MECHANICAL CONSULTING SERVICES

Building Infrastructure Testing and Retro-Commissioning

Final Combined Report

Children's Atrium, OU Children's Physician Building, College of Medicine, OU Physician's Building, Garrison Tower, Nicholson Building, Oklahoma Transplant Center and Samis Education Center

April 12, 2021

Project No. FA20P031

Prepared For:

University Hospitals Authority & Trust (UHAT)
940 NE 13th Street
Oklahoma City, Oklahoma 73104

Prepared by:
Terracon Consultants, Inc.
4701 N. Stiles Avenue
Oklahoma City, Oklahoma 73105

Terracon

April 12, 2021

Mr. Kevin Gates
Chief Operating Officer/Chief Facilities Management Officer
P: 405-271-4962
E: kevin-gates@uhat.org

University Hospitals Authority & Trust (UHAT)
940 NE 13th Street
Oklahoma City, Oklahoma 73104

Reference: **University Hospitals Authority & Trust (UHAT)**
Building Infrastructure Testing & Retro-Commissioning Final Combined Report
Project No. FA20P031

Mr. Gates,

Terracon Consultants, Inc. (Terracon) is pleased to submit this final combined report for the Mechanical Consulting Services performed at the following buildings:

Children's Atrium; Testing	OU Children's Physician Building; Testing
College of Medicine; Testing	OU Physician's Building; Testing
Garrison Tower; Testing & Retro-Commissioning	Nicholson Building; Testing
Oklahoma Transplant Center; Testing	Samis Education Center; Testing

This work was performed in general accordance with the scope of services outlined in the Terracon Proposal for Building Infrastructure Testing & Retro-Commissioning Services dated December 19, 2019. The purpose of this Combined Report is to compile all the findings, field notes, and recommendations related to each of the above referenced locations into one document.

This document also includes the FCI findings outline which correlates the initial scores from the Facility Condition Assessment Terracon performed in 2019 to the above Mechanical Consulting Services reports completed in 2021.

Terracon appreciates the opportunity to be of service to you on this project. If you have any questions regarding this report, please do not hesitate to contact us.

Sincerely,

Terracon Consultants, Inc.

Erik Gonzalez, P.E. (TX), CEM
Senior Engineer
Facilities Services

Jeffrey A. Miller, P.E. (OK)
Senior Principal/Senior Engineer
Facilities Services

Terracon Consultants, Inc. 4701 N. Stiles Avenue Oklahoma City, Oklahoma 73105
P (405) 525-0453 terracon.com

Geotechnical ■ Environmental ■ Construction Materials ■ Facilities

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FACILITY CONDITION INDEX (FCI) OVERVIEW

History:

Terracon initially completed a Facility Condition Assessment (FCA) for the referenced sites in 2019. These FCAs were conducted for UHAT, which desired an independent baseline assessment of facility assets. Through condition assessment and analysis by Terracon's experienced facilities professionals, asset repairs and replacements are prioritized based on collectively established criteria incorporating the client's specific needs.

FCI Ratings, Calculation Method and Summary by Building:

The (FCI) is a standard metric used in the Facility Asset Management industry. It is an indicator of the depleted value of an institution's physical plant. The FCI illustrates the percentage of the capital that an institution would have to spend to eliminate the backlog of current and future maintenance deficiencies. An FCI provides a simple measurement of a facility's current condition.

The "standard" FCI represents the ratio of the cost to correct a facility's deficiencies compared against the current replacement value of the facility. The equation used to calculate FCI is shown below.

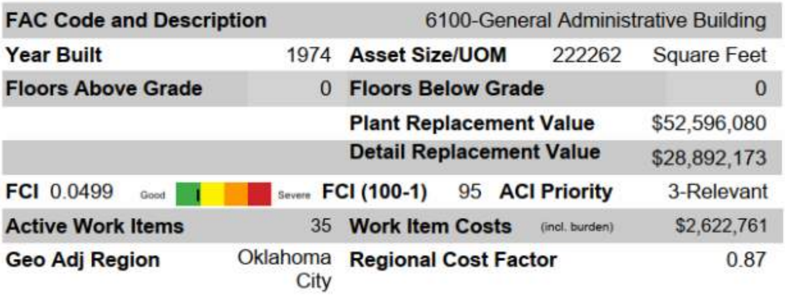
$$\textbf{Facility Condition Index (FCI)} = \frac{\textbf{Cost of Eliminating Deferred Maintenance}}{\textbf{Replacement Value of the Facility}}$$

"Deferred Maintenance" is considered renewal, replacement, and maintenance projects that have been postponed due to perceived lower priority status than those completed with available funding. It is equal to the costs for repairs and replacements of components identified in the list of Work Items created during the time of the FCA.

Below is a breakdown of each of the buildings in this project and summary information from the FCAs conducted:

UHAT

1 - Garrison Tower



FAC Code and Description					6100-General Administrative Building
Year Built	1974	**Asset Size/UOM**		222262	Square Feet
Floors Above Grade	0	**Floors Below Grade**			0
		Plant Replacement Value			$52,596,080
		Detail Replacement Value			$28,892,173
FCI	0.0499 Good 🟩🟨🟧🟥 Severe	**FCI (100-1)**	95	**ACI Priority**	3-Relevant
Active Work Items	35	**Work Item Costs**	(incl. burden)		$2,622,761
Geo Adj Region	Oklahoma City	**Regional Cost Factor**			0.87

2 - Nicholson Tower

FAC Code and Description					6100-General Administrative Building
Year Built	1978	**Asset Size/UOM**		255675	Square Feet
Floors Above Grade	0	**Floors Below Grade**			0
		Plant Replacement Value			$60,502,932
		Detail Replacement Value			$35,224,644
FCI 0.0083	Good 🟩🟨🟧🟥 Severe	**FCI (100-1)**	99	**ACI Priority**	3-Relevant
Active Work Items	38	**Work Item Costs**	(incl. burden)		$501,253
Geo Adj Region	Oklahoma City	**Regional Cost Factor**			0.87

3 - Oklahoma Transplant Center

FAC Code and Description					6100-General Administrative Building
Year Built	1985	**Asset Size/UOM**		43003	Square Feet
Floors Above Grade	0	**Floors Below Grade**			0
		Plant Replacement Value			$10,176,230
		Detail Replacement Value			$7,501,523
FCI 0.0004	Good 🟩🟨🟧🟥 Severe	**FCI (100-1)**	100	**ACI Priority**	3-Relevant
Active Work Items	5	**Work Item Costs**	(incl. burden)		$4,361
Geo Adj Region	Oklahoma City	**Regional Cost Factor**			0.87

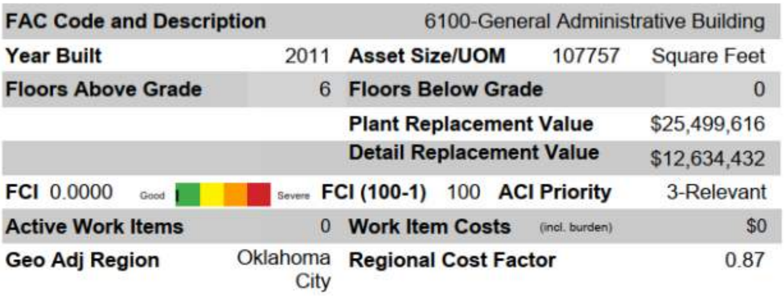
4 - OU Physicians Building

FAC Code and Description					6100-General Administrative Building
Year Built	2001	**Asset Size/UOM**		189525	Square Feet
Floors Above Grade	0	**Floors Below Grade**			0
		Plant Replacement Value			$44,849,196
		Detail Replacement Value			$21,535,732
FCI 0.0000	Good 🟩🟨🟧🟥 Severe	**FCI (100-1)**	100	**ACI Priority**	3-Relevant
Active Work Items	4	**Work Item Costs**	(incl. burden)		$1,328
Geo Adj Region	Oklahoma City	**Regional Cost Factor**			0.87

5 - OU Children's Physicians

FAC Code and Description					6100-General Administrative Building
Year Built	2009	**Asset Size/UOM**		316658	Square Feet
Floors Above Grade	14	**Floors Below Grade**			0
		Plant Replacement Value			$74,933,949
		Detail Replacement Value			$54,328,974
FCI 0.0004	Good 🟩🟨🟧🟥 Severe	**FCI (100-1)**	100	**ACI Priority**	3-Relevant
Active Work Items	8	**Work Item Costs**	(incl. burden)		$31,372
Geo Adj Region	Oklahoma City	**Regional Cost Factor**			0.87

6 - Children's Atrium

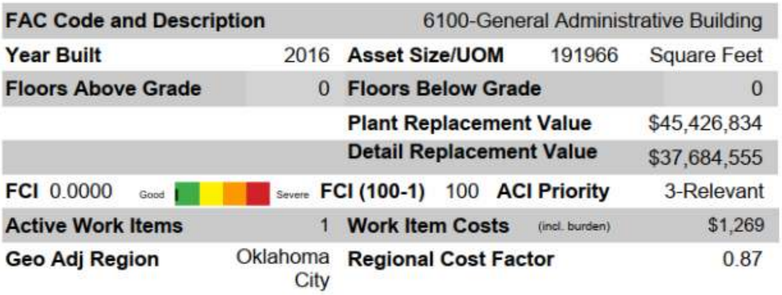


FAC Code and Description			6100-General Administrative Building
Year Built	2011	**Asset Size/UOM**	107757 Square Feet
Floors Above Grade	6	**Floors Below Grade**	0
		Plant Replacement Value	$25,499,616
		Detail Replacement Value	$12,634,432
FCI 0.0000 Good 🟩🟨🟧🟥 Severe	**FCI (100-1)** 100	**ACI Priority**	3-Relevant
Active Work Items	0	**Work Item Costs** (incl. burden)	$0
Geo Adj Region	Oklahoma City	**Regional Cost Factor**	0.87

7 - Samis Education Center

FAC Code and Description			6100-General Administrative Building
Year Built	2012	**Asset Size/UOM**	65063 Square Feet
Floors Above Grade	0	**Floors Below Grade**	0
		Plant Replacement Value	$15,396,508
		Detail Replacement Value	$10,114,040
FCI 0.0001 Good 🟩🟨🟧🟥 Severe	**FCI (100-1)** 100	**ACI Priority**	3-Relevant
Active Work Items	4	**Work Item Costs** (incl. burden)	$1,939
Geo Adj Region	Oklahoma City	**Regional Cost Factor**	0.87

8 - College of Medicine



FAC Code and Description			6100-General Administrative Building
Year Built	2016	**Asset Size/UOM**	191966 Square Feet
Floors Above Grade	0	**Floors Below Grade**	0
		Plant Replacement Value	$45,426,834
		Detail Replacement Value	$37,684,555
FCI 0.0000 Good 🟩🟨🟧🟥 Severe	**FCI (100-1)** 100	**ACI Priority**	3-Relevant
Active Work Items	1	**Work Item Costs** (incl. burden)	$1,269
Geo Adj Region	Oklahoma City	**Regional Cost Factor**	0.87

The scores presented above were based on observations conducted in the field that identified obvious problems and possible visible defects in the components and subcomponents and their physical and operational condition.

Building Infrastructure Testing services:

Following review and analysis of the FCA reports, UHAT contacted Terracon to pursue further assessment and testing of the mechanical systems at the subject buildings. UHAT engaged Terracon to perform the consulting services including Testing, Retro-Commissioning and updates to the FCIs in Paragon.

The purpose of the Building Infrastructure Testing services was to conduct limited visual observations and engineering diagnostics of the HVAC systems. With the observations and measurements taken, a retro-commissioning plan was developed by Terracon with recommended energy conservation opportunities that if implemented may help reduce the operating costs of the subject buildings without compromising comfort for the building occupants.

Included in the appendices are the full reports for the following buildings:

Children's Atrium; Testing	OU Children's Physician Building; Testing
College of Medicine; Testing	OU Physician's Building; Testing
Garrison Tower; Testing & Retro-Commissioning	Nicholson Building; Testing
Oklahoma Transplant Center; Testing	Samis Education Center; Testing

FCI SCORE CORRELATION RESULTING FROM TERRACON SERVICES

(FCIs) were generated for each of the subject buildings at the completion of the Building Infrastructure Testing and Retro-Commissioning, as applicable, for each building. A summary of the FCI score and Direct Condition Rating (DCR) are listed below for each building:

Building Name	Initial Score (2019)	Updated Score (2021)
Children's Atrium	100	100

FCI Comments: The FCI score was unchanged for this building. After reviewing the building assets and the data, Terracon concludes that the currently installed equipment only needs routine maintenance.

Direct Condition Rating: Green (+)
Entire component section or component section sample does not appear to have observable or known distresses.

Note:
Terracon recommended the following items:

- Replace 15-HP motor with 25-HP VFD rated motor and new VFD for AHU G1
- Relocate new outside air measuring flow stations for AHUs G1, G2, G3 and G5

Building Name	Initial Score (2019)	Updated Score (2021)
College of Medicine	100	100

FCI Comments: The FCI score was unchanged for this building. After reviewing the building assets and the data, Terracon concludes that the currently installed equipment only needs routine maintenance.

Direct Condition Rating: Green (+)
Entire component section or component section sample is free of observable or known distresses

Note:
Terracon recommended the following items:

- Modify SF-3 rpm from VFD to modulating fan rpm based on duct static pressure
- Rebalance chilled and hot water flow from pumps and outside air to AHUs

Building Name	Initial Score (2019)	Updated Score (2021)
Garrison Tower	95	91

FCI Comments: The FCI score changed for this building from 95 to 91 based on the following information – Terracon found that AHU BG2, 5G2 and 5G3 did not match the original FCI ratings due to the degraded operating performance for the AHUs when compared to the original design documents.

Direct Condition Rating: Amber (-)
Component-section or sample has significant serviceability or reliability loss. Most subcomponents may have suffered from moderate degradation or a few major (critical) subcomponents may have suffered from severe degradation.

Note:
Terracon recommended the following items:

- Replace selected VAV controllers throughout the building
- Replace existing multizone AHU 7G1
- Replace existing AHU 3G1
- Replace existing AHU with new CO2 sensors on return duct
- Replace cooling and heating coils. Add new CO2 sensors at return duct
- Add new CO2 sensor to return duct for AHU 3RAD (Radiation Area)
- Add new CO2 sensors to return duct. Replace existing chilled water valves
- Repair existing AHU 1G1 and add new CO2 sensors at return duct
- Replace existing chilled water pump CWP-3
- Replace existing VFD for AHU BG1 fan
- Replace AHU BG2
- Replace AHU 5G2
- Replace AHU 5G3

Building Name	Initial Score (2019)	Updated Score (2021)
Oklahoma Transplant Center	100	97

FCI Comments: The FCI score changed for this building from 100 to 97 based on the following information – Terracon found that AHU BM1, 1M1 and 2M1 did not match the original FCI ratings when comparing the operating performance measurements of the AHUs recorded in 2010 to the operating performance measurements recorded in 2020/2021.

Direct Condition Rating: Green
No component section or sample serviceability or reliability reduction. Some, but not all, minor (non-critical) subcomponents may have suffered from slight degradation or few major (critical) subcomponents may have suffered from slight degradation.

Note:
Terracon recommended the following items:

- Replace AHU BM1
- Replace AHU 1M1
- Replace AHU 2M1

Building Name	Initial Score (2019)	Updated Score (2021)
OU Children’s Physician Building	100	100

FCI Comments: The FCI score was unchanged for this building. After reviewing the building assets and the data, Terracon concludes that the currently installed equipment only needs routine maintenance.

Direct Condition Rating: Green (+)
Entire component section or component section sample is free of observable or known distresses

Note:
Terracon recommended the following items:

Building Name	Initial Score (2019)	Updated Score (2021)
OU Physician’s Building	100	100

FCI Comments: The FCI score was unchanged for this building. After reviewing the building assets and the data, Terracon concludes that the currently installed equipment only needs routine maintenance.

Direct Condition Rating: Green (+)
Entire component section or component section sample is free of observable or known distresses

Note:
Terracon recommended the following items:

- Replace existing VFDs for AHU 3 and AHU 5
- Replace existing VFDs for return air fans
- Replace existing chilled water meter system
- Replace existing VFD for chilled water pump
- Replace existing 2 ½” chilled water valves with modulating actuator
- Repair, update and replace some components for building EMS systems
- Replace existing 5” inch chilled water valves with their modulating actuators
- Replace existing CO2 sensors
- Replace existing differential pressure sensors
- Repair and replace existing/missing dampers with the same type and style

Building Name	Initial Score (2019)	Updated Score (2021)
Nicholson Building	99	98

FCI Comments: The FCI score changed for this building from 99 to 98 based on the following information – Terracon found that AHU 5N1 and 6N3 did not match the original ratings issued in Paragon due to the degraded operating performance for the AHUs when compared to the original design documents.

Direct Condition Rating: Green
No component section or sample serviceability or reliability reduction. Some, but not all, minor (non-critical) subcomponents may have suffered from slight degradation or few major (critical) subcomponents and may have suffered from slight degradation. Component section greater than one year old.

Note:
Terracon recommended the following items

- Replace AHU 5N1
- Replace AHU 6N3
- Repair hot water pumps with new bearings

Building Name	Initial Score (2019)	Updated Score (2021)
Samis Education Center	100	100

FCI Comments: The FCI score was unchanged for this building. After reviewing the building assets and the data, Terracon concludes that the currently installed equipment only needs routine maintenance.

Direct Condition Rating: Green (+)
Entire component section or component section sample is free of observable or known distresses.

Note:
Terracon recommended the following items:

- Replace VFD screen for AHU-13
- Relocate new outside air flow monitoring station
- Repair and re-pipe hot water piping to AHU-H4 heating coils

The Direct Condition Rating (DCR) method standard rating definitions have been included for reference (see Table 1) below.

Table 1 - Direct Condition Rating (DCR) Definitions

Rating	SRM Needs	Rating Definition
Green (+)	Sustainment consisting of possible preventative maintenance (where applicable).	Entire component section or component section sample is free of observable or known distresses. Component section is less than one year old.
Green	Sustainment consisting of possible preventative maintenance (where applicable) and minor repairs (corrective maintenance) to possibly few or some subcomponents.	No component section or sample serviceability or reliability reduction. Some, but not all, minor (non-critcal) subcomponents may suffer from slight degradation or few major (critical) subcomponents may suffer from slight degradation. Component section greater than one year old.
Green (-)		Slight or no serviceability or reliability reduction overall to the component-section or sample. Some, but not all, minor (non-critical) subcomponents may suffer from minor degradation or more than one major (critical) subcomponents may suffer from slight degradation.
Amber (+)	Sustainment or restoration to any of the following: Minor repairs to several subcomponents; significant repair, rehabilitation, or replacement of one or more subcomponents, but not enough to encompass the component-section as a whole; or combinations thereof.	Component-section or sample serviceability or reliability is degraded but adequate. A very few major (critical) subcomponents may suffer from moderate deterioration with perhaps a few minor (non-critical) subcomponents suffer from severe deterioration.
Amber		Component-section or sample serviceability or reliability is definitely impaired. Some but not a majority. Major (critical) subcomponents may suffer from moderate deterioration with perhaps many minor (non-critical) subcomponents suffering from severe deterioration.
Amber (-)		Component-section or sample has significant serviceability or reliability loss. Most subcomponents may suffer from moderate degradation or a few major (critical) subcomponents may suffer from severe degradation.
Red (+)	Sustainment or restoration required consisting of major repair, rehabilitation, or replacement to the component-section as a whole.	Significant serviceability or reliability reduction in component-section or sample. A majority of subcomponents are severely degraded and others may have varying degrees of degradation.
Red		Severe serviceability or reliability reduction to the component-section on or sample such that it is barely able to perform. Most subcomponents are severely degraded.
Red (-)		Overall component-section on degradation is total. Few, if any subcomponents salvageable. Complete loss of component-section or sample serviceability.

APPENDIX A
CHILDREN'S ATRIUM REPORT

MECHANICAL CONSULTING SERVICES

Building Infrastructure Testing Report

Atrium

Oklahoma City, Oklahoma

April 12, 2021

Project No. FA20P031

Prepared For:

University Hospitals Authority and Trust (UHAT)
Nathan Miller
940 NE 13th Street
Oklahoma City, Oklahoma 73104

Prepared by:

Terracon Consultants, Inc.
4701 N. Stiles Avenue
Oklahoma City, Oklahoma 73105

April12, 2021

Mr. Nathan Miller
Building Systems Manager
University Hospitals Authority & Trust
940 NE 13th Street
Oklahoma City, Oklahoma 73104
P: 405-271-4962 x44199
E: nathan-miller@uhat.org

Reference: **UHAT**
Building Infrastructure Testing
Atrium Building
1200 Children's Avenue
Oklahoma City, Oklahoma 73104
Project No. FA20P031

Mr. Miller:

Terracon Consultants, Inc. (Terracon) is pleased to submit this Mechanical Consulting Services Report of our Building Infrastructure Testing for the Atrium Building at 1200 Children's Avenue in Oklahoma City, Oklahoma. This work was performed in general accordance with the scope of services outlined in the Terracon Company Proposal for Building Infrastructure Testing dated December 19, 2019 and authorized in February 2020 as identified in the scope section of this Report.

The purpose of this Report is to render our findings, field notes, and recommendations related to our site visits at the above referenced location.

This document includes background information, observations, findings, and recommendations pertaining to the operations of the heating, ventilation, and air conditioning (HVAC) at the site.

Terracon appreciates the opportunity to be of service to you on this project. If you have any questions regarding this report, please do not hesitate to contact us.

Sincerely,

Terracon Consultants, Inc.

Erik Gonzalez, P.E. (TX), CEM
Senior Engineer
Facilities Services

Jeffrey A. Miller, P.E. (OK)
Senior Principal/Senior Engineer
Facilities Services

Terracon Consultants, Inc. 4701 N. Stiles Avenue Oklahoma City, Oklahoma 73105
P (405) 525-0453 terracon.com

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PROJECT OBJECTIVE

The purpose of our Building Infrastructure Testing (BIT) services is to conduct limited visual observations and engineering diagnostics of the HVAC systems of the subject site. With the observations and measurements obtained, a retro-commissioning plan will be developed from recommended energy conservation opportunities in this report that, if enacted, will help improve performance and reduce the operating costs of the building without compromising comfort for the building occupants.

Terracon's representatives, Mr. John Harmon, E.I.T., Mr. Kim Morris QCxP, Mr. Erik Gonzalez, P.E. (TX), CEM, and Mr. Jonathan Curtin P.E. (TX) of Terracon, and our sub-consultant, Engineering Systems & Energy Solutions (ES2), conducted site visits on September 14 - 15, 2020 at the Atrium in order to obtain visual and diagnostic information and field performance measurements for the HVAC systems. During the site visits, visual observations were made to note general operating conditions of the HVAC systems. In addition, diagnostic measurements were taken for the air distribution of the six AHUs, two chilled water pumps, and two hot water pumps comprising the HVAC systems. Measurements recorded were compared to the performance requirements contained in the design documents and EMCS sensor for air flow and water flow characteristics using the software workstation. Observations were made from readily accessible areas and did not include substantial dismantling of components of the building and HVAC equipment, including walls and closed ceilings. With the observations and measurements, Terracon developed energy conservation opportunities and recommendations for improvements to the HVAC systems.

DOCUMENTS AND INFORMATION REVIEWED

Terracon was provided with design documentation for the subject building, utility data for chilled water, steam, and electricity, tariff sheets that breakdown the cost of each utility service, and network access to the *AutomatedLogic Corporation* (*ALC*) *WebCTRL v7.0* energy management control system. The following items were reviewed while performing this assessment:

Document	Source
ATRIUM AS-BUILT MEP DRAWING — HOK Architects and ZRHD, P.C. Engineer, dated May 29, 2008	Client Provided
Utility Bill Data for Terracon.xlsx – e-mailed to Terracon on February 28, 2020	Client Provided
Utility Service Tariff Sheets for OUHSC and OGE services provided to UHAT – e-mailed to Terracon on March 3, 2020	Client Provided

BUILDING DESCRIPTION AND ENERGY USE BASELINE

The subject property is a six-story assembly area that totals approximately 107,757-square feet. The building was originally designed as common area to provide entry into the Samis Education Building, Children's Physicians Hospital and the Children's Hospital. The building was originally constructed around 2011. The HVAC systems were designed to operate with distributed chilled water and distributed steam from a Central Plant associated with the University of Oklahoma Health Sciences Center (OUHSC) at a remote location in downtown Oklahoma City.

The HVAC systems within the building two variable air volume (VAV) air handling units (AHUs), and three constant volume (CV) air handling units (AHUs). All major equipment is controlled and monitored with an *ALC* energy management control system (EMCS) *WebCTRL* (software). The controllers (hardware) are from a variety of different manufacturers including, but not limited to, *ALC* and *InvenSys/Seibe*. and have been installed at different times over the years as renovations have been completed.

Table 1: General Building Information

Attributes	***ATM***
Property Manager	***ONECall***
Year Opened	2011
Enclosed Square Feet	107,757
Floors	6
Annual Metered kWh Consumption (2019)	956,376*
Annual Metered Peak kW Demand	179
Annual Electric $	$57,312
Annual CHW Ton-hrs Consumed (2019)	380,273**
Annual Peak Demand Tons	204
Average Monthly CHW Temp. Diff. (ºF)	14.9
Annual CHW $	$55,537
Annual Steam klbs Consumed (2019)	2,413**
Annual Steam Demand lbs/hr	1,637
Annual Steam Condensate Return (%)	89%
Annual Steam Cost $	$20,776
kWh/sqft	8.88
Peak W/sqft	1.66
Electrical Load Factor	61.1%
CHW Ton-hrs/sqft	3.53
Steam EUI kBtu/sqft	26.8
Electrical EUI (kBtu/sqft)	30.3
CHW EUI (kBtu/sqft)	42.3
Total EUI (kBtu/sqft)	99.4
Annual Utility Spend	$133,626
ECI ($/SqFt)	$1.24
FCI Score	2019 (100) 2021 (100)
Operating Schedule	24-hours/7-days per week
Occupied Hours	24-hours/7-days per week
EMCS - Energy Management Control System	*ALC - WebCTRL*
Cooling Systems	Chilled Water
Heating Systems	Hot Water
Air Distribution	CV AHUs; VAV AHUs with VAV TB's; and SZ FCUs
Outside Air / Ventilation	OA is ducted directly into AHU's

*Electric consumption was estimated based on the calculated ratio of the Atrium sqft to the overall sqft (Samis, Atrium, and OU Childrens Physicians) served by the electric meter at the OU Children's Physicians.

**Steam and chilled water consumption was estimated based on the calculated ratio of the Atrium sqft to the the overall sqft (Samis, and Atrium) served by the Atrium-Samis chilled water meter and Atrium-Sammis steam meter located at the OU Children's Physicians building.

To measure the building's energy utilization and current level of efficiency, two Energy Performance Indicators were calculated in this Report as follows:

Energy Utilization Intensity

The Energy Utilization Intensity (EUI) depicts the total annual energy consumption per square foot of building space, and is expressed in "British Thermal Units" (BTUs). To calculate the EUI, the annual consumption of electricity, steam, and chilled water are first converted to equivalent kBTU consumption via the following formulas:

Total Annual Energy Usage = Total Annual Electrical Energy Usage + Total Annual Steam Energy Usage + Total Annual Chilled Water Energy Usage converted to units of kBTUs/year.

Total Annual Electrical Energy Usage
[Total kWh /yr.] x [3.412 kBTUs/kWh] = __________ kBTUs / yr.

Total Annual Steam Energy Usage
[Total klbs /yr.] x [1,196 kBTUs/klbs] = __________ kBTUs / yr.

Total Annual Chilled Water Energy Usage
[Total Ton/hr /yr.] x [12 kBTUs/hr/Ton/hr] = __________ kBTUs / yr.

The total kBTUs are then divided by the building area.

EUI = [Total annual kBTUs] divided by [Total square feet]

The EUI was compared to the average energy utilization published in the 2012 Commercial Building Energy Consumption Survey (CBECS).

Energy Cost Index

The Energy Cost Index (ECI) depicts the total annual energy cost per square foot building space. To calculate the ECI, the annual costs of electricity, steam, and chilled water are divided by the total square footage of the leased space:

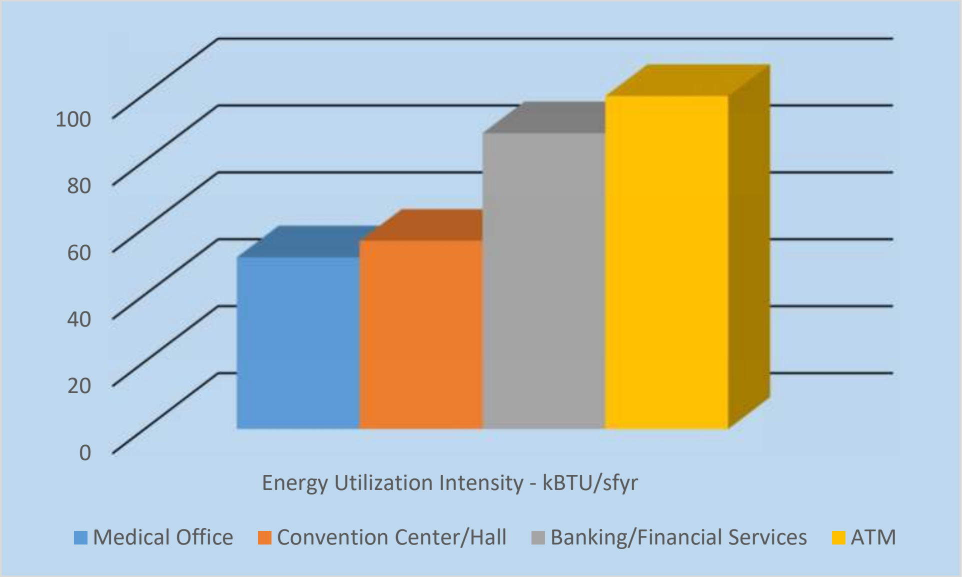
ECI = [Total Energy Cost] divided by [Total square feet]

The ECI was calculated and compared to the statistical average energy cost index published in the 2012 Commercial Building Energy Consumption Survey (CBECS).

The EUI and ECI may be used to compare the facility's approximate usage and cost to other similar facilities in the area. Although the comparisons will not provide specific reasons for unusual operation, they serve as indicators that opportunities may exist by more efficiently operating energy consuming systems.

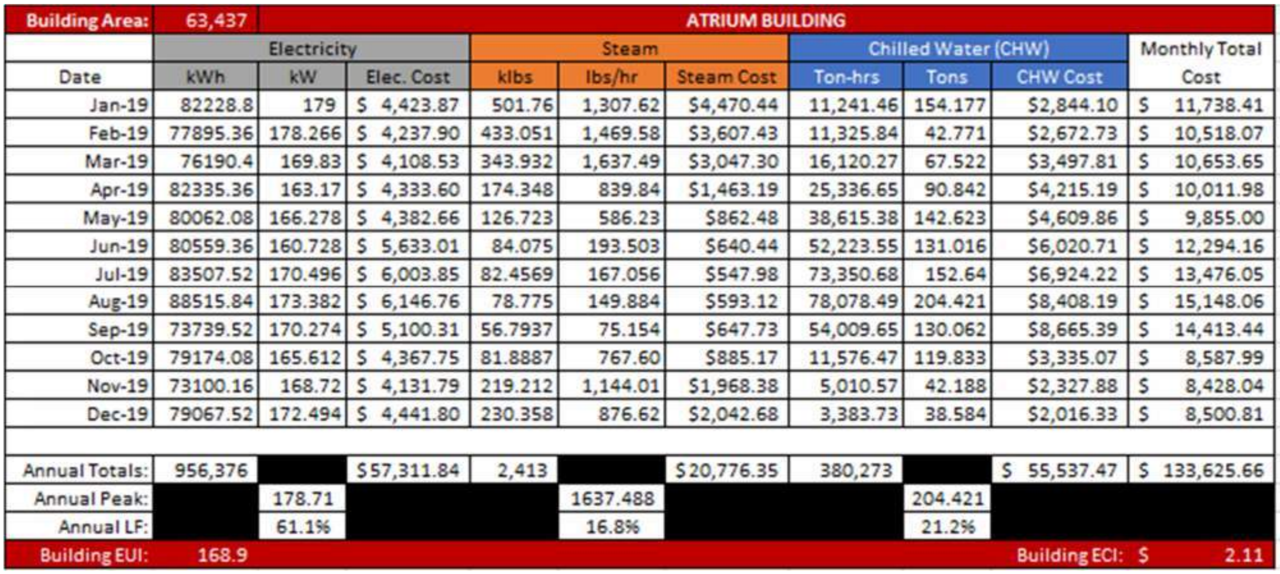
Referring to the 2012 Commercial Building Energy Consumption Survey (CBECS), compiled by the United States Department of Energy, we find the following ranges of comparison with the subject building. The CBECS survey results were based on a national statistical average of a total of 9,941-million square feet reported. The subject site is located within the southwestern section of the United States.

- CBECS utility cost and energy utilization comparison of the EUI and ECI indicates that Atrium has a **moderately high EUI and ECI** compared to similar facilities in the healthcare category.



Oklahoma Gas and Electric (OGE) and OU Health Sciences Center (OUHSC) are the main energy utility providers for the building. Terracon has analyzed the energy consumption for the building and determined the Energy Usage Index (EUI) is approximately 99.4 kBtu/SQFT and the Energy Cost Index (ECI) is $1.24/SQFT. The annual energy consumption ratio shows that electricity accounts for approximately 30% of total energy consumption, chilled water accounts for approximately 43% of total energy consumption, and steam accounts for the remaining 27% of total energy consumption. Annually, electricity accounts for approximately 43% of the total energy cost, chilled water accounts for approximately 42% of the total energy cost, and steam accounts for the remaining 15% of total energy cost. The annual cost ratios are mostly proportionate from the annual consumption ratios, with the costs associated with electricity and steam inversely proportional to their Btu content.

Table 2 – 2019 Energy Use Baseline



Building Area:	63,437	ATRIUM BUILDING								
	Electricity			Steam			Chilled Water (CHW)			Monthly Total Cost
Date	kWh	kW	Elec. Cost	klbs	lbs/hr	Steam Cost	Ton-hrs	Tons	CHW Cost	
Jan-19	82228.8	179	$ 4,423.87	501.76	1,307.62	$4,470.44	11,241.46	154.177	$2,844.10	$ 11,738.41
Feb-19	77895.36	178.266	$ 4,237.90	433.051	1,469.58	$3,607.43	11,325.84	42.771	$2,672.73	$ 10,518.07
Mar-19	76190.4	169.83	$ 4,108.53	343.932	1,637.49	$3,047.30	16,120.27	67.522	$3,497.81	$ 10,653.65
Apr-19	82335.36	163.17	$ 4,333.60	174.348	839.84	$1,463.19	25,336.65	90.842	$4,215.19	$ 10,011.98
May-19	80062.08	166.278	$ 4,382.66	126.723	586.23	$862.48	38,615.38	142.623	$4,609.86	$ 9,855.00
Jun-19	80559.36	160.728	$ 5,633.01	84.075	193.503	$640.44	52,223.55	131.016	$6,020.71	$ 12,294.16
Jul-19	83507.52	170.496	$ 6,003.85	82.4569	167.056	$547.98	73,350.68	152.64	$6,924.22	$ 13,476.05
Aug-19	88515.84	173.382	$ 6,146.76	78.775	149.884	$593.12	78,078.49	204.421	$8,408.19	$ 15,148.06
Sep-19	73739.52	170.274	$ 5,100.31	56.7937	75.154	$647.73	54,009.65	130.062	$8,665.39	$ 14,413.44
Oct-19	79174.08	165.612	$ 4,367.75	81.8887	767.60	$885.17	11,576.47	119.833	$3,335.07	$ 8,587.99
Nov-19	73100.16	168.72	$ 4,131.79	219.212	1,144.01	$1,968.38	5,010.57	42.188	$2,327.88	$ 8,428.04
Dec-19	79067.52	172.494	$ 4,441.80	230.358	876.62	$2,042.68	3,383.73	38.584	$2,016.33	$ 8,500.81
Annual Totals:	956,376		$57,311.84	2,413		$20,776.35	380,273		$ 55,537.47	$ 133,625.66
Annual Peak:		178.71			1637.488			204.421		
Annual LF:		61.1%			16.8%			21.2%		
Building EUI:	168.9								Building ECI:	$ 2.11

Chart 1 – Energy Ratio

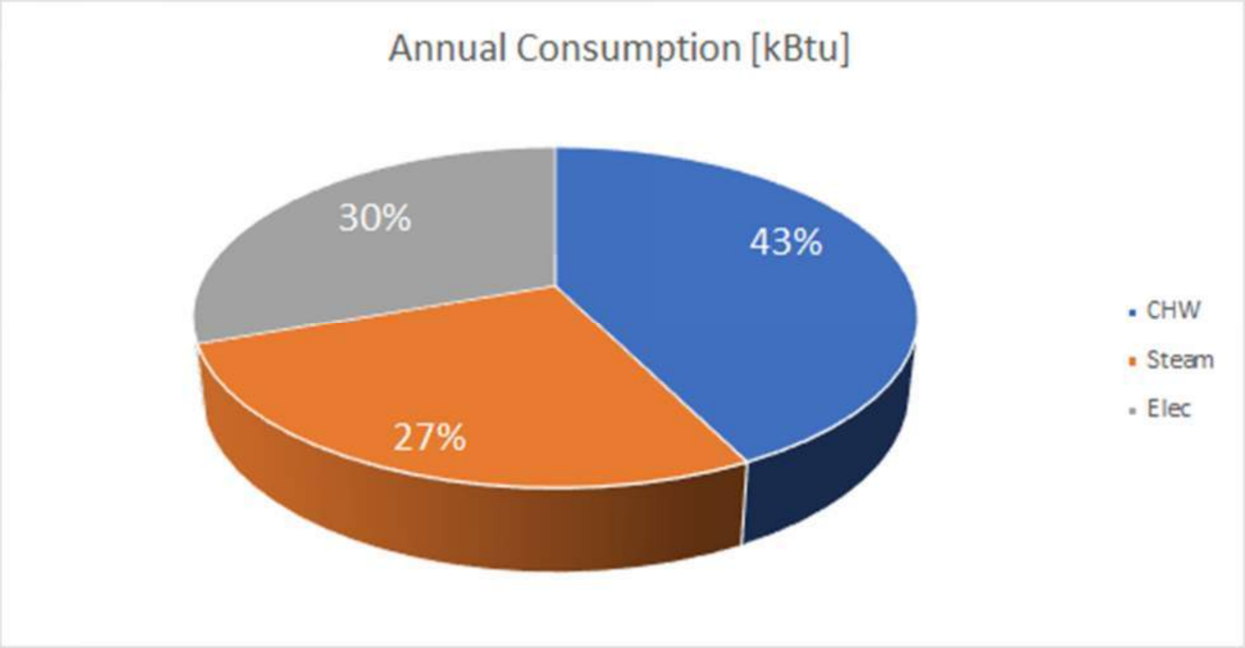
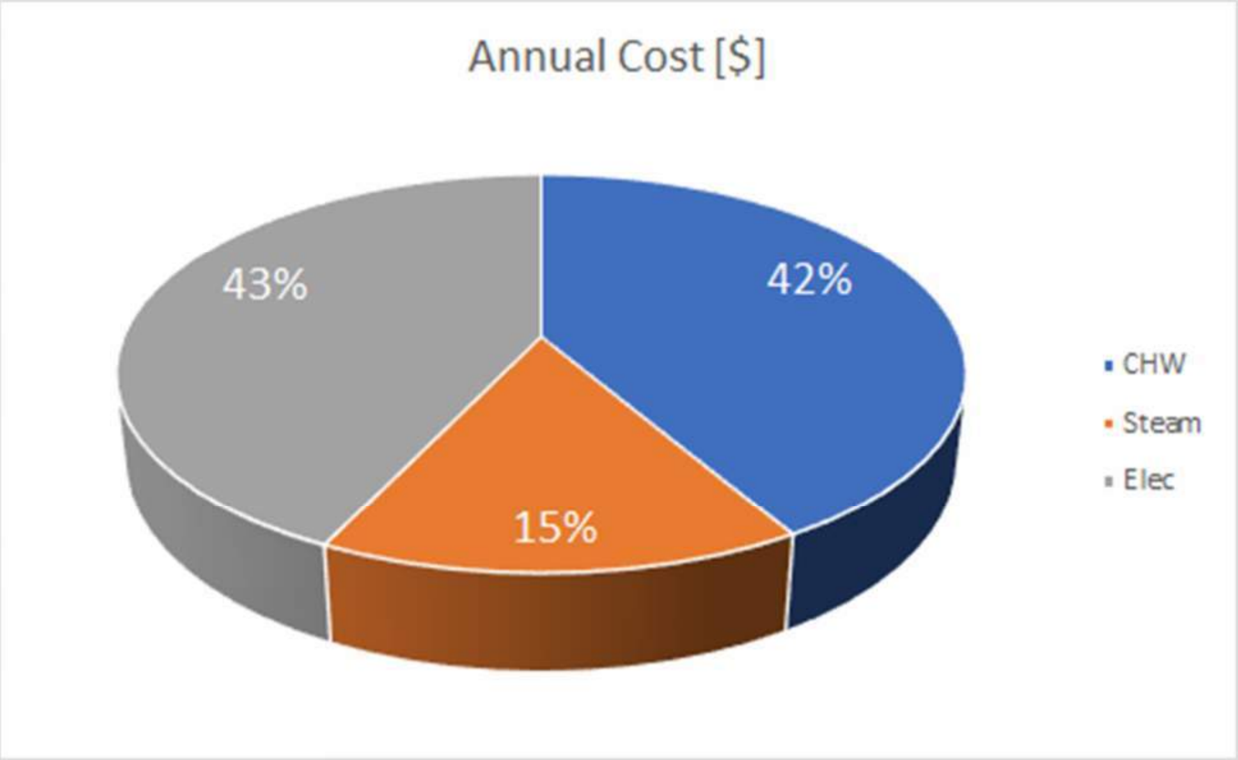


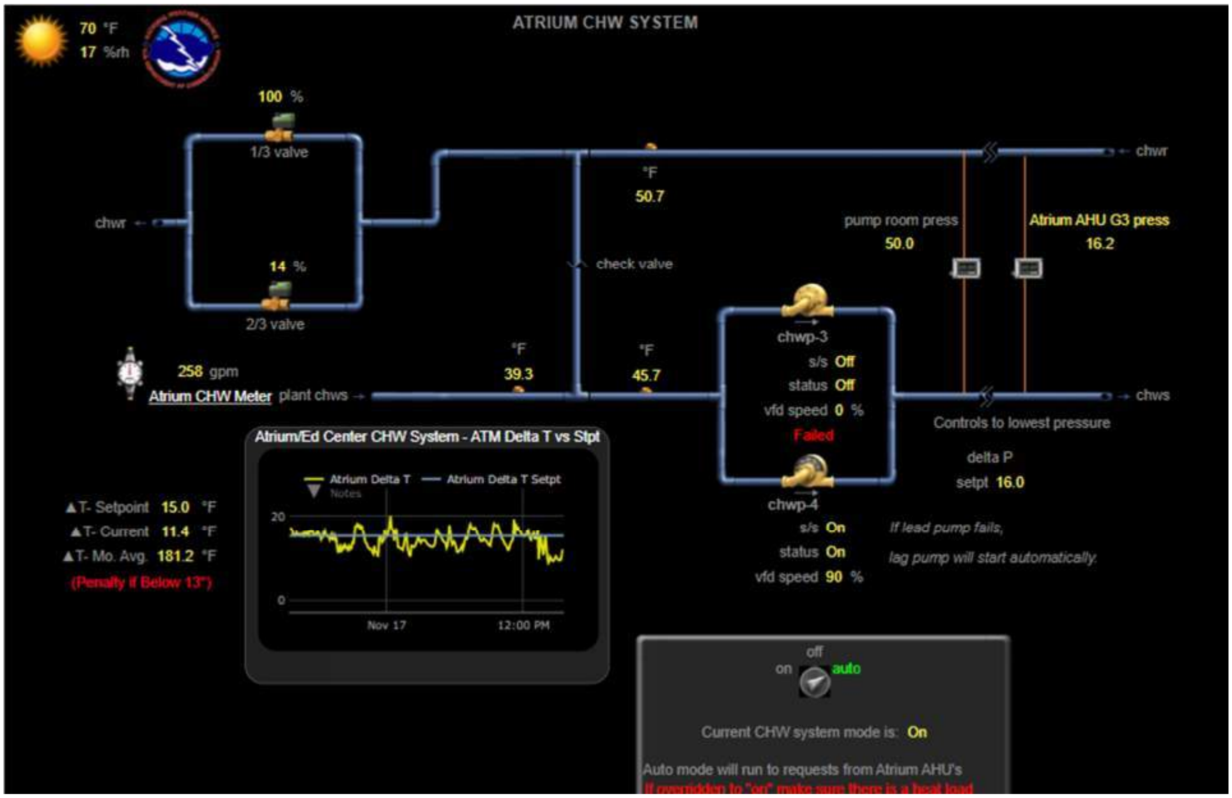
Chart 2 – Energy Cost Ratio



HVAC SYSTEM OBSERVATIONS

During the investigation and pre-task planning portion of this project, Terracon observed a variety of issues that prompted Terracon to investigate further:

The *ALC WebCTRL* EMCS indicated that chilled water and hot water is provided to the Atrium's HVAC systems from the same pumping system that was evaluated for the Samis Education Center building. See the Samis Education Center building report for more information about the current operations of the Atrium chilled water and hot water distribution systems.



chwp-3: s/s Off, status Off, vfd speed 0 %, Failed

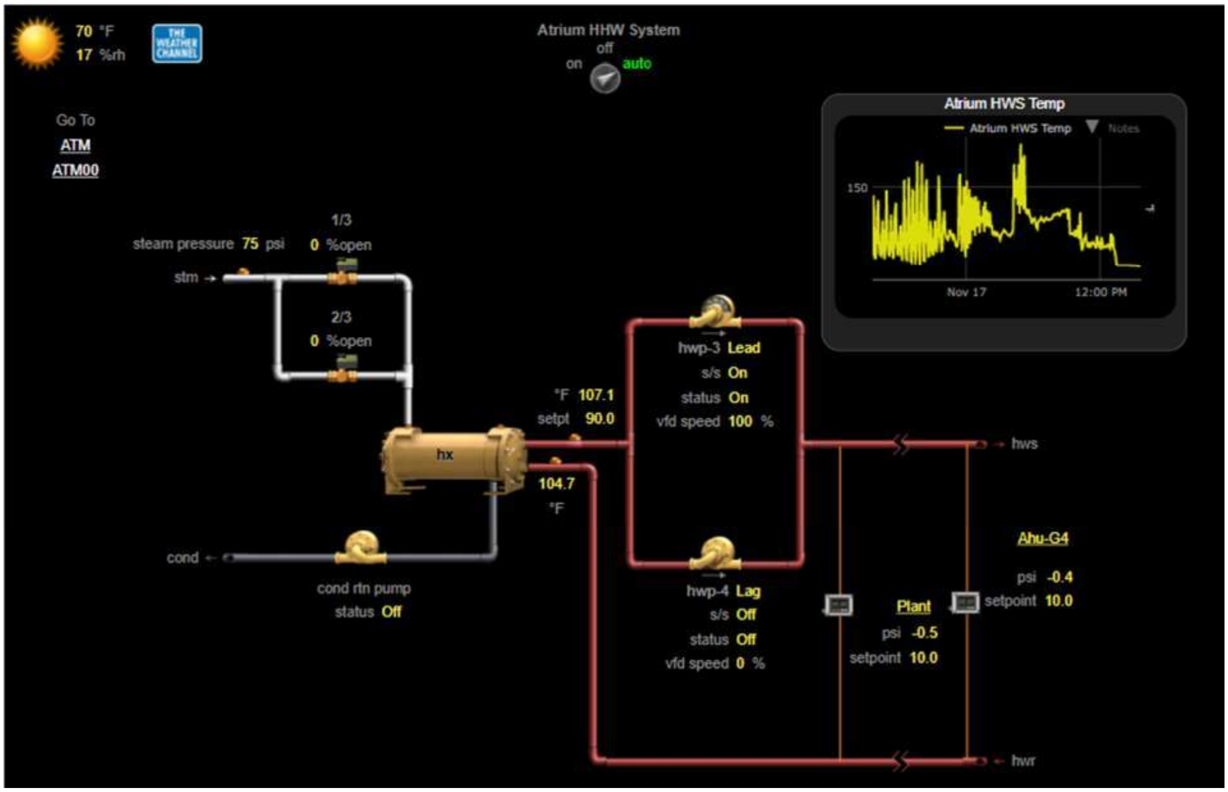
chwp-4: s/s On, status On, vfd speed 90 %

▲T- Setpoint 15.0 °F
▲T- Current 11.4 °F
▲T- Mo. Avg. 181.2 °F
(Penalty if Below 13°)

If lead pump fails, lag pump will start automatically.

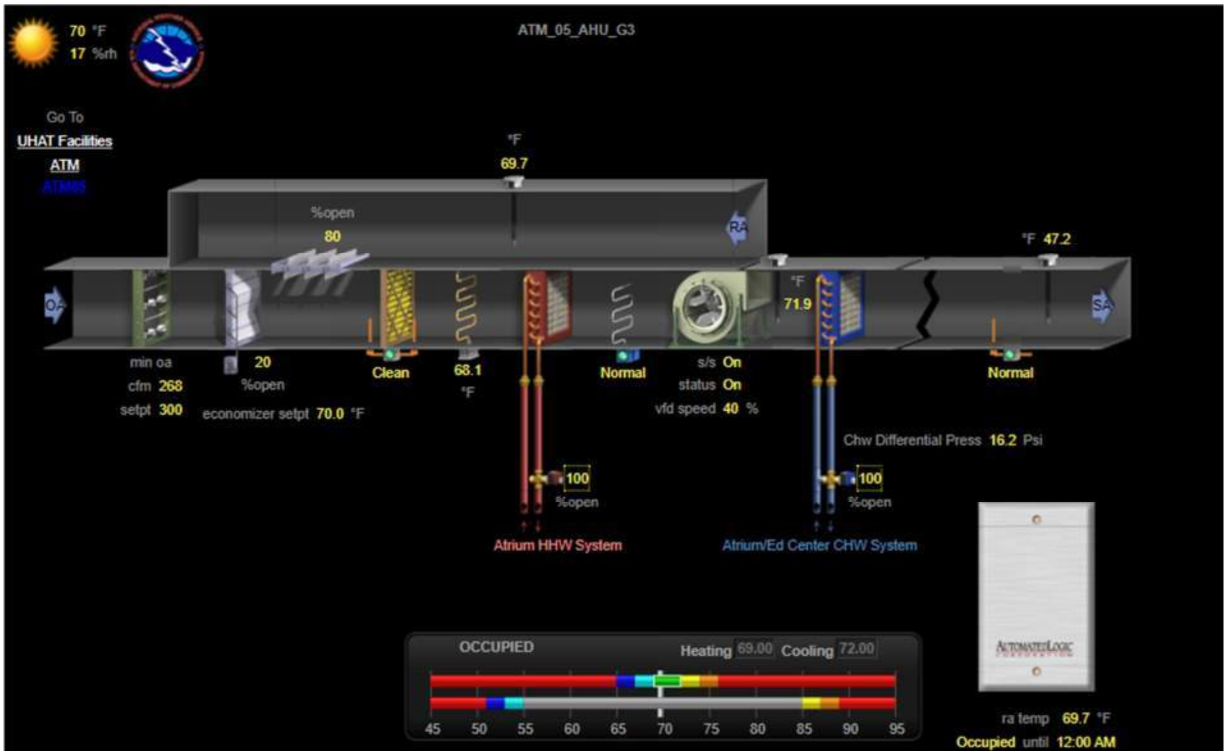
Current CHW system mode is: On

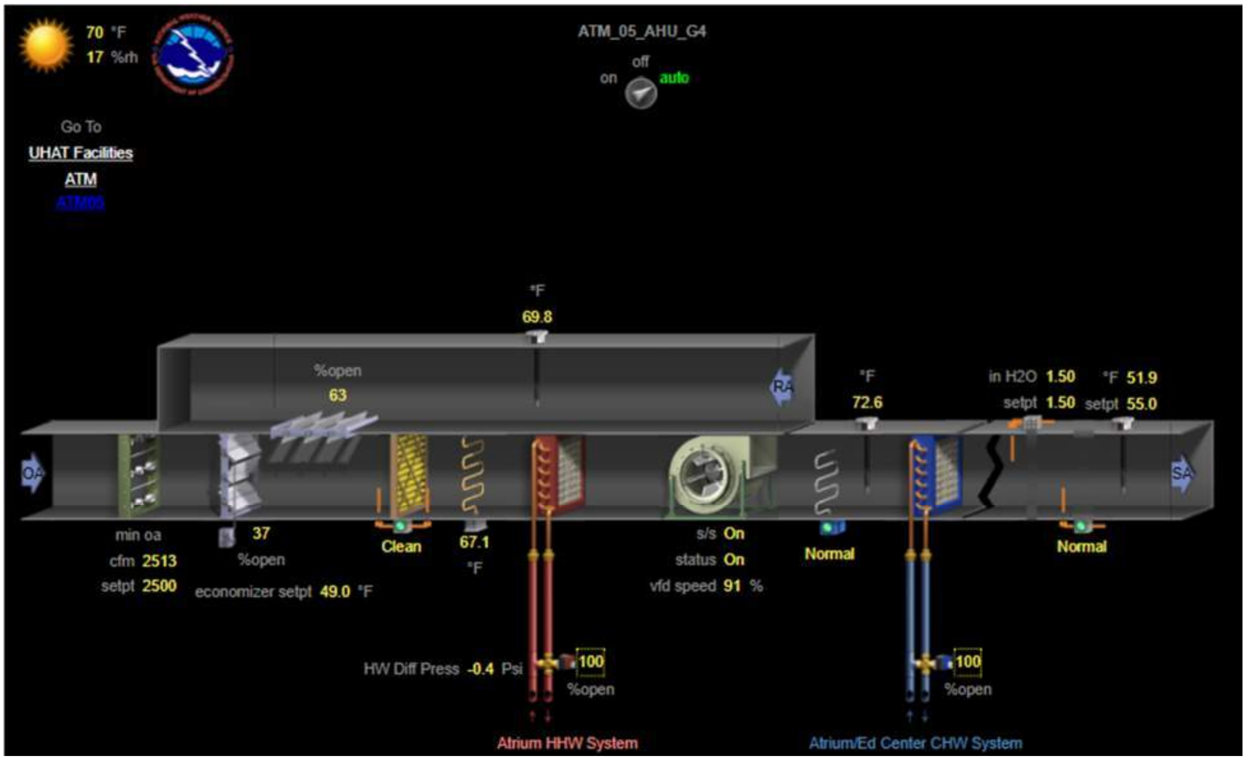
Auto mode will run to requests from Atrium AHU's
If overridden to "on" make sure there is a heat load


70 °F
17 %rh
THE WEATHER CHANNEL
Atrium HHW System
off
on
auto
Go To
ATM
ATM00
Atrium HWS Temp
Atrium HWS Temp
Notes
150
Nov 17
12:00 PM
1/3
steam pressure 75 psi
0 %open
stm →
2/3
0 %open
hwp-3 Lead
s/s On
status On
vfd speed 100 %
°F 107.1
setpt 90.0
hx
104.7
°F
hws
cond ←
cond rtn pump
status Off
Ahu-G4
psi -0.4
setpoint 10.0
hwp-4 Lag
s/s Off
status Off
vfd speed 0 %
Plant
psi -0.5
setpoint 10.0
hwr

While observing the operation of the VAV AHU's, Terracon noticed that air economizer setpoints were inconsistent for most AHUs. Setpoints varied from 45 degF to 70 degF. These operating setpoints can cause the building to be ventilated with excessive humidity during warmer days in the spring and fall seasons.

In addition, it was observed that the chilled water and hot water valves at times will work against each other's load requirements. In the BAS screenshots below. Both the chilled water and hot water valves were observed to be open at 100% despite the outside air conditions being at 70 degF and 17% RH, in order to provide a 47 degF supply air temperature. Chilled water and hot water valves should be locked closed (0% open) once outside air temperatures reach high enough or low enough values to allow supply air temperature temperatures to be reset efficiently with outdoor air.





During the site visits, the Terracon team made the following observations:

1. Terracon observed that the upper floors (4th and 6th) of the Atrium building are warmer and more humid than the bottom floors. This was noted and may be caused by a result of poor air distribution, thermal stratification, and/or building pressurization problems.
2. Terracon personnel viewed five AHUs (AHU G1 through AHU G5) which serve the Atrium.
3. AHU-G1 serves the pre-natal area on the 1st floor.
4. The hot water supply temperature needs to be programmed to reset according to outside air conditions.
5. The differential pressure sensor for the heating water is located on the 4th floor. (10.8psi)
6. The differential pressure sensor for the chill water loop is located on AHU G3. (15.2 psi)
7. Terracon observed that fan coil units serve the lobby, basement and corridors.
8. Two chill water pumps with VFD's provide the Atrium and Samis Education Center buildings with chilled water.
9. Two hot water pumps with VFD's provide the Atrium and Samis Education Center buildings with hot water.
10. High humidity readings (81.0% RH) were observed on the Atrium AHU's graphics on date Terracon was on site.
11. Utility meters supplying chill water and steam should be verified as calibrated and reading accurately.

12. The BAS will need calibration verification upon test, adjustment, and balancing (TAB) work.
13. The outside air flow monitoring stations for each AHU are not readily serviceable, and the BAS indicates that flowrates appear low given the damper positions for AHU G1, AHU G2, AHU G3, AHU G5).
14. Outside air damper positions were observed for AHU G1 (10%), AHU G2 (93%), AHU G3 (20%), AHU G4 (39%), and AHU G5 (36%). AHU G4 and AHU G5 appear to be open more when air economizer operation is not necessary. AHU G2 likely has OA and Return air damper % open conditions reversed in graphics.

BUILDING INFRASTRUCTURE TESTING

Terracon investigated the discrepancy between the design requirements in the drawings provided and the EMCS readings with an independent air flow instrument provided by our subconsultant TAB firm. The AHU air flow parameters at AHU G1, AHU G2, AHU G3, AHU G4, and AHU G5 were all measured in a traverse pattern grid that is in accordance with industry TAB standards for HVAC systems.

In addition to supply air flow measurements, Terracon also tested and verified the following:

1. Supply air temperature being distributed to the VAV terminal boxes
2. Entering and leaving water temperatures for each hot water and chilled water coil
3. Entering and leaving water pressures for each hot water and chilled water coil
4. Entering and leaving air pressure for each hot water and chilled water coil section
5. External air pressure (suction and discharge) for each AHU supply fan.

All measurements were taken independent to the EMCS to verify accuracy of the parameters being read by the *ALC webCTRL* system. The accuracy of the measurements are necessary to validate the HVAC systems are meeting the equipment’s design performance requirements.

The following information was field measured:

AHU G1

Total Supply Air [CFM]	Supply Air Temperature [ºF]	Entering Heating Water Temperature [ºF]	Leaving Heating Water Temperature [ºF]	Entering Chilled Water Temperature [ºF]	Leaving Chilled Coil Temperature [ºF]
11,504	67.1	120	113	45	54

Heating Coil Delta Air Pressure [in H_2O]	Cooling Coil Delta Air Pressure [in H_2O]	Heating Coil Delta Water Pressure [psig]	Cooling Coil Delta Water Pressure [psig]	Total External Fan Static Pressure [in H_2O]
0.12*	0.38	23.6	-^	0.8

AHU G2

Total Supply Air [CFM]	Supply Air Temperature [ºF]	Entering Heating Water Temperature [ºF]	Leaving Heating Water Temperature [ºF]	Entering Chilled Water Temperature [ºF]	Leaving Chilled Water Temperature [ºF]
14,015	55.6	115	106	46	62.4

Heating Coil Delta Air Pressure [in H_2O]	Cooling Coil Delta Air Pressure [in H_2O]	Heating Coil Delta Water Pressure [psig]	Cooling Coil Delta Water Pressure [psig]	Total External Fan Static Pressure [in H_2O]
0.13*	0.14	31.2	-^	1.49

AHU G3

Total Supply Air [CFM]	Supply Air Temperature [ºF]	Entering Heating Coil Temperature [ºF]	Leaving Heating Coil Temperature [ºF]	Entering Cooling Coil Temperature [ºF]	Leaving Cooling Coil Temperature [ºF]
10,797	67.5	126	112	47	53

Heating Coil Delta Air Pressure [in H_2O]	Cooling Coil Delta Air Pressure [in H_2O]	Heating Coil Delta Water Pressure [psig]	Cooling Coil Delta Water Pressure [psig]	Total External Fan Static Pressure [in H_2O]
0.38*	0.27	25.8	-^	1.73

AHU G4

Total Supply Air [CFM]	Supply Air Temperature [ºF]	Entering Heating Coil Temperature [ºF]	Leaving Heating Coil Temperature [ºF]	Entering Cooling Coil Temperature [ºF]	Leaving Cooling Coil Temperature [ºF]
9,552	66.3	120	110	48	53

Heating Coil Delta Air Pressure [in H_2O]	Cooling Coil Delta Air Pressure [in H_2O]	Heating Coil Delta Water Pressure [psig]	Cooling Coil Delta Water Pressure [psig]	Total External Fan Static Pressure [in H_2O]
0.44*	0.37	26.7	-^	1.39

AHU G5

Total Supply Air [CFM]	Supply Air Temperature [ºF]	Entering Heating Coil Temperature [ºF]	Leaving Heating Coil Temperature [ºF]	Entering Cooling Coil Temperature [ºF]	Leaving Cooling Coil Temperature [ºF]
16,020	68.0	118	109	44	52

Heating Coil Delta Air Pressure [in H_2O]	Cooling Coil Delta Air Pressure [in H_2O]	Heating Coil Delta Water Pressure [psig]	Cooling Coil Delta Water Pressure [psig]	Total Fan Static Pressure [in H_2O]
0.25*	0.32	25.4	-^	0.54

* = Pressure Drop is across both coil and filter because access between hot water coil and filters was too difficult for measurements.

^ = Ports and autoflow valves were not available for chilled water coils.

ENERGY CONSERVATION OPPORTUNITIES (ECOs) AND RECOMMENDATIONS

In order to effectively evaluate existing systems and deficiencies and to provide recommended measures, various methods and actions were considered. Considerations include:

- Analysis of existing construction drawings and as-built documentation.
- Analysis of utility bills.
- Conversations with the UHAT personnel regarding HVAC system configuration, controls, and existing trouble spots.
- Collection of information and data from *ALC webCTRL* interface to gather set points, operating conditions, identify anomalies, etc.
- Site surveys and investigations.
- Profiled mechanical equipment (e.g. pumps, chillers, air handling units) affected by the ECO's so that accurate calculations of savings could be produced.
- For weather dependent systems, bin temperature analysis is to be used to calculate baseline and post-installation consumption.
- For weather independent systems, time-of-use methods were used to calculate baseline and post-installation consumption.

Energy conservation opportunities (ECOs) have been listed on the basis of cost, potential benefit and, most importantly, Owner approval.

ECO Master List

Table 3: Master List

Measure #	Equipment or System	Description of Finding	Recommended Improvement
M 1.1.1.	AHU G1	Fan motor rating (15 HP) does not match As-Built/Design drawings (25 HP) and total external static pressure was measured to be significantly lower than design requirements.	Install new 25 HP motor and balance AHU to meet total external static pressure requirements.
M1.1.2.	AHU G1	The outside air flow monitoring stations for each AHU are not readily serviceable, and BAS indicated flowrates appear low (unreliable) given damper position.	Provide service solution for airflow monitoring stations (AFMS), clean, recalibrated, provide access for continued maintenance.
M 1.1.3.	AHU G1	The air economizer setpoint is lower than a typical economizer value (45 degF).	Standardize air economizer setpoint to 59 degF for optimal operation.

Measure #	Equipment or System	Description of Finding	Recommended Improvement
M 1.1.4.	AHU G1	Pressure drop across the chilled water coil is a bit higher than generally expected.	Inspect and clean chilled water coil to remove any dirt or debris that may be fouling the coil and causing a lack of heat transfer.
M 1.2.1.	AHU G2	The outside air flow monitoring stations for each AHU are not readily serviceable, and BAS indicated flowrates appear low (unreliable) given damper positions.	Provide service solution for airflow monitoring stations (AFMS), clean, recalibrated, provide access for continued maintenance.
M 1.2.2.	AHU G2	The air economizer setpoint is lower than a typical economizer value (54 degF).	Standardize air economizer setpoint to 59 degF for optimal operation.

Measure #	Equipment or System	Description of Finding	Recommended Improvement
M 1.3.1	AHU G3	The outside air flow monitoring stations for each AHU are not readily serviceable, and BAS indicated flowrates appear low (unreliable) given damper positions.	Provide service solution for airflow monitoring stations (AFMS), clean, recalibrated, provide access for continued maintenance.
M 1.3.2.	AHU G3	The air economizer setpoint is higher than a typical economizer value (70 degF).	Standardize air economizer setpoint to 59 degF for optimal operation.
M 1.3.3.	AHU G3	Pressure drop across the chilled water coil is a bit higher than generally expected.	Inspect and clean chilled water coil to remove any dirt or debris that may be fouling the coil and causing a lack of heat transfer.

Measure #	Equipment or System	Description of Finding	Recommended Improvement
M 1.3.4.	AHU G3	Pressure drop across the hot water coil is a bit higher than generally expected.	Inspect and clean hot water coil to remove any dirt or debris that may be fouling the coil and causing a lack of heat transfer.
M 1.3.5.	AHU G3	Chilled water and hot water valves appeared to be simultaneously open at 100% when outdoor air conditions showed 70 degF and 17% RH.	Lockout hot water valve (0% open) when outside air temperature is 70 degF or greater. Reconfigure chilled water valve and HHW valve to operate based on supply air temperature.
M 1.4.1.	AHU G4	The air economizer setpoint is lower than a typical economizer value (51 degF).	Standardize air economizer setpoint to 59 degF for optimal operation.

Measure #	Equipment or System	Description of Finding	Recommended Improvement
M 1.4.2.	AHU G4	Pressure drop across the chilled water coil is a bit higher than generally expected.	Inspect and clean chilled water coil to remove any dirt or debris that may be fouling the coil and causing a lack of heat transfer.
M 1.4.3.	AHU G4	Pressure drop across the hot water coil is a bit higher than generally expected.	Inspect and clean hot water coil to remove any dirt or debris that may be fouling the coil and causing a lack of heat transfer.
M 1.4.4.	AHU G4	Chilled water and hot water valves appeared to be simultaneously open at 100% when outdoor air conditions showed 70 degF and 17% RH.	Lockout hot water valve (0% open) when outside air temperature is 70 degF or greater. Reconfigure chilled water valve and HHW valve to operate based on supply air temperature.

Measure #	**Equipment or System**	**Description of Finding**	**Recommended Improvement**
M 1.4.5.	AHU G4	Total external static pressure was measured to be slightly lower than design requirements. Terracon observed that the upper floors (4th and 6th) of the Atrium building are warmer and more humid than other floors below. Poor air distribution, thermal stratification, and/or building pressurization problems are all contributing to this effect.	Verify airflow distribution at upper level floors and rebalance air distribution systems.
M 1.5.1	AHU G5	The outside air flow monitoring stations for each AHU are not readily serviceable, and BAS indicated flowrates appear low (unreliable) given damper positions.	Provide service solution for airflow monitoring stations (AFMS), clean, recalibrated, provide access for continued maintenance.
M 1.5.2.	AHU G5	The air economizer setpoint is higher than a typical economizer value (70 degF).	Standardize air economizer setpoint to 59 degF for optimal operation.

Measure #	Equipment or System	Description of Finding	Recommended Improvement
M 1.5.3.	AHU G5	Pressure drop across the chilled water coil is a bit higher than generally expected.	Inspect and clean chilled water coil to remove any dirt or debris that may be fouling the coil and causing a lack of heat transfer.
M 1.5.4.	AHU G5	Pressure drop across the hot water coil is a bit higher than generally expected.	Inspect and clean hot water coil to remove any dirt or debris that may be fouling the coil and causing a lack of heat transfer.
M 1.5.5.	AHU G5	Total external static pressure was measured to be significantly lower than design requirements. Terracon observed that the upper floors (4th and 6th) of the Atrium building are warmer and more humid than other floors below. Poor air distribution, thermal stratification, and/or building pressurization problems are all contributing to this effect.	Verify airflow distribution at upper level floors and rebalance air distribution systems.

LIMITATIONS

The field observations, tests, findings, and recommendations presented in this report are based upon the information provided to Terracon by the client, UHAT, and observations and field notes collected at the time of our site visits. While additional conditions may exist that could alter our recommendations, we feel that reasonable means have been made to fairly and accurately evaluate the existing conditions of these systems. This report is limited to Terracon's observations of the interior and exterior of the facility. Some of the observations were limited due to obstructions and access to areas of the systems and facility. Although our observations were made with normal care and diligence, it is likely that not all existing conditions were documented. The general intent was to identify representative conditions and provide recommendations based on general findings.

This report has been prepared for the exclusive use of UHAT for specific application to the project discussed and has been prepared in accordance with generally accepted engineering practices using the standard of care and skill currently exercised by professional engineers practicing in this area, for a project of similar scope and nature. No warranties, either expressed or implied, are intended or made. In the event that information described in this document which was provided by others is incorrect, or if additional information becomes available, the recommendations contained in this report shall not be considered valid unless Terracon reviews the information and either verifies or modifies the recommendations of this report in writing.

APPENDIX A
Photographs

Photo #1 The Atrium serves as the gateway to the, SAMIS Education Center and OU Children’s Hospital.

Photo #2 Temtrol AHU-G2.

Photo #3 AHU-G2 Gear Tag. M# ITF-BH34. S# T0010006-003-00 Temtrol

Photo #4 AHU-G4 Temtrol M# ITF-BH26 S # T001006-005-00

Photo #5 Typical electrical disconnects and VFD drives for serving AHU’s.

Photo #6 Typical ALC type enclosure with relays, transformers, and BAS controllers.

Photo#7 Temtrol AHU-5G.

Photo #8 AHU-5G Gear Tag. M# ITF-BH35 S# T001006-006-00

Photo #9 Typical ALC controllers for AHU -5G.

Photo #10 Lead/Lag hot water pumps which serve the Atrium and SAMIS buildings.

Photo #11 Steam bundle heat exchanger serves three buildings from the basement mechanical room in the Atrium.

APPENDIX B
Test and Balancing Report

AIR APPARATUS TEST SHEET

Job Name: ATRIUM
Tested By: OGBURN / ROGERS **Date:** 2/5/2021

DESIGN DATA :

Manufacturer =	TEMTROL	**Model No. =**	ITF-BH25
Type =	AHU	**Serial No. =**	T001006-002-00
Outside Air cfm =			
Total Scheduled cfm =		**Grille Design Schedule cfm =**	
Fan rpm =			
Total Static Pressure =	4.01	**External Static Pressure =**	0.80
Fan Rotation =	CW		

MOTOR DESIGN DATA

Horsepower =	15	**Voltage =**	460	**Phase =**	3	**Rpm =**	1765

AIR TEST DATA

Total cfm by Traverse Readings =	11,504	**Total cfm by Grille Readings =**	
Outside Air =		**Return Air =**	

TEMPERATURE TEST DATA

Outside Air Temperature =	65.4	**Return Air Temperature =**	72.8
Mixed Air Temperature =	73.6		

PRESSURE TEST DATA

Fan Suction Static Pressure =		-0.74	
Fan Discharge Static Pressure =		2.44	
Total Static Pressure =			3.18
External Suction Static Pressure =		-0.20	
External Discharge Static Pressure =		0.60	
External Static Pressure =			0.80
Cooling Coil ΔS.P. =	0.38	**Heating Coil ΔS.P. =**	0.12
Pre Filters ΔS.P. =	N/A	**Final Filters ΔS.P. =**	0.12

MOTOR TEST DATA

Motor Manufacturer / Frame =	BALDOR / 254T						
HP =	15	**Volts/Ph/Hertz =**	460/3/60	**Act. Voltage =**	460	460	460
Full Load Amps =			NG	**Act. Amps =**	12.0	11.9	11.8
Service Factor =			1.15				
Motor Design rpm =			1765	**Act motor rpm =**			1765

FAN TEST DATA

Motor Sheave Diameter =	6"	**Motor Sheave Bore =**	1 5/8"
Fan Sheave Diameter =	8"	**Fan Sheave Bore =**	1 15/16"
Adjustable Sheave Dia. =		**Centerline Distance =**	35.75"
Fan rpm =	1030	**Fan Rotation =**	CW
Frequency Hz=	60		
Belts =	3		
Pre Filters =			
Final Filters =			

Comments: Unit was traversed on suplpy trunk. Traverse was in a good location and was lamnar.

AIR APPARATUS TEST SHEET

Job Name:
Tested By: OGBURN / ROGERS **Date:** 2/5/2021

DESIGN DATA :

Manufacturer =	TEMTROL	**Model No. =**	ITF-BH34
Type =	AHU	**Serial No. =**	T001006-003-00
Outside Air cfm =			
Total Scheduled cfm =		**Grille Design Schedule cfm =**	
Fan rpm =			
Total Static Pressure =	2.26	**External Static Pressure =**	1.49
Fan Rotation =	CW		

MOTOR DESIGN DATA

Horsepower =	15	**Voltage =**	460	**Phase =**	3	**Rpm =**	1765

AIR TEST DATA

Total cfm by Traverse Readings =	14,015	**Total cfm by Grille Readings =**	
Outside Air =		**Return Air =**	

TEMPERATURE TEST DATA

Outside Air Temperature =	39.4	**Return Air Temperature =**	70.2
Mixed Air Temperature =	67.1		

PRESSURE TEST DATA

Fan Suction Static Pressure =		-0.95	
Fan Discharge Static Pressure =		1.31	
	Total Static Pressure =		2.26
External Suction Static Pressure =			
External Discharge Static Pressure =		0.64	
	External Static Pressure =		0.64
Cooling Coil ΔS.P. =	0.14	**Heating Coil ΔS.P. =**	0.13
Pre Filters ΔS.P. =	N/A	**Final Filters ΔS.P. =**	0.13

MOTOR TEST DATA

Motor Manufacturer / Frame =	BALDOR / 254T						
HP =	15	**Volts/Ph/Hertz =**	460/3/60	**Act. Voltage =**	477	482	471
Full Load Amps =			NG	**Act. Amps =**	12.1	11.9	12.3
Service Factor =			1.15				
Motor Design rpm =			1765	**Act motor rpm =**			1772

FAN TEST DATA

Motor Sheave Diameter =	6"	**Motor Sheave Bore =**	1 5/8"
Fan Sheave Diameter =	8"	**Fan Sheave Bore =**	1 15/16"
Adjustable Sheave Dia. =		**Centerline Distance =**	35.75"
Fan rpm =	1028	**Fan Rotation =**	CW
Frequency Hz=	60		
Belts =	3		
Pre Filters =			
Final Filters =			

Comments: Unit was traversed on suplpy trunk. Traverse was in a good location and was lamnar.

AIR APPARATUS TEST SHEET

Job Name: ATRIUM
Tested By: OGBURN / ROGERS **Date:** 2/5/2021

DESIGN DATA :

Manufacturer =	TEMTROL	**Model No. =**	ITF-BH26
Type =	AHU	**Serial No. =**	T001006-004-00
Outside Air cfm =			
Total Scheduled cfm =		**Grille Design Schedule cfm =**	
Fan rpm =	1151		
Total Static Pressure =	2.33	**External Static Pressure =**	0.69
Fan Rotation =	CW		

MOTOR DESIGN DATA

Horsepower =	10	**Voltage =**	460	**Phase =**	3	**Rpm =**	1770

AIR TEST DATA

Total cfm by Traverse Readings =	10,797	**Total cfm by Grille Readings =**	
Outside Air =		**Return Air =**	

TEMPERATURE TEST DATA

Outside Air Temperature =	70.3	**Return Air Temperature =**	70.7
Mixed Air Temperature =	70.5		

PRESSURE TEST DATA

Fan Suction Static Pressure =		-0.93	
Fan Discharge Static Pressure =		1.20	
	Total Static Pressure =		2.13
External Suction Static Pressure =		-0.93	
External Discharge Static Pressure =		0.80	
	External Static Pressure =		1.73
Cooling Coil ΔS.P. =	0.27	**Heating Coil ΔS.P. =**	0.38
Pre Filters ΔS.P. =	N/A	**Final Filters ΔS.P. =**	0.38

MOTOR TEST DATA

Motor Manufacturer / Frame =	BALDOR / 215T						
HP =	10	**Volts/Ph/Hertz =**	460/3/60	**Act. Voltage =**	442	443	442
Full Load Amps =			NG	**Act. Amps =**	10.2	10.5	13.0
Service Factor =			1.15				
Motor Design rpm =			1770	**Act motor rpm =**			1768

FAN TEST DATA

Motor Sheave Diameter =	6"	**Motor Sheave Bore =**	1.375"
Fan Sheave Diameter =	9"	**Fan Sheave Bore =**	1.9375"
Adjustable Sheave Dia. =		**Centerline Distance =**	21.5"
Fan rpm =	1025	**Fan Rotation =**	CW
Frequency Hz=	60		
Belts =	2 BX-64 6L279G		
Pre Filters =			
Final Filters =			

Comments: Unit was traversed on supply side. Traverse is not in the most suitable location, but it is the best option given the return trunk location.

AIR APPARATUS TEST SHEET

Job Name: ATRIUM
Tested By: OGBURN / ROGERS **Date:** 2/5/2021

DESIGN DATA :

Manufacturer =	TEMTROL	**Model No. =**	ITF-BH26
Type =	AHU	**Serial No. =**	T001006-005-00
Outside Air cfm =			
Total Scheduled cfm =		**Grille Design Schedule cfm =**	
Fan rpm =	1455		
Total Static Pressure =	2.78	**External Static Pressure =**	1.02
Fan Rotation =	CW		

MOTOR DESIGN DATA

Horsepower =	10	**Voltage =**	460	**Phase =**	3	**Rpm =**	1455

AIR TEST DATA

Total cfm by Traverse Readings =	9,552	**Total cfm by Grille Readings =**	
Outside Air =		**Return Air =**	

TEMPERATURE TEST DATA

Outside Air Temperature =	70.3	**Return Air Temperature =**	68.9
Mixed Air Temperature =	70.2		

PRESSURE TEST DATA

Fan Suction Static Pressure =		1.54	
Fan Discharge Static Pressure =		-1.24	
	Total Static Pressure =		2.78
External Suction Static Pressure =		-0.16	
External Discharge Static Pressure =		1.23	
	External Static Pressure =		1.39
Cooling Coil ΔS.P. =	0.37	**Heating Coil ΔS.P. =**	0.44
Pre Filters ΔS.P. =	n/a	**Final Filters ΔS.P. =**	0.44

MOTOR TEST DATA

Motor Manufacturer / Frame =		US MOTORS / 215T					
HP =	10	**Volts/Ph/Hertz =**	460/3/60	**Act. Voltage =**	450	450	450
Full Load Amps =			25.30-23.80	**Act. Amps =**	22.1	22.1	22.1
Service Factor =			1.15				
Motor Design rpm =			1765	**Act motor rpm =**			1762

FAN TEST DATA

Motor Sheave Diameter =	5"	**Motor Sheave Bore =**	1.375"
Fan Sheave Diameter =	8.25"	**Fan Sheave Bore =**	1 15/16
Adjustable Sheave Dia. =		**Centerline Distance =**	30.5"
Fan rpm =	1030	**Fan Rotation =**	CW
Frequency Hz=	60		
Belts =	2 BX-806L286G		
Pre Filters =			
Final Filters =			

Comments: Unit was traversed on supply side. Traverse is not in the most suitable location, but it is the best option given the return trunk location. Heating coil pressure drops on all Atrium units include final filters due to close proximity.

