Continuous Commissioning® of a Multipurpose Facility

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ABSTRACT

This paper presents a case study for the optimization of a multipurpose facility in a school district. The facility is a single-story building with a total conditioned area of 35,571 ft^2. It contains a full size basketball court, concession stands, storage areas, restrooms, and a few offices. The building was designed to accommodate up to 5500 people for sporting events, commencement exercises, and meetings. The commissioning process identified many energy saving opportunities, including a critical sensor failure which led to a significant amount of simultaneous heating and cooling based on the existing sequence of operation (SOO). Since this is a rather common control sequence, the solution implemented in this case study has a broad application in many buildings that have similar SOO. Other major adjustments and modifications for the chiller and boiler plant and building HVAC systems operation are discussed in the paper. Measured result indicates approximately $120,000 annual cost savings as a result of the commissioning process, with a simple payback of less than 3 months!

INTRODUCTION

Delco Activity Center (also known as the North Side Activity Center), is a single-story multipurpose building with a total conditioned area of 35,571 ft^2. It contains a single, full size basketball court, concession stands, storage areas, men's and ladies' restrooms, and a few offices. The building was opened in 2003 and was designed to accommodate up to 5,500 people for sporting events, commencement exercises, and meetings. Based on energy billing data supplied by the Austin Independent School District, this facility has one of the highest annual operating cost intensity.

The Energy Systems Laboratory (ESL) of Texas A&M University was contracted by Austin Independent School District (AISD), to perform Continuous Commissioning®[1] (CC®) of the Delco Activity Center. The CC implementation process began in March 2008 for the Delco Activity Center and was substantially completed by June 2008.

In the following sections, a summarized description of the HVAC equipment found in the Delco Activity Center will be provided, parallel with their control sequence before and after the

[1] Continuous Commissioning® and CC® are Registered Trademarks of the Texas Engineering Experiment Station. Contact the Energy Systems Laboratory, Texas A&M University for further information.

CC process. Finally a detailed energy analysis, which reflects the energy savings before and after the CC implementation, is presented.

AIR HANDLING UNITS

Description

There are 4 main variable air volume (VAV) air handling units (AHUs) and 10 smaller constant volume (CV) units. Cooling is provided by chilled water from the chiller plant. The VAV AHUs use heating hot water from the main boiler plant while the CV AHUs are equipped with electric reheat. The main VAV units (AHUs 1-4) use the average of three space sensors as the input for space temperature control. The three sensors are arranged on one side of the main area at varying heights. Space Temp-1 is located on the floor level, Space Temp-2 is located at the top of the seating area and Space Temp-3 is located midlevel at the bottom of the seating area. There are two space relative humidity sensors which will force the VAV AHUs into a dehumidification mode when their average reading is above a given setpoint.

Four of the CV units (AHUs 1E-4E) serve the main stairwells. These units are contained within a mezzanine level mechanical room, located at each of the 4 corners of the building. The remaining six CV AHUs provide conditioned air to the two restrooms, two locker rooms, a storage room, and the main mechanical room. These AHUs do not have outside air. Figures 1 to 3 show the schematic of these AHUs.

