Analysis 2: Mechanical System #1: Controls - Breath

Background

The fan coil unit (FCU) mechanical system is designed to condition the guest rooms and other spaces in addition to masking the noise from the metro tracks that impede the site. The original mechanical fan coil units were intended to run 24 hours a day to condition the space. The primary purpose was to create a white noise background to prevent guests from being disturbed during their stay at the Residence Inn. The Washington area metro tracks near the building create approximately 102 decibels of noise. Long exposure of this level of noise can cause permanent hearing damage. The building façade blocks out 50 decibels, which means that approximately 52 will transmit through the facade. 52 decibels of noise is acceptable for a room during waking hours. However, to get a good night sleep, the noise level should not be more than 30 decibels; which is why the FCU was meant to be run 24 hours a day 7 days a week.

This is a potentially large problem for guests comfort. There will be guests that want to turn off the unit at night because the units can create bothersome noise. Unfortunately the original units will not be able to be turned off, causing some guests to become upset. If the units are too loud it can cause guests to be unhappy and possibly spread this bad experience to other future guests.

Since the original design, there has been a system overhaul. The new system, called INNCOM, is highly intelligent utilizing door switches temperature and occupancy sensors to increase energy efficiency specifically tailored to hotels. This system is activated when a guest checks in at the front desk, otherwise the systems in unoccupied rooms are off. This system is designed to cycle on and off the way a central air system would in a home. The user is able to control the temperature set point during the day. The INNCOM system is designed to run at a low fan speed throughout the night to mask the metro noise.

A possible solution is to provide an intermediate solution. Investigate the options of control systems for the units to provide user control during the day and an "over-ride" noise control at night. This means that the units can be turned off during the day by the occupant, but there will be certain times of the day or night that the unit will be on in the "over-ride" mode. The "over-ride" mode will be in effect from 10:00pm to 7:00am daily to mask the worst of the metro noise. This more advanced control will also help reduce energy use in the building.

Goal

The overriding goal of this analysis focuses on reducing the energy consumption by the fan coil units in the guestrooms. This analysis is also intended to provide a superior system to the original, to save energy for a minimum cost, and not increase complexity during construction. The goal of this analysis is to re-design the controls for the guestroom mechanical units to be

more user oriented during the day and have an automatic override at night to mask the metro noise.

The re-design of the guestroom mechanical unit controls will include investigating energy efficient controls that are able to be controlled on a network, to help reduce energy consumption. The original system and networked system will be evaluated by comparing:

- Total kWh's used per year
- Total Cost per year

The original system, the INNCOM system, and this re-design will be compared on unit cost, installation cost, and constructability.

The kWh's and cost will be calculated using Virginia Dominion Power company's rates. All systems analyzed assume an 81% hotel occupancy rate, as provided by Don Nagl at Marriott. This equates to 147 rooms of the 181 total rooms being used by guests.

Resources

- Southland Industries – Mike Phillips and Laura Slingerland
- Mechanical option faculty – Professor Moses Ling
- Architectural Engineering 5th year Mechanical option students: Max Chen, Will Tang
- Mechanical Textbook: Mechanical and Electrical Equipment for Buildings. 9th ed.

Energy Analysis

Please reference Appendix E for drawings, cut sheets, calculations, comparisons, and tables.

❖ *Step 1: Find a Networkable Thermostat System*

- An internet search was performed in conjunction with consulting Mike Phillips at Southland Industries.
- The programmable thermostat that was selected for this system can be networked with the other thermostats in the building and controlled by a single computer. This means that the building's fan coil units can be controlled from one place and that the guest can be locked out of the system.
- The thermostat chosen is Delta Controls DNT – T103. The cut sheet can be found in Appendix E.
- This thermostat network has the capabilities of the nightly "over-ride" mode and occupant control during the day.

❖ *Step 2: Heating and Cooling Durations*

- Annual weather data was collected from www.weatherdatadepot.com for Washington D.C. but can also be applied to Alexandria, VA, referencing the year 2007.
- The weather data includes charts for average daily temperature, cumulative heating degree days and cooling degree days, and a comparison with 2006, as well as the degree days broken down for heating and cooling based on a balance point of 65° F.
    - Degree Days are "quantitative indices designed to reflect the demand for energy needed to heat or cool a home or business. These indices are derived from daily temperature observations, and the heating (or cooling) requirements for a given structure at a specific location are considered to be directly proportional to the number of heating degree days at that location."
    - This means that if the outside temperature is 85°F and the inside temperature is set to 65°F a cooling degree day of 20 results.
    - 65°F is a typical reference point or balance point because at this temperature heating or cooling is generally not required.
    - Balance point is defined as "the average daily outside temperature at which a building maintains a comfortable indoor temperature without heating or cooling. At this outside temperature, the indoor heat gains (due to people, lighting, equipment, etc) "balance" with heat loss through windows, walls, roof and ventilation."

