

Data Logger Essentials for Building Commissioning

Bryan W. Welsh, P.E. of Welsh Commissioning Group, Inc.

Data loggers are powerful analysis tools that can be used to evaluate complex building relationships and solve control problems.

Data loggers and the subsequent analysis of thousands of points of data can also be a huge waste of time if improperly applied. There are standard procedures and techniques that can help assure that the data logging tools are used for maximum effectiveness.

This white paper focuses on stand-alone data loggers in conjunction with the logging capabilities of the Building Automation System in the context of use by a commissioning provider. It also provides tips and advice on specific procedures and techniques on that will enable the efficient and effective use of data loggers to analyze building performance.

Data Logging Applications

Two of the most common reasons for using data logging in building commissioning is to demonstrate performance or for system troubleshooting. The following are some common performance demonstration and trouble shooting scenarios.

Performance

- Log occupied space environmental parameters (temperature, RH, CO₂, lighting, noise) to demonstrate that the facility meets the contract requirements for the purposes of acceptance. This is generally straightforward, the system either meets the requirements or it does not.
- Log occupied space environmental parameters to demonstrate to an occupant that their environment meets standards. This can be more complicated, as even faced with hard data, some people will feel that the space is not adequate.

- Log overall building or specific system energy use to prove energy savings in support of a Utility funded project, therefore receiving grants or funding. In this case it is critical to have a highly accurate approach as considerable money can be involved.
- Energy use logging to support a Monitoring & Verification Plan to qualify for a USGBC LEED point.

Troubleshooting

- Logging occupied spaces and system parameters to evaluate why a space is having (confirmed) environmental control problems.
- Log space temperature at various distances from the ceiling to evaluate stratification and short-circuiting problems.
- Log duct static pressure, hydronic loop differential pressure or HVAC unit discharge temperature to evaluate and adjust system loop tuning and response.
- Log building static pressure and various HVAC equipment parameters to evaluate why the building static pressure fluctuates all the time to the point of slamming doors or blowing them open.
- Log economizer damper positions and various HVAC temperatures and parameters to evaluate causes for high energy use, occupant comfort problems or other problems.
- Log economizers to verify warm-up period and optimum start/stop functions.
- Log system and component start/stop times to verify scheduling.
- Log lighting controls for conformance to schedule, light levels and occupancy.
- Log heating and chilled water plant parameters to evaluate causes of high energy use and poor performance.

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Measurements

Data loggers are designed to measure and record a variety of characteristics of the physical environment. The following are typical physical characteristics related to building commissioning that may need to be trended to troubleshoot or evaluate the performance of a building system. This list though fairly extensive, is not intended to list all characteristics that may need to be logged. There exists such a broad range of sensors and loggers that the practitioner is free to use their creativity to meet the needs of any particular situation.

Temperature – (deg C or F)

- Heating water
- Steam
- Chilled water
- Condenser water
- Domestic water
- Conditioned space air
- Conditioned air
- Outside air

Relative Humidity (%RH)

- Conditioned space air
- Conditioned air
- Outside air

CO & CO₂ (ppm)

- Occupied space air
- Garage air
- Outside air

Pressure (psi, inches WC)

- Hydronic loop differential
- Steam

- Conditioned space differential air
- Duct static air
- Building static air
- Water tank depth

Light Level (foot candle)

- Occupied space
- Ambient sun
- Work surface

Current (amps)

- Building feed
- Equipment feed
- Power quality
- Mili-Amp signal for sensors

Potential (volts)

- Building feed
- Equipment feed
- Power quality
- Mili-Volt signal for sensors

Resistance (ohms)

- Resistance temperature devices
- Resistance signal for sensors

Sound (db)

- Occupied spaces
- Ambient noise pollution

Pulse (on/off)

- Power meters
- Gas meters
- Water meters

Binary Function (on/off)

- Occupancy sensor
- Photo cell
- Motor Start/Stop
- Flow switch

Miscellaneous Sensors

- Rain gage
- Liquid flow
- Air flow

Data Logger Operation

There are a wide variety of data logging devices available and the exact operation of each cannot be covered here. There are certain steps that will be required regardless of the particular unit and they are as follows:

- Planning
- Configuration
- Deployment
- Recovery
- Analysis and Reporting

Planning:

As with any endeavor, careful planning will be the difference between a successful logging project and one that requires excessive data manipulation at the end or in some cases that has to be done over.