AIR APPARATUS TEST SHEET

Job Name: ATRIUM
Tested By: OGBURN / ROGERS **Date:** 2/5/2021

DESIGN DATA :

Manufacturer =	TEMTROL	**Model No. =**	ITF-BH35
Type =	AHU	**Serial No. =**	T001006-006-00
Outside Air cfm =			
Total Scheduled cfm =		**Grille Design Schedule cfm =**	
Fan rpm =	1151		
Total Static Pressure =	1.95	**External Static Pressure =**	0.45
Fan Rotation =	CW		

MOTOR DESIGN DATA

Horsepower =	15	**Voltage =**	460	**Phase =**	3	**Rpm =**	NG

AIR TEST DATA

Total cfm by Traverse Readings =	16,020	**Total cfm by Grille Readings =**	
Outside Air =		**Return Air =**	

TEMPERATURE TEST DATA

Outside Air Temperature =	57.9	**Return Air Temperature =**	71.7
Mixed Air Temperature =	70.9		

PRESSURE TEST DATA

Fan Suction Static Pressure =		-0.79	
Fan Discharge Static Pressure =		1.11	
	Total Static Pressure =		1.90
External Suction Static Pressure =		0.04	
External Discharge Static Pressure =		0.58	
	External Static Pressure =		0.54
Cooling Coil ΔS.P. =	0.32	**Heating Coil ΔS.P. =**	0.25
Pre Filters ΔS.P. =	N/A	**Final Filters ΔS.P. =**	0.25

MOTOR TEST DATA

Motor Manufacturer / Frame =	BALDOR / 254T						
HP =	15	**Volts/Ph/Hertz =**	460/3/60	**Act. Voltage =**	450	450	450
Full Load Amps =			NG	**Act. Amps =**	13.5	13.5	13.5
Service Factor =			1.15				
Motor Design rpm =			1765	**Act motor rpm =**			1763

FAN TEST DATA

Motor Sheave Diameter =	11"	**Motor Sheave Bore =**	1.625"
Fan Sheave Diameter =	7"	**Fan Sheave Bore =**	1.9375"
Adjustable Sheave Dia. =		**Centerline Distance =**	25.5"
Fan rpm =	1015	**Fan Rotation =**	CW
Frequency Hz=	60		
Belts =	2 BX-78 6L284G		
Pre Filters =			
Final Filters =			

Comments: Unit was traversed on supply side. Traverse location was good and flow was lamnar.

COIL APPARATUS TEST REPORT

Job Name: ATRIUM
Tested By: OGBURN **Date:** 11/18/2020

COIL DATA				
System Number	AHU-G5	AHU-G5	AHU-G1	AHU-G1
Location	5TH FLOOR	5TH FLOOR	BASEMANT	BASEMENT
Coil Type	CHW	HW	CHW	HW
No. Rows-Fins/ In.	NG	NG	NG	NG
Manufacturer	NG	NG	NG	NG
Model Number	NG	NG	NG	NG
Serial Number	NG	NG	NG	NG

Air Test Data	**DESIGN**	**ACTUAL**	**DESIGN**	**ACTUAL**	**DESIGN**	**ACTUAL**	**DESIGN**	**ACTUAL**
Air Qty., CFM(l/s)	NG	16020	NG	16020	NG	11504	NG	11504
Air Vel. FPM (m/s)	NG	NM	NG	NM	NG	NM	NG	NM
Press. Drop In wg (Pa)	NG	0.32	NG	0.45	NG	0.38	NG	0.12
Out. Air DB/WB	NG		NG		NG		NG	
Ret. Air DB/WB	NG		NG		NG		NG	
Ent. Air DB/WB	NG	74.1/54.9	NG	72.3/54.2	NG	74.1/60	NG	73.6/58.8
Lvg. Air DB/WB	NG	68.0/52.0	NG	72.6/54.3	NG	67.1/56.8	NG	73.7/58.5
Air ΔT	NG	6.1	NG	0.3	NG	7.0	NG	0.1

Water Test Data	**DESIGN**	**ACTUAL**	**DESIGN**	**ACTUAL**	**DESIGN**	**ACTUAL**	**DESIGN**	**ACTUAL**
Water Flow, GPM (l/s)	NG	NM	36.0	36.0	NG	NM	36.0	36.0
Press. Drop PSI (kPa)	NG	NO PORTS	2-32'	25.4	NG	NO PORTS	2-32'	23.6
Ent Water Temp.	NG	44.0	NG	118.0	NG	45.0	NG	120.0
Lvg. Water Temp.	NG	52.0	NG	109.0	NG	54.0	NG	113.0
Water ΔT	NG	8.0	NG	9.0	NG	9.0	NG	7.0

Refrigeration Test	**DESIGN**	**ACTUAL**	**DESIGN**	**ACTUAL**	**DESIGN**	**ACTUAL**	**DESIGN**	**ACTUAL**
Exp. Valve/Refrig.	-	-	-	-	-	-	-	-
Refrig. Suction Press.	-	-	-	-	-	-	-	-
Refrig. Suction Temp.	-	-	-	-	-	-	-	-
Inlet Steam Press.	-	-	-	-	-	-	-	-

COMMENTS:

AHU-G5 AND SHU-G1 DOESN'T HAVE AUTOFLOW VALVE ON CHW.

COIL APPARATUS TEST REPORT

Job Name: ATRIUM
Tested By: OGBURN/HIGGINS/GONZALEZ **Date:** 12/12/2020

COIL DATA				
System Number	AHU-G2	AHU-G2		
Location	BASEMENT	BASEMENT		
Coil Type	CHW	HW		
No. Rows-Fins/ In.	NG	NG		
Manufacturer	NG	NG		
Model Number	NG	NG		
Serial Number	NG	NG		

Air Test Data	DESIGN	ACTUAL	DESIGN	ACTUAL	DESIGN	ACTUAL	DESIGN	ACTUAL
Air Qty., CFM(l/s)	NG	14015	NG	14015				
Air Vel. FPM (m/s)	NG	NM	NG	NM				
Press. Drop In wg (Pa)	NG	0.14	NG	0.13				
Out. Air DB/WB	-	-	-	-	-	-	-	-
Ret. Air DB/WB	-	-	-	-	-	-	-	-
Ent. Air DB/WB	NG	79.2/60.4	NG	70.1/55.2				
Lvg. Air DB/WB	NG	55.6/46.3	NG	74.9/58.3				
Air ΔT	NG	23.6	NG	4.8				

Water Test Data	DESIGN	ACTUAL	DESIGN	ACTUAL	DESIGN	ACTUAL	DESIGN	ACTUAL
Water Flow, GPM (l/s)	NG	NM	36.0	36.0				
Press. Drop PSI (kPa)	NG	NO PORTS	2-32'	31.2				
Ent Water Temp.	NG	46.0	NG	115.0				
Lvg. Water Temp.	NG	62.4	NG	106.0				
Water ΔT	NG	16.4	NG	9.0				

Refrigeration Test	DESIGN	ACTUAL	DESIGN	ACTUAL	DESIGN	ACTUAL	DESIGN	ACTUAL
Exp. Valve/Refrig.	-	-	-	-	-	-	-	-
Refrig. Suction Press.	-	-	-	-	-	-	-	-
Refrig. Suction Temp.	-	-	-	-	-	-	-	-
Inlet Steam Press.	-	-	-	-	-	-	-	-

COMMENTS:

CHW DOESN’T HAVE AUTOFLOW VALVE.

COIL APPARATUS TEST REPORT

Job Name: ATRIUM
Tested By: OGBURN **Date:** 11/18/2020

COIL DATA				
System Number	AHU-G4	AHU-G4	AHU-G3	AHU-G3
Location	5TH FLOOR	5th FLOOR	5th FLOOR	5th FLOOR
Coil Type	CHW	HW	CHW	HW
No. Rows-Fins/ In.	NG	NG	NG	NG
Manufacturer	NG	NG	NG	NG
Model Number	NG	NG	NG	NG
Serial Number	NG	NG	NG	NG

Air Test Data	DESIGN	ACTUAL	DESIGN	ACTUAL	DESIGN	ACTUAL	DESIGN	ACTUAL
Air Qty., CFM(l/s)	NG	9552	NG	9552	NG	10797	NG	10797
Air Vel. FPM (m/s)	NG	NM	NG	NM	NG	NM	NG	NM
Press. Drop In wg (Pa)	NG	0.37	NG	0.44	NG	0.27	NG	0.38
Out. Air DB/WB								
Ret. Air DB/WB								
Ent. Air DB/WB	NG	69.5/52.6	NG	67.9/51.9	NG	72.7/54.2	NG	71.1/53.4
Lvg. Air DB/WB	NG	66.3/51.0	NG	68.8/52.9	NG	67.5/51.7	NG	71.3/53.8
Air ΔT	NG	3.2	NG	1.1	NG	5.2	NG	0.2

Water Test Data	DESIGN	ACTUAL	DESIGN	ACTUAL	DESIGN	ACTUAL	DESIGN	ACTUAL
Water Flow, GPM (l/s)	NG	NM	36.0	36.0	NG	NM	36.0	36.0
Press. Drop PSI (kPa)	NG	NO PORTS	2-32'	26.7	NG	NO PORTS	2-32'	25.8
Ent Water Temp.	NG	48.0	NG	120.0	NG	47.0	NG	126.0
Lvg. Water Temp.	NG	53.0	NG	110.0	NG	53.0	NG	112.0
Water ΔT	NG	5.0	NG	10.0	NG	6.0	NG	14.0

Refrigeration Test	DESIGN	ACTUAL	DESIGN	ACTUAL	DESIGN	ACTUAL	DESIGN	ACTUAL
Exp. Valve/Refrig.	-	-	-	-	-	-	-	-
Refrig. Suction Press.	-	-	-	-	-	-	-	-
Refrig. Suction Temp.	-	-	-	-	-	-	-	-
Inlet Steam Press.	-	-	-	-	-	-	-	-

COMMENTS: **PRESSURE DROPS ACROSS HEATING COIL IS INCLUDING FILTERS. AHU-G4 AND AHU-G3 DC**

APPENDIX B
COLLEGE OF MEDICINE REPORT

MECHANICAL CONSULTING SERVICES

Building Infrastructure Testing Report

College of Medicine

800 Stanton L. Young Blvd.

Oklahoma City, Oklahoma

April 12, 2021

Project No. FA20P031

Prepared For:

University Hospitals Authority and Trust (UHAT)
940 NE 13th Street
Oklahoma City, Oklahoma 73104

Prepared by:

Terracon Consultants, Inc.
4701 N. Stiles Avenue
Oklahoma City, Oklahoma 73105

Terracon

April 12, 2021

Mr. Nathan Miller
Building Systems Manager
University Hospitals Authority & Trust
940 NE 13th Street
Oklahoma City, Oklahoma 73104
P: 405-271-4962 x44199
E: nathan-miller@uhat.org

Reference: **UHAT**
Building Infrastructure Testing
College of Medicine Building
800 Stanton L Young Blvd.
Oklahoma City, Oklahoma 73104
Project No. FA20P031

Mr. Miller:

Terracon Consultants, Inc. (Terracon) is pleased to submit this Mechanical Consulting Services Report of our Building Infrastructure Testing for the College of Medicine located at 800 Stanton L Young Blvd. in Oklahoma City, Oklahoma. This work was performed in general accordance with the scope of services outlined in Terracon's Proposal for Building Infrastructure Testing & Retro-Commissioning Services dated December 19, 2019 and authorized in February 2020 as identified in the scope section of this Report.

The purpose of this Report is to render our findings, field notes, and recommendations related to our site visits at the above referenced location.

This document includes background information, observations, findings, and recommendations pertaining to the operations of the heating, ventilation, and air conditioning (HVAC) at the site.

Terracon appreciates the opportunity to be of service to you on this project. If you have any questions regarding this report, please do not hesitate to contact us.

Sincerely,

Terracon Consultants, Inc.

Erik Gonzalez, P.E. (TX), CEM
Senior Engineer
Facilities Services

Jeffrey A. Miller, P.E. (OK)
Senior Principal/Senior Engineer
Facilities Services

Terracon Consultants, Inc. 4701 N. Stiles Avenue Oklahoma City, Oklahoma 73105
P (405) 525-0453 terracon.com

Geotechnical ■ Environmental ■ Construction Materials ■ Facilities

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PROJECT OBJECTIVE

The purpose of the Building Infrastructure Testing services is to conduct limited visual observations and engineering diagnostics of the HVAC systems. With the observations and measurements obtained, a retro-commissioning plan will be developed from recommended energy conservation opportunities in this report that will help improve performance and reduce the operating costs of the building without compromising comfort for the building occupants.

Terracon's representatives, Mr. John Harmon, E.I.T., Mr. Kim Morris QCxP, Mr. Erik Gonzalez, P.E. (TX), CEM, and Mr. Jonathan Curtin P.E. (TX) of Terracon, and our sub-consultant, Engineering Systems & Energy Solutions (ES2), conducted site visits on September 14 - 15, 2020 at the College of Medicine in order to obtain visual and diagnostic information and field performance measurements for the HVAC systems. During the site visits, visual observations were made to note general operating conditions of the HVAC systems. In addition, diagnostic measurements were taken for the air distribution of the two AHUs, associated chilled water and hot water coils, chilled water distribution pumps, and hot water distribution pumps. Measurements recorded were compared to the design documents and EMCS sensor measurements for air flow and water flow characteristics using the software workstation. Observations were made from readily accessible areas and did not include substantial dismantling of components of the building and HVAC equipment, including walls and closed ceilings. With the observations and measurements, Terracon developed energy conservation opportunity recommendations for improvements to the HVAC systems.

DOCUMENTS AND INFORMATION REVIEWED

Terracon was provided with design documentation for the subject building, utility data for chilled water, steam, and electricity, tariff sheets that breakdown the cost of each utility service, and network access to the *AutomatedLogic Corporation* (*ALC*) *WebCTRL v7.0* energy management control system. The following items were reviewed while performing this assessment:

Document	Source
COLLEGE OF MEDICINE EXTG DRAWINGS MEP — BOCKUS, PAYNE, ASSOCIATES, ARCHITECTS dated March 24, 2014	Client Provided
Utility Bill Data for Terracon.xlsx – e-mailed to Terracon on February 28, 2020	Client Provided
Utility Service Tariff Sheets for OUHSC and OGE services provided to UHAT – e-mailed to Terracon on March 3, 2020	Client Provided

BUILDING DESCRIPTION AND ENERGY USE BASELINE

The subject property is a four-story medical education training building which totals approximately 163,303-square feet. The building was originally constructed around 2016.

The HVAC systems within the building include three chilled water pumps, two heating hot water pumps, and two steam-to-hot water heat exchangers to provide domestic hot water for the building and distributes hot water for the HVAC systems. In addition, there are two air handling units (AHUs). All major equipment is controlled and monitored with an *ALC* energy management control system (EMCS) *WebCTRL* (software). The controllers (hardware) are from a variety of different manufacturers including, but not limited to, *ALC* and *InvenSys/Seibe*. and have been installed at different times over the years as renovations have been completed.

Table 1: General Building Information

Attributes	***COM***
Property Manager	***ONECall***
Year Opened	2016
Enclosed Square Feet	191,966
Floors	11
Annual Metered kWh Consumption (2019)	1,407,900
Annual Metered Peak kW Demand	356
Annual Electric $	$90,316
Annual CHW Ton-hrs Consumed (2019)	759,831
Annual Peak Demand Tons	559
Average Monthly CHW Temp. Diff. (ºF)	14.3
Annual CHW $	$121,525
Annual Steam klbs Consumed (2019)	5,598
Annual Steam Demand lbs/hr	3,903
Annual Steam Condensate Return (%)	94%
Annual Steam Cost $	$44,853
kWh/sqft	8.6
Peak W/sqft	2.18
Electrical Load Factor	45.1%
CHW Ton-hrs/sqft	4.65
Steam kBtu/sqft	34.9
Electrical EUI (kBtu/sqft)	25.0
CHW EUI (kBtu/sqft)	47.5
Total EUI (kBtu/sqft)	107.4
Annual Utility Spend	$256,694
ECI ($/SqFt)	$1.34
FCI Score	2019 (100) 2021 (100)
Operating Schedule	M-F 7am-10pm
Occupied Hours	M-F 7am-5pm
EMCS - Energy Management Control System	*ALC - WebCTRL*
Cooling Systems	Chilled Water
Heating Systems	Hot Water
Air Distribution	VAV with VAV TB's
Outside Air / Ventilation	OA preconditioned and is ducted directly to return air section of AHU’s

To measure the building's energy utilization and current level of efficiency, two Energy Performance Indicators were calculated in this Report as follows:

Energy Utilization Intensity

The Energy Utilization Intensity (EUI) depicts the total annual energy consumption per square foot of building space, and is expressed in "British Thermal Units" (BTUs). To calculate the EUI, the annual consumption of electricity, steam, and chilled water are first converted to equivalent kBTU consumption via the following formulas:

> Total Annual Energy Usage = Total Annual Electrical Energy Usage + Total Annual Steam Energy Usage + Total Annual Chilled Water Energy Usage converted to units of kBTUs/year.
>
> Total Annual Electrical Energy Usage
> [Total kWh /yr.] x [3.412 kBTUs/kWh] = __________ kBTUs / yr.
>
> Total Annual Steam Energy Usage
> [Total klbs /yr.] x [1,196 kBTUs/klbs] = __________ kBTUs / yr.
>
> Total Annual Chilled Water Energy Usage
> [Total Ton/hr /yr.] x [12 kBTUs/hr/Ton/hr] = __________ kBTUs / yr.

The total kBTUs are then divided by the building area.

EUI = [Total annual kBTUs] divided by [Total square feet]

The EUI was compared to the average energy utilization published in the 2012 Commercial Building Energy Consumption Survey (CBECS).

Energy Cost Index

The Energy Cost Index (ECI) depicts the total annual energy cost per square foot building space. To calculate the ECI, the annual costs of electricity, steam, and chilled water are divided by the total square footage of the leased space:

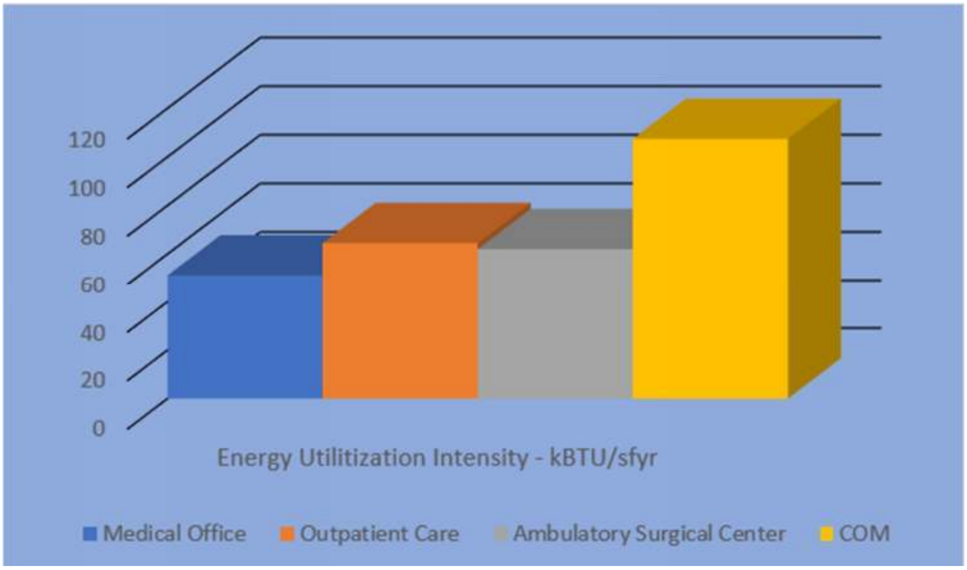
ECI = [Total Energy Cost] divided by [Total square feet]

The ECI was calculated and compared to the statistical average energy cost index published in the 2012 Commercial Building Energy Consumption Survey (CBECS).

The EUI and ECI may be used to compare the facility's approximate usage and cost to other similar facilities in the area. Although the comparisons will not provide specific reasons for unusual operation, they serve as indicators that opportunities may exist by more efficiently operating energy consuming systems.

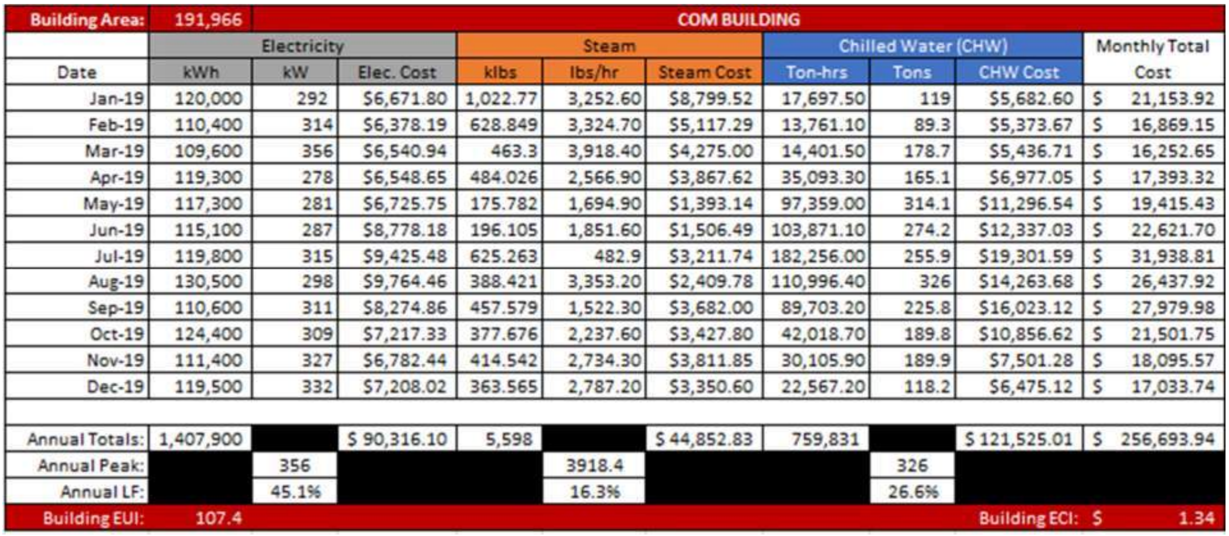
Referring to the 2012 Commercial Building Energy Consumption Survey (CBECS), compiled by the United States Department of Energy, we find the following ranges of comparison with the subject building. The CBECS survey results were based on a national statistical average of a total of 9,941-million square feet reported. The subject site is located within the southwestern section of the United States.

- CBECS utility cost and energy utilization comparison of the EUI and ECI indicates that the College of Medicine has a **moderately high EUI and ECI** compared to similar facilities in the healthcare category.



Oklahoma Gas and Electric (OGE) and OU Health Science Center (OUHSC) are the main energy utility providers for the building. Terracon has analyzed the energy consumption for the building and determined the Energy Usage Index (EUI) is approximately 107.4 kBtu/SQFT and the Energy Cost Index (ECI) is $1.34/SQFT. The annual energy consumption ratio shows that electricity accounts for approximately 29% of total energy consumption, chilled water accounts for approximately 31% of total energy consumption, and steam accounts for the remaining 41% of total energy consumption. Annually, electricity accounts for approximately 39% of the total energy cost, chilled water accounts for approximately 41% of the total energy cost, and steam accounts for the remaining 20% of total energy cost. The annual cost ratios are mostly proportionate from the annual consumption ratios, with the steam cost ratio being much lower than the overall steam energy consumption ratio.

Table 2 – 2019 Energy Use Baseline



Building Area:	191,966	COM BUILDING								
	Electricity			Steam			Chilled Water (CHW)			Monthly Total Cost
Date	kWh	kW	Elec. Cost	klbs	lbs/hr	Steam Cost	Ton-hrs	Tons	CHW Cost	
Jan-19	120,000	292	$6,671.80	1,022.77	3,252.60	$8,799.52	17,697.50	119	$5,682.60	$ 21,153.92
Feb-19	110,400	314	$6,378.19	628.849	3,324.70	$5,117.29	13,761.10	89.3	$5,373.67	$ 16,869.15
Mar-19	109,600	356	$6,540.94	463.3	3,918.40	$4,275.00	14,401.50	178.7	$5,436.71	$ 16,252.65
Apr-19	119,300	278	$6,548.65	484.026	2,566.90	$3,867.62	35,093.30	165.1	$6,977.05	$ 17,393.32
May-19	117,300	281	$6,725.75	175.782	1,694.90	$1,393.14	97,359.00	314.1	$11,296.54	$ 19,415.43
Jun-19	115,100	287	$8,778.18	196.105	1,851.60	$1,506.49	103,871.10	274.2	$12,337.03	$ 22,621.70
Jul-19	119,800	315	$9,425.48	625.263	482.9	$3,211.74	182,256.00	255.9	$19,301.59	$ 31,938.81
Aug-19	130,500	298	$9,764.46	388.421	3,353.20	$2,409.78	110,996.40	326	$14,263.68	$ 26,437.92
Sep-19	110,600	311	$8,274.86	457.579	1,522.30	$3,682.00	89,703.20	225.8	$16,023.12	$ 27,979.98
Oct-19	124,400	309	$7,217.33	377.676	2,237.60	$3,427.80	42,018.70	189.8	$10,856.62	$ 21,501.75
Nov-19	111,400	327	$6,782.44	414.542	2,734.30	$3,811.85	30,105.90	189.9	$7,501.28	$ 18,095.57
Dec-19	119,500	332	$7,208.02	363.565	2,787.20	$3,350.60	22,567.20	118.2	$6,475.12	$ 17,033.74
Annual Totals:	1,407,900		$ 90,316.10	5,598		$ 44,852.83	759,831		$ 121,525.01	$ 256,693.94
Annual Peak:		356			3918.4			326		
Annual LF:		45.1%			16.3%			26.6%		
Building EUI:	107.4								Building ECI:	$ 1.34

Chart 1 – Energy Ratio

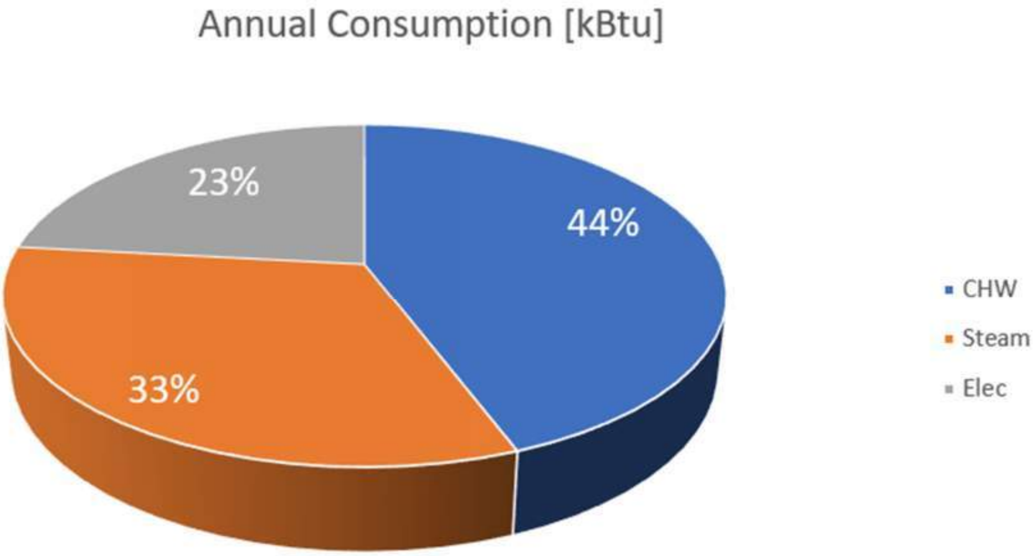
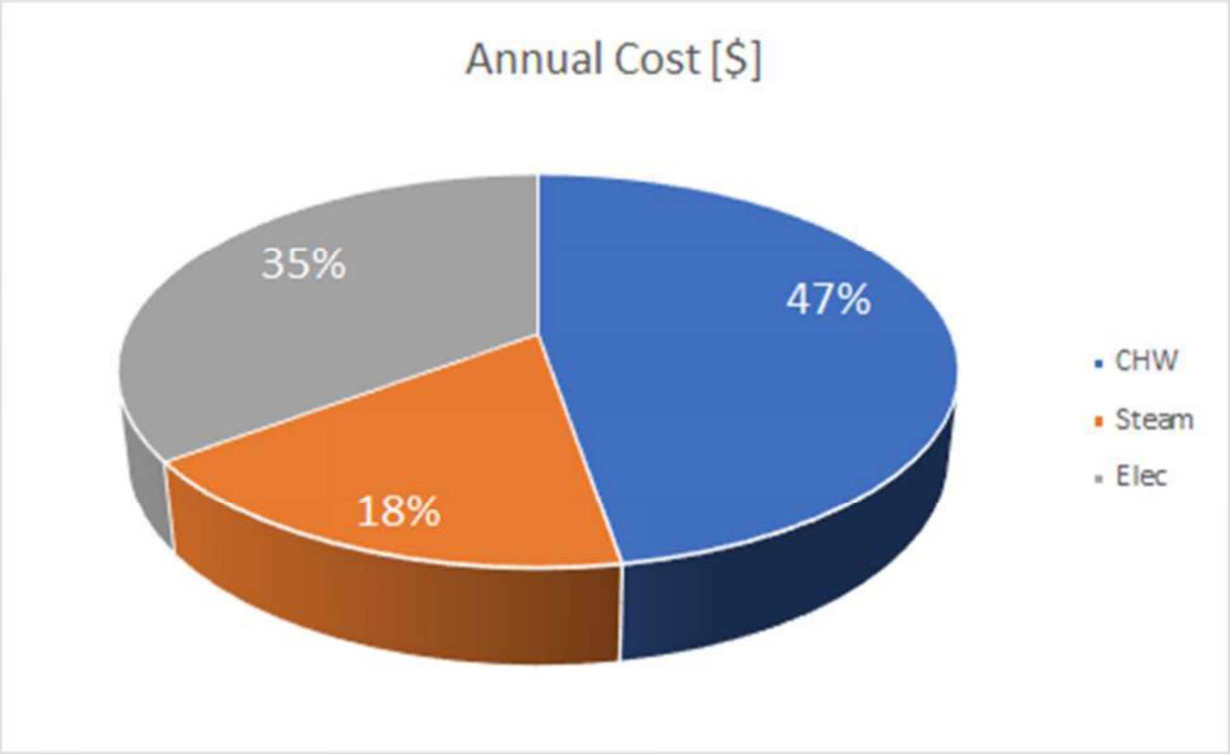


Chart 2 – Energy Cost Ratio



HVAC SYSTEM OBSERVATIONS

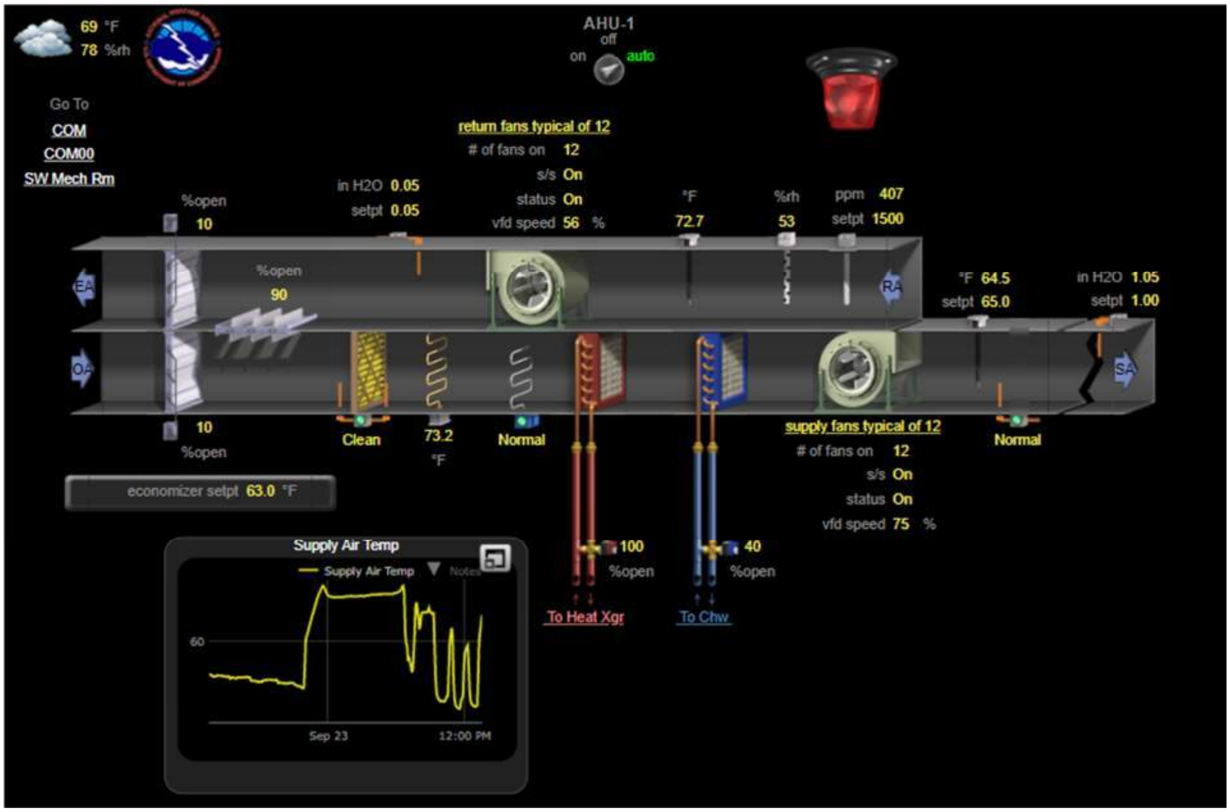
The *ALC WebCTRL* EMCS Terracon was provided access to indicated that AHU-1 was providing simultaneous heating and cooling with the heating coil valve open 100% and the chilled water valve open 40%. The heating and cooling coils are installed in series with the heating coil in the reheat position.

During the site visits, the Terracon team made the following observations:

1. Terracon observed AHU-1 and supply fan SF-3 located in the basement mechanical room.
2. SF-3 is a booster fan interlocked with AHU-2 and provides conditioned air to the main lobby.
3. The steam to hot water heat exchanger located in the basement mechanical room was assessed.
4. The hot water supply temperature setpoint may need to be reset according to outside air conditions.
5. Terracon observed AHU-2 located in Penthouse.
6. The dual chilled water pumps serve the College of Medicine Building AHU’s and are served by variable speed drives. A tertiary chilled water circuit and third pump (CHWP-3) is installed to serve the two Liebert CRAC units in the networking/IT room in the basement. The district plant chilled water system pressures are sufficient for this tertiary loop to supply chilled water flow to the CRAC units without CHWP-3 ever having to run, it therefore remains continuously in the OFF position.
7. Two hot water pumps served by VFD’s were observed.
8. CO^2 sensors were viewed and are located in the return air ducting for both AHU-1 and AHU-2.
9. Utility meters in the chilled water and steam piping need to be verified and confirmed as calibrated and reading correctly.
10. *Automated Logic* brand HVAC controls were viewed and graphic screenshots were studied both before and during Terracon’s site visit.
11. AHU-1 serves the west half of floors 1-10 and AHU-2 serves the east half of the building, with SF-3 (from AHU-2) serving the lobby. When floors request after hours heating, cooling, and ventilating, the operation of both AHU-1 and AHU-2 are required to condition the entirety of any individual floor.
12. Chilled water and heating hot water bypass valves were observed on the 10th floor per the BAS. During one of our observations the CHW bypass valve was open 54%. Given the system configuration, this valve is expected to remain closed under normal operating conditions.
13. In review of the BAS, the HHW and CHW valves to the heating and cooling coils respectively were observed to be open simultaneously on AHU-2, when the unit should have been in cooling mode only. There is no mode of operation that Terracon was aware of that would require both valves to ever be open simultaneously.

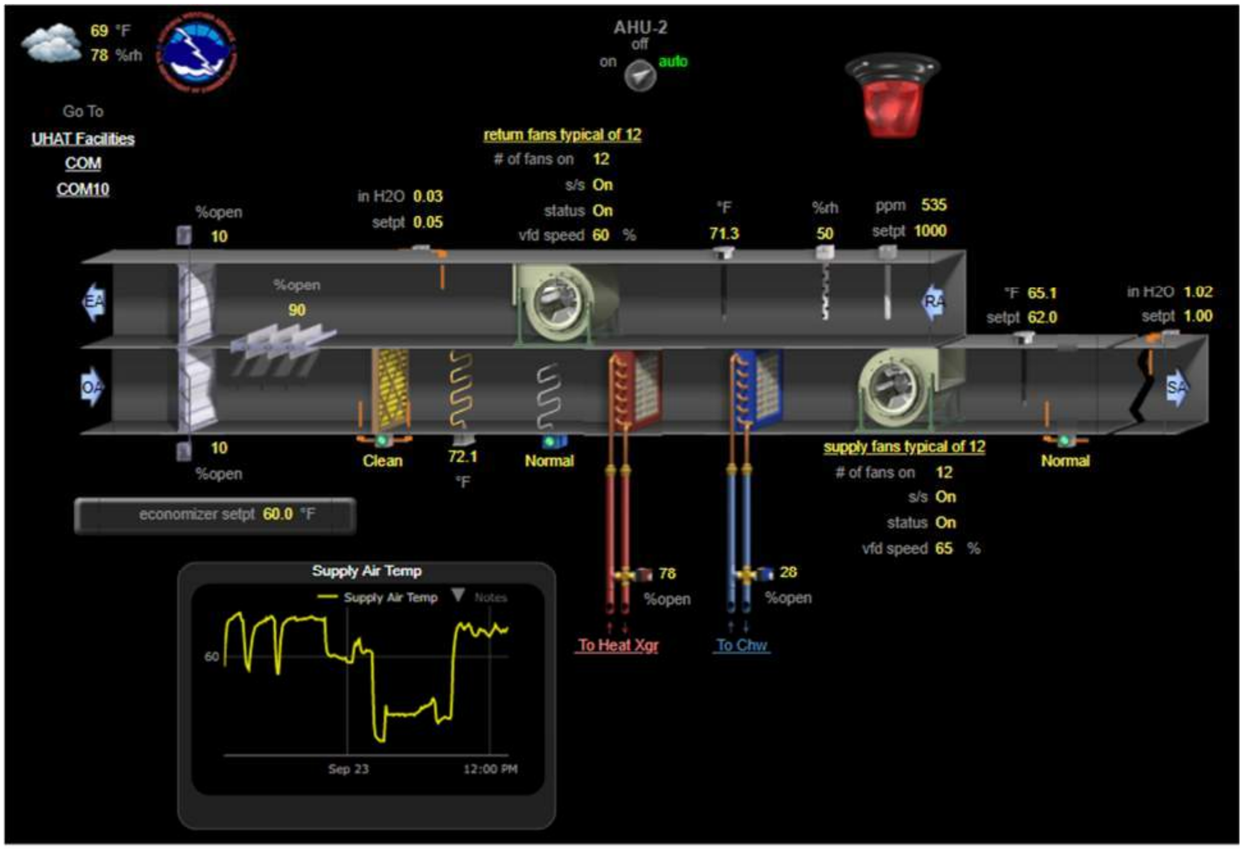
Recommendations Include

1. Verify calibration of all controls.
2. Utility meters supplying chilled water and steam need to be verified and confirmed as calibrated and reading correctly.
3. Perform a Test and Balance of the system.



AHU-1

The EMCS similarly indicated that AHU-2 was operating with simultaneous heating and cooling with the heating hot water valve open 78% and the chilled water open 28%. The heating hot water coil is in the pre-heat position.



AHU-2

BUILDING INFRASTRUCTURE TESTING

Terracon investigated the discrepancy between the design requirements in the drawings provided and the EMCS readings with an independent air flow instrument provided by our subconsultant TAB firm, ES2. The AHU air flow parameters at AHU-1 and AHU-2 were all measured in a traverse pattern grid that is in accordance with industry TAB standards for testing HVAC systems.

In addition to supply air flow measurements, Terracon also tested and verified the following:

1. Supply air temperature being distributed to the VAV terminal boxes
2. Entering and leaving water temperatures for each hot water and chilled water coil
3. Entering and leaving water pressures for each hot water and chilled water coil
4. Entering and leaving air pressure for each hot water and chilled water coil section
5. Total static air pressure (suction and discharge) for each AHU supply fan.

All measurements were taken independent to the EMCS readings to verify accuracy of the parameters being read by the *ALC webCTRL* system. The accuracy of the measurements are necessary to validate the HVAC systems are meeting the equipment's design performance requirements.

The following information was field measured by our sub-consultant TAB firm, ES2:

AHU 1

Total Supply Air [CFM]	Supply Air Temperature [ºF]	Entering Heating Water Temperature [ºF]	Leaving Heating Water Temperature [ºF]	Entering Chilled Water Temperature [ºF]	Leaving Cooling Coil Temperature [ºF]
53,525	74.9	136	124	47	60

Heating Coil Delta Air Pressure [in H_2O]	Cooling Coil Delta Air Pressure [in H_2O]	Heating Coil Delta Water Pressure [psig]	Cooling Coil Delta Water Pressure [psig]	Total Fan Static Pressure [in H_2O]
0.28	0.95	26.3	24.1	4.13

AHU 2

Total Supply Air [CFM]	Supply Air Temperature [ºF]	Entering Heating Water Temperature [ºF]	Leaving Heating Water Temperature [ºF]	Entering Chilled Water Temperature [ºF]	Leaving Chilled Water Temperature [ºF]
62,983	63.5	134	116	48	61

Heating Coil Delta Air Pressure [in H_2O]	Cooling Coil Delta Air Pressure [in H_2O]	Heating Coil Delta Water Pressure [psig]	Cooling Coil Delta Water Pressure [psig]	Total Fan Static Pressure [in H_2O]
0.35	0.79	25.6	23.6	4.21

* = Pressure Drop is across both coils because access between hot water and chilled water coils was difficult for measurements.

^ = Measurement taken in return duct due to limited access around supply duct.

ENERGY CONSERVATION OPPORTUNITIES (ECOs) AND RECOMMENDATIONS

In order to effectively evaluate existing systems and deficiencies and to provide recommended measures, various methods and actions were considered. Considerations include:

- Analysis of existing construction drawings and as-built documentation.
- Analysis of utility bills.
- Conversations with the UHAT and 1Call personnel regarding HVAC system configuration, controls, and existing trouble spots.
- Collection of information and data from *ALC webCTRL* interface to gather set points, operating conditions, identify anomalies, etc.
- Site surveys and investigations.
- Profiled mechanical equipment (e.g. pumps, chillers, air handling units) affected by the ECO's so that accurate calculations of savings could be produced.
- For weather dependent systems, bin temperature analysis is to be used to calculate baseline and post-installation consumption.
- For weather independent systems, time-of-use methods were used to calculate baseline and post-installation consumption.

Energy conservation opportunities (ECOs) have been listed on the basis of installed cost, potential benefit and, most importantly, Owner approval.

ECO Master List

Table 3: Master List

Measure #	Equipment or System	Description of Finding	Recommended Improvement
M1.1.1	CHWP-1	Pump differential pressure (dP) setpoint is fixed.	Implement pressure reset control to allow differential pressure setpoint to reset downwards when loads permit. Control dP such that worst case chilled water valve is no more than 85% open.

Measure #	Equipment or System	Description of Finding	Recommended Improvement
M1.1.2	CHWP-1	CHWP is not achieving the design specifications; head pressure and flows.	Balance CHWP-1 in order to achieve the design head pressure as well as flow in GPM.
M1.2.1	CHWP-2	Pump differential pressure (dP) setpoint is fixed.	Implement pressure reset control to allow differential pressure setpoint to reset downwards when loads permit. Control dP such that worst case chilled water valve is no more than 85% open.
M1.2.2	CHWP-2	CHWP-2 is not achieving the design specifications; head pressure and flows.	Balance CHWP-2 in order to achieve the design head pressure as well as flow in GPM.
M1.3.1	HHWP-1	Pump differential pressure (dP) setpoint is fixed.	Implement pressure reset control to allow differential pressure setpoint to reset downwards when loads permit. Control dP such that worst case heating hot water valve is no more than 85% open.
M1.3.2	HHWP-1	HHWP-1 is not achieving the design specifications; head pressure and flows.	Balance HHWP-1 in order to achieve the design head pressure as well as flow in GPM.
M1.4.1	HHWP-2	Pump differential pressure (dP) setpoint is fixed.	Implement pressure reset control to allow differential pressure setpoint to reset downwards when loads permit. Control dP such that worst case heating hot water valve is no more than 85% open.
M1.4.2	HHWP-2	HHWP-2 is not achieving the design specifications; head pressure and flows.	Balance HHWP-2 in order to achieve the design head pressure as well as flow in GPM.

Measure #	Equipment or System	Description of Finding	Recommended Improvement
M1.5.1	CHW/HHWPiping	Chilled water and heating hot water bypass valves were observed as being located on the 10th floor per the BAS. During one observation of these valves the CHW valve was open 54%. Given the system configuration this valve is expected to remain closed under normal operating conditions.	Verify the CHW and HHW bypass valves are not opening unnecessarily, increasing pumping energy and lowering the building CHW differential temperature.
M2.1.1	AHU-1	In the BAS review the HHW and CHW valves to the heating and cooling coils respectively, the valves were observed to be open simultaneously, when the unit should have been in cooling mode only. There is no mode of operation that would require both valves to ever be open simultaneously.	Review programming and eliminate any simultaneous heating and cooling that is occurring within the AHUs. Implement sufficient control dead bands.
M2.1.2	AHU-1	AHU-1 serves the west half of floors 1-10 and AHU-2 serves the east half of the building, with SF-3 (interlocked AHU-2) serving the lobby. When floors request after hours conditioning, the operation of both AHU-1 and AHU-2 are required to condition the entirety of any individual floor.	Optimize after hours HVAC operation for a single floor. Verify the control settings for unoccupied floor VAV terminal dampers are 0% open, and minimum AHU and pump pressure settings are optimized.
M2.1.3	AHU-1	The air economizer setpoints for AHU-1 (63 degF DB) is not consistenet with the other AHU for the building (61 degF DB).	Functionality test economizer operation for AHU-1 and AHU-2 and optimize setpoints.
M2.1.4	AHU-1	AHU-1 is not achieving the design heat transfer	Investigate possible coil corrosion, scaling, internal contaminants, or unconditioned air infiltration. Clean and rebalance system to achieve design heat transfer.

Measure #	Equipment or System	Description of Finding	Recommended Improvement
M2.2.1	AHU-2	In the BAS review the HHW and CHW valves to the heating and cooling coils respectively, the valves were observed to be open simultaneously, when the unit should have been in cooling mode only. There is no mode of operation that would require both valves to ever be open simultaneously.	Review programming and eliminate any simultaneous heating and cooling that is occurring within the AHUs. Implement sufficient control dead bands.
M2.2.2	AHU-2	AHU-1 serves the west half of floors 1-10 and AHU-2 serves the east half of the building, with SF-3 (interlocked AHU-2) serving the lobby. When floors request after hours HVAC operation, the operation of both AHU-1 and AHU-2 are required to condition the entirety of any individual floor.	Optimize after hours HVAC operation for a single floor. Verify the control settings for unoccupied floor VAV terminal dampers are 0% open, and minimum AHU and pump pressure settings are optimized.
M2.2.3	AHU-2	The air economizer setpoints for AHU-1 (63 degF DB) is not consistenet with the other AHU for the building (61 degF DB).	Functionality test economizer operation for AHU-1 and AHU-2 and optimize setpoints.
M2.2.4	AHU-2	AHU-2 is not achieving the design heat transfer	Investigate possible coil corrosion, scaling, internal contaminants, or unconditioned air infiltration. Clean and rebalance system to achieve design heat transfer.
M3.1.1	SF-3	SF-3 operates at constant air volume, CFM	Modify to variable volume operations at VFD based on duct static pressure requirements.

LIMITATIONS

The field observations, tests, findings, and recommendations presented in this report are based upon the information provided to Terracon by the client, UHAT, and observations and field notes collected at the time of our site visits. While additional conditions may exist that could alter our recommendations, we feel that reasonable means have been made to fairly and accurately evaluate the existing conditions of these systems. This report is limited to Terracon's observations of the interior and exterior of the facility. Some of the observations were limited due to obstructions and access to areas of the systems and facility. Although our observations were made with normal care and diligence, it is likely that not all existing conditions were documented. The general intent was to identify representative conditions and provide recommendations based on general findings.

This report has been prepared for the exclusive use of UHAT for specific application to the project discussed and has been prepared in accordance with generally accepted engineering practices using the standard of care and skill currently exercised by professional engineers practicing in this area, for a project of similar scope and nature. No warranties, either expressed or implied, are intended or made. In the event that information described in this document which was provided by others is incorrect, or if additional information becomes available, the recommendations contained in this report shall not be considered valid unless Terracon reviews the information and either verifies or modifies the recommendations of this report in writing.

APPENDIX A
Photographs

Photo #1 OU College of Medicine mechanical systems viewed by Terracon.

Photo #2 AHU-1 is a Temtrol unit in the basement and features 12 return air and 12 supply air fan arrays.

Photo #3 AHU-1 Gear tag. M# ITF-DHRE-135
S# T016772-001-00

Photo #4 SF-1 and SF-3 serve the basement and first floor and assist to regulate building pressure.

Photo #5 Two Yaskawa VFD’s serve -SF#1 and SF #3 located in the basement mechanical room.

Photo #6 Dual CHW Pumps #1 and #2 serve the College of Medicine Building.

Photo#7 Two separate VFD's and disconnects serve CHW Pumps #1 and #2.

Photo #8 Dual Hot water pumps located in the basement mechanical room serve the College of Medicine Building.

Photo #9 The steam heat exchanger converts steam to hot water for heating water service in the College of Medicine Building.

Photo #10 Terracon observed Automatic Logic Controls serving HVAC equipment in the College of Medicine Building.

Photo #11 Unit heater serving basement mechanical area.

Photo #12 Dual Liebert Units are installed and serve the basement area of the College of Medicine Building.

Photo #13 Exhaust fan for general building exhaust.

Photo #14 AHU-2 is installed in the Penthouse mechanical room and serves half of the College of medicine Building.

Photo #15 AHU-2 Gear Tag. M# ITF-DHRE-135 S# T016772-002-00 and is a Temtrol brand unit also features 12 supply and 12 return fan arrays.

Photo #16 The Automated Logic controls were viewed by Terracon.

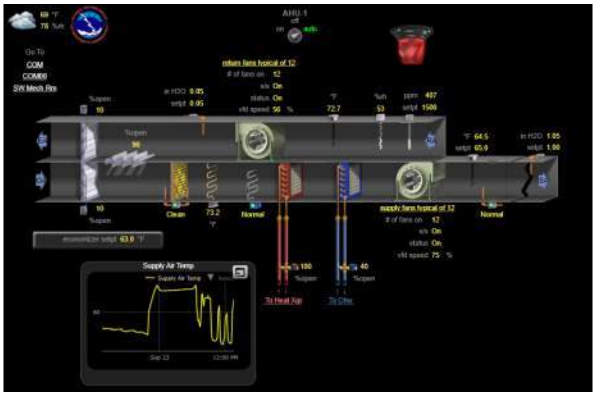


Photo #17 The Automatic Logic graphic packages were viewed serving the College of Medicine Building.

APPENDIX B
Test and Balancing Diagnostic Results

AIR APPARATUS TEST SHEET

Job Name: OU COM
Tested By: OGBURN / ROGERS **Date:** 2/5/2021

DESIGN DATA :

Manufacturer =	TEMTROL	**Model No. =**	ITF-DHRE135
Type =	AHU	**Serial No. =**	T016772-001-00
Outside Air cfm =			
Total Scheduled cfm =		**Grille Design Schedule cfm =**	
Fan rpm =	NG		
Total Static Pressure =	4.13	**External Static Pressure =**	3.74
Fan Rotation =	CW		

MOTOR DESIGN DATA

Horsepower =	12 AT 8 HP	**Voltage =**	480	**Phase =**	3	**Rpm =**	NG

AIR TEST DATA

Total cfm by Traverse Readings =	53,525	**Total cfm by Grille Readings =**	
Outside Air =		**Return Air =**	53,525

TEMPERATURE TEST DATA

Outside Air Temperature =	41.9	**Return Air Temperature =**	70.9
Mixed Air Temperature =	70.9		

PRESSURE TEST DATA

Fan Suction Static Pressure =		-1.89	
Fan Discharge Static Pressure =		2.24	
	Total Static Pressure =		4.13
External Suction Static Pressure =		-1.72	
External Discharge Static Pressure =		2.02	
	External Static Pressure =		3.74
Cooling Coil ΔS.P. =	0.95	**Heating Coil ΔS.P. =**	0.28
Pre Filters ΔS.P. =		**Final Filters ΔS.P. =**	0.28

MOTOR TEST DATA

Motor Manufacturer / Frame =							
HP =	**12 AT 8 HP**	**Volts/Ph/Hertz =**	480/3/60	**Act. Voltage =**	497	497	497
Full Load Amps =			NG	**Act. Amps =**	8.0	8.0	8.0
Service Factor =			NG				
Motor Design rpm =			NG	**Act motor rpm =**			INA

FAN TEST DATA

Motor Sheave Diameter =	DD	**Motor Sheave Bore =**	DD
Fan Sheave Diameter =	DD	**Fan Sheave Bore =**	DD
Adjustable Sheave Dia. =	DD	**Centerline Distance =**	DD
Fan rpm =	INA	**Fan Rotation =**	CW
Frequency Hz=	81.1		
Belts =	DD		
Pre Filters =			
Final Filters =			

Comments: Filters S.P. is across filters and HWC. Unit was trversed on both return trunks with O/A set to 0%. Both traverses were good locations with lamnar flow.

AIR APPARATUS TEST SHEET

Job Name: OU COM
Tested By: OGBURN / ROGERS **Date:** 2/5/2021

DESIGN DATA :

Manufacturer =	TEMTROL	**Model No. =**	ITF-DHRE135
Type =	AHU	**Serial No. =**	T016772-002-00
Outside Air cfm =			
Total Scheduled cfm =		**Grille Design Schedule cfm =**	
Fan rpm =			
Total Static Pressure =	4.21	**External Static Pressure =**	3.78
Fan Rotation =	CW		

MOTOR DESIGN DATA

Horsepower =	12 AT 8 HP	**Voltage =**	480	**Phase =**	3	**Rpm =**	NG

AIR TEST DATA

Total cfm by Traverse Readings =	62,983	**Total cfm by Grille Readings =**	
Outside Air =		**Return Air =**	

TEMPERATURE TEST DATA

Outside Air Temperature =	42.4	**Return Air Temperature =**	71.4
Mixed Air Temperature =	67.4		

PRESSURE TEST DATA

Fan Suction Static Pressure =		-1.71	
Fan Discharge Static Pressure =		2.50	
	Total Static Pressure =		4.21
External Suction Static Pressure =		-1.63	
External Discharge Static Pressure =		2.15	
	External Static Pressure =		3.78
Cooling Coil ΔS.P. =	0.79	**Heating Coil ΔS.P. =**	0.35
Pre Filters ΔS.P. =		**Final Filters ΔS.P. =**	0.35

MOTOR TEST DATA

Motor Manufacturer / Frame =							
HP =	**12 AH 8 HP**	**Volts/Ph/Hertz =**	480/3/60	**Act. Voltage =**	477	477	477
Full Load Amps =			NG	**Act. Amps =**	8.0	8.0	8.0
Service Factor =			NG				
Motor Design rpm =			NG	**Act motor rpm =**			NTS

FAN TEST DATA

Motor Sheave Diameter =	DD	**Motor Sheave Bore =**	DD
Fan Sheave Diameter =	DD	**Fan Sheave Bore =**	DD
Adjustable Sheave Dia. =	DD	**Centerline Distance =**	DD
Fan rpm =	NTS	**Fan Rotation =**	CW
Frequency Hz=	81.1		
Belts =	DD		
Pre Filters =			
Final Filters =			

Comments: Filter SP is across HW coil and filters. Unit was traversed on both suplpy trunks. Both traverses were in a good location, and were lamnar.

COIL APPARATUS TEST REPORT

Job Name: OU COM
Tested By: OGBURN / ROGERS **Date:** 2/5/2021

COIL DATA				
System Number	AHU-1	AHU-1	AHU-2	AHU-2
Location	BASEMENT	BASEMENT	PENTHOUSE	PENTHOUSE
Coil Type	CHW	HW	CHW	HW
No. Rows-Fins/ In.	NG	NG	NG	NG
Manufacturer	NG	NG	NG	NG
Model Number	NG	NG	NG	NG
Serial Number	NG	NG	NG	NG

Air Test Data	**DESIGN**	**ACTUAL**	**DESIGN**	**ACTUAL**	**DESIGN**	**ACTUAL**	**DESIGN**	**ACTUAL**
Air Qty., CFM(l/s)	NG	53,525	NG	53,525	NG	62,983	NG	62,983
Air Vel. FPM (m/s)	NG	NM	NG	NM	NG	NM	NG	NM
Press. Drop In wg (Pa)	NG	0.95	NG	0.28	NG	0.79	NG	0.35
Out. Air DB/WB	-	-	-	-	-	-	-	-
Ret. Air DB/WB	-	-	-	-	-	-	-	-
Ent. Air DB/WB	NG	78.1/61.0	NG	75.3/59.5	NG	70.8/56.4	NG	67.6/53.9
Lvg. Air DB/WB	NG	74.9/59.2	NG	78.1/61.0	NG	63.5/53.0	NG	70.8/56.4
Air ΔT	NG	3.2	NG	2.8	NG	7.3	NG	3.2

Water Test Data	**DESIGN**	**ACTUAL**	**DESIGN**	**ACTUAL**	**DESIGN**	**ACTUAL**	**DESIGN**	**ACTUAL**
Water Flow, GPM (l/s)	105.0	105.0	35.0	35.0	105.0	105.0	35.0	35.0
Press. Drop PSI (kPa)	2-45'	24.1	2-45'	26.3	2-45'	23.6	2-45'	25.6
Ent Water Temp.	NG	47.0	NG	136.0	NG	48.0	NG	134.0
Lvg. Water Temp.	NG	60.0	NG	124.0	NG	61.0	NG	116.0
Water ΔT	NG	13.0	NG	12.0	NG	13.0	NG	18.0

Refrigeration Test	**DESIGN**	**ACTUAL**	**DESIGN**	**ACTUAL**	**DESIGN**	**ACTUAL**	**DESIGN**	**ACTUAL**
Exp. Valve/Refrig.	-	-	-	-	-	-	-	-
Refrig. Suction Press.	-	-	-	-	-	-	-	-
Refrig. Suction Temp.	-	-	-	-	-	-	-	-
Inlet Steam Press.	-	-	-	-	-	-	-	-

COMMENTS:

PUMP TEST SHEET

Job Name: UHAT C.O.M.
Tested By: Jacquemin **Date:** 2/9/2021

PUMP DATA

Pump Number	**CHWP-1**	**CHWP-2**	
Manufacturer	TACO	TACO	
Model Number	FI5011E4LAJ1L0A	FI5011E4LAJ1L0A	
Serial Number	NG	NG	
Impeller Size	10.6	10.6	
Rpm	1750	1750	
Specified gpm	950	950	
Specified Head	90	90	

MOTOR DATA

	Design	Test	Design	Test	Design	Test
Motor Name	BALDOR		BALDOR			
Horsepower	30		30	28		
Motor rpm	1770		1770			
Phase	3					
Voltage	460		460	443		
				-		
				-		
Service Factor	1.15		1.15			
Amperage	35.0		35.0	33.0		
				-		
				-		

TEST RESULTS – CLOSE OFF

Suction Pressure (PSI)		NM	
Discharge Pressure (PSI)		NM	
Differential Pressure (PSI)		NM	
Head (Feet)		NM	

TEST RESULTS - RUNNING

Suction Pressure (PSI)		74.5	
Discharge Pressure (PSI)		109.0	
Differential Pressure (PSI)		34.5	
Head (Feet)		79.6	
Final gpm		NM	

Comments: CHWP-1 was not running during this scenario. CHWP-2 was tested at 60Hz.

PUMP TEST SHEET

Job Name: UHAT C.O.M.
Tested By: Jacquemin **Date:** 2/9/2021

PUMP DATA

Pump Number	**HWP-1**	**HWP-2**	
Manufacturer	TACO	TACO	
Model Number	FI4011E4KAJ1LOC	FI4011E4KAJ1LOC	
Serial Number	NG	NG	
Impeller Size	10.3	10.3	
Rpm	1750	1750	
Specified gpm	600	600	
Specified Head	100	100	

MOTOR DATA

	Design	Test	Design	Test	Design	Test
Motor Name	BALDOR		BALDOR			
Horsepower	25		25			
Motor rpm	1770		1770			
Phase	3		3			
Voltage	460		460	445		
Service Factor	1.15		1.15			
Amperage	30.0		30.0	25.8		

TEST RESULTS – CLOSE OFF

Suction Pressure (PSI)		NM	
Discharge Pressure (PSI)		NM	
Differential Pressure (PSI)		NM	
Head (Feet)		NM	

TEST RESULTS - RUNNING

Suction Pressure (PSI)		76.6	
Discharge Pressure (PSI)		116.0	
Differential Pressure (PSI)		39.4	
Head (Feet)		90.9	
Final gpm		NM	

Comments: HWP-1 was not running during this scenario. HWP-2 was tested at 60Hz.

APPENDIX C
GARRISON TOWER REPORTS

A. Testing Report
B. Retro-Commissioning Report

MECHANICAL CONSULTING SERVICES

Building Infrastructure Testing Report

Garrison Building at 940 NE 13th Street

Oklahoma City, Oklahoma

April 12, 2021

Project No. FA20P031

Prepared For:

University Hospitals Authority and Trust (UHAT)
Nathan Miller
940 NE 13th Street
Oklahoma City, Oklahoma 73104

Prepared by:

Terracon Consultants, Inc.
4701 N. Stiles Avenue
Oklahoma City, Oklahoma 73105

Terracon

April 12, 2021

Mr. Nathan Miller
Building Systems Manager
University Hospitals Authority & Trust
940 NE 13th Street
Oklahoma City, Oklahoma 73104
P: 405-271-4962 x44199
E: nathan-miller@uhat.org

Reference: **UHAT**
Building Infrastructure Testing
Garrison Building
940 NE 13th Street
Oklahoma City, Oklahoma 73104
Project No. FA20P031

Mr. Miller:

Terracon Consultants, Inc. (Terracon) is pleased to submit this Mechanical Consulting Services Report of our Building Infrastructure Testing for the Garrison Building at 940 NE 13th Street in Oklahoma City, Oklahoma. This work was performed in general accordance with the scope of services outlined in the Terracon Company Proposal for Building Infrastructure Testing & Retro-Commissioning Services dated December 19, 2019 and authorized in February 2020 as identified in the scope section of this Report.

The purpose of this Report is to render our findings, field notes, and recommendations related to our site visits at the above referenced location.

This document includes background information, observations, findings, and recommendations pertaining to the operations of the heating, ventilation, and air conditioning (HVAC) at the site.

Terracon appreciates the opportunity to be of service to you on this project. If you have any questions regarding this report, please do not hesitate to contact us.

Sincerely,

Terracon Consultants, Inc.

Erik Gonzalez, P.E. (TX), CEM
Senior Engineer
Facilities Services

Jeffrey A. Miller
Jeffrey A. Miller, P.E. (OK)
Senior Principal/Senior Engineer
Facilities Services

TABLE OF CONTENTS

PROJECT OBJECTIVE

The purpose of the Building Infrastructure Testing (BIT) services is to conduct limited visual observations and engineering diagnostics of the HVAC systems. With the observations and measurements obtained, a retro-commissioning plan will be developed from recommended energy conservation opportunities in this report that will help improve performance and reduce the operating costs of the building without compromising comfort for the building occupants.

Terracon's representatives, Mr. Saeed Foroughi, Mr. John Harmon, E.I.T., Mr. Kim Morris QCxP, Mr. Erik Gonzalez, P.E. (TX), CEM, and Engineering Systems & Energy Solutions (ES2) conducted site visits on May 13 - 14, 2020, May 25 - May 27, 2020, June 2, 2020, June 18 - 19, 2020, and June 23, 2020 at the Garrison Building in order to obtain visual and diagnostic information and measurements for the HVAC systems. During the site visits, visual observations were made to note general operating conditions of the HVAC systems. In addition, diagnostic measurements were taken for the air distribution of the 11 AHUs and two outside air units, associated chilled water and hot water coils, chilled water distribution pumps, and hot water distribution pumps. Measurements recorded were compared to the design documents and EMCS sensor measurements for air flow and water flow characteristics using the software workstation. Observations were made from readily accessible areas and did not include substantial dismantling of components of the building and HVAC equipment, including walls and closed ceilings. With the observations and measurements, Terracon developed energy conservation opportunity recommendations for improvements to the HVAC systems.

DOCUMENTS AND INFORMATION REVIEWED

Terracon was provided with design documentation for the subject building, utility data for chilled water, steam, and electricity, tariff sheets that breakdown the cost of each utility service, and network access to the *AutomatedLogic Corporation* (*ALC*) *WebCTRL v7.0* energy management control system. The following items were reviewed while performing this assessment:

Document	Source
GARRISON EXTG DRAWINGS MEP — HUDGINS, THOMPSON, BALL AND ASSOCIATES, dated September 16, 1974	Client Provided
Utility Bill Data for Terracon.xlsx – e-mailed to Terracon on February 28, 2020	Client Provided
Utility Service Tariff Sheets for OUHSC and OGE services provided to UHAT – e-mailed to Terracon on March 3, 2020	Client Provided

BUILDING DESCRIPTION AND ENERGY USE BASELINE

The subject property is a seven-story medical office building totals approximately 222,262-square feet. The building was originally designed as an inpatient healthcare facility and was repurposed for administrative healthcare use in 2006. The building was originally constructed around 1974. The HVAC systems were designed to operate with distributed chilled water and distributed steam from a Central Plant associated with the University of Oklahoma Health Sciences Center (OUHSC) at a remote location in downtown Oklahoma City.

The HVAC systems within the building include two chilled water pumps, and two heating hot water pumps, and two steam-to-hot water heat exchangers to provide domestic hot water for the building and distributed hot water for the HVAC systems. In addition, there are 10 variable air volume (VAV) air handling units (AHUs), one constant volume pre-conditioning outside air unit, one constant volume multizone AHU, one direct expansion (DX) packaged heat pump, 14 fan coil units, one energy recovery ventilator, 224 VAV terminal units, and 3 exhaust fans. All major equipment is controlled and monitored with an *ALC* energy management control system (EMCS) *WebCTRL* (software). The controllers (hardware) are from a variety of different manufacturers including, but not limited to, *ALC* and *InvenSys/Seibe*. and have been installed at different times over the years as renovations have been completed.

Table 1: General Building Information

Attributes	***GAR***
Property Manager	*ONECall*
Year Opened	1974
Enclosed Square Feet	222,262
Floors	7
Annual Metered kWh Consumption (2019)	2,283,900* (91% GAR & 9% OTC)
Annual Metered Peak kW Demand	442* (91% GAR & 9% OTC)
Annual Electric $	$137,698* (91% GAR & 9% OTC)
Annual CHW Ton/hr Consumed (2019)	704,523
Annual Peak Demand Tons	558.80
Average Monthly CHW Temp. Diff. (ºF)	8.964
Annual CHW $	$144,622
Annual Steam klbs Consumed (2019)	9,156
Annual Steam Demand lbs/hr	2,334
Annual Steam Condensate Return (%)	68%
Annual Steam Cost $	$70,225
kWh/sqft	10.3
Peak W/sqft	1.99
Electrical Load Factor	59.0%
CHW Tons/hr/sqft	3.17
Steam kBtu/sqft	49.3
Electrical EUI (kBtu/sqft)	35.1
CHW EUI (kBtu/sqft)	38.0
Total EUI (kBtu/sqft)	119.2*
Annual Utility Spend	$340,151
ECI ($/SqFt)	$1.53*
FCI Score	2019 (95) 2021 (91)
Operating Schedule	3rd & 4th Floor: 24-hours/7 days per week All Others: M-F 7am-10pm
Occupied Hours	3rd & 4th Floor: 24-hours/7 days per week All Others: M-F 7am-5pm
EMCS - Energy Management Control System	*ALC - WebCTRL*
Cooling Systems	Chilled Water
Heating Systems	Hot Water
Air Distribution	SZ & VAV with VAV TB's
Outside Air / Ventilation	OA preconditioned and is ducted directly to Return Air Section of AHU's

*Electric consumption was estimated based on the calculated ratio of the Garrison building sqft to the overall sqft (Garrison and OTC) served by the electric meter at the Garrison building.

To measure the building's energy utilization and current level of efficiency, two Energy Performance Indicators were calculated in this Report as follows:

Energy Utilization Intensity

The Energy Utilization Intensity (EUI) depicts the total annual energy consumption per square foot of building space, and is expressed in "British Thermal Units" (BTUs). To calculate the EUI, the annual consumption of electricity, steam, and chilled water are first converted to equivalent kBTU consumption via the following formulas:

Total Annual Energy Usage = Total Annual Electrical Energy Usage + Total Annual Steam Energy Usage + Total Annual Chilled Water Energy Usage converted to units of kBTUs/year.

Total Annual Electrical Energy Usage
[Total kWh /yr.] x [3.412 kBTUs/kWh] = __________ kBTUs / yr.

Total Annual Steam Energy Usage
[Total klbs /yr.] x [1,196 kBTUs/klbs] = __________ kBTUs / yr.

Total Annual Chilled Water Energy Usage
[Total Ton/hr /yr.] x [12 kBTUs/hr/Ton/hr] = __________ kBTUs / yr.

The total kBTUs are then divided by the building area.

EUI = [Total annual kBTUs] divided by [Total square feet]

The EUI was compared to the average energy utilization published in the 2012 Commercial Building Energy Consumption Survey (CBECS).

Energy Cost Index

The Energy Cost Index (ECI) depicts the total annual energy cost per square foot building space. To calculate the ECI, the annual costs of electricity, steam, and chilled water are divided by the total square footage of the leased space:

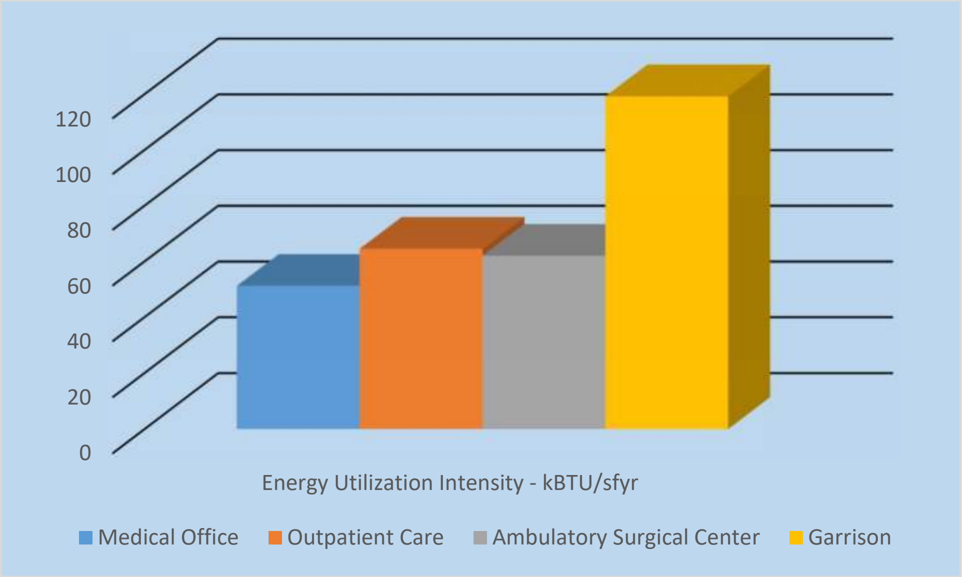
ECI = [Total Energy Cost] divided by [Total square feet]

The ECI was calculated and compared to the statistical average energy cost index published in the 2012 Commercial Building Energy Consumption Survey (CBECS).

The EUI and ECI may be used to compare the facility's approximate usage and cost to other similar facilities in the area. Although the comparisons will not provide specific reasons for unusual operation, they serve as indicators that opportunities may exist by more efficiently operating energy consuming systems.

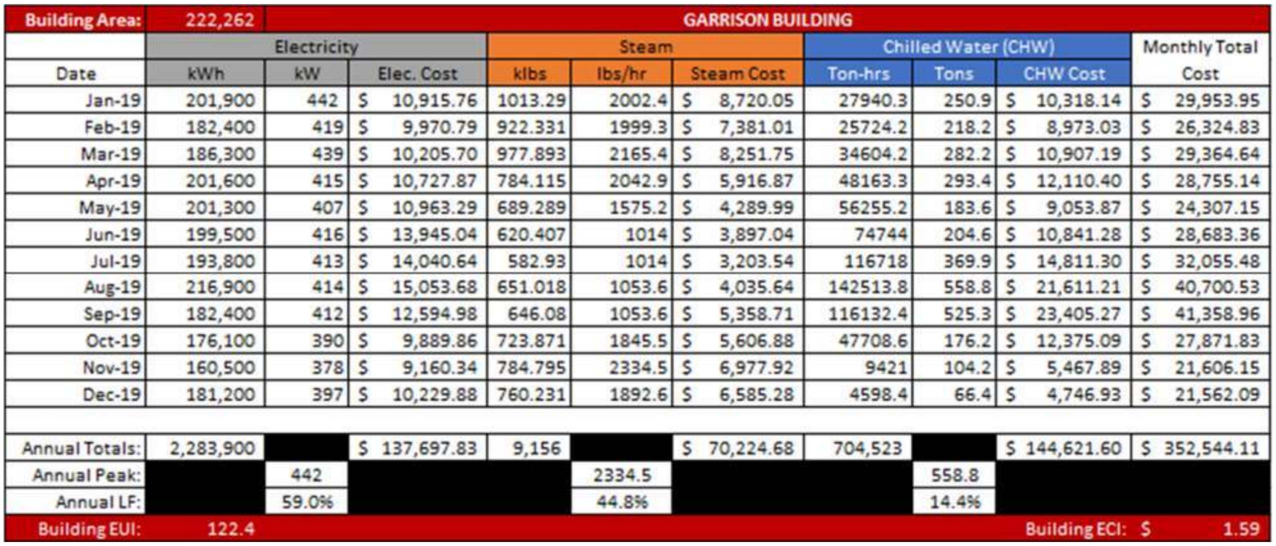
Referring to the 2012 Commercial Building Energy Consumption Survey (CBECS), compiled by the United States Department of Energy, we find the following ranges of comparison with the subject building. The CBECS survey results were based on a national statistical average of a total of 9,941-million square feet reported. The subject site is located within the southwestern section of the United States.

- CBECS utility cost and energy utilization comparison of the EUI and ECI indicates that Garrison has a **moderately high EUI and ECI** compared to similar facilities in the healthcare category.



Oklahoma Gas and Electric (OGE) and OU Health Science Center (OUHSC) are the main energy utility providers for the building. Terracon has analyzed the energy consumption for the building and determined the Energy Usage Index (EUI) is approximately 122.4 kBtu/SQFT and the Energy Cost Index (ECI) is $1.59/SQFT. The annual energy consumption ratio shows that electricity accounts for approximately 29% of total energy consumption, chilled water accounts for approximately 31% of total energy consumption, and steam accounts for the remaining 41% of total energy consumption. Annually, electricity accounts for approximately 39% of the total energy cost, chilled water accounts for approximately 41% of the total energy cost, and steam accounts for the remaining 20% of total energy cost. The annual cost ratios are mostly proportionate from the annual consumption ratios, with the steam cost ratio being much lower than the overall steam energy consumption ratio.

