Continuous Commissioning® of a LEED-EB Gold Certified Office Building

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ABSTRACT

A 320,000 square foot Class A high-rise office building in Nashville, TN achieved LEED-EB Gold Certification. LEED-EB version 2.0 was utilized, which requires Retro-Commissioning (RCx) as a prerequisite for certification. SSRCx performed the RCx services during the LEED-EB performance period, and was contracted after building certification to utilize the Continuous Commissioning® (CC®)[1] process to seek additional energy savings. The building was constructed in 1999 as a Core and Shell project and build-outs were done through 2001. By January 2008, a single company managed and occupied the facility. This paper describes the RCx process for LEED-EB v2.0 and the CC process after LEED Certification. Findings and implementation strategies for energy savings are presented for both processes.

INTRODUCTION

A 320,000 square foot institutional building was constructed in 1999 as a Core and Shell high-rise office building, and subsequent build-outs were performed until 2001. By 2008 a single company managed and occupied the facility and sought to achieve Leadership in Energy and Environmental Design, Existing Building version 2.0® (LEED-EB® v2.0) Certification. This certification required (among many other things) Retro-Commissioning as a prerequisite. The RCx process according to LEED-EB was implemented during the performance period of May-July 2008. The LEED submission was provided to the US Green Building Council (USGBC) – the rating authority for LEED – in August. LEED-EB Gold Certification was awarded in March 2009.

[1] Continuous Commissioning and CC are registered trademarks of the Texas Engineering Experiment Station (TEES), the Texas A&M University System, College Station, Texas. To improve readability, the symbol "®" will sometimes be omitted.

FACILITY DESCRIPTION

The building is a 320,000 square foot Class A high rise consisting of open and enclosed office space, a full service cafeteria, fitness center, TV studio, auditorium, small data center, and attached 7 story parking garage. The base building HVAC system consists of two 500 ton water-cooled chillers with cooling towers and a dedicated constant speed pump per chiller. The chilled water system operates as variable volume with a pressure controlled bypass valve. Thirteen variable volume air handling units distribute conditioned air to variable volume terminal boxes. Exterior zones utilize Parallel Fan Powered Boxes with electric heat and interior zones utilize variable air volume boxes with electric reheat. Unconditioned outside air is introduced into each mechanical room via constant volume terminal boxes with electric heat. This system is served by one supply fan on the roof. One exhaust fan on the roof relieves toilet and general exhaust from the building. The Building Automation System provides full DDC controls.

LEED-EB PROCESS

The project was registered with the USGBC in January utilizing the LEED-EB v2.0 Rating System. LEED-EB is a points-based rating system by which sustainable aspects of a building are measured and reported. There are four certification levels to denote achievement: Certified 32-39 points, Silver 40-47, Gold 48-63, and Platinum 64-85. Points can be achieved in six categories: Sustainable Sites, Water Efficiency, Energy & Atmosphere, Materials & Resources, Indoor Environmental Quality, and Innovation in Operations & Upgrades. Many of these categories contain prerequisite items that must be accomplished or demonstrated through building features or operations.

Regarding LEED-EB process implementation, a performance period of 3-5 consecutive months must be identified wherein aspects of the LEED prerequisites and credits are tracked and implemented. The performance period for Retro-commissioning was April-July 2008.

RCX PROCESS

Retro-commissioning is a prerequisite item noted as Energy & Atmosphere Prerequisite 1: Existing Building Commissioning.

The scope consists of the following:

1. Develop a building operation plan (BOP)
2. Prepare a commissioning plan
3. Implement the commissioning plan
4. Make repairs or upgrades of deficient items
5. Retest items repaired

This Retro-commissioning process is essentially a "return to plans and specs" and is allowed to be carried out over a period of up to five years. It should be noted that LEED-EB version 2.0 is now out of date and new projects are using LEED 2009 Operations and Maintenance which allows two options for commissioning – 1) traditional retro-commissioning and 2) an ASHRAE Level II Energy Audit, and it is now a credit worth two points instead of a project prerequisite.