If data logging is being undertaken then there is some goal

to be achieved. A Data Logging Plan (DLP) should be developed outlining the goals and approach. As with most projects, it is important to start with the end in mind. The DLP should outline the specific goals to be achieved or a problem statement outlining the circumstances requiring troubleshooting and hence data logging and reporting. The following is an outline for the DLP.

- Goals and/or Problem Statement including reporting requirements (charts, graphs, etc.)
- List of the BAS trend logging capabilities
- List of environmental parameters that are to be measured including what BAS trend logging points are to be used and what stand-alone data loggers are to be used
- Accuracy/calibration requirements for all logged points

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- Sample interval for all logged points
- Sensor location for all logged points including any special fixtures required
- Logging period (start/stop date/time) – Identify if there will be some event during that period that is critical to capture
- Communication Plan: intent, impact and duration of study with building owner, facility staff or occupants

Configuration:

The Data Logging Plan will outline the various parameters for the logging project. All stand-alone data loggers and all BAS trend log systems must be configured prior to deployment or starting of trending. The configuration phase typically will include the following steps.

- Define Points
- Sensor Calibration
- Set Sample Interval
- Set Sample Size
- Set Sample Overrun Option
- Set Start Method
- Synchronize Clocks
- Assign File Name
- Trial Run

Define Points: The BAS and the stand-alone data logger may or may not have the needed points defined. In both cases, the individual points need to be activated or turned on. The input type, sensor range, and other parameters must be set specific to each sensor type. This is a critical operation and care should be taken to use the correct point definition for the associated sensor. Many of the sensor definitions appear very similar and selecting the wrong one will result in significant data errors. During this step, it is important to use consistent naming conventions so that the data makes sense later. Often, the names used in the point definitions are the column headings in the data fields and eventually will be used in graphical representations. Careful planning at this stage will reduce the amount of manipulation later when graphs are developed for the report.

Sensor Calibration: If the project is a critical application the sensors should be calibrated. The calibration should include the sensor and recording device as configured.

Changes in wire lengths and other variations may invalidate the calibration. Even if calibration is not required, the calibration should be checked to ensure relative accuracy. Calibration or calibration checks are done by subjecting the sensor to a known standard environment such as an ice bath or calibrated immersion bath.

Set Sample Interval: The appropriate sampling interval is dependent upon the specific application. It used to be that this was a key trade-off because sample storage was more limited. It was critical to set the interval just long enough to capture events in the physical data so as to minimize the number of samples and conserve memory. This philosophy also drove users to use different intervals for different parameters in the same logging session. For example, the outside air temperature changes very slowly so a 15 minute interval might be appropriate for logging it. But 15 minutes is too long to evaluate the dynamics of a mixed air control via economizer dampers, which may take an interval of 2 minutes or less to evaluate properly. This practice results in a data table of values that don't line up and contains voids, making analysis and graphing very difficult. Table 1 demonstrates what a data table would look like if three measured parameters were set at logging intervals of 15, 5 and 2 minutes and the logger started at 12:00, the "X" represents data.

Some stand-alone loggers and most BAS trend loggers have a feature that uses change-of-state or limits to determine when a data point is logged rather than at a set interval. The change-of-state feature is used on binary points such as motor start/stop. The limits feature logs analog points only when a certain limit is reached. Both are designed to reduce the amount of samples taken, conserve memory and to capture specific events. Both will result in data being recorded at arbitrary times that does not line up with the data logged on intervals. The change-of-state feature has also been known to cause some BAS logging systems to malfunction and cause data corruption throughout the entire logging system. These features should only be used in special cases when an exact event needs to be logged.

Because systems now have such large sampling capacities, it is practical to set all logging intervals to the same value equal to the least common denominator. This way, all data lines up and requires minimal manipulation and smoother data. One downside to this approach is large data files, which can be unwieldy if they are later manipulated in third party software such as MS Excel. But the efficiencies gained typically outweigh this problem, and after all, memory is cheap. The following table contains some suggested intervals for various typical commissioning logging activities. Remember, the logging

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Table 1: Data Misalignment Due to Staggered Sample Intervals

Interval	15 Minutes	5 Minutes	2 Minutes
12:00	X	X	X
12:02			X
12:04			X
12:05		X	
12:06			X
12:08			X
12:10		X	X
12:12			X
12:15	X	X	

intervals for both the BAS and the stand-alone loggers should be set the same if the data from these two systems are to be combined later in the analysis. Table 2 contains suggested intervals for various parameters based on a balance of memory usage and need for detail. These are only suggestions and the intervals used should always be determined by the specific needs of the logging project. It is usually better to error on the shorter durations so that short-term events can be captured.