Table 2 – 2019 Energy Use Baseline



Building Area:	222,262	GARRISON BUILDING								
	Electricity			Steam			Chilled Water (CHW)			Monthly Total Cost
Date	kWh	kW	Elec. Cost	klbs	lbs/hr	Steam Cost	Ton-hrs	Tons	CHW Cost	
Jan-19	201,900	442	$ 10,915.76	1013.29	2002.4	$ 8,720.05	27940.3	250.9	$ 10,318.14	$ 29,953.95
Feb-19	182,400	419	$ 9,970.79	922.331	1999.3	$ 7,381.01	25724.2	218.2	$ 8,973.03	$ 26,324.83
Mar-19	186,300	439	$ 10,205.70	977.893	2165.4	$ 8,251.75	34604.2	282.2	$ 10,907.19	$ 29,364.64
Apr-19	201,600	415	$ 10,727.87	784.115	2042.9	$ 5,916.87	48163.3	293.4	$ 12,110.40	$ 28,755.14
May-19	201,300	407	$ 10,963.29	689.289	1575.2	$ 4,289.99	56255.2	183.6	$ 9,053.87	$ 24,307.15
Jun-19	199,500	416	$ 13,945.04	620.407	1014	$ 3,897.04	74744	204.6	$ 10,841.28	$ 28,683.36
Jul-19	193,800	413	$ 14,040.64	582.93	1014	$ 3,203.54	116718	369.9	$ 14,811.30	$ 32,055.48
Aug-19	216,900	414	$ 15,053.68	651.018	1053.6	$ 4,035.64	142513.8	558.8	$ 21,611.21	$ 40,700.53
Sep-19	182,400	412	$ 12,594.98	646.08	1053.6	$ 5,358.71	116132.4	525.3	$ 23,405.27	$ 41,358.96
Oct-19	176,100	390	$ 9,889.86	723.871	1845.5	$ 5,606.88	47708.6	176.2	$ 12,375.09	$ 27,871.83
Nov-19	160,500	378	$ 9,160.34	784.795	2334.5	$ 6,977.92	9421	104.2	$ 5,467.89	$ 21,606.15
Dec-19	181,200	397	$ 10,229.88	760.231	1892.6	$ 6,585.28	4598.4	66.4	$ 4,746.93	$ 21,562.09
Annual Totals:	2,283,900		$ 137,697.83	9,156		$ 70,224.68	704,523		$ 144,621.60	$ 352,544.11
Annual Peak:		442			2334.5			558.8		
Annual LF:		59.0%			44.8%			14.4%		
Building EUI:	122.4								Building ECI:	$ 1.59

Chart 1 – Energy Ratio

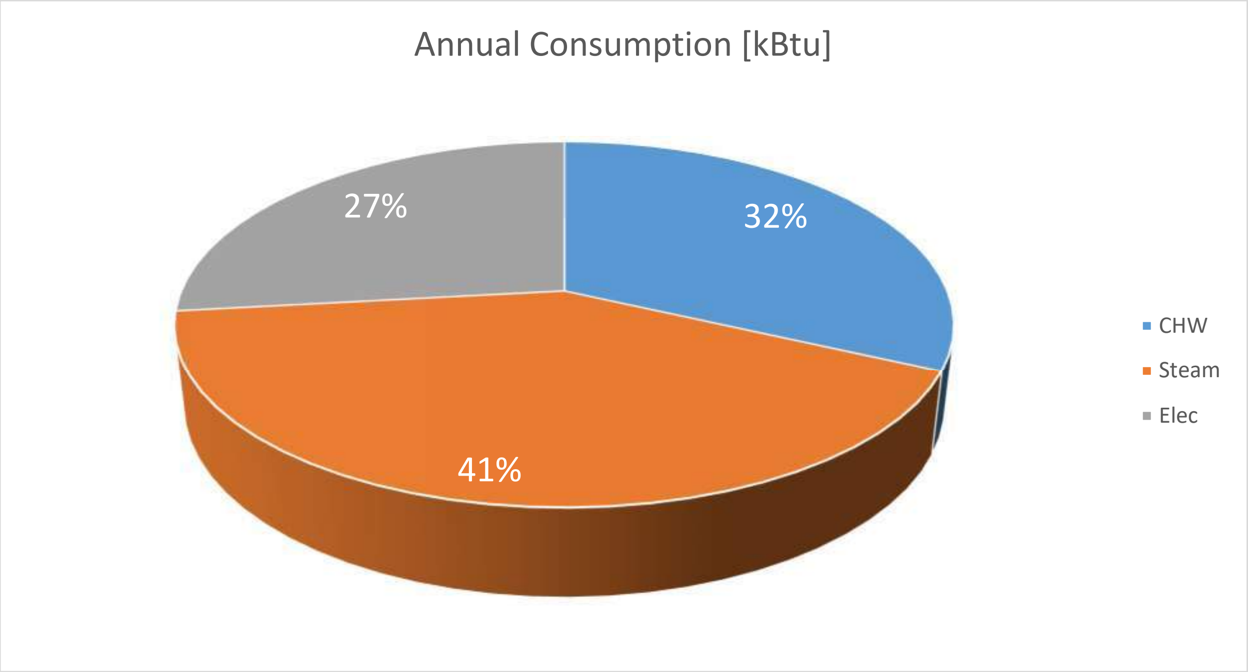
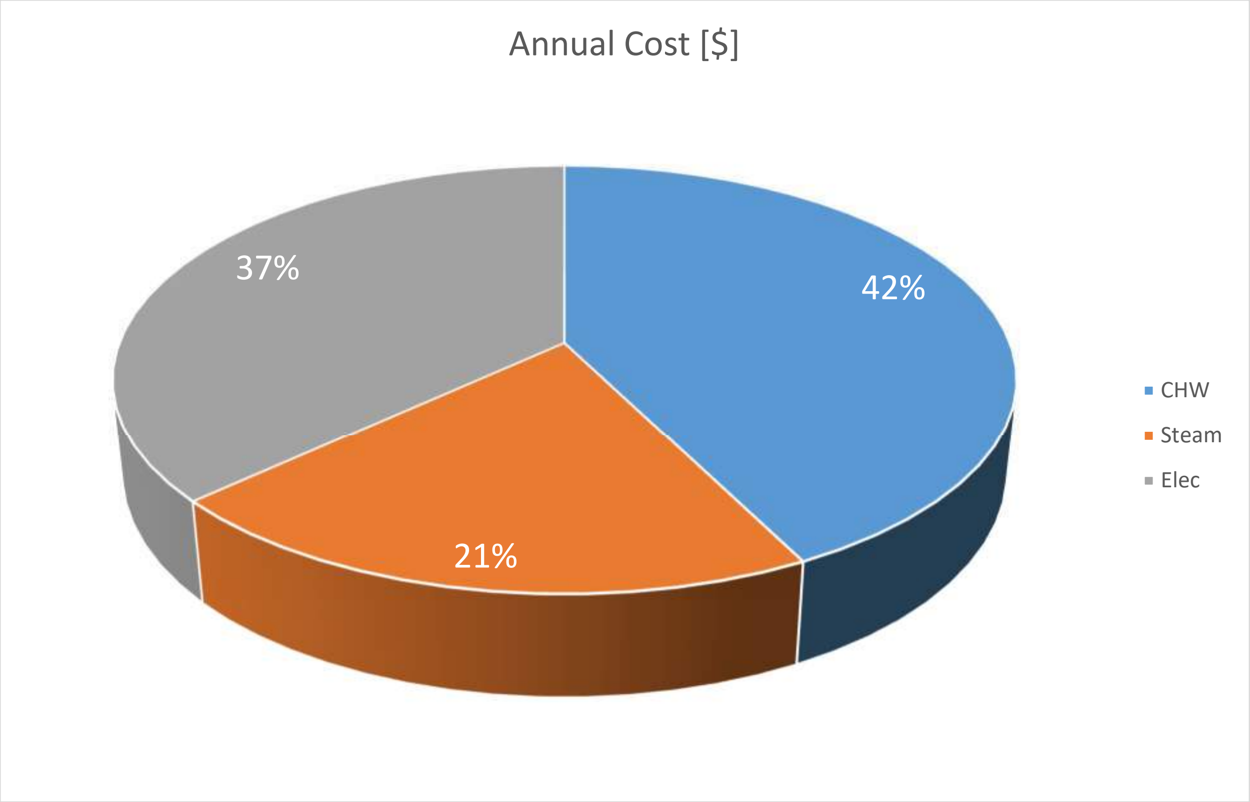


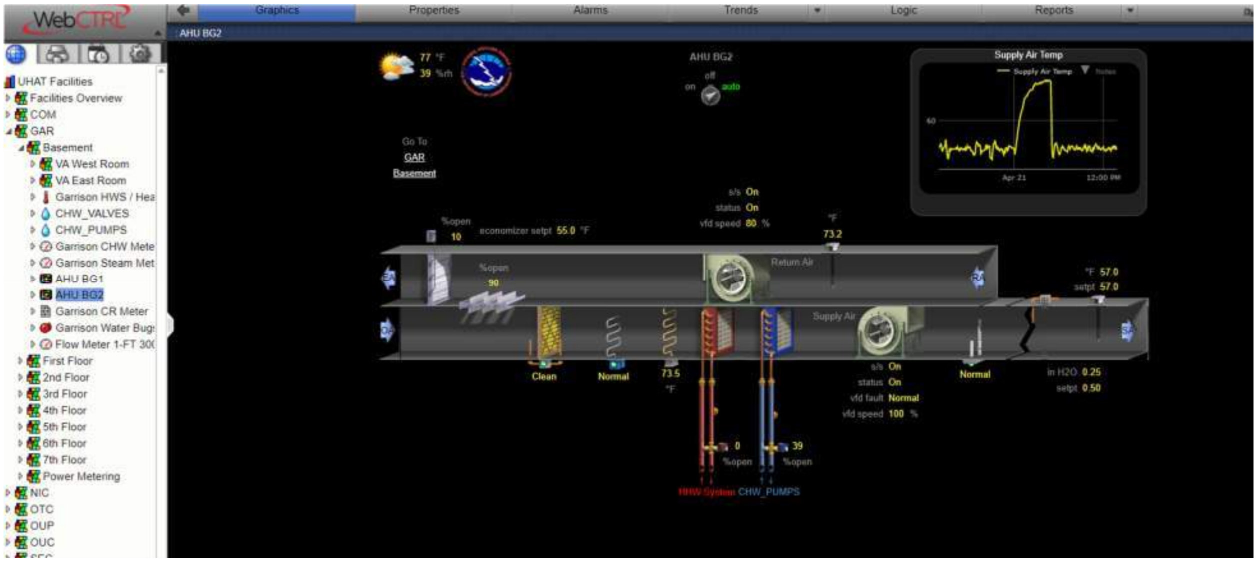
Chart 2 – Energy Cost Ratio



HVAC SYSTEM OBSERVATIONS

During the investigation and pre-task planning portion of this project, Terracon observed a variety of issues that prompted Terracon to investigate further:

The *ALC WebCTRL* EMCS indicated that AHU BG2 was having issues maintaining static pressure setpoint (0.50” w.g.) when the fan speed of the supply air fan was operating at 100%. Supply air temperature setpoint is being met, but air pressure issues could be indicative of an obstruction (fouled coils or coil corrosion) or duct leak. An older unit, such as this one, may need a major overhaul or higher capital expenditure replacement priority in order to improve system performance.



77 °F
39 %rh

AHU BG2
off
on auto

s/s On
status On
vfd speed 80 %

%open 10
economizer setpt 55.0 °F
%open 90
°F 73.2
°F 57.0
setpt 57.0

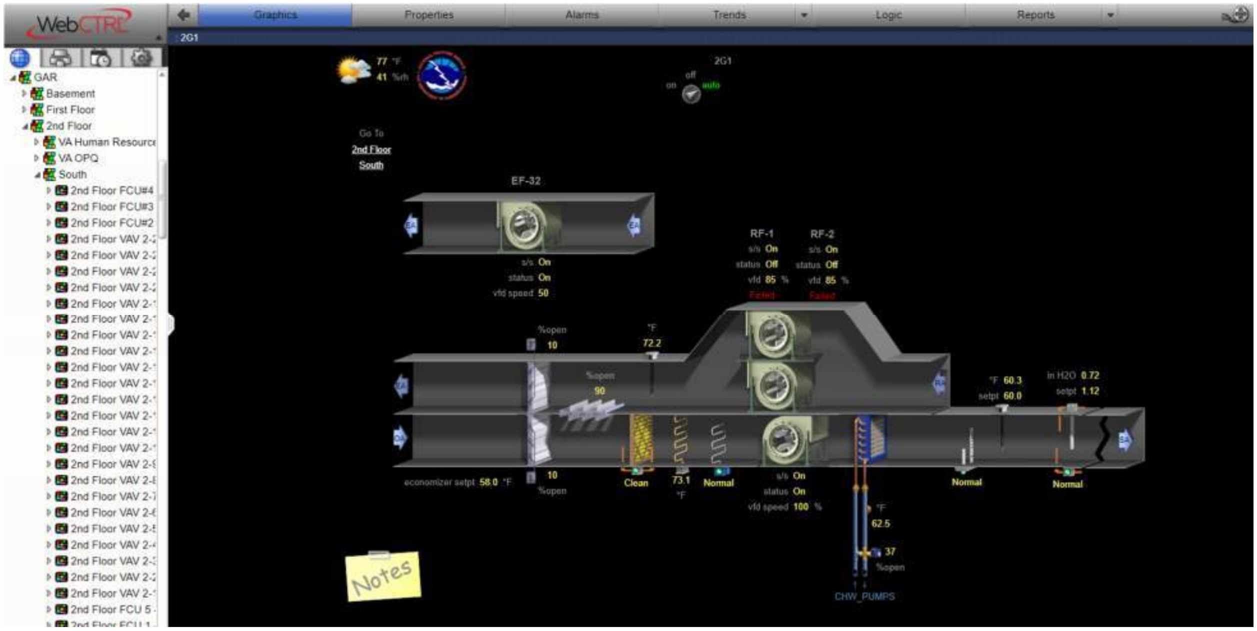
Clean
Normal
73.5 °F

0 %open
39 %open

s/s On
status On
vfd fault Normal
vfd speed 100 %

Normal
in H2O 0.25
setpt 0.50

The EMCS also indicated that AHU 2G1 was having issues maintaining static pressure setpoint (1.12” w.g.) when the fan speed of the supply air fan was operating at 100%. In addition, the two relief/return fans appear to not be functioning. The supply fan may be operating at a higher speed to compensate for the lack of suction pressure from the relief/return fans. Areas being served by AHU 2G1 may have issues properly cooling and heating the space and may requiring extended operating periods than a system with a functioning relief/return fan system.



Terracon also observed AHU 3G1 to have a chilled water valve that was reacting rapidly with the cooling load requirements. A supply air temperature reset schedule could be beneficial to improving operation of AHU 3G1.

The steam-to-hot water heat exchanger for the heating hot water distribution was observed to be set for 160ºF. Heating loads will vary as the weather changes and the building could benefit from a hot water temperature reset schedule. This may also be a contributor to the elevated annual steam energy consumption ratio for the building.

The EMCS indicated that the energy recovery unit (ERU) is not operational (exhaust and supply fans were not operating). The ERU appears to have at one time distributed outside air to many of the VAV AHUs. Outside air is still being distributed to the VAV AHUs, but without the use of the ERU fans. Since the building has been reclassified from an inpatient healthcare building to an administrative healthcare facility with minimal outpatient services, there is no need to fully utilize the ERU's ventilation capabilities. However, a reduction in outside air based on CO2 levels may provide reduced energy consumption.

61 °F
93 %rh

Energy Recovery Unit
off
on auto

vfd speed 28
s/s Off
status Off

°F 63.2
Close
°F 63.2
°F 62.6
in H2O -0.15
setpt 0.01
Clean
61.8 °F
Close
s/s Off
status Off
s/s Off
status Off
vfd speed 35 %
cmd Open

During the site visits, the Terracon team made the following observations:

1. Terracon observed that the exhaust chase running the height of the building does not connect with the outside air chase as previously suspected.
2. Terracon observed that the Energy Recovery Unit (ERU) on the 7th floor has been abandoned and does not appear to be required to operate since the building has been reclassified from Children's Hospital to an administration and medical office with limited outpatient services.
3. AHU BG1 currently has no VFD capability, dirty filters, and a fixed outside air damper which provides the majority of ventilation for the building in lieu of the ERU on the 7th floor.
4. AHU BG2 has newer series *ALC* controller than BG1. The water from the chilled water and hot water coils appeared to be "dirty" in the closed loops, likely from internal piping corrosion. The measured air differential pressure for the coils was lower than expected indicating the coil may be fouled and scaled.
5. While measurements were being recorded for the operational characteristics of hot water pump #2, the differential pressure (DP) sensor was identified to be in the 5th floor mechanical room and appears to have been recently replaced.
6. The steam-to-hot water heat exchanger supply water temperature was set at 160ºF.
7. Chilled water pump #3 was not operational and in need of replacement or repair.
8. AHU 2G1 had failed return fans #1 and #2 due to safety limit switch that had been tripped by fire/smoke dampers. Fire/smoke dampers remained shut during the site visit.
9. AHU 3G1, AHU 3G2, and AHU 3RAD were operating satisfactorily and meeting airflow and temperature setpoints.
10. The 4th floor was under construction and the AHUs are scheduled for replacement soon.
11. AHU 5G1 was commanded on by the EMCS but was not profiled. The unit was replaced in approximately 2014.
12. AHU 5G2 and 5G3 should be replaced based on the corrosion observed around the piping connected to the coils.
13. AHU 6G1 was operating satisfactorily and meeting airflow and temperature setpoints.
14. AHU 7G1 is a multizone AHU with a hot deck, cold deck, and seven individual zones. The unit is in need of maintenance and the controls updated.
15. AHU 7G2 has recently been replaced and may require fan belt adjustments for proper fan performance.
16. The ERU on the roof of the 7th floor has been disabled for several years and needs to be removed. The outside air damper array or louvers for the ERU should be repaired or replaced to properly modulate and operate with the exhaust system on the 7th floor.

BUILDING INFRASTRUCTURE TESTING

Terracon investigated the discrepancy between the design requirements in the drawings provided and the EMCS readings with an independent air flow instrument provided by our subconsultant TAB firm. The AHU air flow parameters at AHU BG1, AHU BG2, AHU 1G1, AHU 2G2, AHU 3G1, AHU 3G2, AHU 3RAD, AHU 5G1, AHU 5G2, AHU 5G3, AHU 6G1, AHU 7G1, and AHU 7G2 were all measured in a traverse pattern grid that is in accordance with industry TAB standards for HVAC systems.

In addition to supply air flow measurements, Terracon also tested and verified the following:

1. Supply air temperature being distributed to the VAV terminal boxes
2. Entering and leaving water temperatures for each hot water and chilled water coil
3. Entering and leaving water pressures for each hot water and chilled water coil
4. Entering and leaving air pressure for each hot water and chilled water coil section
5. External air pressure (suction and discharge) for each AHU supply fan.

All measurements were taken independent to the EMCS to verify accuracy of the parameters being read by the *ALC webCTRL* system. The accuracy of the measurements are necessary to validate the HVAC systems are meeting the equipment's design performance requirements.

The following information was field measured:

AHU BG1

Total Supply Air [CFM]	Supply Air Temperature [ºF]	Entering Heating Coil Temperature [ºF]	Leaving Heating Coil Temperature [ºF]	Entering Cooling Coil Temperature [ºF]	Leaving Cooling Coil Temperature [ºF]
2,925	67.8	159.6	156.3	40.5	47.2

Heating Coil Delta Air Pressure [in H_2O]	Cooling Coil Delta Air Pressure [in H_2O]	Heating Coil Delta Water Pressure [psig]	Cooling Coil Delta Water Pressure [psig]	Total Fan Static Pressure [in H_2O]
0.86*	0.86*	14.7	14.1	1.05

AHU BG2

Total Supply Air [CFM]	Supply Air Temperature [ºF]	Entering Heating Coil Temperature [ºF]	Leaving Heating Coil Temperature [ºF]	Entering Cooling Coil Temperature [ºF]	Leaving Cooling Coil Temperature [ºF]
-	57.1	155.3	147.4	40.4	55.3

Heating Coil Delta Air Pressure [in H_2O]	Cooling Coil Delta Air Pressure [in H_2O]	Heating Coil Delta Water Pressure [psig]	Cooling Coil Delta Water Pressure [psig]	Total Fan Static Pressure [in H_2O]
2.06*	2.06*	8.8	13.8	2.29

AHU 1G1

Total Supply Air [CFM]	Supply Air Temperature [ºF]	Entering Heating Coil Temperature [ºF]	Leaving Heating Coil Temperature [ºF]	Entering Cooling Coil Temperature [ºF]	Leaving Cooling Coil Temperature [ºF]
17,814	62.8	N/A	N/A	52.9	55.5

Heating Coil Delta Air Pressure [in H_2O]	Cooling Coil Delta Air Pressure [in H_2O]	Heating Coil Delta Water Pressure [psig]	Cooling Coil Delta Water Pressure [psig]	Total Fan Static Pressure [in H_2O]
N/A	2.12	N/A	6.3	4.34

AHU 2G1

Total Supply Air [CFM]	Supply Air Temperature [ºF]	Entering Heating Coil Temperature [ºF]	Leaving Heating Coil Temperature [ºF]	Entering Cooling Coil Temperature [ºF]	Leaving Cooling Coil Temperature [ºF]
-	58.6	N/A	N/A	51.0	59.2

Heating Coil Delta Air Pressure [in H_2O]	Cooling Coil Delta Air Pressure [in H_2O]	Heating Coil Delta Water Pressure [psig]	Cooling Coil Delta Water Pressure [psig]	Total Fan Static Pressure [in H_2O]
N/A	0.33	N/A	3.5	5.38

AHU 3G1

Total Supply Air [CFM]	Supply Air Temperature [ºF]	Entering Heating Coil Temperature [ºF]	Leaving Heating Coil Temperature [ºF]	Entering Cooling Coil Temperature [ºF]	Leaving Cooling Coil Temperature [ºF]
7,728^	60.9	159.7	152.1	49.5	58.8

Heating Coil Delta Air Pressure [in H_2O]	Cooling Coil Delta Air Pressure [in H_2O]	Heating Coil Delta Water Pressure [psig]	Cooling Coil Delta Water Pressure [psig]	Total Fan Static Pressure [in H_2O]
0.52	0.28	2.7	2.8	3.21

AHU 3G2

Total Supply Air [CFM]	Supply Air Temperature [ºF]	Entering Heating Coil Temperature [ºF]	Leaving Heating Coil Temperature [ºF]	Entering Cooling Coil Temperature [ºF]	Leaving Cooling Coil Temperature [ºF]
4,057	71.4	160.2	142.6	46.2	53.6

Heating Coil Delta Air Pressure [in H_2O]	Cooling Coil Delta Air Pressure [in H_2O]	Heating Coil Delta Water Pressure [psig]	Cooling Coil Delta Water Pressure [psig]	Total Fan Static Pressure [in H_2O]
1.12*	1.12*	0.5	10.3	1.67

AHU 3RAD

Total Supply Air [CFM]	Supply Air Temperature [ºF]	Entering Heating Coil Temperature [ºF]	Leaving Heating Coil Temperature [ºF]	Entering Cooling Coil Temperature [ºF]	Leaving Cooling Coil Temperature [ºF]
8,844	59.1	163.8	149.2	45.7	56.8

Heating Coil Delta Air Pressure [in H_2O]	Cooling Coil Delta Air Pressure [in H_2O]	Heating Coil Delta Water Pressure [psig]	Cooling Coil Delta Water Pressure [psig]	Total Fan Static Pressure [in H_2O]
0.391*	0.391*	0.9	1.8	2.66

AHU 5G1

Total Supply Air [CFM]	Supply Air Temperature [ºF]	Entering Heating Coil Temperature [ºF]	Leaving Heating Coil Temperature [ºF]	Entering Cooling Coil Temperature [ºF]	Leaving Cooling Coil Temperature [ºF]
-	-	161.5	160.6	49.3	49.9

Heating Coil Delta Air Pressure [in H_2O]	Cooling Coil Delta Air Pressure [in H_2O]	Heating Coil Delta Water Pressure [psig]	Cooling Coil Delta Water Pressure [psig]	Total Fan Static Pressure [in H_2O]
-	-	3.0	4.9	-

AHU 5G2

Total Supply Air [CFM]	Supply Air Temperature [ºF]	Entering Heating Coil Temperature [ºF]	Leaving Heating Coil Temperature [ºF]	Entering Cooling Coil Temperature [ºF]	Leaving Cooling Coil Temperature [ºF]
2,561	54.8	161.6	148.2	50.3	55.9

Heating Coil Delta Air Pressure [in H_2O]	Cooling Coil Delta Air Pressure [in H_2O]	Heating Coil Delta Water Pressure [psig]	Cooling Coil Delta Water Pressure [psig]	Total Fan Static Pressure [in H_2O]
0.4738*	0.4738*	2.4	5.9	0.83

AHU 5G3

Total Supply Air [CFM]	Supply Air Temperature [ºF]	Entering Heating Coil Temperature [ºF]	Leaving Heating Coil Temperature [ºF]	Entering Cooling Coil Temperature [ºF]	Leaving Cooling Coil Temperature [ºF]
7,235	60.0	N/A	N/A	51.0	54.0

Heating Coil Delta Air Pressure [in H_2O]	Cooling Coil Delta Air Pressure [in H_2O]	Heating Coil Delta Water Pressure [psig]	Cooling Coil Delta Water Pressure [psig]	Total Fan Static Pressure [in H_2O]
N/A	0.60	N/A	9.6	3.18

AHU 6G1

Total Supply Air [CFM]	Supply Air Temperature [ºF]	Entering Heating Coil Temperature [ºF]	Leaving Heating Coil Temperature [ºF]	Entering Cooling Coil Temperature [ºF]	Leaving Cooling Coil Temperature [ºF]
17,079	58.4	159.1	151.0	48.3	57.8

Heating Coil Delta Air Pressure [in H_2O]	Cooling Coil Delta Air Pressure [in H_2O]	Heating Coil Delta Water Pressure [psig]	Cooling Coil Delta Water Pressure [psig]	Total Fan Static Pressure [in H_2O]
1.39*	1.39*	-	12.7	4.51

AHU 7G1

Total Supply Air [CFM]	Supply Air Temperature [ºF]	Entering Heating Coil Temperature [ºF]	Leaving Heating Coil Temperature [ºF]	Entering Cooling Coil Temperature [ºF]	Leaving Cooling Coil Temperature [ºF]
5,300	75.6	158.0	155.5	50.6	58.1

Heating Coil Delta Air Pressure [in H_2O]	Cooling Coil Delta Air Pressure [in H_2O]	Heating Coil Delta Water Pressure [psig]	Cooling Coil Delta Water Pressure [psig]	Total Fan Static Pressure [in H_2O]
0.31	0.24	4.4	0.8	2.31

AHU 7G2

Total Supply Air [CFM]	Supply Air Temperature [ºF]	Entering Heating Coil Temperature [ºF]	Leaving Heating Coil Temperature [ºF]	Entering Cooling Coil Temperature [ºF]	Leaving Cooling Coil Temperature [ºF]
2,864	55.5	157.1	133.0	47.8	60.8

Heating Coil Delta Air Pressure [in H_2O]	Cooling Coil Delta Air Pressure [in H_2O]	Heating Coil Delta Water Pressure [psig]	Cooling Coil Delta Water Pressure [psig]	Total Fan Static Pressure [in H_2O]
0.07	0.16	0.6	2.2	0.69

* = Pressure Drop is across both coils because access between hot water and chilled water coils was difficult for measurements.

^ = Measurement taken in return duct due to limited access around supply duct.

During testing, the Terracon team made the following observations:

1. Traverse reading was not possible for AHU BG2 due to access constraints.
2. AHU 1G1 had dirty filters at the time of testing. The Terracon team was unable to get air pressure measurements across individual coils because of space restraints so differential pressure was measured across both hot water and chilled water coils together.
3. Traverse reading would not be accurate for AHU 2G1 due to a fire/smoke damper being shut for one of the relief/return fans.
4. A belt fan for AHU 7G2 was observed to be loose and may be limiting the amount of power and torque transferred from the motor shaft to the fan and causing low measurements.
5. CHWP-4 was the only chilled water pump operating during testing. CHWP-3 was not operational.

ENERGY CONSERVATION OPPORTUNITIES (ECOs) AND RECOMMENDATIONS

In order to effectively evaluate existing systems and deficiencies and to provide recommended measures, various methods and actions were considered. Considerations include:

- Analysis of existing construction drawings and as-built documentation.
- Analysis of utility bills.
- Conversations with the UHAT personnel regarding HVAC system configuration, controls, and existing trouble spots.
- Collection of information and data from *ALC webCTRL* interface to gather set points, operating conditions, identify anomalies, etc.
- Site surveys and investigations.
- Profiled mechanical equipment (e.g. pumps, chillers, air handling units) affected by the ECO’s so that accurate calculations of savings could be produced.
- For weather dependent systems, bin temperature analysis is to be used to calculate baseline and post-installation consumption.
- For weather independent systems, time-of-use methods were used to calculate baseline and post-installation consumption.

Energy conservation opportunities (ECOs) have been listed on the basis of cost, potential benefit and, most importantly, Owner approval.

ECO Master List

Table 3: Master List

Measure #	Equipment or System	Description of Finding	Recommended Improvement
M1.1	Central Plant	Hot water supply temperature from steam-to-hot water heat exchanger is set to 160ºF.	Program the EMCS to reset supply hot water temperature according to outside air conditions. Use a linear relationship of 160ºF supply hot water temperature at 30ºF or below outside air temperature and 90ºF at 80ºF or above outside air temperature.
M1.2	Central Plant	Chilled water pump #3 is not operational.	Replace or repair existing with new pump. Update: On 08/18/2020 Terracon was informed that the pump was in the process of being repaired.
M2.1	AHU BG1	Outside air unit operates at constant volume during building operating hours.	Install new *ABB* VFD on supply air fan and static air pressure sensor in supply air duct. Integrate new VFD and sensor with existing *ALC* controller, if control points are available on controller board. If control points are not available, upgrade controller to allow for additional points.
M2.2	AHU BG1	AHU air filters are “dirty” and in need of replacement.	Replace air filters according to scheduled preventative maintenance plan.
M3.1	AHU BG2	Water from chilled water and hot water coils were observed to be “dirty”. Differential pressure across both coils indicates the unit is having trouble distributing air and keeping up with the load, even at full speed.	AHU is beyond expected useful service life and it is likely the coils have become significantly corroded that replacement will be necessary soon. This unit serves an area with lower occupancy and may not be a priority for replacement.

Measure #	Equipment or System	Description of Finding	Recommended Improvement
M4.1	AHU 1G1	Outside air is set to minimum position unless supply air temperature is reset according to outside air temperature or economizer cycle is activated by EMCS.	Install new CO2 sensors in the return duct of AHU and integrate control point into existing *ALC* controller, if control point is available on controller board, to reduce ventilation provided to space. If control point is not available, upgrade controller to allow for additional point.
M5.1	AHU 2G1	Fire/smoke damper for relief/return fan is shut and preventing AHU from operating optimally.	Repair safety fault causing fire/smoke damper to be shut and operate relief/return fans to prevent a similar occurrence in the future. It may be necessary to relocate the manual reset switch for the fire/smoke damper if it is not easily accessible.
M5.2	AHU 2G1	Outside air is set to minimum position unless supply air temperature is reset according to outside air temperature or economizer cycle is activated by EMCS.	Install new CO2 sensors in the return duct of AHU and integrate control point into existing *ALC* controller, if control point is available on controller board, to reduce ventilation provided to space. If control point is not available, upgrade controller to allow for additional point.
M6.1	AHU 3G1	Outside air is set to minimum position unless supply air temperature is reset according to outside air temperature or economizer cycle is activated by EMCS.	Install new CO2 sensors in the return duct of AHU and integrate control point into existing *ALC* controller, if control point is available on controller board, to reduce ventilation provided to space. If control point is not available, upgrade controller to allow for additional point.
M6.2	AHU 3G1	Chilled water valve reacts rapidly when cooling is needed.	Update supply air reset schedule and select new chilled water valve to replace existing chilled water valve with proper Cv value to allow for optimal flow.

Measure #	Equipment or System	Description of Finding	Recommended Improvement
M7.1	AHU 3G2	Outside air is set to minimum position unless supply air temperature is reset according to outside air temperature or economizer cycle is activated by EMCS.	Install new CO2 sensors in the return duct of AHU and integrate control point into existing *ALC* controller, if control point is available on controller board, to reduce ventilation provided to space. If control point is not available, upgrade controller to allow for additional point.
M8.1	AHU 3RAD	Outside air is set to minimum position unless supply air temperature is reset according to outside air temperature or economizer cycle is activated by EMCS.	Install new CO2 sensors in the return duct of AHU and integrate control point into existing *ALC* controller, if control point is available on controller board, to reduce ventilation provided to space. If control point is not available, upgrade controller to allow for additional point.
M9.1	AHU 5G2	Piping connections to the chilled water and hot water coils are excessively corroded and a low differential temperature was measured indicating the unit is having trouble satisfying the load it serves.	AHU is beyond expected useful service life and it is likely the coils have become significantly corroded that replacement will be necessary soon.
M9.2	AHU 5G2	Outside air is set to minimum position unless supply air temperature is reset according to outside air temperature or economizer cycle is activated by EMCS.	Install new CO2 sensors in the return duct of AHU and integrate control point into existing *ALC* controller, if control point is available on controller board, to reduce ventilation provided to space. If control point is not available, upgrade controller to allow for additional point.
M10.1	AHU 5G3	Piping connections to the chilled water and hot water coils are excessively corroded and a low differential temperature was measured indicating the unit is having trouble satisfying the load it serves.	AHU is beyond expected useful service life and it is likely the coils have become significantly corroded that replacement will be necessary soon.

Measure #	Equipment or System	Description of Finding	Recommended Improvement
M10.2	AHU 5G3	Outside air is set to minimum position unless supply air temperature is reset according to outside air temperature or economizer cycle is activated by EMCS.	Install new CO2 sensors in the return duct of AHU and integrate control point into existing *ALC* controller, if control point is available on controller board, to reduce ventilation provided to space. If control point is not available, upgrade controller to allow for additional point.
M11.1	AHU 6G1	Outside air is set to minimum position unless supply air temperature is reset according to outside air temperature or economizer cycle is activated by EMCS.	Install new CO2 sensors in the return duct of AHU and integrate control point into existing *ALC* controller, if control point is available on controller board, to reduce ventilation provided to space. If control point is not available, upgrade controller to allow for additional point.
M12.1	AHU 7G1	AHU is a constant volume multizone unit with a hot deck, cold, deck, and seven individual zones.	AHU is beyond expected useful service life and the constant volume multizone system is a method that is not energy efficient. Replace or retrofit existing AHU with new VAV AHU and new VAV terminal units for each individual zone.
M12.2	AHU 7G1	Fan belt is loose and preventing proper distribution of air to zones.	Repair (tighten or replace) fan belt to improve operation of AHU.
M13.1	AHU 7G2	Outside air unit operates at constant volume during building operating hours.	Install new *ABB* VFD on supply air fan and static air pressure sensor in supply air duct. Integrate new VFD and sensor with existing *ALC* controller, if control points are available on controller board. If control points are not available, upgrade controller to allow for additional points.

Measure #	Equipment or System	Description of Finding	Recommended Improvement
M14.1	ERU	Outside air damper array/louvers associated with the system do not modulate and excessive amounts of outside can infiltrate the building.	Replace or repair outside air damper array/louvers to close when building is not occupied and open if occupied. ERU is not in use and may also be removed.
M15.1	EMCS – Basement Floor	VAV controllers are over 27 years old and cannot be directly controlled with EMCS.	Upgrade existing controllers with *ALC* controllers, new temperature sensors, and other new end devices with a phased approach (floor-by-floor) due to age and lack of support available by vendor. This area is a lower occupancy area.
M15.2	EMCS – Basement Floor	VAV terminal units in the basement (VAV-SV-1 and VAV-FV-2) are having trouble provide the desired air flow setpoints.	The flow settings may be related to the AHU, but if not, the VAV terminal box flow sensors (K-values) may need to be recalibrated to verify proper flow rates.

LIMITATIONS

The field observations, tests, findings, and recommendations presented in this report are based upon the information provided to Terracon by the client, UHAT, and observations and field notes collected at the time of our site visits. While additional conditions may exist that could alter our recommendations, we feel that reasonable means have been made to fairly and accurately evaluate the existing conditions of these systems. This report is limited to Terracon's observations of the interior and exterior of the facility. Some of the observations were limited due to obstructions and access to areas of the systems and facility. Although our observations were made with normal care and diligence, it is likely that not all existing conditions were documented. The general intent was to identify representative conditions and provide recommendations based on general findings.

This report has been prepared for the exclusive use of UHAT for specific application to the project discussed and has been prepared in accordance with generally accepted engineering practices using the standard of care and skill currently exercised by professional engineers practicing in this area, for a project of similar scope and nature. No warranties, either expressed or implied, are intended or made. In the event that information described in this document which was provided by others is incorrect, or if additional information becomes available, the recommendations contained in this report shall not be considered valid unless Terracon reviews the information and either verifies or modifies the recommendations of this report in writing.

APPENDIX A
Photographs

Photo#7 AHU 2AMI-1 2nd Floor.

Photo #8 AHU-3RAD 3rd Floor.

Photo #9 AHU 3rd Floor Carrier

Photo #10 AHU 5G1 Fifth Floor.

Photo #11 AHU-6G1 Sixth Floor.

Photo #12 AHU 7G1 Multi-Zone 7th-Floor.

Photo #13 AHU-7G2

Photo #14 Controls for Multi-zone unit 7th Floor.

Photo #15 ERU abandoned on the 7th floor roof.

Photo #16 O/A damper array on the 7th floor.

APPENDIX B
Test and Balancing Report

es2 engineered systems & energy solutions, inc.

13401 N. Santa Fe Avenue
Oklahoma City, Oklahoma 73114
Phone: (405) 528-4500

CERTIFIED TEST, ADJUST, AND BALANCE REPORT

Date: June 24, 2020

Project: Garrison Tower CX Assessment

Address: Oklahoma City, OK

ES2 project number 01-20-406

The data presented in this report is an exact record of the system performance and was obtained in accordance with NEBB standard procedures. Any variances from design quantities, which exceed NEBB tolerances, are noted throughout this report.

The air distribution systems and hydronic distribution systems have been tested and balanced and final adjustments have been made in accordance with NEBB "Procedural Standards for Testing-Adjusting-Balancing of Environmental Systems" and the project specifications.

Submitted and Certified by:

<u>David M. Halcomb</u>

NEBB Certified Test and Balance Supervisor

Engineered Systems & Energy Solutions, Inc.
NEBB Certification Number is: 3426

DAVID M. HALCOMB
CERTIFICATION
3426
Exp. 3/31/22

REMARKS

Job Name: Garrison Tower CX Assessment

AHU 2-G-1 ONE OF THE TWO RETURN FAN DUCTS HAS A FIRE/SMOKE DAMPER THAT IS SHUT, LIMITING THE AIR TO THE UNIT. THE SUPPLY FAN IS AT 100% AND BARELY KEEPING UP WITH THE VAV'S ON MINIMUM SETTINGS.

Non Standard Abbreviations Used for Reporting

CCW	- Counter Clockwise
CD	- Ceiling Diffuser
CW	- Clockwise
DD	- Direct Drive
EG	- Exhaust Grille
INA	- Inaccessible
LD	- Linear Diffuser
NA	- Not Applicable
NG	- Not Given
NL	- Not Listed
NM	- Not Measured
NS	- Not Specified
NTS	- No Test Site
NV	- Not Visible
OA	- Outside Air
OTA	- Open To Atmosphere
PD	- Pressure Drop
RG	- Return Grille
SD	- Supply Diffuser
SP	- Static Pressure
SWD	- Sidewall Diffuser
TA	- Throw Away

Table of Contents

Job Name: Garrison Tower CX Assessment

Instruments

Job Name: Garrison Tower CX Assessment

Category	Instrument	Mfr.	Mdl #	Serial #	Last Cal'd	Next Due
Air	Air Data Multimeter	Shortridge	ADM-860	M93293	7/29/2019	7/29/2020
Electrical	Amp, volt meter True RMS	UEI	DL389	180601421	9/10/2019	9/10/2020
Tachometer	Digital Tachometer	Extech	461920	150103258	9/10/2019	9/10/2020
Temperature	Module / Probe	Evergreen Telemetry	RM-T-1 / PR-T-2	2000159 / 1900233	3/9/2020	3/9/2021
Water	Water Meter	Shortridge	HDM 250	W14080	4/14/2020	4/14/2021

AIR APPARATUS TEST SHEET
AHU B-G-1

Job Name: Garrison Tower CX Assessment
Tested By: GLASS/JACQUEMIN **Date:** 6/18/2020

DESIGN DATA :

Manufacturer =	CARRIER	**Model No. =**	
Type =		**Serial No. =**	
Outside Air cfm =			
Total Scheduled cfm =	NG	**Grille Design Schedule cfm =**	
Fan rpm =			
Total Static Pressure =		**External Static Pressure =**	
Fan Rotation =			

MOTOR DESIGN DATA

Horsepower =	**Voltage =**	**Phase =**	**Rpm =**

AIR TEST DATA

Total cfm by Traverse Readings =	2,925	**Total cfm by Grille Readings =**	
Outside Air =		**Return Air =**	

TEMPERATURE TEST DATA

Outside Air Temperature =	NM	**Supply Air Temp Sensor =**	66.3
Mixed Air Temperature =	NM	**Supply Air Temp Measured =**	67.8

PRESSURE TEST DATA

Fan Suction Static Pressure =		-0.99	
Fan Discharge Static Pressure =		0.06	
	Total Static Pressure =		1.05
External Suction Static Pressure =		-0.13	
External Discharge Static Pressure =		0.06	
	External Static Pressure =		0.19
Cooling Coil ΔS.P. =	*.86	**Heating Coil ΔS.P. =**	*.86
Pre Filters ΔS.P. =	*.86	**Final Filters ΔS.P. =**	NA

MOTOR TEST DATA

Motor Manufacturer / Frame =					
HP =	**Volts/Ph/Hertz =**	**Act. Voltage =**			
Full Load Amps =		**Act. Amps =**			
Service Factor =					
Motor Design rpm =		**Act motor rpm =**			

FAN TEST DATA

Motor Sheave Diameter =		**Motor Sheave Bore =**	
Fan Sheave Diameter =		**Fan Sheave Bore =**	
Adjustable Sheave Dia. =		**Centerline Distance =**	
Fan rpm =		**Fan Rotation =**	
Frequency Hz=	60		
Belts =			
Pre Filters =			
Final Filters =			

Comments: * MEASURED ACROSS BOTH COILS AND FILTERS.

AIR APPARATUS TEST SHEET
AHU B-G-2

Job Name: Garrison Tower CX Assessment
Tested By: GLASS/JACQUEMIN **Date:** 6/18/2020

DESIGN DATA :

Manufacturer =	CARRIER	**Model No. =**	
Type =		**Serial No. =**	
Outside Air cfm =			
Total Scheduled cfm =	NG	**Grille Design Schedule cfm =**	
Fan rpm =			
Total Static Pressure =		**External Static Pressure =**	
Fan Rotation =			

MOTOR DESIGN DATA

Horsepower =	**Voltage =**	**Phase =**	**Rpm =**

AIR TEST DATA

Total cfm by Traverse Readings =	*	**Total cfm by Grille Readings =**	
Outside Air =		**Return Air =**	

TEMPERATURE TEST DATA

Outside Air Temperature =	NM	**Supply Air Temp Sensor =**	57.0
Mixed Air Temperature =	NM	**Supply Air Temp Measured =**	57.1

PRESSURE TEST DATA

Fan Suction Static Pressure =		-2.09	
Fan Discharge Static Pressure =		0.20	
	Total Static Pressure =		2.29
External Suction Static Pressure =		-0.03	
External Discharge Static Pressure =		0.20	
	External Static Pressure =		0.23
Cooling Coil ΔS.P. =	*2.06	**Heating Coil ΔS.P. =**	*2.06
Pre Filters ΔS.P. =	*2.06	**Final Filters ΔS.P. =**	NA

MOTOR TEST DATA

Motor Manufacturer / Frame =					
HP =	**Volts/Ph/Hertz =**	**Act. Voltage =**			
Full Load Amps =		**Act. Amps =**			
Service Factor =					
Motor Design rpm =		**Act motor rpm =**			

FAN TEST DATA

Motor Sheave Diameter =		**Motor Sheave Bore =**	
Fan Sheave Diameter =		**Fan Sheave Bore =**	
Adjustable Sheave Dia. =		**Centerline Distance =**	
Fan rpm =		**Fan Rotation =**	
Frequency Hz=	60		
Belts =			
Pre Filters =			
Final Filters =			

Comments: *NO ACCURATE PLACE TO TAKE TRAVERESE READINGS ON THE SUPPLY OR RETURN SIDE. MORE INFO WOULD BE REQUIRED TO MEASURE INDIVIDUAL CEILING DIFFUSERS. PRESSURE DROPS TAKEN ACROSS COILS AND FILTERS TOGETHER.

AIR APPARATUS TEST SHEET
AHU 1-G-1

Job Name: Garrison Tower CX Assessment
Tested By: GLASS/JACQUEMIN **Date:** 6/18/2020

DESIGN DATA :

Manufacturer =	TEMTROL	**Model No. =**	
Type =		**Serial No. =**	
Outside Air cfm =			
Total Scheduled cfm =	NG	**Grille Design Schedule cfm =**	
Fan rpm =			
Total Static Pressure =		**External Static Pressure =**	
Fan Rotation =			

MOTOR DESIGN DATA

Horsepower =	**Voltage =**	**Phase =**	**Rpm =**

AIR TEST DATA

Total cfm by Traverse Readings =	17,814	**Total cfm by Grille Readings =**	
Outside Air =		**Return Air =**	

TEMPERATURE TEST DATA

Outside Air Temperature =	NM	**Supply Air Temp Sensor =**	63.5
Mixed Air Temperature =	NM	**Supply Air Temp Measured =**	62.8

PRESSURE TEST DATA

Fan Suction Static Pressure =		-3.12	
Fan Discharge Static Pressure =		1.22	
	Total Static Pressure =		4.34
External Suction Static Pressure =		-1.00	
External Discharge Static Pressure =		1.16	
	External Static Pressure =		2.16
Cooling Coil ΔS.P. =	*2.12	**Heating Coil ΔS.P. =**	*2.12
Pre Filters ΔS.P. =	*2.12	**Final Filters ΔS.P. =**	NA

MOTOR TEST DATA

Motor Manufacturer / Frame =					
HP =	**Volts/Ph/Hertz =**	**Act. Voltage =**			
Full Load Amps =		**Act. Amps =**			
Service Factor =					
Motor Design rpm =		**Act motor rpm =**			

FAN TEST DATA

Motor Sheave Diameter =		**Motor Sheave Bore =**	
Fan Sheave Diameter =		**Fan Sheave Bore =**	
Adjustable Sheave Dia. =		**Centerline Distance =**	
Fan rpm =		**Fan Rotation =**	
Frequency Hz=	60		
Belts =			
Pre Filters =			
Final Filters =			

Comments: UNABLE TO GET INDIVIDUAL PD'S. MEASURED PRESSURE DROP IS ACROSS THE COILS AND FILTER TOGETHER. FILTERS WERE DIRTY AT TIME OF TESTING.

AIR APPARATUS TEST SHEET
AHU 2-G-1

Job Name: Garrison Tower CX Assessment
Tested By: GLASS/JACQUEMIN **Date:** 6/18/2020

DESIGN DATA :

Manufacturer =	CARRIER	**Model No. =**	
Type =		**Serial No. =**	
Outside Air cfm =			
Total Scheduled cfm =	NG	**Grille Design Schedule cfm =**	
Fan rpm =			
Total Static Pressure =		**External Static Pressure =**	
Fan Rotation =			

MOTOR DESIGN DATA

Horsepower =	**Voltage =**	**Phase =**	**Rpm =**

AIR TEST DATA

Total cfm by Traverse Readings =	*	**Total cfm by Grille Readings =**	
Outside Air =		**Return Air =**	

TEMPERATURE TEST DATA

Outside Air Temperature =	NM	**Supply Air Temp Sensor =**	59.3
Mixed Air Temperature =	NM	**Supply Air Temp Measured =**	58.6

PRESSURE TEST DATA

Fan Suction Static Pressure =			-2.90	
Fan Discharge Static Pressure =			2.48	
		Total Static Pressure =		5.38
External Suction Static Pressure =			-0.83	
External Discharge Static Pressure =			2.47	
		External Static Pressure =		3.30
Cooling Coil ΔS.P. =	0.33	**Heating Coil ΔS.P. =**		NA
Pre Filters ΔS.P. =	0.43	**Final Filters ΔS.P. =**		0.01

MOTOR TEST DATA

Motor Manufacturer / Frame =					
HP =	**Volts/Ph/Hertz =**	**Act. Voltage =**			
Full Load Amps =		**Act. Amps =**			
Service Factor =					
Motor Design rpm =		**Act motor rpm =**			

FAN TEST DATA

Motor Sheave Diameter =		**Motor Sheave Bore =**	
Fan Sheave Diameter =		**Fan Sheave Bore =**	
Adjustable Sheave Dia. =		**Centerline Distance =**	
Fan rpm =		**Fan Rotation =**	
Frequency Hz=	60		
Belts =			
Pre Filters =			
Final Filters =			

Comments: ONE OF THE RETURN FANS HAS A SMOKE DAMPER THAT IS 100% SHUT. REDUCING THE RETURN AIRFLOW TO THE UNIT.

*UNABLE TO TRAVERSE SUPPLY OR RETURN AIR DUE TO TIGHT MECHANICAL CONDITIONS. WILL NEED MORE INFO TO BE ABLE TO ACCESS DIFFERENT DUCT RUNS.

AIR APPARATUS TEST SHEET
AHU 3-G-1

Job Name: Garrison Tower CX Assessment
Tested By: GLASS/JACQUEMIN **Date:** 6/18/2020

DESIGN DATA :

Manufacturer =	CARRIER	**Model No. =**	
Type =		**Serial No. =**	
Outside Air cfm =			
Total Scheduled cfm =	NG	**Grille Design Schedule cfm =**	
Fan rpm =			
Total Static Pressure =		**External Static Pressure =**	
Fan Rotation =			

MOTOR DESIGN DATA

Horsepower =	**Voltage =**	**Phase =**	**Rpm =**

AIR TEST DATA

Total cfm by Traverse Readings =	7,728	**Total cfm by Grille Readings =**	
Outside Air =		**Return Air =**	

TEMPERATURE TEST DATA

Outside Air Temperature =	NM	**Supply Air Temp Sensor =**	60.0
Mixed Air Temperature =	NM	**Supply Air Temp Measured =**	60.9

PRESSURE TEST DATA

Fan Suction Static Pressure =		-1.45	
Fan Discharge Static Pressure =		1.76	
	Total Static Pressure =		3.21
External Suction Static Pressure =		-0.47	
External Discharge Static Pressure =		1.69	
	External Static Pressure =		2.16
Cooling Coil ΔS.P. =	0.28	**Heating Coil ΔS.P. =**	0.52
Pre Filters ΔS.P. =	0.19	**Final Filters ΔS.P. =**	NA

MOTOR TEST DATA

Motor Manufacturer / Frame =					
HP =	**Volts/Ph/Hertz =**	**Act. Voltage =**			
Full Load Amps =		**Act. Amps =**			
Service Factor =					
Motor Design rpm =		**Act motor rpm =**			

FAN TEST DATA

Motor Sheave Diameter =		**Motor Sheave Bore =**	
Fan Sheave Diameter =		**Fan Sheave Bore =**	
Adjustable Sheave Dia. =		**Centerline Distance =**	
Fan rpm =		**Fan Rotation =**	
Frequency Hz=	49.9 (82%)		
Belts =			
Pre Filters =			
Final Filters =			

Comments:

AIR APPARATUS TEST SHEET
AHU 3-G-2

Job Name: Garrison Tower CX Assessment
Tested By: GLASS/JACQUEMIN **Date:** 6/18/2020

DESIGN DATA :

Manufacturer =	NG	**Model No. =**	
Type =		**Serial No. =**	
Outside Air cfm =			
Total Scheduled cfm =	NG	**Grille Design Schedule cfm =**	
Fan rpm =			
Total Static Pressure =		**External Static Pressure =**	
Fan Rotation =			

MOTOR DESIGN DATA

Horsepower =	**Voltage =**	**Phase =**	**Rpm =**

AIR TEST DATA

Total cfm by Traverse Readings =	4,057	**Total cfm by Grille Readings =**	
Outside Air =		**Return Air =**	

TEMPERATURE TEST DATA

Outside Air Temperature =	NM	**Supply Air Temp Sensor =**	71.6
Mixed Air Temperature =	NM	**Supply Air Temp Measured =**	71.4

PRESSURE TEST DATA

Fan Suction Static Pressure =		-1.21	
Fan Discharge Static Pressure =		0.47	
	Total Static Pressure =		1.67
External Suction Static Pressure =		-0.04	
External Discharge Static Pressure =		0.47	
	External Static Pressure =		0.51
Cooling Coil ΔS.P. =	*1.12	**Heating Coil ΔS.P. =**	*1.12
Pre Filters ΔS.P. =	-0.35	**Final Filters ΔS.P. =**	na

MOTOR TEST DATA

Motor Manufacturer / Frame =					
HP =	**Volts/Ph/Hertz =**	**Act. Voltage =**			
Full Load Amps =		**Act. Amps =**			
Service Factor =					
Motor Design rpm =		**Act motor rpm =**			

FAN TEST DATA

Motor Sheave Diameter =		**Motor Sheave Bore =**	
Fan Sheave Diameter =		**Fan Sheave Bore =**	
Adjustable Sheave Dia. =		**Centerline Distance =**	
Fan rpm =		**Fan Rotation =**	
Frequency Hz=	60		
Belts =			
Pre Filters =			
Final Filters =			

Comments: *PRESSURE DROP IS ACROSS BOTH COILS TOGETHER.

AIR APPARATUS TEST SHEET
AHU 3RAD

Job Name: Garrison Tower CX Assessment
Tested By: GLASS/JACQUEMIN **Date:** 6/18/2020

DESIGN DATA :

Manufacturer =	TEMTROL	**Model No. =**	
Type =		**Serial No. =**	
Outside Air cfm =			
Total Scheduled cfm =	NG	**Grille Design Schedule cfm =**	
Fan rpm =			
Total Static Pressure =		**External Static Pressure =**	
Fan Rotation =			

MOTOR DESIGN DATA

Horsepower =	**Voltage =**	**Phase =**	**Rpm =**

AIR TEST DATA

Total cfm by Traverse Readings =	8,844	**Total cfm by Grille Readings =**	
Outside Air =		**Return Air =**	

TEMPERATURE TEST DATA

Outside Air Temperature =	NM	**Supply Air Temp Sensor =**	59.3
Mixed Air Temperature =	NM	**Supply Air Temp Measured =**	59.1

PRESSURE TEST DATA

Fan Suction Static Pressure =		-1.24	
Fan Discharge Static Pressure =		1.42	
Total Static Pressure =			2.66
External Suction Static Pressure =		-0.37	
External Discharge Static Pressure =		1.56	
External Static Pressure =			1.93
Cooling Coil ΔS.P. =	*.391	**Heating Coil ΔS.P. =**	*.391
Pre Filters ΔS.P. =	*.391	**Final Filters ΔS.P. =**	NA

MOTOR TEST DATA

Motor Manufacturer / Frame =					
HP =	**Volts/Ph/Hertz =**	**Act. Voltage =**			
Full Load Amps =		**Act. Amps =**			
Service Factor =					
Motor Design rpm =		**Act motor rpm =**			

FAN TEST DATA

Motor Sheave Diameter =		**Motor Sheave Bore =**	
Fan Sheave Diameter =		**Fan Sheave Bore =**	
Adjustable Sheave Dia. =		**Centerline Distance =**	
Fan rpm =		**Fan Rotation =**	
Frequency Hz=	45		
Belts =			
Pre Filters =			
Final Filters =			

Comments: ALL VAV'S IN MAX COOL SATISFIED AT 45HZ.
*PRESSURE DROP IS ACROSS COILS AND FILTER TOGETHER. NO PLACE FOR INDIVIDUAL READINGS.

AIR APPARATUS TEST SHEET
AHU 5G1

Job Name: Garrison Tower CX Assessment
Tested By: GLASS/JACQUEMIN **Date:** 6/19/2020

DESIGN DATA :

Manufacturer =	CARRIER	**Model No. =**	
Type =		**Serial No. =**	
Outside Air cfm =			
Total Scheduled cfm =	NG	**Grille Design Schedule cfm =**	
Fan rpm =			
Total Static Pressure =		**External Static Pressure =**	
Fan Rotation =			

MOTOR DESIGN DATA

Horsepower =	**Voltage =**	**Phase =**	**Rpm =**

AIR TEST DATA

Total cfm by Traverse Readings =	*	**Total cfm by Grille Readings =**	
Outside Air =		**Return Air =**	

TEMPERATURE TEST DATA

Outside Air Temperature =	NM	**Supply Air Temp Sensor =**	*
Mixed Air Temperature =	NM	**Supply Air Temp Measured =**	*

PRESSURE TEST DATA

Fan Suction Static Pressure =	*	
Fan Discharge Static Pressure =	*	
Total Static Pressure =		*
External Suction Static Pressure =	*	
External Discharge Static Pressure =	*	
External Static Pressure =		*

Cooling Coil ΔS.P. =	*	**Heating Coil ΔS.P. =**	*
Pre Filters ΔS.P. =	*	**Final Filters ΔS.P. =**	*

MOTOR TEST DATA

Motor Manufacturer / Frame =					
HP =	**Volts/Ph/Hertz =**	**Act. Voltage =**			
Full Load Amps =		**Act. Amps =**			
Service Factor =					
Motor Design rpm =		**Act motor rpm =**			

FAN TEST DATA

Motor Sheave Diameter =	**Motor Sheave Bore =**
Fan Sheave Diameter =	**Fan Sheave Bore =**
Adjustable Sheave Dia. =	**Centerline Distance =**
Fan rpm =	**Fan Rotation =**
Frequency Hz= *	
Belts =	
Pre Filters =	
Final Filters =	

Comments: *THIS UNIT IS COMMANDED ON THROUGH THE BAS SYSTEM BUT IT ISN'T RUNNING.

AIR APPARATUS TEST SHEET
AHU 5G2

Job Name: Garrison Tower CX Assessment
Tested By: GLASS **Date:** 6/19/2020

DESIGN DATA :

Manufacturer =	CARRIER	**Model No. =**	
Type =		**Serial No. =**	
Outside Air cfm =			
Total Scheduled cfm =	NG	**Grille Design Schedule cfm =**	
Fan rpm =			
Total Static Pressure =		**External Static Pressure =**	
Fan Rotation =			

MOTOR DESIGN DATA

Horsepower =	**Voltage =**	**Phase =**	**Rpm =**

AIR TEST DATA

Total cfm by Traverse Readings =	2,561	**Total cfm by Grille Readings =**	
Outside Air =		**Return Air =**	

TEMPERATURE TEST DATA

Outside Air Temperature =	NM	**Supply Air Temp Sensor =**	55.2
Mixed Air Temperature =	NM	**Supply Air Temp Measured =**	54.8

PRESSURE TEST DATA

Fan Suction Static Pressure =		-0.70	
Fan Discharge Static Pressure =		0.13	
	Total Static Pressure =		0.83
External Suction Static Pressure =		-0.06	
External Discharge Static Pressure =		0.13	
	External Static Pressure =		0.19
Cooling Coil ΔS.P. =	*.4738	**Heating Coil ΔS.P. =**	*.4738
Pre Filters ΔS.P. =	0.18	**Final Filters ΔS.P. =**	NA

MOTOR TEST DATA

Motor Manufacturer / Frame =				
HP =	**Volts/Ph/Hertz =**	**Act. Voltage =**		
Full Load Amps =		**Act. Amps =**		
Service Factor =				
Motor Design rpm =		**Act motor rpm =**		

FAN TEST DATA

Motor Sheave Diameter =		**Motor Sheave Bore =**	
Fan Sheave Diameter =		**Fan Sheave Bore =**	
Adjustable Sheave Dia. =		**Centerline Distance =**	
Fan rpm =		**Fan Rotation =**	
Frequency Hz=	36.7		
Belts =			
Pre Filters =			
Final Filters =			

Comments: *PRESSURE DROP IS ACROSS BOTH COILS TOGETHER.

AIR APPARATUS TEST SHEET
AHU 5G3

Job Name: Garrison Tower CX Assessment
Tested By: GLASS/JACQUEMIN **Date:** 6/18/2020

DESIGN DATA :

Manufacturer =	CARRIER	**Model No. =**	
Type =		**Serial No. =**	
Outside Air cfm =			
Total Scheduled cfm =	NG	**Grille Design Schedule cfm =**	
Fan rpm =			
Total Static Pressure =		**External Static Pressure =**	
Fan Rotation =			

MOTOR DESIGN DATA

Horsepower =	**Voltage =**	**Phase =**	**Rpm =**

AIR TEST DATA

Total cfm by Traverse Readings =	7,235	**Total cfm by Grille Readings =**	
Outside Air =		**Return Air =**	

TEMPERATURE TEST DATA

Outside Air Temperature =	NM	**Supply Air Temp Sensor =**	59.8
Mixed Air Temperature =	NM	**Supply Air Temp Measured =**	60

PRESSURE TEST DATA

Fan Suction Static Pressure =	-1.85	
Fan Discharge Static Pressure =	1.33	
Total Static Pressure =		3.18
External Suction Static Pressure =	-1.12	
External Discharge Static Pressure =	1.33	
External Static Pressure =		2.45

Cooling Coil ΔS.P. =	0.60	**Heating Coil ΔS.P. =**	NA
Pre Filters ΔS.P. =	0.11	**Final Filters ΔS.P. =**	NA

MOTOR TEST DATA

Motor Manufacturer / Frame =				
HP =	**Volts/Ph/Hertz =**	**Act. Voltage =**		
Full Load Amps =		**Act. Amps =**		
Service Factor =				
Motor Design rpm =		**Act motor rpm =**		

FAN TEST DATA

Motor Sheave Diameter =		**Motor Sheave Bore =**	
Fan Sheave Diameter =		**Fan Sheave Bore =**	
Adjustable Sheave Dia. =		**Centerline Distance =**	
Fan rpm =		**Fan Rotation =**	
Frequency Hz=	57.1		
Belts =			
Pre Filters =			
Final Filters =			

Comments:

AIR APPARATUS TEST SHEET
AHU 6G1

Job Name: Garrison Tower CX Assessment
Tested By: GLASS/JACQUEMIN **Date:** 6/23/2020

DESIGN DATA :

Manufacturer =	TRANE	**Model No. =**	
Type =		**Serial No. =**	
Outside Air cfm =			
Total Scheduled cfm =	NG	**Grille Design Schedule cfm =**	
Fan rpm =			
Total Static Pressure =		**External Static Pressure =**	
Fan Rotation =			

MOTOR DESIGN DATA

Horsepower =	**Voltage =**	**Phase =**	**Rpm =**

AIR TEST DATA

Total cfm by Traverse Readings =	17,079	**Total cfm by Grille Readings =**	
Outside Air =		**Return Air =**	

TEMPERATURE TEST DATA

Outside Air Temperature =	NM	**Supply Air Temp Sensor =**	58.6
Mixed Air Temperature =	NM	**Supply Air Temp Measured =**	58.4

PRESSURE TEST DATA

Fan Suction Static Pressure =		-3.08	
Fan Discharge Static Pressure =		1.43	
	Total Static Pressure =		4.51
External Suction Static Pressure =		-1.30	
External Discharge Static Pressure =		1.43	
	External Static Pressure =		2.73
Cooling Coil ΔS.P. = 1.39*		**Heating Coil ΔS.P. =**	1.39*
Pre Filters ΔS.P. = 0.29		**Final Filters ΔS.P. =**	0.01**

MOTOR TEST DATA

Motor Manufacturer / Frame =					
HP =	**Volts/Ph/Hertz =**	**Act. Voltage =**			
Full Load Amps =		**Act. Amps =**			
Service Factor =					
Motor Design rpm =		**Act motor rpm =**			

FAN TEST DATA

Motor Sheave Diameter =		**Motor Sheave Bore =**	
Fan Sheave Diameter =		**Fan Sheave Bore =**	
Adjustable Sheave Dia. =		**Centerline Distance =**	
Fan rpm =		**Fan Rotation =**	
Frequency Hz=	60		
Belts =			
Pre Filters =			
Final Filters =			

Comments: *PRESSURE DROP ACROSS BOTH HEATING AND COOLING COILS TOGETHER.
**UNABLE TO VERIFY IF FILTERS ARE INSTALLED.

AIR APPARATUS TEST SHEET
AHU 7G1

Job Name: Garrison Tower CX Assessment
Tested By: GLASS/JACQUEMIN **Date:** 6/18/2020

DESIGN DATA :

Manufacturer =	TRANE	**Model No. =**	
Type =	BLOW THRU	**Serial No. =**	
Outside Air cfm =			
Total Scheduled cfm =	NG	**Grille Design Schedule cfm =**	
Fan rpm =			
Total Static Pressure =		**External Static Pressure =**	
Fan Rotation =			

MOTOR DESIGN DATA

Horsepower =	**Voltage =**	**Phase =**	**Rpm =**

AIR TEST DATA

Total cfm by Traverse Readings =	5,300	**Total cfm by Grille Readings =**	
Outside Air =		**Return Air =**	

TEMPERATURE TEST DATA

Outside Air Temperature =	NM	**Supply Air Temp Sensor =**	74.8
Mixed Air Temperature =	NM	**Supply Air Temp Measured =**	75.6

PRESSURE TEST DATA

Fan Suction Static Pressure =		-1.13	
Fan Discharge Static Pressure =		1.18	
	Total Static Pressure =		2.31
External Suction Static Pressure =		-0.83	
External Discharge Static Pressure =		0.56	
	External Static Pressure =		1.39
Cooling Coil ΔS.P. =	0.24	**Heating Coil ΔS.P. =**	0.31
Pre Filters ΔS.P. =	0.30	**Final Filters ΔS.P. =**	NA

MOTOR TEST DATA

Motor Manufacturer / Frame =					
HP =	**Volts/Ph/Hertz =**	**Act. Voltage =**			
Full Load Amps =		**Act. Amps =**			
Service Factor =					
Motor Design rpm =		**Act motor rpm =**			

FAN TEST DATA

Motor Sheave Diameter =		**Motor Sheave Bore =**	
Fan Sheave Diameter =		**Fan Sheave Bore =**	
Adjustable Sheave Dia. =		**Centerline Distance =**	
Fan rpm =		**Fan Rotation =**	
Frequency Hz=	60		
Belts =			
Pre Filters =			
Final Filters =			

Comments:

AIR APPARATUS TEST SHEET
AHU 7G2

Job Name: Garrison Tower CX Assessment
Tested By: GLASS/JACQUEMIN **Date:** 6/18/2020

DESIGN DATA :

Manufacturer =	MCQUAY	**Model No. =**	
Type =		**Serial No. =**	
Outside Air cfm =			
Total Scheduled cfm =	NG	**Grille Design Schedule cfm =**	
Fan rpm =			
Total Static Pressure =		**External Static Pressure =**	
Fan Rotation =			

MOTOR DESIGN DATA

Horsepower =	**Voltage =**	**Phase =**	**Rpm =**

AIR TEST DATA

Total cfm by Traverse Readings =	2,864	**Total cfm by Grille Readings =**	
Outside Air =		**Return Air =**	

TEMPERATURE TEST DATA

Outside Air Temperature =	NM	**Supply Air Temp Sensor =**	56.1
Mixed Air Temperature =	NM	**Supply Air Temp Measured =**	55.5

PRESSURE TEST DATA

Fan Suction Static Pressure =		-0.47	
Fan Discharge Static Pressure =		0.22	
	Total Static Pressure =		0.69
External Suction Static Pressure =		-0.15	
External Discharge Static Pressure =		0.22	
	External Static Pressure =		0.37
Cooling Coil ΔS.P. =	0.16	**Heating Coil ΔS.P. =**	0.07
Pre Filters ΔS.P. =	0.09	**Final Filters ΔS.P. =**	NA

MOTOR TEST DATA

Motor Manufacturer / Frame =					
HP =	**Volts/Ph/Hertz =**	**Act. Voltage =**			
Full Load Amps =		**Act. Amps =**			
Service Factor =					
Motor Design rpm =		**Act motor rpm =**			

FAN TEST DATA

Motor Sheave Diameter =		**Motor Sheave Bore =**	
Fan Sheave Diameter =		**Fan Sheave Bore =**	
Adjustable Sheave Dia. =		**Centerline Distance =**	
Fan rpm =		**Fan Rotation =**	
Frequency Hz=	60		
Belts =			
Pre Filters =			
Final Filters =			

Comments: UPON INSPECTION OF THE MOTOR, THE BELT APPEARS TO BE FAIRLY LOOSE WHICH COULD AFFECT THE PERFROMANCE OF THE FAN.

DUCT TRAVERSE SUMMARY

Job Name: Garrison Tower CX Assessment
Tested By: GLASS/JACQUEMIN **Date:** 6/18/2020

SERVICE OR DESIGNATION	DUCT			DESIGN	PRELIM	ACTUAL	FINAL	FINAL %	FINAL
	TYPE	SIZE	AREA S.F.	CFM	CFM	Avg Velocity	CFM	of Design	S.P.
AHU B-G-1	SA	52X14	5.06	NG	2,925	578	2,925	NA	0.06
AHU B-G-2	*	*	*	*	*	*	*	*	*
AHU 1-G-1	SA	103X52	37.19	NG	17,814	479	17,814	NA	NA
AHU 2-G-1	SA	*	*	*	*	*	*	*	*
AHU 3-G-1	RA	36X23	5.75	NG	7,728	1344	7,728	NA	0.4734
AHU 3-G-2	SA	68X15	7.08	NG	4,057	573	4,057	NA	0.484
AHU 3RAD	SA	48X24	8	NG	6,912	864	6,912	NA	1.17
AHU 3RAD	SA	24X10	1.67	NG	1,932	1157	1,932	NA	1.18
AHU 5G1	SA	27X20.5	3.84	NG	**	**	**	**	**
AHU 5G2	SA	22X12	1.83	NG	430	235	430	NA	0.1308
AHU 5G2	SA	31X12	2.58	NG	1,401	543	1,401	NA	0.2075
AHU 5G2	SA	22X12	1.83	NG	730	399	730	NA	0.0865
AHU 5G3	SA	93X20	12.92	NG	7,235	560	7,235	NA	1.31
AHU 6G1	SA	30.5X18.5 Φ	3.25	NG	4,436	1365	4,436	NA	1.09
AHU 6G1	SA	55x20 Φ	6.49	NG	12,643	1948	12,643	NA	1.07
AHU 7G1	RA	45.25X19.5	6.12	NG	5,300	866	5,300	NA	0.88
AHU 7G2	SA	28X12	2.33	NG	2,864	1229	2,864	NA	0.23

*NO ACCURATE PLACE TO TRAVERSE ON SUPPLY OR RETURN SIDE.

**UNIT NOT RUNNING.

AHU 6G1 HAS TWO OVAL DUCTS ON THE SUPPLY SIDE. THE SIZES ARE DIFFERENT AND THE FREE AREA'S WERE DIFFICULT TO FIGURE OUT AS THEY BOTH ARE DOUBLE WALL DUCTS AS WELL, AND SEEM TO HAVE DIFFERENT SIZE INSULATION LINING BUT I BELIEVE IT TO BE ACURRATE. I ALSO ADDED UP THE OUTPUT OF THE VAV'S ON THE BAS READINGS AND IT'S VERY CLOSE TO MY TRAVERSE READINGS.

PUMP TEST SHEET

Job Name: Garrison Tower CX Assessment
Tested By: JACQUEMIN **Date:** 6/2/2020

PUMP DATA

Pump Number	**HWP-1**	**CHWP-4**	
Manufacturer			
Model Number			
Serial Number			
Impeller Size			
Rpm			
Specified gpm			
Specified Head			

MOTOR DATA

	Design	Test	Design	Test	Design	Test
Motor Name						
Horsepower						
Motor rpm						
Phase						
Voltage						
Service Factor						
Amperage						

TEST RESULTS – CLOSE OFF

Suction Pressure (PSI)			
Discharge Pressure (PSI)			
Differential Pressure (PSI)			
Head (Feet)			

TEST RESULTS - RUNNING

Suction Pressure (PSI)	68.8	65.7	
Discharge Pressure (PSI)	88.4	91.9	
Differential Pressure (PSI)	19.6	26.2	
Head (Feet)	45.5 (203.8-158.3)	60.2 (211.9-151.7)	
Final gpm			

Comments: **HWP-2** / 44.8Hz @ 11.5A (VFD) //// **CHWP-4** / 41.1Hz @ 33A (VFD)

TERMINAL UNIT COIL TEST SHEET

Job Name: Garrison Tower CX Assessment **Date:** 6/2/2020

Tested By: JACQUEMIN

AHU #	CHW/HW	Design gpm	Alternate No. 1			Alternate No. 2			Alternate No. 3			ΔP	ΔT
			Design Δ P	Ent. Wtr. Press.	Lvg. Wtr. Press.	Design ΔT	EWT	LWT	Design ΔT	EAT	LAT		
B-G-1	CHW			88.7	74.6		40.5	47.2				14.1 PSI	6.7
B-G-1	HW			90.7	76		159.6	156.3				14.7 PSI	3.4
B-G-2	CHW			88	74.2		40.4	55.3				13.8 PSI	14.9
B-G-2	HW			86.5	77.7		155.3	147.4				8.8 PSI	7.9
1-G-1	CHW			78.1	71.8		52.9	55.5				6.3 PSI	2.6
2-G-1	CHW			75.7	72.2		51	59.2				3.5 PSI	8.2
3-G-1	CHW			71.7	68.9		49.5	58.8				2.8 PSI	9.3
3-G-1	HW			74.5	71.8		159.7	152.1				2.7 PSI	7.6
3-G-2	CHW			71.4	61.1		46.2	53.6				10.3 PSI	7.4
3-G-2	HW			77.5	77		160.2	142.6				.5 PSI	17.6
3-RAD	CHW			67	65.2		45.7	56.8				1.8 PSI	11.1
3-RAD	HW			66.9	66		163.8	149.2				.9 PSI	14.6
5-G-1	CHW			60.7	55.8		49.3	49.9				4.9 PSI	0.6
5-G-1	HW			51.5	48.5		161.5	160.6				3 PSI	0.9
5-G-2	CHW			62.5	56.6		50.3	55.9				5.9 PSI	5.6
5-G-2	HW			47.1	44.7		161.6	148.2				2.4 PSI	13.4
5-G-3	CHW			63.1	53.5		51	54				9.6 PSI	3
6-G-1	CHW			56.1	43.4		48.3	57.8				12.7 PSI	9.5
6-G-1	HW			INA	INA		159.1	151				INA	8.1
7-G-1	CHW			47	46.2		50.6	58.1				.8 PSI	7.5
7-G-1	HW			48.1	43.7		158	155.5				4.4 PSI	2.5
7-G-2	CHW			47.2	45		47.8	60.8				2.2 PSI	13
7-G-2	HW			36.9	36.3		157.1	133				.6 PSI	24.1

WATER SUPPLY TEMP. ________________ **OUTSIDE AIR TEMP.** ________________

Comments:

MECHANICAL CONSULTING SERVICES

Retro-Commissioning Report

Garrison Building

940 NE 13th Street

Oklahoma City, Oklahoma

April 12, 2021

Project No. FA20P031

Prepared For:

University Hospitals Authority and Trust (UHAT)
940 NE 13th Street
Oklahoma City, Oklahoma 73104

Prepared by:

Terracon Consultants, Inc.
4701 N. Stiles Avenue
Oklahoma City, Oklahoma 73105

April 12, 2021

Mr. Nathan Miller
Building Systems Manager
University Hospitals Authority & Trust
940 NE 13th Street
Oklahoma City, Oklahoma 73104
P: 405-271-4962 x44199
E: Nathan-Miller@uhat.org

Reference: **UHAT**
Retro-Commissioning
Garrison Building
940 NE 13th Street
Oklahoma City, Oklahoma 73104
Project No. FA20P031

Mr. Miller:

Terracon Consultants, Inc. (Terracon) is pleased to submit this Mechanical Consulting Services Report of our Building Infrastructure Testing for the Garrison Building at 940 NE 13th Street in Oklahoma City, Oklahoma. This work was performed in general accordance with the scope of services outlined in the Terracon Company Proposal for Building Infrastructure Testing & Retro-Commissioning Services dated December 19, 2019 and authorized in February 2020 as identified in the scope section of this Report.

The purpose of this Report is to render our findings, field notes, and recommendations related to the Energy Conservation Opportunities (ECO's) from the Building Infrastructure Testing report that have been prioritized by UHAT.

This document includes background information, observations, findings, and recommendations pertaining to the operations of the heating, ventilation, and air conditioning (HVAC) at the site.

Terracon appreciates the opportunity to be of service to you on this project. If you have any questions regarding this report, please do not hesitate to contact us.

Sincerely,

Terracon Consultants, Inc.

Erik Gonzalez, P.E. (TX), CEM
Senior Engineer
Facilities Services

Jeffrey A. Miller, P.E. (OK)
Senior Principal/Senior Engineer
Facilities Services

TABLE OF CONTENTS

PROJECT OBJECTIVE

The purpose of the Retro-Commissioning services is to provide an ASHRAE Level 2 Energy Analysis and Audit to assist building owners with operational and financial decisions. The ASHRAE Level 2 Energy Analysis and Audit identifies no-cost and low-cost opportunities, and also provides Energy Conservation Opportunity (ECO) recommendations in line with the financial plans and potential capital-intensive energy savings opportunities of building owners. Activities include in-depth analysis of energy costs, energy usage and building characteristics and a more refined survey of how energy is consumed in a building.

The operational and financial analysis in this Retro-Commissioning Report is based on the information obtained during the Building Infrastructure Testing. A retro-commissioning plan was developed from recommended energy conservation opportunities (ECOs) that will help improve system performance and reduce the operating costs of the building without compromising comfort for the building occupants. UHAT prioritized the ECOs by importance as Priority 1 (highest priority), Priority 2 (moderate priority), or Priority 3 (lowest priority).

Terracon's representatives, Mr. Saeed Foroughi, Mr. John Harmon, E.I.T., Mr. Kim Morris QCxP, Mr. Erik Gonzalez, P.E. (TX), CEM, and Engineering Systems & Energy Solutions (ES2) conducted site visits on May 13 - 14, 2020, May 25 - May 27, 2020, June 2, 2020, June 18 - 19, 2020, June 23, 2020, and March 12, 2021 at the Garrison Building in order to obtain visual and diagnostic information and measurements for the HVAC systems. During the site visits, visual observations were made for general operating conditions of the HVAC systems. In addition, diagnostic measurements were taken for the air distribution of the 11 AHUs and two outside air units, associated chilled water and hot water coils, chilled water distribution pumps, and hot water distribution pumps. Measurements recorded were compared to the design documents and EMCS sensor measurements for air flow and water flow characteristics using the software workstation. Observations were made from readily accessible areas and did not include substantial dismantling of components of the building and HVAC equipment, including walls and closed ceilings. Trend data from the energy management control system (EMCS) was reviewed and used as the basis of the analysis for operational costs and savings associated with the ECOs. Materials, labor, and equipment costs associated with ECOs from UHAT's asset management program, *Paragon,* were used to provide the financial analysis of the ECOs.

DOCUMENTS AND INFORMATION REVIEWED

Terracon was provided with design documentation for the subject building, utility data for chilled water, steam, and electricity, tariff sheets that breakdown the cost of each utility service, and network access to the *AutomatedLogic Corporation* (*ALC*) *WebCTRL v7.0* energy management control system. The following items were reviewed while performing this assessment:

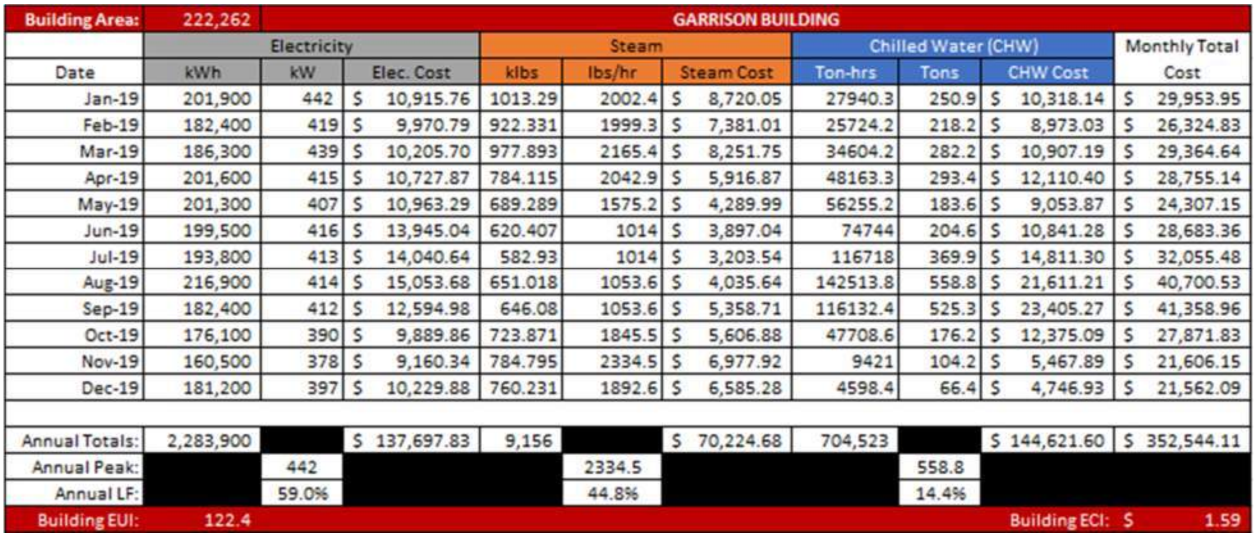
Document	Source
GARRISON EXTG DRAWINGS MEP — HUDGINS, THOMPSON, BALL AND ASSOCIATES, dated September 16, 1974	Client Provided
Utility Bill Data for Terracon.xlsx – e-mailed to Terracon on February 28, 2020	Client Provided
Utility Service Tariff Sheets for OUHSC and OGE services provided to UHAT – e-mailed to Terracon on March 3, 2020	Client Provided
Garrison Building Infrastructure Testing Report – Terracon provided to UHAT on August 21, 2020	Terracon Provided
GAR RCx Improvement List.xlsx – e-mailed to Terracon on October 20, 2020	Client Provided
AutomatedLogic Corporation (*ALC*) *WebCTRL v7.0* energy management control system trend data for Level 1 ECOs – e-mailed to Terracon on March 25, 2021	Client Provided

BUILDING ENERGY USE BASELINE

The 2019 calendar year was established as the energy use baseline for the subject property. The building is a seven-story medical office building that totals approximately 222,262-square feet. The building was originally designed as an inpatient healthcare facility and was repurposed for administrative healthcare use in 2006. The building was originally constructed around 1974. The HVAC systems were designed to operate with distributed chilled water and distributed steam from a Central Plant associated with the University of Oklahoma Health Sciences Center (OUHSC) at a remote location in downtown Oklahoma City.

It was previously established in the Building Infrastructure Testing Report that electricity is metered at a single location for both the Garrison Building and an adjacent building (Oklahoma Transplant Center) and that the ratio of building area to combined building area would be used to split the electricity use between the two buildings.

