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BAS SCREEN CHECKS FOR ONGOING COMMISSIONING

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ABOUT THE AUTHOR

Michael Kaplan has been active in the field of building commissioning for the past 20 years. He is the proud winner of the 2008 BetterBricks Engineering award for his commissioning work. His early work in commissioning helped establish it as standard practice in energy efficient construction. Mr. Kaplan also has an extensive background in commercial HVAC and industrial mechanical design.

Mr. Kaplan has assisted PacifiCorp, PGE, Seattle City Light, Pacific Gas & Electric, Georgia Power, and Los Angeles Water and Power with the development of their commissioning programs, has presented numerous seminars and training workshops, has authored six technical papers on commissioning for national conferences, and has been the Commissioning Authority for millions of square feet of new and existing institutional, commercial, and industrial buildings. He is a Technical Advisor for the BetterBricks Building Operations initiative.

INTRODUCTION

All too often, building operators look at the Building Automation System (BAS) operator terminal screens only if there is a known problem with the HVAC operation – typically in response to occupant complaints. But the BAS GUI (graphic user interface) can be an invaluable tool that facility operations and maintenance staff can use to be proactive to problems in the making, avoid the embarrassment of a large portion of the complaints, and keep their buildings tuned for optimal performance and energy consumption.

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This article investigates techniques for quickly and inexpensively reviewing the BAS GUI screens for ongoing commissioning of the building mechanical systems.[1] Experience shows that it takes between 2 and 10 minutes to identify problems or verify proper performance for a typical air handling or central plant system. Follow-up investigation, as illustrated in the case studies, takes a bit more time.

Figure 1 is an example of a typical GUI screen for a VAV air handling unit. As with most BAS graphics screens, this screen shows real-time data (BAS inputs), setpoints, links to other related graphics, alarms, alarm reset buttons, and buttons for several common overrides. Data are shown in schematically correct locations, assisting the user in understanding the relationships among the data.

[1] This approach can also use the BAS text screens to access current point statuses. I prefer using the GUI screens, assuming they have been verified for accuracy, since they provide a schematic representation of data that can greatly assist in rapidly scanning relationships and discrepancies.