If different sampling intervals are to be used, they should be common multiples so the data has voids, but lines up. For example: 2 minutes and 10 minutes, 5 minutes and 30 minutes to achieve short and long intervals.

Set Sample Size: In most BAS trend logging systems sample size is an option. This is important because system memory is used for operation of the control system as well as trend logging so memory conservation is an issue. In stand-alone data loggers, the maximum size is typically automatically calculated based on the internal memory size, the number of activated channels and the logging interval. Setting the sample size will determine how long the data logging period will be. For example if the logging interval is 1 hour for a single channel, then a sample size of 48 will get two full days of logging.

Set Sample Overrun Options: When the data logger memory is full there are two options, overwrite the oldest data, or stop logging. The first choice is generally used when a particular event that is to be logged is not predictable. The most recent data is always in memory so

the user can stop the process after some event significant to the logging plan has occurred. The second choice of stopping the logging when the memory is full is useful when the exact logging period is known before hand.

Set Starting Method: There are typically several options for starting the beginning of the logging period; instantly after configuration, at a pre-determined time, event logging and via a manual input (push button). Set the appropriate method for the application. The best option to maintain uniform data integration is starting at a pre-defined time. In this way, the data from all stand-alone loggers will be in synch with each other and the BAS trend logger if properly set up. In some loggers a stop time may also be an option to set.

Synchronize Clocks: There are three areas of clock synchronization; the stand-alone logger clock(s), the BAS trend logger clock and the user's timepiece. The user's timepiece should agree with the other system clocks so the time will agree with the deployment records. Most stand-alone data loggers will use the system clock of the computer that launches them so this clock should be set prior to downloading the setup to the logger. BAS systems can have more than one clock to consider. The BAS graphical user interface computer has a clock and so does the main BAS controller. Some BAS systems use the PC while others use the controller clock. Be sure to be clear on what clock is being used to record the trend data.

Assign File Name: Depending on the system, a file name may be entered to describe the logging activity. Like defining the sensor channel names, using a compact yet

Table 2: Suggested Intervals for Various Parameters

Parameter	1 Min	2 Min	5 Min	15 Min	30 Min
Occupied space zone temperature				X	X
Occupied space CO2 level					X
Occupied space lighting level					X
Outside air temperature					X
Duct static pressure of VAV system	X	X			
Building static pressure	X	X			
AHU supply air temperature	X	X	X		

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Table 3: Data Logger Deployment Information Sheet

File	Channel Configuration Sensor Location				Logger	Launch Date/Time	Activation Date/Time	Retrieval Date/Time	Comments
	1	2	3	4					

descriptive file name can simplify organization activities later.

Download Configuration: Once all configuration parameters are set, the configuration is downloaded to the data logger. Typically a BAS trend logger does not require this step, though there may be some that require a similar step.

Trial Run: It is always advisable to perform a trial run to ensure that the data is being recorded as intended and can be recovered in a usable format.

Deployment:

Once the data loggers are configured, the stand-alone data loggers need to be deployed into the environment to be evaluated. The following outlines the deployment process.

- Position Loggers and Sensors
- Record Logger Deployment Information
- Verify BAS Trending
- Activate Logger

Position Loggers and Sensors: Position the stand-alone data loggers and sensors per the Data Logging Plan. Consideration should be given to who might be in the area that may interfere with the devices. It is advisable to notify the occupants if logging activities are to occur in occupied spaces. It is also a good idea to leave a business card with the devices. Protect loggers from any environmental conditions it was not designed for. Sensor wires and logging devices should be secured using screws, clamps, magnets, tie strips, tape, etc. Care should be taken to ensure that the sensor wires do not become disconnected from the sensors or data logger, make a final check before leaving installation.

Record Logger Deployment Information: It is important to record the location and channel definitions of the stand-alone loggers along with other pertinent information about the logging project. Use a standard form such as Table 3.

Verify BAS Trending: Check the BAS system and verify that the trends are active. Observing the trends in real time will typically not affect the BAS trend files.

Activate Logger: If the logger was activated at download or the pre-determined start time option is set then this step is not required. For push-button types activate the logger manually. In all cases, verify that the data record indicator indicates that the unit is recording. Record the start time and any other pertinent information on the Data Logger Deployment Information Sheet.