Table 1 – 2019 Energy Use Baseline



Building Area:	222,262	GARRISON BUILDING								
	Electricity			Steam			Chilled Water (CHW)			Monthly Total
Date	kWh	kW	Elec. Cost	klbs	lbs/hr	Steam Cost	Ton-hrs	Tons	CHW Cost	Cost
Jan-19	201,900	442	$ 10,915.76	1013.29	2002.4	$ 8,720.05	27940.3	250.9	$ 10,318.14	$ 29,953.95
Feb-19	182,400	419	$ 9,970.79	922.331	1999.3	$ 7,381.01	25724.2	218.2	$ 8,973.03	$ 26,324.83
Mar-19	186,300	439	$ 10,205.70	977.893	2165.4	$ 8,251.75	34604.2	282.2	$ 10,907.19	$ 29,364.64
Apr-19	201,600	415	$ 10,727.87	784.115	2042.9	$ 5,916.87	48163.3	293.4	$ 12,110.40	$ 28,755.14
May-19	201,300	407	$ 10,963.29	689.289	1575.2	$ 4,289.99	56255.2	183.6	$ 9,053.87	$ 24,307.15
Jun-19	199,500	416	$ 13,945.04	620.407	1014	$ 3,897.04	74744	204.6	$ 10,841.28	$ 28,683.36
Jul-19	193,800	413	$ 14,040.64	582.93	1014	$ 3,203.54	116718	369.9	$ 14,811.30	$ 32,055.48
Aug-19	216,900	414	$ 15,053.68	651.018	1053.6	$ 4,035.64	142513.8	558.8	$ 21,611.21	$ 40,700.53
Sep-19	182,400	412	$ 12,594.98	646.08	1053.6	$ 5,358.71	116132.4	525.3	$ 23,405.27	$ 41,358.96
Oct-19	176,100	390	$ 9,889.86	723.871	1845.5	$ 5,606.88	47708.6	176.2	$ 12,375.09	$ 27,871.83
Nov-19	160,500	378	$ 9,160.34	784.795	2334.5	$ 6,977.92	9421	104.2	$ 5,467.89	$ 21,606.15
Dec-19	181,200	397	$ 10,229.88	760.231	1892.6	$ 6,585.28	4598.4	66.4	$ 4,746.93	$ 21,562.09
Annual Totals:	2,283,900		$ 137,697.83	9,156		$ 70,224.68	704,523		$ 144,621.60	$ 352,544.11
Annual Peak:		442			2334.5			558.8		
Annual LF:		59.0%			44.8%			14.4%		
Building EUI:	122.4								Building ECI: $	1.59

Chart 1 – 2019 Energy Ratio

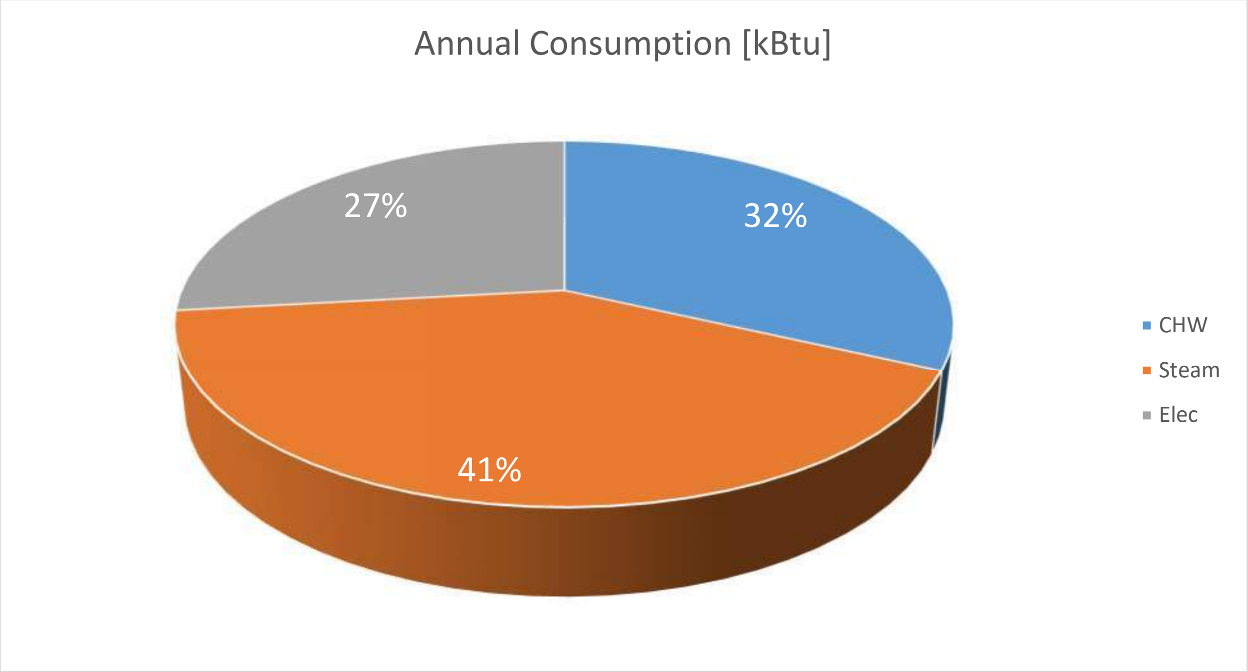
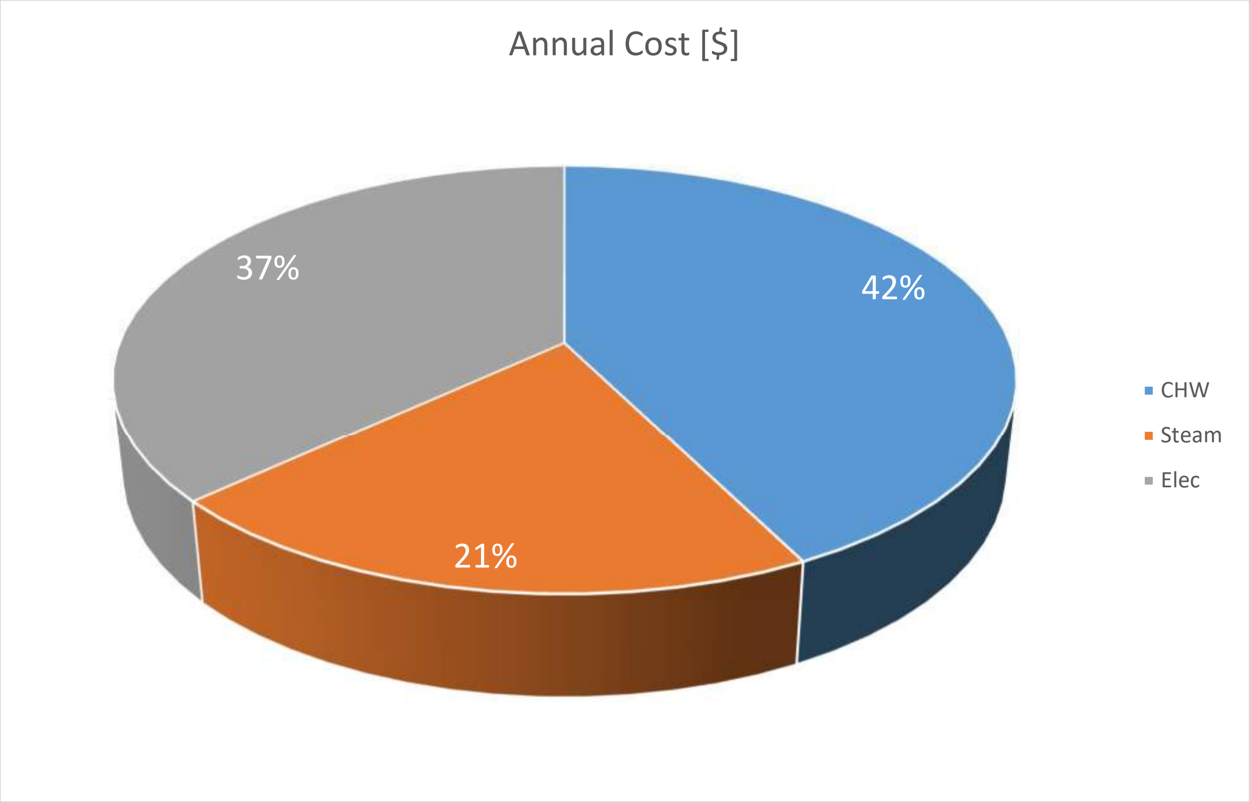


Chart 2 – 2019 Energy Cost Ratio



PRIORITY 1 - ENERGY CONSERVATION OPPORTUNITIES (ECOs) AND ANALYSIS

Priority 1 ECOs are measures that are considered of the highest priority to UHAT at the time of this report. These are measures that UHAT may consider implementing immediately or within one to two years as capital budget becomes available to justify implementation.

Priority 1 ECOs are listed in order from greatest return on investment (ROI) to lowest return on investment based on simple payback period (number of years required to breakeven on your investment) and internal rate of return (IRR). The greatest ECO ROIs are generally associated with large centralized systems that distribute heating and cooling to smaller, dependent systems and the EMCS that affects operation and performance of the larger systems. The Building Infrastructure Testing that Terracon performed was focused on the larger centralized systems to provide UHAT with the largest impact on operational savings.

Terracon's energy consumption and energy savings analysis are based on information and performance measurements gathered during site visits, design and construction documents provided by UHAT, as well as any trend data from the EMCS to determine run hours for equipment. Assumptions were made when information was not available based on *American Society of Heating, Refrigeration, and Air-Conditioning Engineers* (*ASHRAE*) guidelines and general heating, ventilation, and air conditioning (HVAC) practices and performance standards. General guidelines and performance standards include, but are not limited to, discharge air temperatures for cooling that ranged between 48 degF and 58 degF; discharge air temperatures for heating that ranged between 75 degF and 105 degF; cooling coil entering and leaving water temperature differences that ranged between 8 degF and 15 degF; heating coil entering and leaving water temperature differences that ranged between 5 degF and 30 degF; external static pressure differences that ranged between 1.0” w.g. and and entering and leaving static air pressure differences across cooling and heating coils that ranged between 0.1” w.g. and 0.5” w.g.

Table 2: Priority 1 - Retro-Commissioning Improvement List Summary

Measure #	**Description of Finding**	**Recommended Improvement**	**Baseline Energy Consumption**	**Post Retrofit Energy Consumption**	**Energy Savings**	**Energy Cost Savings**	**Estimated Implem. Cost**	**ROI [yrs]**
M5.1	Fire/smoke damper for relief/return fan is shut and preventing AHU from operating optimally.	AHU 2G1 Repair safety fault causing fire/smoke damper to be shut and operate relief/return fans to prevent a similar occurrence in the future. It may be necessary to relocate the manual reset switch for the fire/smoke damper if it is not easily accessible.	93,232 kWh	81,578 kWh	11,654 kWh	$703	$1,000	1.4
M12.2	Fan belt is loose and preventing proper distribution of air to zones.	AHU 7G1 Repair (tighten or replace) fan belt to improve operation of AHU.	16,758 kWh	15,082 kWh	1,676 kWh	$101	$500	5.0
M2.2	AHU air filters are "dirty" and in need of replacement.	AHU BG1 Replace air filters according to scheduled preventative maintenance plan.	16,758 kWh	16,423 kWh	335 kWh	$20	$120	6.0
M14.1	Outside air damper array/louvers associated with the system do not modulate and excessive amounts of outside can infiltrate the building.	ERU Replace or repair outside air damper array/louvers to close when building is not occupied and open if occupied. ERU is not in use and may also be removed.	16,513.6 Ton-hrs 150.4 klbs	14,234 Ton-hrs 103.1 klbs	2,279.5 Ton-hrs 47.3 klbs	$479 $362	$5,800	6.9
M13.1	Outside air unit operates at constant volume during building operating hours.	AHU 7G2 Install new *ABB* VFD on supply air fan and static air pressure sensor in supply air duct. Integrate new VFD and sensor with existing *ALC* controller, if control points are available on controller board. If control points are not available, upgrade controller to allow for additional points.	4,800 kWh	3,200 kWh	1,600 kWh	$96	$13,596	142
M1.2	Chilled water pump #3 is not operational.	Central Plant Replace or repair existing with new pump. Update: On 08/18/2020 Terracon was informed that the pump was in the process of being repaired.	-	-	-	-	$29,412	N/A
		Totals:	**131,548 kWh** **150.4 klbs** **16,513.6 Ton-hrs**	**116,283 kWh** **103.1 klbs** **14,234 Ton-hrs**	**15,265 kWh** **47.3 klbs** **2,279.5 Ton-hrs**	**$920** **$362** **$479**	**$50,428**	**28.6**

PRIORITY 2 – ENERGY CONSERVATION OPPORTUNITIES (ECOs) AND ANALYSIS

Priority 2 ECOs are measures that are considered of moderate priority to UHAT at the time of this report. These are measures that UHAT may consider implementing within three to five years when they are a higher priority because of excessive maintenance costs, the building's operating needs, or other means of justification are necessary besides operating cost savings.

Priority 2 ECOs are listed in order from greatest return on investment (ROI) to lowest return on investment based on simple payback period (number of years required to breakeven on your investment). The greatest ECO ROIs are generally associated with large centralized systems that distribute heating and cooling to smaller, dependent systems and the EMCS that affects operation and performance of the larger systems. The Building Infrastructure Testing that Terracon performed was focused on the larger centralized systems to provide UHAT with the largest impact on operational savings.

Terracon's energy consumption and energy savings analysis are based on information and performance measurements gathered during site visits, design and construction documents provided by UHAT, and generally conservative estimated run hours for equipment and performance expectations. Assumptions were made when information was not available based on *American Society of Heating, Refrigeration, and Air-Conditioning Engineers* (*ASHRAE*) guidelines and general heating, ventilation, and air conditioning (HVAC) practices and performance standards. General guidelines and performance standards include, but are not limited to, discharge air temperatures for cooling that ranged between 48 degF and 58 degF; discharge air temperatures for heating that ranged between 75 degF and 105 degF; cooling coil entering and leaving water temperature differences that ranged between 8 degF and 15 degF; heating coil entering and leaving water temperature differences that ranged between 5 degF and 30 degF; external static pressure differences that ranged between 1.0" w.g. and and entering and leaving static air pressure differences across cooling and heating coils that ranged between 0.1" w.g. and 0.5" w.g.

Table 3: Priority 2 - Retro-Commissioning Improvement List Summary

Measure #	Description of Finding	Recommended Improvement	Baseline Energy Consumption	Post Retrofit Energy Consumption	Energy Savings	Energy Cost Savings	Estimated Implem. Cost	ROI [yrs]
M1.1	Hot water supply temperature from steam-to-hot water heat exchanger is set to 160ºF.	Central Plant Program the EMCS to reset supply hot water temperature according to outside air conditions. Use a linear relationship of 160ºF supply hot water temperature at 30ºF or below outside air temperature and 90ºF at 80ºF or above outside air temperature.	6,156.0 klbs 455,511 Ton-hrs	5,698.2 klbs 432,735 Ton-hrs	457.8 klbs 22,776 Ton-hrs	$3,511 $4,675	$1,500	0.2
M5.2	Outside air is set to minimum position unless supply air temperature is reset according to outside air temperature or economizer cycle is activated by EMCS.	AHU 2G1 Install new CO2 sensors in the return duct of AHU and integrate control point into existing *ALC* controller, if control point is available on controller board, to reduce ventilation provided to space. If control point is not available, upgrade controller to allow for additional point.	453.9 klbs 21,892 Ton-hrs	281.3 klbs 13,568 Ton-hrs	172.6 klbs 8,324 Ton-hrs	$1,324 $1,709	$8,448	2.8
M4.1	Outside air is set to minimum position unless supply air temperature is reset according to outside air temperature or economizer cycle is activated by EMCS.	AHU 1G1 Install new CO2 sensors in the return duct of AHU and integrate control point into existing *ALC* controller, if control point is available on controller board, to reduce ventilation provided to space. If control point is not available, upgrade controller to allow for additional point.	244.9 klbs 11,815 Ton-hrs	116.7 klbs 5,629 Ton-hrs	128.2 klbs 6,185 Ton-hrs	$984 $1,270	$8,448	3.7
M11.1	Outside air is set to minimum position unless supply air temperature is reset according to outside air temperature or economizer cycle is activated by EMCS.	AHU 6G1 Install new CO2 sensors in the return duct of AHU and integrate control point into existing *ALC* controller, if control point is available on controller board, to reduce ventilation provided to space. If control point is not available, upgrade controller to allow for additional point.	529.8 klbs 25,556 Ton-hrs	419.7 klbs 20,243 Ton-hrs	110.2 klbs 5,313 Ton-hrs	$845 $1,091	$8,701	4.5
M6.1	Outside air is set to minimum position unless supply air temperature is reset according to outside air temperature or economizer cycle is activated by EMCS.	AHU 3G1 Install new CO2 sensors in the return duct of AHU and integrate control point into existing *ALC* controller, if control point is available on controller board, to reduce ventilation provided to space. If control point is not available, upgrade controller to allow for additional point.	94.6 klbs 4,564 Ton-hrs	40.3 klbs 1,946 Ton-hrs	54.3 klbs 2,619 Ton-hrs	$416 $538	$8,701	9.1
M10.2	Outside air is set to minimum position unless supply air temperature is reset according to outside air temperature or economizer cycle is activated by EMCS.	AHU 5G3 Install new CO2 sensors in the return duct of AHU and integrate control point into existing *ALC* controller, if control point is available on controller board, to reduce ventilation provided to space. If control point is not available, upgrade controller to allow for additional point.	150 klbs 7,234 Ton-hrs	97.1 klbs 4,682 Ton-hrs	52.9 klbs 2,553 Ton-hrs	$406 $524	$8,701	9.4

M8.1	Outside air is set to minimum position unless supply air temperature is reset according to outside air temperature or economizer cycle is activated by EMCS.	AHU 3RAD Install new CO2 sensors in the return duct of AHU and integrate control point into existing *ALC* controller, if control point is available on controller board, to reduce ventilation provided to space. If control point is not available, upgrade controller to allow for additional point.	330.7 klbs 11,815 Ton-hrs	298 klbs 5,629 Ton-hrs	32.7 klbs 6,185 Ton-hrs	$251 $324	$6,512	11.3
M9.2	Outside air is set to minimum position unless supply air temperature is reset according to outside air temperature or economizer cycle is activated by EMCS.	AHU 5G2 Install new CO2 sensors in the return duct of AHU and integrate control point into existing *ALC* controller, if control point is available on controller board, to reduce ventilation provided to space. If control point is not available, upgrade controller to allow for additional point.	155.9 klbs 7,518 Ton-hrs	125.2 klbs 6,040 Ton-hrs	30.7 klbs 1,478 Ton-hrs	$235 $303	$8,701	16.2
M7.1	Outside air is set to minimum position unless supply air temperature is reset according to outside air temperature or economizer cycle is activated by EMCS.	AHU 3G2 Install new CO2 sensors in the return duct of AHU and integrate control point into existing *ALC* controller, if control point is available on controller board, to reduce ventilation provided to space. If control point is not available, upgrade controller to allow for additional point.	159.8 klbs 7,708 Ton-hrs	119.3 klbs 5,756 Ton-hrs	40.5 klbs 1,952 Ton-hrs	$310 $401	$13,200	18.6
M15.2	VAV terminal units in the basement (VAV-SV-1 and VAV-FV-2) are having trouble provide the desired air flow setpoints.	EMCS – Basement Floor The flow settings may be related to the AHU, but if not, the VAV terminal box flow sensors (K-values) may need to be recalibrated to verify proper flow rates.	50,000 kWh 450 klbs 35,000 Ton-hrs	45,000 kWh 405 klbs 31,500 Ton-hrs	5,000 kWh 45 klbs 3,500 Ton-hrs	$300 $345 $735	$31,000	22.5
M12.1	AHU is a constant volume multizone unit with a hot deck, cold, deck, and seven individual zones.	AHU 7G1 AHU is beyond expected useful service life and the constant volume multizone system is a method that is not energy efficient. Replace or retrofit existing AHU with new VAV AHU and new VAV terminal units for each individual zone.	16,551 kWh	5,959 kWh	10,593 kWh	$639	$63,624	100
M10.1	Piping connections to the chilled water and hot water coils are excessively corroded and a low differential temperature was measured indicating the unit is having trouble satisfying the load it serves.	AHU 5G3 AHU is beyond expected useful service life and it is likely the coils have become significantly corroded that replacement will be necessary soon.	33,421 kWh	25,567 kWh	7,854 kWh	$474	$54,923	116

M9.1	Piping connections to the chilled water and hot water coils are excessively corroded and a low differential temperature was measured indicating the unit is having trouble satisfying the load it serves.	AHU 5G2 AHU is beyond expected useful service life and it is likely the coils have become significantly corroded that replacement will be necessary soon.	16,710 kWh	12,784 kWh	3,926 kWh	$237	$44,000	186
M3.1	Water from chilled water and hot water coils were observed to be "dirty". Differential pressure across both coils indicates the unit is having trouble distributing air and keeping up with the load, even at full speed.	AHU BG2 AHU is beyond expected useful service life and it is likely the coils have become significantly corroded that replacement will be necessary soon. This unit serves an area with lower occupancy and may not be a priority for replacement.	8,355 kWh	6392 kWh	1963 kWh	$118	$76,824	651
		Totals:	**125,037 kWh** **8,725.6 klbs** **588,613 Ton-hr**	**95,701 kWh** **7,600.7 klbs** **527,728 Ton-hrs**	**29,336 kWh** **1,124.9 klbs** **60,885 Ton-hrs**	**$1,768** **$8,627** **$11,560**	**$343,283**	**15.6**

PRIORITY 3 - ENERGY CONSERVATION OPPORTUNITIES (ECOs)

Priority 3 ECOs are considered the lowest priority measures to UHAT at the time of this report. These are measures that UHAT may considered implementing in more than five years or when they are designated a higher priority in the future.

Energy consumption and energy savings analysis were not performed for these measures at the time of this report.

Table 4: Priority 3 - Retro-Commissioning Improvement List Summary

Measure #	**Description of Finding**	**Recommended Improvement**	**Baseline Energy Consumption**	**Post Retrofit Energy Consumption**	**Energy Savings**	**Energy Cost Savings**	**Estimated Implem. Cost**	**ROI [yrs.]**
M2.1	Outside air unit operates at constant volume during building operating hours.	AHU BG1 Install new *ABB* VFD on supply air fan and static air pressure sensor in supply air duct. Integrate new VFD and sensor with existing *ALC* controller, if control points are available on controller board. If control points are not available, upgrade controller to allow for additional points.	TBD	TBD	TBD	TBD	TBD	TBD
M6.2	Chilled water valve reacts rapidly when cooling is needed.	AHU 3G1 Update supply air reset schedule and select new chilled water valve to replace existing chilled water valve with proper Cv value to allow for optimal flow.	TBD	TBD	TBD	TBD	TBD	TBD
M13.1	Outside air unit operates at constant volume during building operating hours.	AHU 7G2 Install new *ABB* VFD on supply air fan and static air pressure sensor in supply air duct. Integrate new VFD and sensor with existing *ALC* controller, if control points are available on controller board. If control points are not available, upgrade controller to allow for additional points.	TBD	TBD	TBD	TBD	TBD	TBD
M15.1	VAV controllers are over 27 years old and cannot be directly controlled with EMCS.	EMCS – Basement Floor Upgrade existing controllers with *ALC* controllers, new temperature sensors, and other new end devices with a phased approach (floor-by-floor) due to age and lack of support available by vendor. This area is a lower occupancy area.	TBD	TBD	TBD	TBD	TBD	TBD

PRIORITY 1 AND 2 ECOs – POST RETROFIT BUILDING ENERGY PROFILE

The post retrofit impact of the Priority 1 and Priority 2 ECOs are presented below with a graphical representation of the individual ECOs impact to the building's 2019 baseline energy profile. Priority 1 ECO's are estimated to reduce electrical consumption by 0.7% annually, steam consumption by 0.5% annually, and chilled water consumption by 0.3% annually. Priority 2 ECO's are estimated to further reduce electrical consumption by 1.4% annually, steam consumption by 12% annually, and chilled water consumption by 8.6% annually.

Priority 1 ECOs are estimated to reduce the overall Energy Utilization Index (EUI) for the building from 119.2 to 118.7 or 0.4% compared to the 2019 baseline energy profile. Priority 2 ECOs are estimated to further reduce the overall EUI for the building from 118.7 to 112.2 or 5.5% compared to the 2019 baseline energy profile.

Chart 3 – Electricity Energy Savings Breakdown from 2019 Baseline Energy Profile

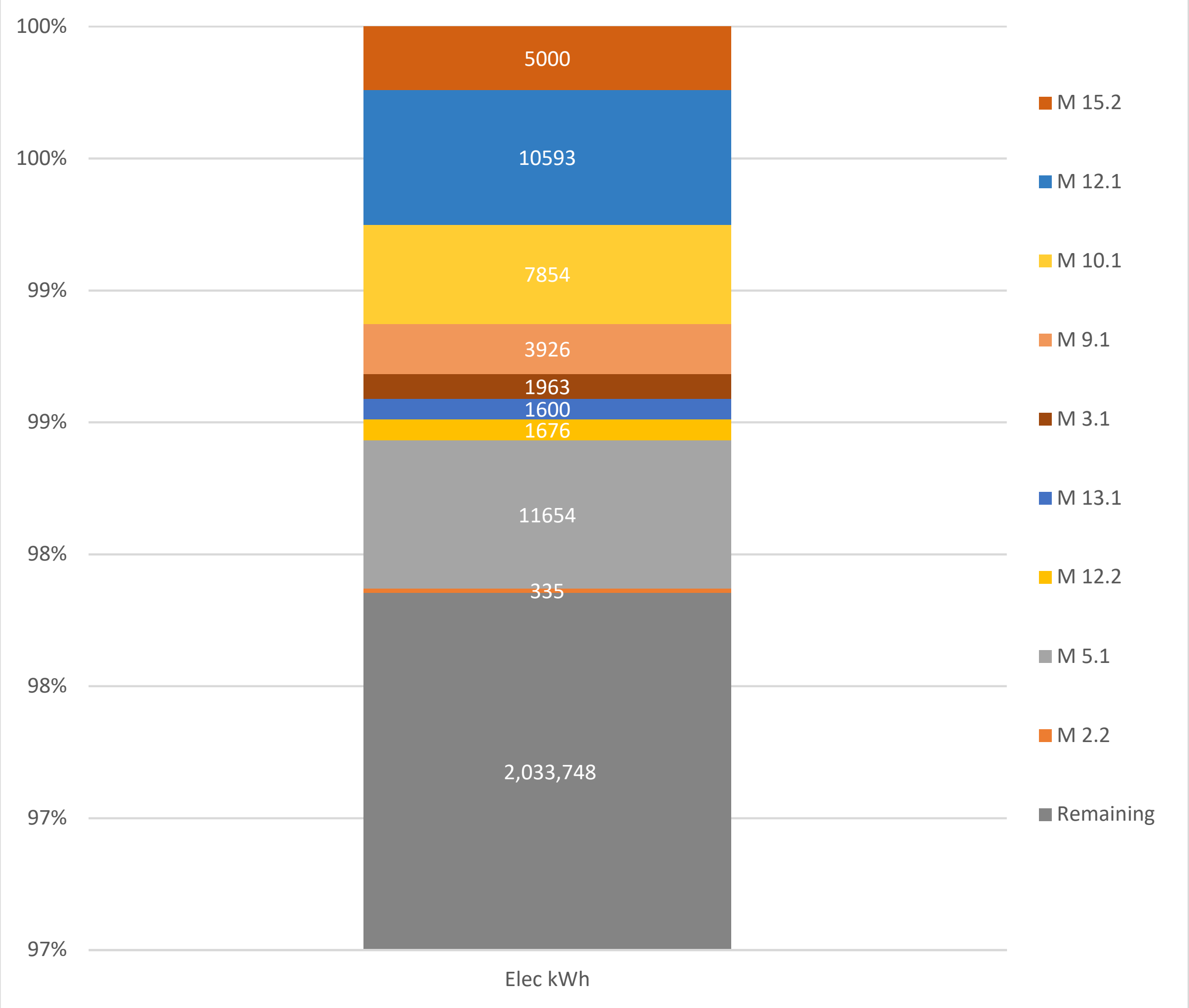


Chart 4 – Steam Energy Savings Breakdown from 2019 Baseline Energy Profile

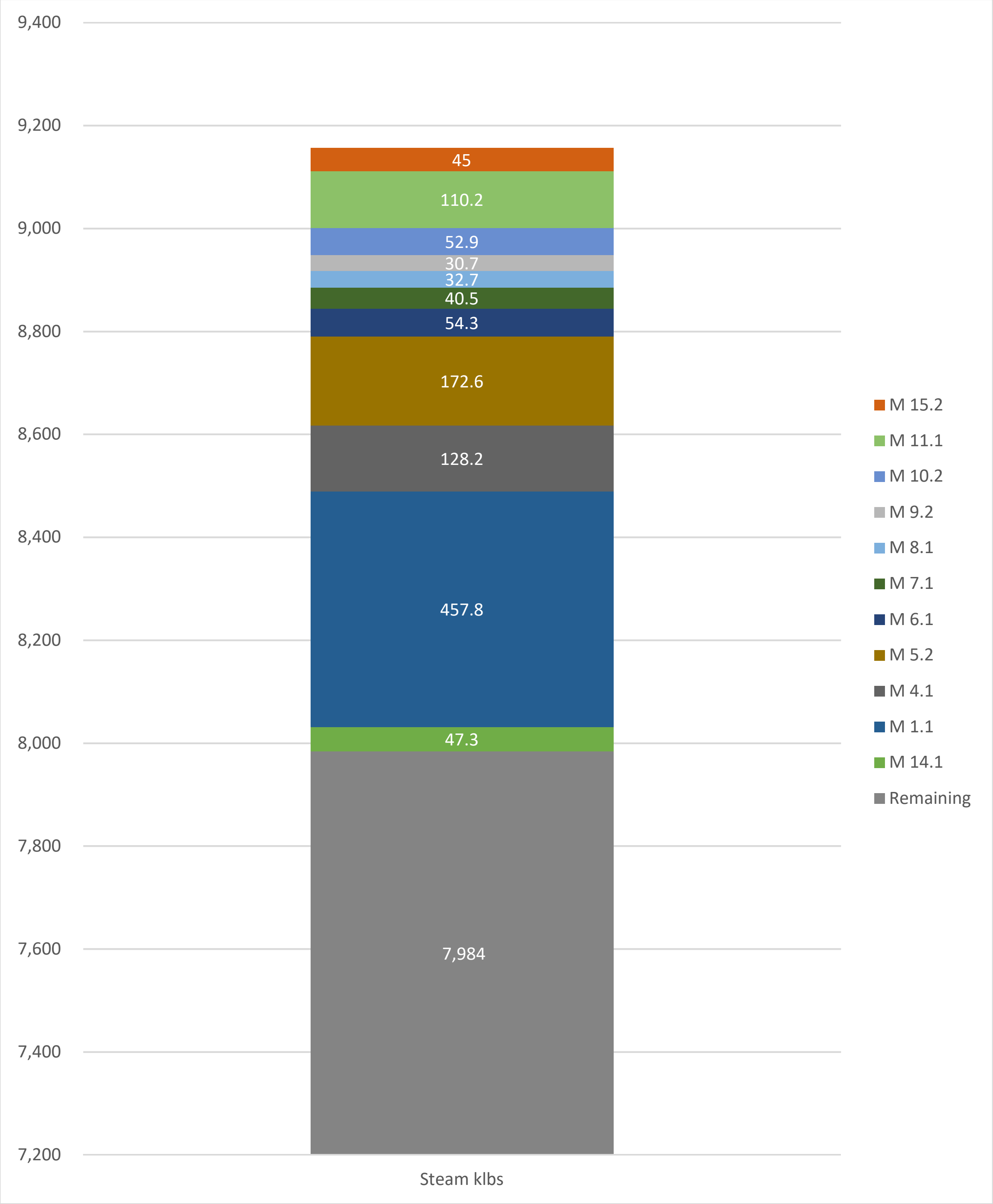
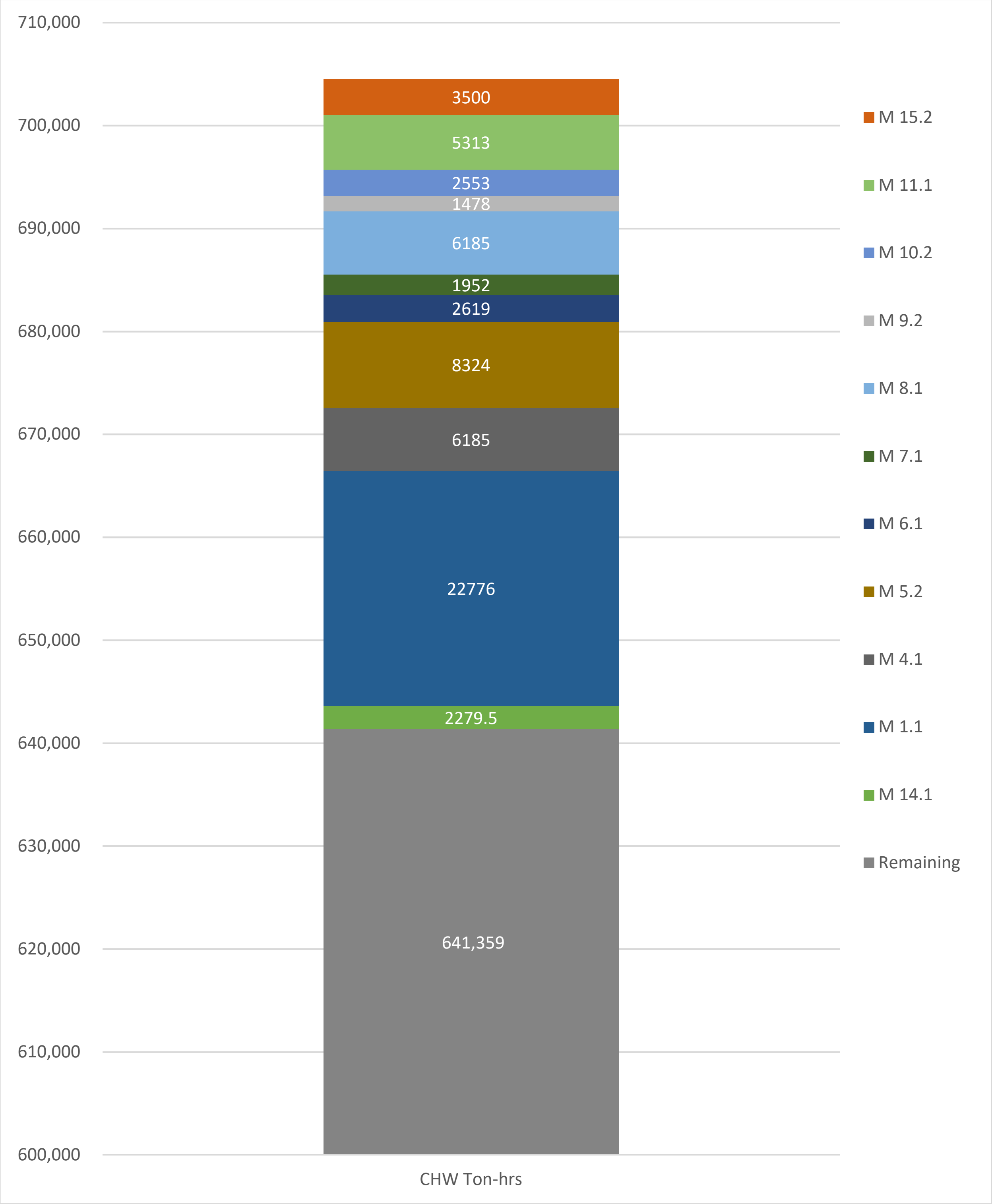


Chart 5 – Chilled Water Energy Savings Breakdown from 2019 Baseline Energy Profile



PRIORITY 1 AND 2 ECOs – POST RETROFIT ENERGY COST PROFILE

The post retrofit impact of the Priority 1 and Priority 2 ECOs are presented below with a graphical representation of the individual ECOs impact to the building's 2019 baseline energy cost profile. Priority 1 ECO's are estimated to reduce the electrical operational cost by 0.7% annually, the steam operational costs by 0.5% annually, and the chilled water operational costs by 0.3% annually. Priority 2 ECO's are estimated to further reduce the electrical operational costs by 1.4% annually, the steam operational costs by 12% annually, and the chilled water operational costs by 8.0% annually.

Priority 1 ECOs are estimated to reduce the overall Energy Cost Index (ECI) for the building from $1.53 to $1.52 or 0.5% compared to the 2019 baseline energy cost profile. Priority 2 ECOs are estimated to further reduce the overall ECI for the building from $1.52 to $1.42 or 6.5% compared to the 2019 baseline energy cost profile.

Chart 6 – Electricity Energy Cost Savings Breakdown from 2019 Baseline Energy Cost Profile

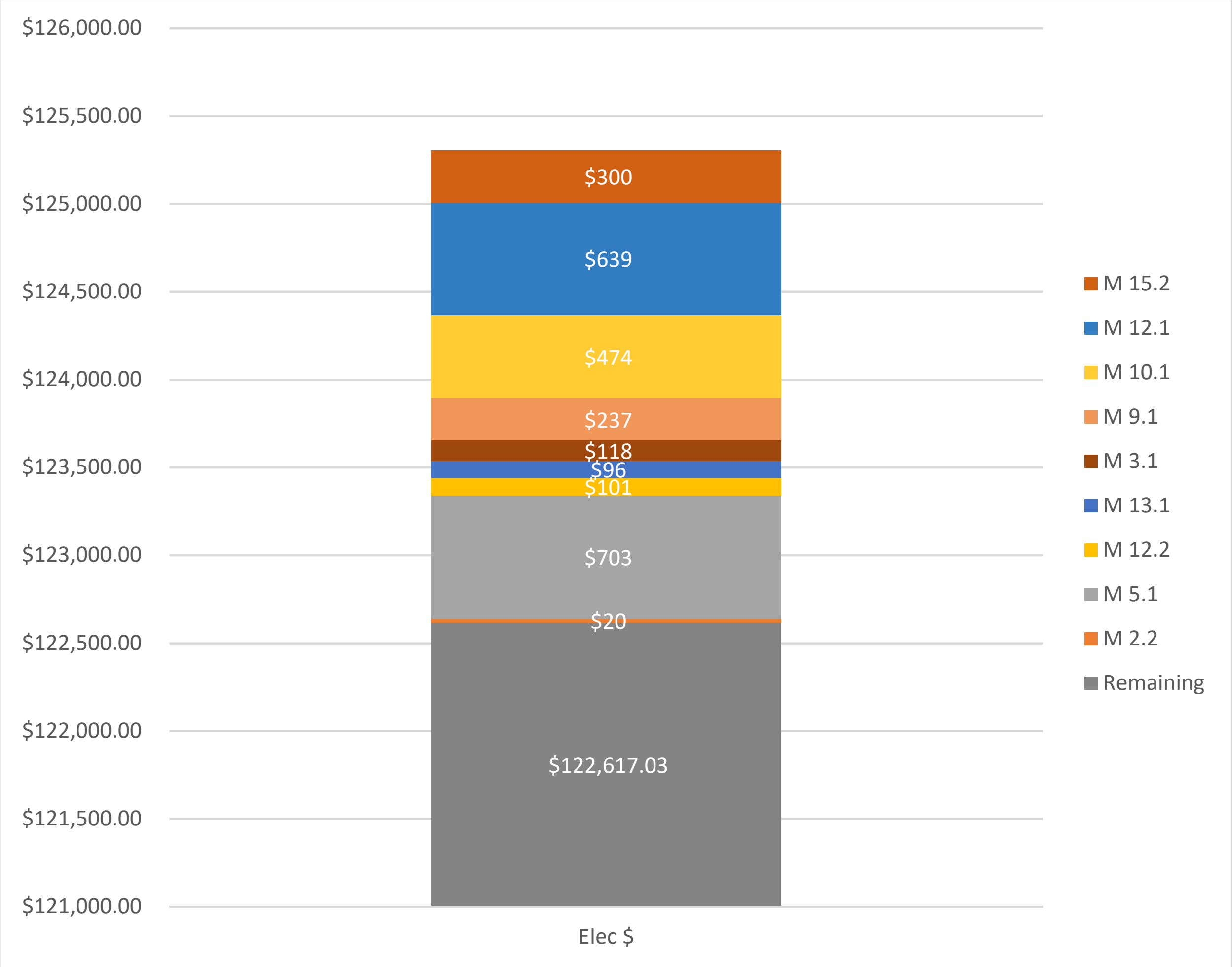


Chart 7 – Steam Energy Cost Savings Breakdown from 2019 Baseline Energy Cost Profile

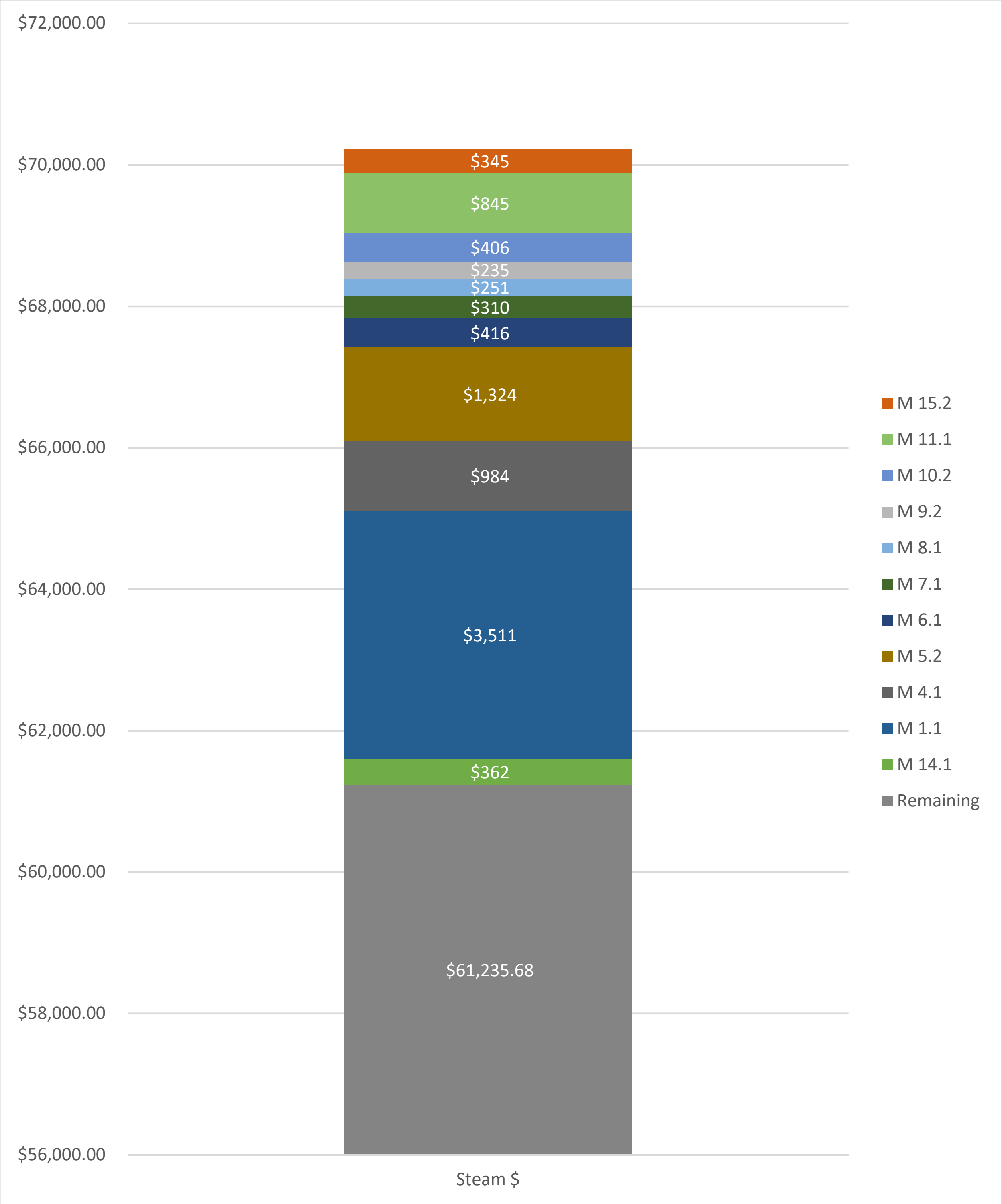
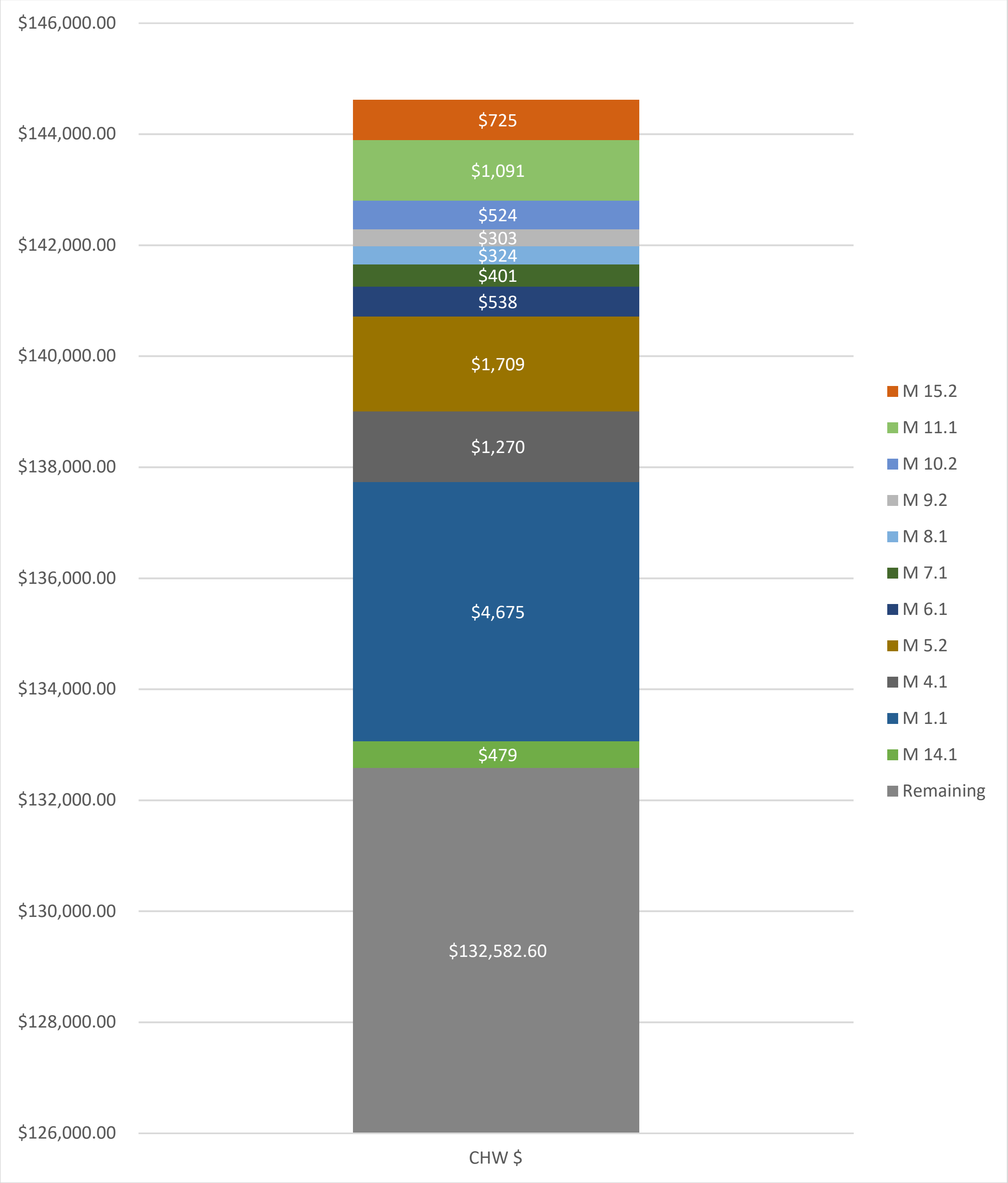


Chart 8 – Chilled Water Energy Cost Savings Breakdown from 2019 Baseline Energy Cost Profile



LIMITATIONS

The field observations, tests, findings, and recommendations presented in this report are based upon the information provided to Terracon by the client, UHAT, and observations and field notes collected at the time of our site visits. While additional conditions may exist that could alter our recommendations, we feel that reasonable means have been made to fairly and accurately evaluate the existing conditions of these systems. This report is limited to Terracon's observations of the interior and exterior of the facility. Some of the observations were limited due to obstructions, lack of design or operational information, and access to areas of the systems and facility. Although our observations were made with normal care and diligence, it is likely that not all existing conditions were documented. The general intent was to representative analysis and recommendations based on general findings.

This report has been prepared for the exclusive use of UHAT for specific application to the project discussed and has been prepared in accordance with generally accepted engineering practices using the standard of care and skill currently exercised by professional engineers practicing in this area, for a project of similar scope and nature. No warranties, either expressed or implied, are intended or made. In the event that information described in this document which was provided by others is incorrect, or if additional information becomes available, the recommendations contained in this report shall not be considered valid unless Terracon reviews the information and either verifies or modifies the recommendations of this report in writing.

APPENDIX A
Detailed Energy Calculations

Garrison ECO Calculations

General Building Assumptions

Equipment Runtime: 3rd & 4th Floor: 24-hours/7 days per week; All Others: 7am - 10pm Mon-Sat

	Annual $				
Cooling (CHW) Costs:	$ 144,622.00	704,523	ton-hr	$ 0.2	$/ton-hr
Heating (STM) Costs:	$ 70,225.00	9156	klbs	$ 7.6	$/klbs
Elecricity Costs:	$ 125,305.00	2078349	kWh	$ 0.0	$/kWh

Priority					**Savings Calculation description/assumptions/needs**	**Calculation Method**
1	M1.2	Central Plant	CHW Pump 3 is not operational.	Replace or repair existing with new pump.	No savings, maintenance item. Necessary to provide redundancy.	
1	M2.2	AHU-BG1	AHU filters are dirty and in need of replacement	Replace air filters according to scheduled preventative maintenance plan.	2925 cfm CV unit. No dP across filter. DP measured across combined filter/CHW coil/HHW coil was 0.86inwg. 2% impact on increased fan motor power. Assume 80% load factor on the 5hp motor and 2% energy impact from reduced fan TSP.	80%x5hp = 4.0 bhp 4.0 bhp x 0.746 kW/bhp = 3.0 kW 2% inpact on fan power = .06 kW 0.06 kW x 18hrs/day * 6 days/wk x 52 wks/yr = 335 kWh saved 335 kWh x $0.06/kWh = $20 /yr ELEC Savings
1	M5.1	AHU-2G1	Fire/Smoke Damper for return fan is shut and preventing AHU from operating optimally	Repair safety fault causing fire/smoke damper to be shut and operate relief/return fans to prevent a similar occurrence in the future. It may be necessary to relocate the manual reset switch for the fire/smoke dmaper if it is not easily accessible.	No CFM from TAB due to measurement difficulties. Fan suction pressure high. No motor or performance details on supply air fan available. Need to make assumption regarding total fan flow, fan power, existing condition versus repair conditions on pressure drop. Trane #50 from schedule 50hp supply, two 5hp return fans. Limited data otherwise on system. Assume added 0.5 inwg to system total static pressure of system. Design cfm 31,000 cfm. 5.38 TSP measured by ES2 with -2.90 inwg suction pressure RF-1 (51.88hz, 4.7A, 5hp motor,87.5% eff) RF-2 (51.88hz, 5.61A, 5hp motor, 87.5% eff) Conservatively estimate 60% average flowrate of scheduled CFM, 4in average total static pressure although 5.38 measured, 5am-11pm run time 6 days/wk, 60% fan efficiency, 87% motor efficiency, airflow obstruction estimated to impact 0.5 inw.g. at average flow, so ideally fan could operate at 3.5 TSP instead of 4.0 TSP on average.	=(60%*30000 cfm)*4inwg TSP/(6344*60% fan mech eff) = 18.92 bhp 18.92 bhp * 0.749 kW/bhp / 85% motor eff = 16.6 kW same calc with 3.5 inwg TSP = 14.5 kW 2.1 kW savings x 5616 hrs/yr (which is 18hrs/day, 6 days/wk) = 11794 kWh 11794 kWh x $0.06/kWh = $707 / yr ELEC Savings
1	M12.2	AHU-7G1	Fan belt is loose and preventing proper distribution of air to zones.	Repair (tighten or replace) fan belt to improve operation of AHU.	Loose fan belt. Maintenance item. Could assume 5-10% impact on increased fan motor power. Assume 80% load factor on the 5hp motor and 10% energy impact from belt slippage. 5300 cfm, 2.31TSP per ES2 TAB report.	80%x5hp = 4.0 bhp 4.0 bhp x 0.746 kW/bhp = 3.0 kW 10% inpact on fan power = .3 kW 0.30 kW x 18hrs/day * 6 days/wk x 52 wks/yr = 1685 kWh saved 1685 kWh x $0.06/kWh = $101 /yr ELEC Savings

Garrison ECO Calculations

General Building Assumptions

Equipment Runtime: 3rd & 4th Floor: 24-hours/7 days per week; All Others: 7am - 10pm Mon-Sat

	Annual $				
Cooling (CHW) Costs:	$ 144,622.00	704,523	ton-hr	$ 0.2	$/ton-hr
Heating (STM) Costs:	$ 70,225.00	9156	klbs	$ 7.6	$/klbs
Elecricity Costs:	$ 125,305.00	2078349	kWh	$ 0.0	$/kWh

Priority					**Savings Calculation description/assumptions/needs**	**Calculation Method**
1	M14.1	ERU	OA damper array/louvers associated with the system do not modulate and excessive amounts of outside air can infiltrate the building.	Replace or repair OA damper array/louvers to close when building is not occupied and open if occupied. ERU is not in use and may also be removed.	Assume 2000 cfm infiltration (based on relief louver sized for approx 20,000 cfm, 10% infiltration) during hours when building systems and OA chase is not in operation which is 36% of the time. Calculation calculated based on 2000*36% = 720 cfm average continuous infiltration impact. Used Infiltration Reduction calculator from Erik G.	Using infiltration reduction excel calculation Assuming 720 cfm average increased infiltration and area weather conditions 2280 ton-hrs/yr cooling savings = 56.4 MMBtu/yr heating savings 56,400,000 btu / 1194 btu/lb = 47,259 lbs steam or 47.3 klbs 2280 ton-hrs/yr * $.21/ton-hr = $479 47 klbs steam * $7.67/klbs = $362
2	M1.1	Central Plant	HHW Supply temp from HX is set to 160°F.	Program the EMCS to reset supply HHW temp according to OA conditions. Use a linear relationship of 160°F supply HHW temp at 30°F or below OA temp and 90°F at 80°F or above OA temp.	Losses include excessive heat transfer throughout facility, increasing cooling load, wasting heat, but also increasing cooling load. Assume 5% waste heat loss reduction from excessively hot temperature supply and return water piping, hundreds of feet of piping, throughout the building. 5% savings = 457.8 klbs steam savings Assume 1/2 of this load added heat load contributes negatively to cooling load in bldg. Other 1/2 are heat losses that may offset other heating in building.	Total steam consumed 9156 klbs Conversion factor 1194 Btu/lb 5% savings 9156 x 5% = 457.8 klbs 457.8 x $7.67/klbs = $3511 1/2 x 457.8 klbs steam x 1194 btu/lb x 1000 lbs/1000lbs = 273,306,600 Btu 273,306,600/12000 = 22,776 ton-hr 22,776 ton-hr x $0.21 = $4,675
2	M3.1	AHU-BG2	Water from CHW&HHW coils was dirty. DP across both coils indicates the unit is having trouble distributing air and keeping up with the load, even at full speed.	AHU is beyond expected useful service life and it is likely the coils have become significantly corroded that replacement will be necessary soon. This unit serves an area with lower occupancy and may not be a priority for replacement.	Likely same cooling and heating loads will be necessary, but with improved heat transfer rates for chilled water and hot water coils. Assume equivalent full load run hours are 2,800 hrs/yr Assume improved heat transfer rate of coils reduces equivalent full load run hours by 15% Assume new AHU full load run hours are 2,380 hrs/yr	80%x5hp = 4.0 bhp 4.0 bhp x 0.746 kW/bhp = 3.0 kW 10% motor efficiency improvement 90%x80%x5hp = 3.6 bhp 3.6 bhp x 0.746 kW/bhp = 2.7 kW 3.0 kW x 2,800/yr = 8,400 kWh 2.7 kW x 2,380/yr = 6,426 kWh 8,400 kWh - 6,426 kWh = 1,974 kWh 1,974 kWh x $0.06/kWh = $118 ELEC Savings
2	M4.1	AHU-1G1	OA set to min position unless SA temp is reset according to OA Temp, or if the economizer cycle is activated by EMCS.	Install new CO2 sensors in the return duct of AHU and integrate control point into existing ALC controller, if control point is available on controller board, to reduce ventilation provided to space. If control point is not available, upgrade controller to allow for additional point.	Assumed 160,000 cfm total supply air Assumed 30,000 cfm total OA (approximately 1/2 of original) with ERU not operational; Based estimated current needs on 250sf/per, 220k sf area, 0.06 cfm/sf + 5cfm/per. Add 20% SF for 3rd floor RAD area and other unknowns (making 21000 cfm total required). Possible reduction of 9000 cfm OA total. Savings Calc performed via Ventilation-Control Calculator per Erik G. Savings from assumed 9000 cfm reductions distributed to systems below with same ECO measure based on unit capacities.	see Ventilation-Control excel calculation CHW Savings - $1,270 STM Savings - $984

Garrison ECO Calculations

General Building Assumptions

Equipment Runtime: 3rd & 4th Floor: 24-hours/7 days per week; All Others: 7am - 10pm Mon-Sat

	Annual $				
Cooling (CHW) Costs:	$ 144,622.00	704,523	ton-hr	$ 0.2	$/ton-hr
Heating (STM) Costs:	$ 70,225.00	9156	klbs	$ 7.6	$/klbs
Elecricity Costs:	$ 125,305.00	2078349	kWh	$ 0.0	$/kWh

Priority					**Savings Calculation description/assumptions/needs**	**Calculation Method**
2	M5.2	AHU-2G1	OA set to min position unless SA temp is reset according to OA Temp, or if the economizer cycle is activated by EMCS.	Install new CO2 sensors in the return duct of AHU and integrate control point into existing ALC controller, if control point is available on controller board, to reduce ventilation provided to space. If control point is not available, upgrade controller to allow for additional point.	see M4.1	see "Ventilation-Control Elec Cooling Gas Htg" excel calculation CHW Savings - $1,709 STM Savings - $1,324
2	M6.1	AHU-3G1	OA set to min position unless SA temp is reset according to OA Temp, or if the economizer cycle is activated by EMCS.	Install new CO2 sensors in the return duct of AHU and integrate control point into existing ALC controller, if control point is available on controller board, to reduce ventilation provided to space. If control point is not available, upgrade controller to allow for additional point.	see M4.1	see "Ventilation-Control Elec Cooling Gas Htg" excel calculation CHW Savings - $538 STM Savings - $416
2	M7.1	AHU-3G2	OA set to min position unless SA temp is reset according to OA Temp, or if the economizer cycle is activated by EMCS.	Install new CO2 sensors in the return duct of AHU and integrate control point into existing ALC controller, if control point is available on controller board, to reduce ventilation provided to space. If control point is not available, upgrade controller to allow for additional point.	see M4.1	see "Ventilation-Control Elec Cooling Gas Htg" excel calculation CHW Savings - $401 STM Savings - $310
2	M8.1	AHU-3RAD	OA set to min position unless SA temp is reset according to OA Temp, or if the economizer cycle is activated by EMCS.	Install new CO2 sensors in the return duct of AHU and integrate control point into existing ALC controller, if control point is available on controller board, to reduce ventilation provided to space. If control point is not available, upgrade controller to allow for additional point.		see "Ventilation-Control Elec Cooling Gas Htg" excel calculation CHW Savings - $324 STM Savings - $251
2	M9.1	AHU-5G2	Piping connections to the CHW&HHW coils are excessively corroded and a low Delta T was measured, indicating the unit is having trouble satisfying the load it serves.	AHU is beyond expected useful service life and it is likely the coils have become significantly corroded that replacement will be necessary soon.		80%x10hp = 8.0 bhp 8.0 bhp x 0.746 kW/bhp = 6.0 kW 10% motor efficiency improvement 90%x80%x510hp = 7.2 bhp 7.2 bhp x 0.746 kW/bhp = 5.4 kW 6.0 kW x 2,800/yr = 16,800 kWh 5.4 kW x 2,380/yr = 12,852 kWh 16,800 kWh - 12,852 kWh = 3,948 kWh 3,948 kWh x $0.06/kWh = $237 ELEC Savings
2	M9.2	AHU-5G2	OA set to min position unless SA temp is reset according to OA Temp, or if the economizer cycle is activated by EMCS.	Install new CO2 sensors in the return duct of AHU and integrate control point into existing ALC controller, if control point is available on controller board, to reduce ventilation provided to space. If control point is not available, upgrade controller to allow for additional point.	see M4.1	see "Ventilation-Control Elec Cooling Gas Htg" excel calculation CHW Savings - $303 STM Savings - $235
2	M10.1	AHU-5G3	Piping connections to the CHW&HHW coils are excessively corroded and a low Delta T was measured, indicating the unit is having trouble satisfying the load it serves.	AHU is beyond expected useful service life and it is likely the coils have become significantly corroded that replacement will be necessary soon.		80%x20hp = 16.0 bhp 16.0 bhp x 0.746 kW/bhp = 12.0 kW 10% motor efficiency improvement 90%x80%x20hp = 14.4 bhp 14.4 bhp x 0.746 kW/bhp = 10.8 kW 12.0 kW x 2,800/yr = 33,600 kWh 10.8 kW x 2,380/yr = 25,704 kWh 33,600 kWh - 25,704 kWh = 7,996 kWh 7,996 kWh x $0.06/kWh = $474 ELEC Savings
2	M10.2	AHU-5G3	OA set to min position unless SA temp is reset according to OA Temp, or if the economizer cycle is activated by EMCS.	Install new CO2 sensors in the return duct of AHU and integrate control point into existing ALC controller, if control point is available on controller board, to reduce ventilation provided to space. If control point is not available, upgrade controller to allow for additional point.	see M4.1	see "Ventilation-Control Elec Cooling Gas Htg" excel calculation CHW Savings - $524 STM Savings - $406

Garrison ECO Calculations

General Building Assumptions

Equipment Runtime: 3rd & 4th Floor: 24-hours/7 days per week; All Others: 7am - 10pm Mon-Sat

	Annual $					
Cooling (CHW) Costs:	$ 144,622.00	704,523	ton-hr	$	0.2	$/ton-hr
Heating (STM) Costs:	$ 70,225.00	9156	klbs	$	7.6	$/klbs
Elecricity Costs:	$ 125,305.00	2078349	kWh	$	0.0	$/kWh

Priority					**Savings Calculation description/assumptions/needs**	**Calculation Method**
2	M11.1	AHU-6G1	OA set to min position unless SA temp is reset according to OA Temp, or if the economizer cycle is activated by EMCS.	Install new CO2 sensors in the return duct of AHU and integrate control point into existing ALC controller, if control point is available on controller board, to reduce ventilation provided to space. If control point is not available, upgrade controller to allow for additional point.	see M4.1	see "Ventilation-Control Elec Cooling Gas Htg" excel calculation CHW Savings - $1,091 STM Savings - $845
2	M12.1	AHU-7G1	AHU is constant volume multizone unit with a hot deck/cold deck and 7 individual zones.	AHU is beyond expected useful service life and the constant volume multizone system is a method that is not energy efficient. Replace or retrofit exisiting AHU with new VAV AHU and new VAV terminal units for each individual zone.	Changing to VAV system would result in primarily VAV fan savings. 5hp supply fan motor. 5300 cfm @2.31 TSP measured. Assume 4bhp fan power consumption and ability to reduce to 60% of current constant volume flowrate on average.	(60%)^2 x 4bhp = assumed average bhp for new system = .36 x 4 = 1.44 bhp (4bhp - 1.44bhp) = 2.56 bhp savings assume 90% motor eff 2.56 bhp * 0.746 kW/bhp / 90% motor eff = 2.12 kW 2.1 2kW savings x 5616 hrs/yr (which is 18hrs/day, 6 days/wk) = 11917 kWh 11917 kWh x $0.06/kWh = $715 / yr
2	M15.2	EMCS-00	VAV terminal units in the basement (VAV-SV-1 and VAV-FV-2) are having trouble provide the desired air flow setpoints.	The flow settings may be related to the AHU, but if not, the VAV terminal box flow sensors (K-values) may need to be recalibrated to verify proper flow rates.		

Calculation of the Baseline Energy Use

Methodology

Baseline

	Ambient Temp, ºF	Flow, CFM	Hours at Flow	P1, in.H2O	Speed, RPM	Flow, % of max at RPM	Flow, % of MaxEff	%max delta-p	Fan head, in.H2O	Fan Δp, In.H2O	P2, in.H2O	P3, in.H2O	P4, in.H2O	min Δp (4 to 5) in.H2O	VAV dmpr Δp	P5, in.H2O
Design		5,000		-0.44	1250	57%	100%	85%	1.48	1.48	1.04	0.59	0.07	0.40	0.25	-0.57
Baseline **Fixed speed or high static setpt.**	102.5	5,000	1	-0.4	871	82%	100%	47%	0.4	0.4	0.0	-0.5	-1.0	0.4	1.8	-3.2
	97.5	4,700	50	-0.4	859	78%	94%	55%	0.5	0.5	0.1	-0.3	-0.8	0.4	2.1	-3.3
	92.5	4,400	250	-0.3	833	76%	88%	60%	0.5	0.5	0.1	-0.2	-0.6	0.3	2.2	-3.2
	87.5	4,100	750	-0.3	811	73%	82%	66%	0.5	0.5	0.2	-0.1	-0.5	0.3	2.3	-3.1
	82.5	3,800	1,000	-0.3	792	69%	76%	72%	0.5	0.5	0.2	0.0	-0.3	0.2	2.4	-3.0
	77.5	4,400	1,000	-0.3	833	76%	88%	60%	0.5	0.5	0.1	-0.2	-0.6	0.3	2.2	-3.2
	72.5	4,100	1,000	-0.3	811	73%	82%	66%	0.5	0.5	0.2	-0.1	-0.5	0.3	2.3	-3.1
	67.5	3,800	750	-0.3	792	69%	76%	72%	0.5	0.5	0.2	0.0	-0.3	0.2	2.4	-3.0
	62.5	3,500	750	-0.2	774	65%	70%	77%	0.5	0.5	0.3	0.1	-0.2	0.2	2.5	-2.9
	57.5	3,300	500	-0.2	760	62%	66%	80%	0.5	0.5	0.3	0.1	-0.1	0.2	2.6	-2.9
	52.5	3,100	500	-0.2	747	60%	62%	83%	0.5	0.5	0.3	0.2	0.0	0.2	2.6	-2.8
	47.5	2,900	250	-0.1	737	56%	58%	86%	0.5	0.5	0.4	0.2	0.0	0.1	2.7	-2.8
	42.5	2,700	105	-0.1	728	53%	54%	89%	0.5	0.5	0.4	0.3	0.1	0.1	2.7	-2.7
	37.5	2,900	105	-0.1	736	57%	58%	86%	0.5	0.5	0.4	0.2	0.0	0.1	2.7	-2.8
	32.5	3,100	53	-0.2	746	60%	62%	83%	0.5	0.5	0.3	0.2	0.0	0.2	2.6	-2.8
	27.5	3,300	25	-0.2	757	63%	66%	80%	0.5	0.5	0.3	0.1	-0.1	0.2	2.6	-2.9
	22.5	3,500	10	-0.2	770	65%	70%	77%	0.5	0.5	0.3	0.1	-0.2	0.2	2.5	-2.9
	17.5	3,700	1	-0.2	785	68%	74%	74%	0.5	0.5	0.3	0.0	-0.3	0.2	2.5	-2.9
	12.5	4,000	0	-0.3	802	72%	80%	68%	0.5	0.5	0.2	-0.1	-0.4	0.3	2.4	-3.1
	7.5	4,300	0	-0.3	823	75%	86%	62%	0.5	0.5	0.1	-0.2	-0.6	0.3	2.3	-3.2

Baseline

at total flow

P6, in.H2O	Pstatic (3) in.H2O	Pstatic setpt, in.H2O	P6calc	P6-P6calc, in.H2O	Residual	Fan Δp, In.H2O	%peak effy	Fan effy	Fan HP	**Flow, CFM**	**Motor effy**	**VFD effy**	**Fan kW**	**Fan kWh**	effective incremental exponent	effective net exponent
0.00	0.59	1.50	-0.67	0.7	0.7	1.5	100%	48%	2.4	5,000	94%	96%	2.0			
0.0	-0.49	1.50	-3.3	3.3	2.0	0.4	65%	31%	1.0	5,000	89%	91%	0.9	1		
0.0	-0.33	1.50	-3.4	3.4	1.8	0.5	75%	36%	0.9	4,700	88%	91%	0.8	42	0.82	0.82
0.0	-0.22	1.50	-3.3	3.3	1.7	0.5	80%	38%	0.8	4,400	86%	91%	0.8	195	1.29	1.06
0.0	-0.11	1.50	-3.1	3.1	1.6	0.5	86%	41%	0.7	4,100	84%	90%	0.7	541	1.08	1.07
0.0	-0.01	1.50	-3.0	3.0	1.5	0.5	92%	44%	0.7	3,800	81%	90%	0.7	672	0.93	1.03
0.0	-0.22	1.50	-3.3	3.3	1.7	0.5	80%	38%	0.8	4,400	86%	91%	0.8	779	1.00	1.06
0.0	-0.11	1.50	-3.1	3.1	1.6	0.5	86%	41%	0.7	4,100	84%	90%	0.7	721	1.08	1.07
0.0	-0.01	1.50	-3.0	3.0	1.5	0.5	92%	44%	0.7	3,800	81%	90%	0.7	504	0.93	1.03
0.0	0.08	1.50	-2.9	2.9	1.4	0.5	97%	46%	0.6	3,500	78%	90%	0.6	472	0.81	0.98
0.0	0.13	1.50	-2.9	2.9	1.4	0.5	99%	47%	0.5	3,300	76%	89%	0.6	300	0.83	0.96
0.0	0.18	1.50	-2.9	2.9	1.3	0.5	100%	48%	0.5	3,100	74%	89%	0.6	289	0.58	0.91
0.0	0.22	1.50	-2.8	2.8	1.3	0.5	100%	48%	0.5	2,900	72%	89%	0.6	140	0.50	0.86
0.0	0.26	1.50	-2.8	2.8	1.2	0.5	100%	48%	0.5	2,700	70%	89%	0.5	57	0.48	0.81
0.0	0.22	1.50	-2.8	2.8	1.3	0.5	100%	48%	0.5	2,900	72%	89%	0.6	59	0.46	0.86
0.0	0.17	1.50	-2.9	2.9	1.3	0.5	100%	48%	0.5	3,100	74%	89%	0.6	30	0.46	0.91
0.0	0.12	1.50	-2.9	2.9	1.4	0.5	99%	47%	0.5	3,300	76%	89%	0.6	15	0.56	0.97
0.0	0.07	1.50	-3.0	3.0	1.4	0.5	97%	46%	0.6	3,500	78%	90%	0.6	6	0.78	1.00
0.0	0.02	1.50	-3.0	3.0	1.5	0.5	94%	45%	0.6	3,700	80%	90%	0.7	1	0.90	1.02
0.0	-0.08	1.50	-3.1	3.1	1.6	0.5	88%	42%	0.7	4,000	83%	90%	0.7	-	0.85	1.07
0.0	-0.19	1.50	-3.2	3.2	1.7	0.5	82%	39%	0.8	4,300	85%	90%	0.8	-	0.99	1.11
					31											

Baseline

reduction

Regression: Fan power vs. flow Note: Regressions may be inaccurate if continuous flows are not input for all 20 load conditions

-9.011E-12	1.343E-07	-4.678E-04	1.004E+00
0	0	0	0
1.00	0.00		
4634	16		
0	0		

Third order equation - (see LINEST in excel help documentation for additional explanation)

kW = 1.00388800518588 + -0.000467765519036442 * [Flow] + 1.34314927425327E-07 * [Flow]^2 + -9.01065849109739E-12* [Flow]^3

3.030E-08	-7.497E-05	5.192E-01
0	0	0
1.00	0.00	
4882	17	
0	0	

Second order equation - (see LINEST in excel help documentation for additional explanation)

kW = 0.519163167329513 + -7.49694067877603E-05 * [Flow] + 3.02969717618222E-08 * [Flow]^2

Calculation of Savings from Reducing Flows or Operating Hours

Methodology

Reduce Average Airflow

	Ambient Temp, ºF	Flow, CFM	Hours at Flow	P1, in.H2O	Speed, RPM	Flow, % of max at RPM	Flow, % of max eff	%max delta-p	Fan head, in.H2O	Fan Δp, In.H2O	P2, in.H2O	P3, in.H2O	P4, in.H2O	min Δp (4 to 5) in.H2O	VAV dmpr Δp	P5, in.H2O
Design		5,000		-0.4	1250	57%	100%	85%	1.48	1.48	1.04	0.59	0.07	0.40	0.25	-0.57
Reduced Flows or hours	102.5	5,000	1	-0.4	828	87%	100%	37%	0.3	0.3	-0.2	-0.6	-1.1	0.4	2.3	-3.8
	97.5	4,700	50	-0.4	806	84%	94%	44%	0.3	0.3	-0.1	-0.5	-0.9	0.4	2.4	-3.6
	92.5	4,400	250	-0.3	787	80%	88%	52%	0.4	0.4	0.0	-0.3	-0.7	0.3	2.5	-3.5
	87.5	4,100	750	-0.3	771	76%	82%	59%	0.4	0.4	0.1	-0.2	-0.6	0.3	2.5	-3.4
	82.5	3,800	1,000	-0.3	757	72%	76%	67%	0.4	0.4	0.2	-0.1	-0.4	0.2	2.6	-3.2
	77.5	4,400	1,000	-0.3	787	80%	88%	52%	0.4	0.4	0.0	-0.3	-0.7	0.3	2.5	-3.5
	72.5	4,100	1,000	-0.3	771	76%	82%	59%	0.4	0.4	0.1	-0.2	-0.6	0.3	2.5	-3.4
	67.5	3,800	750	-0.3	757	72%	76%	67%	0.4	0.4	0.2	-0.1	-0.4	0.2	2.6	-3.2
	62.5	3,500	750	-0.2	745	67%	70%	74%	0.5	0.5	0.2	0.0	-0.2	0.2	2.6	-3.1
	57.5	3,300	500	-0.2	734	64%	66%	78%	0.5	0.5	0.3	0.1	-0.1	0.2	2.7	-3.0
	52.5	3,100	500	-0.2	726	61%	62%	82%	0.5	0.5	0.3	0.1	-0.1	0.2	2.7	-3.0
	47.5	2,900	250	-0.1	718	58%	58%	85%	0.5	0.5	0.3	0.2	0.0	0.1	2.8	-2.9
	42.5	2,700	105	-0.1	712	54%	54%	88%	0.5	0.5	0.4	0.2	0.1	0.1	2.8	-2.8
	37.5	2,900	105	-0.1	718	58%	58%	85%	0.5	0.5	0.3	0.2	0.0	0.1	2.8	-2.9
	32.5	3,100	53	-0.2	725	61%	62%	81%	0.5	0.5	0.3	0.1	-0.1	0.2	2.7	-3.0
	27.5	3,300	25	-0.2	733	65%	66%	78%	0.5	0.5	0.3	0.1	-0.2	0.2	2.7	-3.0
	22.5	3,500	10	-0.2	742	68%	70%	74%	0.4	0.4	0.2	0.0	-0.2	0.2	2.7	-3.1
	17.5	3,700	1	-0.2	752	71%	74%	69%	0.4	0.4	0.2	-0.1	-0.3	0.2	2.6	-3.2
	12.5	4,000	0	-0.3	765	75%	80%	62%	0.4	0.4	0.1	-0.2	-0.5	0.3	2.6	-3.3
	7.5	4,300	0	-0.3	779	79%	86%	54%	0.4	0.4	0.0	-0.3	-0.7	0.3	2.5	-3.5

Reduce Average Airflow

at total flow

P6, in.H2O	Pstatic (3) in.H2O	Pstatic setpt, in.H2O	P6calc	P6-P6calc, in.H2O	Residual	Fan Δp, In.H2O	%peak effy	Fan effy	Fan HP	**Flow, CFM**	**Motor effy**	**VFD effy**	**Fan kW**	**Fan kWh**	effective incremental exponent	effective net exponent
0.00	0.59	1.50	-0.67	0.7	0.7	1.5	100%	48%	2.4	5,000	94%	96%	2.0			
0.0	-0.60	1.50	-3.9	3.9	2.1	0.3	53%	25%	0.8	5,000	87%	91%	0.8	1		
0.0	-0.46	1.50	-3.7	3.7	2.0	0.3	62%	29%	0.8	4,700	85%	90%	0.8	38	1.05	1.05
0.0	-0.33	1.50	-3.6	3.6	1.8	0.4	70%	34%	0.7	4,400	83%	90%	0.7	177	0.95	1.00
0.0	-0.20	1.50	-3.4	3.4	1.7	0.4	79%	38%	0.6	4,100	81%	90%	0.7	500	0.83	0.94
0.0	-0.09	1.50	-3.3	3.3	1.6	0.4	87%	42%	0.6	3,800	78%	89%	0.6	630	0.73	0.88
0.0	-0.33	1.50	-3.6	3.6	1.8	0.4	70%	34%	0.7	4,400	83%	90%	0.7	706	0.78	1.00
0.0	-0.20	1.50	-3.4	3.4	1.7	0.4	79%	38%	0.6	4,100	81%	90%	0.7	666	0.83	0.94
0.0	-0.09	1.50	-3.3	3.3	1.6	0.4	87%	42%	0.6	3,800	78%	89%	0.6	473	0.73	0.88
0.0	0.02	1.50	-3.1	3.1	1.5	0.5	94%	45%	0.5	3,500	76%	89%	0.6	448	0.65	0.83
0.0	0.08	1.50	-3.1	3.1	1.4	0.5	97%	47%	0.5	3,300	74%	89%	0.6	287	0.67	0.81
0.0	0.14	1.50	-3.0	3.0	1.4	0.5	100%	48%	0.5	3,100	71%	89%	0.6	277	0.57	0.77
0.0	0.19	1.50	-2.9	2.9	1.3	0.5	100%	48%	0.5	2,900	70%	89%	0.5	135	0.35	0.72
0.0	0.24	1.50	-2.9	2.9	1.3	0.5	100%	48%	0.4	2,700	68%	89%	0.5	55	0.37	0.68
0.0	0.19	1.50	-2.9	2.9	1.3	0.5	100%	48%	0.5	2,900	70%	89%	0.5	57	0.36	0.72
0.0	0.13	1.50	-3.0	3.0	1.4	0.5	100%	48%	0.5	3,100	71%	89%	0.6	29	0.33	0.78
0.0	0.08	1.50	-3.1	3.1	1.4	0.5	97%	46%	0.5	3,300	73%	89%	0.6	14	0.56	0.81
0.0	0.01	1.50	-3.1	3.1	1.5	0.4	94%	45%	0.5	3,500	75%	89%	0.6	6	0.64	0.84
0.0	-0.05	1.50	-3.2	3.2	1.6	0.4	90%	43%	0.6	3,700	77%	89%	0.6	1	0.72	0.86
0.0	-0.17	1.50	-3.4	3.4	1.7	0.4	82%	39%	0.6	4,000	80%	90%	0.7	-	0.68	0.93
0.0	-0.29	1.50	-3.5	3.5	1.8	0.4	73%	35%	0.7	4,300	82%	90%	0.7	-	0.77	1.00
					32											

Reduce Average Airflow

reduction

Regression: Fan power vs. flow Note: Regressions may be inaccurate if continuous flows are not input for all 20 load conditions

-7.254E-13	3.051E-08	-8.201E-05	5.391E-01
0	0	0	0
0.9995	0.00		
10116	16		
0	0		

Third order equation - (see LINEST in excel help documentation for additional explanation)

kW = 0.539056353060238 + -8.20145670431005E-05 * [Flow] + 3.05117075914822E-08 * [Flow]^2 + -7.2540694453489E-13* [Flow]^3

2.214E-08	-5.039E-05	5.000E-01
0	0	0
1.00	0.00	
15922	17	
0	0	

Second order equation - (see LINEST in excel help documentation for additional explanation)

kW = 0.500033371119799 + -5.03923467699628E-05 * [Flow] + 2.21376972492659E-08 * [Flow]^2

