HVAC Field Evaluation

SDG&E Energy Innovation Center, San Diego, CA

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Short Term Diagnostics

During the timeframe of March 2013 – September 2014, WCEC performed the diagnostic measurements and recorded observations while on-site at the facility. Information regarding normal building maintenance, HVAC set up, building controls, and building settings were determined from conversations with both the building manager of the Energy Innovation Center (EIC) and the HVAC technician that services the building.

Equipment Functionality

WCEC documented the following details of the HVAC equipment during our initial assessment of the building.

RTUs

On the roof of the EIC there are seven high efficiency RTUs. There are four 5-ton units and three 3-ton units. The seven RTUs condition three large seminar rooms, the lobby, hallways, catering kitchen, break room, and office space. All units are gas heat (two stage) and electric cooling (one stage), use refrigerant 410-A, and have direct drive electrically commutated motors (ECM) driving the blower. Each unit was witnessed running in each operating mode and the following details were noted:

1. The economizers are controlled by an outdoor air enthalpy set point of 22 BTU/lb. The EIC has an outdoor air and humidity sensor installed, however, it does not function properly (discussed further in Long Term Monitoring). Figure 1, illustrates an analysis of the local weather station (Montgomery Airport) data that shows that the set point of 22 BTU/lb was only experienced approximately 5% of the cooling season in 2013 and 2014.
2. The zone each unit serves has an indoor air quality (IAQ) sensor that measures the carbon dioxide (CO2) in the space in parts per million (ppm). The RTUs use this input to control the outside air damper position based on settings that are configured during installation. Currently, the dampers are not set to open more than the minimum position until a CO2 level of 1003 ppm is reached. The damper will continue to open as the CO2 level rises until 1400 ppm at which the damper will be 100% open.
3. A load shifting ice storage system is installed in series with AC1. The refrigerant to air heat exchanger for the ice storage system is located on the roof, downstream of the RTU (Figure 2). The ice storage system controls are located inside the electrical panel for AC1. The manufacturer's control algorithm intercepts the compressor activation signal between the hours of 12-4pm. The intercepted signal activates the refrigerant pump on the ice storage system causing refrigerant to cycle through the heat exchanger and ice block.

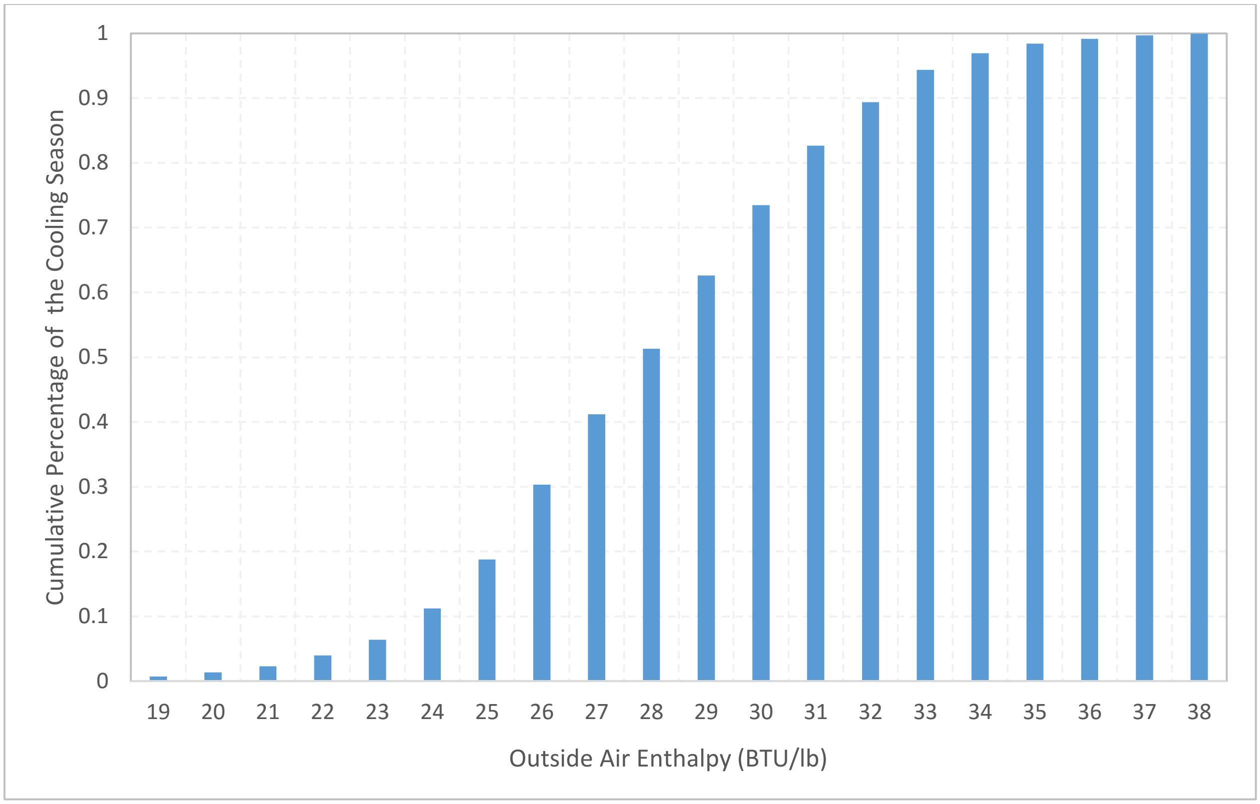

Figure 1: Cumulative percentage of outside air enthalpy (BTU/lb) measured at Montgomery Airport during the cooling season for 2013 and 2014.

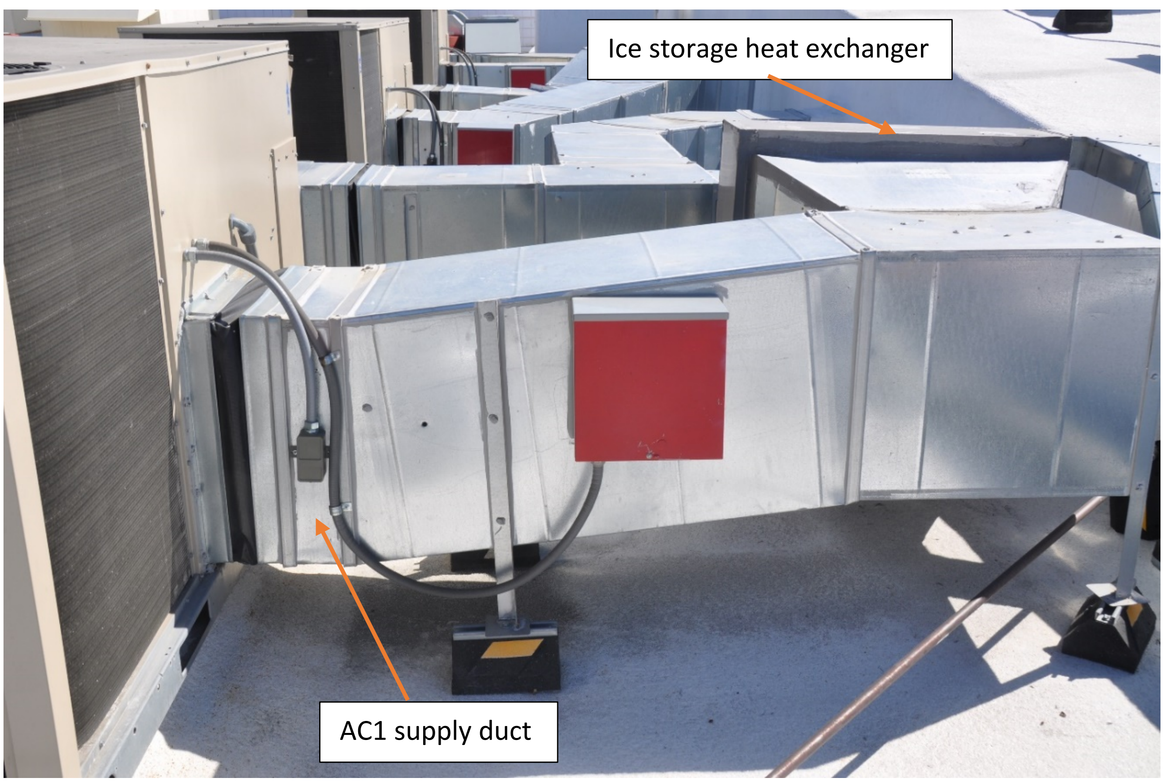

Figure 2: AC-1 in series with ice storage heat exchanger

Packaged heater and hybrid indirect evaporative – direct expansion coolers

The EIC has three packaged hybrid air conditioners that combine indirect evaporative cooling (IEC) with a small direct expansion and heating system. These three systems condition the demonstration kitchen and classroom area. Figure 3, illustrates the airflow for the system in cooling modes. Outside air and return air mix before entering IEC heat exchanger. The airstream is then split into a primary and secondary airstream. The primary air stream is sensibly cooled through the IEC heat exchanger then passes through the DX evaporator before becoming the supply air. The secondary airstream flows through the wet channels of the IEC, then is passes through the DX condenser before being exhausted to the ambient air.

