RESULTS OF CC FOLLOW-UP IN THE G. ROLLIE WHITE BUILDING

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ABSTRACT

An investigation into the increase of energy consumption of G. Rollie White Coliseum was part of the persistence project[1], which investigates the savings in energy consumption of ten buildings that were commissioned by the Continuous Commissioning (CC[SM]) group at the Energy Systems Laboratory (ESL), Texas A&M University (TAMU). The CC process was conducted between 1996 and 1997 under direction of and in cooperation with the TAMU Physical Plant Energy Office. Total savings for the ten building are $4,255,000. Most of them had small savings degradation (or increased savings), but the degradation of savings of G. Rollie White Coliseum was larger than all the other buildings.

The CC follow-up activities on the investigation into the increase of energy consumption of G. Rollie White Coliseum included energy consumption and HVAC system operation data analysis, measurement on HVAC systems, and examination of the control program. HVAC hardware problems, HVAC operation problems, and control program problems were found. By fixing HVAC hardware problems, correcting HVAC operation, and modifying control program, the indoor air temperature and humidity are now under control and annual energy savings of about $36,300 more than the initial CC are being achieved.

FACILITY INTRODUCTION

G. Rollie White Coliseum is a volleyball gymnasium that is located on the campus of Texas A&M University. The building, built in 1954, has spectator seating on sloped surfaces on three sides of the arena area within the building and two office floors under the seating. It can accommodate 7,500 spectators. The conditioned area is about 74,900 ft^2.

Thirteen Air Handling Units (AHUs), AHU#1 to AHU#13, are located near the roof in the approximate positions shown (as numbered rectangles) in Figure 1 and serve the arena. These units are single-duct constant air volume systems with direct digital control (DDC). A typical diagram of one of the 13 AHUs is shown in Figure 2. The chilled water and hot water control valves were originally modulated to maintain the return air

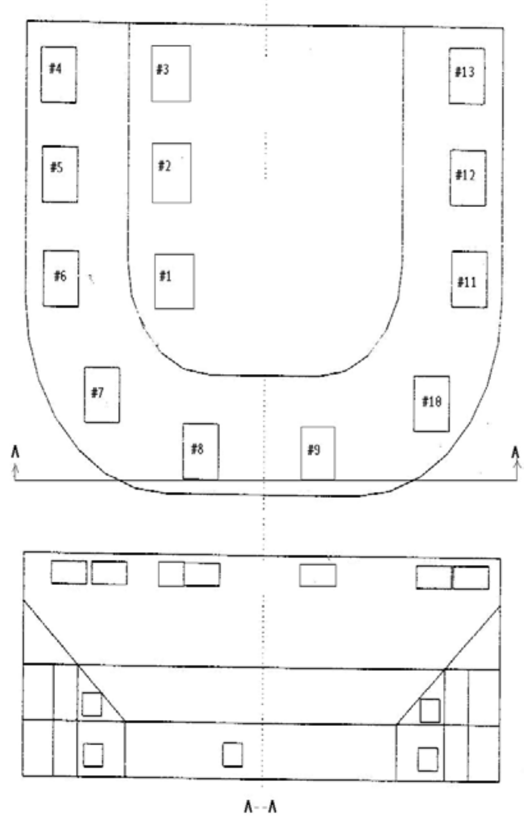

Figure 1: The plan and elevation views of the Coliseum

temperatures at their set-points by pneumatic controllers.

Five AHUs, AHU-A to AHU-E, located on the 1st floor and the 2nd floor, are single-duct constant air volume systems with local pneumatic control (rectangles at lower levels in elevation view in Figure 1). The cooling capacities of these five AHUs are much smaller than the cooling capacity of the 13 AHUs serving the arena.

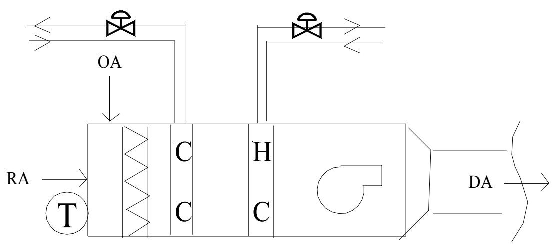

Figure 2: System diagram typical of the 13 large AHUs

The pumps in the pump room on the 1st floor supply the chilled water and hot water to the coils. The chilled water pumps have variable frequency drives (VFDs) while the hot water pumps are constant speed.