Calculation of Savings from Reducing the Static Pressure Setpoint

Methodology

Reduce Static Pressure Setpoint

	Ambient Temp, ºF	Flow, CFM	Hours at Flow	P1, in.H2O	Speed, RPM	Flow, % of max at RPM	Flow, % of max eff	%max delta-p	Fan head, in.H2O	Fan Δp, In.H2O	P2, in.H2O	P3, in.H2O	P4, in.H2O	min Δp (4 to 5) in.H2O	VAV dmpr Δp	P5, in.H2O
Design		5,000		-0.44	1250	57%	100%	85%	1.48	1.48	1.04	0.59	0.07	0.40	0.25	-0.57
Improved VAV box controls flow; VFD controls static press.	102.5	5,000	1	-0.4	694	103%	100%	-11%	-0.1	-0.1	-0.5	-0.9	-1.5	0.4	0.8	-2.6
	97.5	4,700	50	-0.4	666	101%	94%	-4%	0.0	0.0	-0.4	-0.8	-1.3	0.4	0.9	-2.5
	92.5	4,400	250	-0.3	640	99%	88%	4%	0.0	0.0	-0.3	-0.7	-1.1	0.3	1.0	-2.3
	87.5	4,100	750	-0.3	618	95%	82%	15%	0.1	0.1	-0.2	-0.5	-0.9	0.3	1.0	-2.2
	82.5	3,800	1,000	-0.3	599	91%	76%	26%	0.1	0.1	-0.2	-0.4	-0.7	0.2	1.1	-2.0
	77.5	4,400	1,000	-0.3	640	99%	88%	4%	0.0	0.0	-0.3	-0.7	-1.1	0.3	1.0	-2.3
	72.5	4,100	1,000	-0.3	618	95%	82%	15%	0.1	0.1	-0.2	-0.5	-0.9	0.3	1.0	-2.2
	67.5	3,800	750	-0.3	599	91%	76%	26%	0.1	0.1	-0.2	-0.4	-0.7	0.2	1.1	-2.0
	62.5	3,500	750	-0.2	582	86%	70%	38%	0.1	0.1	-0.1	-0.3	-0.5	0.2	1.1	-1.9
	57.5	3,300	500	-0.2	567	84%	66%	44%	0.2	0.2	0.0	-0.2	-0.5	0.2	1.2	-1.8
	52.5	3,100	500	-0.2	554	80%	62%	51%	0.2	0.2	0.0	-0.2	-0.4	0.2	1.2	-1.8
	47.5	2,900	250	-0.1	543	77%	58%	59%	0.2	0.2	0.0	-0.1	-0.3	0.1	1.3	-1.7
	42.5	2,700	105	-0.1	533	73%	54%	66%	0.2	0.2	0.1	-0.1	-0.2	0.1	1.3	-1.6
	37.5	2,900	105	-0.1	542	77%	58%	59%	0.2	0.2	0.0	-0.1	-0.3	0.1	1.3	-1.7
	32.5	3,100	53	-0.2	552	81%	62%	51%	0.2	0.2	0.0	-0.2	-0.4	0.2	1.2	-1.8
	27.5	3,300	25	-0.2	564	84%	66%	44%	0.2	0.2	0.0	-0.2	-0.5	0.2	1.2	-1.8
	22.5	3,500	10	-0.2	578	87%	70%	36%	0.1	0.1	-0.1	-0.3	-0.6	0.2	1.2	-1.9
	17.5	3,700	1	-0.2	593	90%	74%	30%	0.1	0.1	-0.1	-0.4	-0.7	0.2	1.1	-2.0
	12.5	4,000	0	-0.3	610	94%	80%	18%	0.1	0.1	-0.2	-0.5	-0.8	0.3	1.1	-2.1
	7.5	4,300	0	-0.3	630	98%	86%	6%	0.0	0.0	-0.3	-0.6	-1.0	0.3	1.0	-2.3

Reduce Static Pressure Setpoint

at total flow

P6, in.H2O	Pstatic (3) in.H2O	Pstatic setpt, in.H2O	P6calc	P6-P6calc, in.H2O	Residual	Fan Δp, In.H2O	%peak effy	Fan effy	Fan HP	**Flow, CFM**	**Motor effy**	**VFD effy**	**Fan kW**	**Fan kWh**	effective incremental exponent	effective net exponent
0.00	0.59	1.50	-0.67	0.7	0.7	1.5	100%	48%	2.4	5,000	94%	96%	2.0			
0.0	-0.94	1.00	-2.7	2.7	1.9	-0.1	-9%	-4%	1.0	5,000	90%	88%	1.0	1		
0.0	-0.80	1.00	-2.6	2.6	1.8	0.0	0%	0%	-42.0	4,700	######	88%	0.0	0	1986.01	1986.01
0.0	-0.67	1.00	-2.4	2.4	1.7	0.0	11%	5%	0.2	4,400	48%	87%	0.4	105	-1850.38	6.55
0.0	-0.53	1.00	-2.2	2.2	1.5	0.1	25%	12%	0.3	4,100	59%	87%	0.5	356	-1.72	3.61
0.0	-0.41	1.00	-2.1	2.1	1.4	0.1	40%	19%	0.3	3,800	58%	86%	0.5	474	0.03	2.62
0.0	-0.67	1.00	-2.4	2.4	1.7	0.0	11%	5%	0.2	4,400	48%	87%	0.4	421	-0.81	6.55
0.0	-0.53	1.00	-2.2	2.2	1.5	0.1	25%	12%	0.3	4,100	59%	87%	0.5	475	-1.72	3.61
0.0	-0.41	1.00	-2.1	2.1	1.4	0.1	40%	19%	0.3	3,800	58%	86%	0.5	355	0.03	2.62
0.0	-0.29	1.00	-1.9	1.9	1.3	0.1	54%	26%	0.3	3,500	55%	86%	0.5	346	0.32	2.09
0.0	-0.23	1.00	-1.9	1.9	1.2	0.2	62%	30%	0.3	3,300	52%	85%	0.4	225	0.46	1.86
0.0	-0.17	1.00	-1.8	1.8	1.2	0.2	70%	34%	0.2	3,100	49%	85%	0.4	219	0.39	1.67
0.0	-0.11	1.00	-1.7	1.7	1.1	0.2	78%	37%	0.2	2,900	47%	85%	0.4	107	0.34	1.50
0.0	-0.05	1.00	-1.7	1.7	1.1	0.2	86%	41%	0.2	2,700	44%	84%	0.4	44	0.29	1.36
0.0	-0.11	1.00	-1.7	1.7	1.1	0.2	78%	37%	0.2	2,900	46%	85%	0.4	45	0.29	1.50
0.0	-0.17	1.00	-1.8	1.8	1.2	0.2	70%	33%	0.2	3,100	49%	85%	0.4	23	0.32	1.67
0.0	-0.23	1.00	-1.9	1.9	1.2	0.2	61%	29%	0.3	3,300	52%	85%	0.4	11	0.37	1.87
0.0	-0.30	1.00	-2.0	2.0	1.3	0.1	52%	25%	0.3	3,500	55%	86%	0.5	5	0.41	2.11
0.0	-0.37	1.00	-2.0	2.0	1.4	0.1	44%	21%	0.3	3,700	57%	86%	0.5	0	0.43	2.41
0.0	-0.49	1.00	-2.2	2.2	1.5	0.1	29%	14%	0.3	4,000	58%	86%	0.5	-	0.12	3.22
0.0	-0.63	1.00	-2.4	2.4	1.6	0.0	14%	7%	0.3	4,300	52%	87%	0.4	-	-1.04	5.26
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Reduce Static Pressure Setpoint

reduction

Regression: Fan power vs. flow

Note: Regressions may be inaccurate if continuous flows are not input for all 20 load conditions

2.673E-10	-3.005E-06	1.108E-02	-1.294E+01
0	0	0	7
0.2713	0.15	#N/A	#N/A
2	16	#N/A	#N/A
0	0	#N/A	#N/A

Third order equation - (see LINEST in excel help documentation for additional explanation)

kW =-12.9357068458922 + 0.0110771748833467 * [Flow] + -3.00488950240194E-06 * [Flow]^2 + 2.67285354811512E-10* [Flow]^3

8.062E-08	-5.744E-04	1.443E+00
0	0	1
0.07	0.16	#N/A
1	17	#N/A
0	0	#N/A

Second order equation - (see LINEST in excel help documentation for additional explanation)

kW = 1.44280393668804 + -0.000574431748366278 * [Flow] + 8.06204205140054E-08 * [Flow]^2

3/27/2021
Terracon Consultants

Calculation of Savings from adding Static Pressure Reset

Methodology

This Case Not Used

	Ambient Temp, ºF	Flow, CFM	Hours at Flow	P1, in.H2O	Speed, RPM	Flow, % of max at RPM	Flow, % of max eff	%max delta-p	Fan head, in.H2O	Fan Δp, In.H2O	P2, in.H2O	P3, in.H2O	P4, in.H2O	min Δp (4 to 5) in.H2O	VAV dmpr Δp	P5, in.H2O
Design		5,000		-0.44	1250	57%	100%	85%	1.48	1.48	1.04	0.59	0.07	0.40	0.25	-0.57
With reset of static press. setpt.	102.5	5,000	1	-0.4	620	116%	100%	-56%	-0.2	-0.2	-0.7	-1.12	-1.6	0.4	0.0	-2.0
	97.5	4,700	50	-0.4	576	117%	94%	-60%	-0.2	-0.2	-0.6	-1.00	-1.5	0.4	0.0	-1.8
	92.5	4,400	250	-0.3	535	118%	88%	-64%	-0.2	-0.2	-0.5	-0.89	-1.3	0.3	0.0	-1.6
	87.5	4,100	750	-0.3	502	117%	82%	-61%	-0.2	-0.2	-0.5	-0.77	-1.1	0.3	0.0	-1.4
	82.5	3,800	1,000	-0.3	476	115%	76%	-51%	-0.1	-0.1	-0.4	-0.64	-0.9	0.2	0.1	-1.3
	77.5	4,400	1,000	-0.3	535	118%	88%	-64%	-0.2	-0.2	-0.5	-0.89	-1.3	0.3	0.0	-1.6
	72.5	4,100	1,000	-0.3	502	117%	82%	-61%	-0.2	-0.2	-0.5	-0.77	-1.1	0.3	0.0	-1.4
	67.5	3,800	750	-0.3	476	115%	76%	-51%	-0.1	-0.1	-0.4	-0.64	-0.9	0.2	0.1	-1.3
	62.5	3,500	750	-0.2	452	111%	70%	-38%	-0.1	-0.1	-0.3	-0.52	-0.8	0.2	0.1	-1.1
	57.5	3,300	500	-0.2	430	110%	66%	-34%	-0.1	-0.1	-0.3	-0.46	-0.7	0.2	0.2	-1.1
	52.5	3,100	500	-0.2	411	108%	62%	-28%	-0.1	-0.1	-0.2	-0.39	-0.6	0.2	0.2	-1.0
	47.5	2,900	250	-0.1	394	106%	58%	-19%	0.0	0.0	-0.2	-0.33	-0.5	0.1	0.3	-0.9
	42.5	2,700	105	-0.1	378	102%	54%	-8%	0.0	0.0	-0.1	-0.27	-0.4	0.1	0.3	-0.8
	37.5	2,900	105	-0.1	393	106%	58%	-20%	0.0	0.0	-0.2	-0.33	-0.5	0.1	0.3	-0.9
	32.5	3,100	53	-0.2	408	109%	62%	-30%	-0.1	-0.1	-0.2	-0.40	-0.6	0.2	0.2	-1.0
	27.5	3,300	25	-0.2	427	111%	66%	-38%	-0.1	-0.1	-0.3	-0.46	-0.7	0.2	0.2	-1.1
	22.5	3,500	10	-0.2	446	113%	70%	-43%	-0.1	-0.1	-0.3	-0.53	-0.8	0.2	0.2	-1.1
	17.5	3,700	1	-0.2	467	114%	74%	-47%	-0.1	-0.1	-0.4	-0.60	-0.9	0.2	0.1	-1.2
	12.5	4,000	0	-0.3	491	117%	80%	-60%	-0.2	-0.2	-0.4	-0.73	-1.1	0.3	0.1	-1.4
	7.5	4,300	0	-0.3	518	119%	86%	-68%	-0.2	-0.2	-0.5	-0.86	-1.2	0.3	0.0	-1.5

This Case Not Used

at total flow reduction

P6, in.H2O	Pstatic (3) in.H2O	Pstatic setpt, in.H2O	P6calc	P6-P6calc, in.H2O	Residual	Fan Δp, In.H2O	%peak effy	Fan effy	Fan HP	**Flow, CFM**	**Motor effy**	**VFD effy**	**Fan kW**	**Fan kWh**	effective incremental exponent	effective net exponent
0.00	0.59	1.50	-0.67	0.7	0.7	1.5	100%	48%	2.4	5,000	94%	96%	2.0			
0.0	-1.12	1.02	-2.1	2.1	2.1	-0.2	-73%	-35%	0.5	5,000	75%	87%	0.6	1		
0.0	-1.00	0.90	-1.9	1.9	1.9	-0.2	-80%	-38%	0.4	4,700	67%	86%	0.5	27	1.71	1.71
0.0	-0.89	0.79	-1.7	1.7	1.7	-0.2	-85%	-41%	0.3	4,400	60%	84%	0.5	124	1.33	1.51
0.0	-0.77	0.69	-1.5	1.5	1.5	-0.2	-81%	-39%	0.3	4,100	53%	83%	0.5	349	0.89	1.29
0.0	-0.64	0.59	-1.3	1.3	1.2	-0.1	-66%	-31%	0.2	3,800	48%	82%	0.4	446	0.54	1.08
0.0	-0.89	0.79	-1.7	1.7	1.7	-0.2	-85%	-41%	0.3	4,400	60%	84%	0.5	495	0.71	1.51
0.0	-0.77	0.69	-1.5	1.5	1.5	-0.2	-81%	-39%	0.3	4,100	53%	83%	0.5	465	0.89	1.29
0.0	-0.64	0.59	-1.3	1.3	1.2	-0.1	-66%	-31%	0.2	3,800	48%	82%	0.4	335	0.54	1.08
0.0	-0.52	0.50	-1.2	1.2	1.0	-0.1	-47%	-23%	0.2	3,500	43%	81%	0.4	324	0.38	0.92
0.0	-0.46	0.50	-1.1	1.1	1.0	-0.1	-42%	-20%	0.2	3,300	39%	81%	0.4	211	0.43	0.85
0.0	-0.39	0.50	-1.0	1.0	0.9	-0.1	-32%	-15%	0.2	3,100	36%	80%	0.4	207	0.25	0.77
0.0	-0.33	0.50	-0.9	0.9	0.8	0.0	-20%	-10%	0.2	2,900	34%	79%	0.4	103	0.04	0.68
0.0	-0.27	0.50	-0.9	0.9	0.8	0.0	-5%	-2%	0.2	2,700	46%	78%	0.5	48	-1.54	0.43
0.0	-0.33	0.50	-0.9	0.9	0.8	0.0	-21%	-10%	0.1	2,900	34%	79%	0.4	43	-1.58	0.69
0.0	-0.40	0.50	-1.0	1.0	0.9	-0.1	-36%	-17%	0.2	3,100	35%	80%	0.4	22	0.01	0.78
0.0	-0.46	0.50	-1.1	1.1	1.0	-0.1	-47%	-22%	0.2	3,300	38%	80%	0.4	10	0.24	0.87
0.0	-0.53	0.50	-1.2	1.2	1.0	-0.1	-55%	-26%	0.2	3,500	42%	81%	0.4	4	0.37	0.95
0.0	-0.60	0.56	-1.3	1.3	1.2	-0.1	-61%	-29%	0.2	3,700	46%	82%	0.4	0	0.51	1.03
0.0	-0.73	0.65	-1.4	1.4	1.4	-0.2	-79%	-38%	0.3	4,000	51%	83%	0.5	-	0.45	1.23
0.0	-0.86	0.76	-1.6	1.6	1.6	-0.2	-90%	-43%	0.3	4,300	57%	84%	0.5	-	0.79	1.44
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This Case Not Used

Regression: Fan power vs. flow Note: Regressions may be inaccurate if continuous flows are not input for all 20 load conditions

-6.001E-12	1.249E-07	-6.193E-04	1.319E+00
0	0	0	0
0.9689	0.01		
166	16		
0	0		

Third order equation - (see LINEST in excel help documentation for additional explanation)
kW = 1.31946258413159 + -0.000619335188527445 * [Flow] + 1.2486668334612E-07 * [Flow]^2 + -6.00080308614615E-12* [Flow]^3

5.559E-08	-3.577E-04	9.967E-01
0	0	0
0.97	0.01	
255	17	
0	0	

Second order equation - (see LINEST in excel help documentation for additional explanation)
kW = 0.996651736754111 + -0.000357745857965541 * [Flow] + 5.55941357318836E-08 * [Flow]^2

Inflitration Reduction
(Electric Cooling and Gas Heating)

Description of UCRM: (Data needed: use of space, schedule, inside temperature during cooling season, inside temperature during heating season)

Table AF Area Factors

Location Type	Length (ft)	Old Width (in)	New Width (in)	Adjusted Area[1]
				0
				0
				0
				0
				0
				0
			TOTAL:	50

[1] Adjusted Area = Crack Length (ft) * Δ Crack Width (inches)

Data needed for calculations			Description	Resource
A)	35.7	*Δ in-ft*	Adjusted Area Factor (from Table AF above)	
B)	75/50%RH	*°F*	Avg Inside Temp (DB/WB°F, Cooling Season)	Table 5
C)	79F/63FdP	*°F*	Avg Outside Temp (DB/WB°F, Cooling Season)	Table 5
D)	70	*°F*	Avg Inside Temperature (Heating Season)	Table 5
E)	48	*°F*	Avg Outside Temperature (Heating Season)	Table 5
F)	1872	*hrs/yr*	Annual Cooling System Operating Hours	Table 15
G)	3276	*hrs/yr*	Annual Heating System Operating Hours	Table 16
H)	12.25	*mph*	Avg. Wind Velocity (9 - 12 mph, default 10 mph)	
I)	1	*kW/Ton*	Performance of Cooling System	Table 1
J)	100	*%*	Efficiency of Heating System	Table 3
K)		*$/kWh*	Electrical Energy Rate - Summer	
L)		*$/kWh*	Electrical Energy Rate - Winter	
M)		*$/kW-mo*	Electrical Demand Rate - Summer	
N)		*$/kW-mo*	Electrical Demand Rate - Winter	
O)		*$/Mcf*	Natural Gas Rate	
P)		*mo/yr*	Number of Cooling Months (for demand)	
Q)		*$*	Cost of Project, Including Design	
R)	32.6	*Btu/lbm*	Enthalpy Outside (From Psychrometric Chart Using C)	P. Chart
S)	28.1	*Btu/lbm*	Enthalpy Inside (From Psychrometric Chart Using B)	P. Chart

Calculations

T)	Adjusted Infiltration Rate	=	1.65 * A * H	=	721.6	cfm	
U)	Cooling Energy Savings	=	$\frac{4.5 * T * (R - S) * F}{12{,}000 \text{ Btu/Ton-hr}}$	=	2279.5	Ton-hrs/yr	$ 478.69
V)	Annual Cooling Electrical Energy Savings	=	U * I	=	2279.5	kWh/yr	
W)	Cooling Electrical Demand Savings	=	$\frac{V}{F}$	=	1.2	kW	
X)	Annual Cooling Cost Savings	=	V * (K + L)/2 + W * (M + N)/2 * P	=	0.0	$/yr	
Y)	Heating Energy Savings	=	1.085 * T * (D - E) * G	=	56426688.2	Btu/yr	47258.5328 47.2585328
Z)	Annual Natural Gas Savings	=	$\frac{Y / J}{1{,}030{,}000 \text{ Btu/Mcf}}$	=	54.8	Mcf/yr	$ 362.47
AA)	Annual Heating Cost Savings	=	Z * O	=	0.0	$/yr	
BB)	Annual Cost Savings	=	X + AA	=	0.0	$/yr	
CC)	Simple Payback	=	$\frac{Q}{BB}$	=		yrs	

Ventilation Control
(Electric Cooling and Gas Heating)

Description of UCRM: (Data needed: use of space, schedule, inside temperature during cooling season, inside temperature during heating season)

Data needed for calculations			Description	Resource
A)	35000	*cfm*	Existing Ventilation Rate	
B)	25500	*cfm*	Proposed Ventilation Rate	
C)	75/50%RH	*°F*	Avg Inside Temp (DB/WB°F, Cooling Season)	Table 5
D)	79F/63FdP	*°F*	Avg Outside Temp (DB/WB°F, Cooling Season)	Table 5
E)	70	*°F*	Avg Inside Temperature (Heating Season)	Table 5
F)	48	*°F*	Avg Outside Temperature (Heating Season)	Table 5
G)	1872	*hrs/yr*	Annual Cooling System Operating Hours	Table 15
H)	3276	*hrs/yr*	Annual Heating System Operating Hours	Table 16
I)	1	*kW/Ton*	Performance of Cooling System	Table 1
J)	100	*%*	Efficiency of Heating System	Table 3
K)		*$/kWh*	Electrical Energy Rate - Summer	
L)		*$/kWh*	Electrical Energy Rate - Winter	
M)		*$/kW-mo*	Electrical Demand Rate - Summer	
N)		*$/kW-mo*	Electrical Demand Rate - Winter	
O)		*$/Mcf*	Natural Gas Rate	
P)		*mo/yr*	Number of Cooling Months (for demand)	
Q)		*$*	Cost of Project, Including Design	
R)	32.6	*Btu/lbm*	Enthalpy Inside (From Psychrometric Chart Using C)	P. Chart
S)	28.1	*Btu/lbm*	Enthalpy Outside (From Psychrometric Chart Using D)	P. Chart

Calculations						
T)	Adjusted Ventilation Rate	=	A - B	=	9500.0	cfm
U)	Cooling Energy Savings	=	$\frac{4.5 * T * (R - S) * G}{12{,}000 \text{ Btu/Ton-hr}}$	=	30010.5	Ton-hrs/yr
V)	Annual Cooling Electrical Energy Savings	=	U * I	=	30010.5	kWh/yr
W)	Cooling Electrical Demand Savings	=	$\frac{V}{G}$	=	16.0	kW
X)	Annual Cooling Cost Savings	=	V * (K + L)/2 + W * (M + N)/2 * P	=	0.0	$/yr
Y)	Heating Energy Savings	=	1.085 * T * (E - F) * H	=	742882140.0	Btu/yr
Z)	Annual Natural Gas Savings	=	$\frac{Y / J}{1{,}030{,}000 \text{ Btu/Mcf}}$	=	721.2	Mcf/yr
AA)	Annual Heating Cost Savings	=	Z * O	=	0.0	$/yr
BB)	Annual Cost Savings	=	X + AA	=	0.0	$/yr
CC)	Simple Payback	=	$\frac{Q}{BB}$	=		yrs

$ 6,302.21 30010.5

622179.3467 lbs steam
622.1793467 klbs steam

$ 4,772.12

assumed total cfm	176000	160000
assumed oa cfm	30000	
frac oa	0.1705	30000
required	17000	
%reduction	0.5667	21000
conservative		

9000 cfm savings (distributed based on total design flowrate)

System		OA cfm reduction	fraction of total savings calculated	Cooling Savings	Heating Savings
1g1:		1958	0.2176	$ 1,371.08	$ 1,038.20
2g1:		2635	0.2928	$ 1,845.15	$ 1,397.17
3g1:		829	0.0921	$ 580.50	$ 439.56
3g2:		618	0.0687	$ 432.75	$ 327.69
5g3		468	0.0520	$ 327.71	$ 248.15
5g2:		808	0.0898	$ 565.80	$ 428.43
3RAD:		500	0.0556	$ 350.12	$ 265.12
6g1:		1682	0.1869	$ 1,177.81	$ 891.86
	total	9498			
				$ 6,650.93	$ 5,036.17

assumed total cfi	176000	160000
assumed oa cfm	30000	
frac oa	0.1705	30000
required	17000	
%reduction	0.5667	21000
conservative		

Htg Base	Htg Red	Clg Base	Clg Red
244.94	128.2344	11814.7	6185.3
453.86	172.5729	21891.9	8324
94.637	54.29333	4564.8	2618.8
159.8	40.4744	7708	1952.3
155.87	30.65052	7518.4	1478.4
149.98	52.91799	7234.11	2552.5
529.83	110.1585	25556.3	5313.4
330.74	32.74628	15953	1579.5

9000 cfm savings (distributed based on total design flowrate)

System	OA cfm reduction	fraction of total	Cooling Savings	Heating Savings
1g1:	1958	0.217555556	$ 1,371.08	$ 1,038.20
2g1:	2635	0.292777778	$ 1,845.15	$ 1,397.17
3g1:	829	0.092111111	$ 580.50	$ 439.56
3g2:	618	0.068666667	$ 432.75	$ 327.69
5g3	468	0.052	$ 327.71	$ 248.15
5g2:	808	0.089777778	$ 565.80	$ 428.43
6g1:	1682	0.186888889	$ 1,177.81	$ 891.86
3RAD	500	0.055555556	$ 350.12	$ 265.12
total	9498			
			$ 6,650.93	$ 5,036.17

APPENDIX B
UHAT – GAR RCx Improvement List

Terracon Energy Conservation Oppurtunitites- GAR

				1-3 = HI-LO			
Measure #	Equipment or System	Description	Recommended Improvement	Priority	Responsible Party	Status	Notes
M1.1	Central Plant	HHW Supply temp from HX is set to 160°F.	Program the EMCS to reset supply HHW temp according to OA conditions. Use a linear relationship of 160°F supply HHW temp at 30°F or below OA temp and 90°F at 80°F or above OA temp.	2			
M1.2	Central Plant	CHW Pump 3 is not operational.	Replace or repair existing with new pump.	1			
M2.1	AHU-BG1	OA unit, operates at constant volume during building operating hours.	Install new ABB VFD on Supply fan and static air pressure sensor in supply air duct. Integrate new VFD and sensor with existing ALC controller, if control points are available on controller board. If control points are not available, upgrade controller to allow for additional points.	3			
M2.2	AHU-BG1	AHU filters are dirty and in need of replacement	Replace air filters according to scheduled preventative maintenance plan.	1		COMPLETE	
M3.1	AHU-BG2	Water from CHW&HHW coils was dirty. DP across both coils indicates the unit is having trouble distributing air and keeping up with the load, even at full speed.	AHU is beyond expected useful service life and it is likely the coils have become significantly corroded that replacement will be necessary soon. This unit serves an area with lower occupancy and may not be a priority for replacement.	2			
M4.1	AHU-1G1	OA set to min position unless SA temp is reset according to OA Temp, or if the economizer cycle is activated by EMCS.	Install new CO2 sensors in the return duct of AHU and integrate control point into existing ALC controller, if control point is available on controller board, to reduce ventilation provided to space. If control point is not available, upgrade controller to allow for additional point.	2			
M5.1	AHU-2G1	Fire/Smoke Damper for return fan is shut and preventing AHU from operating optimally	Repair safety fault causing fire/smoke damper to be shut and operate relief/return fans to prevent a similar occurrence in the future. It may be necessary to relocate the manual reset switch for the fire/smoke dmaper if it is not easily accessible.	1			
M5.2	AHU-2G1	OA set to min position unless SA temp is reset according to OA Temp, or if the economizer cycle is activated by EMCS.	Install new CO2 sensors in the return duct of AHU and integrate control point into existing ALC controller, if control point is available on controller board, to reduce ventilation provided to space. If control point is not available, upgrade controller to allow for additional point.	2			
M6.1	AHU-3G1	OA set to min position unless SA temp is reset according to OA Temp, or if the economizer cycle is activated by EMCS.	Install new CO2 sensors in the return duct of AHU and integrate control point into existing ALC controller, if control point is available on controller board, to reduce ventilation provided to space. If control point is not available, upgrade controller to allow for additional point.	2			
M6.2	AHU-3G2	CHW valve reacts rapidly when cooling is needed.	Update supply air reset schedule and select new CHW valve to replace existing CHW valve with proper Cv value to allow for optimal flow.	3			
M7.1	AHU-3G2	OA set to min position unless SA temp is reset according to OA Temp, or if the economizer cycle is activated by EMCS.	Install new CO2 sensors in the return duct of AHU and integrate control point into existing ALC controller, if control point is available on controller board, to reduce ventilation provided to space. If control point is not available, upgrade controller to allow for additional point.	2			
M8.1	AHU-3RAD	OA set to min position unless SA temp is reset according to OA Temp, or if the economizer cycle is activated by EMCS.	Install new CO2 sensors in the return duct of AHU and integrate control point into existing ALC controller, if control point is available on controller board, to reduce ventilation provided to space. If control point is not available, upgrade controller to allow for additional point.	2			
M9.1	AHU-5G2	Piping connections to the CHW&HHW coils are excessively corroded and a low Delta T was measured, indicating the unit is having trouble satisfying the load it serves.	AHU is beyond expected useful service life and it is likely the coils have become significantly corroded that replacement will be necessary soon.	2			
M9.2	AHU-5G2	OA set to min position unless SA temp is reset according to OA Temp, or if the economizer cycle is activated by EMCS.	Install new CO2 sensors in the return duct of AHU and integrate control point into existing ALC controller, if control point is available on controller board, to reduce ventilation provided to space. If control point is not available, upgrade controller to allow for additional point.	2			
M10.1	AHU-5G3	Piping connections to the CHW&HHW coils are excessively corroded and a low Delta T was measured, indicating the unit is having trouble satisfying the load it serves.	AHU is beyond expected useful service life and it is likely the coils have become significantly corroded that replacement will be necessary soon.	2			
M10.2	AHU-5G3	OA set to min position unless SA temp is reset according to OA Temp, or if the economizer cycle is activated by EMCS.	Install new CO2 sensors in the return duct of AHU and integrate control point into existing ALC controller, if control point is available on controller board, to reduce ventilation provided to space. If control point is not available, upgrade controller to allow for additional point.	2			
M11.1	AHU-6G1	OA set to min position unless SA temp is reset according to OA Temp, or if the economizer cycle is activated by EMCS.	Install new CO2 sensors in the return duct of AHU and integrate control point into existing ALC controller, if control point is available on controller board, to reduce ventilation provided to space. If control point is not available, upgrade controller to allow for additional point.	2			
M12.1	AHU-7G1	AHU is constant volume multizone unit with a hot deck/cold deck and 7 individual zones.	AHU is beyond expected useful service life and the constant volume multizone system is a method that is not energy efficient. Replace or retrofit exisiting AHU with new VAV AHU and new VAV terminal units for each individual zone.	2			
M12.2	AHU-7G1	Fan belt is loose and preventing proper distribution of air to zones.	Repair (tighten or replace) fan belt to improve operation of AHU.	1			
M13.1	AHU-7G2	OA unit operates at constant volume during building hours.	Install new ABB VFD on Supply fan and static air pressure sensor in supply air duct. Integrate new VFD and sensor with existing ALC controller, if control points are available on controller board. If control points are not available, upgrade controller to allow for additional points.	3		COMPLETE	This is already in place. We have a VFD and a turn-down mode for this unit when there is no occupancy.
M14.1	ERU	OA damper array/louvers associated with the system do not modulate and excessive amounts of outside air can infiltrate the building.	Replace or repair OA damper array/louvers to close when building is not occupied and open if occupied. ERU is not in use and may also be removed.	1			
M15.1	EMCS-00	VAV controllers are over 27 years old and cannot be directly controlled with EMCS.	Upgrade existing controllers with ALC controllers, new temp sensors, and other new end devices with a phased approach (floor-by-floor) due to age and lack of support available by vendor. This area is a lower occupancy area.	3			
M15.2	EMCS-00	VAV terminal units in the basement (VAV-SV-1 and VAV-FV-2) are having trouble provide the desired air flow setpoints.	The flow settings may be related to the AHU, but if not, the VAV terminal box flow sensors (K-values) may need to be recalibrated to verify proper flow rates.	2			

APPENDIX D
NICHOLSON BUILDING REPORT

MECHANICAL CONSULTING SERVICES

Building Infrastructure Testing Report

Nicholson Building

940 NE 13th Street

Oklahoma City, Oklahoma

April 12, 2021

Project No. FA20P031

Prepared For:

University Hospitals Authority and Trust (UHAT)
940 NE 13th Street
Oklahoma City, Oklahoma 73104

Prepared by:

Terracon Consultants, Inc.
4701 N. Stiles Avenue
Oklahoma City, Oklahoma 73105

April 12, 2021

Mr. Nathan Miller
Building Systems Manager
University Hospitals Authority & Trust
940 NE 13th Street
Oklahoma City, Oklahoma 73104
P: 405-271-4962 x44199
E: Nathan-Miller@uhat.org

Reference: **UHAT**
Building Infrastructure Testing
Nicholson Building
940 NE 13th Street
Oklahoma City, Oklahoma 73104
Project No. FA20P031

Mr. Miller:

Terracon Consultants, Inc. (Terracon) is pleased to submit this Mechanical Consulting Services Report of our Building Infrastructure Testing for the Nicholson Building at 940 NE 13th Street in Oklahoma City, Oklahoma. This work was performed in general accordance with the scope of services outlined in the Terracon Company Proposal for Building Infrastructure Testing & Retro-Commissioning Services dated December 19, 2019 and authorized in February 2020 as identified in the scope section of this Report.

The purpose of this Report is to render our findings, field notes, and recommendations related to our site visits at the above referenced location.

This document includes background information, observations, findings, and recommendations pertaining to the operations of the heating, ventilation, and air conditioning (HVAC) at the site.

Terracon appreciates the opportunity to be of service to you on this project. If you have any questions regarding this report, please do not hesitate to contact us.

Sincerely,

Terracon Consultants, Inc.

Erik Gonzalez, P.E. (TX), CEM
Senior Engineer
Facilities Services

Jeffrey A. Miller, P.E. (OK)
Senior Principal/Senior Engineer
Facilities Services

Terracon Consultants, Inc. 4701 N. Stiles Avenue Oklahoma City, Oklahoma 73105
P (405) 525-0453 terracon.com

Geotechnical ■ Environmental ■ Construction Materials ■ Facilities

TABLE OF CONTENTS

PROJECT OBJECTIVE

The purpose of the Building Infrastructure Testing (BIT) services is to conduct limited visual observations and engineering diagnostics of the HVAC systems. With the observations and measurements obtained, a retro-commissioning plan may be developed from recommended energy conservation opportunities in this report that will help improve performance and reduce the operating costs of the building without compromising comfort for the building occupants.

Terracon's representatives Mr. John Harmon, E.I.T., Mr. Kim Morris QCxP, Mr. Erik Gonzalez, P.E. (TX), CEM and Mr. Jonathan Curtin, P.E. (TX) of Terracon, and our subconsultant, Engineering Systems & Energy Solutions (ES2) conducted site visits on September 14 - 15, 2020 at the Nicholson Building in order to obtain visual and diagnostic information and measurements for the HVAC systems. During the site visits, visual observations were made to note general operating conditions of the HVAC systems. In addition, diagnostic measurements were taken for the air distribution of the eight AHUs, associated chilled water and hot water coils, chilled water distribution pumps, and hot water distribution pumps. Measurements recorded were compared to the design documents and EMCS sensor measurements for air flow and water flow characteristics using the software workstation. Observations were made from readily accessible areas and did not include substantial dismantling of components of the building and HVAC equipment, including walls and closed ceilings. With the observations and measurements, Terracon developed energy conservation opportunity recommendations for improvements to the HVAC systems.

DOCUMENTS AND INFORMATION REVIEWED

Terracon was provided with design documentation for the subject building, utility data for chilled water, steam, and electricity, tariff sheets that breakdown the cost of each utility service, and network access to the *AutomatedLogic Corporation* (*ALC*) *WebCTRL v7.0* energy management control system. The following items were reviewed while performing this assessment:

Document	Source
Various Nicholson Existing MEP Drawings — dated from 1979 (original) to 2012 for a variety of renovations.	Client Provided
Utility Bill Data for Terracon.xlsx – e-mailed to Terracon on February 28, 2020	Client Provided
Utility Service Tariff Sheets for OUHSC and OGE services provided to UHAT – e-mailed to Terracon on March 3, 2020	Client Provided

BUILDING DESCRIPTION AND ENERGY USE BASELINE

The subject property is a six-story medical office building totals approximately 255,675-square feet. The building was originally designed as an outpatient healthcare facility and administrative medical office building. The building was originally constructed around 1979. The HVAC systems were designed to operate with distributed chilled water and distributed steam from a Central Plant associated with the University of Oklahoma Health Science College (OUHSC) at a remote location in downtown Oklahoma City.

The HVAC systems within the building include two chilled water pumps, two heating hot water pumps, and two steam-to-hot water heat exchanger to provide distributed hot water for the HVAC systems. In addition, there are nine variable air volume (VAV) air handling units (AHUs), 40 fan coil units, 96 VAV terminal boxes (TB's), and four exhaust fan systems. All major equipment is controlled and monitored with an *ALC* energy management control system (EMCS) *WebCTRL* (software). The controllers (hardware) are from a variety of different manufacturers including, but not limited to *Johnson Controls, Inc.* (*JCI*) *ALC* and *InvenSys/Seibe* pneumatic controls and have been installed at different times over the years as renovations have been completed.

Table 1: General Building Information

Attributes	***NIC***
Property Manager	***ONECall***
Year Opened	1979
Enclosed Square Feet	255,675
Floors	6
Annual Metered kWh Consumption (2019)	1,293,300
Annual Metered Peak kW Demand	231
Annual Electric $	$77,259
Annual CHW Ton-hrs Consumed (2019)	475,227
Annual Peak Demand Tons	308.8
Average Monthly CHW Temp. Diff. (ºF)	12.731
Annual CHW $	$82,394
Annual Steam klbs Consumed (2019)	3,785
Annual Steam Demand lbs/hr	1,802
Annual Steam Condensate Return (%)	94.17%
Annual Steam Cost $	$29,163
kWh/sqft	5.06
Peak W/sqft	0.90
Electrical Load Factor	63.9%
CHW Ton-hrs/sqft	1.86
Steam kBtu/sqft	17.7
Electrical EUI (kBtu/sqft)	17.3
CHW EUI (kBtu/sqft)	22.3
Total EUI (kBtu/sqft)	57.3
Annual Utility Spend	$188,816
ECI ($/SqFt)	$0.74*
FCI Score	2019 (99) 2021 (98)
Operating Schedule	M-F 7am-10pm NRGY Gym: 6am-9pm PCC: 24/7
Occupied Hours	M-F 7am-5pm NRGY Gym: 6am-9pm PCC: 24/7
EMCS - Energy Management Control System	*ALC - WebCTRL*
Cooling Systems	Chilled Water
Heating Systems	Hot Water
Air Distribution	SZ & VAV with VAV TB's
Outside Air / Ventilation	OA is ducted directly to Return Air Section of AHU’s

To measure the building's energy utilization and current level of efficiency, two Energy Performance Indicators were calculated in this Report as follows:

Energy Utilization Intensity

The Energy Utilization Intensity (EUI) depicts the total annual energy consumption per square foot of building space, and is expressed in "British Thermal Units" (BTUs). To calculate the EUI, the annual consumption of electricity, steam, and chilled water are first converted to equivalent kBTU consumption via the following formulas:

> Total Annual Energy Usage = Total Annual Electrical Energy Usage + Total Annual Steam Energy Usage + Total Annual Chilled Water Energy Usage converted to units of kBTUs/year.
>
> Total Annual Electrical Energy Usage
> [Total kWh /yr.] x [3.412 kBTUs/kWh] = __________ kBTUs / yr.
>
> Total Annual Steam Energy Usage
> [Total klbs /yr.] x [1,196 kBTUs/klbs] = __________ kBTUs / yr.
>
> Total Annual Chilled Water Energy Usage
> [Total Ton/hr /yr.] x [12 kBTUs/hr/Ton/hr] = __________ kBTUs / yr.

The total kBTUs are then divided by the building area.

EUI = [Total annual kBTUs] divided by [Total square feet]

The EUI was compared to the average energy utilization published in the 2012 Commercial Building Energy Consumption Survey (CBECS).

Energy Cost Index

The Energy Cost Index (ECI) depicts the total annual energy cost per square foot building space. To calculate the ECI, the annual costs of electricity, steam, and chilled water are divided by the total square footage of the leased space:

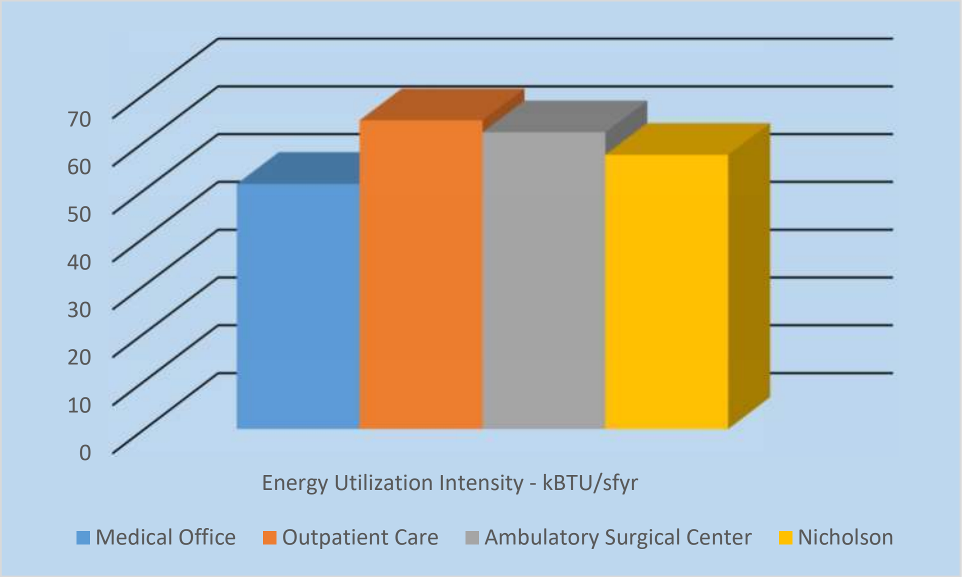
ECI = [Total Energy Cost] divided by [Total square feet]

The ECI was calculated and compared to the statistical average energy cost index published in the 2012 Commercial Building Energy Consumption Survey (CBECS).

The EUI and ECI may be used to compare the facility's approximate usage and cost to other similar facilities in the area. Although the comparisons will not provide specific reasons for unusual operation, they serve as indicators that opportunities may exist by more efficiently operating energy consuming systems.

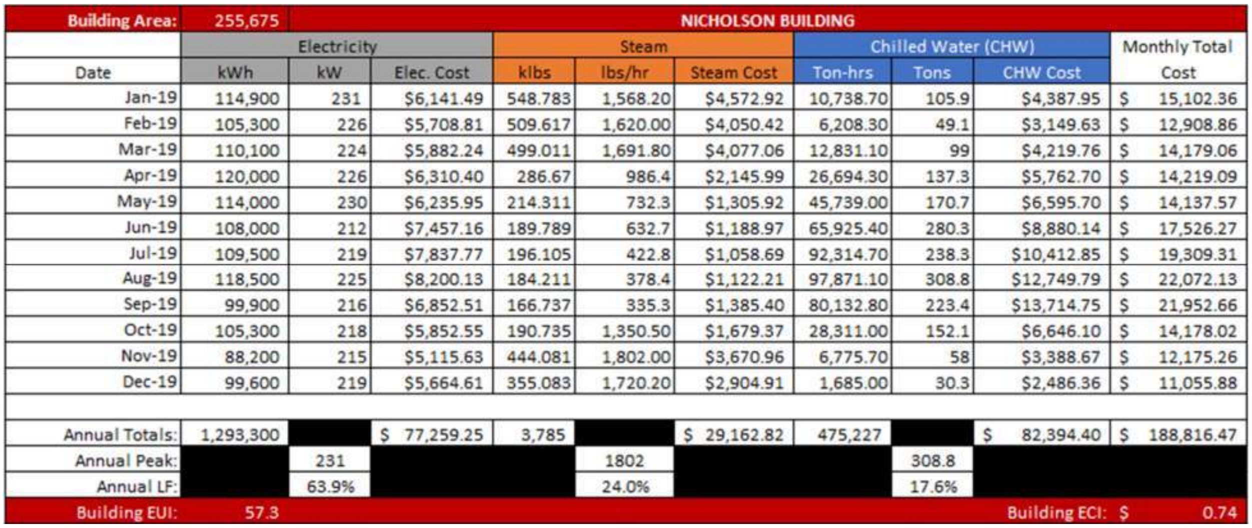
Referring to the 2012 Commercial Building Energy Consumption Survey (CBECS), compiled by the United States Department of Energy, we find the following ranges of comparison with the subject building. The CBECS survey results were based on a national statistical average of a total of 9,941-million square feet reported. The subject site is located within the southwestern section of the United States.

- CBECS utility cost and energy utilization comparison of the EUI and ECI indicates that Nicholson has a **moderately high EUI and ECI** compared to similar facilities in the healthcare category.



Oklahoma Gas and Electric (OGE) and OU Health Science College (OUHSC) are the main energy utility providers for the building. Terracon has analyzed the energy consumption for the building and determined the Energy Usage Index (EUI) is approximately 57.3 kBtu/SQFT and the Energy Cost Index (ECI) is $0.74/SQFT. The annual energy consumption ratio shows that electricity accounts for approximately 30% of total energy consumption, chilled water accounts for approximately 39% of total energy consumption, and steam accounts for the remaining 31% of total energy consumption. Annually, electricity accounts for approximately 41% of the total energy cost, chilled water accounts for approximately 44% of the total energy cost, and steam accounts for the remaining 15% of total energy cost. The annual cost ratios are mostly proportionate from the annual consumption ratios, with the steam cost ratio being much lower than the overall steam energy consumption ratio.

Table 2 – 2019 Energy Use Baseline



Building Area:	255,675	NICHOLSON BUILDING								
	Electricity			Steam			Chilled Water (CHW)			Monthly Total
Date	kWh	kW	Elec. Cost	klbs	lbs/hr	Steam Cost	Ton-hrs	Tons	CHW Cost	Cost
Jan-19	114,900	231	$6,141.49	548.783	1,568.20	$4,572.92	10,738.70	105.9	$4,387.95	$ 15,102.36
Feb-19	105,300	226	$5,708.81	509.617	1,620.00	$4,050.42	6,208.30	49.1	$3,149.63	$ 12,908.86
Mar-19	110,100	224	$5,882.24	499.011	1,691.80	$4,077.06	12,831.10	99	$4,219.76	$ 14,179.06
Apr-19	120,000	226	$6,310.40	286.67	986.4	$2,145.99	26,694.30	137.3	$5,762.70	$ 14,219.09
May-19	114,000	230	$6,235.95	214.311	732.3	$1,305.92	45,739.00	170.7	$6,595.70	$ 14,137.57
Jun-19	108,000	212	$7,457.16	189.789	632.7	$1,188.97	65,925.40	280.3	$8,880.14	$ 17,526.27
Jul-19	109,500	219	$7,837.77	196.105	422.8	$1,058.69	92,314.70	238.3	$10,412.85	$ 19,309.31
Aug-19	118,500	225	$8,200.13	184.211	378.4	$1,122.21	97,871.10	308.8	$12,749.79	$ 22,072.13
Sep-19	99,900	216	$6,852.51	166.737	335.3	$1,385.40	80,132.80	223.4	$13,714.75	$ 21,952.66
Oct-19	105,300	218	$5,852.55	190.735	1,350.50	$1,679.37	28,311.00	152.1	$6,646.10	$ 14,178.02
Nov-19	88,200	215	$5,115.63	444.081	1,802.00	$3,670.96	6,775.70	58	$3,388.67	$ 12,175.26
Dec-19	99,600	219	$5,664.61	355.083	1,720.20	$2,904.91	1,685.00	30.3	$2,486.36	$ 11,055.88
Annual Totals:	1,293,300		$ 77,259.25	3,785		$ 29,162.82	475,227		$ 82,394.40	$ 188,816.47
Annual Peak:		231			1802			308.8		
Annual LF:		63.9%			24.0%			17.6%		
Building EUI:	57.3								Building ECI:	$ 0.74

Chart 1 – Energy Ratio

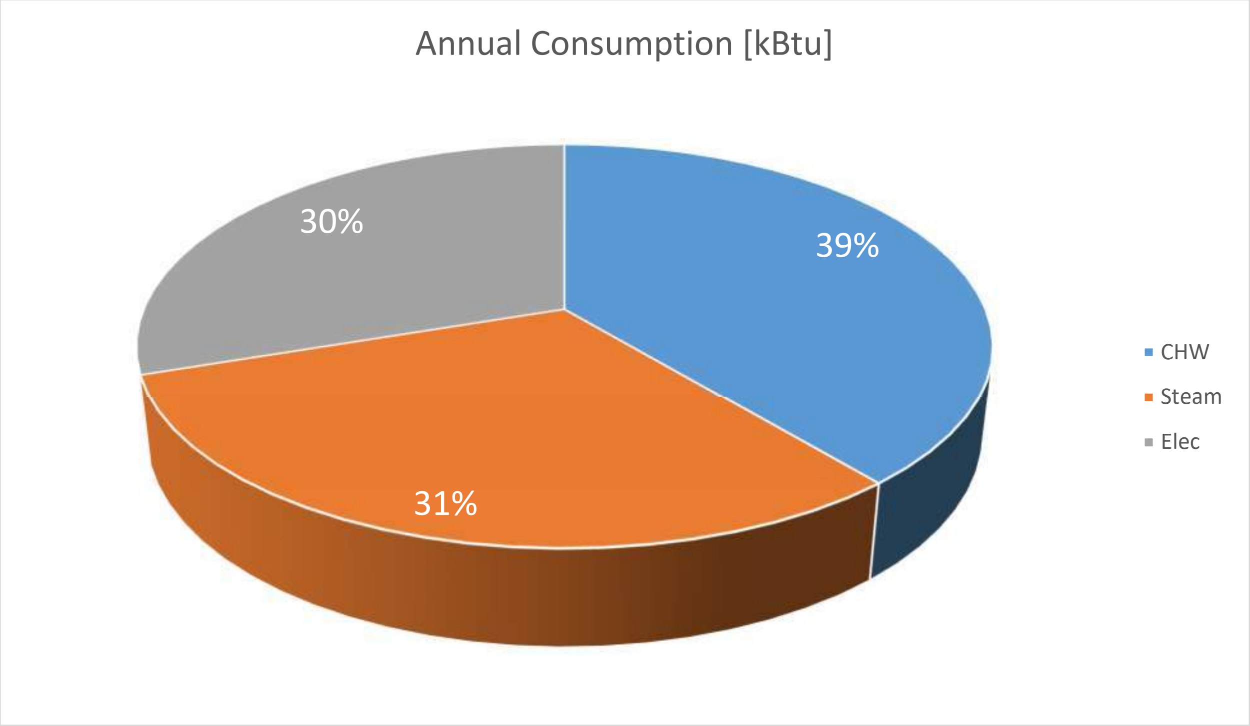
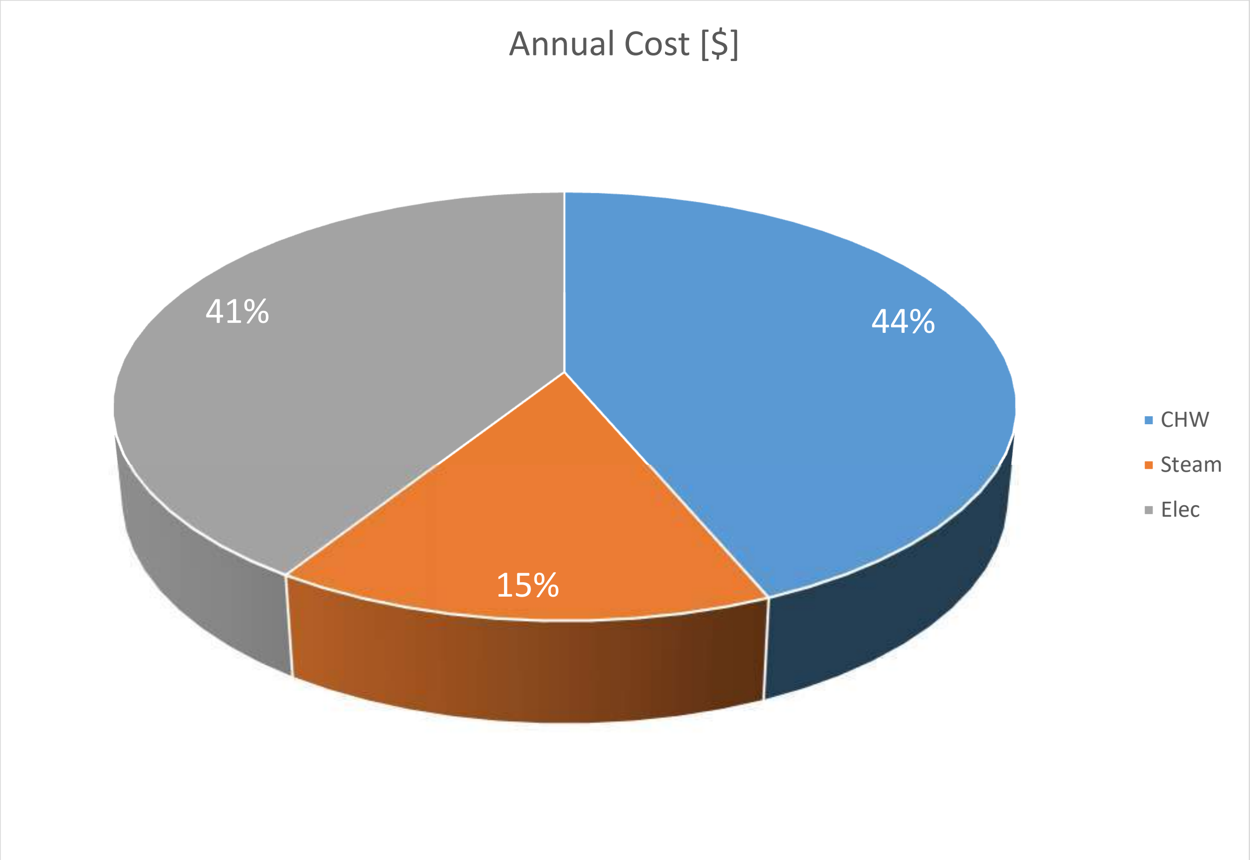


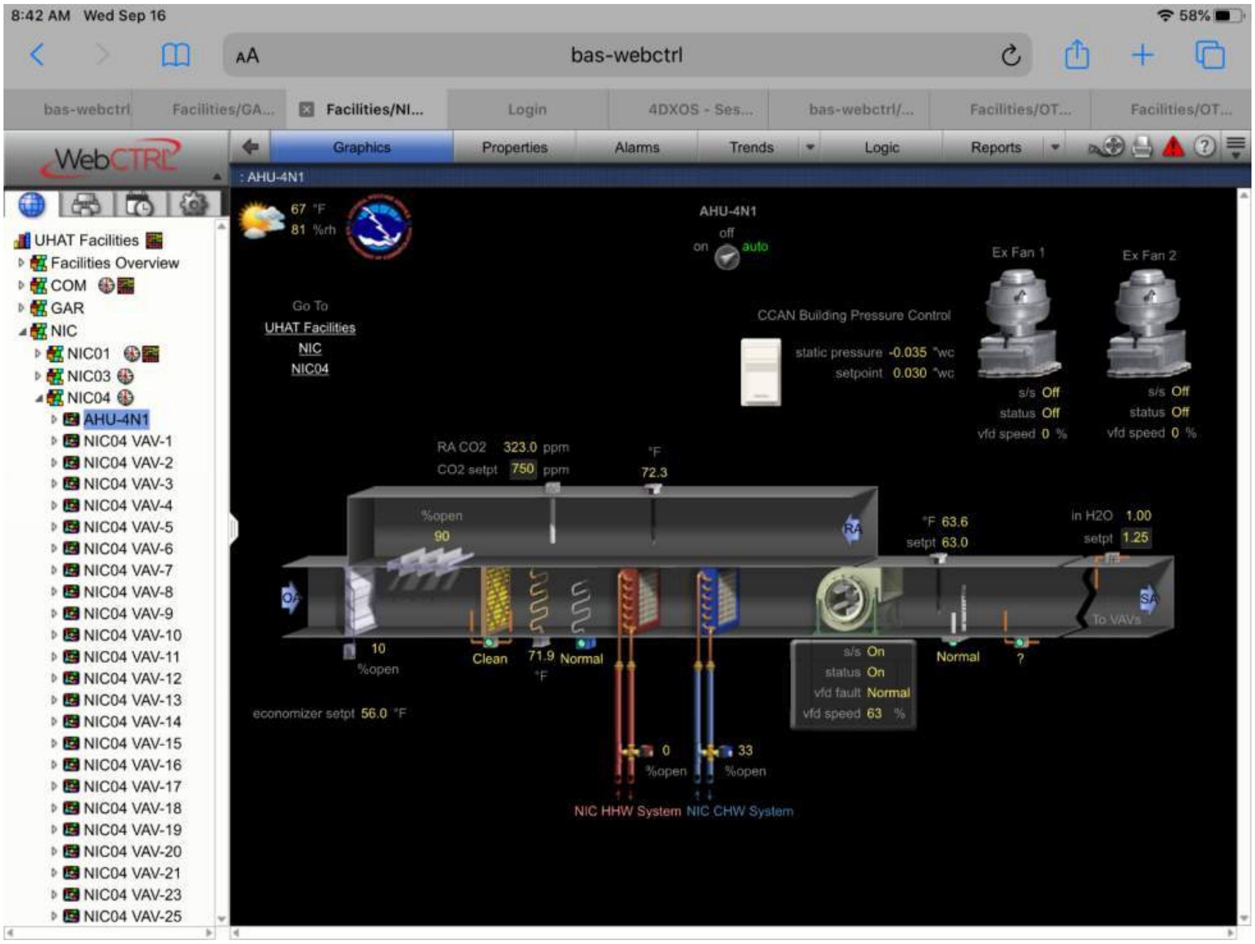
Chart 2 – Energy Cost Ratio



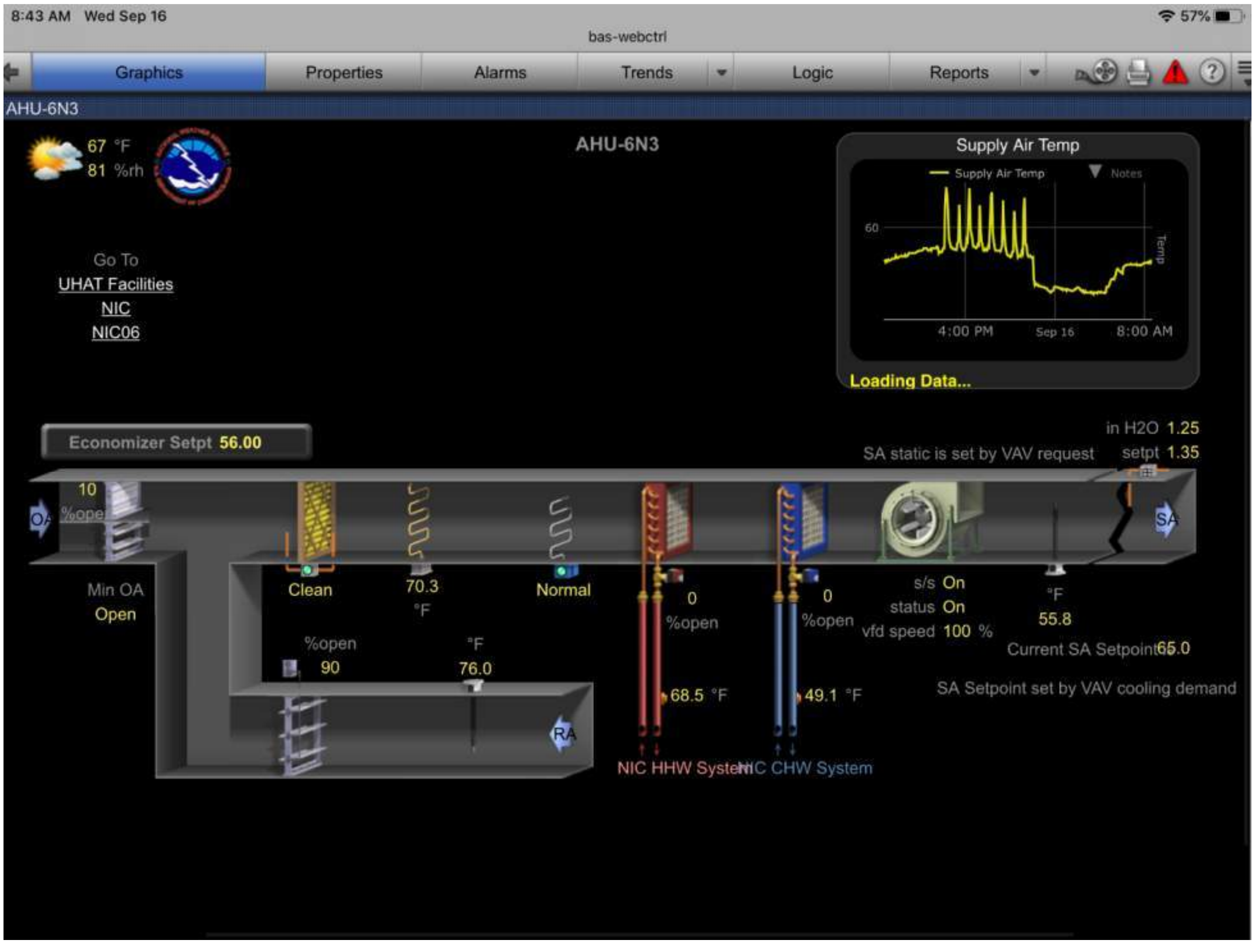
HVAC SYSTEM OBSERVATIONS

During the investigation and pre-task planning portion of this project, Terracon observed a variety of issues that prompted Terracon to investigate further:

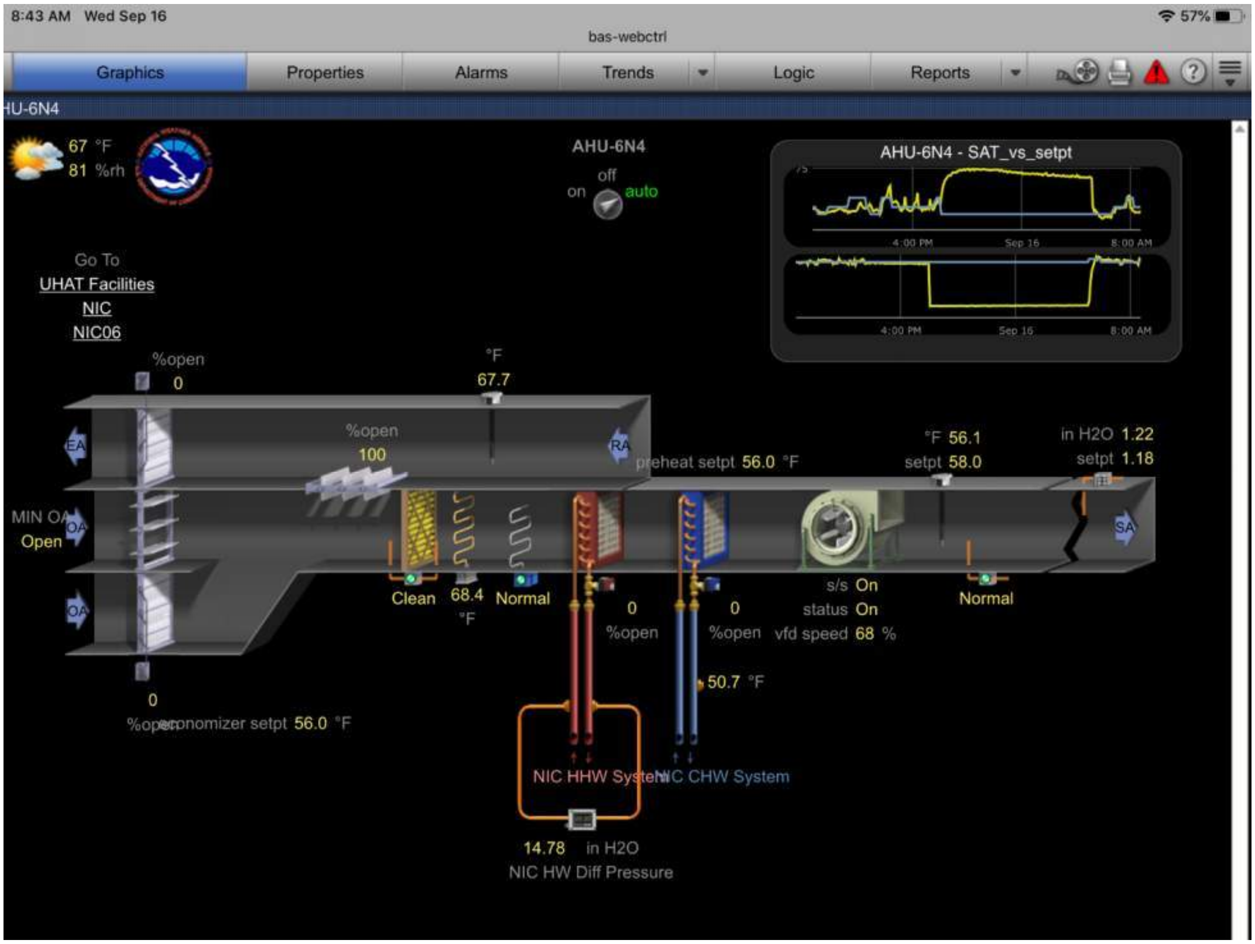
The *ALC WebCTRL* EMCS indicated that AHU 4N1 was having issues maintaining static air pressure setpoint (1.25" w.g.) when the fan speed of the supply air fan was operating at 63%. Supply air temperature setpoint was being met, but static air pressure issues could be indicative of an obstruction (fouled coils or coil corrosion) or duct leakage. The exhaust fans in the mechanical room with AHU 4N1 were off with the outside air damper slightly open at 10%, causing a significant about of negative pressure in the mechanical room from the return plenum.



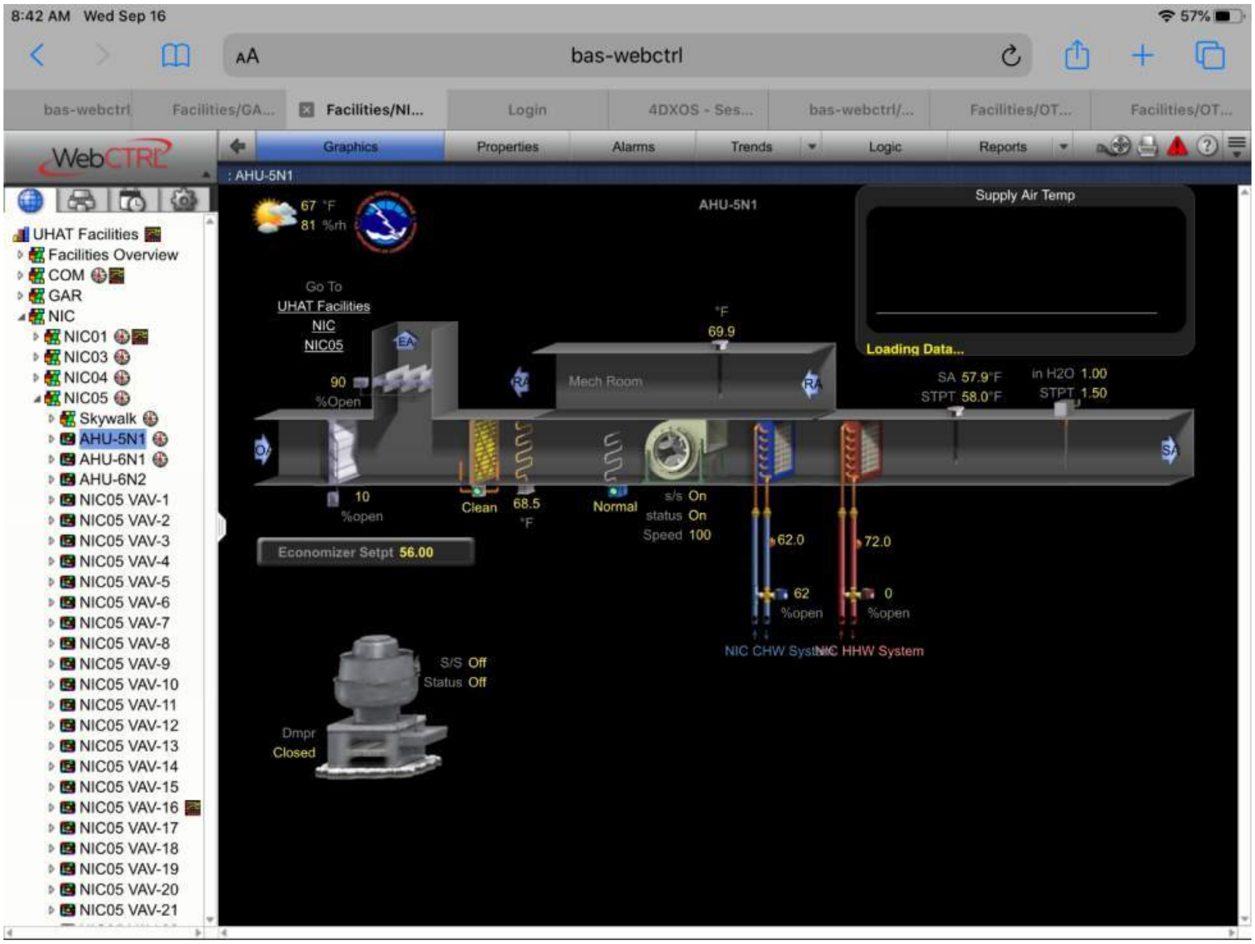
The *ALC WebCTRL* EMCS indicated that AHU 6N3 was having issues maintaining static pressure setpoint (1.35" w.g.) when the fan speed of the supply air fan was operating at 100%. Supply air temperature setpoint was being met, but static air pressure issues could be indicative of an obstruction (fouled coils or coil corrosion) or duct leakage. The AHU serves the majority of the VAV TB's on the fifth floor. An older unit, such as this one, may need a major overhaul or higher priority for capital expenditure replacement in order to improve system performance.



The EMCS also indicated that AHU 6N4 was having issues bypassing chilled water for the chilled water coil when the chilled water control vale was 0% open. The AHU was providing a discharge air temperature lower than the mixed air temperature despite the chilled water control valve being at 0% open.



The EMCS also indicated that AHU 5N1 was having issues maintaining static air pressure setpoint (1.50” w.g.) when the fan speed of the supply air fan was operating at 100%. In addition, the exhaust fan system on the same controller as AHU 5N1 does not appear to be operating, even though the dampers indicate only minimum outside air if being provided. The entering chilled water temperature being measured with the EMCS also indicated that chilled water is being provided at a greater temperature than the discharge air temperature for AHU 5N1. The sensor may be incorrectly monitoring the leaving water temperature instead of the entering water temperature or the sensor may be reading incorrectly, causing the chilled water control valve to open excessively. Independent measurements from the BAS, indicate the entering and leaving temperatures of the chilled water coil are within the generally expected range that the chilled water distribution system is providing to the building.



During the site visits, the Terracon team made the following observations:

1. Terracon observed that the Nicholson Tower has major renovations and construction on-going within the building.
2. The first floor is served by a new FCU and is being re-model and partially used as storage space.
3. A noisy bearing for Heating Hot Water Pump #2 was observed and is in need of repair or replacement for proper operation.
4. Terracon observed new steam piping and a new steam consumption meter being installed.
5. The outside air dampers and actuators in all mechanical rooms were observed and are need of repair, adjustment, or replacement for proper operation.
6. CO2 sensors for the AHUs were observed to be aged and in need of calibration or replacement.
7. AHU 3N2, AHU 3N3, AHU 3N4, AHU 4N1, AHU 5N1, AHU 6N1, AHU 6N3, and AHU 6N4 were all observed to be operating in the “auto” mode.
8. Older controllers and pneumatic end devices were observed and will be require upgrades for optimal operation.
9. Both Heating Hot Water pumps were observed to be operating at higher speeds simultaneously.
10. The mechanical room where AHU 3N2 is located was observed to have a significant amount of negative air pressure. The BAS indicates that the outside air damper for the AHU is 0% open and is likely providing insufficient ventilation.
11. It was observed in the BAS that AHU 6N3 is struggling to maintain the static air pressure setpoint (1.35” w.g.) with the fan speed operating at 100%.
12. It was observed in the BAS that AHU 6N4’s chilled water valve was 0% open with a discharge air temperature of 56degF being provided to the VAV TB’s. The AHU is also having difficulty maintaining a discharge air temperature setpoint of 58degF. The BAS showed outside air and mixed air temperatures were significantly higher than the discharge air temperature, indicating that chilled water may be getting passed the control valve that regulates chilled water flow in the coil.
13. The BAS indicated that the heating hot water and chilled water distribution supply temperatures to the skywalk two-pipe changeover system for the FCU’s were -60.3degF, which appeared to be an error. The changeover setpoint differential temperature between the heating and cooling mode are separated by only 5degF. The typical setpoint differential temperature is 15degF to reduce cycling between heating and cooling modes.
14. It was observed in the BAS that AHU 5N1’s chilled water valve was 62% open and supplying 62degF chilled water to the coil. AHU 5N1 was providing 57.9degF discharge air to the VAV TB’s, despite the chilled water entering the coil at a higher temperature. It’s likely the chilled water temperature sensor is in need of replacement. AHU 5N1 is also struggling to maintain the static air pressure setpoint (1.50” w.g.) with the fan speed operating at 100%.
15. It was observed in the BAS that AHU 4N1 was to operate with demand controlled ventilation sequence but the CO2 level of 290 ppm observed on the BAS appeared to be very low. Sensor likely needs calibration or replacement.
16. The mechanical room where AHU 4N1 is located was observed to have a significant

amount of negative air pressure. The building static pressure was observed to be -0.036 in.w.g. The outside air damper at the AHU was open 10%, and both Exhaust Fan #1 and Exhaust Fan #2 were observed to be stopped (off). AHU 4N1 was also struggling to maintain the static air pressure setpoint (1.25" w.g.) with the fan speed operating at 63%.

17. Multiple VAV TB's appear to require further investigation and potentially re-calibration or replacement of components as follows:
    a. Two VAV terminals (VAV-5 and VAV-6) indicated a 5degF increase in temperature across the heating coil with the HHW valve 0% open. This could be indicative of the control valve not completely closing.
    b. On the 5th floor, VAV-22 indicated only 52 cfm was provided with the damper 100% open and an airflow setpoint of 300 cfm. Space cooling condition was satisfied, and it appeared that the airflow sensor may need re-calibration.
    c. On the 5th floor, VAV-24 indicated only 1042 cfm was provided with the damper 100% open and an airflow setpoint of 1382 cfm. Space cooling condition was also not satisfied, with a space temperature of 74.1degF and a space temperature setpoint of 72degF. External static pressure for the AHU may be too low to have VAV TB reach and maintain temperature and flow setpoints.
    d. On the 5th floor, VAV-33 indicated 433 cfm was provided with the damper is 0% open and an airflow setpoint of 200 CFM. The temperature rise across the heating coil is from 57.5degF to 69.4degF, while the space temperature is satisfied at 70.1degF.

BUILDING INFRASTRUCTURE TESTING

Terracon investigated the discrepancy between the design requirements in the drawings provided and the EMCS readings with an independent air flow instrument provided by our subconsultant TAB firm. The AHU air flow parameters at AHU 6N1, AHU 6N2, AHU 6N3, AHU 6N4, AHU 5N1, AHU 3N2, AHU 3N3, and AHU 3N4 were all measured in a traverse pattern grid that is in accordance with industry TAB standards for HVAC systems.

In addition to supply air flow measurements, Terracon also tested and verified the following:

1. Supply air temperature being distributed to the VAV terminal boxes
2. Entering and leaving water temperatures for each hot water and chilled water coil
3. Entering and leaving water pressures for each hot water and chilled water coil
4. Entering and leaving air pressure for each hot water and chilled water coil section
5. External air pressure (suction and discharge) for each AHU supply fan.

All measurements were taken independent to the EMCS to verify accuracy of the parameters being read by the *ALC webCTRL* system. The accuracy of the measurements are necessary to validate the HVAC systems are meeting the equipment's design performance requirements.

The following information was field measured:

AHU 3N2

Total Supply Air [CFM]	Supply Air Temperature [ºF]	Entering Heating Coil Temperature [ºF]	Leaving Heating Coil Temperature [ºF]	Entering Cooling Coil Temperature [ºF]	Leaving Cooling Coil Temperature [ºF]
15,542	-	120	110	39	71

Heating Coil Delta Air Pressure [in H_2O]	Cooling Coil Delta Air Pressure [in H_2O]	Heating Coil Delta Water Pressure [psig]	Cooling Coil Delta Water Pressure [psig]	External Fan Static Pressure [in H_2O]
-	-	14.7	14.1	1.18

AHU 3N3

Total Supply Air [CFM]	Supply Air Temperature [ºF]	Entering Heating Coil Temperature [ºF]	Leaving Heating Coil Temperature [ºF]	Entering Cooling Coil Temperature [ºF]	Leaving Cooling Coil Temperature [ºF]
6,620	65.3	118	106	42	53

Heating Coil Delta Air Pressure [in H_2O]	Cooling Coil Delta Air Pressure [in H_2O]	Heating Coil Delta Water Pressure [psig]	Cooling Coil Delta Water Pressure [psig]	External Fan Static Pressure [in H_2O]
0.03	0.14	0.4	0.2	1.89

AHU 3N4

Total Supply Air [CFM]	Supply Air Temperature [ºF]	Entering Heating Coil Temperature [ºF]	Leaving Heating Coil Temperature [ºF]	Entering Cooling Coil Temperature [ºF]	Leaving Cooling Coil Temperature [ºF]
8,369	58.7	N/A	N/A	52.9	55.5

Heating Coil Delta Air Pressure [in H_2O]	Cooling Coil Delta Air Pressure [in H_2O]	Heating Coil Delta Water Pressure [psig]	Cooling Coil Delta Water Pressure [psig]	External Fan Static Pressure [in H_2O]
0.02	0.18	1.6	0.7	1.79

AHU 5N1

Total Supply Air [CFM]	Supply Air Temperature [ºF]	Entering Heating Coil Temperature [ºF]	Leaving Heating Coil Temperature [ºF]	Entering Cooling Coil Temperature [ºF]	Leaving Cooling Coil Temperature [ºF]
8,646	-	115	99	39	52

Heating Coil Delta Air Pressure [in H_2O]	Cooling Coil Delta Air Pressure [in H_2O]	Heating Coil Delta Water Pressure [psig]	Cooling Coil Delta Water Pressure [psig]	External Fan Static Pressure [in H_2O]
-	-	13.0	4.6	1.28

AHU 6N1

Total Supply Air [CFM]	Supply Air Temperature [ºF]	Entering Heating Coil Temperature [ºF]	Leaving Heating Coil Temperature [ºF]	Entering Cooling Coil Temperature [ºF]	Leaving Cooling Coil Temperature [ºF]
8,287	-	120.7	108.8	41.0	64.7

Heating Coil Delta Air Pressure [in H_2O]	Cooling Coil Delta Air Pressure [in H_2O]	Heating Coil Delta Water Pressure [psig]	Cooling Coil Delta Water Pressure [psig]	External Fan Static Pressure [in H_2O]
0.14	0.86	4.6	3.5	2.36

AHU 6N2

Total Supply Air [CFM]	Supply Air Temperature [ºF]	Entering Heating Coil Temperature [ºF]	Leaving Heating Coil Temperature [ºF]	Entering Cooling Coil Temperature [ºF]	Leaving Cooling Coil Temperature [ºF]
1,701	-	122	111	43.5	68

Heating Coil Delta Air Pressure [in H_2O]	Cooling Coil Delta Air Pressure [in H_2O]	Heating Coil Delta Water Pressure [psig]	Cooling Coil Delta Water Pressure [psig]	External Fan Static Pressure [in H_2O]
0.11	0.51	4.3	3.6	0.44

AHU 6N3

Total Supply Air [CFM]	Supply Air Temperature [ºF]	Entering Heating Coil Temperature [ºF]	Leaving Heating Coil Temperature [ºF]	Entering Cooling Coil Temperature [ºF]	Leaving Cooling Coil Temperature [ºF]
16,365	-	106.7	91.8	50.8	53.2

Heating Coil Delta Air Pressure [in H_2O]	Cooling Coil Delta Air Pressure [in H_2O]	Heating Coil Delta Water Pressure [psig]	Cooling Coil Delta Water Pressure [psig]	External Fan Static Pressure [in H_2O]
0.36	0.8	-	4.7	1.16

AHU 6N4

Total Supply Air [CFM]	Supply Air Temperature [ºF]	Entering Heating Coil Temperature [ºF]	Leaving Heating Coil Temperature [ºF]	Entering Cooling Coil Temperature [ºF]	Leaving Cooling Coil Temperature [ºF]
9,040	-	125.9	112.2	47.7	54.8

Heating Coil Delta Air Pressure [in H_2O]	Cooling Coil Delta Air Pressure [in H_2O]	Heating Coil Delta Water Pressure [psig]	Cooling Coil Delta Water Pressure [psig]	External Fan Static Pressure [in H_2O]
0.3	0.79	5.2	1.2	1.27

ENERGY CONSERVATION OPPORTUNITIES (ECOs) AND RECOMMENDATIONS

In order to effectively evaluate existing systems and deficiencies and to provide recommended measures, various methods and actions were considered. Considerations include:

- Analysis of existing construction drawings and as-built documentation.
- Analysis of utility bills.
- Conversations with the UHAT personnel regarding HVAC system configuration, controls, and existing trouble spots.
- Collection of information and data from *ALC webCTRL* interface to gather set points, operating conditions, identify anomalies, etc.
- Site surveys and investigations.
- Profiled mechanical equipment (e.g. pumps, chillers, air handling units) affected by the ECO’s so that accurate calculations of savings could be produced.
- For weather dependent systems, bin temperature analysis is to be used to calculate baseline and post-installation consumption.
- For weather independent systems, time-of-use methods were used to calculate baseline and post-installation consumption.

Energy conservation opportunities (ECOs) have been listed on the basis of cost, potential benefit and, most importantly, Owner approval.

