

# **Increasing the Effectiveness of a Commissioning Project**

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## **Synopsis**

One of the items facing the commissioning agent is how to work more efficiently and provide a more cost effective project. This applies to new buildings as well as retro- and recommissioning projects. Whether these efforts are accomplished by an outside contractor or are being instituted by an in-house staff, the concern still exists. This paper will examine ways to utilize data collection equipment as well as building automation systems to help in the process. It will demonstrate locations where data loggers may be effective and point out the possible disadvantages. I will also explain where utilizing the Energy Management Systems may be misleading or result in incomplete conclusions. There are numerous ways of using the building control system to gather information, or by interfacing additional equipment you may be able to collect the data you need. This paper will explain a bit about the type of equipment used and how you may be able to connect to the system. I will also discuss the use of building staff or the owners' subcontractors to augment the commissioning effort and show the benefit they will receive by participating in the process.

## ***About the Authors***

Al Turnbull is employed by the Boeing Company, Seattle, WA. He has worked for over 20 years in the Facilities Department at different sites in the Puget Sound region. He has been responsible for design, programming, training and operation of the building and site wide control and monitoring systems. He has been involved in the commissioning of, and assisted in the commissioning of different building control projects as well as building mechanical and electrical systems.

Prior to being employed at Boeing he worked for a major controls manufacturer, where he worked in field service and then in design and installation of various control systems. With this company as well as previous employers he was involved in the testing and acceptance of various commercial and industrial control systems for private and government customers.

## **Introduction**

Building Commissioning is not universally accepted for new construction or used when buildings or systems are retrofitted. This is despite the evidence presented over the last few years of the benefits shown when executed during initial construction, the cost reduction and avoidance during and after construction, and the operational benefits that have been found for the long term use of the building.

One of the problems facing the designer, construction company and commissioning agent is justifying the expense associated with commissioning the building or its systems. The commissioning agent must show that the costs associated with his efforts are worthwhile, is continually tasked to keep his costs under control and to try to reduce them whenever he can. His role is to provide a cost effective job while still being able to make a living. There are many tools and resources available that can increase his efficiency. New products, advanced software and devices with increased capability are being developed all the time and if he can add them to his toolbox his ability to keep costs down is improved. Building automation systems are also being improved with new capabilities added all the time. Some of the manufacturers now offer the ability for the system to perform diagnostics on the way it is operating and issue reports when functioning outside a set of established parameters. With these new features available the agent can utilize them to increase his productivity and work more efficiently.

I will go over a few of the types of data collection equipment available and show the methods and ways they can be of benefit during the commissioning effort. This discussion will cover some of the capabilities of building automation systems and how their use may assist in the commissioning process. I will also show ways that data loggers can be used to check the building control system, methods for interfacing and how one can augment the other. This paper will also point out some of the items a person should watch for, how the data might be misleading or result in incorrect or misleading conclusions. We will also go over ways that the building staff or owners' subcontractors can assist in the effort and explain some of the benefits they will receive by participating in the project.

The focus in this paper is more on the mechanical equipment and electrical systems in the building, rather than on the envelope or structure. There are devices that can be used to confirm the correct installation of materials and demonstrate proper construction of the shell. If the information gathered from the mechanical systems is accurate, it may be able to tell you something about the envelope and what types of items to look for. However if these are areas where you have a responsibility, you should do some research into the type of equipment available and the methods of use for directly confirming the construction of the envelope. Many of the tools are fairly specialized with limited applicability and I won't be touching on their applications or use. The more sophisticated data collection systems may be able to support the types of sensors used and still be able to be utilized in other parts of the building for commissioning purposes. It may be worthwhile to examine an item that may have this versatility even if the original cost may tend to be higher.

## **Equipment**

Data collection equipment runs a full gamut of types. There are fixed units that are installed in racks or panels, near to or as part of the equipment they monitor. Portable units that vary from multi-channel suitcase style to a single channel sensor unit that is not much larger than a quarter.