Preparation for Retro-commissioning

Prior to the start of the RCx performance period, many building maintenance items were addressed. The building occupant had taken over full building management in January and noted many deferred maintenance items that required immediate attention such as dirty filters, faulty valves, and failed equipment.

The building occupant also determined to fix all retro-commissioning items immediately and not spread them out over the allowed 5-year term. As will be shown later in this paper, this allowed for immediate energy savings to be realized from items discovered during the RCx process.

RCx Implementation

LEED-EB defines many required items to be commissioned including: validation of proper space temperature, space pressurization testing, building envelope inspection, and HVAC testing. It also makes recommendations for implementation of supply temperature reset of chilled water, heating hot water, and discharge air.

Regarding implementation of the commissioning plan, LEED-EB allows two methods:

1) Visual inspection/observation with instantaneous measurements
2) Short-term or continuous measurements (data logging)

Both of these methods were utilized for the project. When data was available through the BAS, trends were set up to collect data that was utilized to verify that systems and equipment were operating as intended. Trends were set up for the following: chilled water supply/return temperature, chiller operating hours, building space temperatures, AHU supply air temperature, VFD speed, and outside air and exhaust air fan operating schedules. Items visually inspected included: AHU damper controls, Fan Powered Terminal Boxes, Chilled Water bypass valve operation, and kitchen and dishwasher exhaust hood operation.

It is not within the scope of this paper to cover all RCx items, but noteworthy items with energy impacts are presented below.

Chilled Water System Operation

The chillers are enabled when the outside air temperature is above 22ºF due to some of the spaces in the building that require cooling 24 hours a day, seven days a week and to maintain night-setback temperature ranges during the cooling season and that there is neither an air-side nor water-side economizer. Chilled water design supply and return temperatures at peak load are 42ºF and 52ºF, respectively.

Prior to the RCx process, the chilled water supply temperature was maintained at a constant 42ºF year-round. The chilled water (CHW) supply temperature set point was reprogrammed to allow a reset of the set point to range from 42ºF to 50ºF based on CHW valve position located at the AHUs. The reset schedule increases the CHW set point 0.2ºF every two minutes when all CHW valves go below 65%. The schedule will decrease the set point 0.2ºF every two minutes when any valve opens more than 65%. The lag chiller will be enabled when the supply CHW temperature rises above set point 4ºF for 10 minutes and be disabled when the temperature difference is 7.5ºF for more than 10 minutes.

A chilled water bypass valve is located in the mechanical room on the 5th floor. The CHW loop has two-way valves located at all the AHUs in the building. The design engineer provided a bypass valve in the loop to maintain proper chilled water flow through the chillers when the AHU chilled water valves modulate towards closed. The bypass valve modulates to maintain 15 PSI in the loop at all times.

Prior to RCx, this chilled water bypass valve was operating exactly reverse of design, thus opening the valve when all AHU chilled water valves were approaching open and closing the valve when all AHU chilled water valves were approaching closed. This was putting tremendous strain on the chillers and causing excessive energy consumption through pumping energy losses and low temperature differential between chilled water supply and return. It is believed that the majority of the initial energy savings were a result of correcting the operation of this chilled water valve.

Air Distribution

During the visual inspection of the Fan Powered Boxes and other Air Terminal Units, it was determined that these units were not properly calibrated for air flow. The building occupant hired a TAB firm to perform a full test and balance of the air terminal units. After the test and balance work was performed, a portion of the air terminal units were re-commissioned to verify proper operation.

After Hours Temperature Setback

The BAS was programmed to allow after hours space temperature setback to 80ºF in the summer and 60ºF in the winter. The air handling units (AHUs) were supposed to shut down after occupied hours and come back on if the space temperature exceeded the after-hours setpoints. It was discovered that this schedule was not operating properly. The AHUs were shutting down properly, but they were not coming back on until scheduled in the morning even if the space temperature exceeded the after-hours setpoint of 80ºF in the summer. This was corrected during the RCx process.