ECO Master List

Table 3: Master List

Measure #	Equipment or System	Description of Finding	Recommended Improvement
M 1.1.1.	Central Plant	Chilled Water Distribution Pump differential pressure (dP) setpoints are fixed.	Implement pressure reset control to allow differential pressure setpoint to reset when loads permit. Control dP such that worst case chilled water valve is no more than 85% open.
M 1.2.1.	Central Plant	Heating Hot Water Distribution Pump differential pressure (dP) setpoints are fixed.	Implement pressure reset control to allow differential pressure setpoint to reset downwards when loads permit. Control dP such that worst case heating hot water valve is no more than 85% open.
M 1.2.2.	Central Plant	Noisy operation observed indicative of faulty/worn Heating Hot Water Distribution Pump bearing.	Repair or replace pump bearing.
M 1.3.1.	Central Plant	The heating hot water and chilled water supply distribution temperatures to the skywalk within the two-pipe changeover system for the FCU's were observed to be -60.3degF temperature which appear to be an error.	Calibrate sensor and increase the setpoint differential temperature to 15degF to reduce short cycling between heating and cooling modes.
M 4.1.1.	AHU 3N2	The mechanical room where AHU 3N2 is located was observed to have a significant amount of negative air pressure and outside air damper was set at 0% open.	Identify minimum ventilation requirements for system and adjust damper actuators to properly balance system.
M 5.1.1.	AHU 4N1	CO2 level of 290ppm appears to be very low.	Calibrate or replace CO2 sensor.
M 5.1.2.	AHU 4N1	The building static pressure was observed to be -0.036 in.w.g. The outside air damper was open 10%, and both Exhaust Fan #1 and Exhaust Fan #2 were observed to be stopped (off).	Rebalance system outside air and exhaust requirements. Calibrate building's differential air pressure sensor to a net positive pressure of 0.02 in w.g.
M 6.1.1.	AHU 5N1	Chilled water coil temperature sensor is reading unusually high	Check location of chilled water coil temperature sensor and

		despite discharge air temperature maintaining setpoint.	verify sensor is on the supply side or replace temperature sensor with new calibrated sensor.
M 6.1.2.	AHU 5N1	System struggling to maintain static pressure setpoint.	AHU is beyond expected useful life and independent measurements validate that an obstruction (scale or corrosion) is reducing heat transfer and air flow across the coils. Design and install new AHU for proper heating and cooling loads.
M 7.1.1.	AHU 6N3	System struggling to maintain static pressure setpoint.	AHU is beyond expected useful life and independent measurements validate that an obstruction (scale or corrosion) is reducing heat transfer and air flow across the coils. Design and install new AHU for proper heating and cooling loads.
M 8.1.1.	AHU 6N4	Chilled water coil control valve is allowing chilled water to circulate through the coil when the valve is 0% open.	Recalibrate or replace chilled water valve.

LIMITATIONS

The field observations, tests, findings, and recommendations presented in this report are based upon the information provided to Terracon by the client, UHAT, and observations and field notes collected at the time of our site visits. While additional conditions may exist that could alter our recommendations, we feel that reasonable means have been made to fairly and accurately evaluate the existing conditions of these systems. This report is limited to Terracon's observations of the interior and exterior of the facility. Some of the observations were limited due to obstructions and access to areas of the systems and facility. Although our observations were made with normal care and diligence, it is likely that not all existing conditions were documented. The general intent was to identify representative conditions and provide recommendations based on general findings.

This report has been prepared for the exclusive use of UHAT for specific application to the project discussed and has been prepared in accordance with generally accepted engineering practices using the standard of care and skill currently exercised by professional engineers practicing in this area, for a project of similar scope and nature. No warranties, either expressed or implied, are intended or made. In the event that information described in this document which was provided by others is incorrect, or if additional information becomes available, the recommendations contained in this report shall not be considered valid unless Terracon reviews the information and either verifies or modifies the recommendations of this report in writing.

APPENDIX A
Photographs

Photo #1 Terracon observed the condition and operation of HVAC equipment at the Nicholson Tower.

Photo #2 FCU serving the first floor four pipe system. This floor is being used for storage during an on-going renovation.

Photo #3 Heating Hot Water Distribution Pump #2 has noisy bearings and should be repaired.

Photo #4 New steam piping, valves and usage meters were being installed at the Nicholson Tower.

Photo #5 Chilled Water Distribution Pump #1.

Photo #6 Typical variable speed drive (VFD) serves the chilled water pumps.

Photo#7 Fifth floor booster pump is served by a typical VFD.

Photo #8 OUHSC Steam and Chilled Water Plant controller for collecting data related to utility metering.

Photo #9 AHU 3N3 is a *TRANE* unit manufactured in 1992.

Photo #10 Separate supply and return air fans are used for AHU 3N3 on the third floor.

Photo #11 AHU 3N1 has been abandoned and is not in service.

Photo #12 AHU 3N2 is a *TRANE* unit manufactured in 2010.

Photo #13 AHU 3N4 is a *TRANE* unit manufactured in 1994 that appears to have had the steam coils replaced by hot water coils.

Photo #14 Separate supply and return air fans are used for AHU 3N4 on the third floor.

Photo #15 AHU 4N1 is a *McQuay* unit manufactured in 2011 with a dirty blower section and dirty coils.

Photo #16 Relief air damper and actuator for AHU ventilation requirements.

Photo #17 AHU 5N1 is a *TRANE* unit manufactured in 1979 that has noisy fan bearings.

Photo #18 AHU 6N1 is a *Temtrol* unit.

Photo #19 HVAC **c**ontrollers for AHU 6N1 and the *AAON* FCU, serving the Auditorium were being updated.

Photo #20 AHU 6N3 is a *York* unit manufactured in 1978 with outdated controllers.

Photo #21 AHU 6N4 is a *York* unit manufactured in 1978.

Photo #22 AHU 6N4 controls are outdated and partially operate on pneumatic air controls.

APPENDIX B
Test and Balancing Report

AIR APPARATUS TEST SHEET

Job Name: UHAT Nich. AHU & Roof

Tested By: **Date:** 2/19/2021

DESIGN DATA :

Manufacturer =	TEMTROL	**Model No. =**	ITF-DH16
Type =	AHU	**Serial No. =**	N000303-001-00
Outside Air cfm =			
Total Scheduled cfm =		**Grille Design Schedule cfm =**	
Fan rpm =			
Total Static Pressure =	3.37	**External Static Pressure =**	2.36
Fan Rotation =	CW		

MOTOR DESIGN DATA

Horsepower =	3.0 X2	**Voltage =**	460	**Phase =**	3	**Rpm =**	1760

AIR TEST DATA

Total cfm by Traverse Readings =	8,287	**Total cfm by Grille Readings =**	
Outside Air =		**Return Air =**	

TEMPERATURE TEST DATA

Outside Air Temperature =	**Return Air Temperature =**
Mixed Air Temperature =	

PRESSURE TEST DATA

Fan Suction Static Pressure =		-1.24	
Fan Discharge Static Pressure =		2.13	
	Total Static Pressure =		3.37
External Suction Static Pressure =		-0.31	
External Discharge Static Pressure =		2.05	
	External Static Pressure =		2.36
Cooling Coil ΔS.P. =	1.00	**Heating Coil ΔS.P. =**	1.00
Pre Filters ΔS.P. =		**Final Filters ΔS.P. =**	

MOTOR TEST DATA

Motor Manufacturer / Frame =	TOSHIBA / 182T						
HP =	3.0 X2	**Volts/Ph/Hertz =**	460/3/60	**Act. Voltage =**	479	479	479
Full Load Amps =			8.0	**Act. Amps =**	6.7	6.7	6.7
Service Factor =			1.15				
Motor Design rpm =			1760	**Act motor rpm =**			2089

FAN TEST DATA

Motor Sheave Diameter =	DD	**Motor Sheave Bore =**	DD
Fan Sheave Diameter =	DD	**Fan Sheave Bore =**	DD
Adjustable Sheave Dia. =	DD	**Centerline Distance =**	DD
Fan rpm =	2089	**Fan Rotation =**	CW
Frequency Hz=	71		
Belts =	0		
Pre Filters =	20X20X2 (X6)		
Final Filters =			

Comments: Unit couldn't be traversed due to not having a good traverse place. We took a coil velocity and read 8287 cfm. HW/CHW Coil pressure drops were taken across both coils, no access in between coils.

AIR APPARATUS TEST SHEET

Job Name: UHAT Nich. AHU & Roof
Tested By:
Date: 2/19/2021

DESIGN DATA :

Manufacturer =	AAON	**Model No. =**	H3-BRB-3-0-24HA-11Q
Type =	AHU	**Serial No. =**	202003-CJWB04166
Outside Air cfm =			
Total Scheduled cfm =		**Grille Design Schedule cfm =**	
Fan rpm =			
Total Static Pressure =		**External Static Pressure =**	0.44
Fan Rotation =			

MOTOR DESIGN DATA

Horsepower =	1.3	**Voltage =**	460	**Phase =**	3	**Rpm =**	2580

AIR TEST DATA

Total cfm by Traverse Readings =	1,701	**Total cfm by Grille Readings =**	
Outside Air =		**Return Air =**	

TEMPERATURE TEST DATA

Outside Air Temperature =		**Return Air Temperature =**	
Mixed Air Temperature =			

PRESSURE TEST DATA

Fan Suction Static Pressure =		INA	
Fan Discharge Static Pressure =		INA	
	Total Static Pressure =		#VALUE!
External Suction Static Pressure =		-0.39	
External Discharge Static Pressure =		0.05	
	External Static Pressure =		0.44
Cooling Coil ΔS.P. =		**Heating Coil ΔS.P. =**	
Pre Filters ΔS.P. =		**Final Filters ΔS.P. =**	

MOTOR TEST DATA

Motor Manufacturer / Frame =							
HP =	1.3	**Volts/Ph/Hertz =**	460/3/60	**Act. Voltage =**	492	492	492
Full Load Amps =			1.6	**Act. Amps =**	0.9	0.9	0.9
Service Factor =			INA				
Motor Design rpm =			2580	**Act motor rpm =**			INA

FAN TEST DATA

Motor Sheave Diameter =	DD	**Motor Sheave Bore =**	DD
Fan Sheave Diameter =	DD	**Fan Sheave Bore =**	DD
Adjustable Sheave Dia. =	DD	**Centerline Distance =**	DD
Fan rpm =	INA	**Fan Rotation =**	CW
Frequency Hz=	60		
Belts =	0		
Pre Filters =	16X20X2 X2		
Final Filters =			

Comments: Unit was traversed on the return side post-outside air tap. Total SP was not taken because we did not want to drill into unit next to magnehelics. This also apllies to coil pressure drops.(HW and CW coil are smashed together.

AIR APPARATUS TEST SHEET

Job Name: NICHOLSON Cx TERRACON
Tested By: JACQUEMIN/ROGERS **Date:** 1/11/2021

DESIGN DATA :

Manufacturer =	YORK	**Model No. =**	
Type =		**Serial No. =**	
Outside Air cfm =			
Total Scheduled cfm =		**Grille Design Schedule cfm =**	
Fan rpm =			
Total Static Pressure =		**External Static Pressure =**	
Fan Rotation =			

MOTOR DESIGN DATA

Horsepower =	NG	**Voltage =**	NG	**Phase =**	NG	**Rpm =**	NG

AIR TEST DATA

Total cfm by Traverse Readings =	16,365	**Total cfm by Grille Readings =**	
Outside Air =		**Return Air =**	

TEMPERATURE TEST DATA

Outside Air Temperature =	43.1/33.0	**Return Air Temperature =**	68.1/50.3
Mixed Air Temperature =	67.8/50.1		

PRESSURE TEST DATA

Fan Suction Static Pressure =		-0.75	
Fan Discharge Static Pressure =		0.41	
	Total Static Pressure =		1.16
External Suction Static Pressure =		NTS	
External Discharge Static Pressure =		0.41	
	External Static Pressure =		0.41
Cooling Coil ΔS.P. =	0.50	**Heating Coil ΔS.P. =**	0.50
Pre Filters ΔS.P. =	0.13	**Final Filters ΔS.P. =**	NA

MOTOR TEST DATA

Motor Manufacturer / Frame =		WESTINGHOUSE/284T					
HP =	25	**Volts/Ph/Hertz =**	460/3/60	**Act. Voltage =**	487	487	487
Full Load Amps =			32.5	**Act. Amps =**	17.7	17.7	17.7
Service Factor =			1.15				
Motor Design rpm =			1765	**Act motor rpm =**			

FAN TEST DATA

Motor Sheave Diameter =	INA	**Motor Sheave Bore =**	INA
Fan Sheave Diameter =	INA	**Fan Sheave Bore =**	INA
Adjustable Sheave Dia. =	INA	**Centerline Distance =**	INA
Fan rpm =	INA	**Fan Rotation =**	CW
Frequency Hz= 60			
Belts =			
Pre Filters =			
Final Filters = NA			

Comments: FAN DISCHARGE SP WAS TAKEN SAME PLACE AS EXTERNAL. PRESSURE DROPS WERE TAKEN ACROSS BOTH COILS, COULDN'T GET INDIVIDUAL DROPS.

AIR APPARATUS TEST SHEET

Job Name: NICHOLSON Cx TERRACON
Tested By: **Date:**

DESIGN DATA :

Manufacturer =	YORK	**Model No. =**	CS-217-SH-FCMP
Type =	AHU	**Serial No. =**	NG
Outside Air cfm =	NG		
Total Scheduled cfm =		**Grille Design Schedule cfm =**	9,550
Fan rpm =	NG		
Total Static Pressure =	NG	**External Static Pressure =**	NG
Fan Rotation =	NG		

MOTOR DESIGN DATA

Horsepower =	NG	**Voltage =**	NG	**Phase =**	NG	**Rpm =**	NG

AIR TEST DATA

Total cfm by Traverse Readings =	9,040	**Total cfm by Grille Readings =**	NA
Outside Air =	NA	**Return Air =**	NA

TEMPERATURE TEST DATA

Outside Air Temperature =		**Return Air Temperature =**	
Mixed Air Temperature =			

PRESSURE TEST DATA

Fan Suction Static Pressure =		-1.34	
Fan Discharge Static Pressure =		0.84	
	Total Static Pressure =		2.18
External Suction Static Pressure =		-0.15	
External Discharge Static Pressure =		1.12	
	External Static Pressure =		1.27
Cooling Coil ΔS.P. =	1.09	**Heating Coil ΔS.P. =**	1.09
Pre Filters ΔS.P. =	0.11	**Final Filters ΔS.P. =**	

MOTOR TEST DATA

Motor Manufacturer / Frame =	BALDOR/254T						
HP =	15	**Volts/Ph/Hertz =**	460/3/60	**Act. Voltage =**	441	441	441
Full Load Amps =			18.0	**Act. Amps =**	10.0	10.0	10.0
Service Factor =			1.15				
Motor Design rpm =			1765	**Act motor rpm =**			1696

FAN TEST DATA

Motor Sheave Diameter =	INA	**Motor Sheave Bore =**	INA
Fan Sheave Diameter =	INA	**Fan Sheave Bore =**	INA
Adjustable Sheave Dia. =	INA	**Centerline Distance =**	INA
Fan rpm =	INA	**Fan Rotation =**	INA
Frequency Hz=	57HZ		
Belts =	INA		
Pre Filters =			
Final Filters =	NA		

Comments: COIL DROPS ARE FOR BOTH HW AND CHW.

AIR APPARATUS TEST SHEET

Job Name: UHAT NICH. TERRACON CX
Tested By: OGBURN / ROGERS / HIGGINS **Date:** 2/22/2021

DESIGN DATA :

Manufacturer =	TRANE	**Model No. =**	NL
Type =	M-21B	**Serial No. =**	K79H63547
Outside Air cfm =			
Total Scheduled cfm =		**Grille Design Schedule cfm =**	
Fan rpm =			
Total Static Pressure =		**External Static Pressure =**	
Fan Rotation =			

MOTOR DESIGN DATA

Horsepower =	7 1/2	**Voltage =**	460	**Phase =**	3	**Rpm =**	1745

AIR TEST DATA

Total cfm by Traverse Readings =		**Total cfm by Grille Readings =**	
Outside Air =		**Return Air =**	8,646

TEMPERATURE TEST DATA

Outside Air Temperature =		**Return Air Temperature =**	
Mixed Air Temperature =			

PRESSURE TEST DATA

Fan Suction Static Pressure =		-0.84	
Fan Discharge Static Pressure =		1.05	
	Total Static Pressure =		1.89
External Suction Static Pressure =		-0.23	
External Discharge Static Pressure =		1.05	
	External Static Pressure =		1.28
Cooling Coil ΔS.P. =		**Heating Coil ΔS.P. =**	
Pre Filters ΔS.P. =	0.26	**Final Filters ΔS.P. =**	

MOTOR TEST DATA

Motor Manufacturer / Frame =	GENERAL ELECTRIC / 213T					
HP = 7 1/2	**Volts/Ph/Hertz =**	460/3/60	**Act. Voltage =**	499	499	499
Full Load Amps =		9.0	**Act. Amps =**	8.4	8.4	8.4
Service Factor =		1.15				
Motor Design rpm =		1745	**Act motor rpm =**			

FAN TEST DATA

Motor Sheave Diameter =	7 1/4	**Motor Sheave Bore =**	1 3/8
Fan Sheave Diameter =	11	**Fan Sheave Bore =**	1 7/16
Adjustable Sheave Dia. =		**Centerline Distance =**	20 3/4
Fan rpm =	1150	**Fan Rotation =**	CW
Frequency Hz=	60		
Belts =	2 BX-68		
Pre Filters =			
Final Filters =			

Comments: There is absoultely no suitable traverse locations on this unit for supply, or O/A.Coil velocity was also not an option on this unit to to filter location/layout. The return is open plenum in the mechanical room, which we read with a velgrid at 0% O/A for total. There are no circuit setters on the CW or HW. HW/CW coils are together so no static pressure drop was taken.

AIR APPARATUS TEST SHEET

Job Name: UHAT NICH. TERRACON CX.
Tested By: OGBURN / HIGGINS **Date:** 2/22/2021

DESIGN DATA :

Manufacturer =	TRANE	**Model No. =**	CSAA030UAA00
Type =	AHU	**Serial No. =**	K10D33113
Outside Air cfm =			
Total Scheduled cfm =		**Grille Design Schedule cfm =**	
Fan rpm =			
Total Static Pressure =	1.15	**External Static Pressure =**	1.18
Fan Rotation =	CCW		

MOTOR DESIGN DATA

Horsepower =	15	**Voltage =**	460	**Phase =**	3	**Rpm =**	1765

AIR TEST DATA

Total cfm by Traverse Readings =	15,542	**Total cfm by Grille Readings =**	
Outside Air =		**Return Air =**	

TEMPERATURE TEST DATA

Outside Air Temperature =		**Return Air Temperature =**	73.4/52.9
Mixed Air Temperature =			

PRESSURE TEST DATA

Fan Suction Static Pressure =		-1.15	
Fan Discharge Static Pressure =		INA	
Total Static Pressure =			1.15
External Suction Static Pressure =		-0.12	
External Discharge Static Pressure =		1.06	
External Static Pressure =			1.18
Cooling Coil ΔS.P. =		**Heating Coil ΔS.P. =**	
Pre Filters ΔS.P. =	0.12	**Final Filters ΔS.P. =**	NA

MOTOR TEST DATA

Motor Manufacturer / Frame =	BALDOR / 254T						
HP =	15	**Volts/Ph/Hertz =**	460/3/60	**Act. Voltage =**	413	413	413
Full Load Amps =			17.7	**Act. Amps =**	12.0	12.0	12.0
Service Factor =			1.15				
Motor Design rpm =			1765	**Act motor rpm =**			

FAN TEST DATA

Motor Sheave Diameter =	3 5/8	**Motor Sheave Bore =**	1 3/8
Fan Sheave Diameter =	8	**Fan Sheave Bore =**	1 5/8
Adjustable Sheave Dia. =		**Centerline Distance =**	21
Fan rpm =		**Fan Rotation =**	CCW
Frequency Hz=	51		
Belts =	2 B-62		
Pre Filters =			
Final Filters =	NA		

Comments: AHU was traversed on Supply Duct. HW/CW coils are together so no static pressure drop was taken.Fan dischage static not taken due to air going straight from the fan into the duct.

AIR APPARATUS TEST SHEET

Job Name: UHAT NICH. TERRACON CX.
Tested By: OGBURN / HIGGINS **Date:** 2/22/2021

DESIGN DATA :

Manufacturer =	TRANE	**Model No. =**	MCCA030NBD0A0B00000
Type =	AHU	**Serial No. =**	K92L60536
Outside Air cfm =			
Total Scheduled cfm =		**Grille Design Schedule cfm =**	
Fan rpm =			
Total Static Pressure =	2.54	**External Static Pressure =**	1.89
Fan Rotation =			

MOTOR DESIGN DATA

Horsepower =	25	**Voltage =**	460	**Phase =**	3	**Rpm =**	1770

AIR TEST DATA

Total cfm by Traverse Readings =	6,620	**Total cfm by Grille Readings =**	
Outside Air =		**Return Air =**	6,620

TEMPERATURE TEST DATA

Outside Air Temperature =	NA	**Return Air Temperature =**	61.6/47.5
Mixed Air Temperature =	NA		

PRESSURE TEST DATA

Fan Suction Static Pressure =		-0.91	
Fan Discharge Static Pressure =		1.63	
	Total Static Pressure =		2.54
External Suction Static Pressure =		-0.33	
External Discharge Static Pressure =		1.56	
	External Static Pressure =		1.89
Cooling Coil ΔS.P. =	0.14	**Heating Coil ΔS.P. =**	0.03
Pre Filters ΔS.P. =	0.26	**Final Filters ΔS.P. =**	NA

MOTOR TEST DATA

Motor Manufacturer / Frame =		TOSHIBA / 256T					
HP =	20	**Volts/Ph/Hertz =**	460/3/60	**Act. Voltage =**	360	360	360
Full Load Amps =			25.0	**Act. Amps =**	15.0	15.0	15.0
Service Factor =			1.15				
Motor Design rpm =			1770	**Act motor rpm =**			

FAN TEST DATA

Motor Sheave Diameter =	6 3/8	**Motor Sheave Bore =**	2 1/8
Fan Sheave Diameter =	6 7/8	**Fan Sheave Bore =**	2 5/8
Adjustable Sheave Dia. =		**Centerline Distance =**	18
Fan rpm =		**Fan Rotation =**	CW
Frequency Hz=	45		
Belts =	3 BX52		
Pre Filters =			
Final Filters =	NA		

Comments: There are no circuit setters on the CW or HW. AHU was traversed on the return duct with OA 100% shut.

AIR APPARATUS TEST SHEET

Job Name: UHAT NICH. TERRACON CX.
Tested By: OGBURN / HIGGINS **Date:** 2/22/2021

DESIGN DATA :

Manufacturer =	TRANE	**Model No. =**	
Type =	AHU	**Serial No. =**	
Outside Air cfm =			
Total Scheduled cfm =		**Grille Design Schedule cfm =**	
Fan rpm =			
Total Static Pressure =	2.74	**External Static Pressure =**	1.79
Fan Rotation =			

MOTOR DESIGN DATA

Horsepower =	37	**Voltage =**	460	**Phase =**	3	**Rpm =**	1755

AIR TEST DATA

Total cfm by Traverse Readings =	8,369	**Total cfm by Grille Readings =**	
Outside Air =		**Return Air =**	8,369

TEMPERATURE TEST DATA

Outside Air Temperature =	NA	**Return Air Temperature =**	61.7/47.6
Mixed Air Temperature =	NA		

PRESSURE TEST DATA

Fan Suction Static Pressure =		-1.70	
Fan Discharge Static Pressure =		1.04	
	Total Static Pressure =		2.74
External Suction Static Pressure =		-0.77	
External Discharge Static Pressure =		1.02	
	External Static Pressure =		1.79
Cooling Coil ΔS.P. =	0.18	**Heating Coil ΔS.P. =**	0.02
Pre Filters ΔS.P. =	0.71	**Final Filters ΔS.P. =**	NA

MOTOR TEST DATA

Motor Manufacturer / Frame =		ALL STATE / 286TC					
HP =	30	**Volts/Ph/Hertz =**	460/3/60	**Act. Voltage =**			
Full Load Amps =			37.0	**Act. Amps =**	19.0	19.0	19.0
Service Factor =			1.15				
Motor Design rpm =			1755	**Act motor rpm =**			

FAN TEST DATA

Motor Sheave Diameter =	7 3/8	**Motor Sheave Bore =**	1 3/4
Fan Sheave Diameter =	7	**Fan Sheave Bore =**	2
Adjustable Sheave Dia. =		**Centerline Distance =**	12 1/2
Fan rpm =		**Fan Rotation =**	CW
Frequency Hz=	56		
Belts =	3 B45		
Pre Filters =			
Final Filters =	NA		

Comments: There are no circuit setters on the CW or HW. AHU was traversed on return duct with OA 100% shut.

DUCT TRAVERSE ZONE TOTAL SHEET

Job Name:

Tested By: Jacquemin/Rogers **Date:** 2/19/2021

SERVICE OR DESIGNATION	DUCT			DESIGN	PRELIM	ACTUAL	FINAL	FINAL %	FINAL
	TYPE	SIZE	AREA S.F.	CFM	CFM	Avg Velocity	CFM	of Design	S.P.
AHU-6N3 SA	RECT	81X26	14.625	25572	16365	1119	16365		0.41
AHU-6N4 SA	RECT	60X16	6.67	9550	9040	1356	9040		1.12
AHU-3N2 SA	RECT	68X24	11.3		15542	1371.43	15542		1.06
AHU-3N3 RA	RECT	72X18	9		6620	735	6620		-0.33
AHU-3N4-RA	RECT	42X36	10.5		8369	797	8369		-0.77

COIL APPARATUS TEST REPORT

Job Name: Nicholson Terracon Cx
Tested By: Rogers/Ogburn **Date:** 2/22/2021

COIL DATA				
System Number	6N1	6N1	6N2	6N2
Location	6TH FLOOR	6TH FLOOR	6TH FLOOR	6TH FLOOR
Coil Type	CHW	HW	CHW	HW
No. Rows-Fins/ In.	NG	NG	NG	NG
Manufacturer	NG	NG	NG	NG
Model Number	NG	NG	NG	NG
Serial Number	NG	NG	NG	NG

Air Test Data	DESIGN	ACTUAL	DESIGN	ACTUAL	DESIGN	ACTUAL	DESIGN	ACTUAL
Air Qty., CFM(l/s)	7500	8287	7500	8287	1825	1701	1825	1701
Air Vel. FPM (m/s)	NG	NM	NG	NM	NG	NM	NG	NM
Press. Drop In wg (Pa)	0.86	1.00	0.14	1.00	0.40	0.31	0.10	0.31
Out. Air DB/WB	-	-	-	-	-	-	-	
Ret. Air DB/WB	-	-	-	-	-	-	-	-
Ent. Air DB/WB	NG	INA	NG	INA	NG	INA	NG	INA
Lvg. Air DB/WB	NG	INA	NG	INA	NG	INA	NG	INA
Air ΔT	NG	NA	NG	INA	NG	NA	NG	NA

Water Test Data	DESIGN	ACTUAL	DESIGN	ACTUAL	DESIGN	ACTUAL	DESIGN	ACTUAL
Water Flow, GPM (l/s)	50.0	50.0	29.0	29.0	13.0	13.0	5.0	5.0
Press. Drop PSI (kPa)	6.0	3.5	6.0	4.6	7.2	3.6	3.0	4.3
Ent Water Temp.	42.0	41.0	180.0	120.7	45.0	43.5	180.0	122.0
Lvg. Water Temp.	59.0	64.7	144.0	108.8	70.0	68.0	145.0	111.0
Water ΔT	17.0	23.7	36.0	11.9	25.0	24.5	35.0	11.0

Refrigeration Test	DESIGN	ACTUAL	DESIGN	ACTUAL	DESIGN	ACTUAL	DESIGN	ACTUAL
Exp. Valve/Refrig.	-	-	-	-	-	-	-	-
Refrig. Suction Press.	-	-	-	-	-	-	-	-
Refrig. Suction Temp.	-	-	-	-	-	-	-	-
Inlet Steam Press.	-	-	-	-	-	-	-	-

COMMENTS: **COIL AIR PRESSURE DROPS ARE FOR BOTH HW AND CHW COILS**

COIL APPARATUS TEST REPORT

Job Name: Nicholson Terracon Cx
Tested By: Rogers/Ogburn **Date:** 2/22/2021

COIL DATA				
System Number	6N3	6N3	6N4	6N4
Location	6TH FLOOR	6TH FLOOR	6TH FLOOR	6TH FLOOR
Coil Type	CHW	HW	CHW	HW
No. Rows-Fins/ In.	NG	NG	NG	NG
Manufacturer	NG	NG	NG	NG
Model Number	NG	NG	NG	NG
Serial Number	NG	NG	NG	NG

Air Test Data	DESIGN	ACTUAL	DESIGN	ACTUAL	DESIGN	ACTUAL	DESIGN	ACTUAL
Air Qty., CFM(l/s)	NG	16365	NG	16365	NG	9040	NG	9040
Air Vel. FPM (m/s)	NG	NM	NG	NM	NG	NM	NG	NM
Press. Drop In wg (Pa)	NG	1.16	NG	1.16	NG	1.09	NG	1.09
Out. Air DB/WB	-	-	-	-	-	-	-	
Ret. Air DB/WB	-	-	-	-	-	-	-	-
Ent. Air DB/WB	NG	INA	NG	INA	NG	INA	NG	INA
Lvg. Air DB/WB	NG	INA	NG	INA	NG	INA	NG	INA
Air ΔT	NG	NA	NG	INA	NG	NA	NG	NA

Water Test Data	DESIGN	ACTUAL	DESIGN	ACTUAL	DESIGN	ACTUAL	DESIGN	ACTUAL
Water Flow, GPM (l/s)	NG	NTS	NG	NTS	NG	NTS	NG	NTS
Press. Drop PSI (kPa)	NG	4.7	NG	NTS	NG	1.2	NG	5.2
Ent Water Temp.	NG	50.8	NG	106.7	NG	47.7	NG	125.9
Lvg. Water Temp.	NG	53.2	NG	91.8	NG	54.8	NG	112.2
Water ΔT	NG	2.4	NG	14.9	NG	7.1	NG	13.7

Refrigeration Test	DESIGN	ACTUAL	DESIGN	ACTUAL	DESIGN	ACTUAL	DESIGN	ACTUAL
Exp. Valve/Refrig.	-	-	-	-	-	-	-	-
Refrig. Suction Press.	-	-	-	-	-	-	-	-
Refrig. Suction Temp.	-	-	-	-	-	-	-	-
Inlet Steam Press.	-	-	-	-	-	-	-	-

COMMENTS: **COIL DROPS ARE FOR BOTH HW AND CHW COILS AHU 6N3 DOES NOT HAVE A TEST PORT ON SUPPLY SIDE OF HW**

COIL APPARATUS TEST REPORT

Job Name: UHAT NICH. TERRACON CX
Tested By: OGBURN / ROGERS / HIGGINS **Date:** 2/22/2021

COIL DATA				
System Number	AHU-5N1	AHU-5N1	AHU-3N2	AHU-3N2
Location	5TH FLOOR	5TH FLOOR	3RD FLOOR	3RD FLOOR
Coil Type	CHW	HW	CHW	HW
No. Rows-Fins/ In.	NG	NG	NG	NG
Manufacturer	NG	NG	NG	NG
Model Number	NG	NG	NG	NG
Serial Number	NG	NG	NG	NG

Air Test Data	DESIGN	ACTUAL	DESIGN	ACTUAL	DESIGN	ACTUAL	DESIGN	ACTUAL
Air Qty., CFM(l/s)	NG	8646	NG	8646	NG	15542	NG	15542
Air Vel. FPM (m/s)	NG	NM	NG	NM	NG	NM	NG	NM
Press. Drop In wg (Pa)	NG	INA	NG	INA	NG	INA	NG	INA
Out. Air DB/WB	-	-	-	-	-	-	-	-
Ret. Air DB/WB	-	-	-	-	-	-	-	-
Ent. Air DB/WB	NG	INA	NG	INA	NG	INA	NG	INA
Lvg. Air DB/WB	NG	INA	NG	INA	NG	INA	NG	INA
Air ΔT	NG	INA	NG	INA	NG	INA	NG	INA

Water Test Data	DESIGN	ACTUAL	DESIGN	ACTUAL	DESIGN	ACTUAL	DESIGN	ACTUAL
Water Flow, GPM (l/s)	NG	NO CS	NG	NO CS	NG	NO CS	NG	NO CS
Press. Drop PSI (kPa)	NG	4.6	NG	13.0	NG	0.2	NG	0.4
Ent Water Temp.	NG	39.0	NG	115.0	NG	39.0	NG	120.0
Lvg. Water Temp.	NG	52.0	NG	99.0	NG	71.0	NG	110.0
Water ΔT	NG	13.0	NG	16.0	NG	32.0	NG	10.0

Refrigeration Test	DESIGN	ACTUAL	DESIGN	ACTUAL	DESIGN	ACTUAL	DESIGN	ACTUAL
Exp. Valve/Refrig.	-	-	-	-	-	-	-	-
Refrig. Suction Press.	-	-	-	-	-	-	-	-
Refrig. Suction Temp.	-	-	-	-	-	-	-	-
Inlet Steam Press.	-	-	-	-	-	-	-	-

COMMENTS:

COIL APPARATUS TEST REPORT

Job Name: UHAT NICH. TERRACON CX.
Tested By: OGBURN / HIGGINS **Date:** 2/22/2021

COIL DATA				
System Number	AHU-3N3	AHU-3N3	AHU-3N4	AHU-3N4
Location	3RD FLOOR	3RD FLOOR	3RD FLOOR	3RD FLOOR
Coil Type	CHW	HW	CHW	HW
No. Rows-Fins/ In.	NG	NG	NG	NG
Manufacturer	NG	NG	NG	NG
Model Number	NG	NG	NG	NG
Serial Number	NG	NG	NG	NG

Air Test Data	DESIGN	ACTUAL	DESIGN	ACTUAL	DESIGN	ACTUAL	DESIGN	ACTUAL
Air Qty., CFM(l/s)	NG	6620	NG	6620	NG	8369	NG	8369
Air Vel. FPM (m/s)	NG	NM	NG	NM	NG	NM	NG	NM
Press. Drop In wg (Pa)	NG	0.14	NG	0.03	NG	0.18	NG	0.02
Out. Air DB/WB	-	-	-	-	-	-	-	-
Ret. Air DB/WB	-	-	-	-	-	-	-	-
Ent. Air DB/WB	NG	61.9/47.6	NG	65.3/49.2	NG	63.9/48.4	NG	62.0/47.5
Lvg. Air DB/WB	NG	65.3/49.2	NG	59.1/46.1	NG	58.7/45.8	NG	63.9/48.4
Air ΔT	NG	3.4	NG	6.2	NG	5.2	NG	1.9

Water Test Data	DESIGN	ACTUAL	DESIGN	ACTUAL	DESIGN	ACTUAL	DESIGN	ACTUAL
Water Flow, GPM (l/s)	NG	NO CS	NG	NO CS	NG	NO CS	NG	NO CS
Press. Drop PSI (kPa)	NG	0.7	NG	1.2	NG	0.7	NG	1.6
Ent Water Temp.	NG	42.0	NG	118.0	NG	42.0	NG	117.0
Lvg. Water Temp.	NG	53.0	NG	106.0	NG	64.0	NG	108.0
Water ΔT	NG	11.0	NG	12.0	NG	22.0	NG	9.0

Refrigeration Test	DESIGN	ACTUAL	DESIGN	ACTUAL	DESIGN	ACTUAL	DESIGN	ACTUAL
Exp. Valve/Refrig.	-	-	-	-	-	-	-	-
Refrig. Suction Press.	-	-	-	-	-	-	-	-
Refrig. Suction Temp.	-	-	-	-	-	-	-	-
Inlet Steam Press.	-	-	-	-	-	-	-	-

COMMENTS:

PUMP TEST SHEET

Job Name: UHAT NICH. PUMPS
Tested By: JACQUEMIN / OGBURN / ROGERS **Date:** 2/25/2021

PUMP DATA

Pump Number	1	2	
Manufacturer	PACO	PACO	
Model Number	99364480	99364480	
Serial Number	1971153385-10	1971169954-10	
Impeller Size	9.42	9.42	
Rpm	NG	NG	
Specified gpm	620	620	
Specified Head	70	70	

MOTOR DATA

	Design	Test	Design	Test	Design	Test
Motor Name	BALDOR		BALDOR			
Horsepower	25	25	25	25		
Motor rpm	1770		1770			
Phase	3		3			
Voltage	460	311	460	NR		
		-		-		
		-		-		
Service Factor	1.15		1.15			
Amperage	30.0	18.5	30.0	NR		
		-		-		
		-		-		

TEST RESULTS – CLOSE OFF

Suction Pressure (PSI)	NM	NR	
Discharge Pressure (PSI)	NM	NR	
Differential Pressure (PSI)	NM	NR	
Head (Feet)	NM	NR	

TEST RESULTS - RUNNING

Suction Pressure (PSI)	67.4	NR	
Discharge Pressure (PSI)	86.1	NR	
Differential Pressure (PSI)	18.8	NR	
Head (Feet)	43.4	NR	
Final gpm	NA	NR	
Hz	46Hz	NR	

Comments: PUMP WAS TESTED AT 46HZ DUE TO 4TH FLOOR AHU'S BEING VALVED OFF, IN TURN UHAT DID NOT WANT TO RUN ANY HIGHER

es2 engineered systems & energy solutions, inc.

PUMP TEST SHEET

Job Name: UHAT NICH. PUMPS
Tested By: JACQUEMIN / OGBURN / ROGERS **Date:** 2/25/2021

PUMP DATA

Pump Number	**1**	**2**	
Manufacturer	GRUNDFOS	PACO	
Model Number	11-25957-133P06-2682P	11-25957-133P08-1682B	
Serial Number	99153244	B-170892	
Impeller Size	7.35	7.9	
Rpm	NG	NG	
Specified gpm	220	NG	
Specified Head	45	NG	

MOTOR DATA

	Design	Test	Design	Test	Design	Test
Motor Name	BALDOR		NEMA			
Horsepower	5	5	5	5		
Motor rpm	1750		1765			
Phase	3		3			
Voltage	460	476	460	500		
		-		-		
		-		-		
Service Factor	1.15		1.15			
Amperage	6.7	4.2	6.2	4.3		
		-		-		
		-		-		

TEST RESULTS – CLOSE OFF

Suction Pressure (PSI)	NM	NM	
Discharge Pressure (PSI)	NM	NM	
Differential Pressure (PSI)	NM	NM	
Head (Feet)	NM	NM	

TEST RESULTS - RUNNING

Suction Pressure (PSI)	INA	INA	
Discharge Pressure (PSI)	INA	INA	
Differential Pressure (PSI)	INA	INA	
Head (Feet)	INA	INA	
Final gpm	INA	INA	
Hz	60.0	60.0	

Comments: EXISITING GAUGES CANNOT BE REMOVED TO READ PUMP. GAUGES ARE CALCIFIED AND WILL NOT BREAK FREE. TEMPS WERE TAKEN ON THE WATER, PER ERIKS REQUEST, AT THE DP SENSOR ON THE 6TH FLOOR AS FOLLOWS (106.7 ENT TEMP // 91.8 LEAV TEMP)

APPENDIX E
OKLAHOMA TRANSPLANT REPORT

MECHANICAL CONSULTING SERVICES

Building Infrastructure Testing Report

Oklahoma Transplant Center

940 NE 13th Street

Oklahoma City, Oklahoma

April 12, 2021

Project No. FA20P031

Prepared For:

University Hospitals Authority and Trust (UHAT)
940 NE 13th Street
Oklahoma City, Oklahoma 73104

Prepared by:

Terracon Consultants, Inc.
4701 N. Stiles Avenue
Oklahoma City, Oklahoma 73105

Terracon

April 12, 2021

Mr. Nathan Miller
Building Systems Manager
University Hospitals Authority & Trust
940 NE 13th Street
Oklahoma City, Oklahoma 73104
P: 405-271-4962 x44199
E: Nathan-Miller@uhat.org

Reference: **UHAT**
Building Infrastructure Testing
Oklahoma Transplant Center
940 NE 13th Street
Oklahoma City, Oklahoma 73104
Project No. FA20P031

Mr. Miller:

Terracon Consultants, Inc. (Terracon) is pleased to submit this Mechanical Consulting Services Report of our Building Infrastructure Testing for the Oklahoma Transplant Center at 940 NE 13th Street in Oklahoma City, Oklahoma. This work was performed in general accordance with the scope of services outlined in the Terracon Company proposal for Building Infrastructure Testing & Retro-Commissioning Services dated December 19, 2019 and authorized in February 2020 as identified in the scope section of this Report.

The purpose of this Report is to render our findings, field notes, and recommendations related to our site visits at the above referenced location.

This document includes background information, observations, findings, and recommendations pertaining to the operations of the heating, ventilation, and air conditioning (HVAC) at the site.

Terracon appreciates the opportunity to be of service to you on this project. If you have any questions regarding this report, please do not hesitate to contact us.

Sincerely,

Terracon Consultants, Inc.

Erik Gonzalez, P.E. (TX), CEM
Senior Engineer
Facilities Services

Jeffrey A. Miller, P.E. (OK)
Senior Principal/Senior Engineer
Facilities Services

TABLE OF CONTENTS

PROJECT OBJECTIVE

The purpose of the Building Infrastructure Testing services is to conduct limited visual observations and engineering diagnostics of the HVAC systems. With the observations and measurements obtained, a retro-commissioning plan will be developed from recommended energy conservation opportunities identified in this report that will help improve performance and reduce the operating costs of the building without compromising comfort for the building occupants.

Terracon's representatives, Mr. John Harmon, E.I.T., Mr. Kim Morris QCxP, Mr. Erik Gonzalez, P.E. (TX), CEM, and Mr. Jonathan Curtin P.E. (TX) of Terracon, and our sub-consultant, Engineering Systems & Energy Solutions (ES2), conducted site visits on September 14 - 15, 2020 at the OU Transplant Center in order to obtain visual and diagnostic information and field performance measurements for the HVAC systems. During the site visits, visual observations were made to note general operating conditions of the HVAC systems. In addition, diagnostic measurements were taken for the air distribution of the four AHUs, associated chilled water and hot water coils, chilled water distribution pumps, and hot water distribution pumps. Measurements recorded were compared to the limited design documents provided by UHAT and EMCS sensor measurements of air flow and water flow characteristics using UHAT's software workstation. Observations were made from readily accessible areas and did not include substantial dismantling of components of the building and HVAC equipment, including walls and closed ceilings. With the observations and measurements obtained, Terracon has developed recommendations for energy conservation opportunities and improvements to the HVAC systems.

DOCUMENTS AND INFORMATION REVIEWED

Terracon was provided with as-built documentation for the subject building, utility data for chilled water, steam, and electricity tariff sheets that breakdown the history of costs of each utility service, and network access to the *AutomatedLogic Corporation* (*ALC*) *WebCTRL v7.0* energy management control system. The following items were reviewed while performing this assessment:

Document	Source
Energy Audit Report – Prepared by Engineered Systems & Energy Solutions, Inc.	Client Provided
Modified Mechanical Floor Plans with OTC HVAC Equipment, Duct Work, Supply, Return, and Exhaust Grille Locations	Client Provided
Utility Bill Data for Terracon.xlsx – e-mailed to Terracon on February 28, 2020	Client Provided
Utility Service Tariff Sheets for OUHSC and OGE services provided to UHAT – e-mailed to Terracon on March 3, 2020	Client Provided

BUILDING DESCRIPTION AND ENERGY USE BASELINE

The subject property is a three-story medical office building containing approximately 43,003-square feet. The building was originally designed as an inpatient healthcare facility and has been renovated a number of times over the years. The building was originally constructed around 1985. The HVAC systems were designed to operate with distributed chilled water and distributed steam from a central plant associated with the University of Oklahoma Health Sciences Center (OUHSC) at a remote location in downtown Oklahoma City, Oklahoma.

The HVAC systems within the building include two chilled water pumps, two heating hot water pumps, and one steam-to-hot water heat exchangers to provide distributed chilled and hot water for the HVAC systems. In addition, there are four variable air volume (VAV) air handling units (AHUs), eight fan coil units, 111 VAV terminal boxes, and six exhaust fans. All major equipment is controlled and monitored with an *ALC* energy management control system (EMCS) *WebCTRL* (software). The controllers (hardware) were manufactured by *ALC* and have been installed at various times over the years as renovations have been completed.

Table 1: General Building Information

Attributes	***OTC***
Property Manager	***ONECall***
Year Opened	1985
Enclosed Square Feet	43,003
Floors	4
Annual Metered kWh Consumption (2019)	2,283,900* (91% GAR & 9% OTC)
Annual Metered Peak kW Demand	442* (91% GAR & 9% OTC)
Annual Electric $	$137,698* (91% GAR & 9% OTC)
Annual CHW Ton-hrs Consumed (2019)	134,387
Annual Peak Demand Tons	70.1
Average Monthly CHW Temp. Diff. (ºF)	13.428
Annual CHW $	$22,268
Annual Steam klbs Consumed (2019)	1,434
Annual Steam Demand lbs/hr	578.4
Annual Steam Condensate Return (%)	16.5%
Annual Steam Cost $	$13,641
kWh/sqft	4.78
Peak W/sqft	0.93
Electrical Load Factor	59.0%
CHW Ton-hrs/sqft	3.13
Steam kBtu/sqft	39.9
Electrical EUI (kBtu/sqft)	16.3
CHW EUI (kBtu/sqft)	38.0
Total EUI (kBtu/sqft)	93.7*
Annual Utility Spend	$48,301
ECI ($/SqFt)	$1.12*
FCI Score	2019 (100) 2021 (97)
Operating Schedule	M-Fri 7am-10pm Basement: 6am-5pm
Occupied Hours	M-Fri 7am-4:30pm Basement: 7am-5pm
EMCS - Energy Management Control System	*ALC - WebCTRL*
Cooling Systems	Chilled Water
Heating Systems	Hot Water
Air Distribution	VAV with VAV TB's
Outside Air / Ventilation	OA is ducted directly to into AHU’s

*Electric consumption was estimated based on the calculated ratio of the OTC sqft to the the overall sqft (Garrison Building and OTC) served by the electric meter at the Garrison Building.

To measure the building's energy utilization and current level of efficiency, two Energy Performance Indicators were calculated in this Report as follows:

Energy Utilization Intensity

The Energy Utilization Intensity (EUI) depicts the total annual energy consumption per square foot of building space, and is expressed in "British Thermal Units" (BTUs). To calculate the EUI, the annual consumption of electricity, steam, and chilled water are first converted to equivalent kBTU consumption via the following formulas:

Total Annual Energy Usage = Total Annual Electrical Energy Usage + Total Annual Steam Energy Usage + Total Annual Chilled Water Energy Usage converted to units of kBTUs/year.

Total Annual Electrical Energy Usage
[Total kWh /yr.] x [3.412 kBTUs/kWh] = __________ kBTUs / yr.

Total Annual Steam Energy Usage
[Total klbs /yr.] x [1,196 kBTUs/klbs] = __________ kBTUs / yr.

Total Annual Chilled Water Energy Usage
[Total Ton/hr /yr.] x [12 kBTUs/hr/Ton/hr] = __________ kBTUs / yr.

The total kBTUs are then divided by the building area.

EUI = [Total annual kBTUs] divided by [Total square feet]

The EUI was compared to the average energy utilization published in the 2012 Commercial Building Energy Consumption Survey (CBECS).

Energy Cost Index

The Energy Cost Index (ECI) depicts the total annual energy cost per square foot building space. To calculate the ECI, the annual costs of electricity, steam, and chilled water are divided by the total square footage of the leased space:

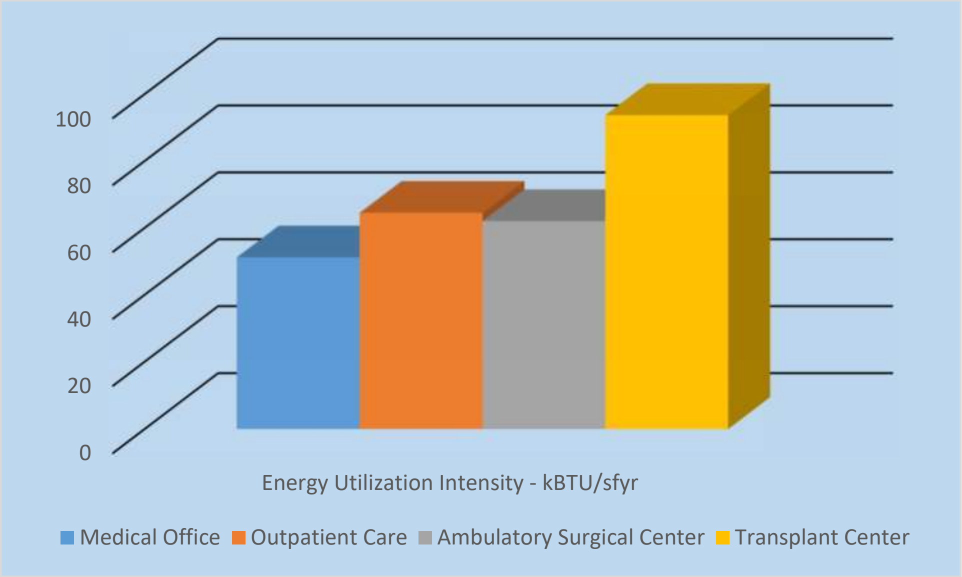
ECI = [Total Energy Cost] divided by [Total square feet]

The ECI was calculated and compared to the statistical average energy cost index published in the 2012 Commercial Building Energy Consumption Survey (CBECS).

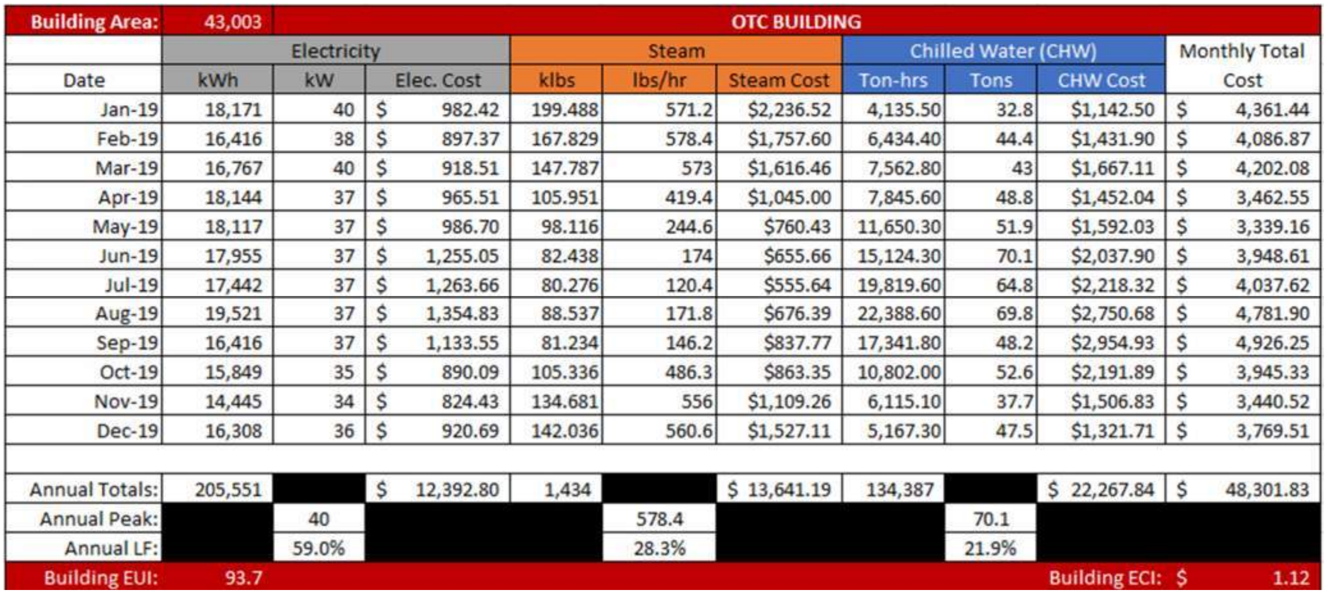
The EUI and ECI may be used to compare the facility's approximate usage and cost to other similar facilities in the area. Although the comparisons will not provide specific reasons for unusual operation, they serve as indicators that opportunities may exist by more efficiently operating energy consuming systems.

Referring to the 2012 Commercial Building Energy Consumption Survey (CBECS), compiled by the United States Department of Energy, we find the following ranges of comparison with the subject building. The CBECS survey results were based on a national statistical average of a total of 9,941-million square feet reported. The subject site is located within the southwestern section of the United States.

- CBECS utility cost and energy utilization comparison of the EUI and ECI indicates that Garrison has a **moderately high EUI and ECI** compared to similar facilities in the healthcare category.



Oklahoma Gas and Electric (OGE) and OU Health Sciences Center (OUHSC) are the main energy utility providers for the building. Terracon has analyzed the energy consumption for the building and determined the Energy Usage Index (EUI) is approximately 93.7 kBtu/SQFT and the Energy Cost Index (ECI) is $1.12/SQFT. The annual energy consumption ratio indicates that electricity accounts for approximately 17% of total energy consumption, chilled water accounts for approximately 40% of total energy consumption, and steam accounts for the remaining 43% of total energy consumption. Annually, electricity accounts for approximately 26% of the total energy cost, chilled water accounts for approximately 46% of the total energy cost, and steam accounts for the remaining 28% of total energy cost. The annual cost ratios are disproportionate from the annual consumption ratios, with the steam cost ratio being much lower than the overall steam energy consumption ratio. Further evaluation of the steam distribution system may be necessary to improve the amount of condensate being returned to the OUHSC distribution center; 16.5% is low and generally 90% or more should be a goal for UHAT.



Building Area:	43,003	OTC BUILDING								
	Electricity			Steam			Chilled Water (CHW)			Monthly Total Cost
Date	kWh	kW	Elec. Cost	klbs	lbs/hr	Steam Cost	Ton-hrs	Tons	CHW Cost	
Jan-19	18,171	40	$ 982.42	199.488	571.2	$2,236.52	4,135.50	32.8	$1,142.50	$ 4,361.44
Feb-19	16,416	38	$ 897.37	167.829	578.4	$1,757.60	6,434.40	44.4	$1,431.90	$ 4,086.87
Mar-19	16,767	40	$ 918.51	147.787	573	$1,616.46	7,562.80	43	$1,667.11	$ 4,202.08
Apr-19	18,144	37	$ 965.51	105.951	419.4	$1,045.00	7,845.60	48.8	$1,452.04	$ 3,462.55
May-19	18,117	37	$ 986.70	98.116	244.6	$760.43	11,650.30	51.9	$1,592.03	$ 3,339.16
Jun-19	17,955	37	$ 1,255.05	82.438	174	$655.66	15,124.30	70.1	$2,037.90	$ 3,948.61
Jul-19	17,442	37	$ 1,263.66	80.276	120.4	$555.64	19,819.60	64.8	$2,218.32	$ 4,037.62
Aug-19	19,521	37	$ 1,354.83	88.537	171.8	$676.39	22,388.60	69.8	$2,750.68	$ 4,781.90
Sep-19	16,416	37	$ 1,133.55	81.234	146.2	$837.77	17,341.80	48.2	$2,954.93	$ 4,926.25
Oct-19	15,849	35	$ 890.09	105.336	486.3	$863.35	10,802.00	52.6	$2,191.89	$ 3,945.33
Nov-19	14,445	34	$ 824.43	134.681	556	$1,109.26	6,115.10	37.7	$1,506.83	$ 3,440.52
Dec-19	16,308	36	$ 920.69	142.036	560.6	$1,527.11	5,167.30	47.5	$1,321.71	$ 3,769.51
Annual Totals:	205,551		$ 12,392.80	1,434		$ 13,641.19	134,387		$ 22,267.84	$ 48,301.83
Annual Peak:		40			578.4			70.1		
Annual LF:		59.0%			28.3%			21.9%		
Building EUI:	93.7								Building ECI:	$ 1.12

Table 2 – 2019 Energy Use Baseline

Chart 1 – Energy Usage Ratio

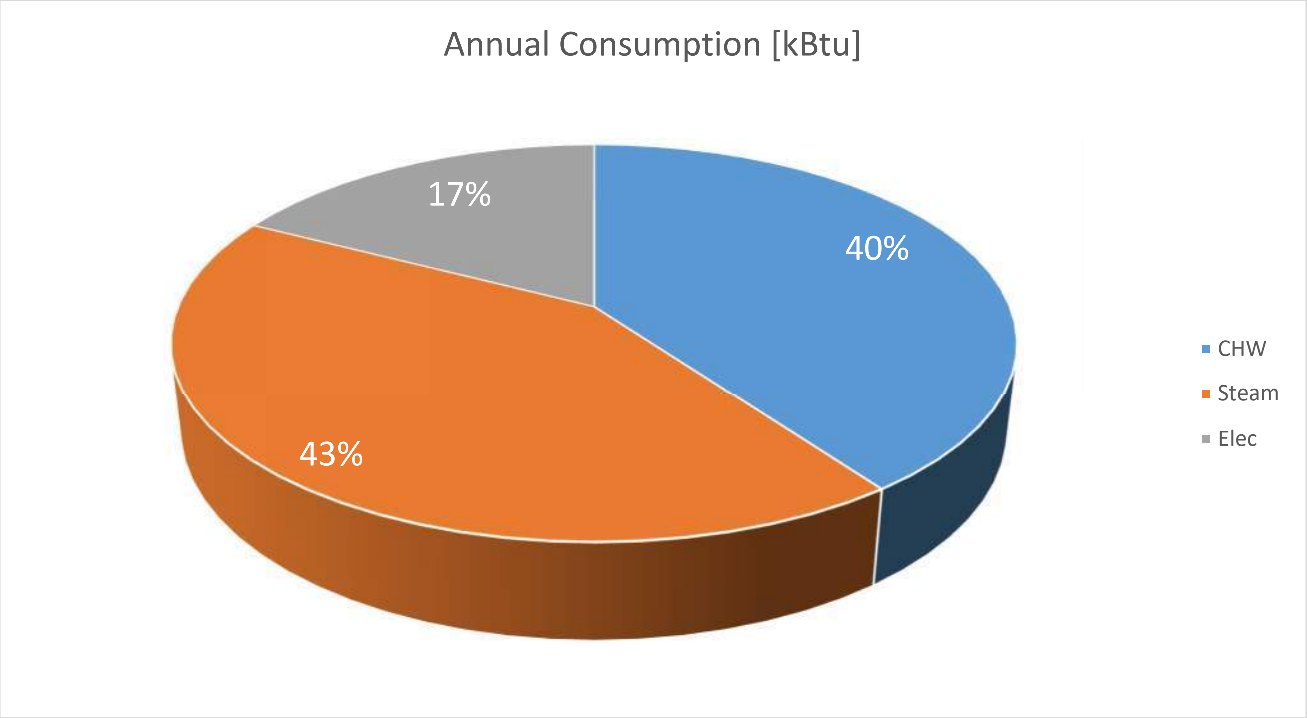
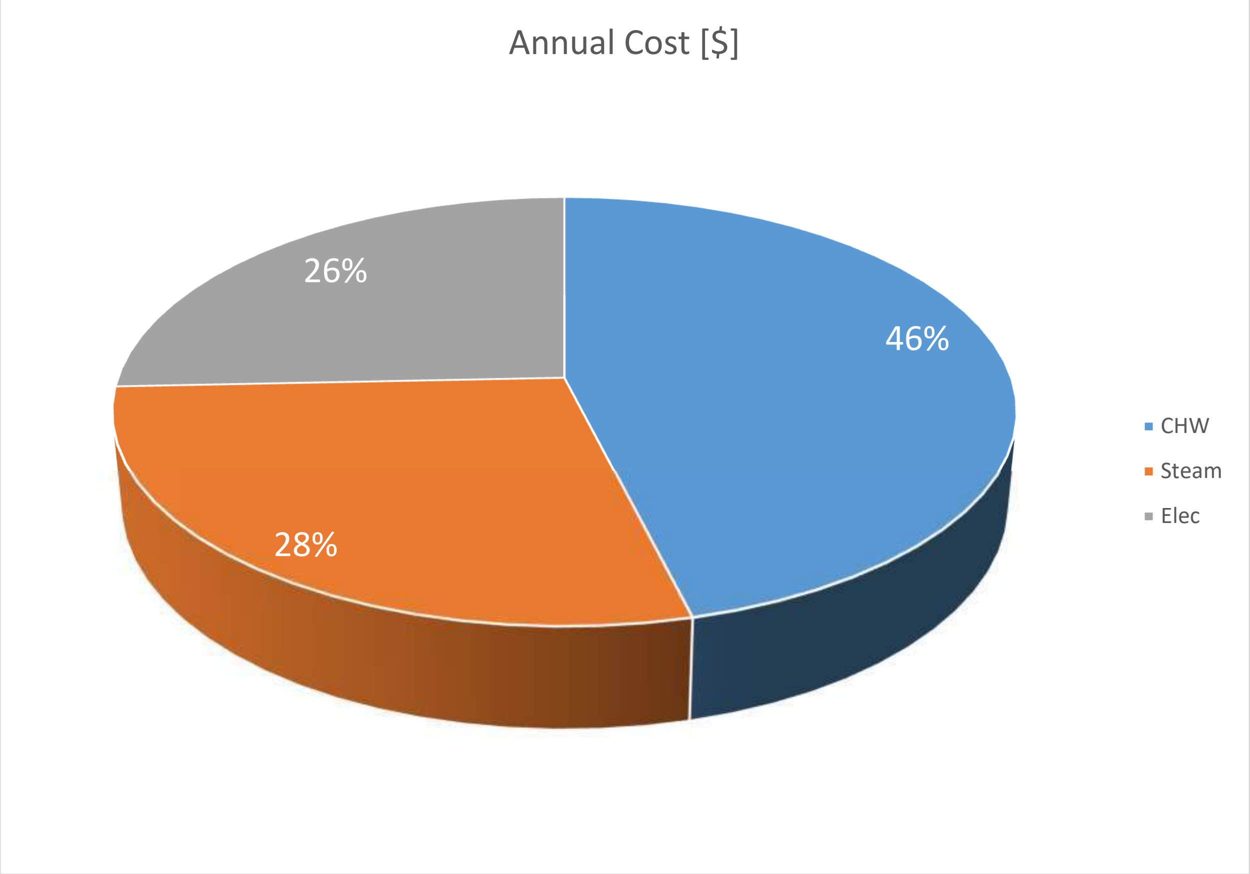


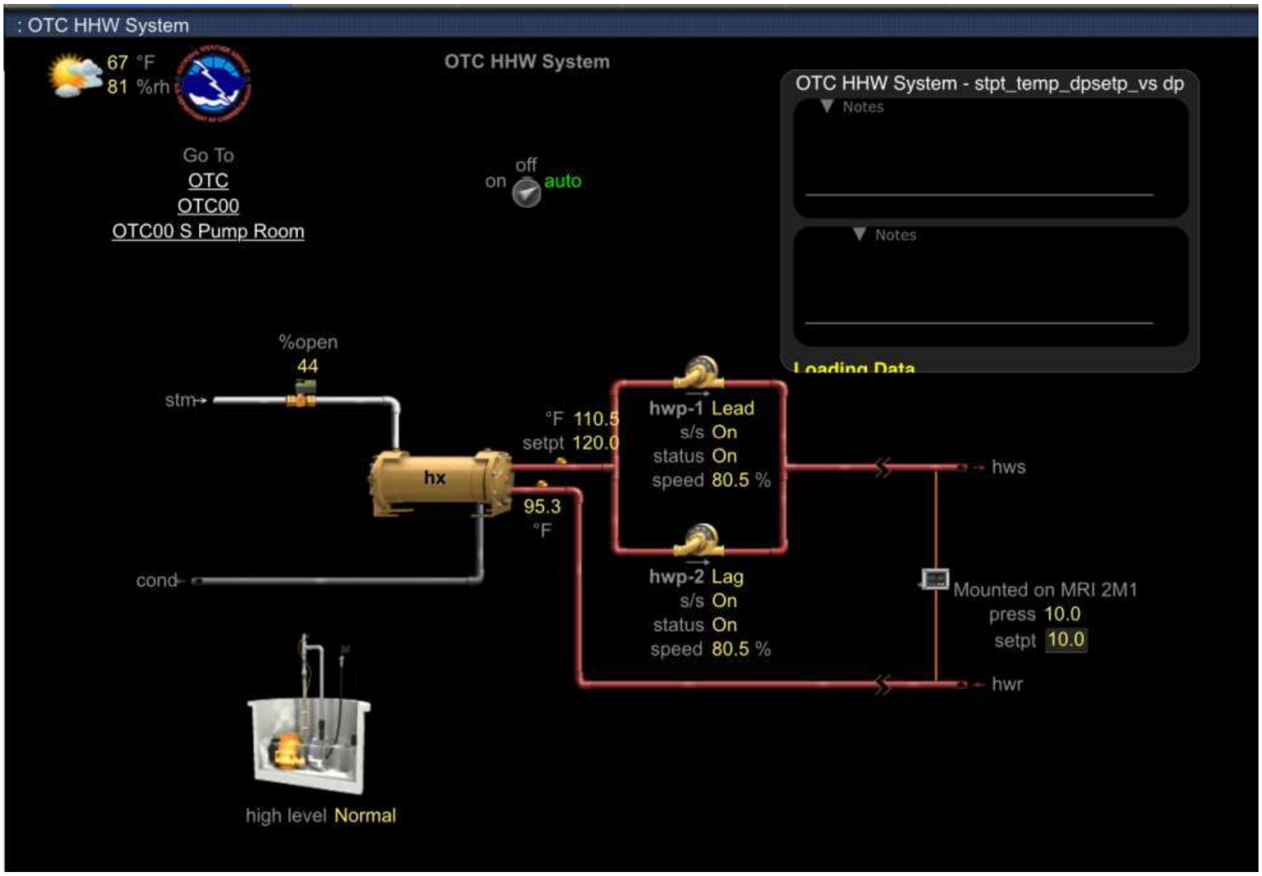
Chart 2 – Energy Cost Ratio



HVAC SYSTEM OBSERVATIONS

During the investigation and pre-task planning portion of this project, Terracon observed a variety of issues that prompted Terracon to investigate further:

The *ALC WebCTRL* EMCS indicated that both heating hot water pumps were operational at 80.5% speed in the morning when the outdoor air temperature was comparable to the indoor temperature and the building was expected to have minimal heating load, and no AHUs were calling for heating hot water. This could be indicative of poor heat transfer for heating coils, valve leak-by/bypass, or excessive differential pressure setpoint in the distributed heating hot water piping.



67 °F
81 %rh

%open 44

°F 110.5
setpt 120.0

95.3 °F

hwp-1 Lead
s/s On
status On
speed 80.5 %

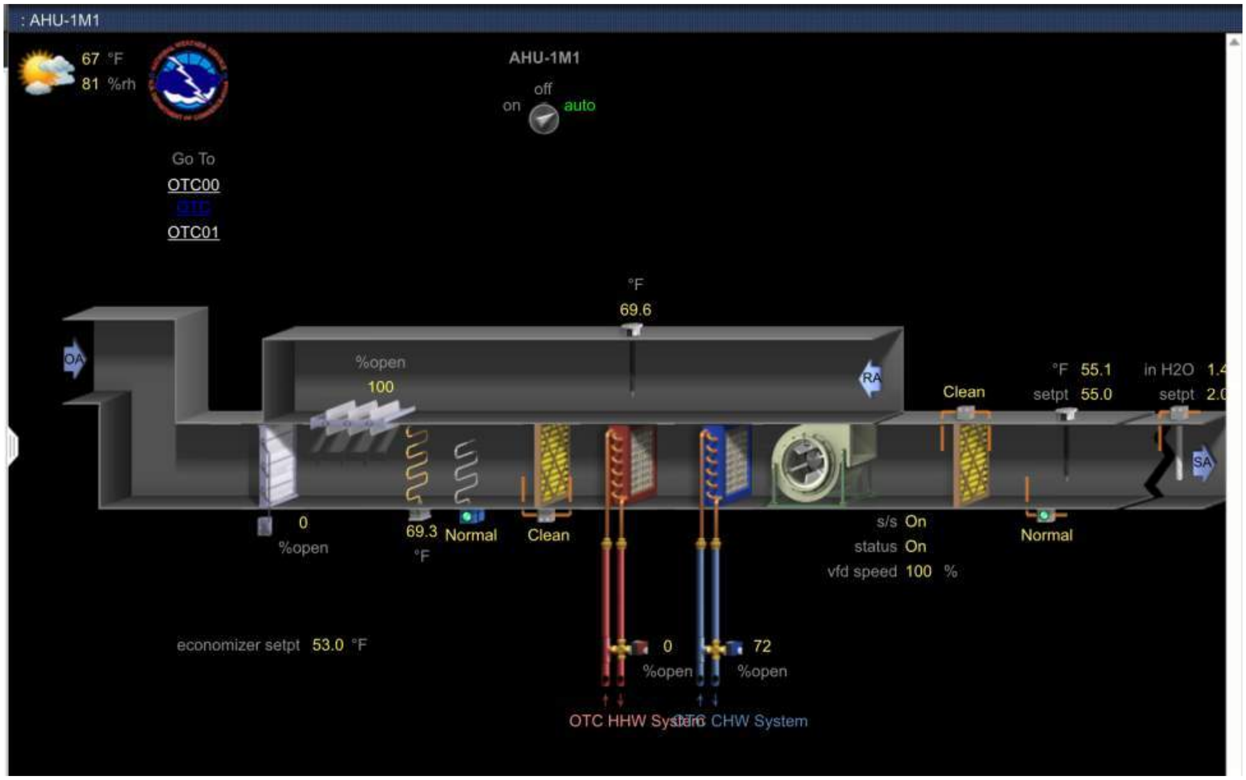
hwp-2 Lag
s/s On
status On
speed 80.5 %

Mounted on MRI 2M1
press 10.0
setpt 10.0

high level Normal

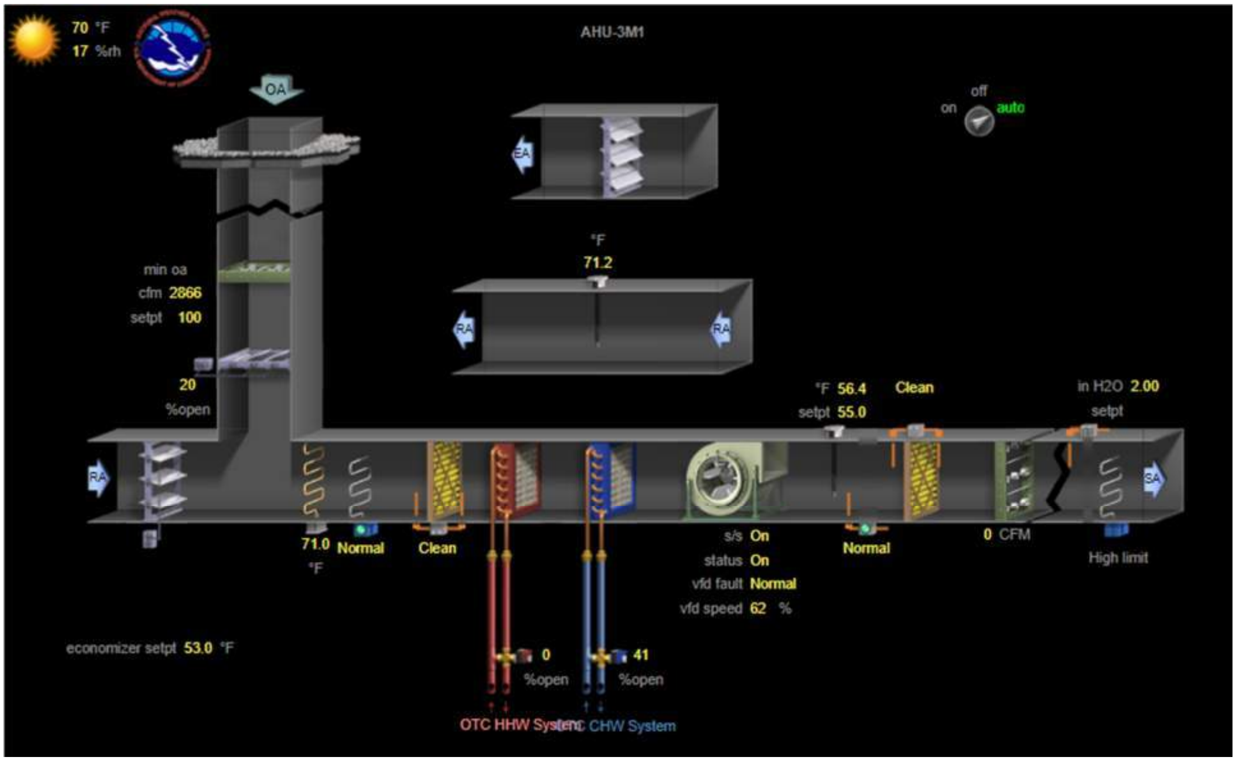
HHW System

Terracon observed AHU 1M1 as having an air static pressure setpoint of 2.0 in.w.g., but only measuring a pressure of 1.4 in.w.g. The system fan speed was operating at 100% during a period where the outdoor conditions were minimally requesting cooling. This is most likely a caused by a lack of air flow across the chilled water and heating hot water coils. Previous notes and measurements taken by ES2 in 2010 indicated that air flow was difficult to measure and static pressure between coils was significantly high due to both water coils being covered in construction dust. More recent measurements in December 2020 were taken via a V*elgrid* inside the AHU across the face of the coil to measure air flow across the coils, since access to measure discharge air was difficult.



AHU-1M1

Terracon also observed AHU 3M1 in operation without a discharge air flow static pressure setpoint indicated on the BAS graphics page. The air flow indicated a measured static pressure of 2.0 in.w.g. This may indicate that discharge air flow of the AHU is being operated independent to the air flow demand required by the VAV TBs. The opportunity to reset air flow to a lower speed during shoulder periods of the year (spring and fall) when the cooling and heating loads are lower than peak periods may be available with a number of programming updates.



AHU-3M1

During the site visits, the Terracon team made the following observations:

1. Terracon observed the heating hot water system pump VFD's and noted that both hot water pumps are required to operate in order to maintain the system's differential pressure setpoint. Both pumps were observed to be operating at 80.5% to maintain a differential pressure of 10.0 psig.
2. The differential pressure sensor for the distributed heating water piping is located on the second floor.
3. The supply hot water heating system setpoint is 120-deg F. The steam valve is showing 44% open while supplying 110.5-deg F with a bit of a lag in response time control.
4. The chilled water system pump VFD's are controlled and set to operate on a lead/lag schedule. The differential pressure sensor setpoint for the chilled water system is 18.0 psig. The measured differential pressure of the system with the indicated at 17.7 psig on the BAS.
5. Terracon observed that FCU-1 is located on the third floor.
6. Terracon personnel observed AHU's BM1, AHU 1M1, AHU 2M1, AHU 3M1 and the FCU

serving the third floor.

7. UHAT personnel indicated that the basement level corridors and hallways have newer controls and VAV TBs that were installed in 2013. This information was verified with BAS drawings provided by UHAT.
8. Terracon observed that the 1/3rd chilled water valve was at 100% open and the 2/3rd chilled water valve was 17% open, while supplying 39.7-deg F chilled water to the AHUs and FCUs. Significant mixing of return chilled water from the building and supply chilled water from the OUHSC provided an entering chilled water temperature to the AHU coils at 46.5-deg F.
9. AHU BM1 was not maintaining discharge setpoint of 58-deg F. The measured temperature was 54-deg F with the cooling coil valve set at 93% open.
10. AHU 1M1 discharge air static pressure setpoint could not be maintained even with the supply fan speed set at 100%. Setpoint was 2.0 in W.C. and measured static pressure was indicated at 1.4 in W.C.
11. AHU 3M1 was missing the discharge air static pressure value setpoint on the graphics page of the EMCS. Discharge air static pressure setpoints displayed on the graphics page would allow the BAS operator to reset the discharge air static pressure setting based on the demand required for air flow by the VAV TBs.
12. The BAS was observed to indicate that AHU 1M1's outside air damper is 0% open and likely not providing adequate ventilation for the area it is serving. Ventilation should be adjusted and balanced to that minimum requirements when the AHU is operational.
13. The BAS was observed to indicate that AHU 2M1's outside air damper is 5% open and likely not providing adequate ventilation for the area it is serving. Ventilation should be adjusted and balanced to that minimum requirements when the AHU is operational.

BUILDING INFRASTRUCTURE TESTING

Terracon investigated various discrepancies between the past operating performance from the documents provided and the EMCS readings with independent air flow instruments provided by our sub-consultant TAB firm. The AHU air flow parameters at AHU BM1, AHU 1M1, AHU 2M1, and AHU 3M1 were all measured in a traverse pattern grid, when applicable, or using a *Velgrid* instrument on the coil face when access to the discharge air ductwork was unavailable. This is in general accordance with industry TAB standards for HVAC systems.

In addition to supply air flow measurements, Terracon and our sub-consultant tested and verified the following:

1. Supply air temperature being distributed to the VAV TBs
2. Entering and leaving water temperatures for each hot water and chilled water coil, where testing ports were available.
3. Entering and leaving water pressures for each hot water and chilled water coil, where testing ports were available.
4. Entering and leaving air pressure for each hot water and chilled water coil section, where access was available.
5. External air pressure (suction and discharge) for each AHU supply fan, where access was available.

All measurements were taken independent to the EMCS to verify accuracy of the parameters being read by the *ALC webCTRL* system. The accuracy of the measurements are necessary to validate that the HVAC systems were meeting the equipment's design performance requirements during our site visit.

The following information was field measured:

AHU BM1

Total Supply Air [CFM]	Supply Air Temperature [ºF]	Entering Heating Coil Temperature [ºF]	Leaving Heating Coil Temperature [ºF]	Entering Cooling Coil Temperature [ºF]	Leaving Cooling Coil Temperature [ºF]
5,715	56.6	-	-	53.4	60.3

Heating Coil Delta Air Pressure [in H_2O]	Cooling Coil Delta Air Pressure [in H_2O]	Heating Coil Delta Water Pressure [psig]	Cooling Coil Delta Water Pressure [psig]	External Fan Static Pressure [in H_2O]
-	0.35	-	19.0	1.77

AHU 1M1

Total Supply Air [CFM]*	Supply Air Temperature [ºF]	Entering Heating Coil Temperature [ºF]	Leaving Heating Coil Temperature [ºF]	Entering Cooling Coil Temperature [ºF]	Leaving Cooling Coil Temperature [ºF]
4,429	54.2	97.3	72.5	46.3	47.8

Heating Coil Delta Air Pressure [in H_2O]	Cooling Coil Delta Air Pressure [in H_2O]	Heating Coil Delta Water Pressure [psig]	Cooling Coil Delta Water Pressure [psig]	External Fan Static Pressure [in H_2O]
0.01	0.54	0.6	8.9	0.73

AHU 2M1

Total Supply Air [CFM]	Supply Air Temperature [ºF]	Entering Heating Coil Temperature [ºF]	Leaving Heating Coil Temperature [ºF]	Entering Cooling Coil Temperature [ºF]	Leaving Cooling Coil Temperature [ºF]
10,350	70.7	101.5	99.2	45.4	65.5

Heating Coil Delta Air Pressure [in H_2O]	Cooling Coil Delta Air Pressure [in H_2O]	Heating Coil Delta Water Pressure [psig]	Cooling Coil Delta Water Pressure [psig]	External Fan Static Pressure [in H_2O]
0.14	1.22	0.9	8.6	0.53

AHU 3M1

Total Supply Air [CFM]*	Supply Air Temperature [ºF]	Entering Heating Coil Temperature [ºF]	Leaving Heating Coil Temperature [ºF]	Entering Cooling Coil Temperature [ºF]	Leaving Cooling Coil Temperature [ºF]
14,965	70.1	84.6	90.2	48.9	52.3

Heating Coil Delta Air Pressure [in H_2O]	Cooling Coil Delta Air Pressure [in H_2O]	Heating Coil Delta Water Pressure [psig]	Cooling Coil Delta Water Pressure [psig]	External Fan Static Pressure [in H_2O]
0.2	0.8	-	10.7	2.09

* = Unit has no suitable traverse locations. Total airflow was read at the cooling coil via velgrid.