These systems use a polymer indirect evaporative heat exchanger where all of the incoming air goes through the dry channels (Figure 4). Within the dry channels are small holes that allow air to pass into the wet channels and cause the remaining air to be cooled sensibly as the water in the wet channels evaporates. The heat exchanger always operates in a cross flow situation. The sensible cooled dry air then passes through the DX evaporator and finally past the heating coils. The air that passes through the wet channels of the IEC passes through the DX condenser before exiting the unit.

During the first visit, all three systems were observed to be functioning. However, shortly afterwards, numerous complaints were received from the occupants of demonstration kitchen for the room being to warm. After several complaints, the building manager measured a supply air temperature of 68 °F while the unit was running with the DX system. WCEC discovered that these systems had not been properly serviced since the original installation and because of that the water lines serving the IEC had been clogged (Figure 5).

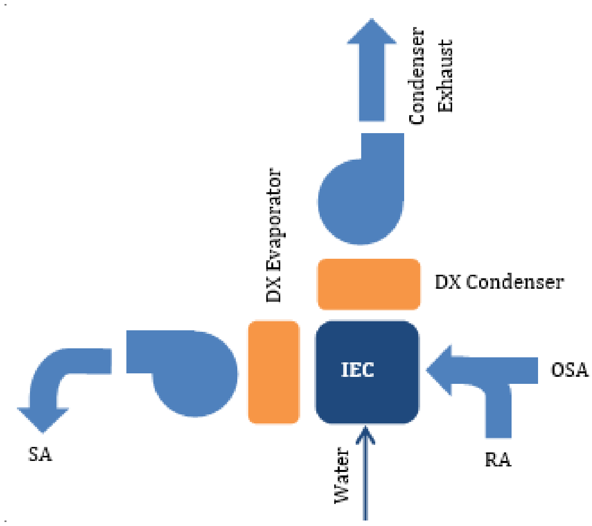

Figure 3: Airflow schematic for hybrid indirect evaporative coolers

WCEC had the manufacturer send a technician to service the units. During the service, the technician cleaned the water distribution system and the IEC heat exchanger for accumulated solids. Since original installation, the manufacturer had started using a different fan motor and impeller. The technician was able to upgrade both fans on all three units. The impact of this can be seen in the section *Airflow measurement* and will be further discussed in the *Discussion* section. As part of the service, WCEC had the manufacture's technician train the EICs HVAC technician and building manager on proper maintenance for the units.

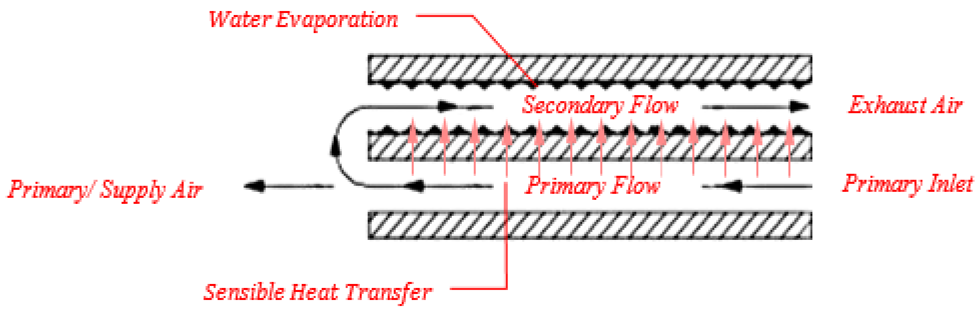

Figure 4: Conceptual schematic for indirect evaporative cooling

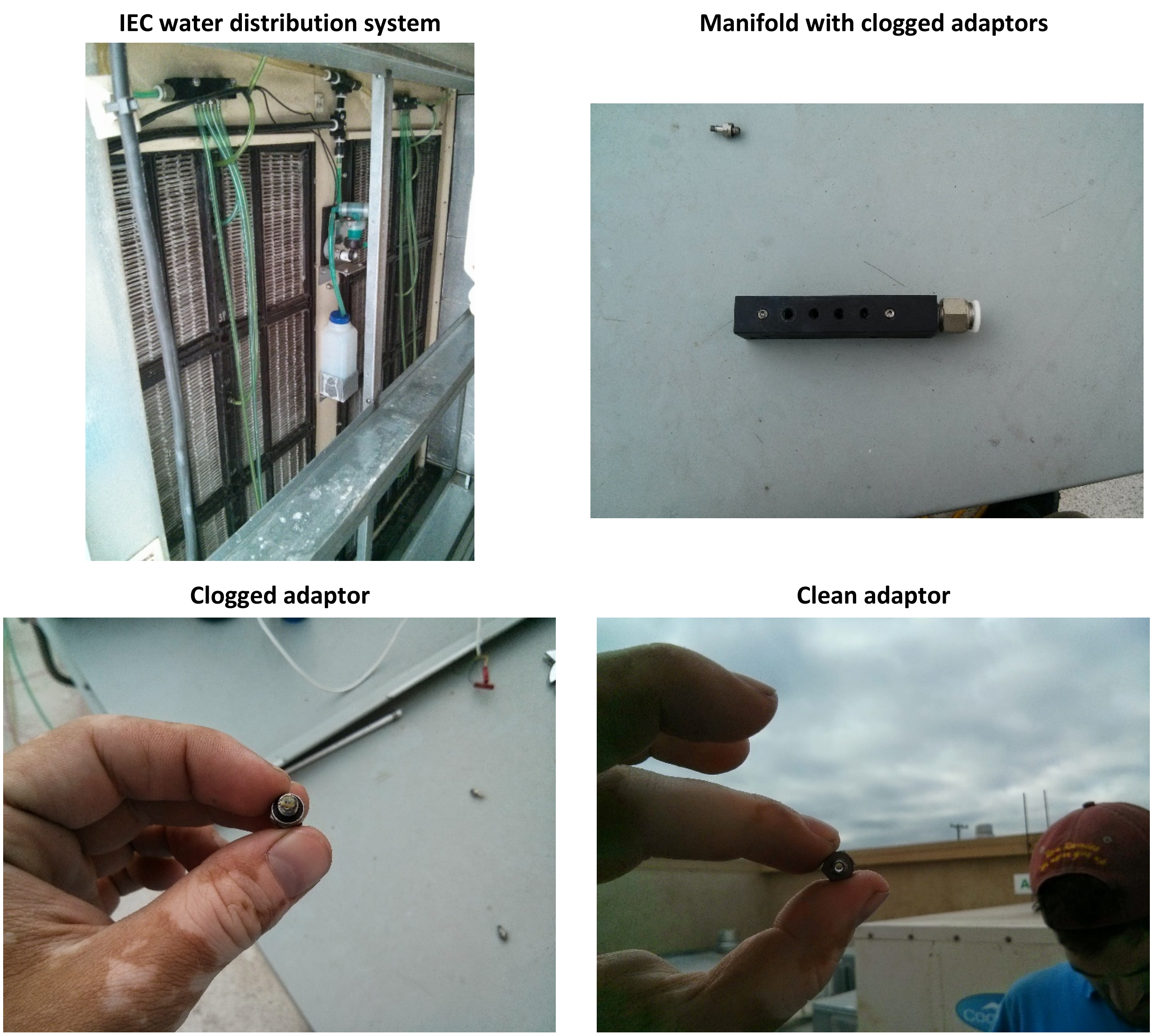

Figure 5: IEC water distribution system with clogged and cleaned adaptors

Air handler units (AHUs)

There are three AHUs at the EIC. AHU1 and AHU2 serve the Smart Home (SH) while AHU3 serves the offices and conference room in the demonstration kitchen. AHU1 and AHU2 are connected to heat pumps are have a rated capacity of 5-tons and 3-tons respectively. AHU3 has gas heat and is connected to a water cooler condenser unit for cooling. The following observations were made:

1. During the airflow testing it was discovered that AHU3 had a leak in the natural gas line.
2. The placement of AHU1 above the drop ceiling in the SH makes it very difficult to replace the filter. During the airflow measurements is was noted that the filter had fatigued and collapsed into the unit.