The multi-channel units are used where a variety or a large number of parameters must be measured simultaneously, such as a test stand or vehicle. The portable multi-channel units can be easily transported even when equipped with extensive monitoring and display capability. Depending on the configuration these units could have a large memory storage capacity, an array of data analysis software available and the ability to interface to a large variety of sensor types. These units would be quite useful in situations where a person needs to confirm the operation of a laboratory or of a process line. They tend to be fairly expensive and originally not meant to be setup for extended periods. Newer units have the ability to have the batteries swapped 'hot' or while the system is operational and might be used for longer time periods. If someone has a project that has need of such extensive monitoring then the cost may be justified because of the total number of points one can monitor at the same time. I have found for the majority of mechanical systems in a typical building that a variety of data loggers can be used quite effectively and at a lower initial cost, so will concentrate on these types of devices.

The trend and data recording functions of building automation or control systems is an area where the vendors are continuing to increase their capabilities. Even the simplest of controllers may record and contain a history of events or faults. The controllers embedded in the mechanical equipment may have the capability of being networked or allowing a down load of operating parameters to a personal computer. Even without the network option the display screen can show the history of events which can then be scrolled through and manually recorded.

Data loggers when applied correctly allow you to obtain information from more than one location simultaneously and over a period of time. This allows the agent the capability of monitoring several places at the same time, rather than a single snapshot of the system he is confirming. Using the data recorded, even for short durations, gives you a more accurate picture of what is really happening in the system. When applied carefully data loggers may detect transients and can provide a history of or show how a system will respond to an upset. When used in conjunction with the building automation one can obtain a great deal more information than by confirming field measurements at single locations. This is very important because of the increasing complexities found in the buildings operation and the interdependence of the systems.

Data loggers and building automation or energy management systems are not analog devices. They are by their nature digital in operation. When we interface this type of equipment to an analog world we need be aware of this aspect of the device. The places where data collection equipment is going to be used and systems they are meant to measure do not work in finite little steps. Even a two state piece of hardware like a relay or light switch still has an analog component to it. This facet of the devices must be kept in mind when we try to use them to monitor the various systems, and be aware of how this will affect the information gleaned from the system.

## **Data Loggers**

The smaller portable type of data loggers that are available come in wide variety of flavors. There are single, dual and multi-channel units. Some have the sensors built in or directly attached. Other units may have a sensor built in and an attachment point for an external sensor or a plug in terminal strip for field wiring. Most of the inexpensive types of data loggers are meant to sample at set intervals and record the data. A more sophisticated type of unit may also monitor for out of limits conditions with some form of alarm indicator or have the ability to record the event or be set to record values around an event. When searching for a logger it is important to have a concept in mind of what it is you are trying to accomplish. This will make it easier for you to compare capabilities and specifications. You need to be cognizant of the types of measurements that will be required for a particular job to best determine the total number of sampling points and of the type of sensing that will be needed. Also become familiar with the software that is supplied, know its limitations, ability to transfer to other programs and if any analysis methods are part of the package.

Most of the lower priced loggers are single or dual temperature types. Their sensors are quite often built in and cannot be remotely located from the logger. Some of the loggers are equipped with magnetic backing so can be placed on metal (steel) surfaces. This would be ductwork, around office furniture or filing cabinets and on some of the mechanical equipment. There are similar types made for detecting the field around a motor to determine total run time and photocell types for monitoring the total time light levels are above a certain threshold. The latter types may not have an event driven log so the start/stop times are not available. The timing of various operations is important to know as comparisons need to be made for a true concept of the system operation. If there are ways to determine when an event may have occurred then the runtime type of units may be all a person would need to prove out a particular sequence.

Some of the sensor types available:

- Temperature, Humidity (remote and built in).
- Pressure (inches WC, PSIG).
- 0-10 Vdc, 0-20 mA, 4-20 mA...
- Volts, Amps...
- Event...

This is a quick sampling of the types you will want to add to your equipment bag. Units that measure and record dc voltages and currents may be directly interfaced to other control sensors to help prove out their functionality or increase the amount of sampling. There are potential problems with this approach which I will point out later. But it is a viable option if care is taken. These types of devices lend themselves to being interfaced to a wide variety of different types of commercial off the shelf (COTS) sensors. This can mean a very wide range of capabilities is available for the commissioning agent. When using this type of device an external power supply will need be available as the loggers typically do not have the capability of providing the necessary power levels for operating these devices. The more sophisticated units (suitcase type) are either battery or line powered and are able to drive the field device. Again there is a matter

of cost trade-off versus capability. Providing power sources in the field is usually not practical. If loggers can be purchased for the intended monitoring point with the type of sensor needed it is easier to set up and place in the field. Data recovery and conversion is also simpler.

