Continuous Commissioning® for a LEED-NC Certified Museum and Cultural Center

Keke (Kirk) Zheng

ICEBO

Energy Systems Laboratory

Texas A&M Engineering TEES

Outline

- Facility Description
- HVAC Systems Description
- LEED Evaluation Facts
- CC Measures Implementation
- Energy Savings Analysis
- Recommendations
- Conclusions
- Acknowledgement

Facility Description

- The George Washington Carver Museum and Cultural Center is located in Austin, Texas, United States.
- The facility has a gross space area of 36,000 ft^2 and includes offices, artist and children's galleries, conference rooms, classrooms, a darkroom, a dance studio, a 134-seat theater, a kitchen, and archival space.
- A 105-kilowatt solar system installed on the roof since July 2012. The solar system will offset about 136,500 kWh of purchased electricity annually or approximately 14% of annual consumption.

HVAC Systems

AHUs

Four SDVAV AHUs and one SZVAV AHU;

One OAHU serving AHU-M2 and M5;

One stand-alone HRU that pretreats the fresh air intake of AHU-M3.

Mark	Supply Air Fan				Area Serving
	Supply Air [CFM]	E.S.P [in.w.c.]	Fan Type	Motor [HP]	
AHU-M1	6000	1.5	Centrifugal	5	Administration Main Level
AHU-M2	7300	1.5	Centrifugal	5	Gallery
AHU-M3	14500	1.5	Centrifugal	10	Theater main level
AHU-M4	6000	1.5	Centrifugal	5	Theater lower level
AHU-M5	3200	1.5	Centrifugal	3	Exhibition Preparation Rooms

HVAC Systems

DX units

Mark	Nominal Tons	EER
CU-M1 A, B	15	10.6
CU-M2A	10	10.6
CU-M2B	7.5	10.3
CU-M3A,B	15	11.5
CU-M3C,D	12.5	10.6
CU-M4A,B	10	10.6
CU-M4C	12.5	10.3
CU-M5A,B	4	10.1

Hot Water Heaters

Mark	Storage Capacity [Gallons]	Recovery Rate [GPH]	Gas Input [BTUH]	Efficiency
HWH-M1-6	100	756	199	94

LEED Evaluation Facts

One of the first 200 LEED registered projects;

One of the first City of Austin projects to work towards sustainable design and construction using the LEED framework;

Awarded a LEED-NC Certified rating in June, 2006.

Category	LEED credits	Achieved credits
Sustainable Sites	14	9
Water Efficiency	5	2
Energy & Atmosphere	17	2
Materials & Resources	13	5
Indoor Environment Quality	15	9
Innovation Design	5	4
Total	69	31

CC Implementation

- Summarization of the Major CC Recommendations

System	CC Measure
All AHUs	- HVAC shutdown/setback scheduling for non-critical areas
	- Optimize the economizer control
	- Supply air temperature reset
	- Optimize the minimum fan speed setting
	- Relocate the OA temperature/humidity sensor
	- Replace or repair the key sensors
AHU-M1, 2, 3, 5	- Duct static pressure reset
AHU-M4	- Improve the space temperature control
	- Improve the mechanical room temperature control
Terminal Boxes	- Optimize terminal VAV box operation
Hot Water Systems	- Domestic hot water schedule optimization
	- Heating water supply temperature reset
	- Boiler stage control optimization

Proceedings of the Twelfth International Conference for Enhanced Building Operations, Manchester, UK, October 23-26, 2012

CC Implementation

HVAC shutdown scheduling for non-critical areas

Description:

The HVAC system originally operated 24/7.

Implemented Solution:

Schedule / AHU	Mon	Tue	Wed	Thu	Fri	Sat	Sun
AHU-M1	7am –9pm	7am –9pm	7am –9pm	7am –9pm	7am –5pm	7am –5pm	7am –5pm
AHU-M2	24/7	24/7	24/7	24/7	24/7	24/7	24/7
AHU-M3	7am –9pm	7am –9pm	7am –9pm	7am –9pm	7am –5pm	7am –4pm	7am –4pm
AHU-M4	7am –9pm	7am –9pm	7am –9pm	7am –9pm	7am –5pm	7am –4pm	7am –4pm
AHU-M5	24/7	24/7	24/7	24/7	24/7	24/7	24/7
HRU-M3	7am –9pm	7am –9pm	7am –9pm	7am –9pm	7am –5pm	7am –4pm	7am –4pm
OAU-M25	24/7	24/7	24/7	24/7	24/7	24/7	24/7

