Case Study on Enhancing Equipment Efficiency and Operational Practices of a Signature LEED Building

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Abstract

Building commissioning enhances the initial operation and efficiency of LEED buildings. For projects pursuing LEED certification, commissioning is a prerequisite. The ideal outcome through the commissioning process is the building systems operate as intended. Yet, the reality of sub-optimal performance and less than reliable operation of building systems in completed LEED projects can not be ignored or dismissed in the euphoria of obtaining the LEED certification. Anecdotal evidences are beginning to emerge that the desired result and improvement in occupant comfort and worker productivity may more difficult to achieve than is generally realized. Similarly, the energy efficiency and consistent equipment performance are sometimes questionable as well.

This paper will offer to take a brief look at an actual LEED signature project in Washington, DC, to evaluate the efficacy of design measures implemented in the building such as daylight harvesting, CO_2 monitoring and DDC controls. The typical building operation will be studied to discern gaps and systemic weakness that often defeat the best efforts of commissioning experts in enhancing performance and improving reliability. A set of potential new operational strategies will be offered for industry review. A model best-practice matrix to maintain performance will be proposed for building owners for further evaluation.

Introduction – LEED and High Performance Building

A "green" building is *planned, designed, constructed, and operated in a way that maximizes energy efficiency and indoor environmental qualities while minimizes negative environmental impact.*1 Ideally, green building minimizes impact to the local environs; uses fewer material resources. It recycles and generate less waste stream; uses energy and water resources efficiently; provides a higher quality, healthier and productive indoor environments. Once occupied, it operates with a set of environmentally friendly housekeeping practices and products. For building owners, it produces a cost-effective economic return over its life span. Two elements in a green building provide direct and substantive involvements – in the areas of improving energy and lighting efficiencies and enhancing indoor environmental qualities. In these two crucial arenas, commissioning providers can make significant contribution to the success of the green building projects.

Building Commissioning and LEED Projects

Rediscover the Goals of Commissioning for Green Buildings:

There are three specific goals for commissioning green buildings and those pursuing LEED certification. It is stated on page 112 of the Reference Guide of the LEED Rating System, version 2.1: *"A commissioned building provides optimized energy efficiency, indoor air quality, and occupant comfort, and sets the stage for minimal operation and maintenance costs."* The focus is further stated as follows: *"Implementation of the commissioning process maintains the focus on high performance building principles from project inception through operation. This typically results in optimized mechanical,* *electrical and architectural systems – maximizing energy efficiency, and thereby minimizing environmental impacts…" 2*

Another reference text on page 114 of the Reference Guide states *"the commissioning process for a LEED project typically focuses on systems and assemblies having to do with the project's operational performance, particularly those relating to LEED prerequisites and credits."2*

The building systems for which commissioning process should be applied include both dynamic and static elements that impact three key performance parameters:

A. Energy Efficiency
B. Water Efficiency
C. Indoor Environmental Quality

The conventional practice of the quality-assurance and control process of commissioning has focused on HVAC systems. However, mechanical engineers charged with the task of acting as the commissioning authority (CA) are faced with non-HVAC building systems with which they may not have the expertise or knowledge. This paper provides suggestions for coordinating the commissioning of sustainable design features and for achieving green-building certification.

Back to the Basics: Commissioning Re-defined:

Commissioning has been defined as *a systematic process to ensure that all building systems, including green building technologies deployed, performed interactively according to the design intent and the owner's project and operational requirements*.3 Three key attributes about commissioning needs to be emphasized at the outset: First, commissioning is a process. Second, commissioning is about quality. Third, commissioning is focuses on performance. Commissioning is often used in projects as a task, a completion exercise, an acceptance checkout and viewed by contractors and designers as a necessary evil like code inspection. For instance, most general contractors merely allocate a few weeks at the end of the project for "commissioning". Many government owners have misapplied commissioning as a "team inspection" task by the project team. Construction managers normally assign manning for commissioning no differently for on-site management tasks. The results often are no better than if no effort is made at commissioning at all. A process means that instead of a task, there exist a flow of tasks each of which reinforce and support the task completed previously. There is a feedback loop and mid-way corrective mechanism to allow the quality of the product, which comprise the building systems, to be continuously enhanced. The quality emphasis of the commissioning process sharpens and concentrates the attention and efforts of the project team at ensuring a higher level of system performance that is attained and persists over time.