Recovery:

At the end of the data logging period, the stand-alone loggers are retrieved and the data is recovered from the BAS trend logs and the stand-alone loggers. The following are the steps for the recovery process:

- Data Logger Upload
- Data Logger Retrieval
- BAS Trend Upload
- Backup Data

Data Logger Upload: Prior to removing the sensors, the data should be uploaded from the logger in the unfortunate event that there was a logger malfunction and the logging session needs to be repeated.

Data Logger Retrieval: Once the data integrity is verified, the loggers and sensors can be picked up and stored.

BAS Trend Upload: If BAS trend logging is part of the Data Logging Plan, the trend logs are recovered from the BAS system. Some BAS systems have the capability to be used for data analysis and reporting but in most cases, the data will be recovered and combined with the stand-alone logger data during the Analysis Phase. Most BAS systems are capable of exporting data files that can be imported by the stand-alone logger software or a third party tool such as MS Excel. Occasionally some creative tricks must be used to extract the data out of some BAS trend systems.

For example, some BAS logger systems do not have an export function, but the text data can be selected in the text-based report in the trend logging system, then copied and pasted using MS Windows to a text editor. In this case, the column headings are typically not in the data that is copied and pasted. Therefore, the user must record what the columns of data represent for use during the data import phase. Column headings can also be typed directly into the text editor on site, being sure to use the exact same delimiters (discussed later in Data Analysis).

Backup Data: The logging effort to this point represents a significant investment. Prior to erasing the data off the loggers or before leaving the site, it is recommended that the data be backed up. There are inexpensive portable storage devices that plug into USB ports that work well for the backup and for transferring the data files from the BAS trend logging system.

Analysis and Reporting:

Once all the pertinent data has been recovered and stored the final step is to analyze the data then produce reports that support the goals of the DLP. There are three basic options for working with the data:

- BAS trending system
- The stand-alone data logging OEM (Original Equipment Manufacturer) software
- A third party software such as MS Excel

BAS trend log system: As has been previously mentioned, some BAS trend log systems have decent graphing and reporting capabilities and others do not. If all that is required is a simple plot of similar logged parameters to demonstrate compliance with standards, then BAS trend log systems with graphing capability can usually get the job done.

If more advanced analysis or reporting is required then these systems usually fall short. Typically none have the ability to merge data from other applications or logging systems. So if stand-alone data loggers are part of the DLP, then they likely data cannot be merged with the BAS data.

A critical issue is that when parameters have large value differences but need to be compared to each other on a graph, the BAS trend log system usually cannot be configured to display correctly. For example, displaying building static pressure (a value around 0.03) along with the relief fan Variable Frequency Drive signal (a value as high as 100) results in a plot of the VFD signal and a straight line at zero representing the building static pressure. No

analysis can be performed on such a plot.

The BAS reporting and graphing outputs typically cannot be annotated to point out important events in the data.

The BAS graphs cannot be easily transferred to an electronic report as the function of displaying the graphs resides in the BAS software and cannot be duplicated away from the BAS operator station. One way to get around this is to take screen captures of the graphs, then paste them into an electronic media such as MS Paint where they can be annotated and saved as an image file. This gets the job done but is cumbersome and the graphs cannot be revised to emphasize different issues later.

OEM Software: Some OEM software is fairly limited while others contain extensive features for data analysis. This paper cannot delve into all the capabilities available (or disadvantages) of using the software from various providers, but in general if the software can perform most of the functions outlined under MS Excel below then it would be the application of choice.

MS Excel: MS Excel is a spreadsheet application with extensive reporting and graphing capabilities. With the spreadsheet functions, there is no limit to the operations that can be performed on the logged data including merging data, scaling data to engineering units and cleaning up bad data. The main disadvantage of using MS Excel is that it takes a few extra steps to bring data into the system then manipulate it. So if the project does not require the power and flexibility that MS Excel can provide, then it is most likely better to use the BAS trend logger system or the OEM software.

Application Example: Office Overheating

A two-story office building had recently undergone a complete HVAC retrofit. The system was a 4-pipe fan coil with economizers. Two office spaces were reported as overheating in the afternoon on mild days (60-65 deg F) while the remainder of the offices in the area controlled fine. The obvious things were checked for first, like leaking heating valves, extra load in the rooms, etc., but these revealed nothing. Stand-alone loggers were set up in the spaces because there was some level of distrust by the occupants that the BAS computer was reporting correctly.