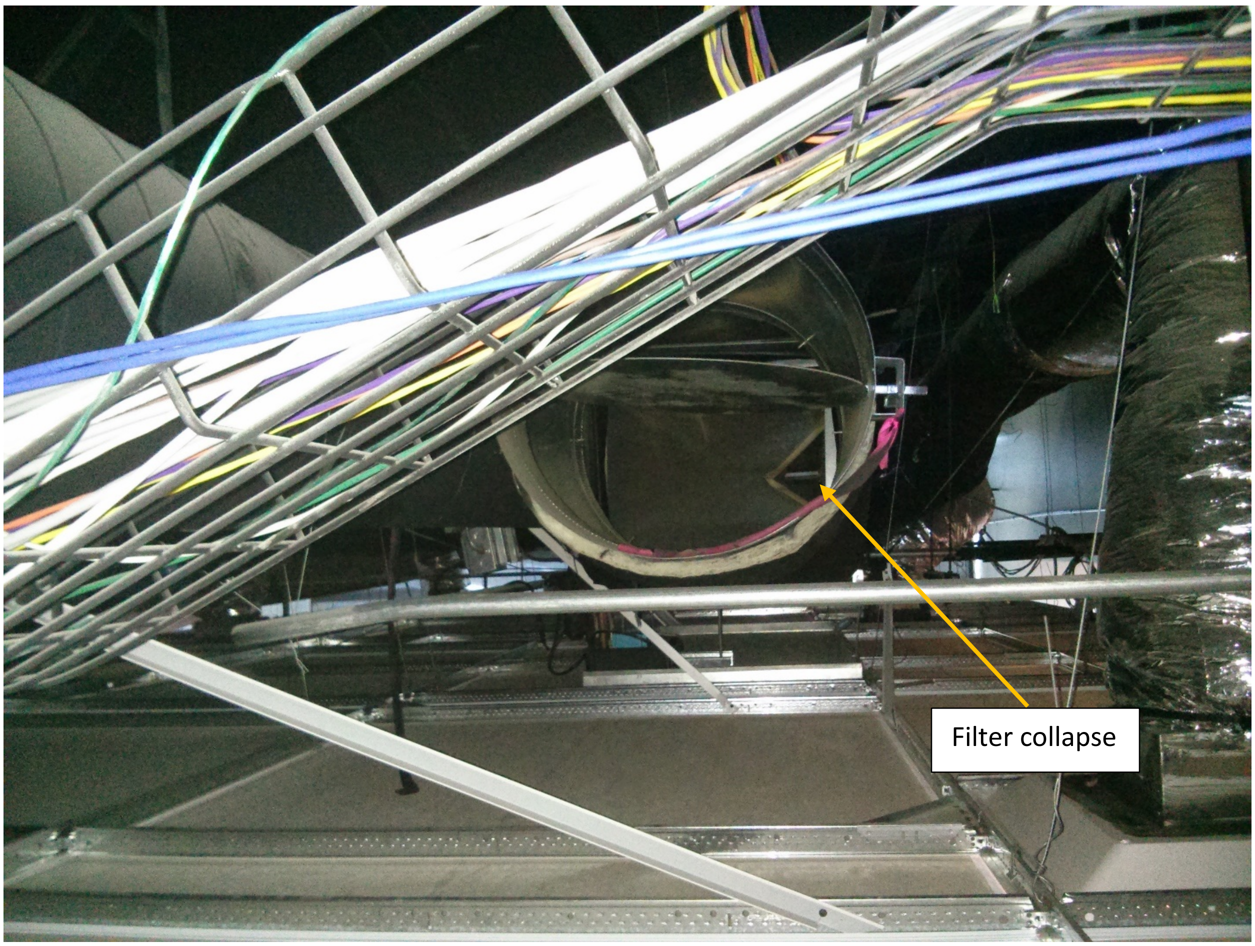

Figure 6: Picture showing AHU1 filter collapse from fatigue

Airflow measurement

Supply airflow rates for the equipment were determined using a tracer gas airflow measurement, conducted according to ASTM E2029 *Standard Test Method for Volumetric and Mass Flow Rate Measurement in a Duct Using Tracer Gas Dilution* [1]. This method mixes a measured mass flow rate of CO_2 into the supply air stream then measures the corresponding rise in CO_2 concentration downstream. The volume flow of air into which the tracer gas is mixed can be calculated by the following relation:

$$\dot{V}_{Airflow} = \frac{\dot{V}_{CO_2}(1 - [CO_2]_{downstream})}{[CO_2]_{downstream} - [CO_2]_{background}} \quad (1)$$

This method has many advantages compared to conventional air balance techniques, the most significant of which is accuracy. The tracer gas airflow tools used can measure airflow with a calculated uncertainty of less than ±2%. The tracer gas measurement was conducted across a range of fan speeds and operating conditions in order to build an airflow map for the system in all possible scenarios. All of the ACs and AHUs have variable speeds fans. However, AC1-8 and the AHUs only vary the fan speed by mode of operation. Therefore, for AC1-8 and the AHUs measurements were taken in each mode and the results are presented in Table 1. To step each unit through its various modes WCEC changed control temperature set points. Each mode was confirmed by visual and audible detection of individual component operation. For AC9-11 the fan varies during normal operation. WCEC controlled the fans to four different fan speeds and used the results to generate the airflow maps presented in Figure 7.

Each piece of equipment provides a range of airflows across the operating modes (Table 1). According to the sequence of operations of the AC and AHU units, ventilation and dehumidification will operate at the low fan speed, economizer and cooling at a high fan speed, and heating with a medium and high fan speed, depending on the stage. Units that have a higher airflow rate in economizer mode experienced less airflow resistance though the outside air damper than the return ducting.

Table 1: Airflow (SCFM) by mode for AC1-8, AHU1-3

UNITS	COOLING-1	COOLING -2	ECONOMIZER	VENTILATION	DEHUMIDIFICATION	HEAT
AC1	1090	N/A	1596	842	756	1088
AC2	1429	N/A	2168	1288	1283	2532
AC3	1083	N/A	1650	820	947	1378
AC4	1567	N/A	1475	1328	1427	1758
AC6	1267	N/A	1204	1016	973	1935
AC7	732	N/A	1137	694	644	1032
AC8	1410	N/A	1374	681	884	1388
AHU1	1556	1991	N/A	844	N/A	N/A
AHU2	1035	1056	N/A	349	N/A	882
AHU3	1023	N/A	N/A	N/A	N/A	561

AC units 9-11 have two fans, the supply fan and the exhaust fan. Unlike conventional rooftop units, where only one fan has to run when you are providing, AC units 9-11 run both fans to keep the appropriate amount of airflow going through the wet channels of the IEC heat exchanger. The manufacturer controls the fan speed on both fans with a 0-10 V_{DC} signal. During the airflow measurements WCEC stepped the fans between 4 – 10 V_{DC} by 2 V_{DC} increments, measured airflow, and recorded the average power draw of the system. Figure 7, illustrates that the new motors are supplying more than the old motors and the fan speed increases. This results in ~15% increase in airflow at the highest fan speed.