An Effective Approach: System Synergy. Because all building systems are inter-related in function and integrated in operation, a deficiency in one component can result in sub-optimal operation and performance among other components. Some component deficiencies may even lead to system failure and building shutdown. The inter-dependence of building systems in actual operation requires verification and proof of performance, two elements of the commissioning process. Remedying these deficiencies enables a variety of benefits including:

- Improved occupant comfort and productivity
- Significant energy and operating cost savings
- Significantly improved indoor environmental quality

- Improved system and equipment reliability
- Improved building operation and maintenance
- Improved building and worker productivity
- Enhanced the market resale value for building owners

Project Description

Building Information

The project is a 12 story mid-rise Class A office building located at 500 New Jersey Avenue, NW in Washington, DC, about three blocks from the U.S. Capitol. The building has a narrow floor foot print with an oval shape. The roof patio has a magnificent view of the dome of the Capitol. With a total floor area of 120,000 sq. ft. and a 10,000 square foot floor plate, the design is a modern all glass building with four below grade parking garage levels. The building design intent is conventional in that it was meant to be built to attract the highest paying tenant. The façade design is noted for the stunning streamline ultra-modern sophisticated look.

The owner of the building, the National Association of Realtors, made a strategic decision to pursue LEED certification for the new project as an organizational commitment to the sustainable design for their membership. The building was completed in May 2004 and was awarded a Silver Level rating from the U.S. Green Building Council, making it the first green commercial speculative office building to receive certification in the U.S. capital. The project demonstrates the feasibility of incorporate green features into a new class of buildings that historically have resisted sustainable design – the speculative office building market.

Sustainable Goals

The sustainable goals for a green building project can be succinctly defined by the list of specific LEED credits the project team has determined to pursue. These goals define the focus of the commissioning for a building. Table 1 lists some of the LEED credits that are relevant to commissioning scope:

Table 1: LEED Credits for Commissioning Scope

LEED Credits	LEED Element
SS Cr. 8	Light Pollution Reduction
WE Cr. 1.1	Water Efficient Landscaping
WE Cr. 2	Innovative Wastewater Technologies
WE Cr. 3.1 - 3.2	Water Use Reduction
EA Prerequisite 1	Fundamental System Commissioning
EA Prerequisite 2	Minimum Energy Performance
EA Prerequisite 3	CFC Reduction in HVAC&R Equipment
EA Cr. 1.1-1.3	Optimize Energy Performance
EA Cr. 2.1-2.3	Renewable Energy
EA Cr. 3	Additional Commissioning
EA Cr. 4	Ozone Depletion
EA Cr. 5	Measurement and Verification

EQ Prerequisite 1	Minimum IAQ Performance
EQ Prerequisite 2	Environmental Tobacco Smoke Control
EQ Cr. 1	CO2 Monitoring
EQ Cr. 2	Ventilation Effectiveness
EQ Cr. 3.1	Construction IAQ Management, During Construction
EQ Cr. 3.2	Construction IAQ Management, Before Occupancy
EQ Cr. 4.1	Low Emitting Materials, Adhesives & Sealants
EQ Cr. 6.1 and 6.2	Controllability of Systems, Perimeter and Non-Perimeter
EQ Cr. 7.1	Thermal Comfort, Comply with ASHRAE 55
EQ Cr. 7.2	Thermal Comfort, Permanent Monitoring System
EQ Cr. 8.1	Daylight & Views, Daylight 75% of Spaces

System Narrative

The HVAC system consisted of central station air handling unit on each floor with direct expansion refrigeration compressors in each packaged air handling unit. A condenser loop provides cooling water from the roof mounted cooling tower to serve each of the air handling units after passing through a water side economizer heat exchanger. The system is a very common system type and, in fact, the system of choice for the speculative office market in the U.S. These air handling equipments, called the self-contained units (SCUs), provide the developers maximum flexibility by providing cooling for each individual floor and, importantly, allow the owner to separately meter the cooling and heating energy use by the tenants in the building by floor.

