Continuous Commissioning® of the Reynolds Army Community Hospital Fort Sill, Oklahoma

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ABSTRACT

Continuous Commissioning® (CC®[1]) of the Reynolds Army Community Hospital facility was a two phase project. The first phase consisted of a point-to-point verification of a newly upgraded Energy Management Control System (EMCS) and calibration of key sensors that would have a significant impact on control system operations. The second phase was the implementation of CC® opportunities identified during the verification phase. Utility data was provided by the Hospital's Facility Management Branch (FMB) during both phases of the project. In this paper the optimization of the facilities Heating, Ventilation, and Air Conditioning (HVAC) systems through the CC® process is presented. Detailed commissioning activities of the Hospital and Central Plant are discussed and documented savings from both phases are provided. The period of this Continuous Commissioning® project is November 1, 2003 to September 30, 2007.

INTRODUCTION

Implementation of Continuous Commissioning measures specific to Reynolds Army Community Hospital (RACH) at Fort Sill, Oklahoma was performed by the Energy Systems Laboratory (ESL) of Texas A&M University and RACH facility personnel. The CC measures implemented focused on the heating, ventilating, and air conditioning (HVAC) system of the facility to include the onsite central plant. The Continuous Commissioning process began shortly after the completion of the point –to- point verification phase which was initially part of a $2 million upgrade of the Energy Management Control System (EMCS) by Johnson Controls Inc. ESL and RACH facility personnel formed a CC team and worked together to implement potential energy saving opportunities identified in the CC plan previously submitted to the RACH Facility Manager (FM) in September 2004. Work began in October 2004 and was completed September 2007.

In the following sections of this paper, summarized information on the CC measures implemented will be provided for the clinic and hospital air handlers, the central plant, followed by a savings analysis. The savings analysis is based on gas and electric consumption information provided by RACH Facilities branch.

HVAC SYSTEM DESCRIPTION

The facility consists of a clinic section, approximately 212,000 ft^2 and a hospital section at approximately 300,100 ft^2. Both sections are contained in one building for a total of 512,000 ft^2. There are a total of 37 air handler units, 12 for the clinic and 25 for the hospital, including fan coil units that serve the elevator equipment rooms. The two main air handler configurations used at RACH are Single Duct Constant Air Volume (SDCAV) and Single Duct Variable Air Volume (SDVAV) air handler systems with terminal box reheat. There are also a few Dual Duct Constant Air Volume (DDCAV) systems. The clinic section of the facility is occupied from approximately 0700 hours – 1700 hours, Monday-Friday. A small section of the clinic

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operates on Saturdays for minor emergencies, while the hospital side operates 24/7.

Chilled water, domestic hot water, and steam are produced and supplied from a central energy plant located adjacent to the facility. Originally, three McQuay chillers totaling 1350 tons (two-500 tons and one-350 ton) provided the chilled water to the facility. During the CC process the central plant went through a chiller improvement project which increased the capacity of the chiller plant to 1850 tons. One of the 500 ton chillers was replaced with a 1000 ton chiller. This facility uses a primary\secondary chilled water distribution system. Associated chilled water primary pumps in addition to secondary chilled water pumps were also replaced.

Heating hot water is provided by central plant steam generation using packaged converter units (PCUs) or heat exchangers located in the hospital and clinic. Three natural gas steam boilers, two at 350-BHP and one 250-BHP, operate at this facility.

POINT-TO-POINT VERIFICATION

Phase I began in January of 2004 after the $2 million dollar energy management control system upgrade was completed. ESL Engineers and RACH facility personnel (CC team) verified temperature, airflow, static pressure, and relative humidity sensors on each air handler unit serving the clinic and hospital areas. Priority was given to the sensors that were used in the air handler control strategy.

It was found that the majority of the air handler supply and return air flow stations were out of calibration. Further investigation found that the multi-pitot tube (averaging) type airflow stations were clogged with dust. RACH facility maintenance personnel reverse flushed the pitot tube assemblies with compressed air. In most cases there were positive results. However, the percent difference between direct field measured values and the control system values were significant, approximately 10-30%. In some cases the airflow stations were completely clogged or had other mechanical issues that warranted a recommendation for replacement.

Chilled water loop differential pressure and the two chilled water flow meters located on the bypass and secondary portion of the distribution loop were verified. In addition to the chilled water loop, each chiller's supply water temperature was verified.