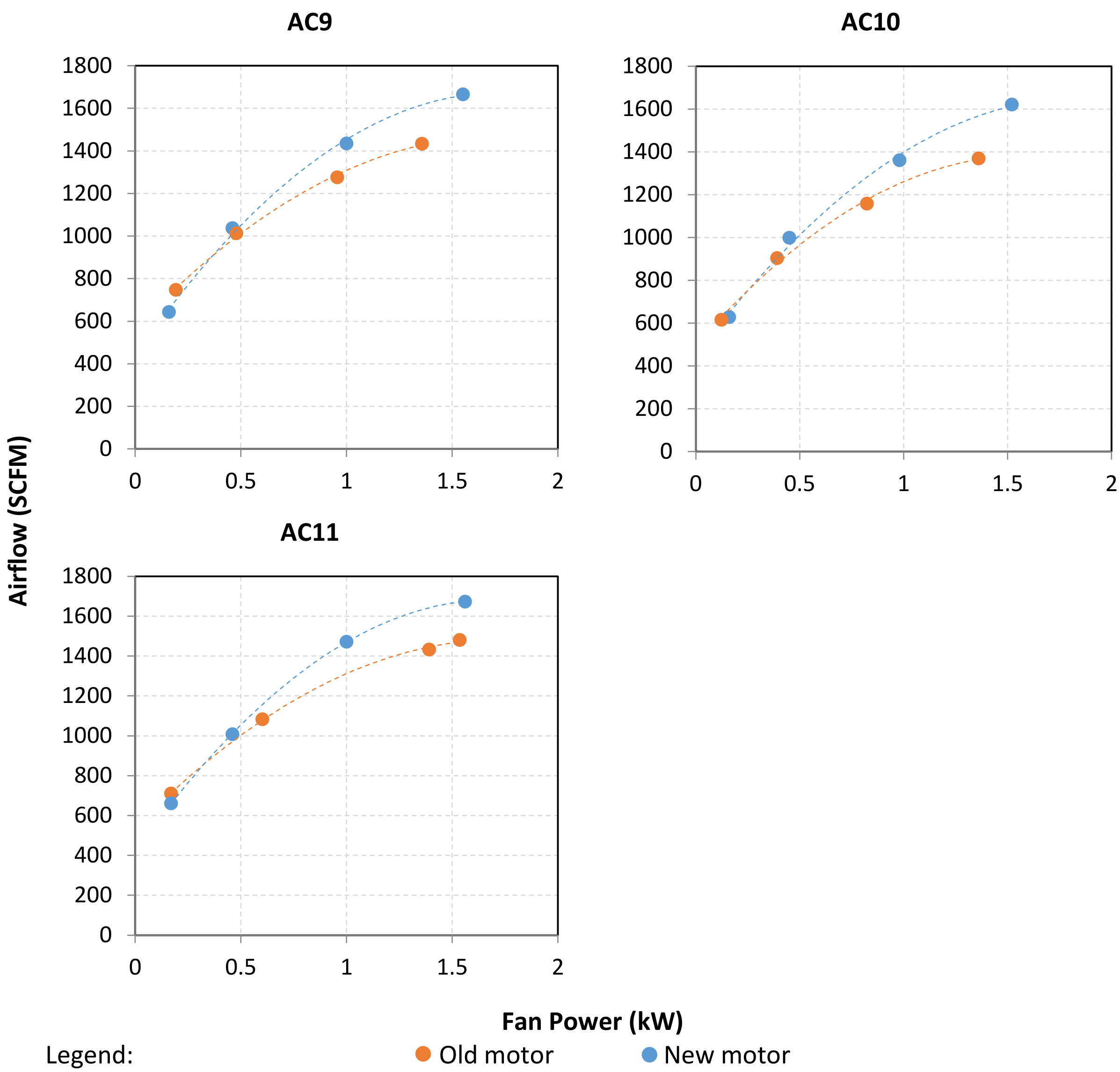

Figure 7: Old and new motor airflow vs power draw

Duct Leakage Testing

Duct leakage was measured used using method C from the ASTM E1554/E1554M – 13 Standard [2]. This method measures the total leakage from both the supply and return ducting as well as the leakage through the unit. The results from the measurements are presented in Table 2.

The numbers in Table 2 are quite large in most cases. The impact of leakage on building conditioning performance and efficiency is affected by whether or not the duct work is located in conditioned space. For example, when the duct leakage is located within the conditioned space, the leaked air is still delivered to the conditioned space but with no control over its distribution. However, when ducts are located outside or in non- conditioned space, leaks allow air from the non-conditioned space to mix with conditioned air. This can have a noticeable impact on energy performance by increasing the conditioning load and delivering conditioned air to unconditioned spaces. At the EIC, the majority of the ductwork penetrates the roof and runs above the drop ceiling in the conditioned space. However, in the case of AC1-3, and 10 a significant amount of the duct work is located on the rooftop. For AC4 and AHU3, the majority of the duct work in inside the EIC, but it run through storage areas that are not conditioned. In all cases duct sealing and reduced leakage would improve energy efficiency and performance of the air conditioning units, however the impact will be greater for systems with ducts in unconditioned spaces.

Table 2: Duct leakage results at 25pa

UNIT	LEAKAGE AT 25 PA (CFM25)	LEAKAGE AREA AT 25 PA (IN^2)	DUCTS ON ROOFTOP OR UNCONDITIONED SPACE
AC1	880	203	YES
AC2	344	79	YES
AC3	316	73	YES
AC4	488	113	YES
AC6	255	59	NO
AC7	410	95	NO
AC8	347	80	NO
AC9	594	137	NO
AC10	842	195	YES
AC11	331	77	NO
AHU1	199	46	NO
AHU2	91	21	NO
AHU3	154	36	YES

Long Term Monitoring

The building management system (BMS) was configured to log various values for the building, including the HVAC system, with logging intervals between 1 – 15 minutes for each day. WCEC reviewed and analyzed the data from the HVAC systems on 15-minute interval from May 2013 – September 2014 and the made the following observations.

First, the form of the daily files is difficult to analyze because of different logging intervals and how the comma separate value (CSV) output file is written. Data points are logged instantaneously on four separate time intervals- 1 minute, 5 minute, 10 minute, and 15 minutes. The different intervals, specifically the 10 minute intervals, add difficulty when looking at time dependent trends in the data. There is also inconsistency in the logging intervals for similar measurements. For example, the space temperature for AC1 is logged on a 10 minute interval, whereas every other unit is on a 15 minute interval. Since all the data points are instantaneous, if someone wanted to look at time dependent trends, interpolation or regression techniques need to be applied to the data.

Second, the output CSV file is written by appending each timestamp, point name, and value to the file. This creates a file that has three columns (the timestamp, name, and value) and over 100,000 rows. Having the file created in this manor makes it very difficult to inspect the data without having a complex program capable of manipulating the file. It is possible to open the CSV in a program with basic filtering capabilities, however, with only three columns, only one measurement point can be viewed at a time. Furthermore, the output in the value column contains units for some points and nothing for others. This causes even more issues with trying to view the data without some form of processing. WCEC spent a significant amount of time developing a Python script capable of producing CSV files with one unified timestamp in the first column and a column for each measurement point. This results in a data file that is 1440 rows by 386 columns. More importantly, multiple variables can be viewed at a single time which makes visualizing the data easier. An example of the output CSV file and WCEC processed file can be seen in Table 3 and Table 4 respectively.

After reworking the data into a usable format the following issues were observed:

- The outside air (OA) temperature is not properly shielded from solar radiation (Figure 8).
- The OA relative humidity sensor only works intermittently (Figure 8).
- The field measurements power draw of AC1-11 and AHU1-3 are different than the values logged by the BMS for the same time period. The worst comparison is for AC1-8 (Table 5 and Table 6).

Lastly, while analyzing the data it was apparent there is an opportunity for networking the systems at the EIC. Currently, there are 15 pieces of HVAC equipment and each one has its own controller that receives inputs from a single thermostat that measures temperature, relative humidity, and CO_2 concentration. There is a BMS system installed at the EIC, however, it is not configured to control the systems. It only provides the building manager with a portal to change thermostat set points, set runtime schedules, and log historical data. While analyzing the data WCEC observed the following inefficiencies that could be corrected with integrated control of the HVAC systems:

- Heating and cooling on the same day
- The automated windows in the lobby are not connected to AC4 and over ventilation can occur when the unit is running and the windows are open. It is also possible for AC4 to heat or cool the lobby while the windows are open.