Proceedings of the Twelfth International Conference for Enhanced Building Operations, Manchester, UK, October 23-26, 2012

CC Implementation

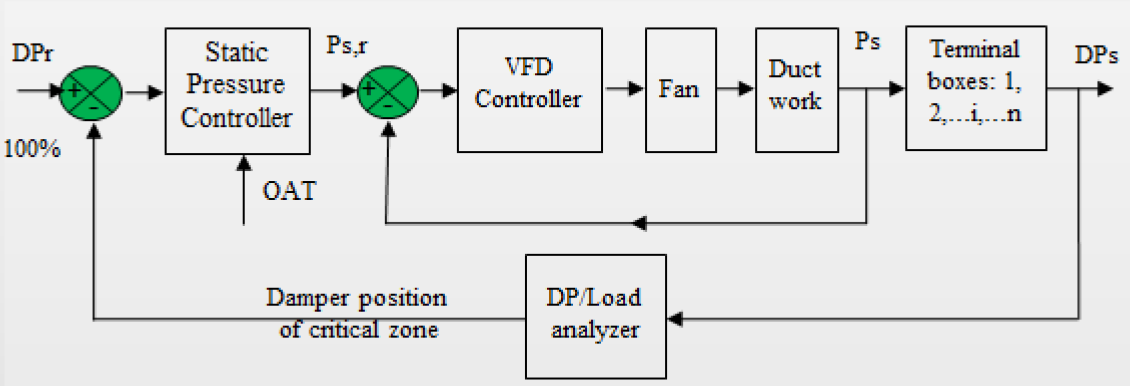
Duct static pressure reset

Description:

The original supply air fan static pressure was set at a constant setpoint of 1.0 in.wc.

Implemented Solution:

The implemented schedule is based on maximum zone damper position value with a reset based on outside air temperature as a failsafe.



Max DP[%]	*SP [in.wc]*	*OAT [°F]*	*SP [in.wc]*
80	*0.4*	*60*	*0.4*
95	*0.8*	*100*	*0.8*

Proceedings of the Twelfth International Conference for Enhanced Building Operations, Manchester, UK, October 23-26, 2012

CC Implementation

Supply air temperature reset for VAV units

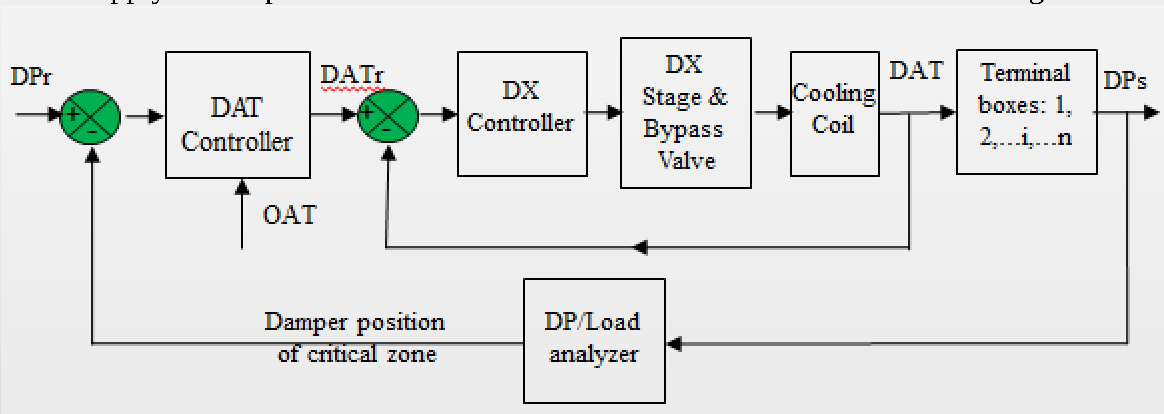
Description:

The SAT setpoint was maintained at 49ºF when the OA temperature was above 50ºF; otherwise, the setpoint was reset based on the maximum damper position among the boxes only in HEATING mode.

Implemented Solution:

"Maximum Damper Position" is defined as the maximum open zone damper position signal and is unrelated to the terminal box mode. All terminal boxes remain at minimum flow during heating mode.

The SAT setpoint reset schedule is based on maximum zone damper position value with a reset based on OAT as a failsafe. The AHU supply air temperature controller uses the maximum value of the following reset tables as set point.



