Continuous Commissioning® of an Office/Laboratory Building

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Abstract

Initial implementation of Continuous Commissioning® (CC®) measures in Building 6585, the Technology Support Center at Sandia National Laboratory, was conducted during February and March, 2005. The major measures implemented were reduction of minimum flow settings of VAV boxes as appropriate, correction of an error in the control code that resulted in continuous operation of one AHU, and reduction of static pressure settings on the AHUs. In addition, AHU start times were generally delayed by one to two hours, chilled and hot water secondary loop performance was improved, and the preheat control strategy was changed. Data for heating and electricity consumption were analyzed for approximately four months following implementation of most of the measures, and savings of approximately 127,000 kWh of electricity and 250 MCF of gas were observed. If the savings continue at the same weather adjusted rate for one year, total cost savings will exceed $30,000, or more than 50% of the HVAC energy consumption of the building.

Background Information

Continuous Commissioning® (CC®)[1] has been shown to be a highly cost effective way of reducing energy cost while improving comfort in many different types of facilities in widely varying climates. (Liu et al. 2002) The Energy Management Team (EMT) at Sandia National Laboratory (SNL) was tasked to determine the effectiveness of CC in existing buildings at the Laboratory and determine if CC could become an important part of the overall energy management program at the SNL. The SNL staff chose Building 6585, a 99,579 ft^2 office and laboratory building as the test case. This building was built in 1995 as a design-build project, and control schemes had not been changed significantly since. Hence it was believed that there would be significant opportunities present in this building. Initial review of utility bills indicated that while chiller consumption was not excessive due to extensive use of economizers, evaporative cooling and cooling tower water for cooling, gas consumption seemed higher than necessary for a building with VAV air handling systems.

Given the level of ongoing team responsibilities, it was decided to contract with the Energy Systems Laboratory (ESL) to implement Continuous Commissioning® (CC®) in this trial building.

Facility Description and Energy Use

SNL Building 6585, the Technology Support Center is a 2-story building with a basement and an HVAC penthouse (see Figure 1). The total conditioned space is 99,579 ft^2 of which the mechanical rooms in the basement and penthouse account for approximately 20%. Heating and cooling

Figure 1. Technology Development Center at Sandia National Laboratory.

[1] Continuous Commissioning and CC are registered trademarks of the Texas Engineering Experiment Station. To improve readability, the symbol will sometimes be omitted.

for the building are provided by two 4 MMBtu/hr hot water boilers and three 225 ton electric screw chillers. Five single duct, Variable Air Volume (VAV) systems, with reheat at the terminal boxes serve the building. Air handler units 1 and 4 serve the exterior zones, which are primarily office space; air handler unit 5 provides conditioned air for a conference room; and the remaining air handlers, units 2 and 3 were originally designed to use 100% outside air and serve laboratory areas, which are interior zones. Some time near the end of the design phase or just prior to the construction phase, a decision was made to install returns with dampers for AHUs 2 and 3. This was done because it was anticipated that significant square footage would not be used as laboratories. Each of the AHUs contains both a chilled water coil and a cooling coil that is connected to the cooling tower sump through a heat exchanger. The cooling towers are used to provide building cooling for nearly six months per year since Albuquerque has over 5,000 hours per year when wet bulb temperature is below 50ºF (Air Force 1978). The EMCS (Energy Management Control System) is a Siemens Apogee system. The DDC (Direct Digital Control) hierarchical level is capable of monitoring and controlling down to the VAV terminal box.

Energy use in the building is measured using two electrical meters and a gas meter. The electrical meters provide hourly readings while the gas meter is normally read on the first day of each month. Since the CC project began, it has generally been read daily. One of the electric meters primarily monitors a number of computer servers so the nominal load of 100 kW on this meter shows very little variation throughout the day or the year. The other electric meter monitors all remaining electricity use in the building including the chillers and distribution systems.

Gas use from November 2003 – November 2004 is shown in Figure 2. Total use for the 12-month period beginning with December, 2003 which will be used as the baseline period for this project was 3464 MCF. An average gas cost of $7.00/MCF will be used. Electricity use was 3,070,189 kWh during the same December – November period, for an average use level of approximately 350 kW is shown in Figure 3. Figure 3 shows both total electricity consumption in the top series and process electricity consumption in the bottom series. The electricity price paid for September-November, 2004 averaged $0.0407/kWh, so this value will be used as the basis for this project. Using these prices, annual baseline energy costs for Building 6585 total $149,205 including $24,248 for gas and $124,957 for electricity as shown in Table 1.