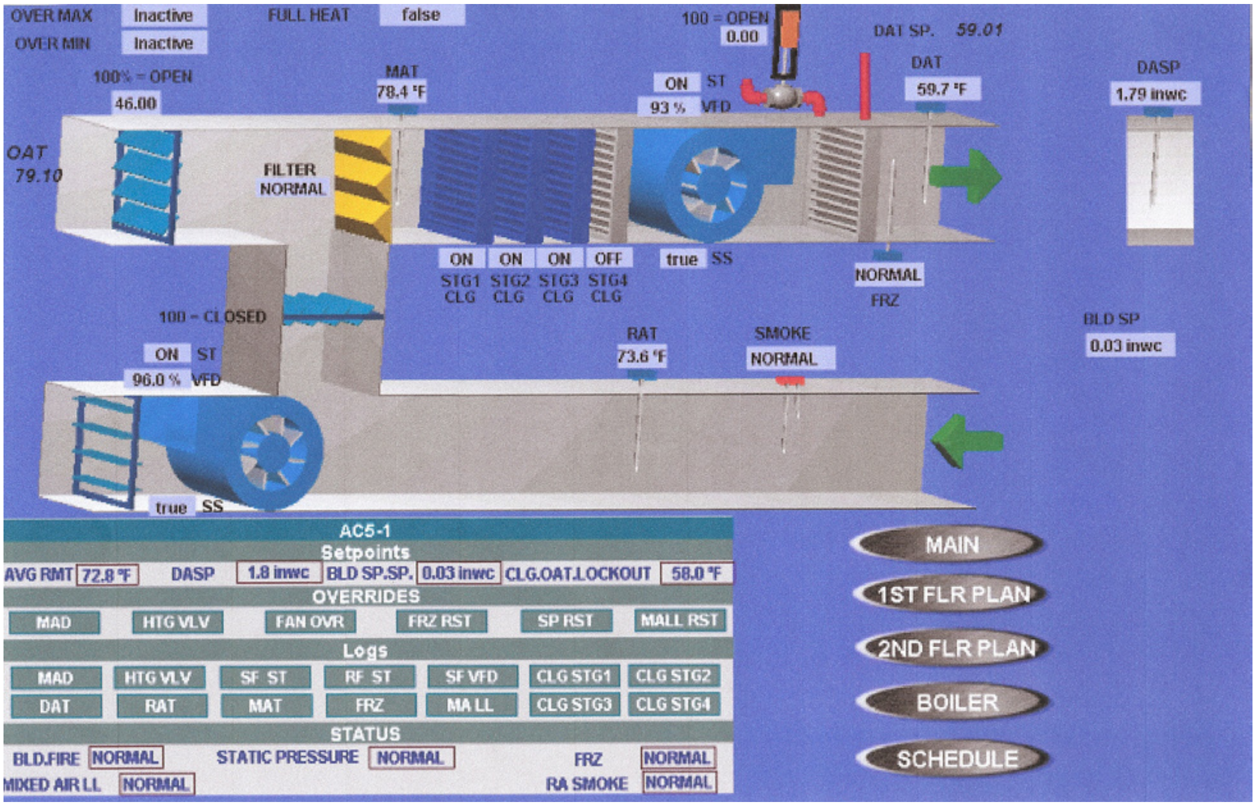

Figure 1: VAV Air Handling Unit BAS Graphics Screen

There are a couple important caveats for using this approach. First, it doesn't catch all problems. Since it's essentially a snapshot of current operation, it often won't catch problems in other modes of operation or other load or occupancy conditions. Judicious use of BAS trending expands the range of the screen check tool.

Second, the BAS is only useful for system diagnosis if it can be trusted. This means that the BAS must have had a recent thorough and documented point-to-point check. In addition, the GUI must also have been commissioned to ensure points have been mapped correctly and system schematics are correct.

This article begins with a discussion of the preparation that's required to skillfully use BAS screen checks. Next I'll present general guidelines for execution of the approach. Finally, I'll use several case studies of how screen checks were used to identify problems.

PREPARATION

Screen Check Forms

The screen check approach requires simple data forms. The forms should:

1. Be tailored to each system or major piece of equipment.
2. Include all points that are used for control or information, including inputs, outputs, and setpoints.
3. Include a space to note active alarms.
4. Include prompts for date, time, outside air temperature, and user's initials.
5. Include space for notes.
6. Record fixed setpoints such as building and duct static pressures, minimum outside air damper command in CFM or percent open, terminal unit minimum and maximum CFM setpoints, and so forth.

Figure 2 is an example of a data form for one single zone constant volume air handling unit and one

Point	AC3-2 (single zone)	AC3-3 (VAV)
Discharge Air Temperature		
DAT setpoint		
Mixed Air Temperature		
Outside Air Temperature		
Return Air Temperature		
Average Zone Temperature		
Return Air CO2, ppm		
Bldg Static Pressure / Setpt=		
Duct Static Pressure / Setpt		
Mixed Air Dampers % Command / Min Stpt		
Heating Valve %		
Supply Fan VFD% or status		
Exhaust Fan VFD % / Start-Stop / Status		
DX Stages On		
Room Temp Setpoint		
Room Temperature		
ALARMS?		
Zone Temps Near Setpt?		
OKAY?		
Date/Time/Initials		

Figure 2: Air Handling Unit BAS Screen Check Form

Figure 3 is an example of a data form for a heating water central boiler plant

Point	Data	Point	Data
HWST / Setpt		Boiler #1 Enable	
HWRT		Boiler #2 Enable	
Mixing Valve Command (100% is open to boilers)		HWP-1 Command	
HWP-1 Status		HWP-2 Command	
HWP-2 Status		Boiler #1 Isolation Valve Cmd	
HW Diff Pressure / Setpt		Boiler #2 Isolation Valve Cmd	
Diff Pressure Valve %		Alarms?	
HW Flow, GPM		OKAY?	
Date / Time / Initials			
Notes:			

Figure 3: Heating Water Plant BAS Screen Check Form

Figure 4 is an example of a data form for VAV terminal units (parallel fan-powered and reheat).

Terminal Unit (TU) ID#	FTU1-1 (parallel, fan-pwrd)	TU1-1 (reheat)
Max CFM Flow Setpoint		
Min CFM Flow Setpoint		
Room Temperature Setpoint, Deg F		
Room Temperature, Deg F		
Current Flow Setpoint, CFM		
Current Flow, CFM		
Primary Temperature (ACU DAT), Deg F		
TU Discharge Temperature, Deg F		
TU Fan Command, On or Off		
Reheat Valve Command, %		
Notes:		

Figure 4: Terminal Unit BAS Screen Check Form

KNOWLEDGE

Some familiarity with the HVAC control sequences and programming is needed so that we know what to expect to see in the screen checks. Note that expected operation is not necessarily good operation. Within the confines of your scope, it may be appropriate to push existing operation that conforms with as-built documentation towards more efficient operation.