The other item to look at when purchasing any type of logger is the accuracy of the unit. There are several things to watch for, the accuracy of the sensor itself, the accuracy and resolution of the unit (its data conversion) and the accuracy of the overall device with sensor. These may not be spelled out clearly as part of the specifications of the device. I have found that the specifications will call out one but not the other, and it has been difficult to determine the overall accuracy, repeatability and range of the device. The accuracy may also be specified at a single point rather than the range or may be percentage of the overall range of the device. Make sure you know what standards the unit is measuring or specified in. The global marketplace is becoming more of a commonplace thing and many of the devices are from other parts of the world.

Additional items to consider when using these devices are the amount of time it may take to respond, the batteries and how the data is retrieved. One set of units that I was looking at showed a response time of approximately 4 minutes. This was measured by immersing in water. The response time in air moving at 1 m/sec was 20 minutes. And even for that interval it was for a 90% step change. The batteries that are supplied with the unit will have a finite lifetime. This is both for shelf (storage) and for use. There are also temperature limits that can decrease the life of the battery. Some units are field changeable, others by disassembly of the unit and many are only factory replaceable. The recording interval can also affect the life expectancy. One unit has a five year battery that becomes a 14 day when set up for recording multiple samples at a reasonable sample rate. Data retrieval can be time consuming and may require bringing in units from the field. There are many different options available, match these to your requirements.

## ***Building Automation***

As with the loggers the control vendors have a variety of different methods for interface, different software packages and capabilities, varied trend or historical tracking and considerable diversity of sensor types. Often as part of a building design the control system is not spelled out except by a performance specification. Details about sensors their installation and wiring are not clearly defined. It is left up to a controls contractor to meet the criteria, sequence of operation and specifications. As a result it is sometimes difficult to know, plan in advance for and review how the vendor will meet the design intent.

The capabilities of the control system for trending may not be known prior to the installation. Commissioning agents need to make themselves familiar with and work closely with the controls vendor to ascertain what the supplier's equipment is capable of. You need to know how this data is obtained, compiled and stored to be able to formulate your strategy. An assumption about the nature, quality and type of information you are able to get from the system may cause a great deal of effort being spent trying to have the vendor perform to a set of criteria that they are not able to do. A bit of homework upfront can make the process much smoother and will help you formulate a plan to work around or gather the information they are not able to supply.

The automation equipment may be able to trend the data at a panel level and then upload to the main control console or there maybe a requirement for the main console to be online at all times in order to store the trend data that is transmitted periodically from the field. Other systems only record while online with the field device and as soon as a screen is cleared the data is also. If the system stores information it may not be in a format that is easy to transfer from one application to another. Be sure to discuss the format that the information is received in, how it is stored and retrieved. You will need this information in order to bring the data up to perform the analysis.

Keep in mind that the data from the devices in the field is converted, a math routine is run and the information then presented to the operator. People have a tendency to believe that what is shown is accurate and the more decimals available the more accurate the value. The values displayed must be confirmed before someone places any reliance on them in determining how the system behaves. Some interpretation is always required to be sure the information you are tracking is correct.

A device or value shown on a graphic display or as part of a points list may not be controlled or monitored. What is being sent to the field may not be what the field is operating on. This is especially true where signal conversion or positioners are used. Watch for the difference between a control signal output and a feedback signal. I have run across several instances where the output value shown is interpreted as what the device is actually doing. And the actual monitoring point on the system that shows the correct position not believed. Again the world is analog and the signal that a computer generates, no matter how small, is a digital signal. There is some conversion and sometimes several conversions made before the device operates.

Having data loggers that are capable of being interfaced to the sensors or transmitted signals can help understand what is happening at the field device. 4 to 20 mA monitoring devices can be inserted in the control or sensor loop and record at intervals or be set with alarm limits that the automation system may not be able to do. It is also another way to confirm the operation of the control system. When you insert one of these devices in the field wiring you are breaking or interrupting the loop. You need to be concerned about the ability of the device to operate with the increased resistance, so check and match specifications of the equipment. Another type of device can monitor the 0-10 v control signals. These loggers are paralleled with the sensor and have a loading affect on the sensor signal, again match specifications.