Examination of the pattern of gas consumption shows that summer use is typically half of the winter consumption indicating that there is significant reheat in the building. Similar examination of the electricity consumption pattern shows that base process consumption increased by 15-20 kW during May and that chillers were used beginning in early May and continuing through late October with scattered use during November. Chiller operation appears to have been continuous from about mid-June through mid-August. Analysis of the consumption data, observations of AHUs and pumps during the site visit including selected pressure measurements and flow measurements, and use of EMCS schedule information lead to the estimates of HVAC consumption provided in Table 1.

Table 1. Electricity and gas consumption for Building 6585 from December 2003 – November 2004 including estimated HVAC use.

Use	Annual Consumption	Cost ($/year)
Electricity	3,070,189 kWh	$124,957
Gas	3464 MCF	$24,248
Baseline Energy Cost		$149,205
Estimated HVAC Use/Cost		
Heating	3464 MCF	$24,248
Chiller cooling	224,400 kWh	$9,135
Fans and pumps	475,000 kWh	$19,337
Total HVAC Cost		$52,720

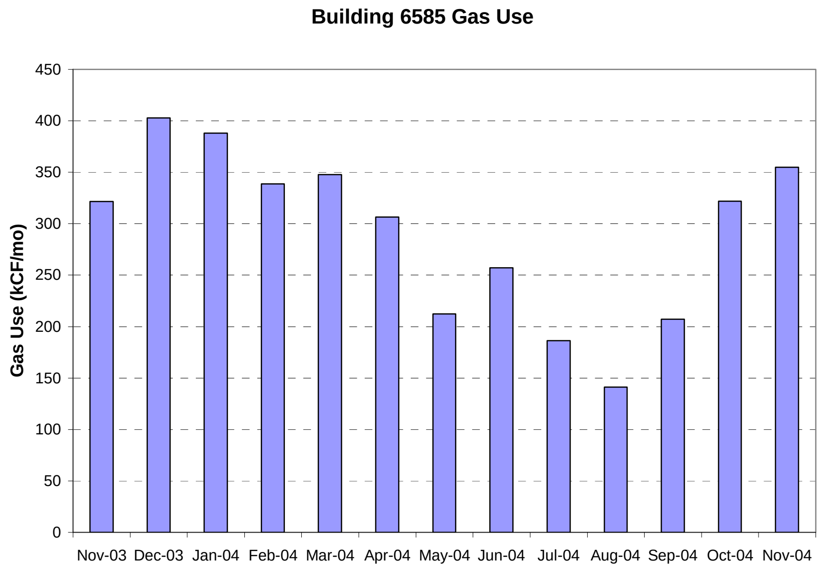

Figure 2. Gas use for Building 6585 from December, 2003 through November, 2004 in thousands of cubic feet per month.

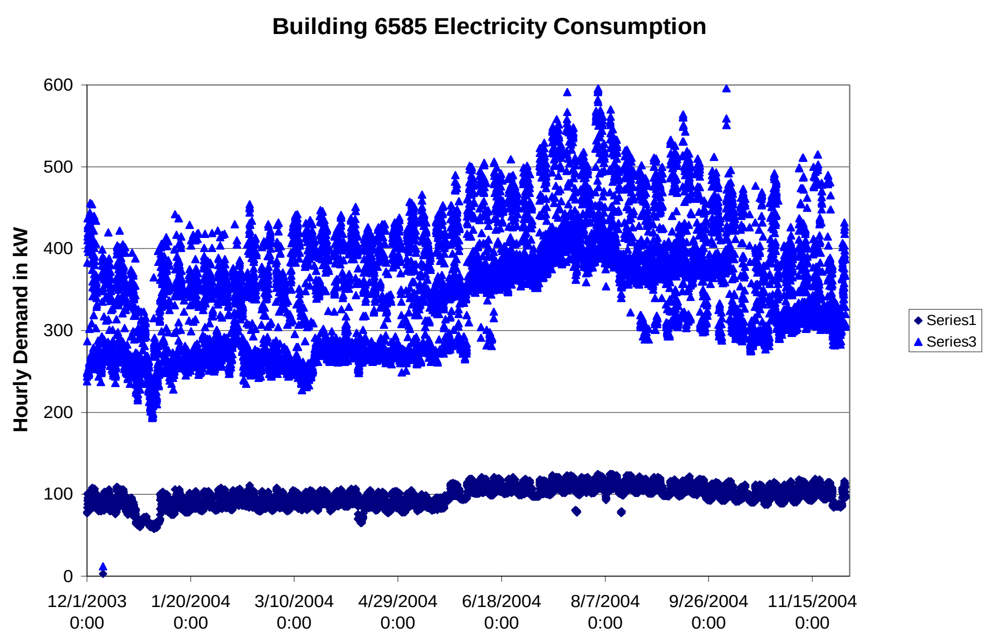

Figure 3. Total hourly electricity use for Building 6585 from December, 2003 through November, 2004 in kW (light blue). Bottom data is process consumption.