- The openable walls in the hallway, demonstration kitchen classroom, and SH are not connected to the equipment serving those areas and can cause the equipment to run while open.
- There are cooling and heating setback temperatures for non-scheduled occupancy hours. However, there is no setback for the humidity set point. Units continue to dehumidify throughout the night when the building is unoccupied.

Table 3: Example of daily output CSV file with all data points

Date / Time	Name Path Reference	Object Value
6/28/2014 23:59	Energy Innovation Center:NAE-01/BACnet.BB-MODBUS.L2A RELAY-03.Lights.kW5sec (Trend2)	0.062094
6/28/2014 23:59	Energy Innovation Center:NAE-01/BACnet.BB-MODBUS.L2A RELAY-01.Lights.kW1min (Trend1)	0.035055
6/28/2014 23:59	Energy Innovation Center:NAE-01/BACnet.BB-MODBUS.L2 RELAY-08.kW1min (Trend1)	0.395688
6/28/2014 23:59	Energy Innovation Center:NAE-01/BACnet.BB-MODBUS.L2 RELAY-06.kW1min (Trend1)	0.393762
6/28/2014 23:59	Energy Innovation Center:NAE-01/BACnet.BB-MODBUS.L2 RELAY-04.kW1min (Trend1)	0.411534
6/28/2014 23:59	Energy Innovation Center:NAE-01/BACnet.BB-MODBUS.L1 RELAY-05.EF-6.kW1min (Trend1)	0
⋮	⋮	⋮
6/28/2014 0:00	Energy Innovation Center:NAE-01/FCB-01.MAU-05.SF-S.Trend - Present Value (Trend1)	Off
6/28/2014 0:00	Energy Innovation Center:NAE-01/FCB-01.MAU-05.OAD-S.Trend - Present Value (Trend1)	Close
6/28/2014 0:00	Energy Innovation Center:NAE-01/FCB-01.MAU-05.OA-CO2.CX (Trend1)	291.9868 ppm
6/28/2014 0:00	Energy Innovation Center:NAE-01/FCB-01.FC-1/CU-1.RM-T.Trend - Present Value (Trend1)	69.23376 deg F
6/28/2014 0:00	Energy Innovation Center:NAE-01/FCB-01.FC-2/CU-2.RM-T.Trend - Present Value (Trend1)	72.03792 deg F

Table 4: Partial example of WCEC processed file on 15 minute interval for temperature trending

name	ac01_cooling_occupied_setpoint_1min_trend2	ac01_space_temperature_trend__present_value_trend1	…
6/26/2014 0:00	73	73	…
6/26/2014 0:15	73	73.25	…
6/26/2014 0:30	73	73.25	…
6/26/2014 0:45	73	73	…
6/26/2014 1:00	73	73	…
6/26/2014 1:15	73	73	…
6/26/2014 1:30	73	73.25	…
6/26/2014 1:45	73	73.25	…
6/26/2014 2:00	73	73.25	…
⋮	⋮	⋮	⋮

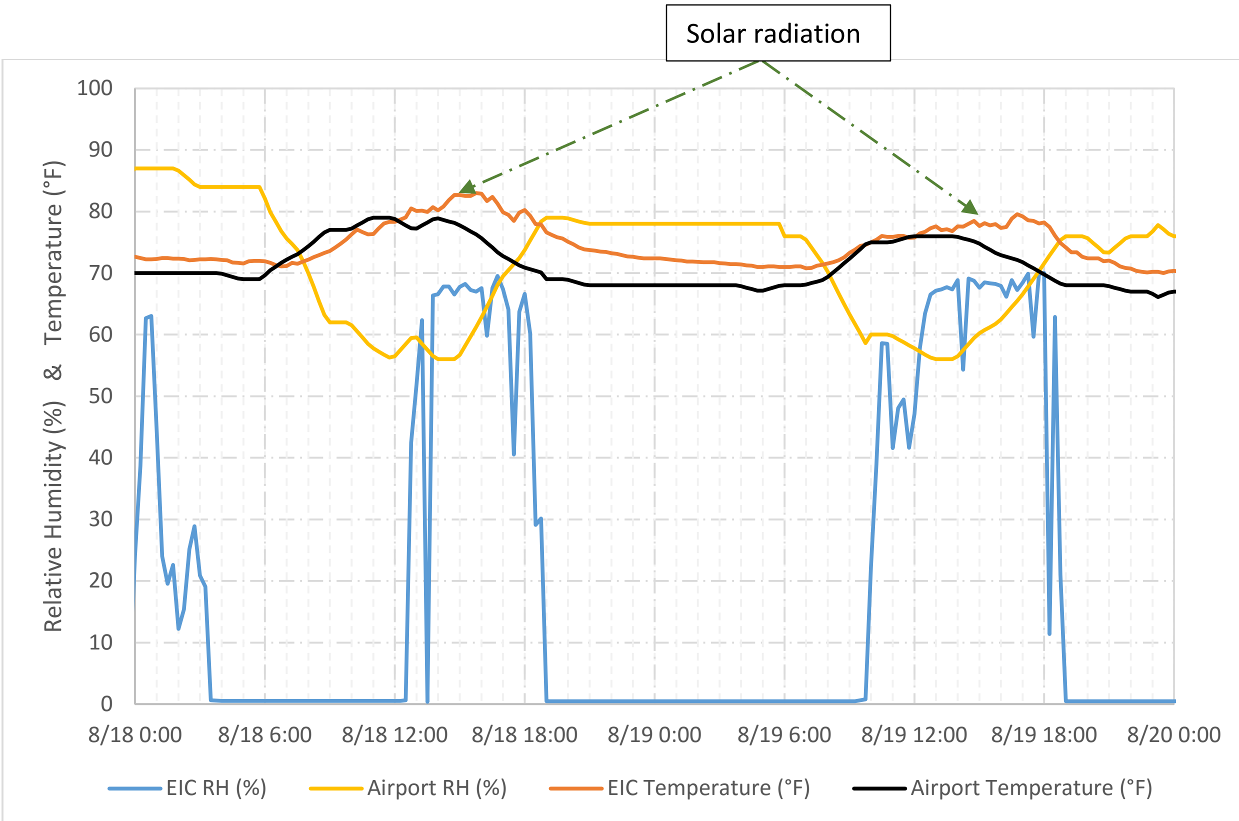

Figure 8: EIC Outside Air Temperature and Humidity vs Closest Weather Station (Montgomery Airport)

Table 5: Comparison of field power measurements to BMS values for hybrid system (all values are in kW)

UNIT	4 V_{DC}	6 V_{DC}	8 V_{DC}	10 V_{DC}
AC9				
FIELD MEASUREMENT	0.2	0.5	1.0	1.6
BMS VALUE	0.14	0.4	0.87	1.36
AC10				
FIELD MEASUREMENT	0.2	0.5	1.0	1.5
BMS VALUE	0.14	0.39	0.85	1.33
AC11				
FIELD MEASUREMENT	0.2	0.5	1.0	1.6
BMS VALUE	0.15	0.4	0.87	1.33

Table 6: Comparison of field power measurements to BMS values for RTUs and AHUs (all values are in kW)

UNIT	COOLING	ECONOMIZER	VENTILATION	DEHUMIDIFICATION	HEATING
AC1					
FIELD MEASUREMENT	2.3	1.5	0.4	2.3	0.5
BMS VALUE	1.4	0.2	0.007	1.3	0.2
AC2					
FIELD MEASUREMENT	4.8	1.9	0.4	2.3	0.5
BMS VALUE	1.7	1.7	0.06	1.2	0.5
AC3					
FIELD MEASUREMENT	4.1	1.0	0.2	3.7	0.6
BMS VALUE	1.2	1.4	0.06	1.2	0.2
AC4					
FIELD MEASUREMENT	4.49	0.44	0.32	4.06	0.74
BMS VALUE	1.33	0.89	0.89	1.38	0.91
AC6					
FIELD MEASUREMENT	2.4	0.2	0.1	2.0	0.4
BMS VALUE	0.8	0.8	0.005	0.6	0.1
AC7					
FIELD MEASUREMENT	2.18	0.7	0.2	1.9	0.4
BMS VALUE	0.7	0.7	0.02	0.6	0.2
AC8	2.3	0.4	0.1	2.0	0.4
FIELD MEASUREMENT	0.7	0.4	0.007	0.6	0.1
BMS VALUE					
AHU1					
FIELD MEASUREMENT	0.2	0.2	0.02	N/A	N/A
BMS VALUE	0.1	0.1	0.02	N/A	N/A
AHU2					
FIELD MEASUREMENT	1.9	N/A	0.1	N/A	0.3
BMS VALUE	N/A	N/A	N/A	N/A	N/A
AHU3					
FIELD MEASUREMENT	0.4	0.4	0.4	N/A	0.4
BMS VALUE	0.4	0.4	0.4	N/A	0.2