Max DP[%]	SAT[°F]
Minimum	65
80	49

OAT [°F]	SAT[°F]
40	65
60	49

Proceedings of the Twelfth International Conference for Enhanced Building Operations, Manchester, UK, October 23-26, 2012

CC Implementation

- ***Economizer control for AHU M1, M3 and M4***

Description:

The economizer control was based on the OA dry-bulb temperature and activated when OAT was below 55°F.

Implemented Solution:

The economizer control is now based on both the OAT and enthalpy. Economizer mode is enabled when OA enthalpy is below 26 Btu/lb and OAT is below 70°F.

Additionally, the Return Air Damper is no longer reversely linked to the OA damper. The RA damper now starts to close only when the OA damper is fully open.

Proceedings of the Twelfth International Conference for Enhanced Building Operations, Manchester, UK, October 23-26, 2012

CC Implementation

- ***Optimize the minimum supply air fan speed setting***

Description:

The original minimum fan speed settings were 50% or above.

Implemented Solution:

The minimum supply fan VFD speed settings were changed to 30% of the maximum frequency.

Unit Name	Original value		Current Values	
	Max (%)	Min (%)	Max (%)	Min (%)
AHU-M1	100	50	100	30
AHU-M2	100	50	100	30
AHU-M3	100	50	100	30
AHU-M4	100	75	100	30
AHU-M5	100	50	100	30

Proceedings of the Twelfth International Conference for Enhanced Building Operations, Manchester, UK, October 23-26, 2012

CC Implementation

- ***Optimize terminal box operation***

Description:

Most of VAV boxes had minimum air flow of 30% of the maximum flow.

AHU-2 minimum supply air damper positions were et at 50%.

Implemented Solution:

An minimum air flow setting of 15% based on the Ventilation Rate Procedure

(ASHRAE Standard 62.1: Ventilation for Acceptable Indoor Air Quality);

Reduce the potential reheat significantly and the fan energy during low cooling loads while satisfying minimum ventilation requirement.

Proceedings of the Twelfth International Conference for Enhanced Building Operations, Manchester, UK, October 23-26, 2012

CC Implementation

- ***Replace/repair failed key sensors***

Relocate the OA temperature/humidity sensor

Description:

The integrated OAT/RH sensor was located near an east-facing wall without shading, therefore, the morning sun shines directly on the sensor in the summer.

The sensor is close to the wall and its reading will be impacted by the radiation from the wall.

The sensor is critical for economizer operation, supply air temperature reset and so on.

Implemented Solution:

The sensor was relocated to the north-side wall, a shaded area with sufficient for clearance from any large thermal mass.

Proceedings of the Twelfth International Conference for Enhanced Building Operations, Manchester, UK, October 23-26, 2012

CC Implementation

- ***Replace/repair failed key sensors***

Zone temperature and humidity sensors in the gallery area

Description:

Both temperature and humidity sensors of zone 1 and 2 were significantly lower than the field measured readings. The hot water valve signals are both 100%, and the humidifier enable signal are also both ON. The maintenance staff manually disable both hot water heater and the humidifier to avoid that the space is over-heated and over-humidified.

Zone	Temperature, ºF			Relative Humidity, %		
	Measured	BAS (Interface)	Local Controller	Measured	BAS (Interface)	Local Controller
1	74.0	69.5	47.7	36.6	34.3	14.3
2	79.1	76.9	58.9	37.3	42.0	22.1

Implemented Solution:

These sensors were calibrated through a linear offset compensation during the CC implementation period, and were replaced on January, 2012.

Proceedings of the Twelfth International Conference for Enhanced Building Operations, Manchester, UK, October 23-26, 2012