ENERGY CONSERVATION OPPORTUNITIES (ECOs) AND RECOMMENDATIONS

In order to effectively evaluate existing HVAC systems and deficiencies and to provide recommended measures, various methods and actions were considered. Considerations include:

- Analysis of existing construction drawings and as-built documentation.
- Analysis of utility bills.
- Conversations with the UHAT personnel regarding HVAC system configuration, controls, and existing trouble spots.
- Collection of information and data from *ALC webCTRL* interface to gather set points, operating conditions, identify anomalies, etc.
- Site surveys and investigations.
- Profiled mechanical equipment (e.g. pumps, chillers, air handling units) affected by the ECO's so that accurate calculations of savings could be produced.
- For weather dependent systems, bin temperature analysis is to be used to calculate baseline and post-installation consumption.
- For weather independent systems, time-of-use methods were used to calculate baseline and post-installation consumption.

ECOs have been listed on the basis of cost, potential benefit and Owner approval.

ECO Master List

Table 3: Master List

Measure #	Equipment or System	Description of Finding	Recommended Improvement
M1.1.1.	CHW Pumps	Pump differential pressure (DP) setpoint is fixed.	Implement differential pressure reset control to allow differential pressure setpoint to reset to a lower differential when cooling loads permit. Control DP such that worst case chilled water valve open is no more than 85%.
M1.1.2	CHW	Chilled water meter is overdue for calibration.	Calibrate chilled water metering system.
M1.2.1.	HHW Pumps	Pump differential pressure (DP) setpoint is fixed. Both heating hot water pumps observed to be operating at 80% speed on moderately warm fall day.	Implement differential pressure reset control to allow differential pressure setpoint to reset lower differential when heating loads permit. Control DP such that worst case heating hot water valve open is no more than 85%.
M1.3.1.	Steam	Steam energy flow meter is overdue for calibration.	Calibrate steam energy flow metering system.
M1.3.2.	Steam	Condensate return for steam system is significantly low.	Conduct a steam system survey to identify deficiencies, such as poorly operational steam traps, valves that are leaking by, and other joint leaks that are impacting low condensate return values to appear on the billing.
M2.1.1.	AHU BM1	AHU appears to be oversized based on fan motor size and UHAT flow restrictions.	AHU is near or beyond the end of useful service life and it is likely that the coils have become significantly scaled

Measure #	Equipment or System	Description of Finding	Recommended Improvement
			from construction dust during a past renovation. The AHU should be replaced with a new unit that has been redesigned with the proper operating parameters to meet the performance of the spaces it serves.
M3.1.1.	AHU 1M1	Ventilation may be inadequate for spaces served when outside air damper is set to 0% open during normal operating and occupancy hours.	Determine the minimum ventilation requirements for the system during operating and occupancy hours and adjust system to provide the proper ventilation required by code in effect.
M3.1.2.	AHU 1M1	AHU appears to be underperforming for air flow requirements based on recent measurements and in comparison to measurements taken in 2010.	AHU is near or beyond end of useful service life and it is likely that the coils have become significantly scaled from construction dust during a past renovation. The AHU should be replaced with a new unit that has been redesigned with the proper operating parameters to meet the performance of the spaces it serves.
M4.1.1.	AHU 2M1	Ventilation may be inadequate for spaces served when outside air damper is set to 0% open during normal operating and occupancy hours.	Determine the minimum ventilation requirements for the system during operating and occupancy hours and adjust system to provide the proper ventilation required by code in effect.
M4.1.2.	AHU 2M1	AHU appears to be underperforming for air flow requirements based on recent measurements and when compared to measurements taken in 2010.	AHU is near or beyond end of useful service life and it is likely that the coils have become significantly scaled from construction dust during a past renovation. The AHU should be replaced with a new unit that has been redesigned with the proper operating parameters to meet the performance of the spaces it.

Measure #	Equipment or System	Description of Finding	Recommended Improvement
M5.1.1.	AHU 3M1	AHU was observed to display discharge air static pressure setpoint value without monitoring value on the *ALC* graphics.	Provide monitoring value on BAS and install new discharge air flow sensor to AHU. Reset discharge air flow static pressure setpoint value to operate and maintain static pressure value based on air flow demand from VAV TB dampers.
M6.1.1.	EFs	Only one of the six exhaust fans are currently controlled and monitored by the *ALC*. Building air pressure should be properly monitored and controlled in critical areas to improve infection prevention control measures.	Provide start/stop; status, and air flow monitoring associated with all exhaust fans in critical areas (EF-1 Basement; EF-180; EF-301).

LIMITATIONS

The field observations, tests, findings, and recommendations presented in this report are based upon the information provided to Terracon by the client, UHAT, and observations and field notes collected at the time of our site visits. While additional conditions may exist that could alter our recommendations, we feel that reasonable means have been made to fairly and accurately evaluate the existing conditions of these systems. This report is limited to Terracon's observations of the interior and exterior of the facility. Some of the observations were limited due to obstructions and access to areas of the systems and facility. Although our observations were made with normal care and diligence, it is likely that not all existing conditions were documented. The general intent was to identify representative conditions and provide recommendations based on general findings.

This report has been prepared for the exclusive use of UHAT for specific application to the project discussed and has been prepared in accordance with generally accepted engineering practices using the standard of care and skill currently exercised by professional engineers practicing in this area, for a project of similar scope and nature. No warranties, either expressed or implied, are intended or made. In the event that information described in this document which was provided by others is incorrect, or if additional information becomes available, the recommendations contained in this report shall not be considered valid unless Terracon reviews the information and either verifies or modifies the recommendations of this report in writing.

APPENDIX A
Photographs

Photo #1 AHU BM1 is a 1985 *TRANE* cooling only AHU.

Photo #2 *Automated Logic Controls* (ALC) controllers have been upgraded since building was originally constructed.

Photo #3 Lead/lag chilled water pumps serve the OTC building.

Photo #4 VFD's controlling chilled water pump #1 and #2.

Photo #5 VFDs with electrical disconnects are utilized for flow control of the heating hot water distribution.

Photo #6 Hot water differential pressure sensors for the building are installed on the second floor.

Photo#7 AHU 1M1 is a VAV multizone unit located in Rm# 1005 first floor.

Photo #8 *TRANE* AHU 2M1 is a 1994 air handling unit serving the second floor of the OTC. S# K94J67844.

Photo #9 AHU 3M1 is a *Temtrol* unit serving the third floor.

Photo #10 AHU 3M1 gear tag. Model number WF8H25M; serial number 61878.

Photo #11 VFD serving AHU 3M1.

Photo #12 AHU 3MI has return air damper control along with outside air control dampers and actuators.

APPENDIX B
Test and Balancing Report

AIR APPARATUS TEST SHEET

Job Name: UHAT Cx OTC
Tested By: OGBURN/HIGGINS **Date:** 12/19/2020

DESIGN DATA :

Manufacturer =	TRANE	**Model No. =**	CCDB25EE0
Type =	AHU	**Serial No. =**	K85J71866
Outside Air cfm =			
Total Scheduled cfm =		**Grille Design Schedule cfm =**	
Fan rpm =			
Total Static Pressure =	2.00	**External Static Pressure =**	1.77
Fan Rotation =	NG		

MOTOR DESIGN DATA

Horsepower =	20	**Voltage =**	460	**Phase =**	3	**Rpm =**	1770

AIR TEST DATA

Total cfm by Traverse Readings =	5,715	**Total cfm by Grille Readings =**	
Outside Air =		**Return Air =**	

TEMPERATURE TEST DATA

Outside Air Temperature =	42.6	**Return Air Temperature =**	68.5
Mixed Air Temperature =	56.6		

PRESSURE TEST DATA

Fan Suction Static Pressure =		-0.39	
Fan Discharge Static Pressure =		1.94	
	Total Static Pressure =		2.33
External Suction Static Pressure =		0.02	
External Discharge Static Pressure =		1.94	
	External Static Pressure =		1.77
Cooling Coil ΔS.P. =	0.35	**Heating Coil ΔS.P. =**	NTS
Pre Filters ΔS.P. =	0.10	**Final Filters ΔS.P. =**	1.70

MOTOR TEST DATA

Motor Manufacturer / Frame =	WORLDWIDE / 256T					
HP = 20	**Volts/Ph/Hertz =**	460/3/60	**Act. Voltage =**	460	460	460
Full Load Amps =		NG	**Act. Amps =**	12.4	12.4	12.4
Service Factor =		1.15				
Motor Design rpm =		1770	**Act motor rpm =**			1769

FAN TEST DATA

Motor Sheave Diameter =	7 1/2"	**Motor Sheave Bore =**	4"
Fan Sheave Diameter =	11 1/2"	**Fan Sheave Bore =**	4"
Adjustable Sheave Dia. =		**Centerline Distance =**	
Fan rpm =	1769	**Fan Rotation =**	CW
Frequency Hz=	46.3		
Belts =	3 BX75		
Pre Filters =			
Final Filters =			

Comments: Due to unit being oversized, UHAT was would not run unit to 60hz. Vav's were driven 100% open and already greatly exceeding design airflow at 30hz. Unit was tested at 46hz per UHAT's request.

AIR APPARATUS TEST SHEET

Job Name: UHAT Cx OTC
Tested By: OGBURN/HIGGINS **Date:** 12/19/2020

DESIGN DATA :

Manufacturer =	TRANE	**Model No. =**	GAP0BBA000F0EAA00C0A0000BC000C
Type =	AHU	**Serial No. =**	K97D42962
Outside Air cfm =			
Total Scheduled cfm =		**Grille Design Schedule cfm =**	
Fan rpm =	1755		
Total Static Pressure =	1.73	**External Static Pressure =**	0.73
Fan Rotation =	CW		

MOTOR DESIGN DATA

Horsepower =	7.5	**Voltage =**	460	**Phase =**	3	**Rpm =**	1750

AIR TEST DATA

Total cfm by Traverse Readings =	4,429	**Total cfm by Grille Readings =**	
Outside Air =		**Return Air =**	

TEMPERATURE TEST DATA

Outside Air Temperature =	44.8	**Return Air Temperature =**	69.9
Mixed Air Temperature =	54.2		

PRESSURE TEST DATA

Fan Suction Static Pressure =		-1.18	
Fan Discharge Static Pressure =		0.55	
	Total Static Pressure =		1.73
External Suction Static Pressure =		-0.07	
External Discharge Static Pressure =		0.66	
	External Static Pressure =		0.73
Cooling Coil ΔS.P. =	0.54	**Heating Coil ΔS.P. =**	0.01
Pre Filters ΔS.P. =	0.45	**Final Filters ΔS.P. =**	0.11

MOTOR TEST DATA

Motor Manufacturer / Frame =	MAGNETEK / S213T						
HP =	7.5	**Volts/Ph/Hertz =**	460/3/60	**Act. Voltage =**	475	475	475
Full Load Amps =			NG	**Act. Amps =**	7.5	7.5	7.5
Service Factor =			1.15				
Motor Design rpm =			1750	**Act motor rpm =**			1755

FAN TEST DATA

Motor Sheave Diameter =	INA	**Motor Sheave Bore =**	INA
Fan Sheave Diameter =	9 3/4"	**Fan Sheave Bore =**	1 1/4"
Adjustable Sheave Dia. =		**Centerline Distance =**	INA
Fan rpm =	1755	**Fan Rotation =**	CW
Frequency Hz=	60		
Belts =	1 BX46		
Pre Filters =			
Final Filters =			

Comments: Unit has no suitable traverse locattions. Total airflow was read at the cooling coil via velgrid.

AIR APPARATUS TEST SHEET

Job Name: UHAT Cx OTC
Tested By: OGBURN/HIGGINS **Date:** 12/19/2020

DESIGN DATA : **AHU-2M1**

Manufacturer =	TRANE	**Model No. =**	MCCA021MAD0CAB0BB0AC0E0000
Type =	AHU	**Serial No. =**	K94J67845
Outside Air cfm =			
Total Scheduled cfm =		**Grille Design Schedule cfm =**	
Fan rpm =	NTS		
Total Static Pressure =	0.61	**External Static Pressure =**	0.53
Fan Rotation =	CW		

MOTOR DESIGN DATA

Horsepower =	15	**Voltage =**	460	**Phase =**	3	**Rpm =**	1750

AIR TEST DATA

Total cfm by Traverse Readings =	10,350	**Total cfm by Grille Readings =**	
Outside Air =		**Return Air =**	

TEMPERATURE TEST DATA

Outside Air Temperature =	55.1	**Return Air Temperature =**	69.7
Mixed Air Temperature =	70.7		

PRESSURE TEST DATA

Fan Suction Static Pressure =		-0.38	
Fan Discharge Static Pressure =		0.23	
	Total Static Pressure =		0.61
External Suction Static Pressure =		-0.26	
External Discharge Static Pressure =		0.27	
	External Static Pressure =		0.53
Cooling Coil ΔS.P. =	0.13	**Heating Coil ΔS.P. =**	0.05
Pre Filters ΔS.P. =	0.14	**Final Filters ΔS.P. =**	2.80

MOTOR TEST DATA

Motor Manufacturer / Frame =		MAGNETEK / S254T					
HP =	15	**Volts/Ph/Hertz =**	460/3/60	**Act. Voltage =**	480	480	480
Full Load Amps =			NG	**Act. Amps =**	12.3	12.3	12.3
Service Factor =			1.15				
Motor Design rpm =			1750	**Act motor rpm =**			1760
Frequency Hz=	60						

Comments: FAN DIAMETER:16" / FAN BORE:1 5/8" / MOTOR DIAMETER: INA / MOTOR BORE: INA / CENTERLINE: INA / BELTS: 1 5VX-670

AIR APPARATUS TEST SHEET

Job Name: UHAT Cx OTC
Tested By: Jacquemin/Ogburn **Date:** 11/17/2020

DESIGN DATA : **AHU-1 3rd Floor**

Manufacturer =	Temtrol	**Model No. =**	WF-DH25-1
Type =	AHU	**Serial No. =**	61878
Outside Air cfm =			
Total Scheduled cfm =		**Grille Design Schedule cfm =**	
Fan rpm =			
Total Static Pressure =	3.21	**External Static Pressure =**	2.09
Fan Rotation =	CW		

MOTOR DESIGN DATA

Horsepower =	15	**Voltage =**	460	**Phase =**	3	**Rpm =**	NG

AIR TEST DATA

Total cfm by Traverse Readings =	14,965	**Total cfm by Grille Readings =**	
Outside Air =		**Return Air =**	

TEMPERATURE TEST DATA

Outside Air Temperature =	68.7/51.7	**Return Air Temperature =**	69.4/53
Mixed Air Temperature =	70.1/53.3		

PRESSURE TEST DATA

Fan Suction Static Pressure =		-1.29	
Fan Discharge Static Pressure =		1.92	
	Total Static Pressure =		3.21
External Suction Static Pressure =		-0.17	
External Discharge Static Pressure =		1.92	
	External Static Pressure =		2.09
Cooling Coil ΔS.P. =	0.80	**Heating Coil ΔS.P. =**	0.21
Pre Filters ΔS.P. =	0.11	**Final Filters ΔS.P. =**	NA

MOTOR TEST DATA

Motor Manufacturer / Frame =			WORLDWIDE / 254T				
HP =	15	**Volts/Ph/Hertz =**	460/3/60	**Act. Voltage =**	480	480	480
Full Load Amps =			18.0	**Act. Amps =**	16.0	16.0	16.0
Service Factor =			1.15				
Motor Design rpm =			NG	**Act motor rpm =**			1770
Frequency Hz=	60						
Belts =	2 5VX-600						
Pre Filters =							
Final Filters =							

Comments: FAN DIAMETER:5 1/2" / FAN BORE:1 7/8" / MOTOR DIAMETER:7 1/2" / MOTOR BORE:1 1/2" / CENTERLINE:20"

COIL APPARATUS TEST REPORT

Job Name: UHAT Cx OTC
Tested By: OGBURN/HIGGINS **Date:** 12/19/2020

COIL DATA				
System Number	AHU-BM1		AHU-1M1	AHU-1M1
Location	Basement		1st Floor	1st Floor
Coil Type	CHW		CHW	HW
No. Rows-Fins/ In.	NG		NG	NG
Manufacturer	NG		NG	NG
Model Number	NG		NG	NG
Serial Number	NG		NG	NG

Air Test Data	DESIGN	ACTUAL	DESIGN	ACTUAL	DESIGN	ACTUAL	DESIGN	ACTUAL
Air Qty., CFM(l/s)	NG	5715			NG	4429	NG	4429
Air Vel. FPM (m/s)	NG	NM			NG	NM	NG	NM
Press. Drop In wg (Pa)	NG	0.15			NG	0.54	NG	0.01
Out. Air DB/WB	-	-	-	-	-	-	-	-
Ret. Air DB/WB	-	-	-	-	-	-	-	-
Ent. Air DB/WB	NG	52.8/46.6			NG	69.2/55.4	NG	54.2/46
Lvg. Air DB/WB	NG	52.4/49.1			NG	56.1/47.4	NG	69.2/55.4
Air ΔT	NG	0.4			NG	13.1/8.0	NG	15.0/9.4

Water Test Data	DESIGN	ACTUAL	DESIGN	ACTUAL	DESIGN	ACTUAL	DESIGN	ACTUAL
Water Flow, GPM (l/s)	NG	NG			NG	NG	NG	NG
Press. Drop PSI (kPa)	NG	19.0			NG	8.9	NG	0.6
Ent Water Temp.	NG	53.4			NG	46.3	NG	97.3
Lvg. Water Temp.	NG	60.3			NG	47.8	NG	72.5
Water ΔT	NG	6.9			NG	1.5	NG	24.8

Refrigeration Test	DESIGN	ACTUAL	DESIGN	ACTUAL	DESIGN	ACTUAL	DESIGN	ACTUAL
Exp. Valve/Refrig.	-	-	-	-	-	-	-	-
Refrig. Suction Press.	-	-	-	-	-	-	-	-
Refrig. Suction Temp.	-	-	-	-	-	-	-	-
Inlet Steam Press.	-	-	-	-	-	-	-	-

COMMENTS: **HAD TO PUT SENSOR ON THE PIPE TO GET EWT AND LWT ON CHW COIL ON AHU-BM1.**

COIL APPARATUS TEST REPORT

Job Name: UHAT Cx OTC
Tested By: JACQUEMIN/OGBURN **Date:** 11/17/2020

COIL DATA				
System Number	AHU-2M1	AHU-2M1	AHU-3M1	AHU-3M1
Location	2nd Floor	2nd Floor	3rd Floor	3rd Floor
Coil Type	CHW	HW	CHW	HW
No. Rows-Fins/ In.	NG	NG	NG	NG
Manufacturer	NG	NG	NG	NG
Model Number	NG	NG	NG	NG
Serial Number	NG	NG	NG	NG

Air Test Data	DESIGN	ACTUAL	DESIGN	ACTUAL	DESIGN	ACTUAL	DESIGN	ACTUAL
Air Qty., CFM(l/s)	NG	10350	NG	10350	NG	14965	NG	14965
Air Vel. FPM (m/s)	NG	NM	NG	NM	NG	NM	NG	NM
Press. Drop In wg (Pa)	NG	1.22	NG	0.14	NG	0.80	NG	0.20
Out. Air DB/WB	-	-	-	-	-	-	-	-
Ret. Air DB/WB	-	-	-	-	-	-	-	-
Ent. Air DB/WB	NG	76.4/59.7	NG	71.7/56.8	NG	74.5/58.3	NG	66.4/53.6
Lvg. Air DB/WB	NG	56.8/47.9	NG	76.4/59.7	NG	64.4/52.3	NG	74.5/58.3
Air ΔT	NG	19.6/11.8	NG	4.7/2.9	NG	10.1/6.0	NG	8.1/4.7

Water Test Data	DESIGN	ACTUAL	DESIGN	ACTUAL	DESIGN	ACTUAL	DESIGN	ACTUAL
Water Flow, GPM (l/s)	NG	NG	NG	NG	NG	NG	NG	NG
Press. Drop PSI (kPa)	NG	8.6	NG	0.9	NG	10.7	NG	NTS
Ent Water Temp.	NG	45.4	NG	101.5	NG	48.9	NG	84.6
Lvg. Water Temp.	NG	65.5	NG	99.2	NG	52.3	NG	90.2
Water ΔT	NG	20.1	NG	2.3	NG	3.4	NG	5.6

Refrigeration Test	DESIGN	ACTUAL	DESIGN	ACTUAL	DESIGN	ACTUAL	DESIGN	ACTUAL
Exp. Valve/Refrig.	-	-	-	-	-	-	-	-
Refrig. Suction Press.	-	-	-	-	-	-	-	-
Refrig. Suction Temp.	-	-	-	-	-	-	-	-
Inlet Steam Press.	-	-	-	-	-	-	-	-

COMMENTS: HAD TO PUT SENSOR ON METAL PIPES FOR HC ENT/LWT. LWT DOESN'T HAVE PORT ON HWS FOR ME TO GET PSID FOR HWC

SUMMARY/REMARKS

Job Name: UHAT OTC CHW Cx

Nathan with UHAT did not want to take the pump any higher than 55Hz as not to put excess pressure on the piping system.

The GPM was determined by taking a pressure drop across the Armstrong CBV4FS Balance Valve. Our pressure drop was about 5.5-5.6 FT.H20 which correlates to approximately 400 GPM. I will attach the chart we used in the email.

During our testing CHW-2 was the pump that was staged on, CHW-1 was not tested.

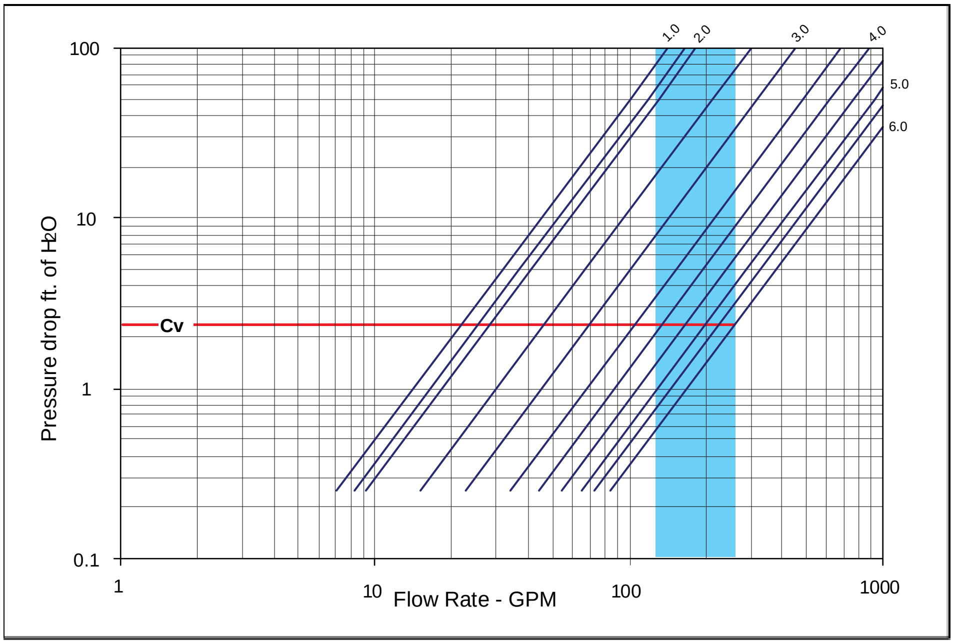
ARMflo CBV Performance Curves – 2.5” to 12” - USgpm

For head loss determination, valve selection, and valve pressure drop to flow correlation.

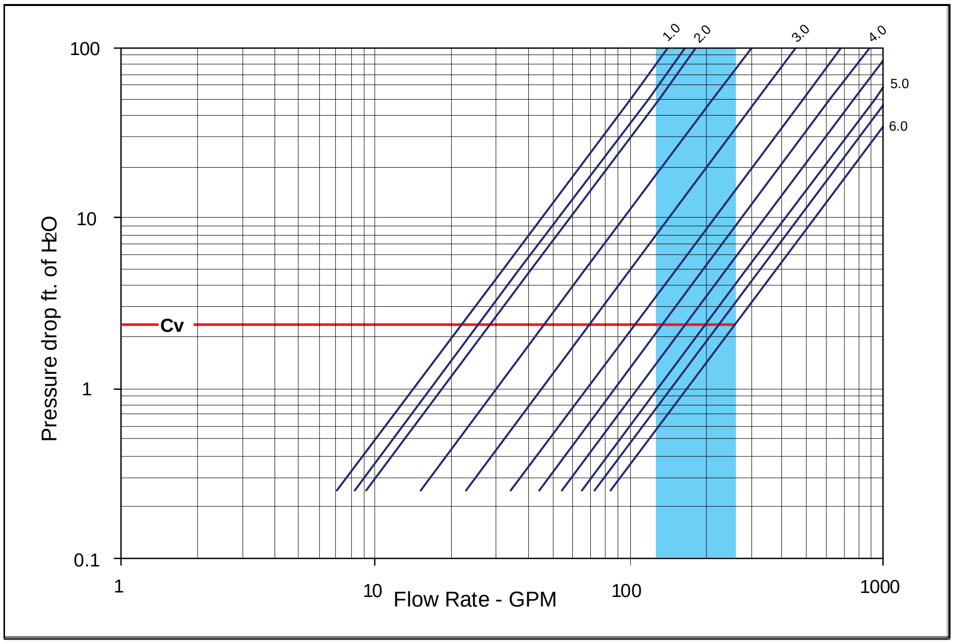
For reliable flow measurement with less than 3” (water gauge) of differential pressure across the valve, use a separate Armstrong flowmeter or equivalent.

The shaded area is the flowrate range representing headloss between 1 to 4 ft/100 ft for the nominal pipe size. Operating below 1 ft/100 ft may reduce system air extraction efficiency, and above 4 ft/100 ft may induce velocity related noise or erosion in system components.

CBV 4 G Straight



CBV 4 G Angled



PUMP TEST SHEET

Job Name: UHAT OTC CHWP
Tested By: OGBURN **Date:** 2/23/2021

PUMP DATA

Pump Number	CHWP-01	CHWP-02	
Manufacturer	ARMSTRONG	ARMSTRONG	
Model Number	5X4X11.5 4030	5X4X11.5 4030	
Serial Number	811419	811420	
Impeller Size	11.5	11.5	
Rpm	1800	1800	
Specified gpm	450	450	
Specified Head	90	90	

MOTOR DATA

	Design	Test	Design	Test	Design	Test
Motor Name	WEG		WEG			
Horsepower	15	15	15	15		
Motor rpm	1770		1770			
Phase	3		3			
Voltage	460	NM	460	420		
		NM		-		
		NM		-		
Service Factor	1.15		1.15			
Amperage	18.2	NM	18.2	15.0		
		NM		-		
		NM		-		

TEST RESULTS – CLOSE OFF

Suction Pressure (PSI)	NA	NM	
Discharge Pressure (PSI)	NA	NM	
Differential Pressure (PSI)	NA	NM	
Head (Feet)	NA	NM	

TEST RESULTS - RUNNING

Suction Pressure (PSI)	NA	97.5	
Discharge Pressure (PSI)	NA	98.5	
Differential Pressure (PSI)	NA	2.4	
Head (Feet)	NA	5.5	
Final gpm	NA	400.0	
Hz	NA	55.0	

Comments:

APPENDIX F
OU CHILDREN'S PHYSICIANS BUILDING REPORT

MECHANICAL CONSULTING SERVICES

Building Infrastructure Testing Report

OU Children's Physicians Building

1200 Children's Avenue

Oklahoma City, Oklahoma

April 12, 2021

Project No. FA20P031

Prepared For:

University Hospitals Authority and Trust (UHAT)
940 NE 13th Street
Oklahoma City, Oklahoma 73104

Prepared by:

Terracon Consultants, Inc.
4701 N. Stiles Avenue
Oklahoma City, Oklahoma 73105

Terracon

April 12, 2021

Mr. Nathan Miller
Building Systems Manager
University Hospitals Authority & Trust
940 NE 13th Street
Oklahoma City, Oklahoma 73104
P: 405-271-4962 x44199
E: Nathan-Miller@uhat.org

Reference: **UHAT**
Building Infrastructure Testing
OU Children's Physicians Building
1200 Children's Avenue
Oklahoma City, Oklahoma 73104
Project No. FA20P031

Mr. Miller:

Terracon Consultants, Inc. (Terracon) is pleased to submit this Mechanical Consulting Services Report of our Building Infrastructure Testing for the OU Children's Physicians Building located at 1200 Children's Avenue in Oklahoma City, Oklahoma. This work was performed in general accordance with the scope of services outlined in the Terracon Company Proposal for Building Infrastructure Testing & Retro-Commissioning Services dated December 19, 2019 and authorized in February 2020 as identified in the scope section of this Report.

The purpose of this Report is to render our findings, field notes, and recommendations related to our site visits at the above referenced location.

This document includes background information, observations, findings, and recommendations pertaining to the operations of the heating, ventilation, and air conditioning (HVAC) at the site.

Terracon appreciates the opportunity to be of service to you on this project. If you have any questions regarding this report, please do not hesitate to contact us.

Sincerely,

Terracon Consultants, Inc.

Erik Gonzalez, P.E. (TX), CEM
Senior Engineer
Facilities Services

Jeffrey A. Miller, P.E. (OK)
Senior Principal/Senior Engineer
Facilities Services

TABLE OF CONTENTS

PROJECT OBJECTIVE

The purpose of the Building Infrastructure Testing services is to conduct limited visual observations and engineering diagnostics of the HVAC systems. With the observations and measurements obtained, a retro-commissioning plan will be developed from recommended energy conservation opportunities in this report that will help improve performance and reduce the operating costs of the building without compromising comfort for the building occupants.

Terracon's representatives, Mr. John Harmon, E.I.T., Mr. Kim Morris QCxP, Mr. Erik Gonzalez, P.E. (TX), CEM, and Mr. Jonathan Curtin, P.E. (TX) of Terracon, and our sub-consultant, Engineering Systems & Energy Solutions (ES2) conducted site visits on September 14 - 15, 2020 at the OU Children's Physicians Building in order to obtain visual and diagnostic information and measurements for the HVAC systems. During the site visits, visual observations were made to note general operating conditions of the HVAC systems. In addition, diagnostic measurements were taken for the air distribution of the 13 AHUs, associated chilled water and hot water coils, chilled water distribution pumps, and hot water distribution pumps located in the building. Measurements recorded were compared to the design documents provided by UHAT and EMCS sensor measurements of air flow and water flow characteristics using UHAT's software workstation. Observations were made from readily accessible areas and did not include substantial dismantling of components of the building and HVAC equipment, including walls and closed ceilings. With the observations and measurements, Terracon developed recommendations for energy conservation opportunities and improvements to the HVAC systems.

DOCUMENTS AND INFORMATION REVIEWED

Terracon was provided with design documentation for the subject building, utility data for chilled water, steam, and electricity, tariff sheets that breakdown the cost of each utility service, and network access to the *AutomatedLogic Corporation* (*ALC*) *WebCTRL v7.0* energy management control system. The following items were reviewed while performing this assessment:

Document	Source
OU CHILDREN'S PHYSICIANS AS-BUILT DRAWINGS MEP — HOK Architects and ZRHD, P.C. Engineer, dated May 24, 2007	Client Provided
Utility Bill Data for Terracon.xlsx – e-mailed to Terracon on February 28, 2020	Client Provided
Utility Service Tariff Sheets for OUHSC and OGE services provided to UHAT – e-mailed to Terracon on March 3, 2020	Client Provided

BUILDING DESCRIPTION AND ENERGY USE BASELINE

The subject property is a 14-story medical office building containing approximately 316,658-square feet. The building was originally designed and constructed as an outpatient healthcare and administrative healthcare facility in 2009. The HVAC systems were designed to operate with distributed chilled water and distributed steam from a Central Plant associated with the University of Oklahoma Health Sciences Center (OUHSC) at a remote location in downtown Oklahoma City.

The HVAC systems within the building include two chilled water pumps, two heating hot water pumps, and one steam-to-hot water heat exchanger that provides hot water for distribution to the HVAC systems. There are 13 variable air volume (VAV) air handling units (AHUs), 12 relief air fans, 13 ventilation fans, 19 fan coil units, 522 VAV terminal boxes, and 16 exhaust fans. All major equipment is controlled and monitored with an *ALC* energy management control system (EMCS) *WebCTRL* (software). The controllers (hardware) were manufactured by *ALC* and were installed in 2014 as replacements to the original Invensys controllers installed in 2009.

Table 1: General Building Information

Attributes	***OUCP***
Property Manager	***ONECall***
Year Opened	2009
Enclosed Square Feet	316,658
Floors	14
Annual Metered kWh Consumption (2019)	4,309,120*
Annual Metered Peak kW Demand	805
Annual Electric $	$258,161
Annual CHW Ton-hrs Consumed (2019)	805,793**
Annual Peak Demand Tons	613.9
Average Monthly CHW Temp. Diff. (ºF)	11.13
Annual CHW $	$151,191
Annual Steam klbs Consumed (2019)	8,444**
Annual Steam Demand lbs/hr	8,593.9
Annual Steam Condensate Return (%)	89%
Annual Steam Cost $	$77,998
kWh/sqft	13.6
Peak W/sqft	2.54
Electrical Load Factor	61.1%
CHW Ton-hrs/sqft	2.54
Steam kBtu/sqft	31.9
Electrical EUI (kBtu/sqft)	46.4
CHW EUI (kBtu/sqft)	30.6
Total EUI (kBtu/sqft)	108.9
Annual Utility Spend	$487,350
ECI ($/SqFt)	$1.54
FCI	2019 (100) 2021 (100)
Operating Schedule	M-F 7am-10pm First Floor: 24-hours/7 days per week Second Floor: M-F 7am-10pm, Sat/Sun 10am-5pm
Occupied Hours	M-F 7am-10pm First Floor: 24-hours/7 days per week Second Floor: M-F 7am-10pm, Sat/Sun 10am-5pm
EMCS - Energy Management Control System	*ALC - WebCTRL*
Cooling Systems	Chilled Water
Heating Systems	Hot Water
Air Distribution	SZ & VAV with VAV TB's
Outside Air / Ventilation	OA is ducted directly to Return Air Section of AHU’s

*Electric consumption was estimated based on the calculated ratio of the OU Children’s Physicians sqft to the overall sqft (Samis, Atrium, and OU Children’s Physicians) served by the electric meter at the OU Children’s Physicians building.

To measure the building's energy utilization and current level of efficiency, two Energy Performance Indicators were calculated in this Report as follows:

Energy Utilization Intensity

The Energy Utilization Intensity (EUI) depicts the total annual energy consumption per square foot of building space, and is expressed in "British Thermal Units" (BTUs). To calculate the EUI, the annual consumption of electricity, steam, and chilled water are first converted to equivalent kBTU consumption via the following formulas:

> Total Annual Energy Usage = Total Annual Electrical Energy Usage + Total Annual Steam Energy Usage + Total Annual Chilled Water Energy Usage converted to units of kBTUs/year.
>
> > Total Annual Electrical Energy Usage
> > [Total kWh /yr.] x [3.412 kBTUs/kWh] = __________ kBTUs / yr.
> >
> > Total Annual Steam Energy Usage
> > [Total klbs /yr.] x [1,196 kBTUs/klbs] = __________ kBTUs / yr.
> >
> > Total Annual Chilled Water Energy Usage
> > [Total Ton/hr /yr.] x [12 kBTUs/hr/Ton/hr] = __________ kBTUs / yr.

The total kBTUs are then divided by the building area.

EUI = [Total annual kBTUs] divided by [Total square feet]

The EUI was compared to the average energy utilization published in the 2012 Commercial Building Energy Consumption Survey (CBECS).

Energy Cost Index

The Energy Cost Index (ECI) depicts the total annual energy cost per square foot building space. To calculate the ECI, the annual costs of electricity, steam, and chilled water are divided by the total square footage of the leased space:

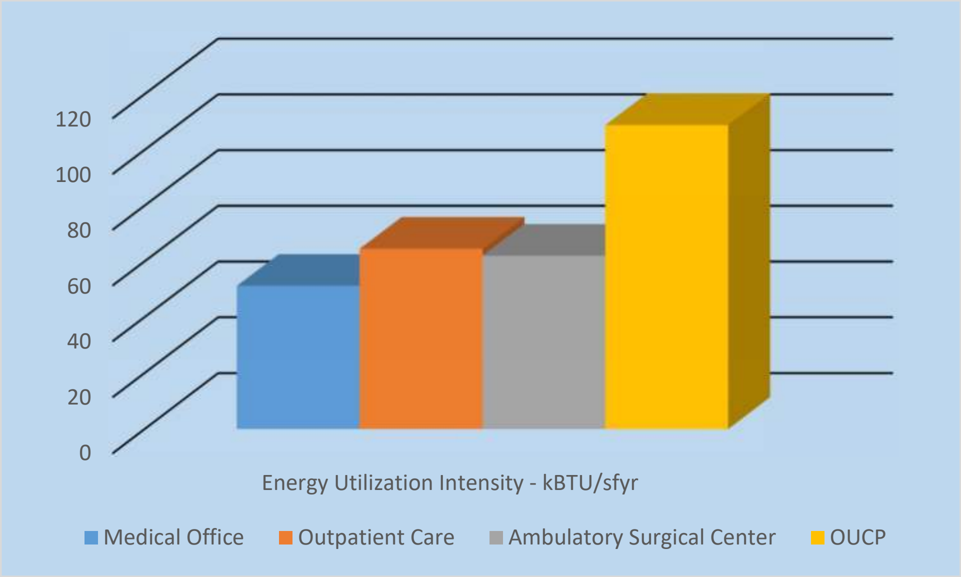
ECI = [Total Energy Cost] divided by [Total square feet]

The ECI was calculated and compared to the statistical average energy cost index published in the 2012 Commercial Building Energy Consumption Survey (CBECS).

The EUI and ECI may be used to compare the facility's approximate usage and cost to other similar facilities in the area. Although the comparisons will not provide specific reasons for unusual operation, they serve as indicators that opportunities may exist by more efficiently operating energy consuming systems.

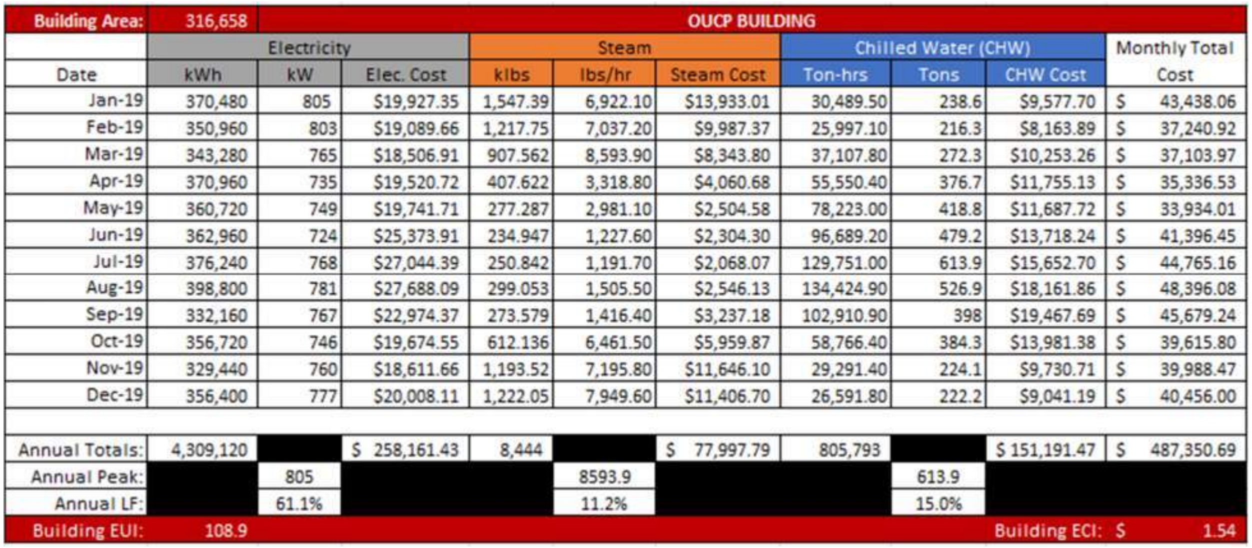
Referring to the 2012 Commercial Building Energy Consumption Survey (CBECS), compiled by the United States Department of Energy, we find the following ranges of comparison with the subject building. The CBECS survey results were based on a national statistical average of a total of 9,941-million square feet reported. The subject site is located within the southwestern section of the United States.

- CBECS utility cost and energy utilization comparison of the EUI and ECI indicates that OU Children's Physicians has a **moderately high EUI and ECI** compared to similar facilities in the healthcare category.



Oklahoma Gas and Electric (OGE) and OU Health Science Center (OUHSC) are the main energy utility providers for the building. Terracon has analyzed the energy consumption for the building and determined the Energy Usage Index (EUI) is approximately 108.9 kBtu/SQFT and the Energy Cost Index (ECI) is $1.54/SQFT. The annual energy consumption ratio shows that electricity accounts for approximately 43% of total energy consumption, chilled water accounts for approximately 28% of total energy consumption, and steam accounts for the remaining 29% of total energy consumption. Annually, electricity accounts for approximately 53% of the total energy cost, chilled water accounts for approximately 31% of the total energy cost, and steam accounts for the remaining 16% of total energy cost. The annual cost ratios are mostly proportionate from the annual consumption ratios, with the steam cost ratio being much lower than the overall steam energy consumption ratio.

Table 2 – 2019 Energy Use Baseline



Building Area:	316,658	OUCP BUILDING								
	Electricity			Steam			Chilled Water (CHW)			Monthly Total
Date	kWh	kW	Elec. Cost	klbs	lbs/hr	Steam Cost	Ton-hrs	Tons	CHW Cost	Cost
Jan-19	370,480	805	$19,927.35	1,547.39	6,922.10	$13,933.01	30,489.50	238.6	$9,577.70	$ 43,438.06
Feb-19	350,960	803	$19,089.66	1,217.75	7,037.20	$9,987.37	25,997.10	216.3	$8,163.89	$ 37,240.92
Mar-19	343,280	765	$18,506.91	907.562	8,593.90	$8,343.80	37,107.80	272.3	$10,253.26	$ 37,103.97
Apr-19	370,960	735	$19,520.72	407.622	3,318.80	$4,060.68	55,550.40	376.7	$11,755.13	$ 35,336.53
May-19	360,720	749	$19,741.71	277.287	2,981.10	$2,504.58	78,223.00	418.8	$11,687.72	$ 33,934.01
Jun-19	362,960	724	$25,373.91	234.947	1,227.60	$2,304.30	96,689.20	479.2	$13,718.24	$ 41,396.45
Jul-19	376,240	768	$27,044.39	250.842	1,191.70	$2,068.07	129,751.00	613.9	$15,652.70	$ 44,765.16
Aug-19	398,800	781	$27,688.09	299.053	1,505.50	$2,546.13	134,424.90	526.9	$18,161.86	$ 48,396.08
Sep-19	332,160	767	$22,974.37	273.579	1,416.40	$3,237.18	102,910.90	398	$19,467.69	$ 45,679.24
Oct-19	356,720	746	$19,674.55	612.136	6,461.50	$5,959.87	58,766.40	384.3	$13,981.38	$ 39,615.80
Nov-19	329,440	760	$18,611.66	1,193.52	7,195.80	$11,646.10	29,291.40	224.1	$9,730.71	$ 39,988.47
Dec-19	356,400	777	$20,008.11	1,222.05	7,949.60	$11,406.70	26,591.80	222.2	$9,041.19	$ 40,456.00
Annual Totals:	4,309,120		$ 258,161.43	8,444		$ 77,997.79	805,793		$ 151,191.47	$ 487,350.69
Annual Peak:		805			8593.9			613.9		
Annual LF:		61.1%			11.2%			15.0%		
Building EUI:	108.9								Building ECI:	$ 1.54

Chart 1 – Energy Ratio

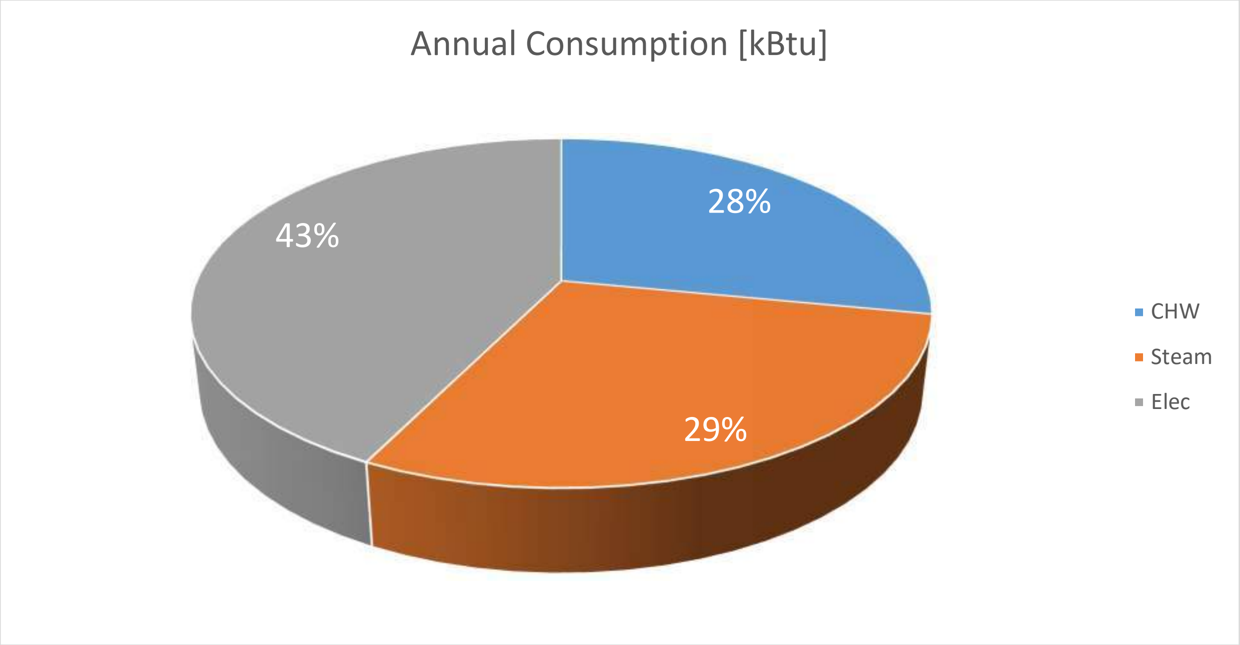
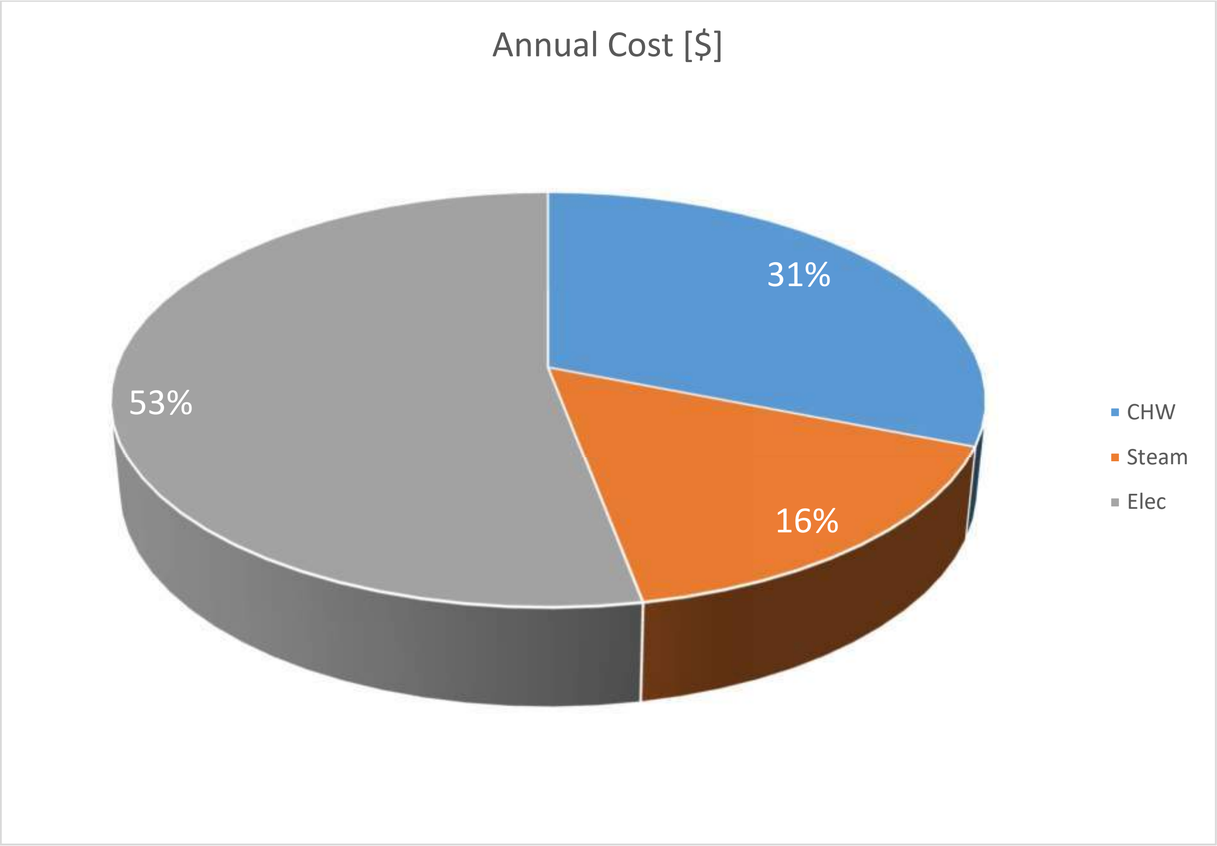


Chart 2 – Energy Cost Ratio

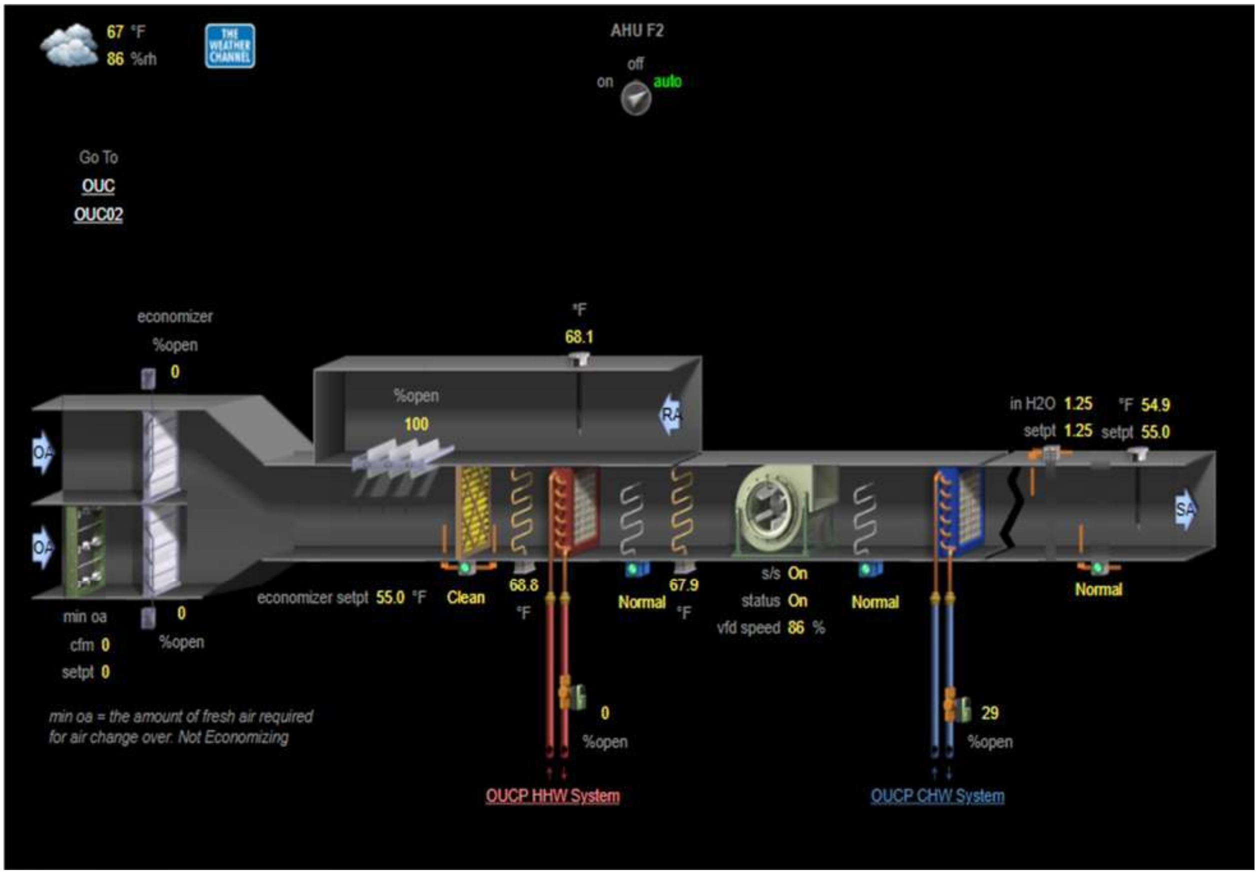


HVAC SYSTEM OBSERVATIONS

During the investigation and pre-task planning portion of this project, Terracon observed a variety of issues that prompted Terracon to investigate further:

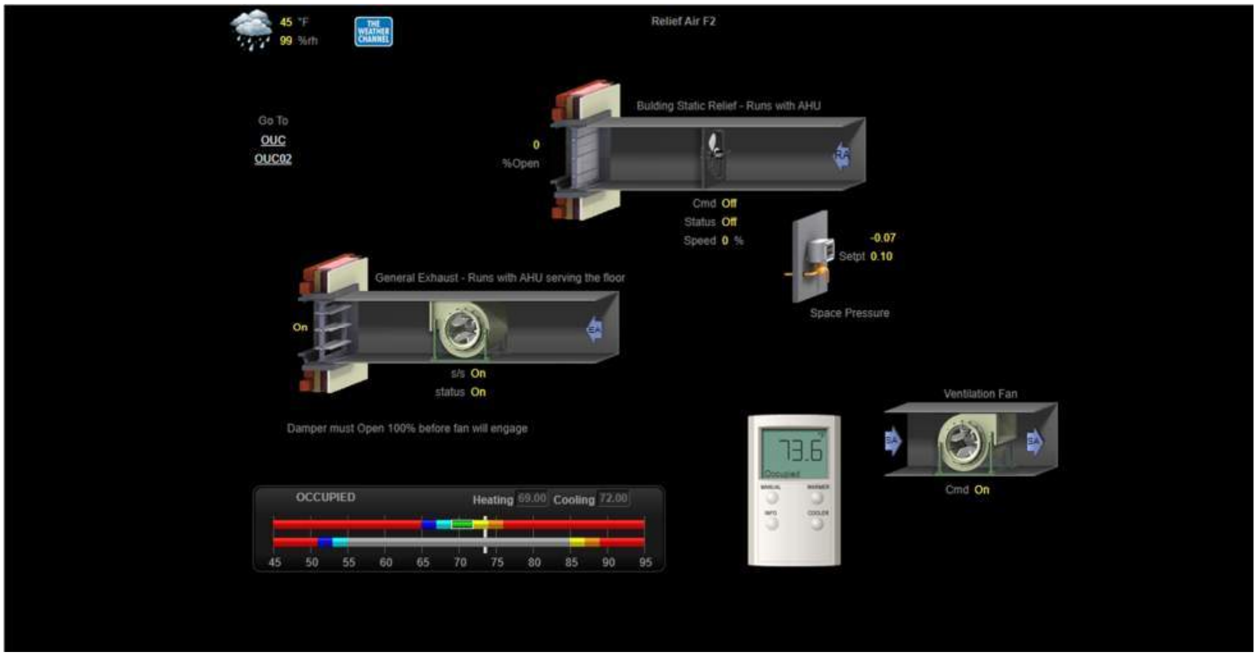
The *ALC WebCTRL* EMCS indicated that the outside air damper position for AHU F2 was 0% open with an outdoor air setpoint of 0 CFM when the fan speed of the supply air fan was operating at 86%. The AHU supply air fan is interlocked with a constant speed EF in another mechanical room on the other side of the 2nd Floor indicating that the floor could be at a negative air pressure. The mechanical room with the EF also has a constant speed ventilator fan (VF) that operates based on room temperature (local thermostat) in the mechanical room and exhausts air into the return plenum above the ceiling.

The combination of no outside air supplied by the AHU, the EF operating at constant speed, and the VF operating at constant speed may all be impacting the 2nd floor by creating negative air pressurization.



min oa = the amount of fresh air required for air change over. Not Economizing

AHU F2



Relief Air F2

45 °F
99 %rh

Building Static Relief - Runs with AHU
0 %Open
Cmd Off
Status Off
Speed 0 %

-0.07
Setpt 0.10
Space Pressure

General Exhaust - Runs with AHU serving the floor
On
s/s On
status On

Damper must Open 100% before fan will engage

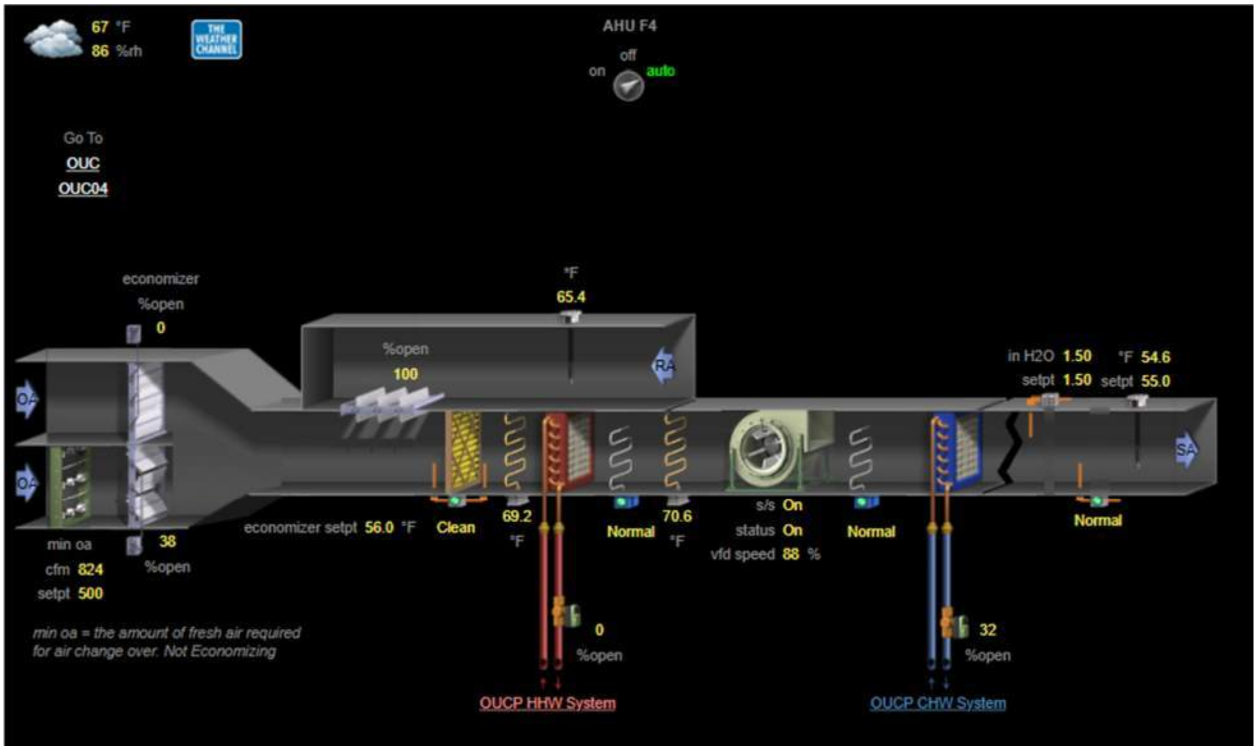
Ventilation Fan
Cmd On

OCCUPIED
Heating 69.00
Cooling 72.00

RF F2, EF F2, and VF (2nd Floor)

The *ALC WebCTRL* EMCS indicated that the outside air damper position for AHU F4 was 38% open with an outdoor air setpoint of 500 CFM when the fan speed of the supply air fan was operating at 88%. The AHU supply air fan is interlocked with a constant speed EF in another mechanical room on the other side of the 4th Floor. The mechanical room with the EF also has a constant speed VF that operates based on room temperature (local thermostat) in the mechanical room and exhausts air into the return plenum above the ceiling.

The AHU is designed to operate with a minimum amount of outside air when the EF is operating at constant speed as designed for the space to have a slight positive air pressure. The combination of the AHU providing less than the minimum amount of outside air as designed and the EF operating at constant speed may be impacting the 4th Floor creating negative air pressurization.

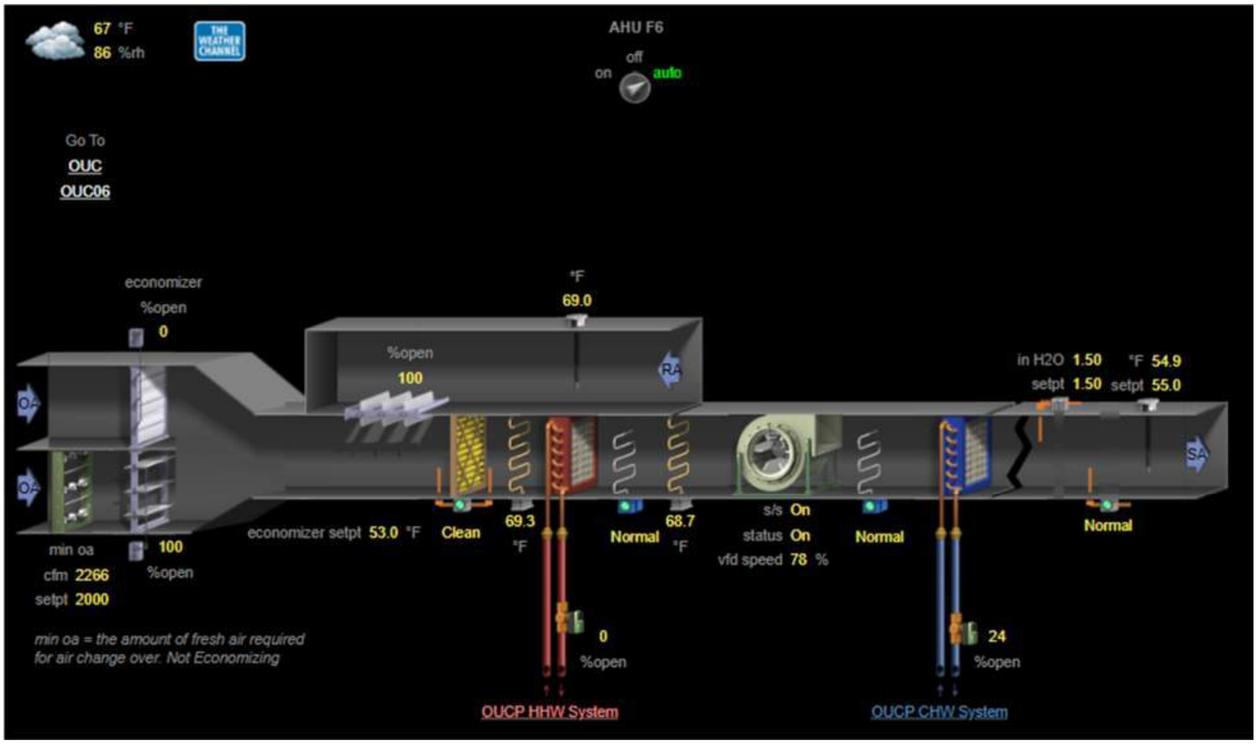


min oa = the amount of fresh air required for air change over. Not Economizing

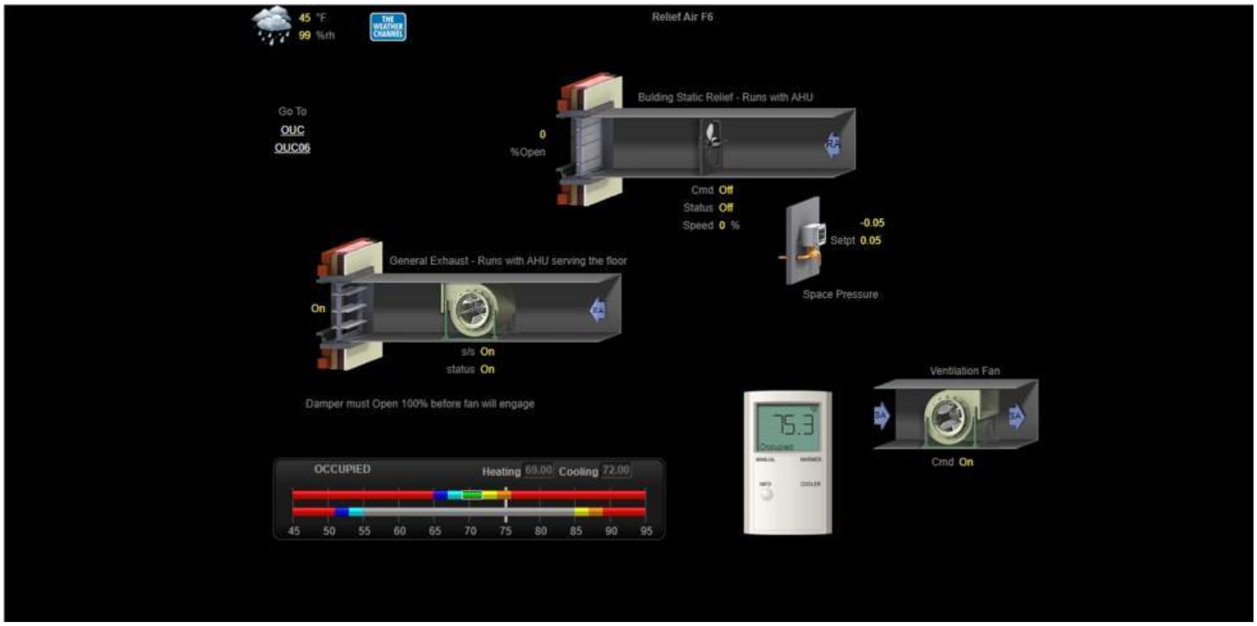
AHU F4

The *ALC WebCTRL* EMCS indicated that the outside air damper position for AHU F6 was 100% open with an outdoor air setpoint of 2,000 CFM when the fan speed of the supply air fan was operating at 78%. The AHU supply air fan is interlocked with a constant speed EF in another mechanical room on the other side of the 6th Floor. The mechanical room with the EF also has a constant speed VF that operates based on room temperature (local thermostat) in the mechanical room and exhausts air into the return plenum above the ceiling.

The AHU is designed to operate with a minimum amount of outside air when the EF is operating at constant speed as designed for the space to have a slight positive air pressure. The combination of the AHU providing less than the minimum amount of designed outside air as designed, the EF operating at constant speed, and the VF operating at constant speed may all be impacting the 6th Floor by creating negative air pressurization.



AHU F6



45 °F
99 %rh

0
%Open

Cmd Off
Status Off
Speed 0 %

-0.05
Setpt 0.05

On

s/s On
status On

Damper must Open 100% before fan will engage

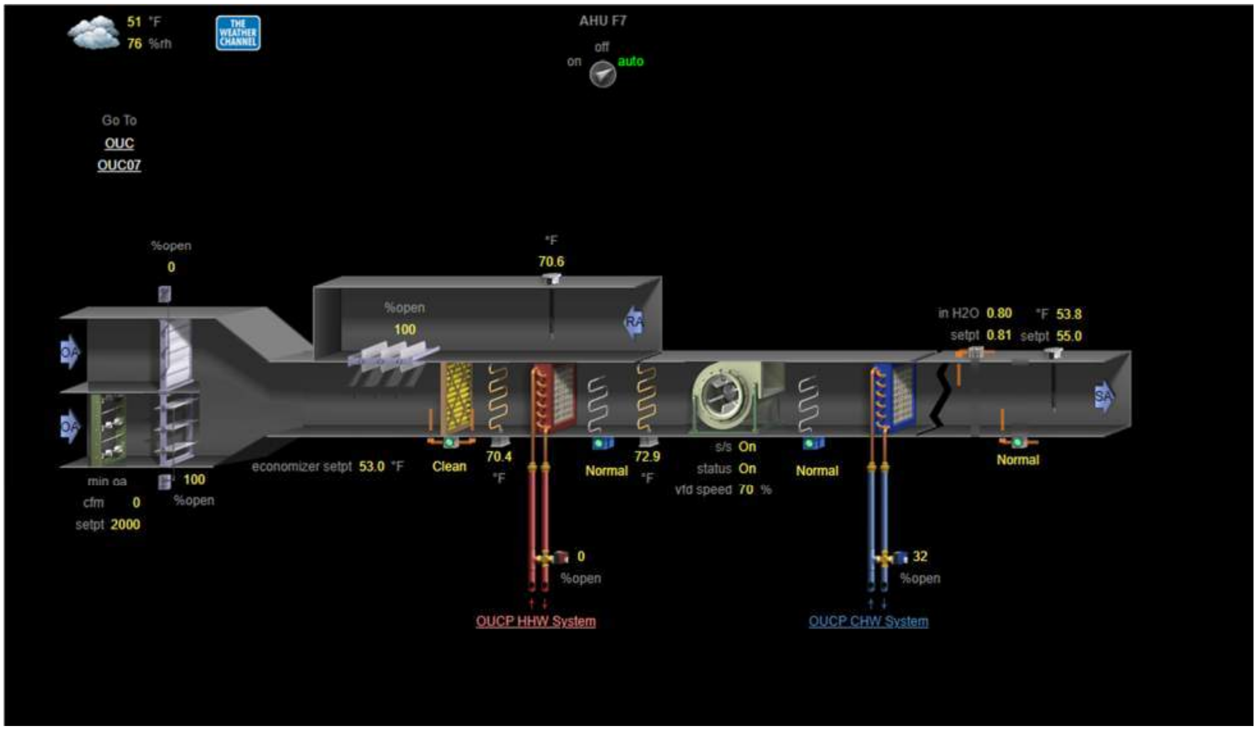
Heating 69.00 Cooling 72.00

Cmd On

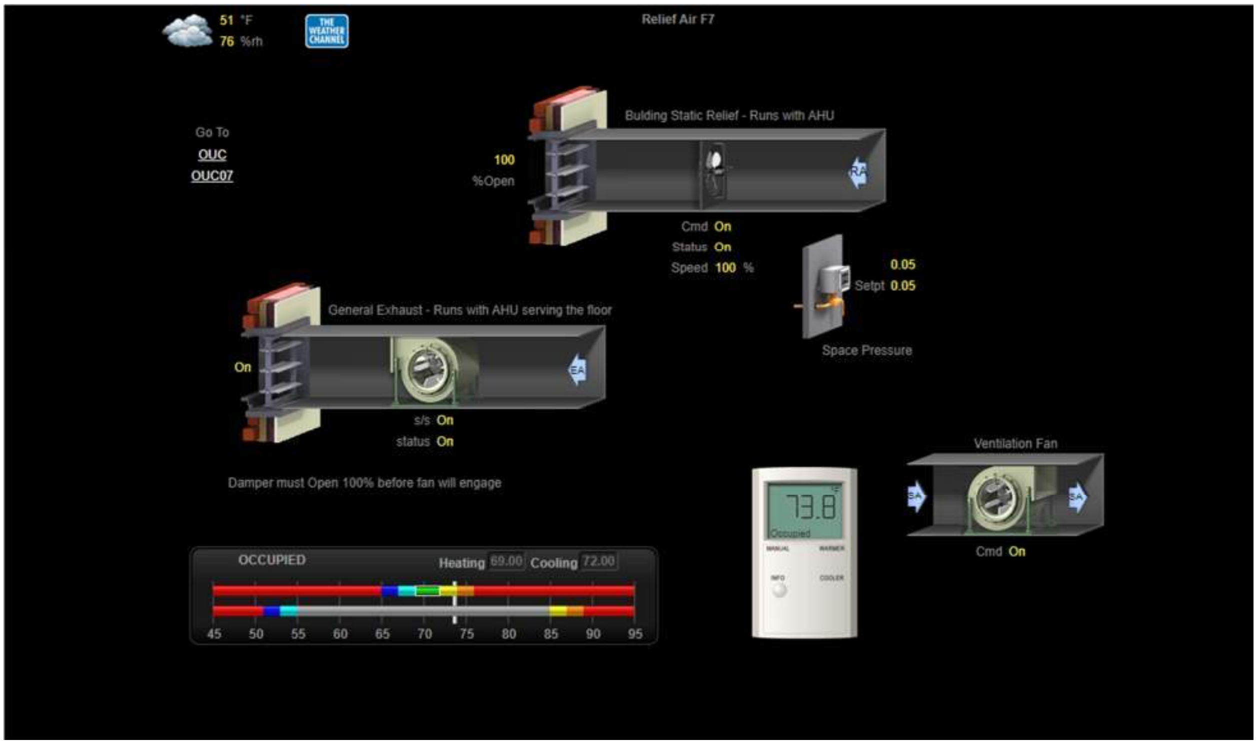
RF F6, EF F6, and VF (6th Floor)

The *ALC WebCTRL* EMCS indicated that the outside air damper position for AHU F7 was 100% open with an outdoor air setpoint of 2,000 CFM, economizer outside air damper position was 0% open when the fan speed of the supply air fan was operating at 70%. The outside air flow monitoring station was observed to be reading 0 CFM, likely due to the air flow monitoring station having excess debris obstructing the air flow ports or the sensor in need of calibration/replacement. The AHU supply air fan is interlocked with a constant speed EF and a variable speed relief air fan (RF) in another mechanical room on the other side of the 7th Floor. The RF was observed to be operating at 100% with the economizer outside air dampers open at 0%. The mechanical room with the EF and RF also has a constant speed VF that operates based on room temperature (local thermostat) in the mechanical room and exhausts air into the return plenum above the ceiling.

The AHU, RF, and EF are designed to operate in the control sequence to provide the 7th floor with a slightly positive air pressure. The combination of the AHU providing less than the minimum amount of outside air as designed, the RF and EF each operating at 100%, and the VF operating at constant speed may all be impacting the 7th Floor by creating negative air pressurization. The air differential pressure sensor indicated a static air pressure of +0.05 in w.g. It is likely the reference points (room pressure and adjacent room pressure) for the measurements of the floor are not installed correctly.



AHU F7



Relief Air F7

51 °F
76 %rh

100 %Open

Cmd On
Status On
Speed 100 %

0.05
Setpt 0.05

On

s/s On
status On

Damper must Open 100% before fan will engage

73.8 °F Occupied

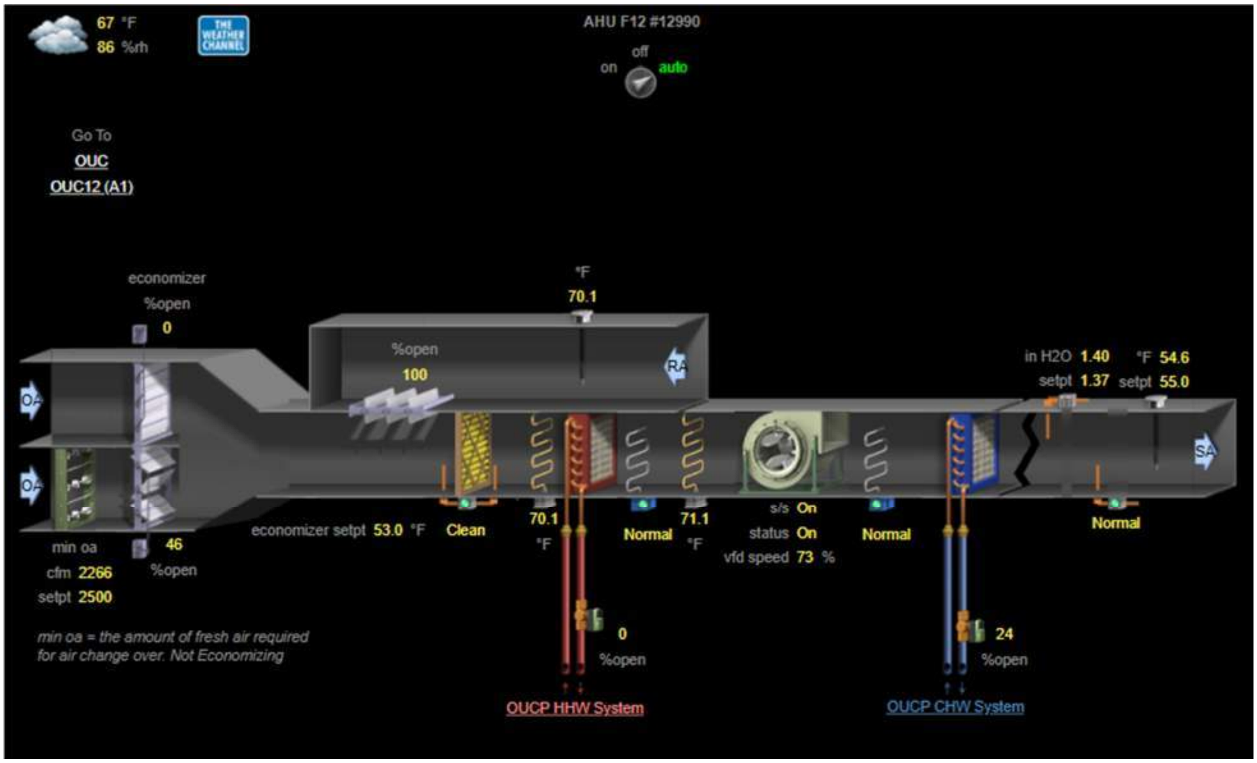
Cmd On

OCCUPIED Heating 69.00 Cooling 72.00

RF F7, EF F7, and VF (7th Floor)

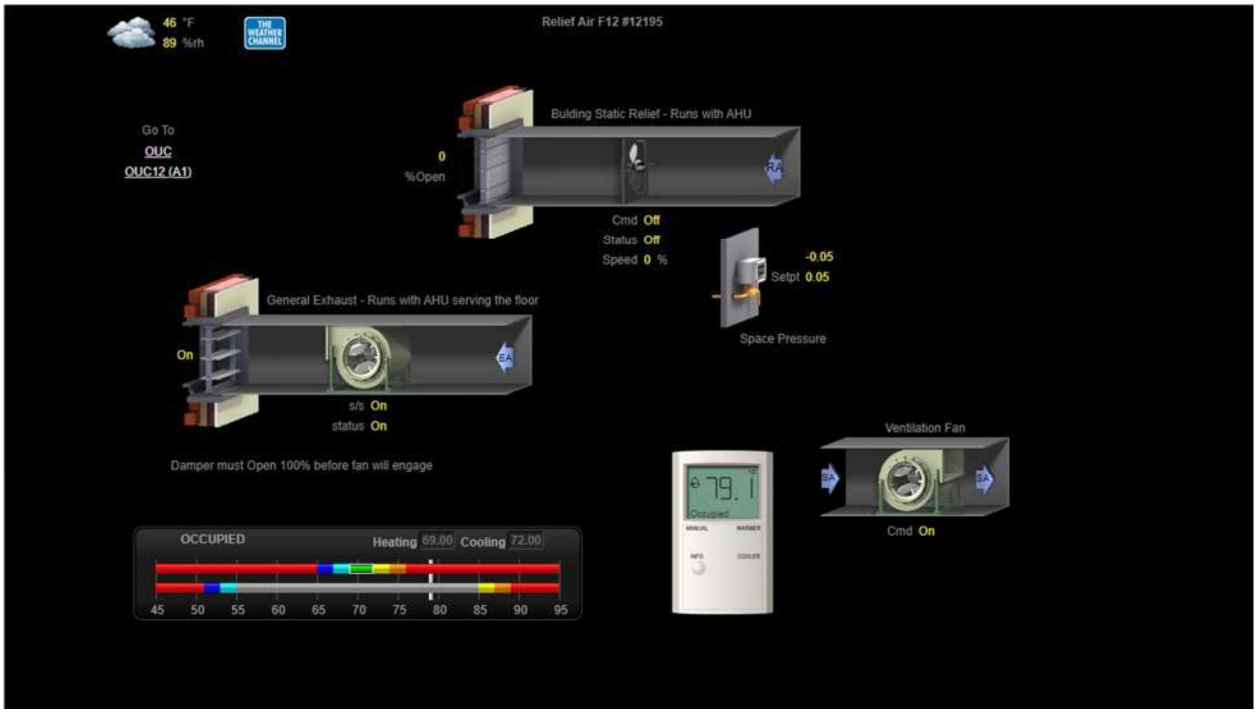
The *ALC WebCTRL* EMCS indicated that the outside air damper position for AHU F12 was 46% open with an outdoor air setpoint of 2,500 CFM when the fan speed of the supply air fan was operating at 73%. The AHU supply air fan is interlocked with a constant speed EF in another mechanical room on the other side of the 12th Floor. The mechanical room with the EF also has a constant speed VF that operates based on roof temperature (local thermostat) in the mechanical room and exhausts air into the return plenum above the ceiling.