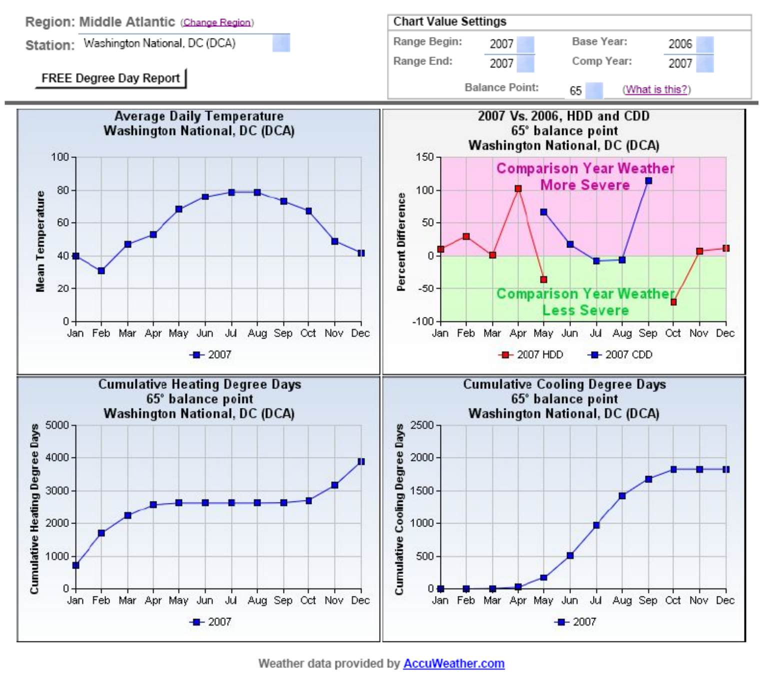

Figure 13: Annual Weather Charts, Washington D.C., courtesy of Weatherdatadepot.com

- Based on the cumulative annual degree days, the percentage of annual heating and cooling was calculated to be 68% and 32% respectively. The detailed degree day chart can be found in Appendix E.
- The daily heating and cooling durations can be seen below.

System	Conditioning	Duration (hrs.)
Original	Heating	16.32
	Cooling	7.68
Networked	Heating*	9.96
	Cooling*	4.69

*Duration includes "Over-ride" and User Controlled modes.

Figure 14: Daily Heating and Cooling Durations

❖ *Step 3: Original Energy Use and Cost*

- As noted in the Electrical drawings on sheet E 3.3 the total kW's for all electric heating units equals 349 kW.
- The building demand equals 656.1 kVA, also on drawing E 3.3.
- The horsepower for the motor of the FCU is 1/15 hp, as seen in the schedule on drawing M-602 in Appendix E. For one motor the horsepower of 1/15 is equivalent to 0.05 kW.
- The total kW of the motors for all 189 FCU's equal 9.45 kW.
- Thus the total heating energy equals 358.45 kW and the total cooling energy equals 9.45 kW. This neglects the energy to for the chiller to cool the water that is used in the FCU during cooling conditions.
- Based on the published billing data from Virginia Dominion Power, the Residence Inn is assumed to be in Schedule GS-4, the Large General Service Primary Voltage category, as confirmed by Southland Industries.
    - The peak energy cost is $0.404 per kWh during 6/1 to 9/30 Monday through Friday from 10:00am to 10:00pm and 10/1 to 5/31 Monday through Friday from 7:00am to 10:00pm
    - The off peak energy cost is $0.272 per kWh during 1/1 to 12/31 Evenings and Weekends.
    - Detailed calculations can be found in Appendix E.
- The total kWh and cost for peak and off-peak time can be seen below.

Total kWh =	1,765,059.67
Total Cost =	$5,764.27

Figure 15: Original System Total kWh and Cost

❖ *Step 4: Occupancy per Hour*

- The hourly occupancy rates for a typical hotel room were taken from the mechanical software program, Trane Trace. These rates were then adjusted for a business commute.
  - Trace Schedule for Hotel Occupancy Rate:

    12 am - 9 am = 100%
    9 am - 11 am = 20%
    11 am - 5 pm = 0%
    5 pm - 12 am = 100%
- The Residence Inn is slated for mainly long term business people. Average hours of commute are between 7 am and 9 am.
  - Adjusted Schedule for Hotel Occupancy Rate:

    12 am - 9 am = 85% * Assumes leaving at 7:30 am
    9 am - 11 am = 0%
    11 am - 5 pm = 0%
    5 pm - 12 am = 100%
- Based on these occupancy rates, the total hours the room is occupied by a guest was calculated to be 14.56. This includes the "over-ride" time from 10:00pm to 7:00am and from 5:00pm to 10:00pm and 7:00am to 7:30am of user controlled time.
- Of the user controlled time, 3.84 hrs are heating and 1.81 hrs are cooling time.

