Improving Building Comfort and Energy Savings of McKenzie Airport Terminal by Maintaining and Improving Pneumatic Control Systems

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ABSTRACT

McKenzie Airport Terminal is located at Easterwood Airport, which is owned and operated by Texas A&M University. It was built in 1988. Most all HVAC equipment, which includes boiler, chiller, pumps, AHUs and exhaust fans, due to lack of maintenance, had some form of deteriorated controls, components, and operational function. For example, most of pneumatic controls were failed due to bad components, wrong settings, and disconnection before the Continuous Commissioning[R] (CC[SM]). This caused humid and hot problems of the building, and wasted energy. After maintaining and improving the pneumatic controls, the boiler and hot water pump is now turned off when outside air temperature is higher than 80°F. The chiller is now shut off when the outside air temperature is below 55 °F, and the economizers activate to maintain discharge air temperature when the outside air temperature is below 60 °F. The building comfort in temperature and relative humidity (RH) is improved after CC[SM]. For example, average space temperature of the building was above 75 °F most of the time before CC[SM] and is now 73 °F after CC[SM]. The relative humidity in the baggage claim area was 70% before CC[SM] and is now 55% after CC[SM]. The annual savings of electricity for chiller and natural gas for boiler are $5,040 and $12,090 respectively. The total annual energy savings are $17,130.

INTRODUCTION

The McKenzie Airport Terminal is a two-story building with about 32,600 ft^2. The east area of the 1st floor and part of the 2nd floor is mainly offices. The west area of the 1st floor is the mechanical room and baggage area. The north area of the 1st floor is car rent desk and lobby. The south area of the 1st floor is the secure area and baggage claim. The southeast area of