THE INITIAL CC MEASURES IMPLEMENTED AND ENERGY CONSUMPTION

The G. Rollie White Coliseum had initial CC measures implemented during the period May 1997 to July 1997. The thirteen AHUs serving the arena, the chilled water pumps and the hot water pumps were retrofitted with DDC control during that time. VFDs were also installed on the chilled water pumps. Since DDC control was installed, only AHU#2 runs all the time. Other AHUs cycle on and off as needed. The control scheme starts or stops one AHU at a time in 15-minute intervals to maintain the space temperature setpoint. The building chilled water differential pressure (DP) setpoint was changed from 54 psi to a variable value with a maximum of 18 psi as determined by the equation

$$DP=0.0000226*GPM*GPM$$

Here GPM is chilled water flow rate. Building chilled water DP setpoints for a range of flow rates are shown in Table 1.

GPM	300	600	900
DP (psi)	2.03	8.14	18.31

Table 1: Building chilled water DP setpoints

The hot water pump serving the thirteen AHUs had DDC start/stop before CC measures were implemented. But other hot water pumps were on all the time before the CC implementation. The cooling and heating coils on all AHUs were cleaned and outside air balances were performed as part of the CC effort.

The chilled water consumption, hot water consumption and electricity consumption for the period from January 1997 to July 2001 are shown in Figure 2 to Figure 4, respectively. Figure 2 shows that chilled water consumption came down significantly during the first two years after CC implementation, but it came back up during 1999, 2000, and the first half of 2001. The hot water consumption likewise decreased during the first two