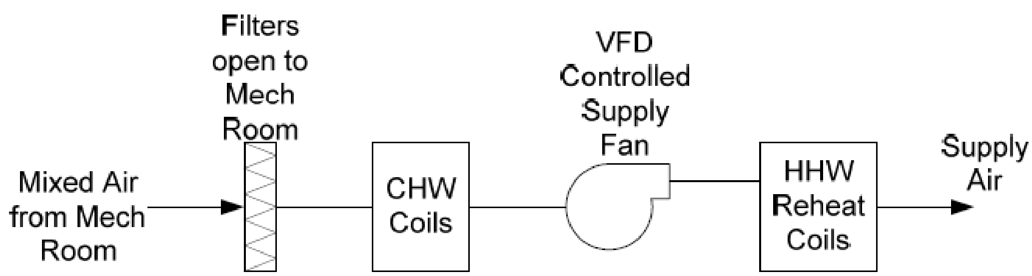

Figure 1: Schematic of a typical Single Duct VAV AHU

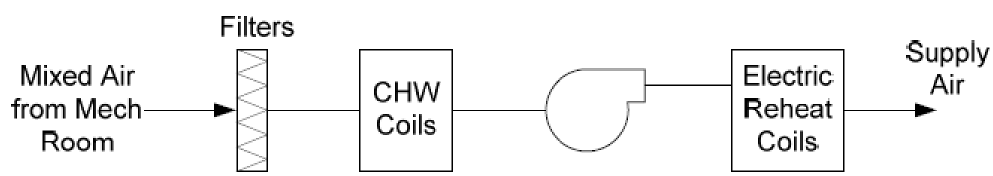

Figure 2: Schematic of a typical Single Zone CV AHU serving the stairwells

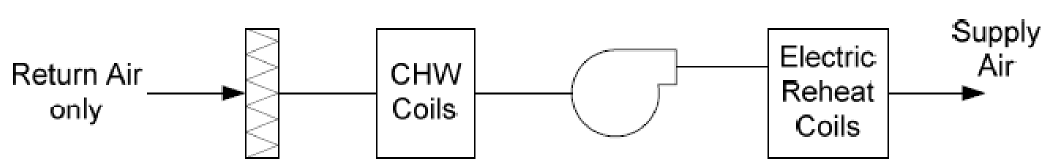

Figure 3: Schematic of a typical Single Zone CV AHU (AHUs 1R-4R, AHU-CP and AHU-ST)

AHUs 1R, 2R, and 1E through 4E each contain a 19.9 kW heater, for a total of 119.4 kW. AHUs 3R, 4R, ST, and CP each contain a 9 kW heater, for a total of 36 kW. The total heating capacity for the 10 air handling units is 155.4 kW.

Tempered outside air is provided to the mechanical room by means of four heat recovery units (HRUs) also located in the mechanical room. The tempered outside air is mixed with return air in the mechanical room before entering AHUs 1-4 and AHUs 1E-4E. The HRUs bring in outside air to the mechanical room and exhausts return air from the space. Both the outside air and exhaust air are blown through a heat recovery wheel but the air streams do not mix. Figure 4 shows the schematic of these HRUs. The wheel allows some energy to be recovered from the exhaust air to precondition the incoming fresh air.

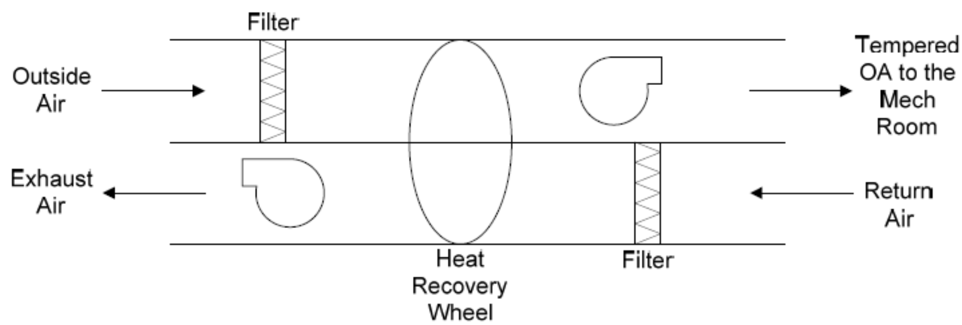

Figure 4: HRU schematic (typical of HRUs 1-4)

When the units are in occupied mode, the supply and exhaust fans of the HRUs are activated. The design maximum outside airflow for each unit is 9,000 cfm and the design exhaust airflow is 7,880 cfm. When the CO_2 level measured by the sensors in the return air duct is above 900 parts per million (ppm), the fans run at a higher speed (9000 cfm/unit). If the level is below 900 ppm, they run at a lower speed (5000 cfm/unit).