OPERATING CONDITIONS PRIOR TO CONTINUOUS COMMISSIONING

RACH is a very well maintained medical facility. The mechanical and control system personnel are well trained and qualified in their assigned duties, especially in the HVAC and Energy Management Control System (EMCS) or Facility Management System (FMS), as they prefer.

Initial assessment of the facility's HVAC system operation found that all the air handlers operated in a 24 hours a day/7 days a week mode. The supply and return fans on the fifteen VAV air handler units serving the hospital and clinic areas were also found to be operating at 100 %, according to the Variable Frequency Drive (VFD) displays.

The typical air handler schematic for the CAV and VAV systems is shown in Figure 1. The VAV air handlers used a return air volume tracking control strategy. This basically means that the return air fan tracks the supply fan by an airflow differential, where the differential is theoretically the amount of outside air being drawn into the air handler. The discharge air temperature setpoints were maintained at constant values, ranging from 55°F to 60°F depending on the area served by the air handler and its ability to maintain the space temperature within the human comfort zone. The supply air static pressure was maintained at a constant setpoint value ranging from 1.0 to 2.5 in H_2O. No supply air temperature or static pressure reset schedules were used.

Every air handler that operates at this facility was designed for economizer capability. The economizer control strategy used was based on maintaining a mixed air temperature setpoint of 51°F. The control strategy enabled the economizer when the outside air temperature was below the return air temperature. Central station heating was maintained via the preheat coil. If the mixed air temperature fell below 50°F, the preheat valve would open to heat the air. In a few instances the mixed air setpoint and the preheat setpoint were the same. Faulty sensors also caused heating within the air handler.

With the exception of the return air volume tracking portion used in the VAV air handler control strategy, the CAV and the DDCAV air handler control strategies were found to be similar. The DDCAV maintained a hot deck supply temperature of 105°F.

The terminal boxes used in the HVAC system were not fan powered. However they were configured with reheat coils. The minimum air flow setting in each terminal box was found to be approximately 50% of the maximum airflow setting. Many of the terminal boxes were operating in heating mode during the summer time, creating unnecessary cooling loads for the chilled water system.

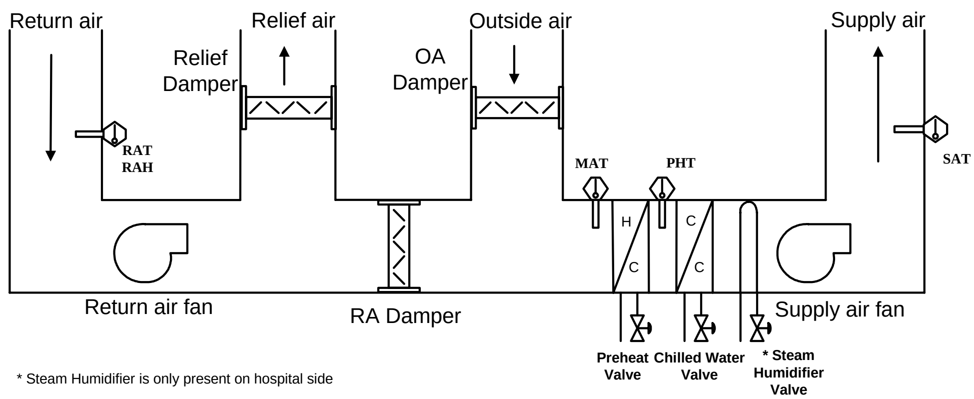

Figure 1: AHU Schematic

There was limited automation control for the chilled water and hot water systems. The only control used was for the secondary chilled water loop. The secondary pumps for the hospital and clinic chilled water loops maintained a constant differential pressure of 17 psi, where the differential pressure sensors were located directly off the discharge side of the secondary pumps (See Figure 2). The hot water system for the clinic and hospital maintained a supply water temperature of 160°F throughout yearly operation.

Facility personnel would manual start and stop the boilers and chillers. There was no automated staging of the equipment, with the exception of the cooling towers which used a cooling fan staging algorithm to maintain a constant chiller condenser supply water temperature.