HVAC Equipment Analysis

Table 7, illustrates the measured performance for AC1-8 compared to the manufacturer's data at an outside air temperature of 75 °F, indoor dry bulb of 75 °F, and indoor wet bulb of 65 °F. It is clear from the sensible heat ratio that a sizeable portion of the capacity is being used for dehumidification. The measured sensible capacity shown in Table 7 is calculated from the airflow values previous shown in *Airflow measurement*, the supply air temperature, and the return air temperature. Supply air relative humidity data was not available so total capacity could not be calculated.

Table 7: Comparison of manufactures' stated performance versus field measurements at 75°F T_{DB} and 65°F T_{WB}

UNIT	STATED TOTAL CAPACITY (BTU/HR)	STATED SENSIBLE HEAT RATIO	STATED SENSIBLE CAPACITY (BTU/HR)	MEASURED SENSIBLE CAPACITY (BTU/HR)	SENSIBLE EER	MEASURED SENSIBLE EER
AC1	48,900	0.60	29,340	21,800	12.7	9.5
AC2	51,700	0.65	33,600	33,400	7.0	7.0
AC3	48,900	0.60	29,300	25,800	7.1	5.4
AC4	51,700	0.65	33,600	37,300	7.5	7.8
AC6	28,900	0.7	20,300	21,600	8.4	8.9
AC7	27,800	0.66	18,300	17,800	8.4	8.2
AC8	37,900	0.74	28,000	25,300	12.4	11.2

Figure 9 and Figure 10 illustrate the total capacity and coefficient of performance (COP) for AC9-11 pre-maintenance (August 2014) and post maintenance (September 2014) periods. Capacity and COP were calculated from the one-time airflow measurements mapped to the power values (to determine operating mode) and temperature data from the BMS system. This method did not account for any changes in airflow resistance during the study. The power data for AC10 was not recorded during September 2014 and therefore the airflow, capacity, and COP could not be calculated.

In Figure 9, there is a clear difference between the pre and post maintenance period. Before the maintenance, at a wet bulb depression of 5 °F, the IEC for AC9 - 11 had a total capacity of -10 kBTU/hr to 15 kBTU/hr, -5 kBTU/hr to 15 kBTU/hr, and -5 kBTU/hr to 15 kBTU/hr respectively. The negative capacity is due to the lack of cooling combined with the added fan heat from the system. After the maintenance, AC9 and AC11 had a total capacity of 7 kBTU/hr to 30 kBTU/hr and -3 kBTU/hr to 18 kBTU/hr respectively.

In dryer conditions, at a wet bulb depression of 20 °F, AC9 and AC11 ran with the DX system and had a total capacity of 40 kBTU/hr and 35 kBTU/hr. AC10 ran in both IEC only mode and with DX and had a total capacity of 18 kBTU/hr (IEC only) and 30 kBTU/hr (IEC+DX). After the maintenance, AC9 and AC11 had periods of operation in both IEC only mode and with the DX system. AC9 had a total capacity of 40 kBTU/hr for IEC only and 90 kBTU/hr with the DX. AC11 had a total capacity of 30 kBTU/hr for IEC only and 50 kBTU/hr with the DX.

Unlike AC1-8, AC9-11 do not operate in response to building humidity, but only in response to temperature. The units do not provide dehumidification in IEC mode, but do provide de-humidification in IEC+DX mode. Figure 11 illustrates the sensible capacity for AC9-11. There is a noticeable difference between the pre and post maintenance periods, however, none of the units are able to provide more than 5-tons of sensible cooling.

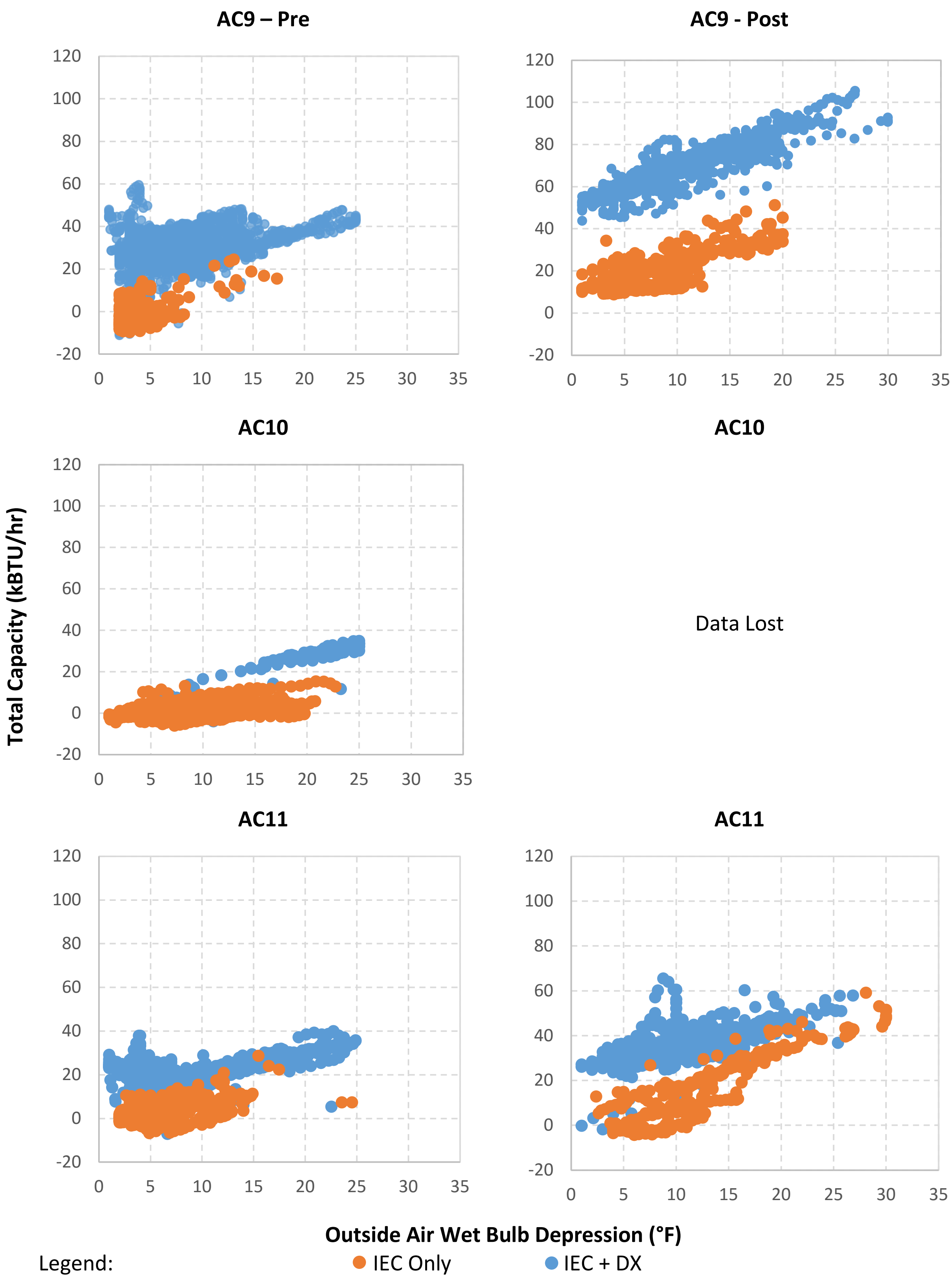

Figure 9: AC9-11 Total Capacity versus Outside Air Wet Bulb Depression for pre and post maintenance and motor change