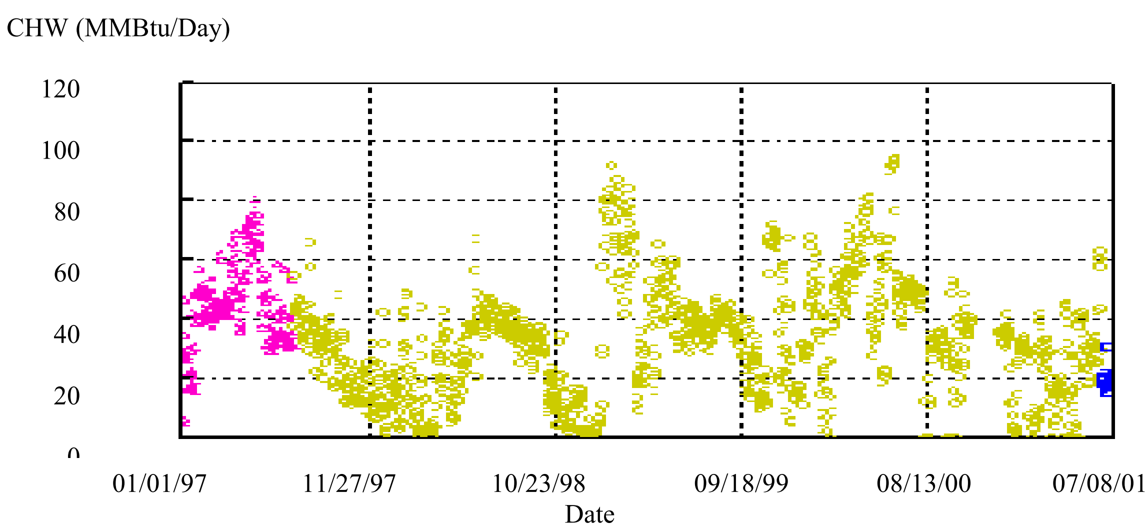

Figure 2: Chilled water consumption

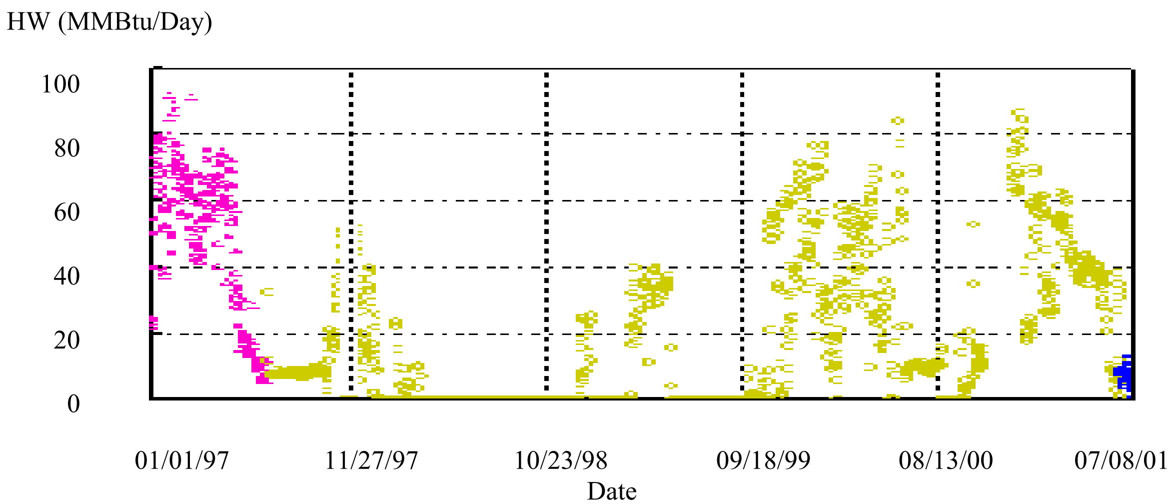

Figure 3: Hot water consumption

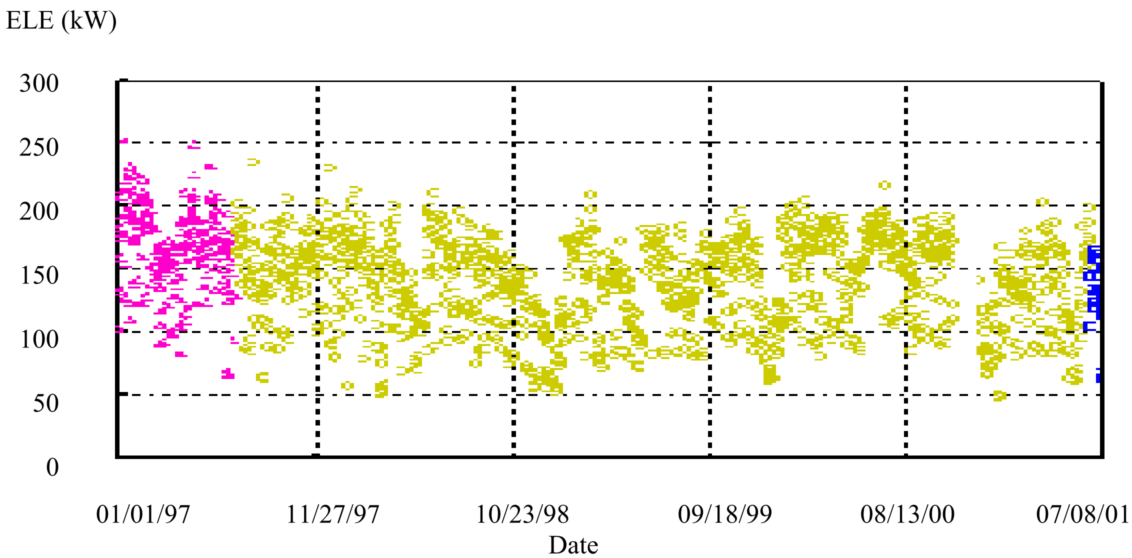

Figure 4: Daily electricity consumption (in average kW)

years after the CC implementation, as shown in Figure 3. But then during 1999 and 2000, hot water consumption increased and was even higher than the hot water consumption before CC implementation. The electricity consumption was reduced slightly after the CC implementation. There is no obvious increase or decrease in the electricity consumption shown in Figure 4 during the past couple of years.

