changes in the occupancy schedule, equipment run-time schedule, design set points, lighting levels or system specifications.

EA Credit 3.1, 3.2 and 3.3 for monitoring and verification include the following requirements. Note the requirements for recommended intervals, demonstrating that the BAS is being used to inform decisions regarding operation, system level monitoring and data logging. These are all elements of a good OCx Plan.

EA Credit 3.1

Requirements

Have in place a computer-based building automation system (BAS) that monitors and controls key building systems, including, but not limited to, heating, cooling, ventilation and lighting. Have a preventive maintenance program in place that ensures BAS components are tested and repaired or replaced according to the manufacturer's recommended interval. Demonstrate that the BAS is being used to inform decisions regarding changes in building operations and energy-saving investments.

EA Credit 3.2 and 3.3

Requirements

Develop a breakdown of energy use in the building, either through EA Credits 2.1 and 2.2 or by using energy bills, spot metering or other metering to determine the energy consumption of major mechanical systems and other end-use applications. This analysis of major energy-use categories must have been conducted within two years prior to the date of application for LEED for Existing Buildings: O&M certification.

Based on the energy-use breakdown, employ system-level metering covering at least 40% or 80% of the total expected annual energy consumption of the building. Permanent metering and recording are required. All types of submetering are permitted.

- ❑ **EA Credit 3.2** (1 point): Demonstrate that system-level metering is in place covering at least 40% of the total expected annual energy consumption of the building. Further, at least one of the two largest energy-use categories from the breakdown report must be covered to the extent of 80% or more (i.e., if energy use in the two largest categories is each 100 BTUs/year, at least 80 BTUs/year in one of them must be metered).
- ❑ **EA Credit 3.3** (1 point): Demonstrate that system-level metering is in place covering at least 80% of the total expected annual energy consumption of the building. Further, at least two of the three largest energy-use categories from the breakdown report must be covered to the extent of 80% or more.

Metering must be continuous and data logged to allow for an analysis of time trends. The project must compile monthly and annual summaries of results for each system covered. Meters must be calibrated within the manufacturer's recommended interval if the building owner, management organization or tenant owns the meter. Meters owned by third parties (e.g., utilities or governments) are exempt.

Elements of an Integrated OCx Plan

The following is a list of the elements of a comprehensive and integrated OCx plan:

- Overview, goals, roles & responsibilities, etc.
- List of systems/equipment/parameters to be included & performance criteria
- Detailed procedures for all elements
- Action plan for all elements – reporting requirements
- A schedule for all elements, tie into CMMS if possible, use Outlook tasks, etc.
- DDC alarm plan, with reporting and response
- Trend logging plan, with analysis procedures
- Data logging plan, with analysis procedures
- Manual (paper) test forms and procedures
- Automated test forms and procedures
- Utility bill acquisition and analysis procedure
- Utility meter download acquisition, with analysis procedures

Ongoing Commissioning Using the BAS and Loggers

Overview

The Building Automation System (BAS) is often the most underutilized and/or misused tool available to the building operator. Alarms are a simple and powerful tool to provide a proactive response to critical failures. Trend log systems and data loggers are powerful analysis tools that can be used to evaluate complex building relationships and solve control problems. The BAS can also be programmed and configured to perform self-diagnostics and automated testing.

BAS alarming systems are powerful, easy to set up, inexpensive and can provide a very effective element to any OCx plan. At the same time, they are often poorly configured or the alarm plan is overly ambitious, creating many nuisance alarms which ultimately get ignored – including the important ones.

BAS trend logs or stand alone data loggers are another powerful tool for inclusion into the OCx plan. Trend graphs can be used to make proactive and predictive decisions about systems controlled by the BAS. The old saying that a picture is worth a thousand words applies here. Trend logs are often improperly set up and require a fair amount of skills to acquire and analyze.

Automation of common testing activities is an advanced method for use in the OCx plan. Automation is very powerful, predictive and proactive and is easy to use when configured properly. Automating tests properly can reduce the time to test various system components from days to a few hours. Automated testing is relatively untried and can be intimidating to the operations staff. Automation can also be expensive to set up.