❖ *Step 5: New Energy Use and Cost*

- Based on the "over-ride" mode and user controlled mode the heating and cooling was calculated. The same 68% and 32% were used for heating and cooling.
- This new Delta system assumes that when the room is occupied the FCU will be on to prevent the air form becoming "stagnant". This also assumes that while the room is unoccupied the FCU is off.
- Schedule GS-4 form Virginia Dominion Power kW rates were applied.
  - The peak energy cost is $0.404 per kWh during 6/1 to 9/30 Monday through Friday from 10:00am to 10:00pm and 10/1 to 5/31 Monday through Friday from 7:00am to 10:00pm
  - The off peak energy cost is $0.272 per kWh during 1/1 to 12/31 Evenings and Weekends.
  - Detailed calculations can be found in Appendix E.
- The total kWh and cost of the new networked system can be seen below. This is a savings of 696,231.65 kWh in energy and $2,312.94 in energy costs.

Total kWh =	**1,068,828.11**
Total Cost =	**$3,451.33**

Figure 16: Networked System Total kWh and Cost

System Comparison

A controls system comparison chart can be seen below.

The original control system utilizes thermostats (t-stat) that cost approximately $30 each, $5,670 for all 189, with very basic in room wiring, no networking, which totals $37,900. This is the total system cost of the controls for the building. There is no networking with this system because the thermostats do not have the capabilities; they are controlled in each room independent of each other.

The new networked Delta system employing the "over-ride" mode and user controlled mode, has thermostats that cost $98 each, $18,522 for all 189 units. This system does have temperature sensors that help control when the system should condition the air based on temperature. These are similar to thermostats and sensors found in a home. These sensors add approximately $19,350 to the total cost. The wiring installation is about $50,000. This cost is much greater than the original because wiring must be run to a central location for the networking of the system. This system costs about $87,872, which equates to $49,972 more than the original system.

The INNCOM system which is currently being employed uses thermostats that cost about $200 each, and $37,800 for all 189. These thermostats also use many sensors for doors, infrared, and occupancy, as well as a specific type of software to run the network. This accounts for $96,550 of the total price. The wiring installation is the same as the re-designed network because the same amount of wiring is required to install a thermostat network. This costs approximately $50,000. The INNCOM system costs about $184,350 total. This is $146,450 more than the original and $96,478 more than the re-designed system in this analysis.

Controls System Comparison			
System Type	**Original**	**Networked**	**INNCOM**
Price / Unit	$30.00	$98.00	$200.00
Total T-stat Cost	$5,670.00	$18,522.00	$37,800.00
Installation	$32,230.00	$50,000.00	$50,000.00
Sensors, etc.	n/a	$19,350.00	$96,550.00
Total System Cost	**$37,900.00**	**$87,872.00**	**$184,350.00**

Figure 17: Controls System Comparison

Constructability Review

Please reference the wiring diagram on the following page, and in Appendix E.

The original wiring of the system was very simple. The thermostat was tied directly to the FCU in each room. For the two bedroom units each FCU has its own thermostat. A wiring detail of typical studio rooms can be seen below circled in red, from drawing E 2.1.