The lighting system incorporated a daylight harvesting dimming control system that allows each light fixture to be individually dimmed. Instead of a group of lights control by a zone-base dimming control, the “fixture-based” lighting allows maximum flexibility to serve the needs of the occupants and also optimize the daylighting potential. For a 100% glazed envelope system, daylight harvesting is an ideal application, provided the visible light transmittance (VLT) has been properly determined to provide the most daylight available while still maintains thermal performance.

The plumbing system deployed waterless urinals, dual flush water closets and low flow automatic faucets. There is also a rainwater collection and retention system to collect the rainwater run-offs from the roof patio in a tank located in the garage. The collected rainwater is used to provide water to a new urban park adjacent to the building as a public amenity.

Findings of System Performance

1. HVAC System Performance

During the commissioning effort, five of the twelve (12) air handling units were evaluated. Since the sizes of all units are similar, five were chosen to determine if patterns of performance demonstrated correct operation. The Table 2 shows the actual performance of the installed air conditioners. In Table 2, Stg means the specific stage, SP means setpoint, ….

Table 2 Air Handling System Performance – Self-Contained Direct Expansion Cooling Units

Site: National Board of Realtors
Owner: Advance Building Performance, Inc.
Name: National Board of Realtors
Address: 500 New Jersey Ave. NW

Time	Unit	Stg	Tons	Unit Descriptior	SP	LP	ST	LT	Cwi	ET	SH	SC	CTOCWi
6/10/2004 8:34	5	1	6.1	McQuay SWP(	60	184	57	86	80	34	23	9	16
6/10/2004 8:51	5	2	6.1	McQuay SWP(	48	175	60	85	81	25	35	8	12
6/10/2004 8:39	5	3	10.7	McQuay SWP(	56	181	58	86	81	31	28	8	14
6/10/2004 8:47	5	4	6.1	McQuay SWP(	65	181	60	85	81	38	22	10	14
6/9/2004 18:19	6	1	6.1	McQuay SWP(	57	172	58	85	80	31	26	6	11
6/9/2004 18:39	6	2	6.1	McQuay SWP(	44	171	58	83	79	21	37	8	12
6/9/2004 18:23	6	3	10.7	McQuay SWP(	62	182	58	86	80	35	23	9	15
6/9/2004 18:32	6	4	6.1	McQuay SWP(	56	179	56	84	79	31	26	10	14
6/9/2004 17:01	7	1	6.1	McQuay SWP(	61	191	49	90	81	35	14	8	18
6/9/2004 17:26	7	2	6.1	McQuay SWP(	48	172	62	86	79	24	37	6	12
6/9/2004 17:06	7	3	10.7	McQuay SWP(	63	181	54	90	80	36	18	5	15
6/9/2004 17:20	7	4	6.1	McQuay SWP(	63	179	60	88	79	36	24	6	15
6/9/2004 15:28	8	1	6.1	McQuay SWP(	59	184	57	89	80	33	24	7	15
6/9/2004 15:49	8	2	6.1	McQuay SWP(	47	174	58	84	79	23	35	8	13
6/9/2004 15:33	8	3	10.7	McQuay SWP(	64	176	57	89	80	37	20	4	13
6/9/2004 15:44	8	4	6.1	McQuay SWP(	65	179	66	87	80	37	28	7	14
6/9/2004 14:31	9	1	6.1	McQuay SWP(	22	194	58	87	81	-2	61	13	19
6/9/2004 14:49	9	2	6.1	McQuay SWP(	66	181	62	85	81	38	24	10	13
6/9/2004 14:23	9	3	10.7	McQuay SWP(	53	173	47	83	80	28	19	9	12
6/9/2004 14:41	9	4	6.1	McQuay SWP(	55	175	57	83	83	30	27	9	10

The data shows that refrigerant charge is within that acceptable range as specified by the manufacturer for a unit without hard faults. The superheat measurements are all higher than specified and in some cases much higher than specified. Adjusting the thermal expansion valve (TXV) to achieve superheat of 10-12°F is the recommendation in the McQuay installation and maintenance manual. The technician would adjust the TXV to allow more refrigerant flow to increase the capacity of the system and lower the superheat. One would expect that operation would also raise the suction pressure and evaporating temperature. But we would have to wait for that to be done after occupancy with real cooling load and then re-test to see if the effect is great enough to bring the evaporator temperature into the acceptable range. Where the effect is not great enough, airflow will have to be increased to present more heat to the evaporator and the TXV adjusted again to match the capacity of the system to the higher load in the building.