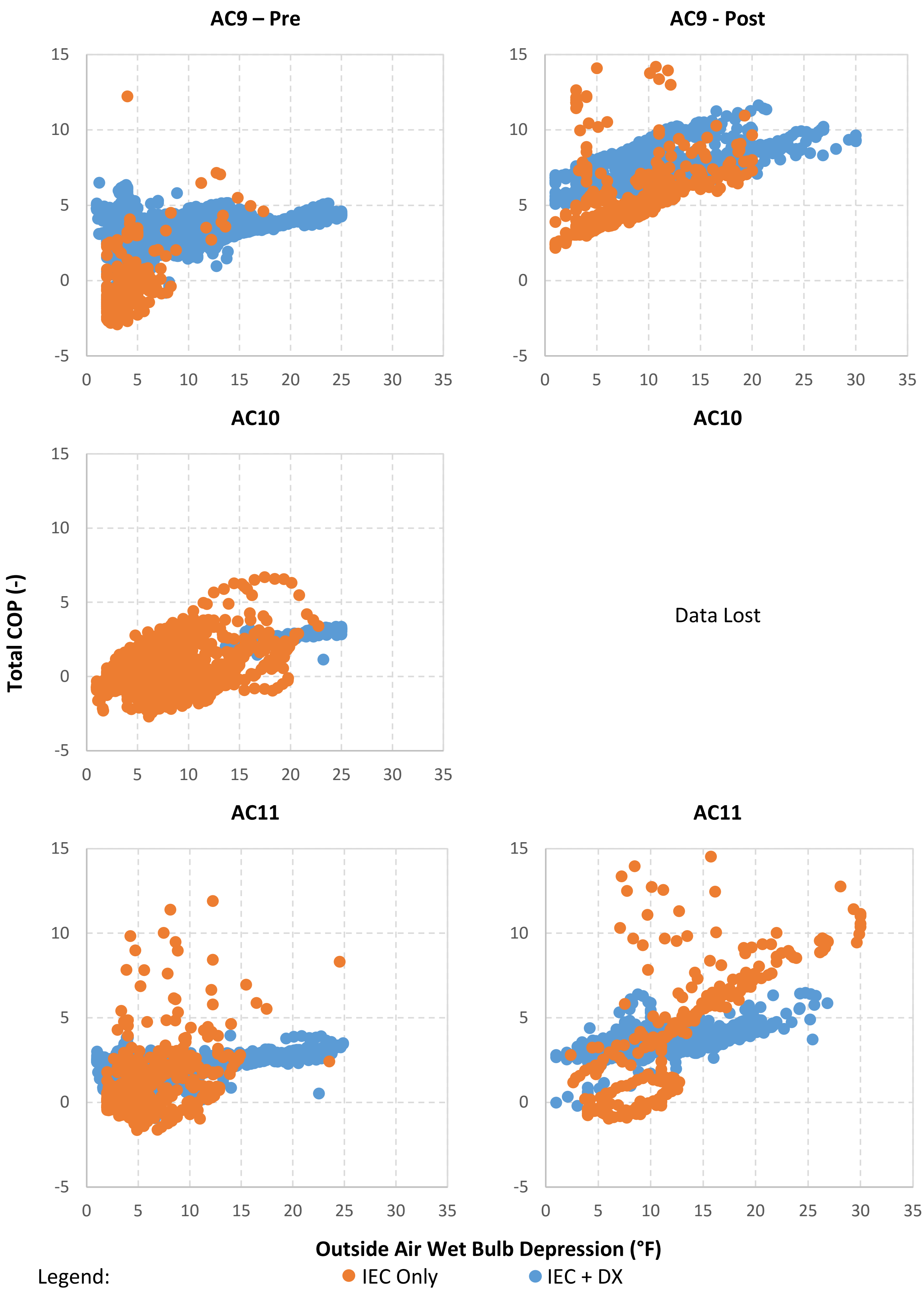

Figure 10: AC9-11 Total COP versus Outside Air Wet Bulb Depression

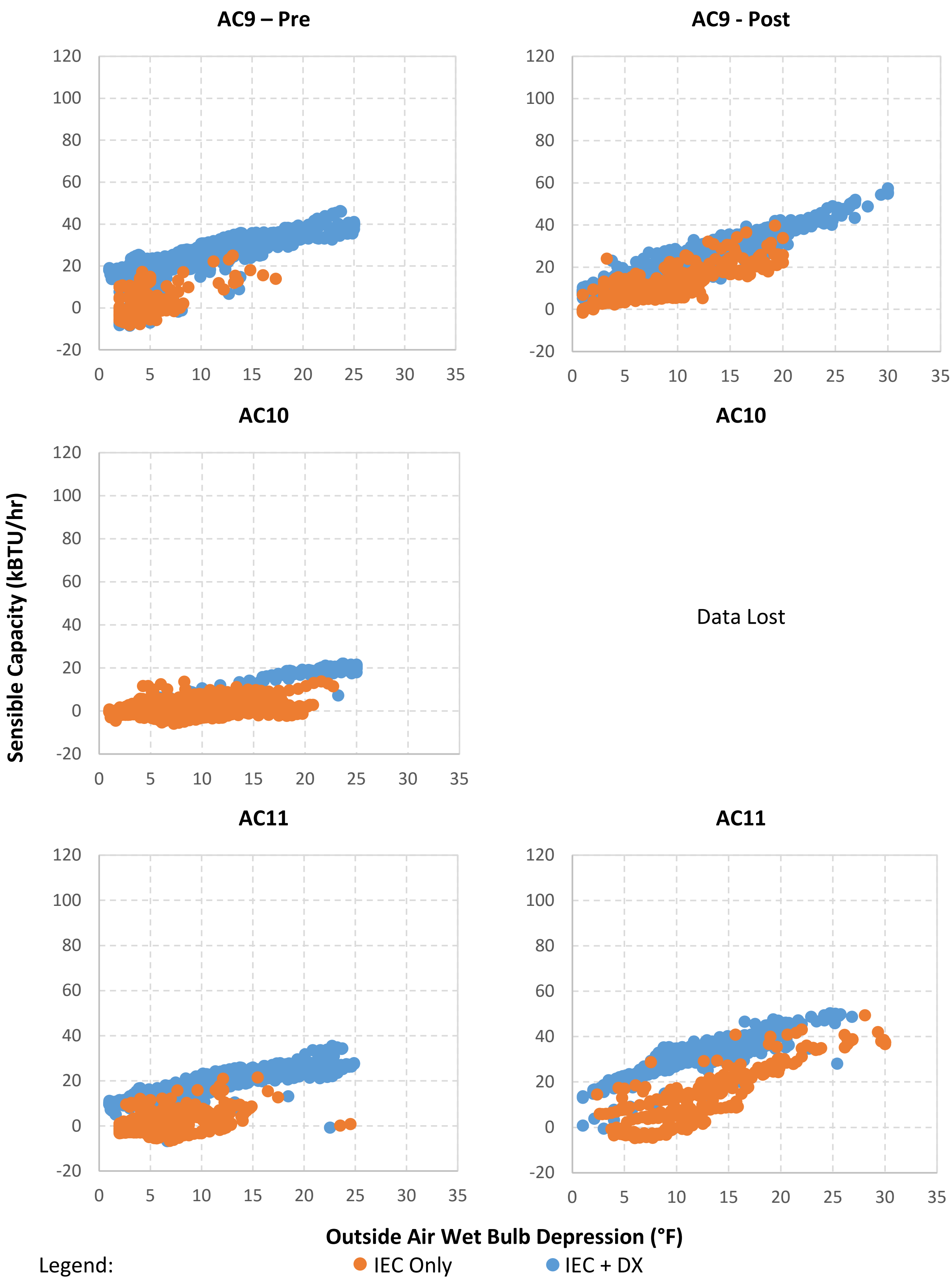

Figure 11: AC9-11 Sensible COP versus Outside Air Wet Bulb Depression

Discussion/Recommendations

During the Short Term Diagnostics, WCEC noted the behavior of the outside air damper on AC1-8. It should be noted that these settings result in uncomfortable room conditions before the damper starts to open. According to ASHRAE Standard 62.1 [3] the room CO_2 level should not exceed a differential of 650 ppm with the outside air. E.g. if the outside air is 400 ppm the room CO_2 concentration should never exceed 1050 ppm. Currently, when the rooms are “stuffy” enough to warrant a complaint, the building manager will lower the set point in the room to cause the RTU to switch into a cooling mode. This action is taken because the current BMS system does not allow for manual control of the RTUs outside air damper. This solution causes the RTU to switching into cooling which increases the volume of outside air being delivered into the space, but with the penalty of over cooling. This remedy does not always return the room to appropriate CO_2 levels. The BMS data showed periods of time where the CO_2 concentration remained above 1100ppm for 2-3 hour periods. WCEC recommends a solution that allows the outside air dampers to open to 100% before the room CO_2 concentration reaches 1000ppm.