Preliminary analysis included setting up stand-alone loggers to monitor the supply air temperature, space temperature at the thermostat and space temperature near where the occupant sits to evaluate zone control and microclimates. This preliminary analysis did not reveal the problem, but demonstrated that the system was capable of good control and the BAS trend log data could be trusted for further

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analysis. Figure D is a graph from MS Excel using data collected from both the BAS trend logging system and the stand-alone data loggers. In this case it demonstrated good room temperature control. It also shows how sensor calibrations can be different for the different systems. In this type of analysis, the goal is to find the root cause of the problem and minor disagreements of a couple of degrees are not significant to the analysis. As can be seen, both the BAS and stand-alone data show very stable space control and the absolute value of the space temperature is less of a concern because it is reflective of the user adjustable space set point.

In Figure D below, the problem was being caused by two overlapping issues that combined to make the situation worse. The economizer dampers leaked, allowing warmer air to re-circulate back resulting in a less effective economizer function. As a side note, the installation did not include damper access doors. If they had, then this would have been checked early in the process.

The more complex issue had to do with the fact that the chiller was manually shut off by the maintenance staff during this season but the sequence of operations still activated the system on cooling demand. So as the room would start to overheat due to the ineffective free cooling in economizer, the chilled water valve would open, creating a demand for chilled water. Because the chiller was not enabled, the chilled water loop heated up due to pumping energy and the pipes passing through ambient spaces. The chilled water coil then became a heating coil, adding heat to the system and really driving the space temperature up. Figure E is a graph of the BAS trend data using MS Excel. The BAS trend logging system did not have the capability to create this level of graphics.

So in conclusion, the occupant had a legitimate complaint and the stand-alone data was not really needed to prove anything to them. The dampers were re-indexed and the sequence of operations was modified to prevent the chilled water system from running unless there is a status proof after several minutes of being commanded on.