On Unit #9 in the stage 1 of the refrigerant circuit, a problem was detected that is unlikely to be correctable by an adjustment. Low evaporating temperature along with high superheat and higher that expected subcooling is definitive evidence for a refrigerant flow restriction. Such restriction was clearly detected. The restriction is in the liquid line. The common causes for restrictions include a closed liquid valve, a crushed liquid line, a plugged liquid drier, solder or other debris plugging the entrance to the expansion valve, a defective TXV power head or plugged evaporator distribution tubes. The commissioning effort enables an early detection of this problem that can lead to premature compressor failure and other warranty related issues. The detection of such quality defect also indicate the need to fully test the built-in systems by the equipment manufacturer since such problem may not lead to actual failure before warranty ends.

Table 3 Summary of HVAC System Findings

1	The installed units are running with high superheat and often with low evaporating temperatures.
2	The adjustment of the TXVs could resolve many of the problems.
3	There is a possibility that the airflow is restricted through the units to an extent where the TXV adjustment alone will not bring the performance indicators into the normal range.
4	Unit 9 stage 1 has a more serious problem that will have to be addressed through a more invasive repair to the liquid line or the metering devise.
5	A re-test of each unit after the completion of the repairs and adjustments to verify that the performance indices are in the normal range, assuring efficient and reliable equipment operation.

2. Condenser Water Loop Testing

The initial effort at the condenser water system verification test was not completed prior to occupancy for the following reasons on the project site:

1) Cooling tower basin heater is not operable. This render the tower inoperable until the heater is fixed.
2) Air handling units were not operable and could not load cooling tower when the tower was scheduled for tests. The cooling tower test was delayed until the controls on the air handling units are completed.
3) Cooling tower sequence does not included control of bypass valve. This design omission seriously hamper the operation of the tower as well as the testing of the condenser water loop.
4) Cooling tower controller has not been tuned. The result is the overflow of excess water over the tower and wasted considerable amount of water until the problem was finally fixed.
5) Water balance set to operate pumps at full rpm negating savings from the installed variable frequency drive(VFD). The contractor responsible for the checkout of the VFD failed to set the calibration properly on the VFD. This omission was detected by the commissioning process and fixed..

Conclusion

This brief case study illustrates the need for commissioning during the construction phase of LEED projects and any green buildings. The two examples on the performance of the HVAC systems and the condenser water loop point to the alarmingly high level of uncertainty with respect to equipment performance as intended. A further evaluation or post-occupancy evaluation (POE) of the systems in green buildings is highly recommended to assist the project team and building owners to address the issue of persistence of system performance and commissioning benefits.

Persistence of Performance and Savings: The examples in the case study attempts to demonstrate the transitory nature of system performance with the common practice of equipment startup by the contractors. The standard method of checkout may not be sufficient to ensure persistence of performance or energy savings. A more rigorous functional testing as part of commissioning can increase the reliability of equipment operation and system resilience.

Energy Savings: An energy model, using DOE2, determined the building energy performance is predicted to outperform the ASHRAE 90.1 baseline by over 23%. The main reason was surprisingly not due to a superior envelope or a higher efficiency HVAC system. It was, instead, due to the significant lighting power reduction from the daylight harvesting dimming lighting that greatly contributed to lower the cooling loads year round from the lower lighting power intensity.

The case study recognize the importance of commissioning in enabling the project to achieve the design intent and owner's sustainable goals.

References:

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2. United States Green Building Council (USGBC). 2004. *LEED Reference Manual, Version 2.1*. Internet: www.usgbc.org.
3. ASHRAE. *The HVAC Commissioning Process, ASHRAE Guideline 0-2005*, www.ashrae.org.