The energy savings after CC implementation are shown in Figure 5 for the years from 1997 to 2000. During 1997 and 1998, chilled water savings of 54% and 55% were achieved. But the savings dropped to 23% in 1999 and 16% in 2000. The hot water savings were 71%, 97% and 77% in 1997, 1998 and 1999 respectively, but dropped to 52% in 2000. The electricity savings were 12% in 1997, 21% in 1998 and 1999, and 13% in 2000.

After the energy consumption increase was noted, the CC group performed CC follow-up from May 28, 2001 to June 15, 2001 under the direction of and in cooperation with the TAMU Physical Plant Energy Office.

DDC CONTROL AND HARDWARE CONCERNS FOUND

It is found that the energy consumption increase was caused by wrong control schemes and hardware problems. Operators made the wrong control schemes when they performed trouble shootings or control program maintenance. These wrong control schemes are listed as bellow.

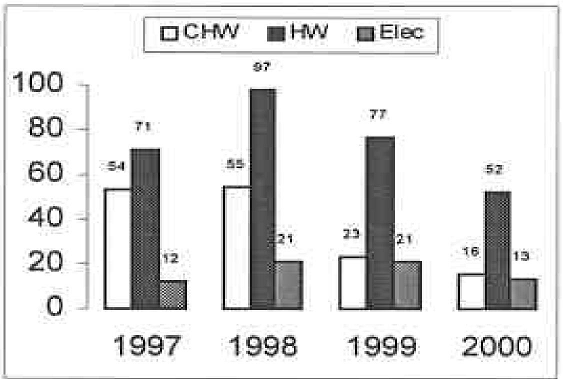

Figure 5: Energy savings after CC implementation

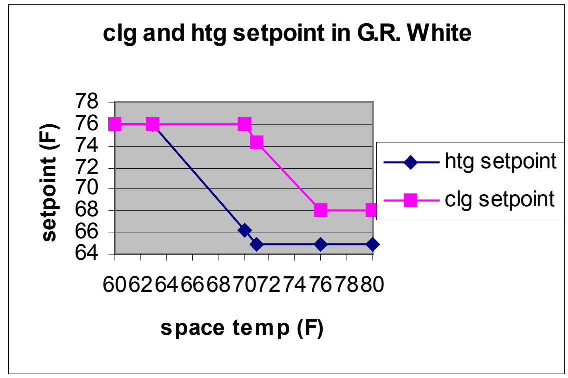

Figure 6: cooling and heating setpoints when there was no event

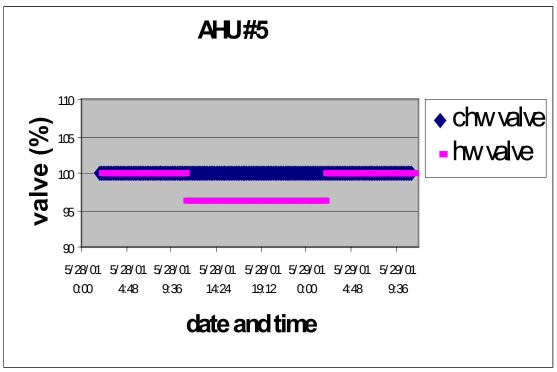

Figure 7: Simultaneous cooling and heating on AHU#5

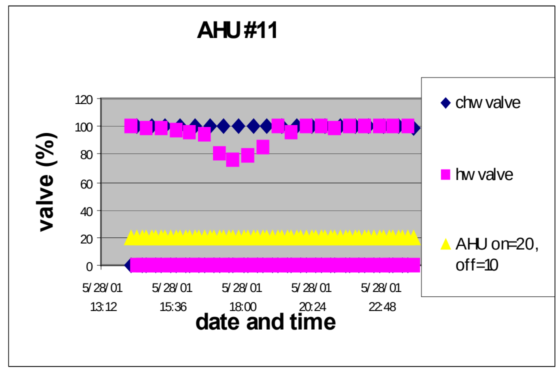

Figure 8: Simultaneous cooling and heating on AHU#11

The thirteen AHUs located near the roof each have cooling and heating coils as shown in Figure 2. When the arena is in use, the chilled water control valve is modulated to assure that the return air temperature remains at or below its setpoint of 74 °F and the hot water control valve is modulated to assure that the return air temperature does not drop below its setpoint of 68 °F. But a cooling setpoint of 68 °F and a heating setpoint of 74 °F were overridden by an operator. This caused the cooling valve and heating valve to be open simultaneously. Simultaneous cooling and heating were observed in six AHUs during the investigation. The examples of simultaneous cooling and heating are shown in Figures 7 and 8. The graphs in Figure 7 and Figure 8 were generated from EMCS trend data. Figure 7 shows that both the cooling and heating control valves on AHU#5 were fully open from 1:00 am to 11:00 am of May 28 and May 29, 2001. The cooling control valve was 96% open, while the heating valve was fully open for the period from 11:00 am on May 28, 2001 to 1:00 am of the next day. The result was that much energy was wasted. The trended data in Figure 8 likewise verifies the cooling valve and heating valve of AHU#11 were also on simultaneously from May 28, 2001 to May 29, 2001. These problems were also caused by incorrect space humidity set-points.