Supply Air Reset of Pressure and Temperature

Prior to RCx, all AHUs maintained a constant static pressure through VFD operation. A reset schedule was implemented as follows: when the average damper position in a VAV box is greater than 95%, the static pressure (SP) set point increases 0.1" every 5 minutes until set point is satisfied. When the average damper is less than 75%, the SP set point decreases 0.1" every 5 minutes until the set point is satisfied. This enables fan energy savings during periods of moderate space conditioning requirements.

The outside air quantity is constant as introduced by a terminal box into the mechanical room plenum. Only the percentage of outside air modulates as the total air modulates to the spaces.

Prior to RCx, all AHUs maintained a constant supply air temperature (SAT) in all seasons. A reset schedule was implemented as follows: the SAT at the AHUs is reset via a schedule when the outside air temperature OAT is between 35ºF and 70ºF. When the OAT is below 35ºF, the SAT is set at 65ºF, and when the OAT is above 70ºF, the DAT is 55ºF. The DAT is reset linearly 0.29ºF for every one degree of OAT rise or drop between 35ºF and 70ºF.

Building Envelope

Building envelope commissioning was required as a part of the LEED-EB v2.0 process. Two primary concerns arose during the post-season (winter) commissioning: 1) the first floor offices were extremely cold and 2) the building pressure was negative on the first floor, although the test and balance had just confirmed that the supply air to exhaust air ratio was positive for the building as a whole.

Regarding the cold offices, it was determined that there was a gap in the insulation in the parking garage ceiling (just below the first floor) which was allowing substantial heat loss from the space. This insulation is planned for replacement before the next heating season.

Regarding the negative pressure, commissioning agents discovered that the column caps on the roof were not properly sealed and were venting building air like an exhaust fan. The construction of the building was such that there was an air gap from the first floor to the roof between the interior and exterior walls. This was producing a "chimney effect" where hot air was rising through the building, escaping through these gaps, and causing a negative pressure on the lower floors. Additionally, these gaps allowed moisture intrusion (humidity, not direct water) into the space between the walls, which caused the exterior wall insulation to come un-taped in various locations and the building insulation fell away in these un-taped areas. These items will have all been fixed before the next heating season, and should provide additional energy savings for the project.

Figure1. Air leakage bends paper at roof column exposure.

Figure 2. Insulation not present along column, but present in most of parking garage drop ceiling.

Energy Savings for RCx Process

As seen from the figure below, implementation of the Retro-commissioning process as described above produced an instant energy savings over the previous two years.

The entire annual energy savings was 6% (Jan – Dec 2008) and the highest monthly energy savings was 14% over the average of the previous two years (2006 and 2007).

There is no gas usage for any building equipment. The electricity usage presented represents the entire building energy usage.

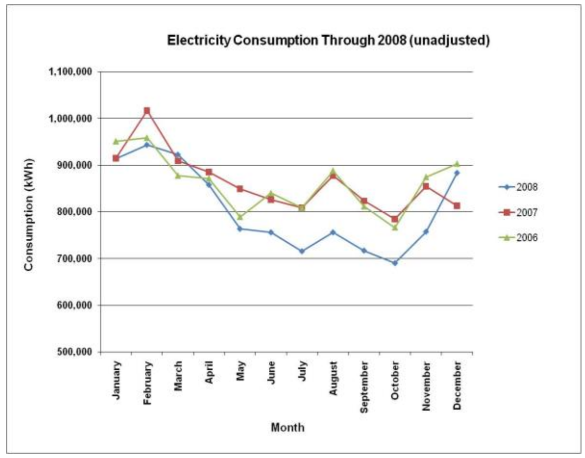

Figure 3. Unadjusted energy consumption (kwh) through December 2008.

CC PROCESS

After LEED-EB Gold Certification was achieved, the building occupant decided to keep commissioning continuous. SSRCx, a CC Licensee, was hired to perform Continuous Commissioning services for the 2009 calendar year. The remainder of the report provides the findings, implementation strategies, and results of the CC process.

Building Supply and Exhaust Air

The prior to the CC process, the building supply fan and exhaust fan were trended and found to be running continuously 24/7 because the electrical rooms and telecommunications closets were conditioned through exhaust air only. It was thought, based on the design, that exhaust had to be maintained in these rooms in order maintain room temperature. Since exhaust had to be maintained, and there was only one exhaust fan, then the supply fan had to run continuously as well so that building pressure would always remain positive.