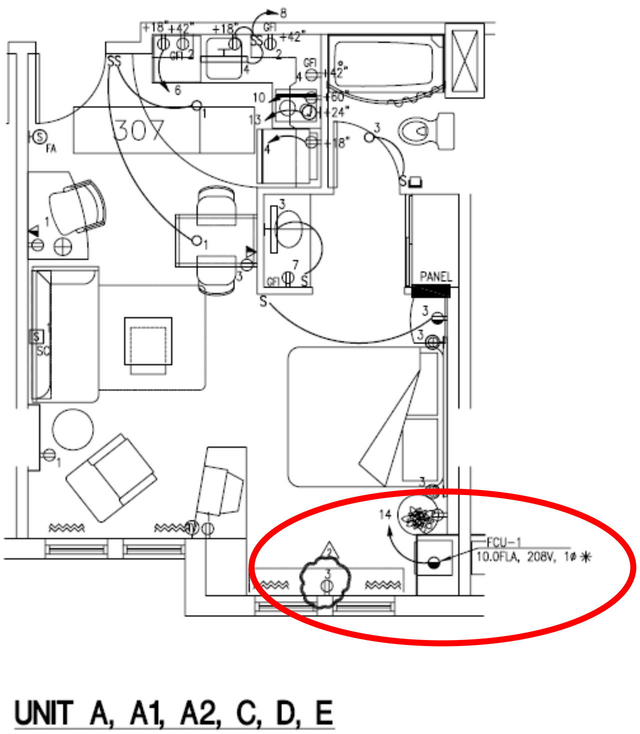

Figure 18: Original Wiring Diagram, Drawing E 2.1

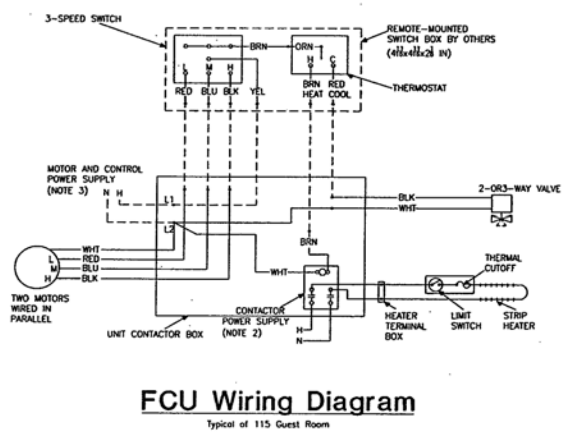

Figure 19: Detailed FCU Wiring Diagram

The re-designed networked Delta system will have more complex construction very similar to the new INNCOM system that will be installed. The re-designed Delta system will have extra wiring to connect all the thermostats to one network. This system will not require as much wiring for the sensors that the INNCOM system has. In addition, The Delta system does not require any specific software installation. On the next page a detail of the network wiring is shown as well as a detailed wiring diagram of a typical studio room. The full detailed INNCOM wiring diagram can be found in Appendix E. This wiring is more complex than the original but not as complex as what the INNCOM drawings show.

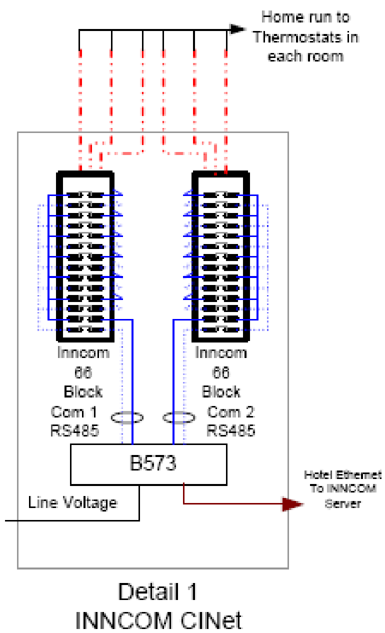

Figure 20: Detailed INNCOM Network Wiring Diagram, provided by Southland Industries

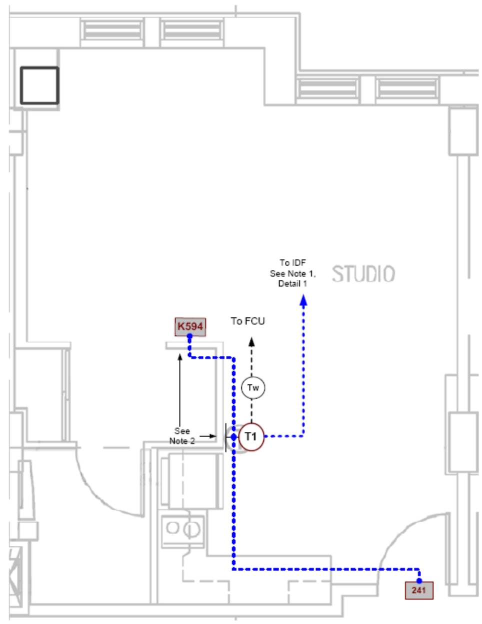

Figure 21: Typical INNCOM Wiring Diagram for a Studio Room, provided by Southland Industries

Conclusion & Recommendation

The benefits of changing the controls system for the FCU's are apparent; a great deal of energy and money can be saved starting the first year. The construction of the system is also within reasonable complexity. The re-designed controls system utilizing the Delta DNT – T103 is an excellent alternative to the original system.

- The Delta system saves 696,231.56 kWh in energy and $2,312.94 in energy costs each year.
- This system costs $49,972 more in construction compared to the original but saves $96,478 compared to the new INNCOM system.
- The construction is comparable to the INNCOM system; neither is too complex to maintain a swift schedule. Networked thermostats are very common in commercial buildings.

Based on this analysis, the Delta Controls system using the DNT – T103 is the recommended system. It produces a superior system to the original but is not as expensive as the INNCOM system. Its performance results are nearly equivalent to the INNCOM. This system provides the guests with an acceptable environment thermally and acoustically as well as providing savings to the owner.