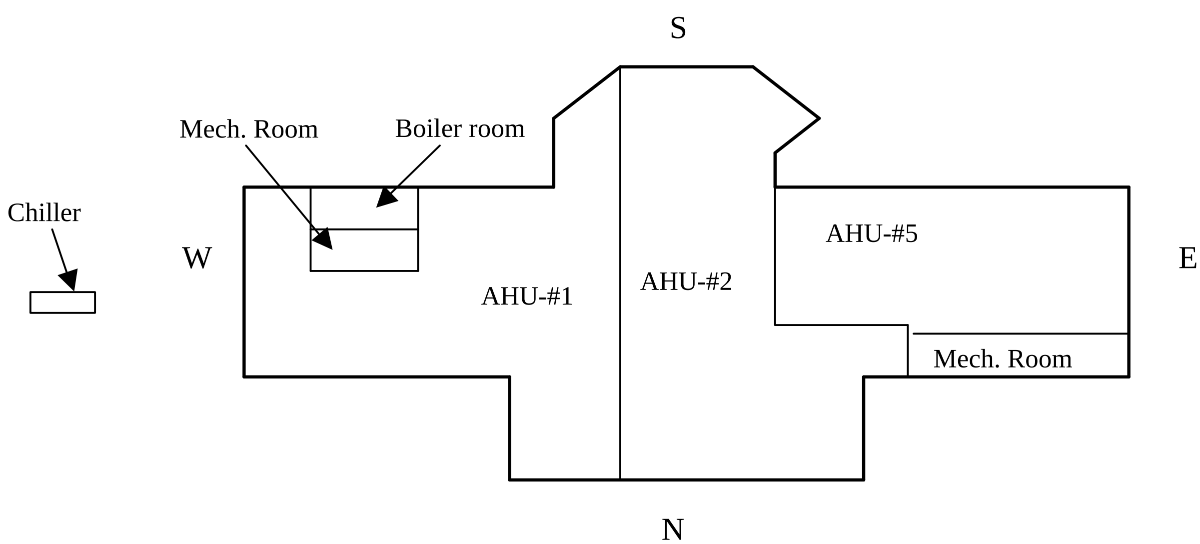

Figure 1: First Floor

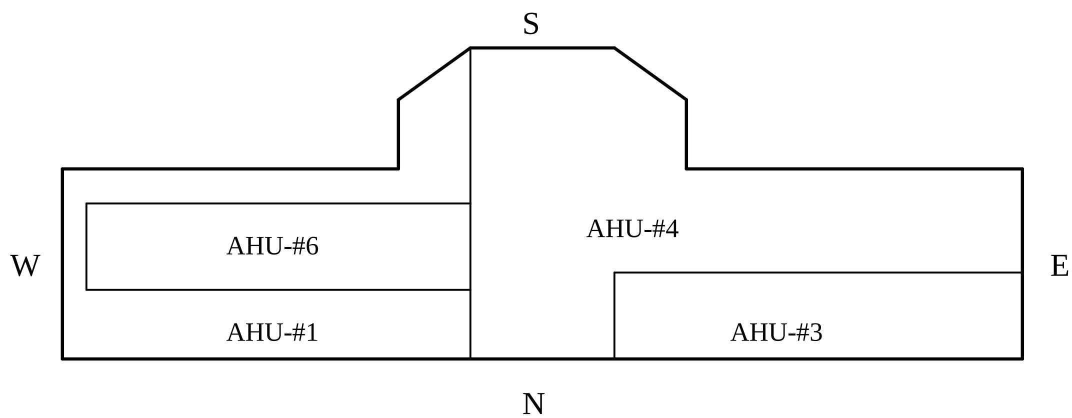

Figure 2: Second Floor

the 2nd floor is the kitchen and lounge area. The west area of the 2nd floor is the ticket area and the airline offices. The 2nd floor south area is the departure lounge.

There is one boiler with 120-ton heating capacity and one constant speed heating hot water pump with 148 GPM flow rate located in the boiler room on the 1st floor, which generates the heating hot water for the building. There are two domestic hot water gas heaters with 2.5-ton heating capacity and one circulation pump located in the boiler room. One domestic hot water heater is for the building and one is for the kitchen. On the east side of the building there is an outdoor chiller with 120-ton cooling capacity, which generates the chilled water for the air-handling units (AHUs). The 325 GPM chilled water pump is constant speed and is located in the mechanical room. The building possesses six AHUs with local pneumatic control and nine exhaust fans. AHU#1(14,000 cfm, 38 ton), #2 (7,200cfm, 20 ton) and #4 (12,600 cfm, 35 ton) are single duct systems with the inlet vane fan and variable air volume (VAV) terminal reheat boxes. AHU #1 serves the east part of the 1st and 2nd floors of the building. AHU #2 serves the 1st floor hall and the west car rent area. AHU #4 serves the 2nd floor hall and ticket area. AHU #3 (7,500 cfm, 20 ton) and #5 (6,650 cfm) are single duty constant air volume systems. AHU #3 serves the ticket lobby. AHU #5 serves the baggage area and is a heating only unit with an economizer cycle for cooling when outside air temperature is below the setpoint of 72°F.

SYSTEMS OPERATION AND AS FOUND CONDITIONS

The chiller has four compressors with six stages and is air-cooled. Compressors are turned on and off to maintain the adjustable chilled water supply temperature at the setpoint of 43 °F. The existing chilled water supply temperature was 41 °F, because the thermostat, which is controlling the chilled water supply temperature, was out of calibration.

The chiller is interlocked with the chilled water pump and a flow switch in such a way that it shall not run if the chilled water pump is off or the flow switch indicates a loss of flow. Because all the AHUs have individual economizers, the chilled water pump is switched on and off by the outside air thermostat. It shall be on if the sensed temperature is above 55 °F and shall remain on until the sensed temperature falls below 53 °F. Prior to CC^{SM}, the chiller was on all the time during the winter, because the thermostat was set below 30°F. The flow switch was inoperable indicating flow all the time.

For freeze protection of the chiller and chilled water system, a thermostat, which is mounted in the chilled water supply pipe, overrides the outside air thermostat and switch the chilled water pump on if the sensed chilled water temperature falls below 38 °F. The pump shall remain on until the sensed chilled water temperature rises above 40 °F. The thermostat was installed in the chilled water supply pipe, which is in the building where the temperature is controlled at 73 °F. The chiller could freeze if the outside air thermostat turns off the pump in winter. Therefore, the chiller, the pump, and the system were in unsafe working condition and the energy consumptions were increased.