Usage of the facility is sporadic so an occupied command must be given by an operator prior to an event. Rotating schedules are in place to keep 1 of 4 air handlers in occupied mode from 8:00-17:00 during the week. The schedules for the HRUs and smaller constant volume AHUs are tied through a master schedule used for events. This master schedule is independent from the main VAV AHUs but mirrored with the smaller CV AHUs. The HRUs and smaller AHUs do not operate with the rotating schedule like the larger AHUs. The unoccupied time schedules can be overridden when humidity exceeds a given set point.

Lastly, there are two DX units that provide conditioned air to the administration area located at the front of the building. An outdoor air fan (OAF-1), rated at 230 cfm, provides fresh air to the office area. The DX units are enabled with an occupancy schedule set for 6:30-17:30. The OAF follows the DX unit occupancy schedule.

<u>Problems identified</u>

- The existing control sequence for AHUs-1-4 uses the chilled water valve to maintain a constant cooling coil discharge air temperature of 55°F. This 55°F setpoint is designed to limit the space relative humidity (below 55-60%). However, it is not needed when the outside air temperature is low. Therefore, this strategy could result in simultaneous heating and cooling during cool/cold days, as shown in Figure 5 below. The mixed air is cooled from 69F to 54.9F at the discharge of the cooling coil. It is then reheated to 67.2 F before being sent to the space.