Some of the other types of loggers such as a pneumatic logger can be used by with sensors that convert to the proper range. Electronic devices for changing the range or signal level also exist, as well as linearizers and translators. These devices may require an external supply or may present loading problems to the sensors or controllers they are being used to check.

If the commissioning agent is onboard and a case made, it can be advantageous to add additional sensing devices or monitoring points during the design phase. At this point in a project the price is lowest, as changes made during construction have additional costs associated with them and can be considerably higher. The additional points make the commissioning effort easier and in the long run assist the building operators in maintaining proper control. If the owner is part of

the process you might approach him with the concept of purchasing a series of loggers that can be used during checkout and then have them available for his staff at turnover. All of these techniques can make for a more maintainable building and are typically worth the additional costs. The difficulty lies in not being in at the beginning of a project and in justifying the additional expenditures.

## **Collecting Information**

The loggers are on site and ready to setup for use. You have a plan (documented) for where they will be located and the type of data you are looking for. First set up the data collection interval, start time or trigger as the case may be and place them in the field. It is important to make a record of where and when, so they can be retrieved and checked and in the case of errors or loss of data be redeployed. You also don't want to lose too many of them either.

One item that is critical is to have the clocks or time date stamps set to match on all the devices. Quite often the time is matched to the computer that launches the device. Double check that it is set correctly in the logger. If any correlation of data is going to be made the time base must be accurate. Measure the parameter at the location you are installing the logger so you have a record of the start value, record the time you made the measurement and match the values of the data logger's recording to check the accuracy.

If you are using the devices to confirm building control systems sensors, do so after you have checked the accuracy and readings of the BAS (end to end) and be sure that the location is going to read the same as the sensor. Quite often measurements are taken at slightly different locations and errors are shown that may be a result of some other factor such as stratification or turbulence.

Collect the sensors or retrieve the data and then download it to the computer you'll be using for the compilation of information. You want to be familiar with and know the limitations of the software that came with or was purchased for the loggers. If the information cannot be analyzed or transferred to another program for analysis there could be quite a bit of hand typing or manual correlation done. You also need to know the units that the logger will be recording in. If the unit records directly in the values it is measuring then less manipulation will have to be made in the software or for analysis. However if the units are a say for a 0 – 10vdc device and you are using it to monitor a differential pressure sensor, you need to know the zero point and how the plus and minus may record and to what values you use to convert the voltage to in order to display the numbers in the correct engineering units.

Once you have retrieved the data you then can relocate the units to other locations and continue with the building check out. If you have used them to confirm the BAS sensors, you can then use the data obtained from the automation system with a degree of confidence and relocate the loggers to places the control system may not have points installed. By relocating the loggers to those locations that are not monitored you'll be able to cover a larger area and by doing so confirm other aspects of the control system and building operation.

You might wish to start the historical trending of the BAS inputs (and outputs) at the same time as the loggers you'll be using. This will allow you the opportunity to examine how the system behaves and demonstrates some of the aspects of the trend log capabilities of the automation system. It is important to know its limitations from a hardware and software aspect. It is very easy to set up a trend with snapshots taken at intervals that are too far apart to catch excursions from setpoints or upsets to the system. The same is true of loggers. The downside to collecting large amounts of data is you will have to transfer, read, store and manipulate it.

## ***Analysis***

Once you have the volumes of data required, it is time to make some sense of the information. Match your readings from the loggers and the BAS to the test reports you receive from the vendors checkout and contractors tests. Pay special attention to the balancing report and verify the data that may be imbedded in the control system matches what the contractor found. This serves as another confirmation of the data and the vendors' responsibilities.

The information you are compiling serves several purposes. It will confirm the installation, demonstrate the proper operation of the building systems, the correct functioning of the equipment and establish a baseline for future activities. This baseline if used correctly will allow the maintenance personnel the opportunity to keep the building trimmed out and operating the way it was designed. The report may also be used show the energy benefits to the building from the choice and operation of the equipment. In cases of energy retrofits it is important to demonstrate the effect to the new baseline of the building compared to the initial operational of the systems. In these types of cases loggers are quite often used to monitor the energy usage prior to and after the retrofits.