When there was no event is scheduled, the cooling and heating setpoints were set based on the space temperature as shown in Figure 6. Practically, this controls so room temperature is floating between 68.5 °F and 72.6 °F. It used more energy when the cooling setpoint was changed from 74 °F to 72.6 °F, when there was no event. The cooling setpoint should be higher if there was no event.

Further both the chilled water and hot water control valves on AHU#13 were reverse action valves, while the control program assumed normal action valves. Consequently, the cooling valve would open when the space needed heating and vice versa. Since the space needs cooling more often than heating, the common response was for the cooling valves on the other AHUs to open more to counter the heat coming from AHU#13.

It is apparent the AHUs were turned on/off by the wrong control scheme.

Also the hot water pump was off, when it should be on and vice versa. This control error increased chilled water consumption and hot water consumption due to hot water leakage due to the high pressure across the hot water valves on the AHUs when they were closed.

The hardware problems found are listed as bellow.

The hot water electric control valve on AHU#5 did not move when commanded closed or open and the chilled water control valve PXP on AHU#9 was not functional which kept the valve fully open.

Another problem was that the chilled water flow sensor failed and gave a reading of 1447 GPM. This resulted building chilled water DP setpoint of 49 psi (based on the DP equation) that is much higher than the normal range of 2-18 psi. That in turn resulted in

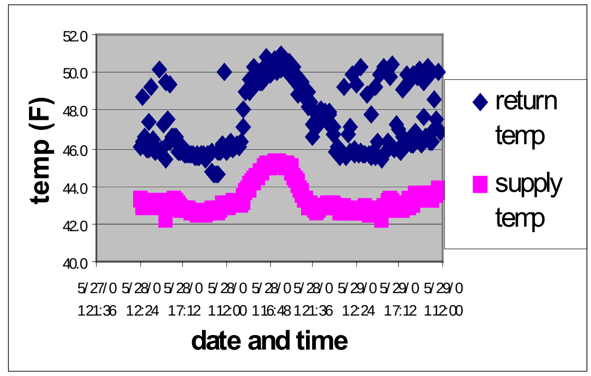

Figure 9: Building chilled water supply and return temperatures

the low building chilled water delta T of only 5°F shown in Figure 9.

SAVINGS ANALYSIS

Major activities of the CC follow-up started on 5/28/01 and ended on 6/15/01. Daily whole building chilled water, hot water and electricity consumption data was retrieved from the Physical Plant energy