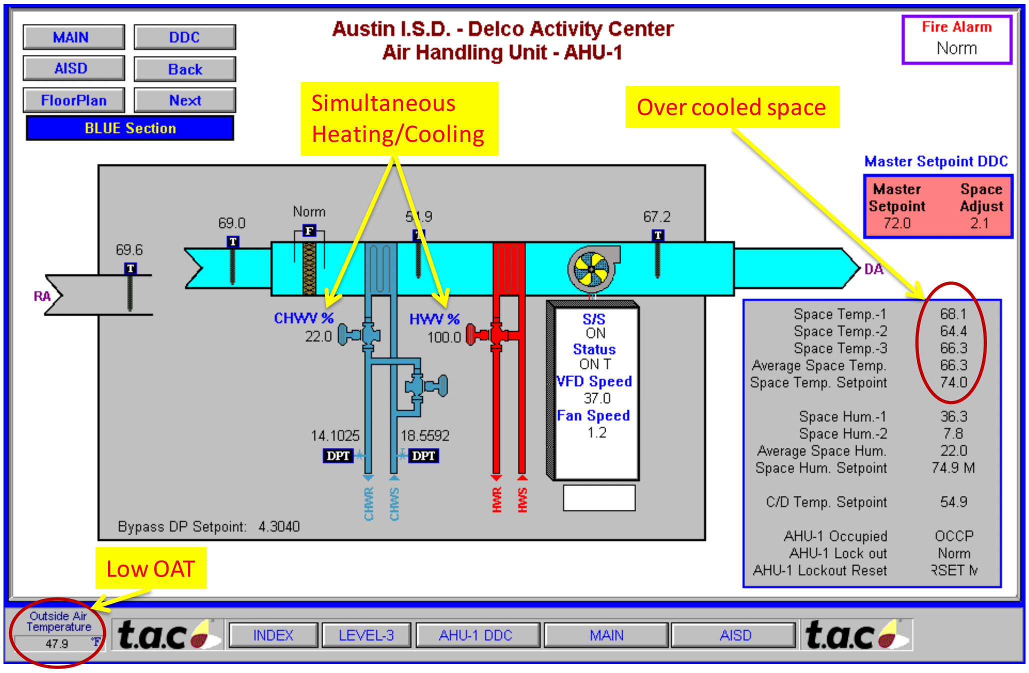

Figure 5 AHU-1 in simultaneous heating and cooling

- Bad humidity sensors forced the system into the humidity override mode during the summer which overrode unoccupied time schedules and forced the chilled water valves to 100% open. The facility was maintained around 68°F 24/7 and experienced high electrical usage during the summer of 2007.
- Space temperature set point was 72˚F plus a locally controlled offset. During the summer of 2007, all thermostats were recording colder than set point because the units were locked in humidity control. When in humidity override, the space occupied commands no longer shut down the AHUs and the space temperature is no longer a controlling point until the coldest space reached 68˚F.
- Due to the overcooling of the main gym area, the smaller adjacent rooms served by the CV units were too cold. Both electric heating stages were on for the small restroom units.
- Many of the daytime events involve meetings with occupancy on the floor level only. During these meetings, which contain anywhere from 50-150 attendees, we frequently observed all AHUs in operation. There was too much space conditioning for these types of daily loads (the four AHUs can handle 5,500 people).
- The sequence of operation for the Heat Exchanger heat wheels called for the wheel to disengage with an outside air temperature between 45°F and 55°F for an economizer cycle. The actual program reference point was the supply air temperature instead of the outside air temperature.
- AHU-2 supply fan motor was extremely noisy. The VFD for this unit had been taken out of auto mode and placed in hand mode causing the unit to operate at 100% without regard to occupancy time schedules.
- The AHU-1 VFD was in bypass mode and was therefore operating at 100% speed. The existing control sequence modulated the VFD speed to regulate temperature. While in bypass, this temperature control was not possible.
- The CO_2 sensor in HRU-1 reported 780 ppm, but only 446 ppm was measured in the space.
- The outside air fan on HRU-2 did not increase to high speed when commanded, but the supply air fan did. In addition, one of the two heat wheels was not operational.
- Neither heat wheel in HRU-4 would operate.

- The outside air temperature sensor needed a shield to protect it from the morning sun. The sensor recorded a temperature spike each sunny morning.

CC Measures

Optimization of the discharge air temperature control sequence (SDVAV)

Previously, the chilled water valve would always open to maintain a discharge air temperature of 55°F to control relative humidity levels. The sequence was modified so that the discharge air temperature is maintained at 55°F when the outside air temperature is greater than 55°F. If the outside air temperature is below 55°F (with a 2°F deadband), the chilled water valve is sequenced with the hot water valve to maintain the space temperature setpoint only. This will reduce the cooling and reheat requirements for the space during the winter.

Disabled the relative humidity control override

With the optimized discharge air temperature control for the VAV AHUs, the relative humidity override was disabled as the space relative humidity would be limited at appropriate levels. This will reduce the amount of unnecessary reheat that was being used by AHUs 1 through 4.

Optimization of the space temperature control sequence (SZCV)

The heating and cooling setpoints were separated for better temperature control. A 70°F setpoint for heating and a 73°F for cooling were implemented. A wider setpoint range was used for AHU-CP since that space is rarely occupied. The sequence for the discharge air temperature calculation on AHUs 1E-4E was eliminated and simplified to control space temperature directly using the same strategy as the rest of the single-zone CV units.

Space temperature control and time scheduling (SDVAV)

Sequencing the AHU occupancy and space temperature sensors references with the size of the event. For meetings, use one AHU and reference the floor level sensor. For larger games and events, reference all three sensors and bring more AHUs online. It was recommended that the size of the events taking place be submitted ahead of time to determine the amount of units required to be scheduled on. Individual zones like the dressing rooms can be scheduled off when the only event for the day is an administrative meeting. Space temperature control during unoccupied periods was refined to a range of 65°F to 80°F from the existing 50°F to 85°F.

Reprogrammed the economizer mode operation for the HRUs

Correct the reference point on all HRUs for proper economizer control, which now reference the OA temperature instead of the supply air temperature. Also, the range of economizer we expanded from 45-55°F to 40-64°F.

Sensor calibration

All key sensors were field verified and calibrated as needed. The following maintenance related issues were identified during the process of CC and reported to the AISD Service Center. ESL engineers worked with the mechanical contractors to address these issues.