One must be careful in the interpretation of the data. Don't get too caught up in absolute accuracy. The devices you use as well as the sensors and equipment installed in the building have tolerances that need to be accounted for. The main sensors should have already been confirmed for accuracy and the display indicates the correct readings. The main things you should be watching are the trends and reactions from the system. One of the main problems with any analysis is the perception of the person. What a person wants is all too often what he will see. Any deviation from what is expected should be analyzed carefully before changes are made to the systems involved. There could be unseen interactions or some facet of the monitoring or installation that might account for the questionable reading.

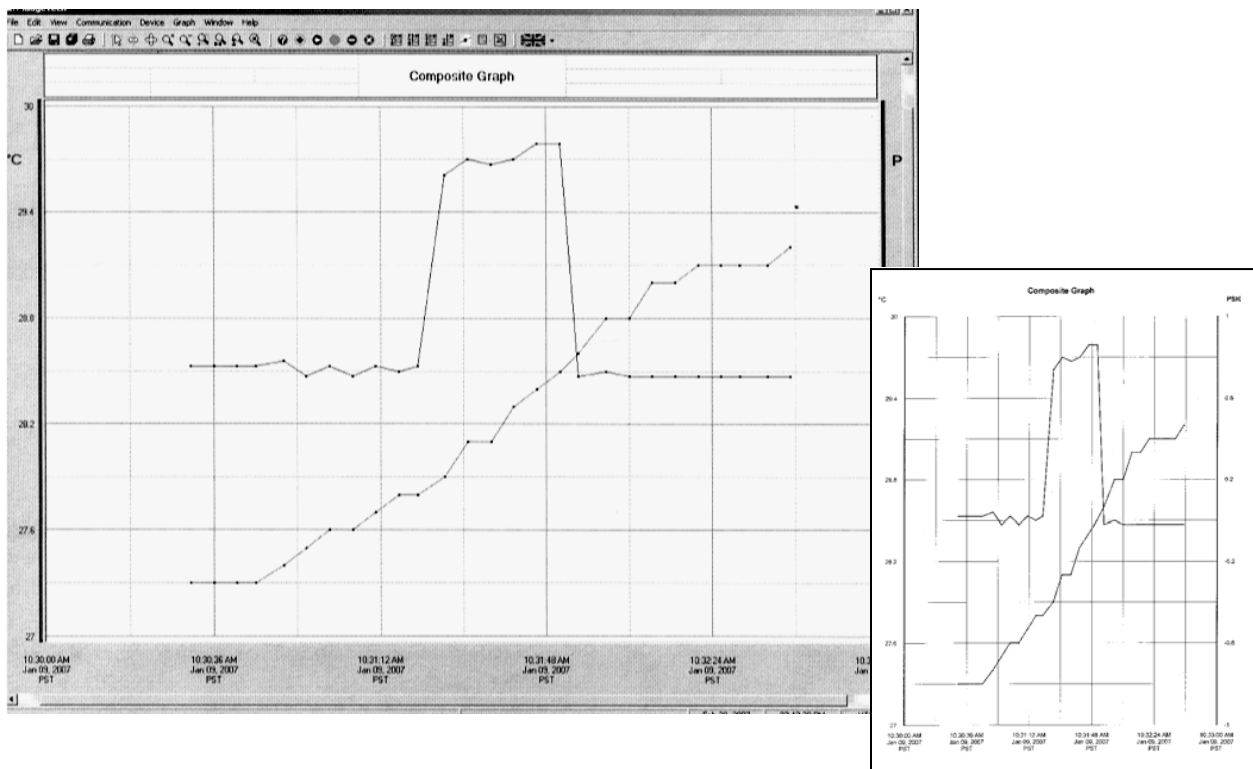
I need to stress the importance of the time base again. There are two aspects, one is the correct time, used to match events, the other is the sample time. If the sample times are not at intervals that can be matched between parts of a system, the analysis of interactions is more difficult. This is especially true for transient events. One trick is to use multiples of the sample times, i.e. 2 minutes for fast acting and 20 minutes for the slow responding components. This facilitates the comparison and graphing of the trends. It is important to spot interactions between systems and accurate time stamps can make this possible. The air handler may be responding to a change in chiller staging and not be fluctuating from its setpoint. An event like this is easier to determine and explain when you are able to match the time of occurrence.