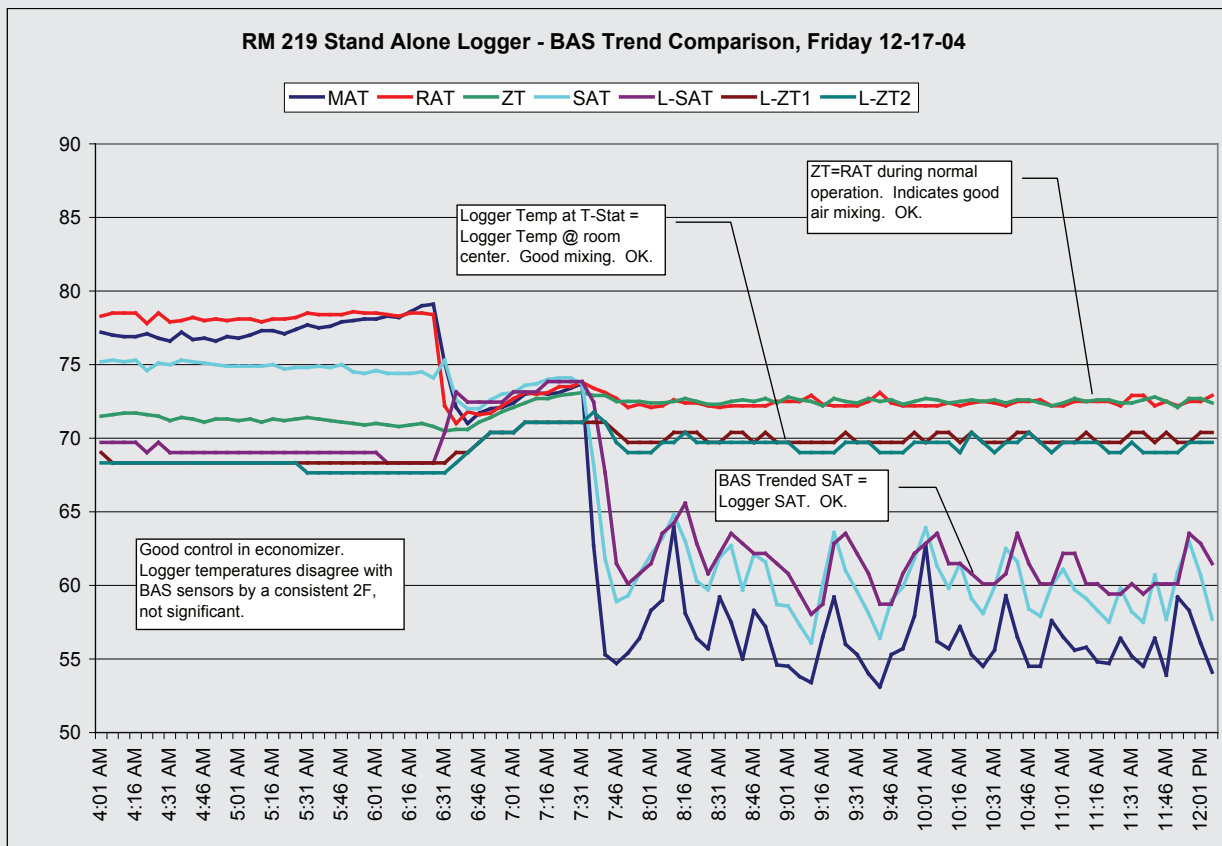


Figure D: BAS and Stand-Alone Data Comparison – Zone Temperature Control

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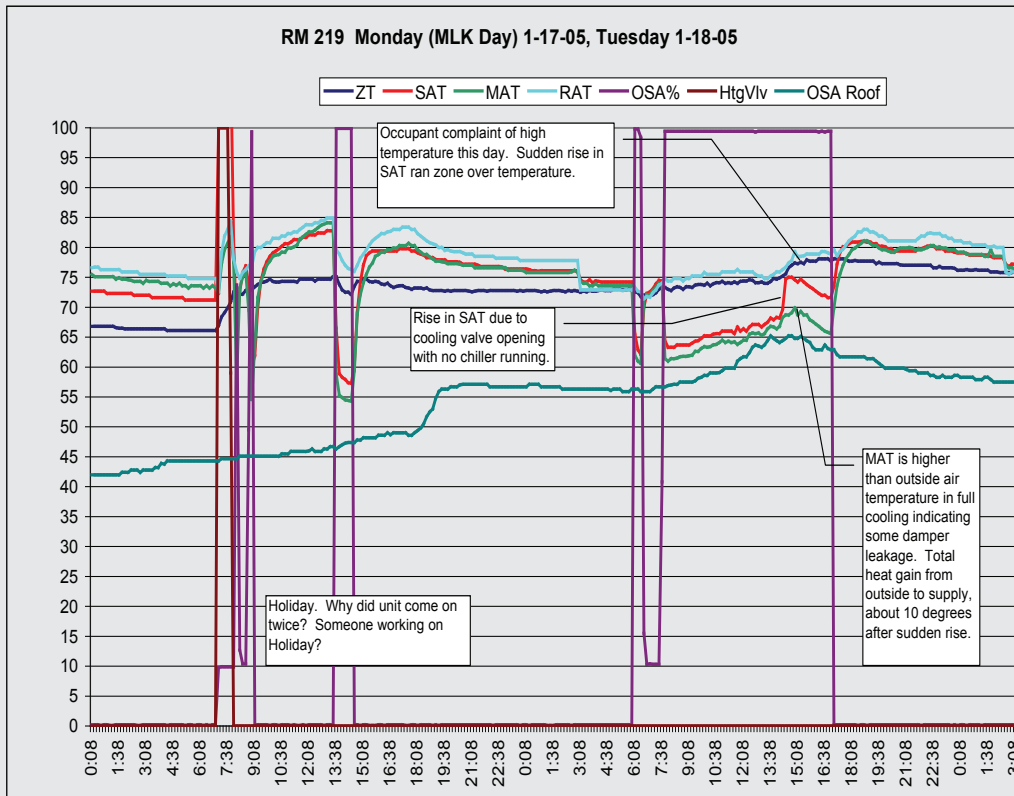


Figure E: BAS Trend Data – Occupied Space Overheating

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 US 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 has over 20 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.

For more information about Welsh Commissioning Group, Inc, please visit: <http://www.wcxg.com>

About Onset

Onset Computer Corporation has been producing small, inexpensive, battery-powered data loggers and embedded controllers since 1981, and has sold over one million loggers that are used around the world by over 50,000 customers. The company manufactures a broad range of data logger and weather station products that are used to measure temperature, humidity, light intensity, voltage, and a broad range of other parameters. Onset products are used widely in research, commercial, industrial, and educational applications.

Onset Computer Corporation
<http://www.onsetcomp.com>
 1-800-564-4377 / 508-759-9500
 Fax: 508-759-9100
sales@onsetcomp.com