Table 1: AHUs operation and maintenance issues

System	Detailed Description
AHU-1	The VFD was not working and was in bypass mode.
AHU-2	The supply fan has a severe vibration when the speed is around 30 Hz.
AHU-4	The VFD is not working.
AHU-4	The hot water control valve is leaking by.
HRU-2	Outside air fan cannot switch from low to high speed
HRU-2	One of the two heat wheels was not operational
HRU-4	Both heat wheels have their motor transformers burned out
EMS	Install a shield for the OAT sensor

CHILLED WATER LOOP

Description

The building HVAC systems consist of three packaged air-cooled helical rotary chillers. Two of the chillers, designated as ACCU-1 and ACCU-2, are rated at 185 tons total cooling capacity each, provided by two independent circuits. Circuit #1 is rated at 100 tons, while circuit #2 is rated at 85 tons. Chiller ACCU-3 is rated at 80 tons total capacity, with two 40 ton circuits. All three of the chillers are staged internally by means of the on-board controllers.

The chiller plant is enabled with any occupied main or auxiliary AHU in the building as long as the lowest space temperature from the 3 separate sensors in the main area is above the “SpaceChlr SetPnt”. The default for the temperature cutoff is 65°F. The chillers operate on a rotating lead/lag/standby configuration. The lag and standby chillers stage on and off as required by demand through fixed %RLA set points in the program. The lag chiller starts when the lead %RLA reaches 80% and the standby chiller starts when the %RLA from the lag chiller reaches 90%. The lag chiller off command is initiated when the lead chiller %RLA is below 45%. The standby chiller stages off when the maximum %RLA from the lead or lag is below 50%.

Each of the three chillers is connected to a common chilled water supply manifold, whereas the chilled water returns are routed to individual chilled water pumps designated as CHWP-1 (20 hp), CHWP-2 (20 hp), and CHWP-3 (10 hp), thence back to their respective chiller. AHUs 1 and 2, the most remote units from the chillers, possess separate bypass valve arrangements that control the differential pressure across the unit.

Problems Identified

- The chiller plant is enabled when any AHU is occupied unless the space temperature drops below 68°F.
- The original chiller staging sequence used chiller alarm status points to turn on chillers and resulted in unnecessary chiller operation even when the plant was disabled.

CC Measures

Optimization of the chiller plant enable condition

Changed the chiller plant enable point calculation to activate when a cooling demand exists. A call for cooling will be activated when the maximum chilled water valve position from any AHU is over 95% for at least 10 minutes and deactivated when the maximum position is less than 5% for 10 minutes. This will prevent the chiller from turning on during cold weathers where it is not required.

In addition,. the chiller alarm status pointwas removed in the new sequence.

HOT WATER LOOP

Description

Each of the four main air handling units contains a hot water coil, supplied by one operational gas fired hot water boiler located in the main mechanical room. A second hot water boiler was installed, but not functioning. Repairs were underway during the CC process. The hot water is circulated by means of a heating water pump, designated as HWP-1(5hp). It is important to note that only the four main air handlers contain hot water heating coils. All of the remaining air handlers contain electric strip heaters. The boiler plant is activated when the outside air temperature is below the OA temperature override setpoint and an occupancy call from the air handlers that are active. The AHU occupancy command is the same used for the chiller plant and includes some of the smaller CV units that are not part of the hot water loop.

Problems Identified

- The boiler plant was originally enabled when any AHU is occupied and the OA temperature is below the cutoff set point of 85°F.
- The domestic hot water heater was originally called to be on when the plant was

enabled or when any AHU is occupied. If the OA temperature ever exceeded the cutoff temperature of 85°F, there would be no domestic hot water. .

<u>CC Measures</u>

<u>Optimization of the boiler enable condition</u>
The boiler enable sequence has been changed to refer only to AHUs that use hot water. Similar to the chiller enable control, the boiler plant can be activated by a demand for heat from the space by looking at the maximum hot water valve position. As long as the OA temperature is below the cutoff setpoint and the maximum hot water valve is over 90% for 15 minutes, the boiler plant will be enabled.

<u>Optimization of the domestic hot water enable condition</u>
The domestic water heater S/S calculation will only look at occupancies of the areas that require domestic hot water (AHUs 1R-4R). AHU-1R and AHU-2R serve the bathrooms and concession stand. AHU-3R and AHU-4R units serve the showers and dressing rooms.