The heating hot water boiler has six gas burners. Those burners are turned on and off to maintain the hot water supply temperature at the setpoint. The setpoint was set from 130°F to 160°F corresponding to outside air temperature from 70°F to 20°F. A new set point of 110°F to 150°F was implemented to correspond to outside air temperature from 70°F to 20°F. The boiler is interlocked with the hot water pump in such a way that it shall not run if the hot water pump is off. The hot water pump is switch on and off by the outside air thermostat. The pump shall be on if the sensed outside air temperature is below 78 °F and shall remain on until the sensed temperature rises above 80 °F. The boiler was on the whole year, because the outside air thermostat for the pump was set above 100°F, prior to CC^{SM}.

The sensors of the outside air thermostats, which are for the controls of the hot water pump and the hot water supply temperature, were located on the louver of exhaust air, which is on the south wall of the boiler room. The sensors will receive sunshine during the day and, its reading is affected by solar radiation. Figure 3 demonstrates that there is a maximum difference of 15°F to 20°F between two sensors, one is in the sunshine and the other is not. Two of six burners had mechanical problems. Those problems result in an increase of the natural gas consumption.

The original AHU design sequence of operation is as follows. The temperature controller of AHU modulates the chilled water control valve to maintain the supply air temperature of 55°F. The room thermostat modulates the terminal reheat control valve and variable air volume (VAV) damper to maintain the desired room temperature. The AHU static pressure sensor, through receiver controller and signal actuator, modulates the fan inlet vanes to maintain the duct static pressure of 1? WG as designed. If the outside air temperature is above 60°F, the outside air damper on the AHU shall be at its minimum open position and the return air damper shall be at its fully open position. A sensed outside air temperature at or below 60 °F shall activate the economizer cycle as follows. If the outside air temperature is between 60 °F and 55 °F, the outside air damper shall be fully open and the return air damper shall be fully closed. If the outside air temperature is below 55 °F, the outside air damper shall modulate through the action of temperature controller to maintain a

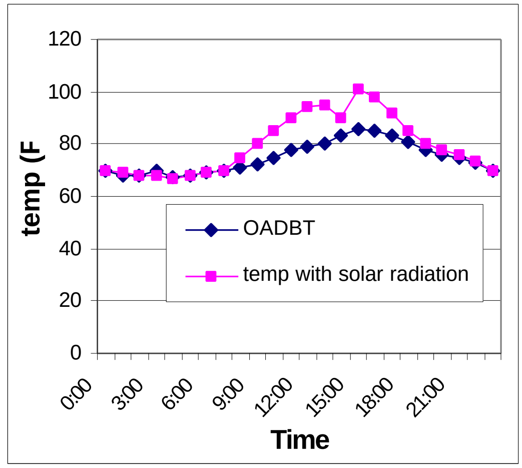

Figure 3. The outside air temperature sensor in solar radiation

mixed air temperature of 55 °F. The relief air damper actuator shall operate the relief air damper in proportion to the outside air damper. AHU#1, thru AHU#5, are turned on and off by a 7-day mechanical timer. A 2-hour override timer allows for after-hour AHU operation. Fan powered terminal VAV boxes with reheat are controlled, when their AHU is off, by a night setback thermostat. This night setback thermostat shall enable the VAV boxes fan to run when a temperature below 55 °F in the building is sensed. Each VAV box fan is allowed to run but the local VAV temperature sensor commands the action of the fan and reheat valve, so only the fans that need to run, to meet room temperature set point, will operate.

There are two relief air dampers on the roof. One is for the economizers of AHU#1 and #2, the other is for AHU#3 and #4. The relief damper for AHU#1 and #2 was disconnected from the damper actuator. The relief air hood for AHU#3 and #4 was capped off, when the roof was remodeled. Therefore the air relief systems for the economizers were not in working condition. The outside air dampers of AHU#1 and #3 were frozen at a shut position. The outside air temperature sensor for the economizers of AHU#2 and #4 was not operating properly. The electronic-pneumatic switches were not set properly. Therefore all the economizers could not work properly. That is the reason why the thermostat for the chiller on and off control was set at 30 °F.

Due to the mechanical problems, none of the AHU timers was working. The AHUs were staying on during the night when the Airport was closed. The duct static was not under control, because the inlet vanes were either frozen or inoperative.