No matter what your familiarity with the controls, it's useful to have available for your screen checks the mechanical drawings and schedules, as-built control drawings, the test and balance report, and any commissioning reports. All of these can inform your screen observations.

Drawing on your familiarity with the control sequences, you can identify the various modes of operation you wish to verify with the screen check approach. Some of these modes are a function of time of day and day of week (e.g. occupied mode, unoccupied mode), some are a function of load and outside air temperature (e.g. heating, economizing, and mechanical cooling), and some are a function of both time and load (e.g. night low limit, optimal start, night purge).

I always make it a part of my commissioning to do screen checks under the appropriate time, temperature, and load conditions to observe as many of these modes as possible.

ATTITUDE

It's not enough to approach BAS screen checks with good forms. It's also important to come with the proper attitude.

First, try to block out enough time for a building or facility to get through all the systems in one sitting. This is important for two reasons: 1) It gives you a shot at making all observations under similar weather and occupancy conditions. This simplifies your task by limiting the range of possible explanations for observed observation. 2) It also makes it more likely that you'll spot problems because your observations about each system's operation tends to inform your understanding of all the other systems.

Second, before you start looking at the BAS screens, pause to consider what you expect the operation to be for each similar groups of equipment and systems. (If you're very familiar with the facility, you'll probably already have operation expectations in mind. In that case, this conscious step may not be necessary.)

For example, if it's 3PM on a sunny 85°F weekday in a typical commercial or institutional building, you'd probably expect properly operating HVAC equipment to be in a cooling mode. For air handling units, outdoor air dampers should likely be stroked to a minimum OSA position, and mechanical cooling (chilled water or DX) would likely be enabled. You wouldn't expect to see a heating coil valve open or a gas burner firing, though for some older equipment this might be appropriate operation. The supply fan, if variable volume, would likely be operating towards the upper end of its capacity. One or more chillers would likely be running, and boilers would probably be disabled by outdoor temperature. Setpoints that are reset as a function of outdoor air temperature or building load would probably be towards the full cooling side of their reset range. These might include setpoints for air handling unit discharge air temperature and chilled water supply temperature. Based on these expectations, you might also expect the mixed air temperature to be closer to the return air temperature than to the outside air temperature, and the return air temperature to be fairly close to the room or average room temperature.

This is a starting point for your observations, to put you into a mindset for noticing discrepancies from "reasonable" operation. It is not an end point. There may be discrepancies from the expected that can be explained within the parameters of good operation.

One last matter of attitude: This your chance to be a detective, or indulge in your CSI fantasies. BE CURIOUS. Train your mind to ask these questions: What am I seeing? Does this make sense? Is this what I expect? Why not?

EXECUTION

After you've used the screen check approach for awhile, you'll likely develop your own strategies. But here is an approach that I find useful in maintaining a disciplined and comprehensive analysis of BAS data.

Start with the central plant systems and equipment if applicable. Record the current point data for the boilers, chillers, cooling towers, and pumps. This tells you whether heating and/or cooling is available to the air handling units or other distribution equipment – an important clue to understanding the performance of that equipment.

For air handling units, complete one system at a time. For VAV air handling units, check the air handling units, then look at zone temperatures (most conveniently on a GUI plan view), then spot-check several terminal units – especially those serving zones with temperatures with the greatest deviations from setpoints.

As you record every point, question whether it makes sense, both alone and in relation to other points. Does it fit your expectation?

When you complete the point status documentation for each system, look back over it to see if it makes sense and indicates expected proper operation. Compare its operation to that of similar systems. Question why similar systems might reasonably differ in operation.

If you note data that don't make sense, appear to indicate problems, or are inconsistent with other data, it's often helpful to examine available trends.[2] As an example of where this might be the case, consider a high building static pressure noted during an air handling unit screen check. With minimal trending you can see whether the static pressure is always that high, whether it drops to near zero when the air handling unit is off (an indicator of whether the building static pressure transducer is to be believed), whether it's related to the operation or failure of some exhaust fan, whether it's a recurring or one-time event, and so forth.

Finally, document and communicate your findings. Follow-up until issues are resolved. It's not terribly useful to find problems or other opportunities for improvement if you don't take the necessary steps to enable corrective action.

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[2] If you are working on a facility that you will be revisiting periodically, consider setting up archived trends for the data that will most assist your screen checks and ongoing trouble-shooting. Specific points and intervals that should be trended are beyond the scope of this article. As a general approach though, the points that are on the screen check forms are the points that should be trended.