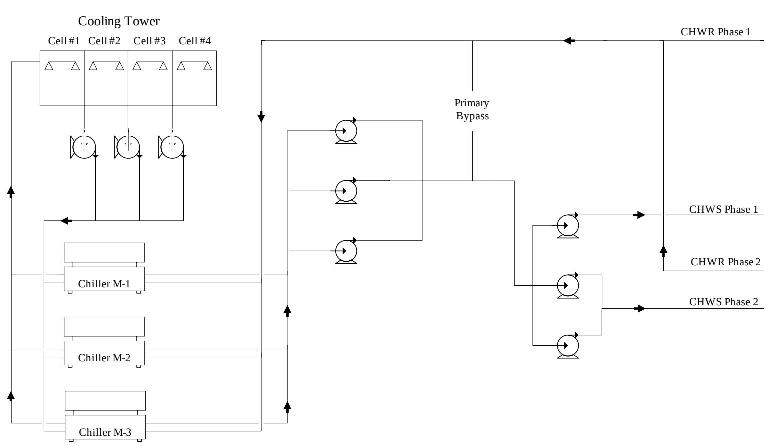

Figure 2 Chiller Plant Schematic.

CONTINUOUS COMMISSIONING (CC)

Prior to the commencement of the CC phase, a CC workshop was provided by ESL to train the HVAC and control system personnel that would make up the CC team on the CC methodology and how each measure would be implemented. ESL developed a Commissioning plan for RACH, based on information collected during the point-to-point verification phase of the project. The potential CC measures that were implemented at RACH were approved by FMB and are listed in the following sections.

Terminal Box Optimization

Initial observation of the single duct VAV terminal boxes used throughout the hospital and clinic areas indicated that excessive airflow was being supplied to the conditioned space. The majority of the box issues resided on the clinic side. Similar situations existed for AHU-355 on the hospital side. This excessive airflow required that the air handlers serving these systems operate at higher speeds. Comparing the "AS BUILT" mechanical drawings, VAV terminal box schedules, and the VAV box controller software programs, it was determined that a large amount of VAV boxes were operating with default programs. Specifically, the airflow station parameters did not have the correct values. These parameters, the pick-up factor and areas, are key elements in determining airflow through each VAV box and are specific for each box size.

These parameters were corrected and airflows verified by the CC team. By making these key adjustments to the VAV boxes it has greatly impacted the operation of the HVAC systems. VAV air handlers began reducing fan speeds and the amount of reheat used to condition the spaces also reduced. In addition to the parameter corrections made to the VAV controllers, the programmed minimum airflow settings in each VAV controller were reduced to 20% of the maximum airflow settings.

AHU-325 which is a dual duct constant air volume (DDCAV) system serving the hospital had similar issues with the mixing boxes. The pick-up factor and areas programmed into the controllers were wrong. The CC team corrected each program and downloaded them to their corresponding controller.

Air Handler Optimization

AHU Occupied/Unoccupied Schedules.

Based on walk through surveys and information provided by RACH facility personnel it was determined that the clinic air handlers equipped with VFDs could be turned off during the night with the exception of AHU 40, AHU 140, and AHU 210. The schedule for each air handler is shown in

Table 1. These air handler units serve critical areas. AHU 40 serves the basement and morgue. AHU 140 conditions the pharmacy and records areas. A computer room with servers requires that AHU 210 be kept on.

Table 1: Air handler Unit (AHU) Schedules

AHU	Sunday	Monday	Tuesday-Friday	Saturday
110	7:00 - 18:00	5:00 - 20:00	5:00 - 20:00	7:00 - 18:00
120	OFF	5:00 - 19:00	5:00 - 19:00	5:00 - 15:00
130	OFF	5:00 - 19:00	5:00 - 19:00	5:00 - 15:00
220	OFF	4:00 - 18:30	5:00 - 18:30	OFF
230	OFF	4:00 - 18:30	5:00 - 18:30	OFF
240	OFF	4:00 - 18:30	5:00 - 18:30	OFF

A Saturday clinic is open in areas served by air handlers 120 and 130. The air handlers serving these areas have been programmed to be in occupied mode during this time. Air handler 110 serves pediatrics and was identified as an area that doctors were likely to come into their offices on the weekends when they had a patient in the hospital.

Two air handler units on the hospital side were also put on similar occupancy schedules. These units were AHU-335 and AHU-245.

However, the occupancy schedule for AHU-335 was later removed because the functionality of the space changed. It became a sleep study area.