There are forty-six fan powered VAV reheat boxes in the building. Some thermostats were either out of calibration, broken, or missing. Most of the velocity controllers for the VAV damper controls were out of calibration. It resulted in that some boxes were either in full heat or in full cooling or both. Some areas of the building were hot, some areas were cold, and energy consumption of both electricity and nature gas were significantly increased.

The exhaust fan in the under-floor crawlspace is turned on and off by the thermostat and humidity-stat to maintain the under-floor crawlspace temperature of 60 °F and relative humidity of 50%. The exhaust fan was not running, because of mechanical problems and non-functional stats. It results in the building being humid.

AFTER CONTINUOUS COMMISSIONING[R]

The pneumatic controls were replaced, repaired, and/or correctly reconfigured when the building was commissioned. The thermostat, which is controlling the chilled water supply temperature, was calibrated to maintain the chilled water supply temperature of 43 °F.

The flow switch, which is for the chiller safety, was replaced, because it was inoperable indicating flow all the time. The outside air thermostat was calibrated and will switch the chilled water pump on if the sensed outside temperature is above 55 °F and remain on until the sensed outside air temperature falls below 53 °F.

The thermostat for the freeze protection of the chiller and chilled water system was relocated from the pipe inside of the building mechanical room to the pipe outside of the building. The chilled water pump will be switched on if the sensed chilled water temperature falls below 38 °F. The pump shall remain on until the sensed chilled water temperature rises above 40 °F.

Two burners of the boiler, which were not operational, were fixed. The controller of the hot water supply temperature with the range from 110°F to 150°F were reset to corresponding outside air temperature from 70°F to 20°F. The outside air thermostat for the boiler on and off was reset from 100°F to 80°F. Now the boiler will be on if the sensed outside air temperature is below 78 °F and shall remain on until the sensed temperature rises above 80 °F. Most of the time last summer the boiler stayed off.

The two sensors of the outside air thermostats, which are for the controls of the hot water pump and the hot water supply temperature, are recommended to be relocated from the exhaust louver to somewhere not

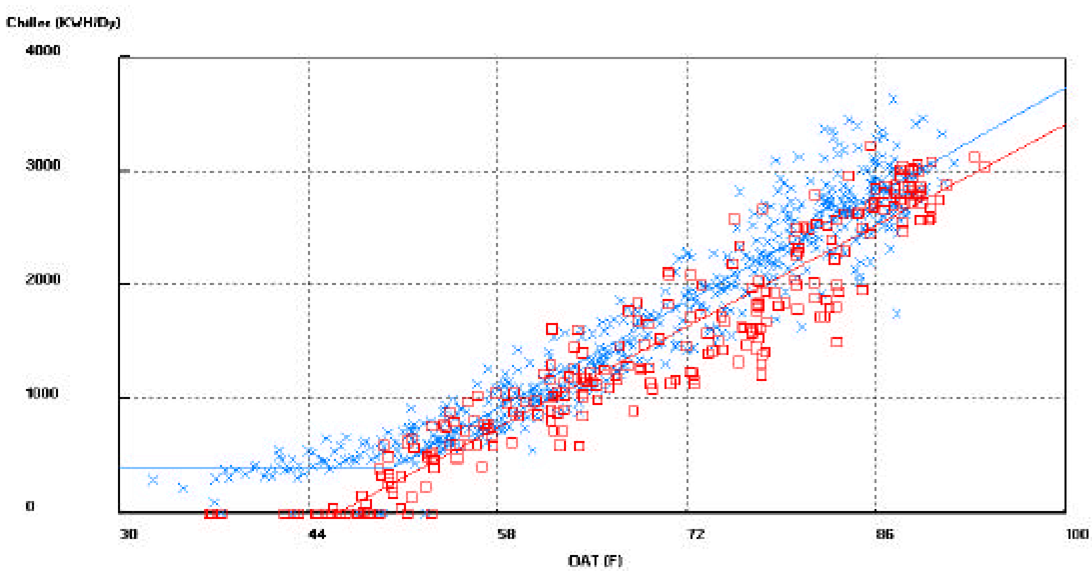

Figure 4. Chiller electricity consumption

affected by solar radiation.