BAS Alarms

Alarms are a feature of all current BAS systems. An alarm is the process of monitoring an analog parameter or a binary state, then comparing it to an alarm threshold or alarm condition. An analog example is monitoring the duct static pressure of a variable volume air handling unit. If the duct static pressure drops below a set limit, an alarm is produced. This particular alarm can identify belt degradation prior to failure (predictive), sudden belt failure and the VFD left in hand at a low speed.

A binary alarm example is if a motor is commanded on and the motor status is indicated as off, then an alarm condition will occur.

Both the previous examples have the ability to notify the operations staff of important events or failures. Both examples also have the potential for creating nuisance alarms. In the duct static pressure alarm case, if the sequence is not modified to indicate that the alarm should only be checked when the air handler is enabled and after a delay time to allow the speed controller to ramp up, then a nuisance alarm will be produced during unoccupied hours and daily on unit start up.

In the motor failure case, if a delay is not programmed in, then a false alarm will typically occur due to the delay time from motor command on and how long the status takes to report a positive.

Typical reasons why alarms fail to produce the desired results are as follows:

- Alarms poorly specified without limiters. As discussed above an alarm may be specified, but if enable limiters and delays are not programmed in, then nuisance alarms will occur. Programming these limiters takes time, so a control contractor may not be willing to add the limiters later. Nuisance alarms are like the boy who cried “Wolf,” at some point the alarms are consistently ignored or disabled.
- Alarms not specified in the first place. If left to the control contractor, they may not put any in, or put in what they want. This may or may not be what the building operators desire.
- An alarming strategy that is overly aggressive. If there are a lot of things in the alarm system, then there will be a lot of alarms. For example, we have seen zone temperatures set to alarm when high or low. This becomes very difficult to manage with various people’s threshold for temperature. Plus why alarm something you can be fairly certain the occupant will let the operations staff know when there is a problem.
- No one is monitoring alarms. If no one has the assignment of consistently monitoring the alarms and taking appropriate action, then the alarms are ineffective.

The alarm plan for the BAS should be reviewed with the operations staff in detail to understand their needs and ability to respond to alarms. The alarm plan should be part of the owner’s project requirements document.

BAS Trend Logs and Stand Alone Data Loggers

All modern BAS systems include the ability to provide trend logs of all analog and binary data in the system. The capabilities and features however differ greatly across various platforms and systems. Memory capacity at each device, archiving of data, graphing capabilities and exporting capabilities are some key differences. Some systems are very easy to set new trend logs up on; others are more difficult and may require a special interface tool not made available to the BAS installation. Because of this, it is very important to put specific trend logging requirements into the project documents, do not leave anything up for interpretation.

Do not use terms such as “shall have the capability of.” This will typically not produce the desired result. The control contractor may come back and say it has the capability, but you have to set it up. Each trended point should be defined in detail, point by point, with pre-grouping, intervals and total sample number defined. It is this author’s opinion that it is easiest and best if change of value or event driven trends are not used. This is for two reasons. First, using set intervals allows for easy alignment of different data sources if the data is to be exported. Second, the change of value method produces an unknown quantity of data and is often misapplied. For example, we have seen temperature trends set up with a change of value of 0.1

degree F. This causes the systems to record data every time it changes by 0.1, which fills the trend buffer in minutes or hours.

Stand-alone data loggers can be used in situations where BAS trending is not available. This may be the case on an older BAS system with limited or no trending. There also may be situations where a particular control point is not in the BAS such as a stand alone controller.

There is a vast array of stand-alone logging systems including wireless and networkable configurations. These units should be synchronized for time and interval with the BAS trend logs as applicable.

BAS trends and stand-alone data logger use should be thoroughly described in the OCx plan. The trending/logging parameters are to be defined in terms of each point trended, sample interval, sample size, engineering units and archiving strategies.

Analysis of trend data can be time consuming, particularly if they are downloaded for analysis in a third-party application such as Microsoft Excel. There are other third-party applications that can be used for combining and analyzing data such as the freeware "Universal Translator" provided by The Pacific Energy Center. A simple yet effective alternative to using a third-party analysis tool is to use the BAS trend system and print screen captures or text data lists directly from the system.