HVAC Systems and Operation

On each single duct VAV unit, the supply fan speed is controlled by the duct static pressure set point. The control algorithms indicate that constant value set points are used. The static pressure set points range from 1.0-1.8 in. H_2O. Air handler units 1, 4, and 5 are configured with return air fans as shown in Figure 4. The return fan speeds for units 1 and 4 are modulated and sequenced with the relief air dampers to control building pressurization. The return fan speed for unit 5 is controlled to maintain a constant ratio of 95% of the supply fan speed. Air handler units 2 and 3 are not configured with return air fans. They use face and bypass dampers.

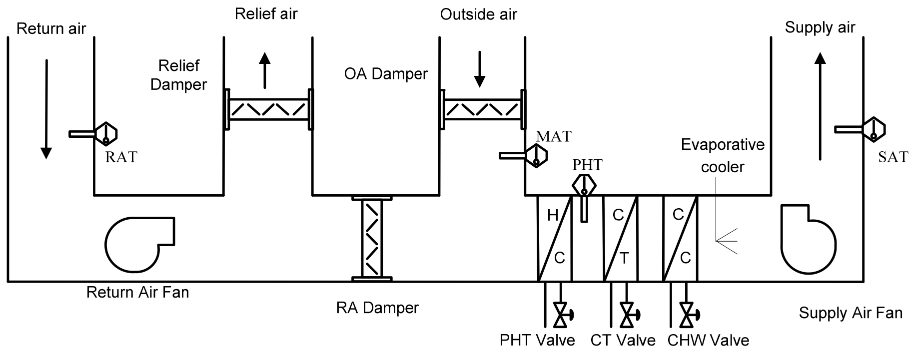

Figure 4. Air handler schematic for units 1, 4, and 5.

The supply air temperature set point for each unit uses a linear reset schedule based on outside air temperature (see Table 2), with the exception of unit 5. The supply air temperature set point for unit 5 is based on the VAV box cooling loop output values. According to the control program, the preheat valve, the cooling tower coil valve, the evaporative cooling (when ambient conditions meet the enthalpy and wet bulb temperature criteria for the outside and return air), and the chilled water valve are sequenced to maintain the supply air temperature.

Table 2. Supply air temperature reset schedules.

Supply Air Reset Schedule based on OAT				
AHU #	OAT LO (°F)	OAT HI (°F)	SA HI (°F)	SA LO (°F)
1	60	100	63	55
2	60	100	65	55
3*	60	100	65	55
4	60	100	63	55
Supply Air Reset Schedule based on VAV load				
AHU#	Load LO (%)	Load HI (%)	SA HI (°F)	SA LO (°F)
5	50	85	65	55

* No control programming available. Assumed reset schedule is the same as AHU #2.

A dedicated chilled water and hot water system is provided for the building cooling and heating loads. The cooling load for this building consists of the sensible and latent loads met by the AHUs in addition to process loads in the laboratory sections of the building met by fan coil units. The chilled water system is located in the basement of the building. Three chillers (with R-22, each at 225 tons) are operating in a parallel configuration supplying chilled water to a primary/secondary distribution system. The control strategy for the chiller staging is based on loop flow rate. If the loop flow rate is greater than 560 GPM, the chiller load is greater than 78%, and the loop supply water temperature is 2°F greater than its set point, then the lag chiller will be brought online. Typically, one chiller is online during the summer months (May-October). During extreme cooling load conditions a second chiller is called online. The logged runtime hours of the three chillers are 9,699, 8,495 and 8,016 for a total of 26,210 hours of chiller operating time, or an average of 2621 hours/year in the approximately 10 years since the building was built. This corresponds to 24 hour operation of a single chiller for 2 months with an average of 33 hours per week of chiller operation for an additional four The supply air temperature set point for each unit uses a linear reset schedule based on outside air temperature (see Table 2), with the exception of unit 5. The supply air temperature set point for unit 5 is based on the VAV box cooling loop output values.