## Samples

I want to point out a couple of the items to be aware of when you try to analyze or present the data. One of them is loggers and BAS trend points are snapshots in time. This will be apparent if you have set the time base to wide and find widely varying numbers. You will also find strange results from trying to graph the data. Some logging software will assume the values are linear readings and will display them as such. It is important to be able to spot this type of occurrence or have enough data points to show the true response of the system. Another thing to watch is the format of the data. It may be difficult or time consuming to manipulate the data points so you can ascertain the information you are after.

Key points to remember: Time base, Data format, Engineering units, Sensor response time, Scaling, Data loss or gaps in recording and Variance in readings.

Below is a screenshot of a sample test trend I had setup prior to the deployment of a pair of loggers. To the lower right is a reduced picture of what the printout looked like.



**Figure A: Temperature and Pressure Chart**

Note the straight line graph and jumps in data points, the scales were on opposite sides and were automatically generated based on the values recorded. Note in the printout the exaggeration in the scaling. I did not find a method in the software to allow me to resize or manipulate the image or layout. The data was stored in a CSV file so I could import into an 'Excel' spreadsheet.

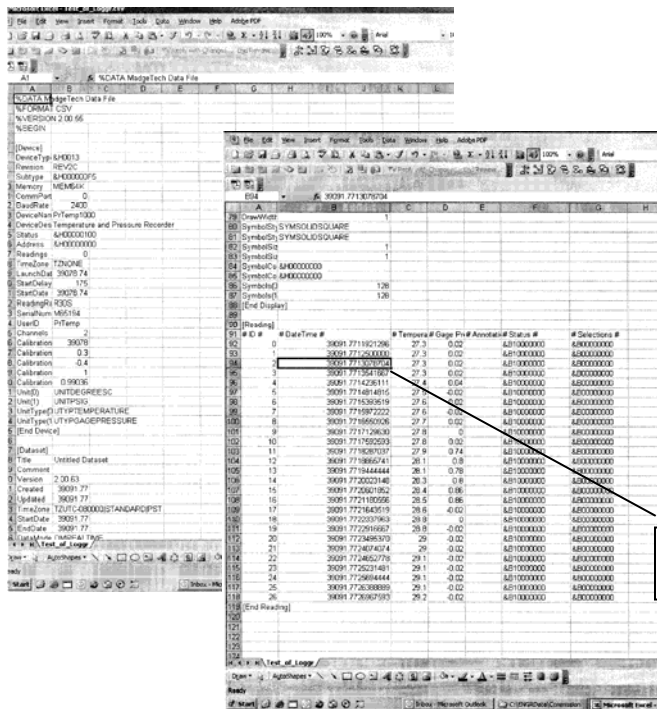
A couple of items to note in the following prints and screen captures is the type of data and the way it is presented. The scaling could be changed either through the logger software or once it is imported to a spreadsheet. Figure B is a partial scan of the printout from the manufacturer's software, while the two screen captures in Fig. C are the imported CSV file in 'Excel'.

Report Name:	PrTemp1000 Data Table
Report Date:	Feb 20, 2007 02:43:52 PM UTC-08:00
File Name:	C:\ENGRData\Loggers\Test_of_Loggr.csv
Title:	Untitled Dataset
Device:	PrTemp 1000 - Temperature and Pressure Recorder
Hardware Revision:	REV2C (64K)
Serial Number:	M65194
Device ID:	PrTemp
Data Start Date:	Jan 09, 2007 10:30:31 AM PST
Data End Date:	Jan 09, 2007 10:32:41 AM PST
Reading Rate:	30 Seconds
Readings:	1 to 27 of 27
Last Calibration Date:	Dec 27, 2006
Next Calibration Date:	Dec 27, 2007