Regardless of the analysis method, the OCx plan must include detailed instructions on how to acquire and analyze the trend data. The plan should include annotated graphs of a pass and fail condition for each concept being trended.

Typical trending/logger applications for an OCx plan include the following

- Any meters available such as gas, water and electricity. The more that is understood about consumption the better.
- Boiler/Chiller parameters as these are high energy consuming devices.
- AHU parameters for warm-up and optimum start, these are important to stay on top of energy use.
- Zone temperatures are important for confirming occupant complaints.
- Any loop controlled parameter such as pressure, temperature, etc. including hydronic loop temperature, hydronic loop pressure, air handler duct static pressure and air handler supply air temperature.
- Any parameter downstream of coils or dampers as these can be an indication of valve or damper failure.
- Outside air temperature, relative humidity and CO₂ as these are important to understand the load on the building.

In addition to BAS trending and stand-alone data logging, there are often other data systems available to be included in the OCx plan. The most significant of these is the utility company metering system. Many of these now have data logging capabilities that can be requested from

the utility company. Advanced systems include the ability to dial into the meter at any time and get a data history.

There are also many stand alone systems that include trending capability. For example a solar cell inverter that logs all parameters including DC volts, AC volts, KW and efficiency. These could be monitored as part of the OCx to evaluate solar cell degradation.

BAS Automated Testing

Automated testing utilizes advanced programming techniques to reproduce typical commissioning functional performance testing both automatically and many systems at once. During commissioning of a new building with 30 constant-volume air handlers, the commissioning provider will typically test the units one at a time or maybe a few at a time. A typical test would be to confirm that the heating valve does not leak by when shut off. The heating plant is enabled and set to design temperature and the air handler heating valve overridden to 0% by the BAS operator or commissioning provider. After a few minutes, the mixed air temperature (coil entering temperature) is compared to the supply air temperature (coil leaving temperature) to determine if there is any leakage. An unacceptable rise as determined by the commissioning provider is an indication of leak by. In a similar manner, the coil heating capacity is verified with the valve at 100%.

This process can be automated by providing the operator a single button to push that will override the heating plant to design temperature and forcing the heating valve to a predetermined position. The process then waits the prescribed delay time to make the mixed air to supply air comparison and then produces an alarm or other indication if the expected results are not within predetermined parameters. In this way, all 30 air handlers can be tested for valve leakage and heating capacity in a matter of minutes rather than hours.

Automated testing is most affectively and economically applied to systems that are most likely to fail. This includes anything with an actuator such as heating/cooling valves and dampers. For example a four-pipe air handler with economizer will have a heating valve, cooling valve and mixing dampers. A variable air volume terminal with reheat has a primary air damper and heating valve. As noted in existing building commissioning, units with valves and dampers have a high rate of failure in the field.

Other systems to be included in automated testing are those that consume a lot of energy, units that are hidden or difficult to access and systems that are critical to the operation of the facility. There is a direct correlation to the level of care a system receives and its location in terms of access. The more difficult to access, the more likely it is to be in poor condition. Automating the testing of these units allows the operations to go to the trouble of accessing these units only as needed.

An example of this is fan powered variable air terminal units with hot water reheat located above the ceiling tile in an open office area. Typically the office cubical walls and desk locations will evolve as a function of occupant need, not maintenance access. As a result the terminal units are

located such that accessing them will disturb the occupants, can't be access without moving furniture or as a minimum leaves a mess of ceiling tile dust on the desks. The net result is these units are frequently avoided by the maintenance and operation staff. If they knew the unit was for certain in need of repair, they could justify the inconvenience and schedule the repairs.

Real World Applications

Alarms

Heating and chilled water systems are a typical application for alarming. Both a high and low alarm can be of value to inform the operator of abnormalities in the system. In a recent project, these alarms were specified, but no limiters were noted. If the alarms were programmed with no limiters, then the chilled water high temperature and the heating water low temperature alarms would activate any time that system was not enabled. The control submittals were reviewed by the commissioning provider and this issue was avoided.