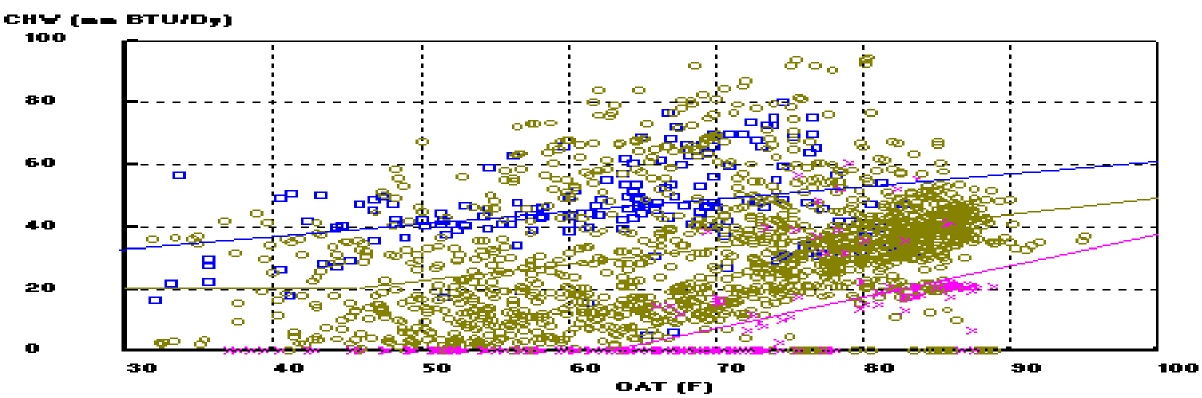

Figure 10: Chilled water consumption
(□--before CC, o--between CC implementation and follow-up, x--after CC follow-up)

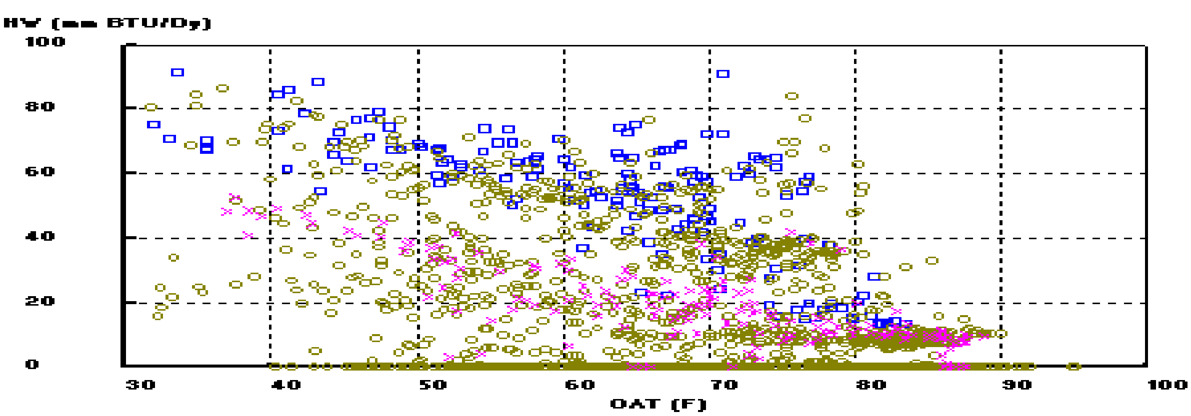

Figure 11: Hot water consumption
(□--before CC, o--between CC implementation and follow-up, x--after CC follow-up)

management database. All the data was grouped for comparison, with data prior to CC implementation (1/1/1997 to 7/20/1997) shown as □; data after CC implementation and before follow-up (7/21/1997 to 6/20/2001) shown as o; and data after the CC follow-up (6/20/2001 to 1/9/2002), shown as "x". The data for chilled water, hot water and electricity consumption are shown respectively in Figures 10, 11 and 12.

Compared with CC implementation, the chilled water savings from the CC follow-up is about 15MMBtu/day, or about $22,500 annually; hot water savings are about 5 MMBtu/day, or $8,500 annually; and electricity savings are about 15 kW on average or about $5,300 per year. This gives total savings from the CC follow-up of about $36,300 per year.