Supply Air Temperature Reset Schedules

Linear reset schedules based on outside air temperature were implemented into the air handler control strategies on NC (Network Controller) trunks 3, 4, 5, 6, and 14, with the exception of AHUs 225, 226, 56, and 116. The standard supply air temperature reset schedule for air handlers on the hospital NCs sets the supply air temperature to 62°F when the outside air temperature is 40°F. When the outside air temperature rises to 70°F, the supply air temperature setpoint reduces to 55°F. The supply air temperature setpoint will vary linearly between the maximum and minimum settings based on the outside air temperature. There are a few deviations to the basic reset schedule as shown in Table 2. The supply air temperature reset schedules for the clinic air handlers are less aggressive. The air handlers serve interior and exterior zones.

Table 2 Supply Air Temperature Reset Schedules

AHU	Setpoint @ 40°F OAT	Setpoint @ 70°F OAT
315	62°F	57°F
316	62°F	57°F
175	64°F	55°F
155	59°F	55°F

If the supply temperature is increased above 58°F hot spots will develop throughout the area. These hot spot areas govern the high limit on the supply air temperature reset. Therefore, when the outside air temperature is 40°F the supply air temperature is 58°F. When the outside air temperature rises to 70°F, the supply air temperature setpoint reduces to 55°F. The supply air temperature setpoint will vary linearly between the maximum and minimum settings based on the outside air temperature.

Air handlers 215 and 325 are dual duct units. They have been programmed with resets for the hot deck temperature setpoint as well as the cold deck temperature setpoint. The cold deck setpoint at 40°F outside air temperature is 62°F, but the cold deck temperature setpoint falls to 55°F when outside air temperature rises to 70°F. The cold deck temperature setpoint varies linearly between the maximum and minimum settings based on the outside air temperature. The hot deck temperature setpoint at an outside air temperature of 40°F will be 105°F. When the outside air temperature is at 80°F the hot deck temperature will be 70°F. The hot deck temperature setpoint will vary linearly between the maximum and minimum setting based on the outside air temperature.

Static Pressure Reset Schedules.

Static Pressure reset schedules have been programmed into all VAV air handlers control strategies. Nine VAV air handlers serve the clinic and 6 VAV air handlers serve the hospital. There are a few air handlers whose fans are in manual due to flow stations or static pressure sensors that need to be replaced. While the resets have been implemented on these air handlers, they will have no effect until the mechanical issues are fixed and the air handlers returned to automatic operation. The static pressure reset schedules are found in Table 3. The minimum and maximum static pressure values were determined by field measurements. The use of static pressure reset schedules will reduce energy consumption during the fall and spring time periods as cooling loads are typically lower as compared to summertime.

Humidity control.

Based on the initial findings it was determined that the relative humidity sensors used to monitor and control space relative humidity needed to be replaced. However, after careful investigation by RACH personnel, it was found that a software parameter in the DX-9100 controller was not configured correctly. The CC team corrected the situation and verified the accuracy of the relative humidity sensors. Humidity control is only used only on the Hospital air handler units. Steam injectors are located within the air handler between the cooling coil and the supply fan and controlled by the return air humidity sensor. A 45% return air humidity setpoint was typically found. No changes were made to the control sequence.

Economizer mode.

Originally the economizer control strategy was based on mixed air temperature. The mixed air damper modulated to maintain a programmed mixed air temperature setpoint. This control strategy was modified to incorporate the discharge air temperature in lieu of the mixed air temperature. The mixed air dampers now modulate to maintain a discharge air temperature setpoint minus 2°F.

The 2°F offset is used to compensate for heat generated by the fan which was based on field temperature measurements. The mixed air temperature sensor is now only used as a troubleshooting reference point.

Table 3: Static Pressure Reset Schedules

AHU	Static Pressure [in. W.G] at 50°F OAT	Static Pressure [in. W.G.] at 90°F OAT
40	0.8	1.1
110	0.9	1.1
120	0.9	1.2
130	0.8	1.2
140	0.5	0.8
210	0.8	1.1
220	0.8	1.1
230	1.1	1.5
240	0.9	1.2
125	1.2	1.5
135	1.2	1.5
145	1.2	1.5
165	1.2	1.5
175	1.2	1.5
355	1.1	1.3

The possibility of central station heating was eliminated at the air handler level by reducing the preheat setpoint from 50-52°F to 45°F, depending on the air handler program. All the heating is now being done at the terminal box level by the reheat coil. This control strategy has performed well in most cases because many of the air handler systems serve interior and exterior zones. The interior zones will typically be in cooling mode regardless of outside ambient conditions while the exterior zones, which can be influenced by outside ambient condition, can be in either heating or cooling mode.