SAVINGS ANALYSIS

Weather normalized energy consumption baselines for the period from March 2007 to February 2008 were developed. Figure 7 compares the actual energy consumption data for electricity from March 2008 to May 2009 with the baselines. Figure 8 compares the actual energy consumption data for natural gas from March 2008 to February 2009 with the baseline. All consumption data is normalized to daily usage and plotted against the outside air temperature.

The cumulative electricity and gas avoided cost savings total $119,822 which composes the electricity savings of $87,997 for the time period of March 2008 through May 2009 and the natural gas savings of $31,825 for the time period of March 2008 through February 2009 (See Figure 6).

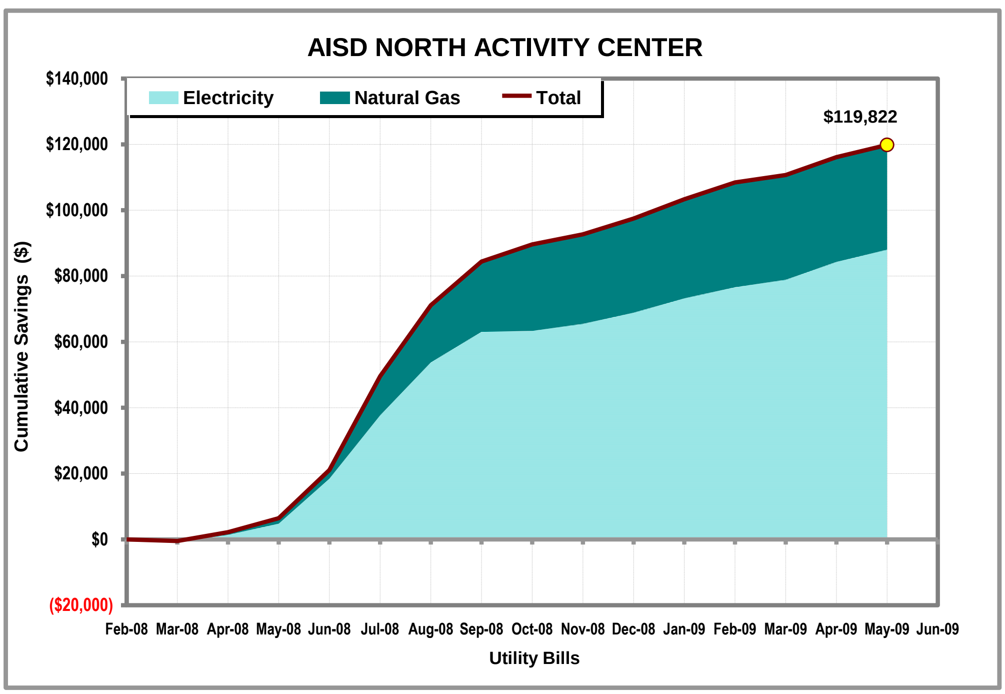

Figure 6: Cumulative avoided cost corresponding to the energy savings in the period of March 2008 through May 2009 for the AISD North Activity Center