The whole building chilled water, hot water and

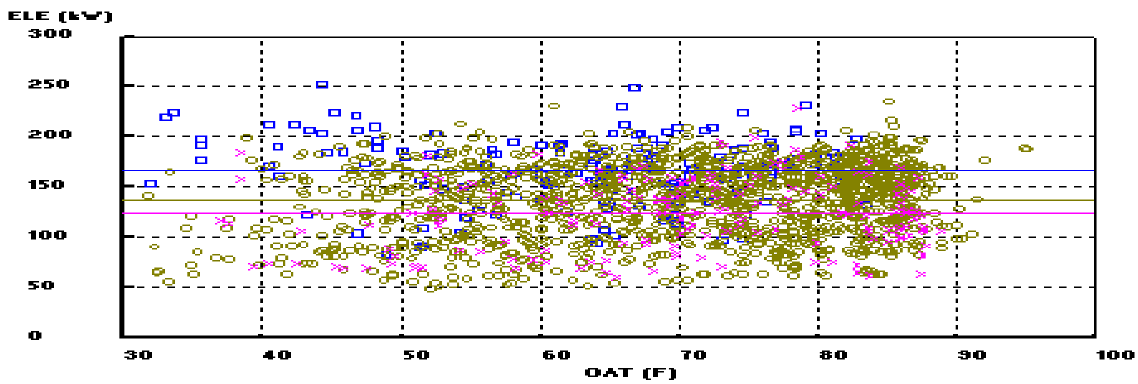

Figure 12: Electricity consumption
□--before CC, o--between CC implementation and follow-up, x--after CC follow-up)

G.White	wbcool	Savings	wbheat	Savings	Elec.	Savings	total savings	Ltotal in seven month
Month	MMBTU	USD ($)	MMBTU	USD ($)	kWh	$	USD ($)	USD ($)
Jun-97	1,207	$5,636	594	$2,823	-1,159	($31)	$8,428	
Jul-97	1,466	$6,847	374	$1,779	16,678	$465	$9,091	
Aug-97	1,572	$7,341	426	$2,024	30,957	$863	$10,228	
Sep-97	1,499	$7,002	717	$3,404	20,262	$565	$10,971	
Oct-97	1,221	$5,703	1,243	$5,906	17,877	$498	$12,107	
Nov-97	881	$4,116	1,062	$5,046	16,934	$472	$9,634	
Dec-97	835	$3,898	1,217	$5,781	17,049	$475	$10,154	$70,613
Jun-00	-1,499	($7,004)	-92	($443)	-2,101	($58)	($7,505)	
Jul-00	1,308	$6,110	143	$678	9,987	$278	$7,066	
Aug-00	2,191	$10,234	282	$1,337	22,519	$628	$12,199	
Sep-00	1,646	$7,685	762	$3,619	14,142	$394	$11,698	
Oct-00	950	$4,435	1,078	$5,121	16,316	$455	$10,011	
Nov-00							$0	
Dec-00	185	$865	-63	($302)	62,664	$1,747	$2,310	$35,779
Jun-01	1,583	$7,390	506	$2,402	19,148	$534	$10,326	
Jul-01	2,273	$10,616	335	$1,590	43,617	$1,216	$13,422	
Aug-01	2,152	10,051	306	1,452	40,673	1,134	12,637	
Sep-01	1,310	6,118	628	2,982	23,186	646	9,746	
Oct-01	1,745	8,149	966	4,588	30,721	857	13,594	
Nov-01	1,592	7,436	1,245	5,912	37,878	1,056	14,404	
Dec-01	1,423	6,644	1,046	4,970	50,987	1,422	13,036	$87,165

Table 2: Whole building savings in MMBtu and dollars

electricity savings were determined by the Data Analysis group at the ESL for each month from 1997 to 2001. The monthly savings for June through December of 1997, 2000 and 2001are shown in Table 2 for comparison. The total savings in seven month from July through December of 1997, 2000 and 2001 are $70,613, $35,779 and $87,165 respectively. The savings level in 2001after the CC follow-up is more than it was immediately after CC implementation in 1997, and much more than it was prior to the follow-up effort in 2001.

CONCLUSIONS

The building HVAC systems operation has been improved by continuous commissioning. Savings after the CC follow-up effort are greater than the initial CC implementation achieved, after wrong control schemes were corrected and hardware problems were fixed. This investigation, as a CC follow-up, shows that continuing to commission can keep energy consumption optimized. Compared with savings immediately after CC implementation, savings from the CC follow-up is about $36,300 per year.

ACKNOWLEDGEMENTS

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