Good choices for alarming points include the following:

- Any binary failure such as pump motors, fan motors, etc.
- Boiler/Chiller/VFD as they have many programmable faults.
- Loop temperature (valve controlled) to notify of system failures.
- Duct static pressure can predict belt failure or need for adjustment.
- Any freeze point or safety devices on critical equipment.
- Water flow at night can be monitored, if there is excessive flow at night then there may be a leak.

Trending/Logging

Monitoring fan status, damper position and supply air temperature is an excellent method for verifying two very important energy saving strategies on air handling units: morning warm-up and optimum start. With these three variables, it can be determined that the unit started at the optimum time, the dampers remained shut during warm-up, the unit heated in warm-up and the space reached set point by the occupied time.

Supply air temperature and supply duct static pressure trending on variable air-volume air handling units can demonstrate appropriate supply air conditions to the terminal unit. Degradation over time can be noted and proactive action taken.

Many system controllers have built in trend capability. One recent example is a solar cell inverter system. Among the trended points were AC power, DC power and inverter efficiency. These can be used to monitor the system for degradation.

Stand-alone data loggers can be used when BAS or system controllers with trending capability are not available. A recent example is the use of loggers to monitor chiller parameters including

entering and leaving water temperatures and power consumption. This can be very effective in keeping this high energy consuming system operating at peak efficiency.

More and more utility companies are going to digital metering systems with internal real time trending capabilities of the power consumption. In a recent retro-commissioning project, the meters also had remote downloading capability so the data can be collected at any time without going out to the meter. Electrical demand trends are extremely valuable in monitoring the overall performance of the building.

Automated Testing

This author's first attempt at automated testing was a large office building with 230 fan-powered terminal units with hot water reheat served by one large air handling unit. The project was undertaken due to the difficulty of accessing the terminal devices above the ceilings of the large cubical office areas. The project was an extension of an ongoing retro-commissioning project.

Seven tests were programmed as follows:

1. Air Flow Sensor Zero
2. Heating Valve Leakage
3. Heating Capacity
4. Air Valve Leakage
5. Full Cooling Air Flow
6. Air Mass Balance (fan on?)
7. Full Heating Air Flow

Mixed results were obtained. The automated testing worked well in finding issues. Unfortunately, the programming over-taxed the control system to the point that the execution of code was unreliable. Ultimately, the building operators removed the code because they needed room in the panel memory. Last checked, they were considering reactivating the system after a recent system upgrade.

Recently on a small addition to a high school, the design team included some more advanced automation that is typically not seen on projects. It included automatically checking the CO2 calibration, providing for automatically testing the heat pumps in heating/cooling and extensive alarming on various system parameters.

The carbon dioxide calibration system included an algorithm to check the CO2 level at 2 a.m. on the assumption that it should be above 300ppm and below 500ppm. If not, an alarm is generated. The automated heat pump test uses a single button to initiate a heating and cooling check of all units at once, providing an alarm if the discharge air did not achieve the desired result in heating or cooling (after a delay).

These systems worked well. Each required testing during commissioning to confirm that they operated as desired. Once commissioned, they can be relied on to effectively identify problems with the associated system.

The most recent project this author has undertaken is the automation of a barracks and administration building that were newly constructed on an army reserve base. The base staff was very interested in automating the testing of systems to reduce manpower needs.

The barracks are equipped with 4-pipe blower coils without economizer. The administration building included 4-pipe air handlers with economizer and VAV terminal units with hot water reheat.

The following automated tests were specified in the project bid documents:

4-Pipe Blower Coils without economizer

- Heating valve leak
- Heating coil capacity
- Cooling valve leak
- Cooling coil capacity

Air Handling Units, 4-Pipe

- Heating valve leak
- Heating coil capacity
- Cooling valve leak
- Cooling coil capacity
- Outside air damper leakage
- Return air damper leakage

VAV Terminal Units with hot water reheat

- Test 1 - Flow sensor zero
- Test 2 - Air valve leakage
- Test 3 - Cooling air flow control & Test 4 - Heating valve leakage
- Test 5 - Heating air flow control & Test 6 - Heating coil capacity

The automated test proved very effective in identifying simulated failures of the various components. A challenge on the air handling damper testing is using the mixed air sensor to identify damper problems. The air handlers have very short mixing boxes and the mixed air temperature may not be accurately reflected by the averaging sensor installed. The limitation of this portion of the system can only be determined during colder weather (the system was tested in warmer weather).