The AHU discharge air temperature sensors were calibrated to maintain the supply air temperature of 55°F. The room thermostats and the velocity controllers were either calibrated or replaced to modulate the terminal reheat control valve and variable air volume (VAV) damper to maintain the desired room temperature. The AHU static pressure sensors were either calibrated or replaced to modulate the fan inlet vanes to maintain the duct static pressure of 1? WG. All the dampers on the AHUs were lubricated and fixed. The relief air dampers were connected with their actuators and the exhaust hood, which was capped off, is now open. Now the economizer cycle works, when outside air temperature is below 60°F.

Five timers for AHU#1 to #5 were replaced. A timer was installed on the AHU#6, which serves lounge area. Now all of six AHUs cycle on at 4:30 AM, and off at 10:30 PM.

The mechanical problem of the exhaust fan in the crawlspace was fixed and its thermostat and humidity-stat were replaced to maintain the crawlspace temperature of 60 °F and relative humidity of 50%.

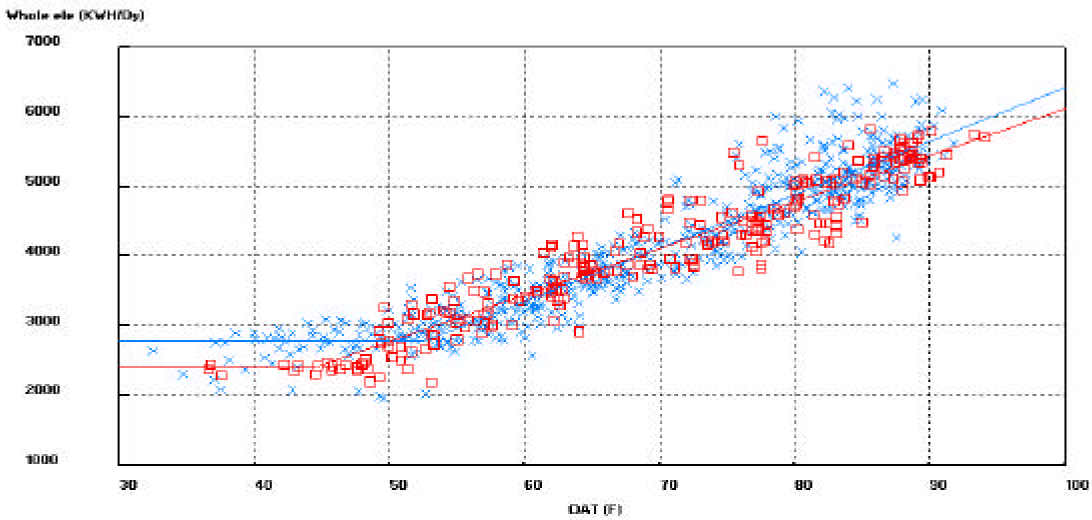

Figure 5. Whole building electricity consumption

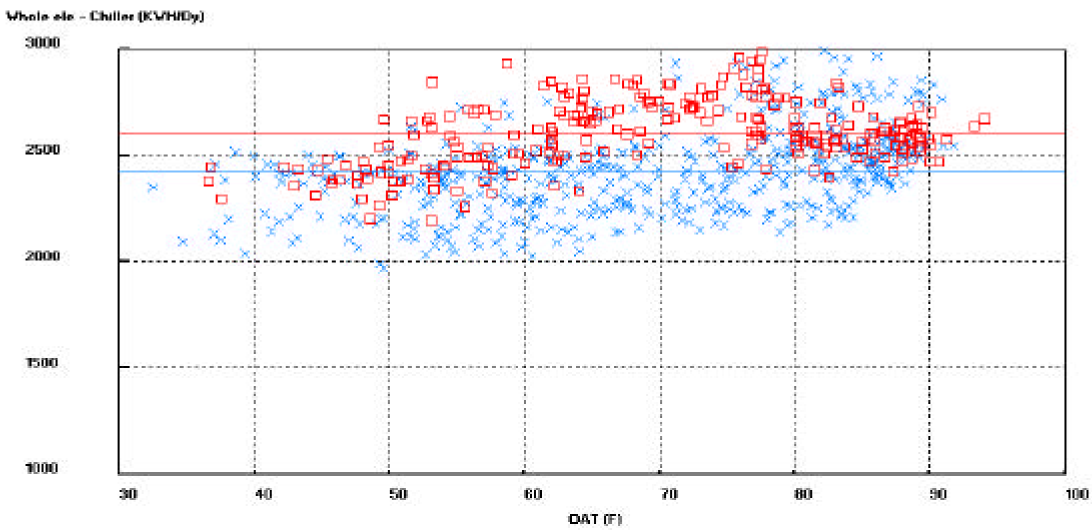

Figure 6. Building electricity consumption, which does not include chiller's

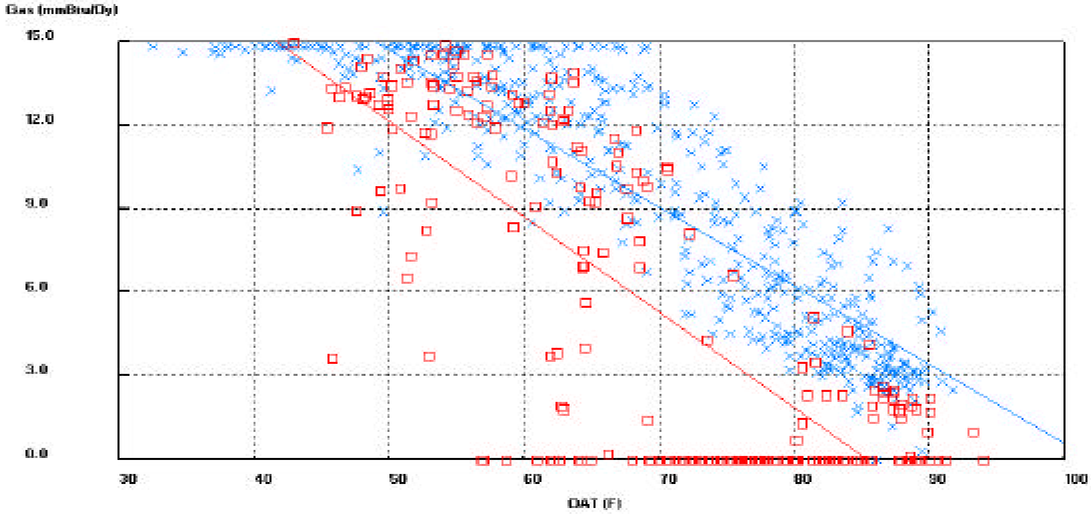

Figure 7. Whole building gas consumption

BUILDING COMFORT AND ENERGY SAVINGS

The commissioning started on April, 2003 and ended on July 2003. The indoor air quality was improved and energy savings were achieved. For example, the radio room temperature was above 74 °F sometime before CC^{SM} and 72 °F after CC^{SM}. The temperature and RH