CC Implementation

- ***AHU-4 optimal control***

Improve the Space temperature control

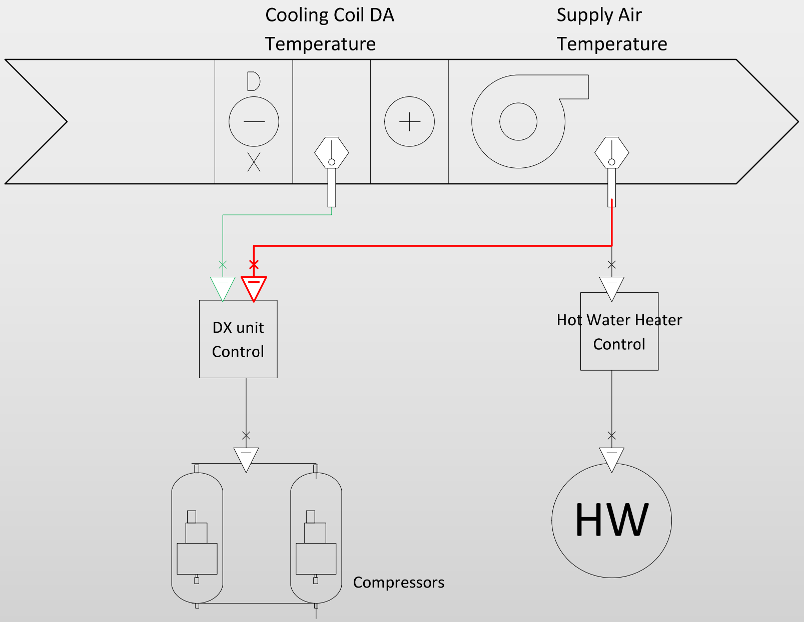
<u>*Description:*</u>

DX unit's compressor staging was determined by the difference between SAT and the cooling SAT setpoint.

The SAT is also adopted as the input of the heating control module. This will result in simultaneous heating and cooling during heating season.

<u>*Implemented Solution:*</u>

New control consequence for the DX unit stage control adopted the cooling coil temperature as input instead of the SAT to eliminate the common process variable between the two control loops.



Proceedings of the Twelfth International Conference for Enhanced Building Operations, Manchester, UK, October 23-26, 2012

CC Implementation

- ***AHU-4 optimal control***

Improve the mechanical room temperature control

Description:

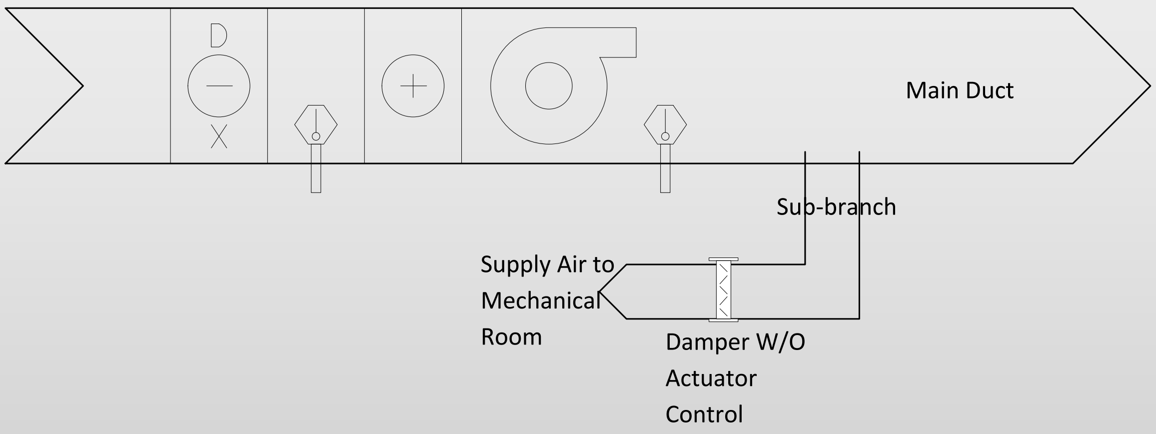
A sub-branch from the main supply air duct is designed to condition the mechanical room.

Supply air damper of the branch was fully open and there was no space temperature control. During a summer field trip, the space temperature was 62 °F due to over-cooling.

Implemented Solution:

The supply air damper position was temporarily adjusted to about 30% open.