As part of the freeze protection strategy, the preheat coil will modulate to maintain the preheat temperature setpoint of 45°F. At this temperature, the preheat coil does not conflict with the dampers or cooling coil. In very cold weather when the damper is at minimum outside air, the preheat air temperature could drop below 45°F. This will enable the preheat valve, even if the air handler shuts down during unoccupied time periods.

Minimum outside air.

It was determined that the clinic air handlers were able to be reduced to approximately 10%. Large portions of the clinic treatment rooms were converted into Doctor's offices or storage space. However, it was not possible to reduce the minimum outside air for each air handler serving the hospital. Exhaust flow rates dictated the outside air reduction limitation. Areas within the hospital are constantly being converted from patient rooms to offices and vice versa on a random basis. Because of this situation, FMB requested that the design outside air requirements be implemented for these units to ensure adequate ventilation for the areas in question.

Central Plant Optimization

Hot water/steam system.

No action was taken on the steam boilers. They are operating at their lowest pressure setting possible to maintain sterilizers and other equipment throughout the facility.

Hot water supply temperature reset schedules based on outside air temperature were implemented for the clinic and hospital package converter units (PCUs). See Figure 3. When the outside air temperature reaches below 20°F, the maximum hot water supply temperature setpoint is 160°F. When the outside air temperature reaches 70°F the minimum hot water supply temperature setpoint is 100°F. The hot water supply temperature will vary linearly as the outside air temperature varies between its maximum and minimum settings.

The clinic and hospital PCU pumps were programmed to turn off when the outside air temperature reached above 70°F. Turning off the hot water to the reheat coils for non-critical areas reduced the natural gas consumption and indirectly made a positive impact on the chilled water consumption for the hospital and clinic during summertime operation.

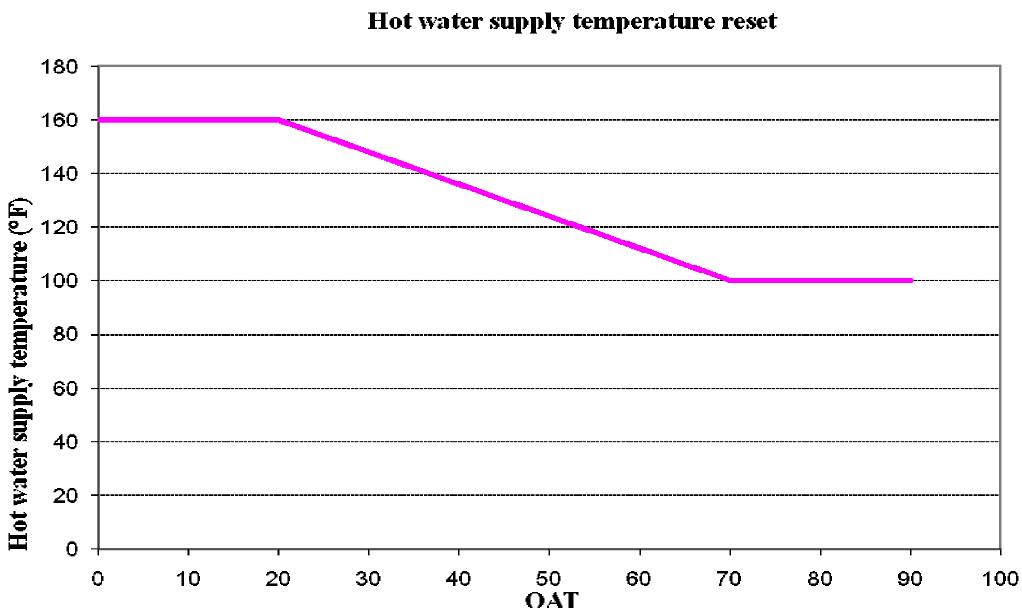

Figure 3 The Hospital and Clinic Hot Water Supply Temperature Reset Schedule

<u>Chillers, Cooling Towers, and Secondary Chilled Water Loop.</u>

Minimal control strategy optimization was implemented for the chillers, and cooling towers because of the central plant upgrade being performed. As mentioned previously, a 1000 ton chiller has replaced a 500 ton chiller. This increases the tonnage capacity of the chillers from 1350 tons to 1850 tons. In addition to the new chiller and primary pump, all three secondary chilled water pumps and cooling tower pumps were replaced. The secondary chilled water pumps were replaced with pumps designed to increased supply flow and head pressure.