Further investigation into this matter during the CC process revealed that there were automatic Fire/Smoke Dampers at the exhaust air shaft on every floor, and that these dampers were controlled through the BAS. Temperature data of the electrical and telecomm rooms revealed that these dampers were closing at 7pm and opening at 7am, thus shutting off exhaust airflow to each floor even though the exhaust fan itself continued to operate. No description of this time-of-day operation of these dampers was found in the original design drawings. The temperature in these rooms was elevated when exhaust air flow was restricted, but not beyond the range required by the equipment in the rooms, except for one telecomm room. This telecomm room was dealt with separately, and an additional VAV box was added to handle the heat load.

An operation schedule for the outside air supply fan and building exhaust fan was implemented to allow these fans to shut down after building occupied hours, thus saving fan energy and heating/cooling energy from no longer introducing outside air to the building during these times.

Air Terminal Boxes

Regarding after-hours temperature setback during winter operation, it was determined through the CC process that the perimeter Parallel Fan Powered VAV (FPVAV) boxes with electric reheat were not coming on to provide heating as intended. Space temperature trends revealed that these air terminal units were not allowing the electric heat to come on during a drop in space temperature below after-hours setpoint. Further investigation into this matter revealed that the terminal boxes were factory programmed to require main air from the AHU before turning on the electric heat in the box. This posed a problem because turning on the main AHU after hours would consume additional fan energy. Additionally, since many areas of the building were cold during morning start-up, the building temperature recovery through electric heat set the peak electric demand early in the morning and resulted in additional demand energy charges.

The equipment representative for the terminal units assisted in determining a programming solution to allow the electric heat to come on with the fan in the terminal unit (each FPVAV box controller was reprogrammed to reference box fan status rather than air flow to bring on the box heat). This allowed maintenance of after-hours space temperature without requiring the main supply fan to come on.

Air Handling Units

Several building spaces on various floors require continuous air conditioning 24/7. Prior to Continuous Commissioning, the AHU for the respective floor remained in occupied mode 24/7 and after-hours reset could not occur. If after-hours reset had been implemented in this scenario, it would have caused significant reheat in the summer season for spaces that were truly un-occupied.

The solution proposed was to allow only the air terminal units serving the spaces that need 24/7 conditioning to operate in occupied mode, and allow all other boxes on the floor to go to unoccupied mode and close off their damper. Testing of the AHU fan was required to determine if too much static pressure would build up in the duct when the majority of the air terminal units closed down. Due to the fan type (backward-inclined airfoil), VFD minimum setting, and AHU configuration, the static pressure in the duct did not climb high enough to trip the high-static sensor nor cause a concern.

This allowed for a significant reduction in after-hours fan energy and cooling energy consumption, thus compounding our energy savings for the facility.

Changes to After-Hours Operation

The system is equipped with thermostats that allow push-button over-ride for after-hours operation. Prior to CC, a few building occupants would come to work overtime, and would require conditioned work space. In these instances, employees would notify building operations staff and they would over-ride a whole floor (there is only one AHU per floor) for occupied operation. This was standard practice for four hours on Saturday, and occurred at other times almost weekly.

Through previous findings described above regarding after-hours operation of the 24/7 spaces, where an AHU could be operated for very low supply air conditions, it was determined that this same strategy could be used to allow user over-ride of only a few zones to occupied mode instead of having to over-ride an entire floor for one or two people. Now, instead of over-riding an entire floor, building staff over-rides the space (and maybe an adjacent space) where the occupant will reside to provide heating or cooling comfort needs.

Continued Energy Savings

Savings resulting from the implementation of the FPVAV box re-programming in mid-February can be seen in the March utility bill, as the energy consumption was reduced by 12% over the average of the previous three years in that month where heating demand was still significant. The electricity demand (kW, not shown) remained high, indicating that equipment staging or other peak demand reduction strategies may be necessary.