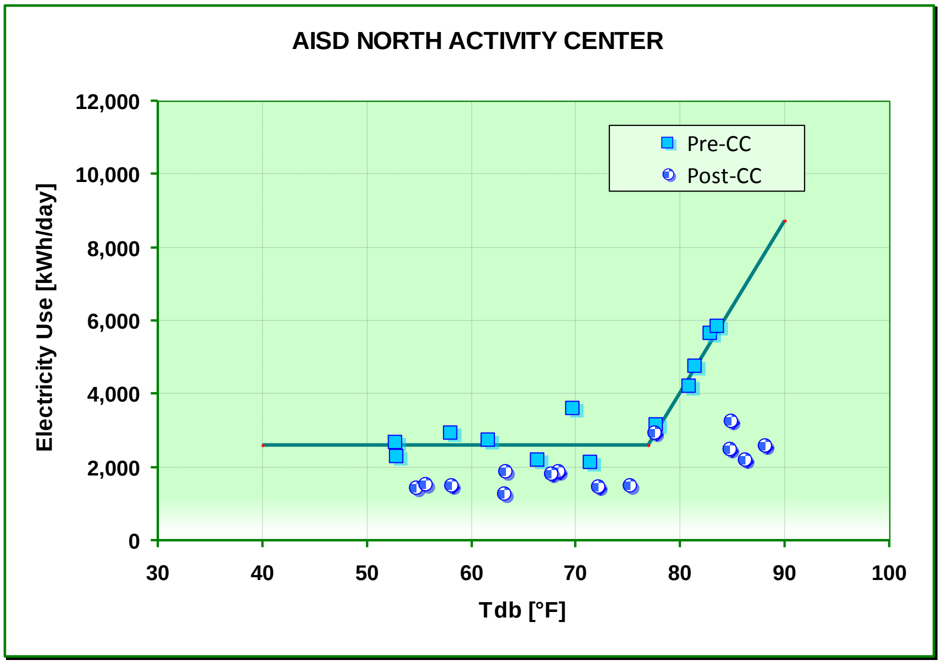

Figure 7: Monthly Pre- and Post-CC daily average Electricity use versus outside dry-bulb temperature for the AISD North Activity Center

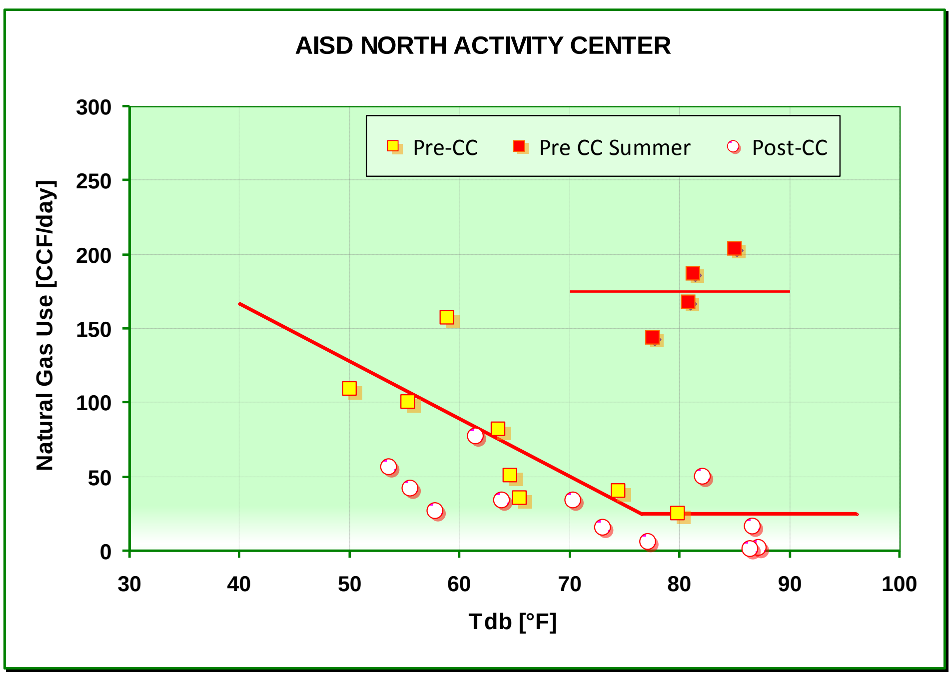

Figure 8: Monthly Pre- and Post-CC daily average Gas Natural use versus outside dry-bulb temperature for the AISD North Activity Center

CONCLUSIONS

Several problems were identified, among the most important is the way the relative humidity was being controlled, where a bad humidity sensor was causing simultaneous cooling and heating. By optimizing the operating sequences and repairing/calibrating faulty devices, the cumulative electricity savings for the site were $87,997 (47%) for the time period of 03/2008 – 05/2009 (14 months) and for gas $31,825 (73%) for the time period of 03/2008 – 02/2009 (11 months). This represents a short payback period of 3 months!

ACKNOWLEDGEMENTS

The ESL would like to thank the AISD Service Center personnel for their cooperation through the project, which involved solving technical problems, and answering inquiries about their system. Also, Dr. Juan Carlos Baltazar of ESL for providing the detailed energy analysis found in this report.