Differential pressure reset schedules were implemented into the secondary pump control strategy for both the hospital and clinic loops. When the outside air is above 90°F the differential pressure setpoint is 12 psi. When the outside air temperature is below 50°F the differential pressure setpoint is 7 psi. When the outside air temperature is between the maximum and minimum outside air temperature settings the differential pressure setpoint will vary linearly.

SAVINGS ANALYSIS

Based on actual monthly utility charges and meter readings provided by RACH Facilities Management Branch and baseline consumption models developed by ESL, the cumulative electricity and gas savings for this project totals approximately $511,570 for the time period between January 2004 and October 2006 (See

Figure 4). This includes the savings from the point-to-point verification and Continuous Commissioning phases. The total savings-to-date is based on current utility rates of $0.070/KWh for electricity and $11.37/MCF for gas.

A meter change out occurred in October 2006, and the meter readings after that date are suspect. The savings will be updated when the new meter reading are validated.

COMFORT

Since this is a medical care facility, it is extremely important to maintain an acceptable level of human comfort, especially for patient that require hospitalization. Based on conversational feedback from the FMB, the comfort within the facility has improved.

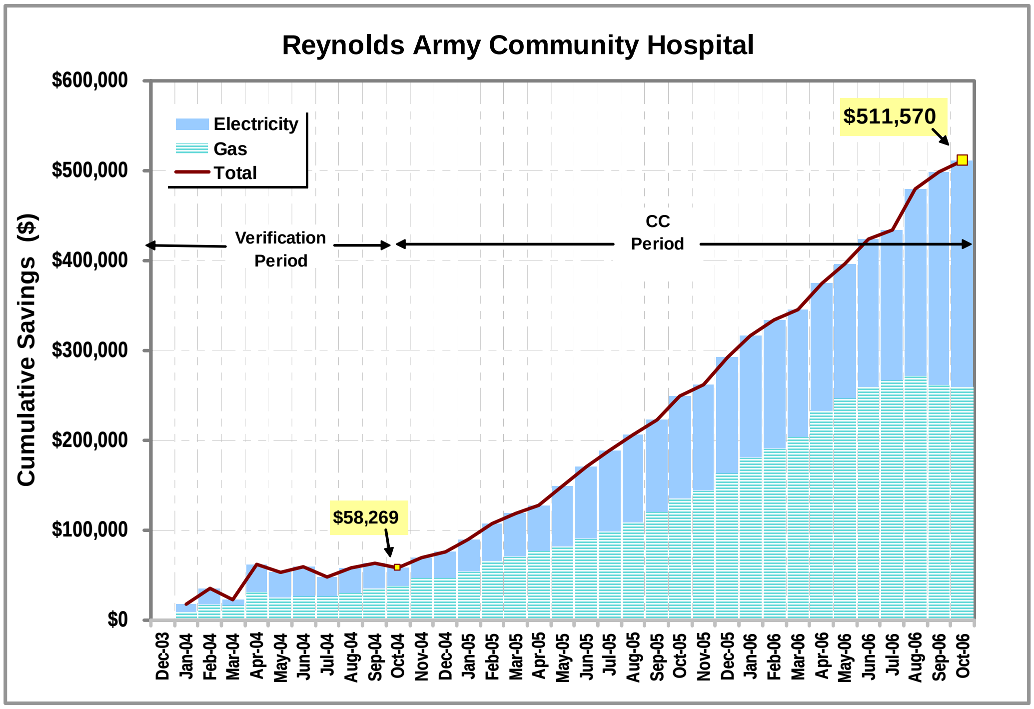

Figure 4 Cumulative total savings based on actual utility rates for RACH.

ACKNOWLEDGEMENTS

ESL would like to thank RACH Facility Management Branch for their involvement and cooperation. The hard work and dedication of the HVAC maintenance and control system personnel has made this project a joint team success.