An additional source of cooling for the building is provided by the cooling tower system. Three cooling towers are located on the south side of building 6585. Each tower has a nominal cooling capacity of 235 tons. Original cooling tower piping design allows the towers to operate with any chiller that is enabled. Two remote sumps for the cooling towers are located in the basement pump room. These remote sumps have a maximum storage capacity of 2,850 gallons. Under ambient conditions when the cooling tower sump temperature is sufficiently low, tower supply water can be used to provide cooling to the air handler units and the process chilled water system through a plate-frame heat exchanger. The cooling towers are enabled when a chiller condenser water pump is running, a process heat exchanger tower water pump is running, or the building supply fan tower water coil pump is running. Typically, two fans operate when the towers are enabled.

The building hot water system is located in the penthouse. Heating is provided by two natural gas water tube boilers (4 MMBTUH max. output/boiler). According to information provided, these boilers were converted from LPG and capacities corrected for 5500 ft elevation. The boilers and the secondary hot water pumps are controlled by unitary controllers. Apogee programming is used to interlock the two unitary controllers and stage the boilers based on outside air temperature set points. The hot water system is configured in a primary/secondary distribution system. The secondary hot water distribution system is driven by two variable speed hot water pumps (85 GPM each). In addition to the secondary distribution system, two variable speed pumps (41 GPM each) deliver hot water to the laboratory section.

CC Assessment

A Continuous Commissioning® (CC®) Assessment of Building 6585 was conducted in January 2005. The assessment began with a meeting between two engineers from the ESL, the Energy Manager, two other engineers on the Sandia EMT, and the building controls technician. At this meeting the HVAC system characteristics and control as currently implemented in the building were discussed and current gas and electricity consumption data was reviewed. It revealed that the building basically works well, but SNL staff indicated that they expected opportunities to improve operational characteristics of the building since the basic building operation was determined and set up as part of a turn-key project in the mid-1990s and has not been optimized since then. This was followed by examination and printing of EMCS screens providing current operating status for all major air handlers, chillers, boilers, and water side distribution systems in the building.

A walkthrough of Building 6585 was conducted the afternoon and the morning of the next day by the ESL personnel and the lab EMT. This walkthrough was primarily devoted to a detailed examination of the systems in the basement and penthouse mechanical rooms supplemented by visits to several offices on the first floor. Measurements of key temperatures, flows and pressures were made during the walkthrough. Information obtained during the walkthrough, supplemented by building drawings, energy consumption data, and additional information supplied by the EMT was subsequently analyzed to identify a preliminary list of CC® measures recommended for implementation in Building 6585.

Observations and Findings of the Walkthrough

During the walkthrough of the building, CO_2 measurements were taken in the office areas of the first floor. The average CO_2 reading was 385 ppm, or only 35 ppm above the ambient level of 350 ppm. This was due to the operation of the economizers in the air handlers at the time of the walk through.

Air Handler Operation

Air handler units 3, 4, and 5 were started at approximately 4:00 a.m. and stopped at 7:00 p.m., Monday through Friday. Air handler unit 2 was started at approximately 5:00 a.m. and stopped at 6:00 p.m. Air Handler unit 1 was operating on a continuous basis. During the periods when an air handler unit is scheduled off, occupants can use the override buttons located on the thermostats to activate the air handler unit for a two hour period. . Static pressure set points on all five AHUs were constant values.

Loop Balancing

In evaluating the chilled water and hot water systems, special attention was given to the positioning of all manual valves. The manual valves located on the discharge side of the secondary chilled water pumps were 50% closed. The manual valves located on the chilled water return lines for each air handler were also 50% closed. Rebalancing was recommended to reduce the pumping power needed to supply the loop.

The hot water system did not have any flow restriction. However, the bypass for the primary and secondary distribution system has a manual valve in place. The valve is 100% open. Only one pump was running at the time of the assessment and the VFD for the pump motor was operating at 60 Hz. No trend data was collected for the hot water supply and return temperatures.

VAV Box Operation

Based on information gathered through discussion with facility personnel, sensor calibration is not performed except when a problem is noted. VAV box calibration plays an important role in the reduction of fan power. Because of time constraints, verification of maximum and minimum air flows for individual terminal boxes was not possible. Because functions within the building change, minimum design flow settings may exceed the necessary airflow requirements. The combined minimum supply flow of 46,800 cfm currently set on the terminal boxes will lead to requirements for reheat during a significant portion of the year and is a