RECOMMENDED FREQUENCY FOR SCREEN CHECKING

I've been in facilities where building operators performed comprehensive BAS screen checks daily. The complex and critical nature of those facilities warranted that. Most facilities don't have the person-power or budget for that frequency of ongoing commissioning. For those facilities, I recommend that screen checks for non-critical equipment be done at least seasonally (hot and cold weather), if not quarterly. As mentioned earlier, it is important to look at equipment and system operation under different weather and load conditions. Also, as operators become more practiced at using this tool, the effectiveness of screen checking will increase.

CASE STUDY #1

During a screen check of a VAV air handling unit with an open return air plenum I noticed that the temperature of the return air (RAT) was much lower than the average zone temperature. In fact it was close to the discharge air temperature (DAT). Figure 5 is a modified version of the documentation that brought this to my attention. Key data for this case study are in bold larger font.[3]

Point		**Point**	
Unit #	AC3-3	Heating Valve %	58%
DAT (discharge air)	**60.3°F**	SF VFD % speed	82%
DAT setpt	62.1°F	DX Stages	0
MAT (mixed air)	55.8°F	ALARMS?	None
OSAT (outside air)	60.8°F	Zone temperatures near setpoint?	Yes
RAT (return air)	**61.7°F**	OKAY?	No; MAT and RAT low
Avg Zone Temp	**70.3°F**	Date/Time/Initials	4/19/07; 17:40; MBK
OSA damper command, %	10%		

Figure 5: BAS Screen Check of VAV Air Handling Unit Operation

I wanted to know whether this observation was an aberration or whether it was typical of this unit's operation. So I followed up this observation with a look at the trended data. Figure 6 is the trend graph I saw.

This graph confirmed to me that something unusual was influencing the return air temperature. The close relationship of the mixed air temperature to the return and discharge air temperatures was further evidence that there was a physical explanation for what I was seeing.

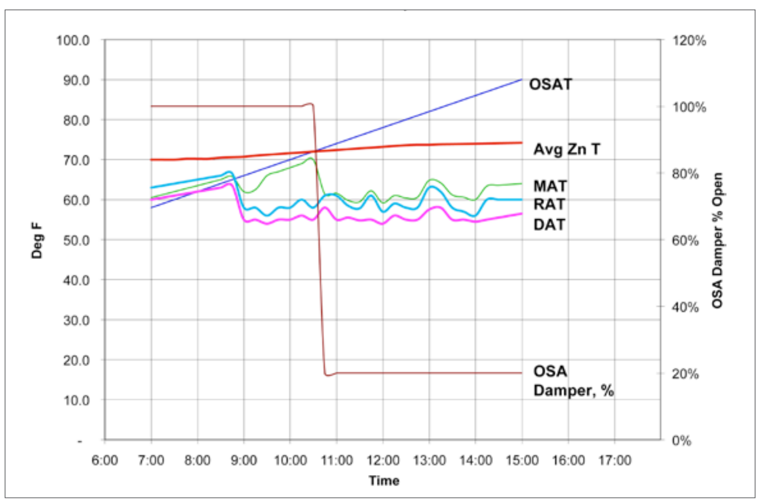

Figure 6: Trend of Air Handling Unit (AC3-3) Operation

[3] Some other data values also stand out, but are not directly relevant to the problem. The mixed air temperature is lower than either the outside air temperature value or the return air temperature value, seemingly an impossibility. The mixed air temperature value is valid though, within the ±2 F degree calibration allowance, and is explained partly by the fact that the indicated OSAT value comes from sensors located well away from the unit and partly by the likelihood that one or more DX system compressors were just on, influencing the MAT sensor that's mounted at the coil's upstream side. Also, the minimum outside air damper command is just that – a command, not necessarily indicative of the actual percentage of outside air. In fact, the explanation of the low return air temperature – which I won't divulge quite yet – is likely forcing a higher portion of OSA than the command would suggest. The trend graph shown in Figure 6 lent further evidence to the MAT being a valid value. In short, it appeared that the odd MAT was largely an aberration of the micro-conditions at the moment of the screen check. The heating valve is open in response, to bring the discharge air temperature up to the discharge air temperature setpoint.

When I brought this issue up at the next commissioning team meeting, I was met with blank stares and general doubt that this was a real problem. It didn't meet any of the usual definitions of a problem. There were no broken pipes, clogged strainers, mis-mapped points, faulty programming that seemed to be involved. I voiced my suspicion that somehow discharge air was short-circuiting to the return air plenum and back to the air handling unit return.