Another challenge encountered was with some of the VAV tests. The control system does not have the capability of overriding the zone temperature or zone set point in code. This makes the automated testing for heating and cooling air flow impossible. As a compromise, the tests that can be automated will be. The remainder will be handled by a VAV summary screen that brings

all pertinent variables on to one screen for ease of testing. Overall, this should provide the majority of the benefits of the original concept.

Key Concepts and Lessons Learned

As a result of observing how maintenance and operation staff perform their work and the practical application of OCx including alarming, trending/logging and automated testing in the field, the following key concepts and lessons learned were noted:

Alarms

- Confirm alarm requirements in the owner's project requirements, talk to the operators to get their thoughts, make an assessment of their capabilities and resources
- Limit to major, actionable parameters – don't be too aggressive
- Specify delays, limits and enable parameters to prevent nuisance alarms
- Be specific, do not leave open for interpretation or at the discretion of the control contractor
- Commission the alarms
- List alarms and response in OCx plan

BAS Trending

- Confirm trending requirements in the owner's project requirements, talk to the operators to get their thoughts, make an assessment of their capabilities and resources.
- Specify minimum trending requirements, capacity, archiving, etc. in the project documents
- Use the same, standard interval for all trend logs
- Don't use event or change of value logging for standard logs
- Commission the trend logs
- Write detailed instructions on acquisition, analysis and actionable items - include in OCx plan

Stand Alone Data Loggers

- Use the same, standard interval for all loggers
- Synchronize loggers with trend logging if applicable
- Write detailed instructions on acquisition, analysis and actionable items - include in OCx plan

Automated BAS Testing

- Confirm automated testing requirements in the owner's project requirements, talk to the operators to get their thoughts, make an assessment of their capabilities and resources.
- Don't be too aggressive at first. Follow the "KISS" principal (Keep It Simple Stupid)

- If the control system type is known in advance, consult the controls contractor on capabilities.
- The mixed air sensor location is critical to use in damper tests. Coordinate with design team to get an actual mixing box so the temperature can be accurately determined. Specify averaging sensors.
- Specify all sensors needed for automated testing. For example, a VAV box discharge temperature is not required for a normal sequence of operations but is mandatory for automated testing.
- Commission the Automated Testing thoroughly. It is virtually assured, that the automated testing will not work as designed unless fully tested. Budget for testing the systems.
- Include companion trending. This is trending that may be set up at shorter intervals to catch automated testing actions that may be missed by longer trend intervals.
- Write detailed instructions and include them in the OCx plan. Assume that at any given time, a brand new operator will be utilizing the plan.

Ongoing Commissioning (OCx)

- Get buy-in from all stake holders including upper management to manage expectations and shift cost of implementing the OCx plan from reactive maintenance and utility budgets to the OCx budget.
- The OCx plan should include the typical Why, What, Who, When & How.
- Provide an overview, goals, roles & responsibilities, etc.
- Provide a detailed list of systems and equipment to be included.
- Provide detailed instructions, for manual testing, automated testing, trending, etc. This should include pass/fail criteria and samples.
- Include a detailed schedule for each element of the plan. If a computerized maintenance management system is available, the OCx plan activities should be integrated into that system.
- Provide an action plan for all elements of the OCx plan.

Closing Comments

True sustainability cannot be achieved without proper building maintenance. Maintenance is typically underfunded and underappreciated. Any tools that can be provide to the maintenance and operations staff to make maintaining the facility easier will improve sustainability.

Simply put, OCx is good maintenance practice. A comprehensive and effective OCx plan requires planning and the appropriate resources.

Building automation systems and stand-alone data loggers are very effective and efficient tools that should be included in any OCx plan.