Additionally, WCEC recorded an economizer change over set point of 22 BTU/lb which is low considering the conditions in California Climate Zone 7. Figure 12 illustrates the enthalpy difference between the outside and average indoor air during the cooling season at the EIC for 2013 and 2014. WCEC recommends one of two options. One option is to increase the economizer change over set point to 27 BTU/lb. This change would increases the possible economizer runtime from <5% to >40%. The second option is to use a differential enthalpy economizer which would allow the unit to use whichever airstream, return air or outside air, has less enthalpy.

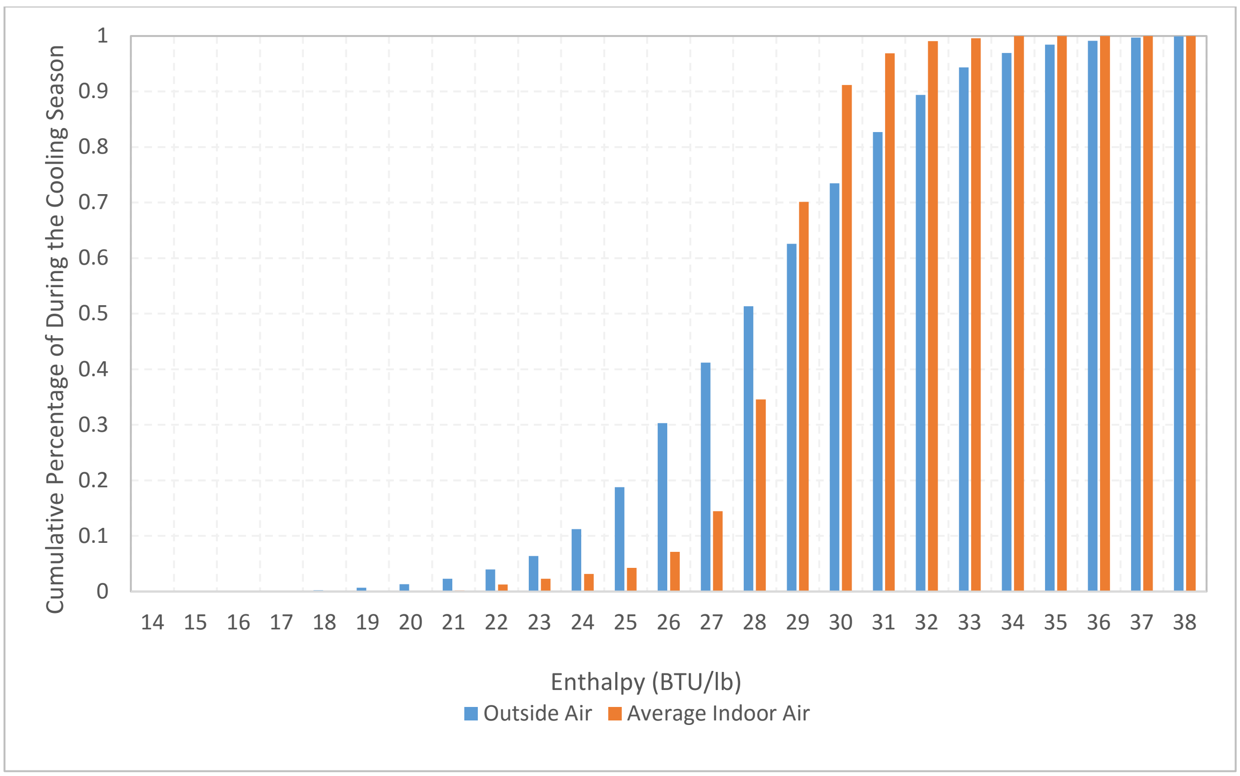

Figure 12: Enthalpy of the outside air and average inside air during business hours

During the Short Term Diagnostics, WCEC noted a potential for improvement in the operation of the ice storage system. The manufactures' controls are set up to keep the AC1s compressor from running during peak-demand times. However, the controller is unable to differentiate between compressor activation signals for cooling or dehumidification. AC1 uses a hot gas bypass in dehumidification mode to reheat the supply air closer to the room temperature. The ice storage system is capable of providing dehumidification, however, it cannot reheat the air. Therefore, during the 12-4pm time frame the compressor is locked out, the room will likely be overcooled. WCEC recommends increasing the complexity of controls to differentiate when the thermostat is calling for dehumidification and cooling. This will allow AC1 to use the ice storage system for cooling and operate normally for dehumidification. This will result is less over cooling and better use of the load shifting ice storage system.

The Duct Leakage Testing results illustrated the condition of the ducting at the EIC. The biggest concern is with the ducting located on the rooftop as it recorded the highest leakage numbers. WCEC recommends sealing all ducts, especially the ducts located in unconditioned space.

Figure 9, Figure 10, and Figure 11 illustrate the difference in performance for the hybrid indirect evaporative coolers. AC9-11 condition the demonstration kitchen and classroom. AC9 serves the demonstration kitchen is which is approximately 1600 ft^2. AC10 and AC11 serve the smaller 200 ft^2 kitchen that is part of the 1400 ft^2 classroom. Since the hybrid systems total cooling capacity varies with outdoor conditions, AC9 provides a range of 0.375 tons/400ft^2 to 2.1 tons/400ft^2 for humid to dry conditions respectively. Likewise, AC11 delivers 0.75 tons/400ft^2 to 1.2 tons/400ft^2 for humid to dry conditions respectively. WCEC would recommend using pre-cooling techniques to temporarily overcool the space prior to larger events or equipment replacement to avoid further temperature related complaints. If new equipment is to be installed, it should be noted that hybrid systems are currently installed on the largest zones at the EIC. Considering they are on the border of being undersized for the demonstration kitchen and classroom they would be more appropriate for slightly smaller zones.

Lastly, WCEC strongly recommends upgrading the EICs BMS system from a scheduling, set point, and monitoring system to a fully functional BMS system. A fully functional BMS system could identify many of the issues identified in this audit. The EIC is a Double LEED Platinum Certified building, however, the current BMS system is not capable of fully actuating the systems based on the information currently being sensed by the vast number of sensors installed. Having a BMS system that was able to control the systems would allow for AC4, AC7, AC10, AC11, and AHU1 to be turned off when the walls or windows are opened. It would allow for the CO_2 levels to be appropriately managed by opening the outside air dampers. Finally, it will streamline any configuration changes made to the HVAC systems. To implement any of the setting changes recommended in this report, the building manager or HVAC technician will be required to reprogram the setting in each of the 13 controllers. Having an appropriate BMS system would allow for all of these changes to be made, verified, and monitored from a single user interface.

[1] ASTM E2029-11, Standard Test Method for Volumetric and Mass Flow Rate Measurement in a Duct Using Tracer Gas Dilution, ASTM International, West Conshohocken, PA, 2011, www.astm.org
[2] ASTM E1554 / E1554M-13, Standard Test Methods for Determining Air Leakage of Air Distribution Systems by Fan Pressurization, ASTM International, West Conshohocken, PA, 2013, www.astm.org
[3] ASHRAE 62.1-2007, Ventilation for Acceptable Indoor Air Quality, American Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc., Atlanta, GA, 2007, www.ashrae.org