The test and balance contractor suggested doing a smoke test. We all gathered on the roof by the unit while he introduced smoke to the supply section and we immediately started the unit up. Within seconds smoke was pouring out from the exhaust dampers. When the mechanical contractor removed the supply discharge section panel at my request, we were able to see that the factory had omitted two sheet metal strips that were to seal off gaps at the transition to the supply ductwork. There was a 4" wide by 6 foot long opening directly to the return air plenum. I calculated by temperatures that under certain conditions, up to 2/3 of the supply air was short-circuiting directly to the return section. This constituted not only a major waste of energy, but also a serious compromise of unit capacity.

This experience led to changes in standard procedure for both the mechanical contractor and myself. The mechanical contractor stated that he intended to routinely remove the supply discharge section panel for inspection of the unit transition to the ductwork on all future air handling unit installation. For my part, I resolved to always ask to be notified so I could be present to observe unit placement.

CASE STUDY #2

A routine BAS screen check of a large 6 year old middle school revealed a number of problems. Figure 7 shows the relevant data that brought the problems to my attention. Again, key data are in bold larger font.

AHU-2	**Data**	**Chilled Water System**	**Data**
DAT (discharge air)	**65.6°F**	Chilled Water Supply Temp	55.3°F
DAT setpt	**55.0°F**	CHWST Setpoint	44.0°F
MAT (mixed air)	80.4°F	CHW Pump-1 Status	On
OSAT (outside air)	83.6°F	CHW Pump-2 Status	On
RAT (return air)	73.8°F	Chilled Water Flow, GPM	**34 GPM**
Avg Zone Temp	74.6°F	Chiller #1 Enable	**False**
OSA damper %	30% (min)	Chiller #2 Enable	True
Cooling Valve %	100%	Chiller #1 Isolation Valve Status	**Open**
Heating Valve %	0%	Chiller #1 Flow Switch Status	**Off**
Alarms?	None	Chiller #2 Isolation Valve Status	Open
Zone temps near setpoint?	**No; up to 77.5°F**	Chiller #2 Flow Switch Status	On
		Alarms?	No
OKAY?	No; High DAT & zn temps	OKAY?	No; High CHWST, CH-1 should be on, low CHW flow.
Date/Time/Initials	9/5/08;14:30;MK	Date/Time/Initials	9/5/08;14:00;MK

Figure 7: BAS Screen Check of Middle School HVAC

I typically begin screen checks of facilities that have central boiler or chiller plants with those plants. The chilled water system data in Figure 7 show that the chilled water supply temperature was significantly higher than the setpoint. Both chilled water loop pumps were running and both chillers' isolation valves were open to flow. However, Chiller #1 was not enabled by the BAS, which seemed strange to me. It also seemed strange that the building loop flow was so low given that most AHU cooling valves were 100% open and both 200 GPM chilled water pumps were running. I looked back at data I had recorded during the original commissioning and found typical loop flows under similar conditions were 140 to 200 GPM, or 4 to 6 times that observed in this screen check.

Next I looked at the air handling units and zone conditions. Many zones were 5 or 6 degrees above setpoint though they were meeting their supply CFM setpoint (maximum cooling). Most of the air handling units had discharge air temperatures well above setpoint, with their cooling coil valves commanded fully open. This confirmed that the high chilled water supply temperature (and low flow?) were problems.

I decided to trace the chiller programming to see why Chiller #1 was not enabled. I found that the "off" status of the Chiller #1 flow switch was responsible. This was not programmed as an alarm condition, so an alarm was not registered. The program trace also confirmed that load was high enough to call for both chillers had the flow been proved.

My interpretation of this combination of events was that the flow switch had failed, that a manual valve was closed, that the automatic isolation valve had failed, or that there was some other flow restriction or water loss that caused the flow switch not to make. I reported my observations and suspicions to the school district's maintenance department, and recommended that they trouble-shoot the low chilled water flow indications.

The Maintenance tech found that both chillers' flow switches had problems. One required adjustment, and the other required replacement. He also found what appeared to be some odd parameter values in the flow meter setup programming. I followed up on this and learned that the main BAS global controller had failed and been replaced several years ago. The new controller had apparently been downloaded with a program version that pre-dated changes made during the commissioning process, causing the flow values to be off by a factor of 10, among other things.

CONCLUSION

BAS screen checking is a highly cost-effective method of keeping tabs on mechanical equipment performance. In each of the two case studies I've presented, about 10 minutes of attentive BAS screen checking highlighted serious problems. An additional ½ hour to one hour of investigation through trends or programming provided enough confirmation and detail that it was possible to point technicians towards the corrective action needed. These problems were causing significant occupant discomfort, excessive energy consumption, or both.