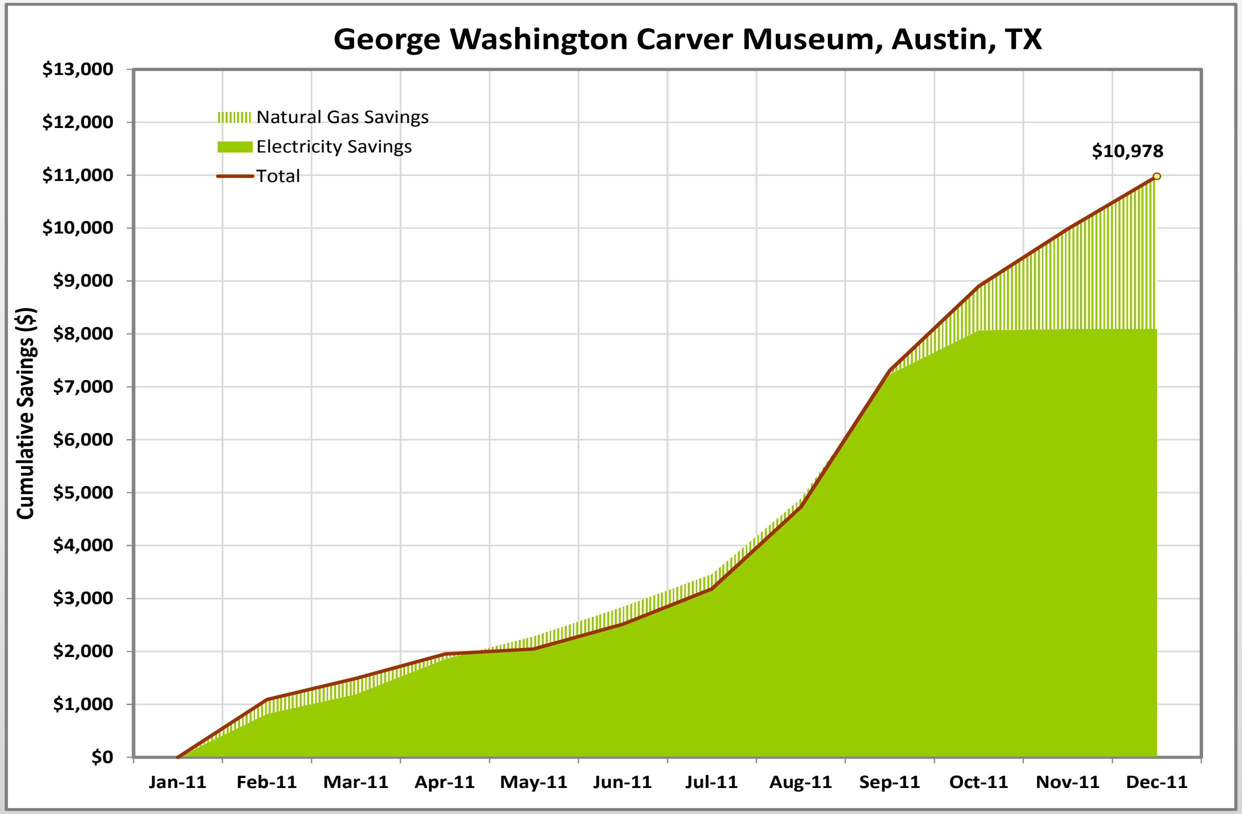
A temperature sensor is recommended to install for the room temperature control.



Proceedings of the Twelfth International Conference for Enhanced Building Operations, Manchester, UK, October 23-26, 2012

Energy Savings Analysis

- A weather normalized analysis is conducted for electricity consumption and natural gas use based on the available utility bills and weather data.
- The cumulative savings (electricity and natural gas) during the implementation periods total approximately 21% on average at actual rates.



(Courtesy of Juan-Carlos Baltazar & Yifu Sun)

Future Recommendation

- ***Additional CC measures recommendation***

	CC Measure	Reason it was not implemented
A1.	OAU-25 operation optimization	OAU-25 is off due to fan failure.
A2.	Heating Hot Water Heaters Stage Control optimization	Control points for each heater should be physically added into the boiler controller.
A3.	Event-based schedule for AHU-M4	Curator neglected this suggestion considering some special events beyond the schedule.

Proceedings of the Twelfth International Conference for Enhanced Building Operations, Manchester, UK, October 23-26, 2012

Savings Persistence Plan

- ***Sensors Calibration***

All the key sensors should be calibrated regularly, including: zone temperature sensor, zone humidity sensor, supply air temperature sensor, duct static pressure sensor, outside air temperature sensor, outside air humidity sensor and the CO_2 sensor.

- ***Operation & Maintenance***

One of the major problems observed throughout the project was the abundance of control signal overrides.

Most of the CC measures require that control signals for the valves, setpoints, and AHUs start/stop commands, etc., are not overridden.

Periodically, these points should be checked for overrides.

Conclusion

- The implementation of CC measures improved the building indoor comfort and reduced the energy consumption, an average 21% savings acquired during the implementation period.
- Potential LEED credit points could be achieved through CC: EA C1 Optimize Energy Efficiency Performance (7 points or above), and EA C2 Existing Building Commissioning (6 points).
- Additional measures were proposed for more energy savings.
- Critical recommendations on O&M and sensor calibration were presented to maintain the enhanced building performance.

Thanks!