Total unadjusted savings for January 2008 – August 2009 is 10% over the previous two years. Additional savings from the CC process during the cooling season was as high as 16% for the month of August 2009, making the combined savings for this month 28% over the 2006-2007 baseline. These savings are represented graphically in Figure 4.

The energy use index (EUI) in January 2008 was 107.5 (kBtu/sf/yr) and is now 95.2 as of August 2009.

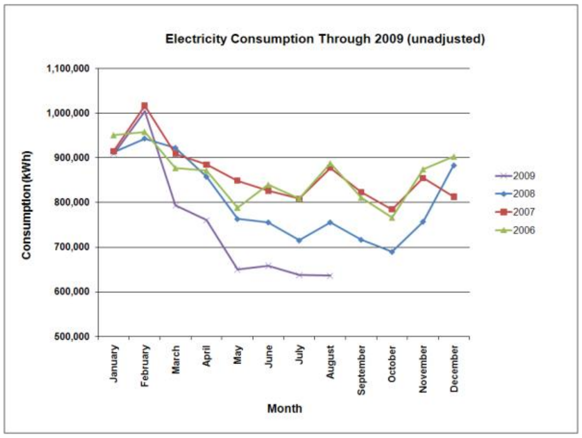

Figure 4. Unadjusted energy consumption (kwh) through August 2009.

Table 1. Summary of Energy Conservation Measures for RCx and CC.

Category	LEED RCx Result	Additional CC Enhancements
AHU Discharge Air Temperatures	Reset linearly based on outside air temperature.	Continued verification of proper operation through BAS trend data.
AHU Duct Static Pressure Set Point	Reset linearly based on worst-case VAV box damper position	Continued verification of proper operation through BAS trend data.
Water Loop Differential Pressure	Modified operation of chilled water bypass valve	Continued verification of proper operation through BAS trend data.
Chilled Water Temperature Reset	Reset linearly based on outside air temperature.	Continued verification of proper operation through BAS trend data.
Building sealing and additional insulation	Sealing installed, insulation not yet installed.	Will check building pressure during winter to verify strategy was successful.
Supply/Exhaust Fan Schedule	N/A	Implemented a time of day schedule for supply fan and exhaust fan operation.
FPVAV Box Program Modification	N/A	Modified FBVAV Box program to provide heating after-hours, reducing overall demand during startup.
AHU operation for 24/7 spaces	N/A	Modified operation of air terminal units to only provide heating/cooling for 24/7 spaces without conditioning the entire building floor.
AHU operation for after-hours setback	N/A	Modified operation of thermostats to allow occupant over-ride after-hours, similar to operation of spaces requiring 24/7 conditioning.

CONCLUSIONS

From the savings analysis performed, it is apparent that the CC process was beneficial in further reducing energy consumption in the building, beyond the reductions which occurred during the LEED-EB Retro-commissioning process. This was partly due to the commissioning agent having more time to study and learn about building systems operation, and partly due to building operations staff gaining confidence in the ability of their systems to respond to the operational changes implemented – and achieve expected energy results.

The client is extremely encouraged by the energy savings that have been achieved to date, and has substantial goals for additional energy savings in the future, including CC and capital improvement projects. Most of the energy savings to-date on the project was the result of implementing the RCx and CC processes. Some energy savings and other financial savings through water and solid waste management was achieved through capital expenditure projects such as some lighting retrofits, a non-chemical cooling tower water treatment system, and a recycling program, respectively. Additional energy savings is expected during the coming heating season due to changes to Fan Powered Box operation and additional building insulation that will be added this fall.

The building occupant has calculated a simple payback of 3.5 years for the entire LEED-EB Gold Certification process based on the current energy savings. If energy savings exceeds the current trend, as is anticipated, then the payback will be even faster.

Regarding the cost vs. savings of the combined RCx and CC processes, the simple payback is less than 2 years.

It can be concluded that the use of Continuous Commissioning in a facility, even after a full Retro-commissioning process, can harness additional energy savings through operational adjustments.

REFERENCES

LEED for Existing Buildings Version 2.0 Reference Guide. (2006). U.S. Green Building Council.

LEED Reference Guide for Green Building Operations and Maintenance 2009 Edition. (2009). U.S. Green Building Council.