of the hall of the 1st floor was 74 °F and 70%. There was condensation on the discharge grill before CC^{SM}. After CC^{SM}, the hall temperature and RH was 73 °F and 50%. Also the ticket area on the 2nd floor used to be very humid before CC^{SM}. Now the ticket area is comfortable with 73 °F and 55% RH. The airline office temperature was 74 °F to 76 °F before CC^{SM}. Now it is about 73 °F. The comfort in the airport offices and kitchen area were also improved.

Figure 4 to Figure 7 demonstrates the energy consumption before and after CC^{SM}. Data with "X" mark is energy consumption before CC^{SM}. Data with "? " mark is energy consumption after CC^{SM}. The energy savings were estimated. Data with "X" mark is energy consumption before CC^{SM}. Figure 6 shows that average daily electricity consumption, which is not including chiller, was increased by 200KWH, because a $7^1/_2$ hp exhaust fan for craw space was operated, a $^1/_2$ hp ventilation fan for boiler room was functional, and other equipment, such as server and refrigerator, were installed during CC^{SM}. The annual savings of electricity for chiller and natural gas for boiler are $5,040 and $12,090 respectively. The total annual energy savings are $17,130. Total commissioning cost is $20,000. The payback is one year and two months.

RECOMMDATIONS

Install variable frequency devices on chilled water and hot water pumps, and AHU#1, 2, 4, and 6.

CONCLUTIONS

The McKenzie Terminal **CC^{SM}** gives a good example that building comfort can be improved and savings can be achieved by maintaining and improving the pneumatic control systems.

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