Reading	Date and Time (PST)	Temperature	Gage Pressure	Annotation
1	Jan 09, 2007 10:30:31 AM	27.300 °C	0.020 PSIG	
2	Jan 09, 2007 10:30:36 AM	27.300 °C	0.020 PSIG	
3	Jan 09, 2007 10:30:41 AM	27.300 °C	0.020 PSIG	
4	Jan 09, 2007 10:30:46 AM	27.300 °C	0.020 PSIG	
5	Jan 09, 2007 10:30:51 AM	27.400 °C	0.040 PSIG	
6	Jan 09, 2007 10:30:56 AM	27.500 °C	-0.020 PSIG	
7	Jan 09, 2007 10:31:01 AM	27.600 °C	0.020 PSIG	
8	Jan 09, 2007 10:31:06 AM	27.600 °C	-0.020 PSIG	
9	Jan 09, 2007 10:31:11 AM	27.700 °C	0.020 PSIG	
10	Jan 09, 2007 10:31:16 AM	27.800 °C	0.000 PSIG	
11	Jan 09, 2007 10:31:20 AM	27.800 °C	0.020 PSIG	
12	Jan 09, 2007 10:31:26 AM	27.900 °C	0.740 PSIG	
13	Jan 09, 2007 10:31:31 AM	28.100 °C	0.800 PSIG	
14	Jan 09, 2007 10:31:36 AM	28.100 °C	0.780 PSIG	

Figure B: Partial Time/Temperature and Pressure Printout



Notice how the spreadsheet is fairly large. It used 119 lines for the 26 readings. The first 90 were used for the description of the logger, and its settings. The data was shown in correct engineering values and is very straight forward to use.

The main item of note is the format that the time is presented in.

This equates to Jan 09, 2007 10:30:41

39091.7713078704

Figure C: Spreadsheet Screen Capture

## **Owner/Operator**

One other aspect of trying to do a better job, be more productive and efficient is to include the owner's operations and maintenance personnel. This is usually not possible, but where it is, it can be helpful to the commissioning agent. In cases of larger companies the maintenance staff may have equipment that is not readily available to the commissioning agent. For retrofits hopefully they are familiar with the equipment and have historical records of how systems behaved. This information can be quite helpful when trying to form a strategy or plan on how to monitor and check out the building.

For new construction they also can be brought onboard at an early stage to help with confirming the maintenance access and feasibility of the design. They also can be used during construction to point out places where equipment could be difficult to maintain or where sensors may be located in spots that might not work correctly. You must keep in mind and it stressed to the personnel that they are there to help and learn about the system. Any changes or requests must go through the proper channels. Off hand remarks can sometimes result in change orders unless it is clear from all parties what their roles are. Be sure to stress in training or when their assistance is requested, the design intent of the building or its systems. The maintenance personnel may not understand how a piece of equipment is meant to be operated and can draw wrong conclusions or misinterpret what might be happening with system.

This is an excellent time, if it is carefully thought out and planned, for increasing the knowledge and training of the operations and maintenance staff. It can be pointed out to the owner the benefits he will see from including his people early on in the project, and gain his support.

The crew can follow along and assist with their own training, understanding and knowledge of the building and its systems. They can be used to setup and recover loggers or gather data from the field sensors. They also can watch how the systems behave and report back the visual findings. This can be very helpful when trying to confirm data, especially where it appears there are major fluctuations in the readings.

## **Summary**

As buildings are increasing in complexity all personnel associated with the design, construction and checkout of the building are asked to do more in less time and at a lower cost. The commissioning agent is sometimes seen as an extra expense despite evidence published to the contrary. It's his task to demonstrate his value before, during and after the construction or remodel. Using the automation system's capabilities to demonstrate its own operation, and data loggers to augment what he measures in the field can increase his apparent presence. These tools need to be carefully utilized and there needs to be a well thought out plan in place for them to be of benefit. Bringing the O&M staff onboard early has benefits to owner as well as the commissioning agent. If the right methods are used the data gathered can be a major benefit to all concerned with the proper and continued operation of the building.

## **References**

Portland Energy Conservation, Inc, (PECI), 2006 NCBC Proceedings, Welsh, Bryan W.,  
'Data Logging Applications'

PECI, O & M Best Practices Series, 'Portable Data Loggers'

Energy Engineering, Vol. 104, No. 2, Dr. Wayne C. Turner, Editor-in-Chief

PECI, 'A Practical Guide for Commissioning Existing Buildings' April, 1999

'Building Operations Documentation Manual' Building Operator Training and Certification  
Washington State Energy Extension Service