The AHU is designed to operate with a minimum amount of outside air when the EF is operating at constant speed for the 12th Floor to have a slightly positive air pressure. The AHU was observed to be providing less than the minimum amount of outside air as designed, but the EF was observed to be exhausting less air than the amount of outside air provided to the AHU as designed. The static pressure on the floor was observed to be -0.05 in w.g. when a positive static air pressure was expected to be recorded.



min oa = the amount of fresh air required for air change over. Not Economizing

AHU F12



0 %Open

Cmd Off
Status Off
Speed 0 %

-0.05
Setpt 0.05

On

s/s On
status On

Damper must Open 100% before fan will engage

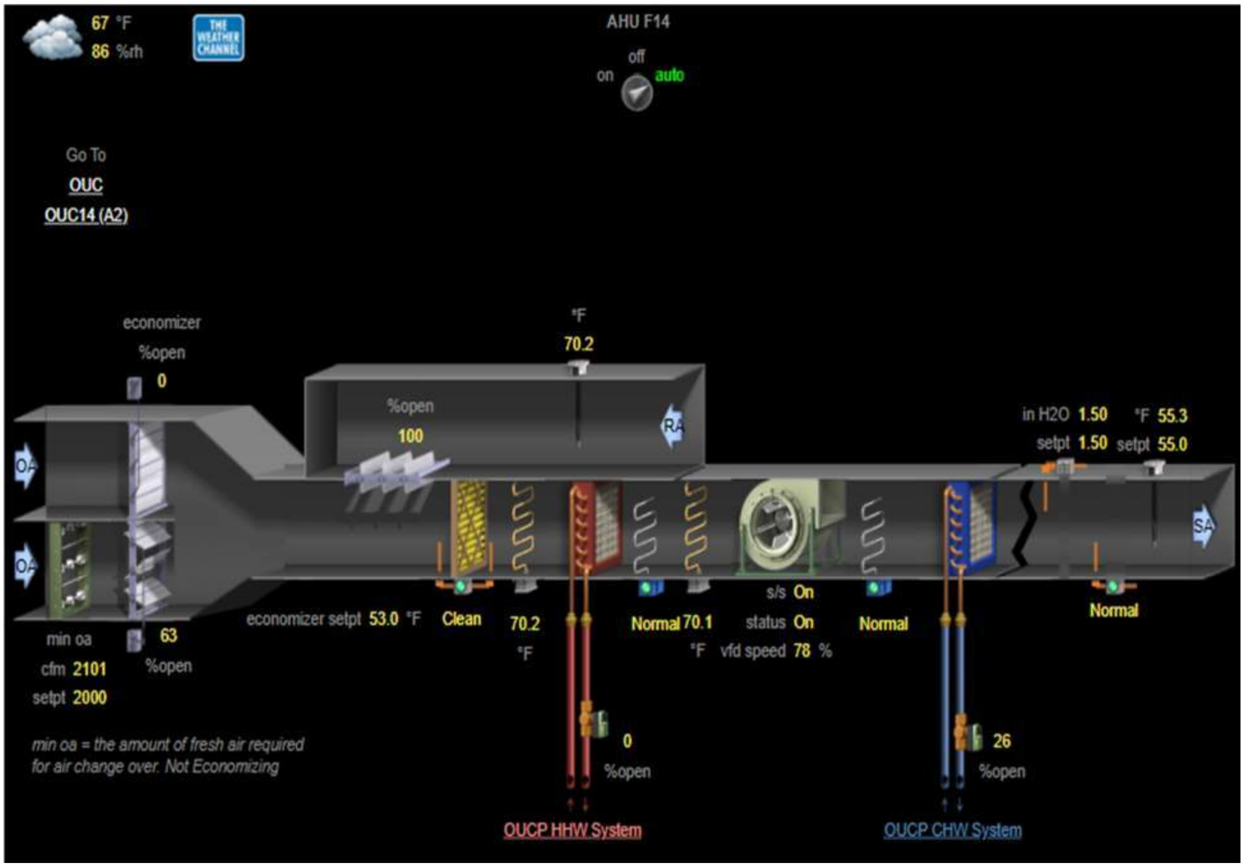
Cmd On

Heating 69.00 Cooling 72.00

RF F12, EF F12, VF (12th Floor)

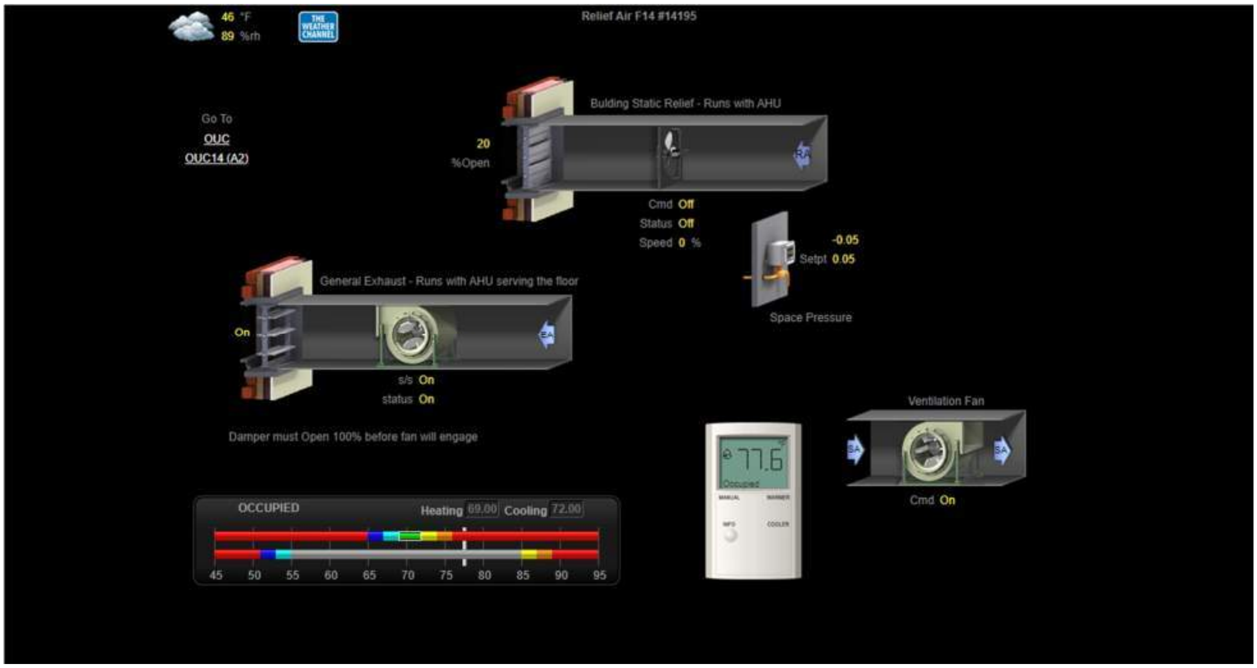
The *ALC WebCTRL* EMCS indicated that the outside air damper position for AHU F14 was 63% open with an outdoor air setpoint of 2,000 CFM when the fan speed of the supply air fan was operating at 78%. The AHU supply air fan is interlocked with a constant speed EF in another mechanical room on the other side of the 14th Floor. The mechanical room with the EF also has a constant speed VF that operates based on room temperature (local thermostat) in the mechanical room and exhausts air into the return plenum above the ceiling.

The AHU is designed to operate with a minimum amount of outside air when the EF is operating at constant speed for the 14th Floor to have a slightly positive air pressure. The combination of the AHU providing less than the minimum amount of outside air as designed, the EF operating at constant speed, and the VF operating at constant speed may all be impacting the 14th Floor by creating negative air pressurization.



min oa = the amount of fresh air required for air change over. Not Economizing

AHU F14



Relief Air F14 #14195

46 °F
89 %rh

Go To
OUC
OUC14 (A2)

Building Static Relief - Runs with AHU

20 %Open

Cmd Off
Status Off
Speed 0 %

-0.05
Setpt 0.05

Space Pressure

General Exhaust - Runs with AHU serving the floor

On

s/s On
status On

Damper must Open 100% before fan will engage

Ventilation Fan

Cmd On

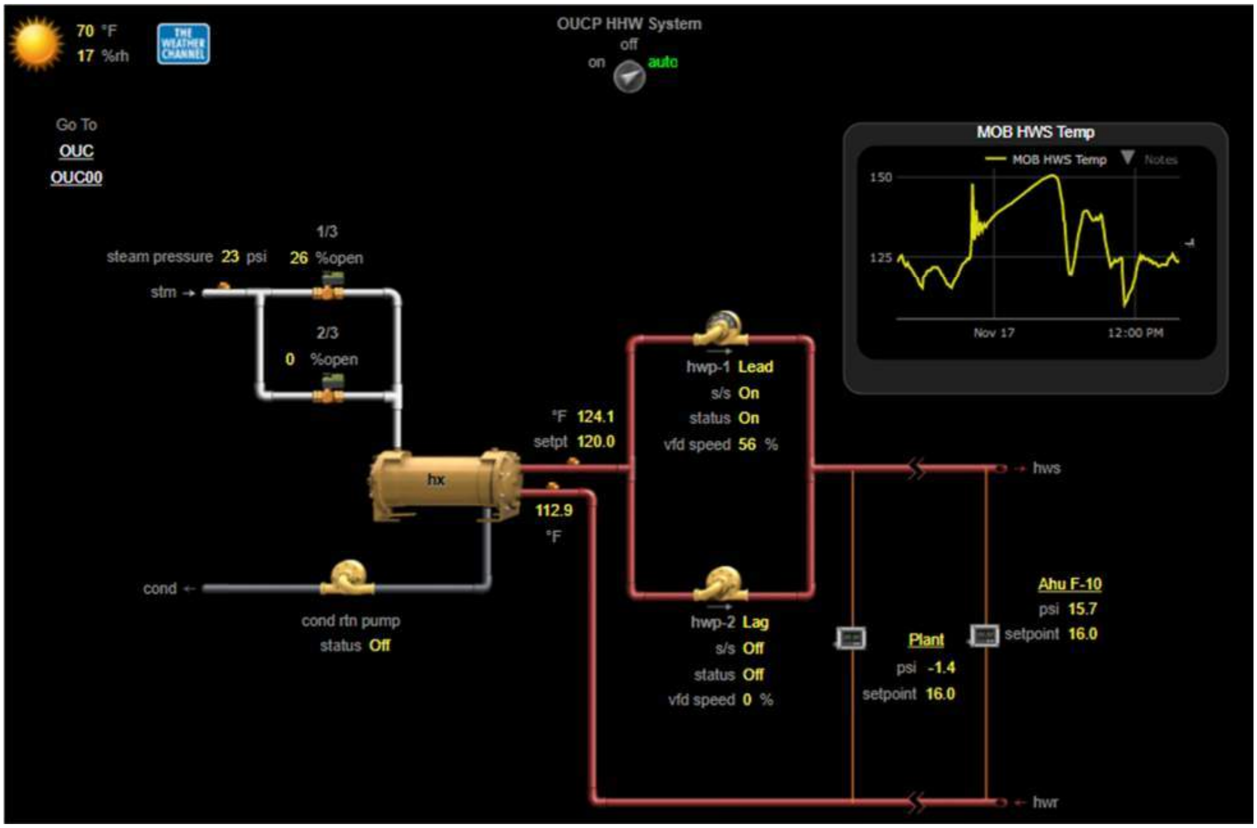
OCCUPIED

Heating 69.00 Cooling 72.00

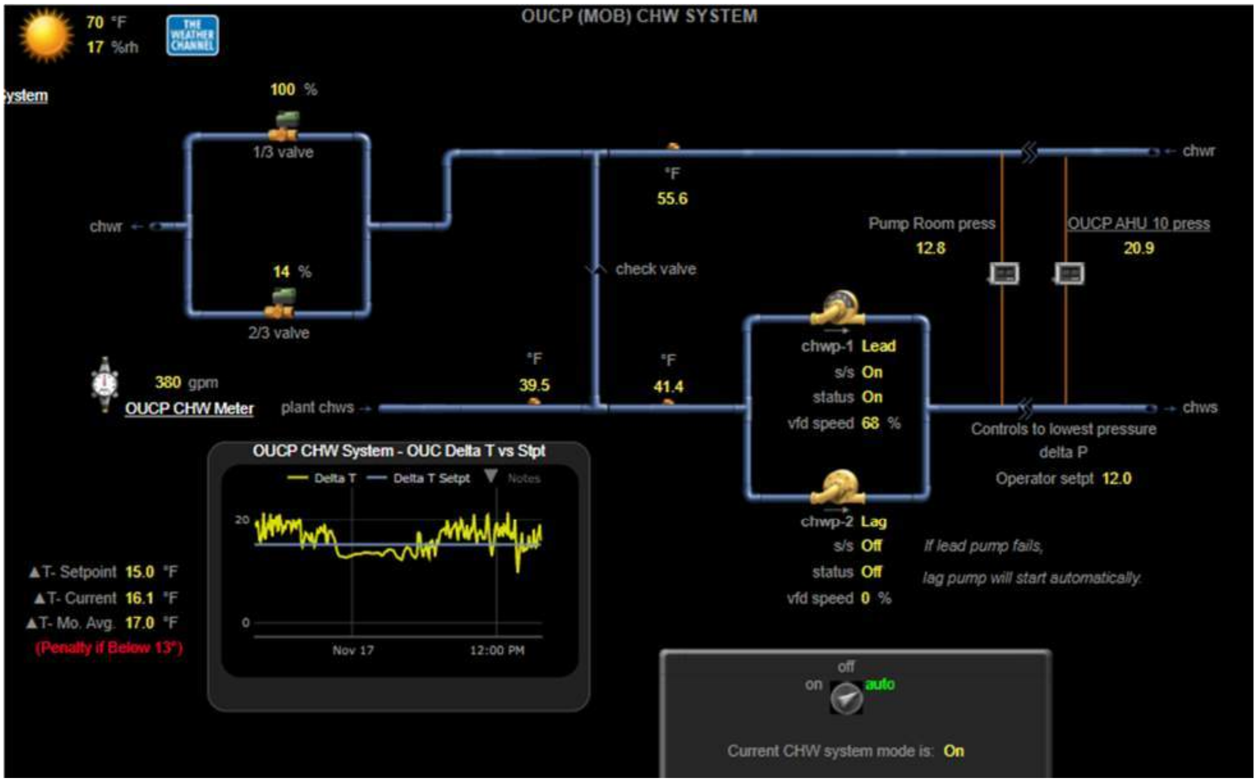
RF F14, EF F14, VF (14th Floor)

The steam-to-hot water heat exchanger for the heating hot water distribution system was observed to be resetting the supply water temperature between 120ºF and 180ºF and inversely proportional to outside air temperatures between 20ºF and 60ºF. The heating hot water distribution system temperature reset schedule appeared to modulate the pump speed between 50% and 100%. The heating hot water distribution system differential pressure reset schedule was observed to be set at a constant speed of 100% at any differential pressure, or effectively inactivating the reset schedule. This may be due to the lowest differential pressure readings on the ECMS being observed to be less than 0.0 psig at different periods of time. These low readings may be indicative of a differential pressure sensor being out of calibration. Heating loads will vary as the weather changes and as the AHUs in the building attempt to maintain a discharge air temperature setpoint. The building could benefit from a more aggressive hot water temperature reset schedule and an active differential pressure reset schedule, although steam usage for the building is proportionally low compared to other utilities such as electricity and chilled water.

The chilled water distribution system differential pressure was observed to be resetting the lead pump speed between 20% and 100% and proportional to the differential pressure of the supply chilled water and the return chilled water pressure range between 20 and 30 psig. The building could benefit from a more aggressive differential pressure reset schedule and reduce operating costs associated with the chilled water and electric utilities by reducing consumption of the pump motors and demand for chilled water from the OUHSC central plant.



HHW Distribution System



70 °F
17 %rh

100 %
14 %

°F 55.6
°F 39.5
°F 41.4

380 gpm

Pump Room press 12.8
OUCP AHU 10 press 20.9

chwp-1 Lead
s/s On
status On
vfd speed 68 %

chwp-2 Lag
s/s Off
status Off
vfd speed 0 %

If lead pump fails,
lag pump will start automatically.

Controls to lowest pressure
delta P
Operator setpt 12.0

▲T- Setpoint 15.0 °F
▲T- Current 16.1 °F
▲T- Mo. Avg. 17.0 °F
(Penalty if Below 13°)

Current CHW system mode is: On

CHW Distribution System

During the site visits, the Terracon team made the following observations:

1. Terracon observed AHU F0 in basement and AHU F2 thru AHU F12 in mechanical rooms aligned by floor throughout the building.
2. Terracon observed the relief air fans and exhaust fans located in separate mechanical rooms from the AHUs on each floor.
3. The two chilled water distribution pumps and two heating hot water distribution pumps are designated to operate with individual variable speed drives and utilize differential pressure reset schedules based on cooling or heating load demand.
4. The two heating hot water distribution pumps operate with supply temperature reset schedules based on outside air temperature.
5. The *ALC* EMCS software graphics were observed before and during Terracon's site visit to verify that the graphic representation of the AHU damper positions matched the physical operating parameters of the damper actuators.
6. Serviceability of outside airflow monitoring stations for maintenance associated with the AHUs is very limited given obstructions from the chilled water piping risers.
7. Air pressure for each floor directly outside of the mechanical rooms was significantly negative on the 2nd and 4th Floors, indicating potential problem with ventilation associated with the AHUs such as potential obstruction like fire damper closure or failed fire/smoke damper actuators.
8. The relief fan on the 7th Floor was observed to be operating without the AHU in economizer mode in lieu of the system as designed.
9. Many of the static air pressure measurements on various floors were observed on the EMCS to be less than 0.00 in w.g.
10. The economizer setting activation for AHUs ranged between when outside air temperatures were 53-degF and 58degF.
11. The outside air dampers and separate economizer dampers for AHU F0, AHU F2, AHU F3 were all observed to be 0% open. The outside air dampers are expected to be open and modulating when the AHU is operating and provide the minimum outside air as required by the outside airflow monitoring setpoint in the EMCS. The economizer dampers are only expected to open and modulate when the outside air temperature drops below the economizer temperature setpoint to engage the AHU to operate in economizer mode.
12. The outside air dampers for AHU F4 was observed to be open 38% providing outside air for the AHU based on the airflow monitor setpoint in the EMCS. The separate economizer dampers were observed to be open at 0%.
13. The outside air dampers for AHU F7 were observed to be open 100% providing outside air for the AHU based on the airflow monitor setpoint in the EMCS. The separate economizer dampers were observed to be open at 0% with the relief fan speed operating

at 100%. The static air pressure reading in the EMCS was observed to be +0.05 in w.g.

14. The outside air dampers for AHU F9 were observed to be open 56% providing outside air for the AHU based on the airflow monitor setpoint in the EMCS. The separate economizer dampers were observed to be open at 0%.
15. The outside air dampers for AHU F12 were observed to be open 56% providing outside air for the AHU based on the airflow monitor setpoint in them EMCS. The separate economizer dampers were observed to be open at 0%.
16. The outside air dampers for AHU F14 were observed to be open 76% providing outside air for the AHU based on the airflow monitor setpoint in the EMCS. The separate economizer dampers were observed to be open at 0%.

Recommendations Include:

1. Ventilation settings should be adjusted to provide positive static air pressure on each floor.
2. The supply heating hot water distribution temperature setpoint should be reset according to outdoor air temperature to further reduce operation costs.
3. Verify calibration of all control sensors due to age of end devices.
4. Verify economizer functionality and optimize outside air temperature setpoints to activate economizer dampers and relief fan operation.
5. Calibrate differential pressure sensors and observe location of reference points, verifying they are free of obstructions.
6. Clean, filter, and calibration outside air flow monitoring stations. Provide access panels for regular maintenance.

BUILDING INFRASTRUCTURE TESTING

Terracon investigated various discrepancies between the design requirements in the drawings provided and the EMCS readings with independent air flow instruments provided by our sub-consultant TAB firm. The AHU air flow parameters at AHU F0, AHU F2, AHU F3, AHU F4, AHU F5, AHU F6, AHU F7, AHU F8, AHU F9, AHU F10, AHU F11, AHU F12, and AHU F14 were all measured in a traverse pattern grid that is in accordance with industry TAB standards for testing HVAC systems.

In addition to supply air flow measurements, Terracon also tested and verified the following:

1. Supply air temperature being distributed to the VAV TBs.
2. Entering and leaving water temperatures for each hot water and chilled water coil, where testing ports were available.
3. Entering and leaving water pressures for each hot water and chilled water coil, where testing ports were available.
4. Entering and leaving air pressures for each hot water and chilled water coil section, where access was available.
5. External static air pressure (suction and discharge) for each AHU supply fan, where access was available.

All measurements were taken independent to the EMCS readings to verify accuracy of the parameters being read by the *ALC webCTRL* system. The accuracy of the measurements are necessary to validate the HVAC systems are meeting the equipment's design performance requirements.

The following information was field measured by our sub-consultant TAB firm, ES2:

AHU F0

Total Supply Air [CFM]	Supply Air Temperature [ºF]	Entering Heating Coil Temperature [ºF]	Leaving Heating Coil Temperature [ºF]	Entering Cooling Coil Temperature [ºF]	Leaving Cooling Coil Temperature [ºF]
15,589	56.4	115.0	104.0	41.0	59.0

Heating Coil Delta Air Pressure [in H_2O]	Cooling Coil Delta Air Pressure [in H_2O]	Heating Coil Delta Water Pressure [psig]	Cooling Coil Delta Water Pressure [psig]	External Fan Static Pressure [in H_2O]
0.52	0.46	47.2	22.7	1.63

AHU F02

Total Supply Air [CFM]	Supply Air Temperature [ºF]	Entering Heating Coil Temperature [ºF]	Leaving Heating Coil Temperature [ºF]	Entering Cooling Coil Temperature [ºF]	Leaving Cooling Coil Temperature [ºF]
25,116	57.7	112.0	102.0	47.0	60.0

Heating Coil Delta Air Pressure [in H_2O]	Cooling Coil Delta Air Pressure [in H_2O]	Heating Coil Delta Water Pressure [psig]	Cooling Coil Delta Water Pressure [psig]	External Fan Static Pressure [in H_2O]
0.27	0.39	6.2	-	3.30

AHU F03

Total Supply Air [CFM]	Supply Air Temperature [ºF]	Entering Heating Coil Temperature [ºF]	Leaving Heating Coil Temperature [ºF]	Entering Cooling Coil Temperature [ºF]	Leaving Cooling Coil Temperature [ºF]
27,490	59.7	120.0	106.0	45.0	50.0

Heating Coil Delta Air Pressure [in H_2O]	Cooling Coil Delta Air Pressure [in H_2O]	Heating Coil Delta Water Pressure [psig]	Cooling Coil Delta Water Pressure [psig]	External Fan Static Pressure [in H_2O]
0.44	0.40	3.7	-	3.34

AHU F04

Total Supply Air [CFM]	Supply Air Temperature [ºF]	Entering Heating Coil Temperature [ºF]	Leaving Heating Coil Temperature [ºF]	Entering Cooling Coil Temperature [ºF]	Leaving Cooling Coil Temperature [ºF]
25,424	59.2	180.0	154.0	52.0	63.0

Heating Coil Delta Air Pressure [in H_2O]	Cooling Coil Delta Air Pressure [in H_2O]	Heating Coil Delta Water Pressure [psig]	Cooling Coil Delta Water Pressure [psig]	External Fan Static Pressure [in H_2O]
0.35	0.38	-	-	3.27

AHU F05

Total Supply Air [CFM]	Supply Air Temperature [ºF]	Entering Heating Coil Temperature [ºF]	Leaving Heating Coil Temperature [ºF]	Entering Cooling Coil Temperature [ºF]	Leaving Cooling Coil Temperature [ºF]
25,601	54.0	135.0	120.0	35.0	38.0

Heating Coil Delta Air Pressure [in H_2O]	Cooling Coil Delta Air Pressure [in H_2O]	Heating Coil Delta Water Pressure [psig]	Cooling Coil Delta Water Pressure [psig]	External Fan Static Pressure [in H_2O]
0.30	0.31	8.3	19.9	1.99

AHU F06

Total Supply Air [CFM]	Supply Air Temperature [ºF]	Entering Heating Coil Temperature [ºF]	Leaving Heating Coil Temperature [ºF]	Entering Cooling Coil Temperature [ºF]	Leaving Cooling Coil Temperature [ºF]
28,007	59.0	114.0	104.0	48.0	61.0

Heating Coil Delta Air Pressure [in H_2O]	Cooling Coil Delta Air Pressure [in H_2O]	Heating Coil Delta Water Pressure [psig]	Cooling Coil Delta Water Pressure [psig]	External Fan Static Pressure [in H_2O]
0.33	0.43	4.5	-	3.13

AHU F07

Total Supply Air [CFM]	Supply Air Temperature [ºF]	Entering Heating Coil Temperature [ºF]	Leaving Heating Coil Temperature [ºF]	Entering Cooling Coil Temperature [ºF]	Leaving Cooling Coil Temperature [ºF]
28,252	56.5	113.0	106.0	47.0	58.0

Heating Coil Delta Air Pressure [in H_2O]	Cooling Coil Delta Air Pressure [in H_2O]	Heating Coil Delta Water Pressure [psig]	Cooling Coil Delta Water Pressure [psig]	External Fan Static Pressure [in H_2O]
0.42	0.38	4.3	-	2.70

AHU F08

Total Supply Air [CFM]	Supply Air Temperature [ºF]	Entering Heating Coil Temperature [ºF]	Leaving Heating Coil Temperature [ºF]	Entering Cooling Coil Temperature [ºF]	Leaving Cooling Coil Temperature [ºF]
26,451	71.0	119.0	109.0	47.0	60.0

Heating Coil Delta Air Pressure [in H_2O]	Cooling Coil Delta Air Pressure [in H_2O]	Heating Coil Delta Water Pressure [psig]	Cooling Coil Delta Water Pressure [psig]	External Fan Static Pressure [in H_2O]
0.54	0.49	3.4	8.8	3.51

AHU F09

Total Supply Air [CFM]	Supply Air Temperature [ºF]	Entering Heating Coil Temperature [ºF]	Leaving Heating Coil Temperature [ºF]	Entering Cooling Coil Temperature [ºF]	Leaving Cooling Coil Temperature [ºF]
23,774	56.7	180.0	154.0	52.0	63.0

Heating Coil Delta Air Pressure [in H_2O]	Cooling Coil Delta Air Pressure [in H_2O]	Heating Coil Delta Water Pressure [psig]	Cooling Coil Delta Water Pressure [psig]	External Fan Static Pressure [in H_2O]
0.40	0.36	3.3	-	2.84

AHU F10

Total Supply Air [CFM]	Supply Air Temperature [ºF]	Entering Heating Coil Temperature [ºF]	Leaving Heating Coil Temperature [ºF]	Entering Cooling Coil Temperature [ºF]	Leaving Cooling Coil Temperature [ºF]
25,102	57.8	114.0	104.0	44.0	56.0

Heating Coil Delta Air Pressure [in H_2O]	Cooling Coil Delta Air Pressure [in H_2O]	Heating Coil Delta Water Pressure [psig]	Cooling Coil Delta Water Pressure [psig]	External Fan Static Pressure [in H_2O]
0.40	0.36	18.2	-	1.87

AHU F11

Total Supply Air [CFM]	Supply Air Temperature [ºF]	Entering Heating Coil Temperature [ºF]	Leaving Heating Coil Temperature [ºF]	Entering Cooling Coil Temperature [ºF]	Leaving Cooling Coil Temperature [ºF]
22,500	67.7	114.0	102.0	48.0	60.0

Heating Coil Delta Air Pressure [in H_2O]	Cooling Coil Delta Air Pressure [in H_2O]	Heating Coil Delta Water Pressure [psig]	Cooling Coil Delta Water Pressure [psig]	External Fan Static Pressure [in H_2O]
0.24	0.35	4.3	8.1	2.53

AHU F12

Total Supply Air [CFM]	Supply Air Temperature [ºF]	Entering Heating Coil Temperature [ºF]	Leaving Heating Coil Temperature [ºF]	Entering Cooling Coil Temperature [ºF]	Leaving Cooling Coil Temperature [ºF]
27,402	56.4	119.5	107.5	52.0	58.9

Heating Coil Delta Air Pressure [in H_2O]	Cooling Coil Delta Air Pressure [in H_2O]	Heating Coil Delta Water Pressure [psig]	Cooling Coil Delta Water Pressure [psig]	External Fan Static Pressure [in H_2O]
0.30	0.40	3.9	-	2.70

AHU F14

Total Supply Air [CFM]	Supply Air Temperature [ºF]	Entering Heating Coil Temperature [ºF]	Leaving Heating Coil Temperature [ºF]	Entering Cooling Coil Temperature [ºF]	Leaving Cooling Coil Temperature [ºF]
30,145	52.0	137.3	99.7	49.0	60.0

Heating Coil Delta Air Pressure [in H_2O]	Cooling Coil Delta Air Pressure [in H_2O]	Heating Coil Delta Water Pressure [psig]	Cooling Coil Delta Water Pressure [psig]	External Fan Static Pressure [in H_2O]
0.20	0.40	1.24	-	2.51

During testing, the Terracon team made the following observations:

1. Access to some chilled water and hot water coil ports were not possible due to obstructions.

ENERGY CONSERVATION OPPORTUNITIES (ECOs) AND RECOMMENDATIONS

In order to effectively evaluate existing systems and deficiencies and to provide recommended measures, various methods and actions were considered. Considerations include:

- Analysis of existing construction drawings and as-built documentation.
- Analysis of utility bills.
- Conversations with the UHAT and 1CALL personnel regarding HVAC system configuration, controls, and existing trouble spots.
- Collection of information and data from *ALC webCTRL* interface to gather set points, operating conditions, identify anomalies, etc.
- Site surveys and investigations.
- Profiled mechanical equipment (e.g. pumps, chillers, air handling units) affected by the ECO's so that accurate calculations of savings could be produced.
- For weather dependent systems, bin temperature analysis is to be used to calculate baseline and post-installation consumption.
- For weather independent systems, time-of-use methods were used to calculate baseline and post-installation consumption.

Energy conservation opportunities (ECOs) have been listed on the basis of cost, potential benefit and, most importantly, Owner approval.

ECO Master List

Table 3: Master List

Measure #	Equipment or System	Description of Finding	Recommended Improvement
M1.1.1.	Central Plant	Supply chilled water distribution pump speed is to reset between 20% and 100% proportional to the differential pressure of the supply chilled water and return chilled water range between 20 and 30 psig.	Program the EMCS to reset chilled water distribution pump speed. Use a linear relationship of 20% pump speed at 10 psig differential pressure and 100% pump speed at 30 psig or above differential pressure.
M1.2.1.	Central Plant	Supply heating hot water distribution pump speed is not currently utilizing a differential pressure reset schedule.	Program the EMCS to reset heating hot water distribution pump speed. Use a linear relationship of 20% pump speed at 10 psig differential pressure and 100% pump speed at 28 psig or above differential pressure.
M1.2.2.	Central Plant	Supply heating hot water distribution temperature from steam-to-hot water heat exchanger are set to reset between 120ºF and 180ºF inversely proportional to outside air temperatures between 20ºF and 60ºF.	Program the EMCS to reset supply hot water temperature according to outside air conditions. Use a linear relationship of 160ºF supply hot water temperature at 20ºF or below outside air temperature and 90ºF at 80ºF or above outside air temperature.
M2.1.1.	AHU F0	Outside air dampers are open at 0% when AHU and EF are operating. This is causing negative air pressure in the space and bringing unconditioned outside air into the building that is an unnecessary load inside the building that can affect occupant comfort and potentially cause adverse environmental conditions for critical spaces.	Clean and calibrate/replace outside air flow monitoring station and sensors. Also consider adding a small filter at the intake of the monitoring station to provide debris from obstruction sensor ports. Program EMCS to allow AHU to provide minimum outside air (5,680 CFM) when EF fan (4,930 CFM) speed is operating at 100%.

Measure #	Equipment or System	Description of Finding	Recommended Improvement
M2.1.2.	AHU F0	Outside air dampers are open at 0% when AHU and EF are operating. This is causing negative air pressure in the space and bringing unconditioned outside air into the building that is an unnecessary load inside the building that can affect occupant comfort and potentially cause adverse environmental conditions for critical spaces.	Clean and calibrate/replace outside air flow monitoring station and sensors. Also consider adding a small filter at the intake of the monitoring station to provide debris from obstruction sensor ports. Install new VFD for interlocked EF, integrate VFD points to field controller, and program EMCS to modulate EF fan speed and CFM based on outside air readings at AHU.
M2.2.1.	AHU F0	Differential pressure across the chilled water coil was slightly greater than expected when independent air measurements were taken.	Clean chilled water coil to improve discharge air flow and discharge air temperatures.
M2.2.2.	AHU F0	Differential pressure across the heating hot water coil was slightly greater than expected when independent air measurements were taken.	Clean heating hot water coil to improve discharge air flow and discharge air temperatures.
M3.1.1	AHU F2	Outside air dampers are open at 0% when AHU and EF are operating. This is causing negative air pressure in the space and bringing unconditioned outside air into the building that is an unnecessary load inside the building that can affect occupant comfort and potentially cause adverse environmental conditions for critical spaces.	Clean and calibrate/replace outside air flow monitoring station and sensors. Also consider adding a small filter at the intake of the monitoring station to provide debris from obstruction sensor ports. Program EMCS to allow AHU to provide minimum outside air (4,000 CFM) when EF fan (1,630 CFM) speed is operating at 100%.
M3.1.2.	AHU F2	Outside air dampers are open at 0% when AHU and EF are operating. This is causing negative air pressure in the space and bringing unconditioned outside air into the building that is an unnecessary load inside the building that can affect occupant comfort and potentially cause adverse environmental conditions	Clean and calibrate/replace outside air flow monitoring station and sensors. Also consider adding a small filter at the intake of the monitoring station to provide debris from obstruction sensor ports. Install new VFD for interlocked EF, integrate VFD points to

Measure #	Equipment or System	Description of Finding	Recommended Improvement
		for critical spaces.	field controller, and program EMCS to modulate EF fan speed and CFM based on outside air readings at AHU.
M4.1.1	AHU F3	Outside air dampers are open at 0% when AHU and EF are operating. This is causing negative air pressure in the space and bringing unconditioned outside air into the building that is an unnecessary load inside the building that can affect occupant comfort and potentially cause adverse environmental conditions for critical spaces.	Clean and calibrate/replace outside air flow monitoring station and sensors. Also consider adding a small filter at the intake of the monitoring station to provide debris from obstruction sensor ports. Program EMCS to allow AHU to provide minimum outside air (4,625 CFM) when EF fan (2,165 CFM) speed is operating at 100%.
M4.1.2.	AHU F3	Outside air dampers are open at 0% when AHU and EF are operating. This is causing negative air pressure in the space and bringing unconditioned outside air into the building that is an unnecessary load inside the building that can affect occupant comfort and potentially cause adverse environmental conditions for critical spaces.	Clean and calibrate/replace outside air flow monitoring station and sensors. Also consider adding a small filter at the intake of the monitoring station to provide debris from obstruction sensor ports. Install new VFD for interlocked EF, integrate VFD points to field controller, and program EMCS to modulate EF fan speed and CFM based on outside air readings at AHU.
M5.1.1.	AHU F4	Outside air dampers are open at 38% (500 CFM setpoint, 824 CFM EMCS flow) when AHU, EF, and VF are all operating simultaneously. This is causing negative air pressure in the space and bringing unconditioned outside air into the building that is an unnecessary load inside the building that can affect occupant comfort and potentially cause adverse environmental conditions for critical spaces.	Clean and calibrate/replace outside air flow monitoring station and sensors. Also consider adding a small filter at the intake of the monitoring station to provide debris from obstruction sensor ports. Program EMCS to allow AHU to provide minimum outside air (3,850 CFM designed, but increase to approximately 4,200 CFM) when EF fan (3,940 CFM) speed is operating at 100%.

Measure #	Equipment or System	Description of Finding	Recommended Improvement
M5.1.2.	AHU F4	Outside air dampers are open at 38% (500 CFM setpoint, 824 CFM EMCS flow) when AHU, EF, and VF are all operating simultaneously. This is causing negative air pressure in the space and bringing unconditioned outside air into the building that is an unnecessary load inside the building that can affect occupant comfort and potentially cause adverse environmental conditions for critical spaces.	Clean and calibrate/replace outside air flow monitoring station and sensors. Also consider adding a small filter at the intake of the monitoring station to provide debris from obstruction sensor ports. Install new VFD for interlocked EF, integrate VFD points to field controller, and program EMCS to modulate EF fan speed and CFM based on outside air readings at AHU.
M6.1.1.	AHU F6	Outside air dampers are open at 100% (2,000 CFM setpoint, 2,266 CFM EMCS flow) when AHU, EF, and VF are all operating simultaneously. This is causing negative air pressure in the space and bringing unconditioned outside air into the building that is an unnecessary load inside the building that can affect occupant comfort and potentially cause adverse environmental conditions for critical spaces.	Clean and calibrate/replace outside air flow monitoring station and sensors. Also consider adding a small filter at the intake of the monitoring station to provide debris from obstruction sensor ports. Program EMCS to allow AHU to provide minimum outside air (4,550 CFM) when EF fan (2,285 CFM) speed is operating at 100%.
M6.1.2.	AHU F6	Outside air dampers are open at 100% (2,000 CFM setpoint, 2,266 CFM EMCS flow) when AHU, EF, and VF are all operating simultaneously. This is causing negative air pressure in the space and bringing unconditioned outside air into the building that is an unnecessary load inside the building that can affect occupant comfort and potentially cause adverse environmental conditions for critical spaces.	Clean and calibrate/replace outside air flow monitoring station and sensors. Also consider adding a small filter at the intake of the monitoring station to provide debris from obstruction sensor ports. Install new VFD for interlocked EF, integrate VFD points to field controller, and program EMCS to modulate EF fan speed and CFM based on outside air readings at AHU.
M7.1.1.	AHU F7	Outside air dampers are open at 100% (2,000 CFM setpoint, 0 CFM EMCS flow) when AHU, EF, and VF are all operating simultaneously. This is causing negative air pressure in the space	Clean and calibrate/replace outside air flow monitoring station and sensors. Also consider adding a small filter at the intake of the monitoring station to provide debris from

Measure #	Equipment or System	Description of Finding	Recommended Improvement
		and bringing unconditioned outside air into the building that is an unnecessary load inside the building that can affect occupant comfort and potentially cause adverse environmental conditions for critical spaces.	obstruction sensor ports. Program EMCS to allow AHU to provide minimum outside air (4,710 CFM) when EF fan (4,210 CFM) speed is operating at 100%.
M7.1.2.	AHU F7	Outside air dampers are open at 100% (2,000 CFM setpoint, 0 CFM EMCS flow) when AHU, EF, and VF are all operating simultaneously. This is causing negative air pressure in the space and bringing unconditioned outside air into the building that is an unnecessary load inside the building that can affect occupant comfort and potentially cause adverse environmental conditions for critical spaces.	Clean and calibrate/replace outside air flow monitoring station and sensors. Also consider adding a small filter at the intake of the monitoring station to provide debris from obstruction sensor ports. Install new VFD for interlocked EF, integrate VFD points to field controller, and program EMCS to modulate EF fan speed and CFM based on outside air readings at AHU.
M8.1.1.	AHU F8	Outside air dampers are open at 38% (500 CFM setpoint, 3,582 CFM EMCS flow) when AHU, EF, and VF are all operating simultaneously. This is causing negative air pressure in the space and bringing unconditioned outside air into the building that is an unnecessary load inside the building that can affect occupant comfort and potentially cause adverse environmental conditions for critical spaces.	Clean and calibrate/replace outside air flow monitoring station and sensors. Also consider adding a small filter at the intake of the monitoring station to provide debris from obstruction sensor ports. Program EMCS to allow AHU to provide minimum outside air (5,015 CFM) when EF fan (4,515 CFM) speed is operating at 100%.
M8.1.2.	AHU F8	Outside air dampers are open at 38% (500 CFM setpoint, 3,582 CFM EMCS flow) when AHU, EF, and VF are all operating simultaneously. This is causing negative air pressure in the space and bringing unconditioned outside air into the building that is an unnecessary load inside the building that can affect occupant comfort and potentially cause adverse environmental conditions for critical spaces.	Clean and calibrate/replace outside air flow monitoring station and sensors. Also consider adding a small filter at the intake of the monitoring station to provide debris from obstruction sensor ports. Install new VFD for interlocked EF, integrate VFD points to field controller, and program EMCS to modulate EF fan speed and CFM based on

Measure #	Equipment or System	Description of Finding	Recommended Improvement
			outside air readings at AHU.
M8.2.1.	AHU F8	Differential pressure across the chilled water coil was slightly greater than expected when independent air measurements were taken.	Clean chilled water coil to improve discharge air flow and discharge air temperatures.
M8.2.2.	AHU F8	Differential pressure across the heating hot water coil was slightly greater than expected when independent air measurements were taken.	Clean heating hot water coil to improve discharge air flow and discharge air temperatures.
M9.1.1.	AHU F10	Outside air dampers are open at 100% (3,500 CFM setpoint, 3,204 CFM EMCS flow) when AHU, EF, and VF are all operating simultaneously. This is causing negative air pressure in the space and bringing unconditioned outside air into the building that is an unnecessary load inside the building that can affect occupant comfort and potentially cause adverse environmental conditions for critical spaces.	Clean and calibrate/replace outside air flow monitoring station and sensors. Also consider adding a small filter at the intake of the monitoring station to provide debris from obstruction sensor ports. Program EMCS to allow AHU to provide minimum outside air (3,800 CFM) when EF fan (2,940 CFM) speed is operating at 100%.
M9.1.2.	AHU F10	Outside air dampers are open at 100% (3,500 CFM setpoint, 3,204 CFM EMCS flow) when AHU, EF, and VF are all operating simultaneously. This is causing negative air pressure in the space and bringing unconditioned outside air into the building that is an unnecessary load inside the building that can affect occupant comfort and potentially cause adverse environmental conditions for critical spaces.	Clean and calibrate/replace outside air flow monitoring station and sensors. Also consider adding a small filter at the intake of the monitoring station to provide debris from obstruction sensor ports. Install new VFD for interlocked EF, integrate VFD points to field controller, and program EMCS to modulate EF fan speed and CFM based on outside air readings at AHU.
M9.2.1.	AHU F10	Differential pressure across the chilled water coil was slightly greater than expected when independent air measurements were taken.	Clean chilled water coil to improve discharge air flow and discharge air temperatures.

Measure #	Equipment or System	Description of Finding	Recommended Improvement
M10.1.1.	AHU F12	Outside air dampers are open at 46% (2,500 CFM setpoint, 2,266 CFM EMCS flow) when AHU, EF, and VF are all operating simultaneously. This is causing negative air pressure in the space and bringing unconditioned outside air into the building that is an unnecessary load inside the building that can affect occupant comfort and potentially cause adverse environmental conditions for critical spaces.	Clean and calibrate/replace outside air flow monitoring station and sensors. Also consider adding a small filter at the intake of the monitoring station to provide debris from obstruction sensor ports. Program EMCS to allow AHU to provide minimum outside air (4,300 CFM) when EF fan (1,200 CFM) speed is operating at 100%.
M10.1.2.	AHU F12	Outside air dampers are open at 46% (2,500 CFM setpoint, 2,266 CFM EMCS flow) when AHU, EF, and VF are all operating simultaneously. This is causing negative air pressure in the space and bringing unconditioned outside air into the building that is an unnecessary load inside the building that can affect occupant comfort and potentially cause adverse environmental conditions for critical spaces.	Clean and calibrate/replace outside air flow monitoring station and sensors. Also consider adding a small filter at the intake of the monitoring station to provide debris from obstruction sensor ports. Install new VFD for interlocked EF, integrate VFD points to field controller, and program EMCS to modulate EF fan speed and CFM based on outside air readings at AHU.
M11.1.1.	AHU F14	Outside air dampers are open at 63% (2,000 CFM setpoint, 2,101 CFM EMCS flow) when AHU, EF, and VF are all operating simultaneously. This is causing negative air pressure in the space and bringing unconditioned outside air into the building that is an unnecessary load inside the building that can affect occupant comfort and potentially cause adverse environmental conditions for critical spaces.	Clean and calibrate/replace outside air flow monitoring station and sensors. Also consider adding a small filter at the intake of the monitoring station to provide debris from obstruction sensor ports. Program EMCS to allow AHU to provide minimum outside air (4,300 CFM) when EF fan (1,400 CFM) speed is operating at 100%.
M11.1.2.	AHU F14	Outside air dampers are open at 63% (2,000 CFM setpoint, 2,101 CFM EMCS flow) when AHU, EF, and VF are all operating simultaneously. This is causing negative air pressure in the space and bringing unconditioned	Clean and calibrate/replace outside air flow monitoring station and sensors. Also consider adding a small filter at the intake of the monitoring station to provide debris from obstruction sensor ports.

Measure #	Equipment or System	Description of Finding	Recommended Improvement
		outside air into the building that is an unnecessary load inside the building that can affect occupant comfort and potentially cause adverse environmental conditions for critical spaces.	Install new VFD for interlocked EF, integrate VFD points to field controller, and program EMCS to modulate EF fan speed and CFM based on outside air readings at AHU.
M12.1.1.	VF-1 (2nd Floor)	Ventilation fan is operating continuously when mechanical room is above cooling setpoint (72ºF). Deadband was observed to be 3ºF (69ºF). Ventilation fan is operating often simultaneously with exhaust fan in the same room and possibly causing static pressure issues for the floor.	Program EMCS or local thermostat to operate ventilation fan with a cooling setpoint of 80ºF and a 20ºF deadband (60ºF low limit) to limit operation of ventilation fan.
M12.1.2.	VF-1 (3rd Floor)	Ventilation fan is operating continuously when mechanical room is above cooling setpoint (72ºF). Deadband was observed to be 3ºF (69ºF). Ventilation fan is operating often simultaneously with exhaust fan in the same room and possibly causing static pressure issues for the floor.	Program EMCS or local thermostat to operate ventilation fan with a cooling setpoint of 80ºF and a 20ºF deadband (60ºF low limit) to limit operation of ventilation fan.
M12.1.3.	VF-1 (4th Floor)	Ventilation fan is operating continuously when mechanical room is above cooling setpoint (72ºF). Deadband was observed to be 3ºF (69ºF). Ventilation fan is operating often simultaneously with exhaust fan in the same room and possibly causing static pressure issues for the floor.	Program EMCS or local thermostat to operate ventilation fan with a cooling setpoint of 80ºF and a 20ºF deadband (60ºF low limit) to limit operation of ventilation fan.
M12.1.4.	VF-1 (5th Floor)	Ventilation fan is operating continuously when mechanical room is above cooling setpoint (72ºF). Deadband was observed to be 3ºF (69ºF). Ventilation fan is operating often simultaneously with exhaust fan in the same room and possibly causing static pressure issues for the floor.	Program EMCS or local thermostat to operate ventilation fan with a cooling setpoint of 80ºF and a 20ºF deadband (60ºF low limit) to limit operation of ventilation fan.

Measure #	Equipment or System	Description of Finding	Recommended Improvement
M12.1.5.	VF-1 (6th Floor)	Ventilation fan is operating continuously when mechanical room is above cooling setpoint (72ºF). Deadband was observed to be 3ºF (69ºF). Ventilation fan is operating often simultaneously with exhaust fan in the same room and possibly causing static pressure issues for the floor.	Program EMCS or local thermostat to operate ventilation fan with a cooling setpoint of 80ºF and a 20ºF deadband (60ºF low limit) to limit operation of ventilation fan.
M12.1.6.	VF-1 (7th Floor)	Ventilation fan is operating continuously when mechanical room is above cooling setpoint (72ºF). Deadband was observed to be 3ºF (69ºF). Ventilation fan is operating often simultaneously with exhaust fan in the same room and possibly causing static pressure issues for the floor.	Program EMCS or local thermostat to operate ventilation fan with a cooling setpoint of 80ºF and a 20ºF deadband (60ºF low limit) to limit operation of ventilation fan.
M12.1.7.	VF-1 (8th Floor)	Ventilation fan is operating continuously when mechanical room is above cooling setpoint (72ºF). Deadband was observed to be 3ºF (69ºF). Ventilation fan is operating often simultaneously with exhaust fan in the same room and possibly causing static pressure issues for the floor.	Program EMCS or local thermostat to operate ventilation fan with a cooling setpoint of 80ºF and a 20ºF deadband (60ºF low limit) to limit operation of ventilation fan.
M12.1.8.	VF-1 (9th Floor)	Ventilation fan is operating continuously when mechanical room is above cooling setpoint (72ºF). Deadband was observed to be 3ºF (69ºF). Ventilation fan is operating often simultaneously with exhaust fan in the same room and possibly causing static pressure issues for the floor.	Program EMCS or local thermostat to operate ventilation fan with a cooling setpoint of 80ºF and a 20ºF deadband (60ºF low limit) to limit operation of ventilation fan.
M12.1.9.	VF-1 (10th Floor)	Ventilation fan is operating continuously when mechanical room is above cooling setpoint (72ºF). Deadband was observed to be 3ºF (69ºF). Ventilation fan is operating often simultaneously with exhaust fan in the same room and possibly causing static pressure issues for the floor.	Program EMCS or local thermostat to operate ventilation fan with a cooling setpoint of 80ºF and a 20ºF deadband (60ºF low limit) to limit operation of ventilation fan.

Measure #	Equipment or System	Description of Finding	Recommended Improvement
M12.1.10.	VF-1 (11th Floor)	Ventilation fan is operating continuously when mechanical room is above cooling setpoint (72ºF). Deadband was observed to be 3ºF (69ºF). Ventilation fan is operating often simultaneously with exhaust fan in the same room and possibly causing static pressure issues for the floor.	Program EMCS or local thermostat to operate ventilation fan with a cooling setpoint of 80ºF and a 20ºF deadband (60ºF low limit) to limit operation of ventilation fan.
M12.1.11.	VF-1 (12th Floor)	Ventilation fan is operating continuously when mechanical room is above cooling setpoint (72ºF). Deadband was observed to be 3ºF (69ºF). Ventilation fan is operating often simultaneously with exhaust fan in the same room and possibly causing static pressure issues for the floor.	Program EMCS or local thermostat to operate ventilation fan with a cooling setpoint of 80ºF and a 20ºF deadband (60ºF low limit) to limit operation of ventilation fan.
M12.1.12.	VF-1 (14th Floor)	Ventilation fan is operating continuously when mechanical room is above cooling setpoint (72ºF). Deadband was observed to be 3ºF (69ºF). Ventilation fan is operating often simultaneously with exhaust fan in the same room and possibly causing static pressure issues for the floor.	Program EMCS or local thermostat to operate ventilation fan with a cooling setpoint of 80ºF and a 20ºF deadband (60ºF low limit) to limit operation of ventilation fan.

LIMITATIONS

The field observations, tests, findings, and recommendations presented in this report are based upon the information provided to Terracon by the client, UHAT, and observations and field notes collected at the time of our site visits. While additional conditions may exist that could alter our recommendations, we feel that reasonable means have been made to fairly and accurately evaluate the existing conditions of these systems. This report is limited to Terracon's observations of the interior and exterior of the facility. Some of the observations were limited due to obstructions and access to areas of the systems and facility. Although our observations were made with normal care and diligence, it is likely that not all existing conditions were documented. The general intent was to identify representative conditions and provide recommendations based on general findings.

This report has been prepared for the exclusive use of UHAT for specific application to the project discussed and has been prepared in accordance with generally accepted engineering practices using the standard of care and skill currently exercised by professional engineers practicing in this area, for a project of similar scope and nature. No warranties, either expressed or implied, are intended or made. In the event that information described in this document which was provided by others is incorrect, or if additional information becomes available, the recommendations contained in this report shall not be considered valid unless Terracon reviews the information and either verifies or modifies the recommendations of this report in writing.

APPENDIX A
Photographs

Photo #1 AHU F0 is a typical AHU serving the basement. Terracon viewed all air handling units on the basement through 14th Floor.

Photo #2 Typical *ALC* field controllers and panel that operates the exhaust and relief fans for each floor.

Photo #3 Typical AHU supply fan VFD controller that modulates fan speed.

Photo #4 Typical constant volume exhaust fan serving each floor needed to achieve static air pressure design conditions.

Photo #5 Typical relief fan with damper actuator for each floor necessary to achieve static air pressure design conditions when AHUs are in air economizer mode.

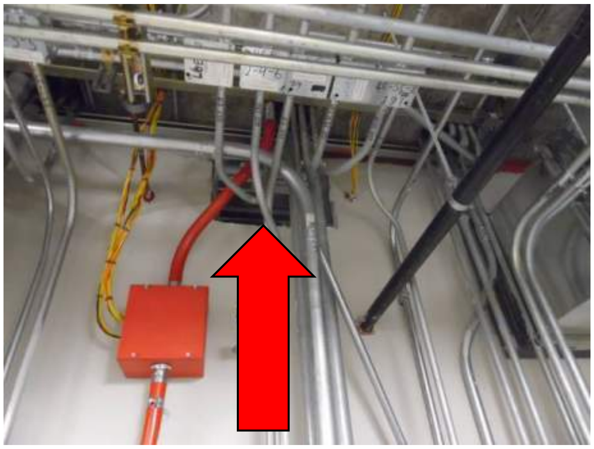


Photo #6 Typical fire and smoke dampers observed in return to each mechanical room.

Photo#7 Typical Titus VAV box with reheat coil throughout the building.

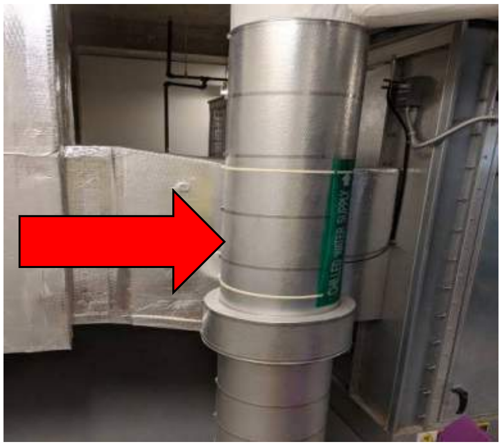


Photo #8 Access to clean and maintain sensor for outside air flow monitoring station is obstructed by chilled water piping in mechanical room.

Photo #9 Typical condition of corroded and debris laden outside air dampers with airflow monitoring station.

Photo #10 Typical ceiling-mounted air pressure sensor on each floor used to monitor and control static air pressure.

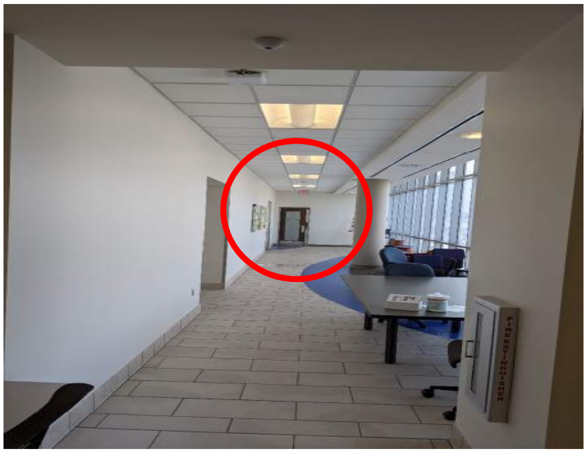


Photo #11 Excessive negative air pressure on the 4th Floor causing the corridor door opposite the mechanical room to open.

APPENDIX B
Test and Balancing Report

es2 engineered systems & energy solutions, inc.

13401 N. Santa Fe Avenue
Oklahoma City, Oklahoma 73114
Phone: (405) 528-4500

CERTIFIED TEST, ADJUST, AND BALANCE REPORT

Date: June 12, 2020

Project: Oncology Licensed Outpatient Clinic-10th Flr

Address: OU Children's MOB
Oklahoma City, OK

Mechanical Engineer: Alvine Engineering

ES2 project number 01-20069T

The data presented in this report is a record of system measurements and final adjustments that have been obtained in accordance with the current edition of the NEBB *Procedural Standard for Testing, Adjusting and Balancing of Environmental Systems*. The measurements shown, and the information given, in this report are certified to be accurate and complete, at the time and date information was gathered. Any variances from design quantities, which exceeds NEBB tolerances, are noted in the TAB report project summary/remarks.

Submitted and Certified by:

David M. Halcomb

NEBB Certified Test and Balance Supervisor

Engineered Systems & Energy Solutions, Inc.
NEBB Certification Number is: 3426
Expiration Date: March 31, 2022

DAVID M. HALCOMB
CERTIFICATION
3426
Exp. 3/31/22

SUMMARY/REMARKS

Job Name: Oncology Licensed Outpatient Clinic-10th Flr

1. AHU-F10: VAV boxes total up to 27685 cfm while AHU is only scheduled for 25000 cfm. This gives a diversity factor of 90%. AHU system was tested with 90% of boxes open and 10% shut to simulate this diversity.

2. There was no test site for an accurate traverse of the supply duct for AHU-F10. Total airflow was determined from box total flow readings through BAS system after calibration of all VAV controllers.

3. AT-F10-36,37,40: The fan motors are bad and will need to be replaced.

4. Output via BAS system is 100%, but there is an offset in the programming that gives a 5% reduction in fan speed. Also, amperage readings are just over design FLA, but this is marginal and could be due to variance in testing equipment. Sean O'Hara was notified of this and stated that it is acceptable.

Non Standard Abbreviations Used for Reporting

CCW	- Counter Clockwise
CD	- Ceiling Diffuser
CW	- Clockwise
DD	- Direct Drive
EG	- Exhaust Grille
INA	- Inaccessible
LD	- Linear Diffuser
NA	- Not Applicable
NG	- Not Given
NL	- Not Listed
NM	- Not Measured
NS	- Not Specified
NTS	- No Test Site
NV	- Not Visible
OA	- Outside Air
OTA	- Open To Atmosphere
PD	- Pressure Drop
RG	- Return Grille
SD	- Supply Diffuser
SP	- Static Pressure
SWD	- Sidewall Diffuser
TA	- Throw Away

Table of Contents

Job Name: Oncology Licensed Outpatient Clinic-10th Flr

Instruments

Job Name: Oncology Licensed Outpatient Clinic-10th Flr

Category	Instrument	Mfr.	Mdl #	Serial #	Last Cal'd	Next Due
Air	Air Data Multimeter	Shortridge	ADM-860	M93293	7/29/2019	7/29/2020
Electrical	Amp, volt meter True RMS	UEI	DL389	180601421	9/10/2019	9/10/2020
Tachometer	Digital Tachometer	Extech	461920	150103258	9/10/2019	9/10/2020
Temperature	Module / Probe	Evergreen Telemetry	RM-T-1 / PR-T-2	2000159 / 1900233	3/9/2020	3/9/2021
Water	Water Meter	Shortridge	HDM 250	W14080	4/14/2020	4/14/2021

AIR APPARATUS TEST SHEET

Job Name: Oncology Licensed Outpatient Clinic-10th Flr
Tested By: GLASS/JACQUEMIN **Date:** 6/5/2020

DESIGN DATA : **AHU-F10**

Manufacturer =	CLIMATECRAFT	**Model No. =**	CAH78X120E
Type =	NG	**Serial No. =**	22256
Outside Air cfm =	3,800		
Total Scheduled cfm =	25,000	**Grille Design Schedule cfm =**	27,685
Fan rpm =	NG		
Total Static Pressure =	NG	**External Static Pressure =**	2.00
Fan Rotation =	NG		

MOTOR DESIGN DATA

Horsepower =	30	**Voltage =**	460	**Phase =**	3	**Rpm =**	1750

AIR TEST DATA

Total cfm by Traverse Readings =	25,102	**Total cfm by Grille Readings =**	27,402
Outside Air =	5,001	**Return Air =**	20,101

TEMPERATURE TEST DATA

Outside Air Temperature =	NM	**Return Air Temperature =**	71.5/62.6
Mixed Air Temperature =	77/66.2	**Supply Air Temperature =**	57.8/56.1

PRESSURE TEST DATA

Fan Suction Static Pressure =		-2.43	
Fan Discharge Static Pressure =		1.80	
Total Static Pressure =			4.23
External Suction Static Pressure =		-1.21	
External Discharge Static Pressure =		0.66	
External Static Pressure =			1.87
Cooling Coil ΔS.P. =	0.53	**Heating Coil ΔS.P. =**	0.31
Pre Filters ΔS.P. =	0.32	**Final Filters ΔS.P. =**	NA

MOTOR TEST DATA

Motor Manufacturer / Frame =	BALDOR/286T						
HP =	30	**Volts/Ph/Hertz =**	460/3/60	**Act. Voltage =**	468	469	469
Full Load Amps =			35.5	**Act. Amps =**	34.1	33.9	34.0
Service Factor =			1.15				
Motor Design rpm =			1760	**Act motor rpm =**			1760

FAN TEST DATA

Motor Sheave Diameter =	INA	**Motor Sheave Bore =**	INA
Fan Sheave Diameter =	INA	**Fan Sheave Bore =**	INA
Adjustable Sheave Dia. =	INA	**Centerline Distance =**	INA
Fan rpm =	INA	**Fan Rotation =**	INA
Frequency Hz=	60 Hz		
Belts =	INA		
Pre Filters =	NA		
Final Filters =	20- 20x24x4		

Comments: 1. Unable to turn unit off to measure sheave sizes.

DUCT TRAVERSE ZONE TOTAL SHEET

Job Name: OUCP 10th Floor
Tested By: GLASS **Date:** 6/5/2020

SERVICE OR DESIGNATION	DUCT			DESIGN	PRELIM	ACTUAL	FINAL	FINAL %	FINAL
	TYPE	SIZE	AREA S.F.	CFM	CFM	Avg Velocity	CFM	of Design	S.P.
AHU-F10	SA	80X22	12.222	25000	25102	2053	25102	100	0.6
AHU-F10	RA	80X20	11.111	21200	20101	1809	20101	95	-1.21

TERMINAL UNIT SUMMARY

Job Name: Oncology Licensed Outpatient Clinic-10th Flr

Tested By: GLASS **Date:** 5/29/2020

Box #	Location	Size	Min Flow Cal	Max Flow Cal	Design Min CFM	Design Max CFM	Actual Min CFM	Actual Max CFM
AT-F10-1	10251	6	126-27	281-57.25	100	265	270	103
AT-F10-2	10262	6	82-17	351-72.15	100	370	395	110
AT-F10-3	10190	8	--	525-65.23	0	470	485	485
AT-F10-4	10036	6	60-13.00	125-28.07	70	140	140	69
AT-F10-5	10037	6	103-21	441-79.39	120	390	394	129
AT-F10-6	10040	8	122-20	435-55.35	135	460	467	129
AT-F10-7	10249	6	94-22.03	298-64.99	100	310	326	103
AT-F10-8	10245B	8	130-15.74	447-50.93	150	475	476	148
AT-F10-9	10241	8	133-20.00	500-52.27	150	430	417	143
AT-F10-10	10248	8	121-15.00	492-54.25	135	520	522	137
AT-F10-11	10239	8	160-22.0	559-59.83	150	510	493	155
AT-F10-12	10235	8	135-21.34	636-8137	150	680	688	155
AT-F10-13	10244	6	66-17.0	220-46.78	70	220	214	71
AT-F10-14	10240	6	77-11.45	199-40.14	70	220	228	68
AT-F10-15	10221	8	139-16.00	551-62.62	150	500	504	145
AT-F10-16	10231	8	135-17.11	753-78.96	150	650	628	156
AT-F10-17	10230	8	183-15.0	879-75.27	150	660	641	151
AT-F10-18	10236	6	105-26.0	383-80.06	100	300	312	102
AT-F10-19	10227	8	121-17.0	508-57.16	135	460	460	137
AT-F10-20	10225	6	65-15.0	251-53.3	70	260	276	76
AT-F10-21	10216D	10	334-9.4	1204-75.36	300	1050	1076	329
AT-F10-22	10216A	10	383-24.69	1279-85.06	300	1050	1017	287
AT-F10-23	10228	6	99-24.0	394-78.29	100	270	259	95
AT-F10-24	10213	8	201-23.41	534-60.78	150	580	574	161
AT-F10-25	10234	8	128-17.00	603-65.24	150	550	542	164
LT-8	10209	8	--	--	150	575	443	NM
AT-F10-27	10212	6	125-24.62	312-76.49	70	260	252	67
AT-F10-28	10259	8	139-17.55	684-74.67	150	640	640	149
AT-F10-29	10258	6	103-10.26	310-61.61	70	250	242	77
AT-F10-30	10201	6	59-15.98	184-38.09	70	160	169	76
AT-F10-31	10006	10	221-15.8	930-58.74	225	840	816	210
AT-F10-32	10004	6	77-14.82	192-39.91	70	190	195	74
AT-F10-33	10200	6	101-26.00	423-90.73	160	390	393	175
AT-F10-34	10263	14	416-20	1583-60.54	450	1700	1612	481
AT-F10-35	10075	12	282-19.69	1550-72.3	310	1500	1425	290
AT-F10-36	10074	12	309-20.22	1450-77.91	310	1500	1500	295
AT-F10-37	10074	12	295-20.95	1600-82.86	310	1500	1500	290
AT-F10-38	10218	12	308-18.68	1625-78.35	310	1500	1500	295
AT-F10-39	10216	12	305-21.04	1516-84.74	310	1500	1500	300
AT-F10-40	10216	12	303-19.94	1465-80.78	310	1500	1525	320
AT-F10-41	10216	12	300-22.00	1346-71.73	310	1290	1275	325
AT-F10-42	10101	8	195-25.0	742-74.16	150	600	611	152
						27685	27402	

Limiting Box
AT-F10-12,17,33,36,38,42

Box Manufacturer
TITUS

BAS Duct SP Setpoint
1.5"

Model Number
DESV/DTQS

VFD Speed
100% (60 Hz)

VAV AIR OUTLET TEST SHEET

Job Name: Oncology Licensed Outpatient Clinic-10th Flr
Tested By: GLASS

Outlet Number	Room Number	Code	Size	Design cfm	First Test	Second Test	--	Final cfm	%
AHU-F10									
AT-F10-1					**Date Tested:**		4/30/2020		
1	10251	CD	824	165	163	-	--	161	98%
2	10261	CD	624	100	110	-	--	109	109%
				265				270	102%
Box Type	**Box Size**				**Design Minimum**		**Test Minimum**		
VAV	6				100		103		103%
AT-F10-2					**Date Tested:**		4/30/2020		
1	10253	CD	624	120	136	111	--	130	108%
2	10255	CD	624	120	147	123	--	132	110%
3	10262	CD	624	130	102	138	--	133	102%
				370				395	107%
Box Type	**Box Size**				**Design Minimum**		**Test Minimum**		
VAV	6				100		110		110%
AT-F10-3					**Date Tested:**		4/30/2020		
1	10111	SD	12X8	235	178	231	--	232	99%
2	10111	SD	12X8	235	185	241	--	253	108%
				470				485	103%
Box Type	**Box Size**				**Design Minimum**		**Test Minimum**		
VAV	8				0		--		
AT-F10-4					**Date Tested:**		4/29/2020		
1	10250	CD	624	140	133	-	--	140	100%
Box Type	**Box Size**				**Design Minimum**		**Test Minimum**		
VAV	6				70		69		99%

VAV AIR OUTLET TEST SHEET

Job Name: Oncology Licensed Outpatient Clinic-10th Flr
Tested By: GLASS

Outlet Number	Room Number	Code	Size	Design cfm	First Test	Second Test	--	Final cfm	%

AHU-F10

AT-F10-5 **Date Tested:** 4/29/2020

1	10252	CD	624	130	132	-	--	123	95%
2	10254	CD	624	130	140	-	--	134	103%
3	10256	CD	624	130	143	-	--	137	105%
				390				394	101%
Box Type	**Box Size**				**Design Minimum**		**Test Minimum**		
VAV	6				120		129		108%

***AT-F10-6** **Date Tested:** 4/29/2020

1	10245	CD	824	230	252	-	--	244	106%
2	10245	CD	824	230	224	-	--	223	97%
				460				467	102%
Box Type	**Box Size**				**Design Minimum**		**Test Minimum**		
VAV	6				135		129		96%

*Unit scheduled for 430 cfm. Grilles total 460 cfm.

AT-F10-7 **Date Tested:** 4/29/2020

1	10249	CD	1024	310	310	-	--	326	105%
Box Type	**Box Size**				**Design Minimum**		**Test Minimum**		
VAV	6				100		103		103%

AT-F10-8 **Date Tested:** 4/29/2020

1	10245B	CD	1224	450	460	-	--	449	100%
2	10245A	CD	612	25	26	-	--	27	108%
				475				476	100%
Box Type	**Box Size**				**Design Minimum**		**Test Minimum**		
VAV	8				150		148		99%

VAV AIR OUTLET TEST SHEET

Job Name: Oncology Licensed Outpatient Clinic-10th Flr
Tested By: GLASS

Outlet Number	Room Number	Code	Size	Design cfm	First Test	Second Test	--	Final cfm	%

AHU-F10

AT-F10-9 **Date Tested:** 4/29/2020

Outlet Number	Room Number	Code	Size	Design cfm	First Test	Second Test	--	Final cfm	%
1	10241	CD	824	215	204	229	--	216	100%
2	10243	CD	824	215	240	211	--	201	93%
				430				417	97%

Box Type	Box Size		Design Minimum	Test Minimum	
VAV	8		150	143	95%

AT-F10-10 **Date Tested:** 4/29/2020

Outlet Number	Room Number	Code	Size	Design cfm	First Test	Second Test	--	Final cfm	%
1	10248A	CD	824	200	221	209	--	202	101%
2	10248A	CD	624	160	155	145	--	148	93%
3	10248	CD	624	160	176	156	--	172	108%
				520				522	100%

Box Type	Box Size		Design Minimum	Test Minimum	
VAV	8		135	137	101%

AT-F10-11 **Date Tested:** 4/29/2020

Outlet Number	Room Number	Code	Size	Design cfm	First Test	Second Test	--	Final cfm	%
1	10239	CD	1024	255	265	-	--	236	93%
2	10239	CD	1024	255	258	-	--	257	101%
				510				493	97%

Box Type	Box Size		Design Minimum	Test Minimum	
VAV	8		150	155	103%

VAV AIR OUTLET TEST SHEET

Job Name: Oncology Licensed Outpatient Clinic-10th Flr
Tested By: GLASS

Outlet Number	Room Number	Code	Size	Design cfm	First Test	Second Test	--	Final cfm	%
AHU-F10									
AT-F10-12					**Date Tested:**		4/29/2020		
1	10233	CD	824	210	189	-	--	213	101%
2	10235	CD	824	260	251	-	--	259	100%
3	10237	CD	824	210	215	-	--	216	103%
				680				688	101%
Box Type	**Box Size**				**Design Minimum**		**Test Minimum**		
VAV	8				150		155		103%
AT-F10-13					**Date Tested:**		4/29/2020		
1	10244	CD	624	110	114	-	--	109	99%
2	10246	CD	624	110	108	-	--	105	95%
				220				214	97%
Box Type	**Box Size**				**Design Minimum**		**Test Minimum**		
VAV	6				70		71		101%
AT-F10-14					**Date Tested:**		4/29/2020		
1	10240	CD	624	110	127	112	--	110	100%
2	10242	CD	624	110	123	104	--	118	107%
				220				228	104%
Box Type	**Box Size**				**Design Minimum**		**Test Minimum**		
VAV	6				70		68		97%
AT-F10-15					**Date Tested:**		4/29/2020		
1	10221	CD	1024	250	264	-	--	260	104%
2	10221	CD	1024	250	251	-	--	244	98%
				500				504	101%
Box Type	**Box Size**				**Design Minimum**		**Test Minimum**		
VAV	8				150		145		97%

VAV AIR OUTLET TEST SHEET

Job Name: Oncology Licensed Outpatient Clinic-10th Flr
Tested By: GLASS

Outlet Number	Room Number	Code	Size	Design cfm	First Test	Second Test	--	Final cfm	%
AHU-F10									
AT-F10-16					**Date Tested:**		4/29/2020		
1	10231	CD	1024	325	297	-	--	297	91%
2	10231	CD	1024	325	332	-	--	331	102%
				650				628	97%
Box Type	**Box Size**				**Design Minimum**		**Test Minimum**		
VAV	8				150		156		104%
AT-F10-17					**Date Tested:**		4/30/2020		
1	10238	CD	824	225	193	204	--	206	92%
2	10238	CD	824	225	216	237	--	221	98%
3	10230	CD	824	210	212	229	--	214	102%
				660				641	97%
Box Type	**Box Size**				**Design Minimum**		**Test Minimum**		
VAV	8				150		151		101%
AT-F10-18					**Date Tested:**		4/29/2020		
1	10223	CD	624	30	21	27	--	29	97%
2	10219	CD	624	25	20	27	--	24	96%
3	10217	CD	612	25	18	23	--	27	108%
4	CORR	CD	624	100	71	107	--	106	106%
5	10236	CD	624	90	110	96	--	95	106%
6	STORAGE	CD	624	30	67	30	--	31	103%
				300				312	104%
Box Type	**Box Size**				**Design Minimum**		**Test Minimum**		
VAV	6				100		102		102%

VAV AIR OUTLET TEST SHEET

Job Name: Oncology Licensed Outpatient Clinic-10th Flr
Tested By: GLASS

Outlet Number	Room Number	Code	Size	Design cfm	First Test	Second Test	--	Final cfm	%
AHU-F10									
AT-F10-19					**Date Tested:**		4/29/2020		
1	10229	CD	1024	300	301	-	--	297	99%
2	10227	CD	624	160	176	-	--	163	102%
				460				460	100%
Box Type	**Box Size**				**Design Minimum**		**Test Minimum**		
VAV	8				135		137		101%
AT-F10-20					**Date Tested:**		4/30/2020		
1	10225	CD	824	260	280	251	--	276	106%
Box Type	**Box Size**				**Design Minimum**		**Test Minimum**		
VAV	6				70		76		109%
AT-F10-21					**Date Tested:**		4/28/2020		
1	10216D	CD	1024	350	346	330	--	333	95%
2	10216E	CD	1024	350	424	372	--	379	108%
3	10216F	CD	1024	350	434	372	--	364	104%
				1050				1076	102%
Box Type	**Box Size**				**Design Minimum**		**Test Minimum**		
VAV	10				300		329		110%
***AT-F10-22**					**Date Tested:**		4/28/2020		
1	10216A	CD	1024	350	405	352	--	338	97%
2	10216B	CD	1024	350	441	357	--	348	99%
3	102160	CD	1024	350	433	344	--	331	95%
				1050				1017	97%
Box Type	**Box Size**				**Design Minimum**		**Test Minimum**		
VAV	10				300		287		96%

*Unit scheduled for 1200 cfm. Grilles total 1050 cfm.

VAV AIR OUTLET TEST SHEET

Job Name: Oncology Licensed Outpatient Clinic-10th Flr
Tested By: GLASS

Outlet Number	Room Number	Code	Size	Design cfm	First Test	Second Test	--	Final cfm	%

AHU-F10

AT-F10-23 **Date Tested:** 4/30/2020

1	10228	CD	624	110	111	102	--	104	95%
2	10260	CD	624	25	52	27	--	27	108%
3	10226	CD	612	85	21	93	--	77	91%
4	10224	CD	612	25	42	23	--	25	100%
5	10222	CD	624	25	45	25	--	26	104%
				270				259	96%
Box Type	**Box Size**				**Design Minimum**		**Test Minimum**		
VAV	6				100		95		95%

(1) AT-F10-24 **Date Tested:** 4/30/2020

1	10211	CD	624	190	225	196	--	204	107%
2	10211	CD	624	190	211	196	--	180	95%
3	10211	--	--	--	--	--	--	--	--
4	10213	CD	824	200	164	196	--	190	95%
				580				574	99%
Box Type	**Box Size**				**Design Minimum**		**Test Minimum**		
VAV	8				150		161		107%

(1) Outlet 3 is capped above ceiling. CFM from this grille was distributed evenly between outlets 1 and 2.

***(2) AT-F10-25** **Date Tested:** 5/29/2020

1	10234	CD	1024	400	422	390	--	377	94%
2	10234	CD	624	150	181	164	--	165	110%
				550				542	99%
Box Type	**Box Size**				**Design Minimum**		**Test Minimum**		
VAV	8				150		164		109%

*Unit scheduled for 400 cfm. Diffusers total 550 cfm.

(2) This unit is labeled 10-26 in the BAS system.

VAV AIR OUTLET TEST SHEET

Job Name: Oncology Licensed Outpatient Clinic-10th Flr
Tested By: GLASS

Outlet Number	Room Number	Code	Size	Design cfm	First Test	Second Test	--	Final cfm	%

AHU-F10

(1) LT-8 **Date Tested:** 5/29/2020

1	10209	CD	1024	250	260	-	--	75	30%
2	10209	CD	1024	325	317	-	--	368	113%
				575				443	77%
Box Type	**Box Size**				**Design Minimum**		**Test Minimum**		
VAV	8				150		NM		--

(1) Unable to drive Phoenix valve to min position while pharmacy was in operation.

*Outlet 1 has a mvd that has been shut.

AT-F10-27 **Date Tested:** 4/30/2020

1	10212	CD	624	130	137	-	--	126	97%
2	10210	CD	624	130	143	-	--	126	97%
				260				252	97%
Box Type	**Box Size**				**Design Minimum**		**Test Minimum**		
VAV	6				70		67		96%

AT-F10-28 **Date Tested:** 4/29/2020

1	10215	CD	1024	320	349	-	--	336	105%
2	10214	CD	1024	320	342	-	--	304	95%
				640				640	100%
Box Type	**Box Size**				**Design Minimum**		**Test Minimum**		
VAV	8				150		149		99%

VAV AIR OUTLET TEST SHEET

Job Name: Oncology Licensed Outpatient Clinic-10th Flr
Tested By: GLASS

AHU-F10

AT-F10-29 — **Date Tested:** 4/30/2020

Outlet Number	Room Number	Code	Size	Design cfm	First Test	Second Test	--	Final cfm	%
1	10258	CD	624	80	80	-	--	82	103%
2	10206	CD	612	60	61	-	--	55	92%
3	10204	CD	612	60	55	-	--	56	93%
4	10202	CD	624	50	50	-	--	49	98%
				250				242	97%
Box Type	**Box Size**				**Design Minimum**		**Test Minimum**		
VAV	6				70		77		110%

AT-F10-30 — **Date Tested:** 4/30/2020

Outlet Number	Room Number	Code	Size	Design cfm	First Test	Second Test	--	Final cfm	%
1	10201	CD	624	160	174	-	--	169	106%
Box Type	**Box Size**				**Design Minimum**		**Test Minimum**		
VAV	6				70		76		109%

AT-F10-31 — **Date Tested:** 4/30/2020

Outlet Number	Room Number	Code	Size	Design cfm	First Test	Second Test	--	Final cfm	%
1	10203	CD	1024	420	510	459	--	434	103%
2	10203	CD	1024	420	420	378	--	382	91%
				840				816	97%
Box Type	**Box Size**				**Design Minimum**		**Test Minimum**		
VAV	10				225		210		93%

AT-F10-32 — **Date Tested:** 4/30/2020

Outlet Number	Room Number	Code	Size	Design cfm	First Test	Second Test	--	Final cfm	%
1	10207	CD	624	130	143	-	--	131	101%
2	10205	CD	624	60	65	-	--	64	107%
				190				195	103%
Box Type	**Box Size**				**Design Minimum**		**Test Minimum**		
VAV	6				70		74		106%

VAV AIR OUTLET TEST SHEET

Job Name: Oncology Licensed Outpatient Clinic-10th Flr
Tested By: GLASS

Outlet Number	Room Number	Code	Size	Design cfm	First Test	Second Test	--	Final cfm	%

AHU-F10

AT-F10-33 **Date Tested:** 4/30/2020

1	10200	CD	624	130	117	138	--	131	101%
2	10200	CD	624	130	148	137	--	136	105%
3	10200	CD	624	130	118	133	--	126	97%
				390				393	101%
Box Type	**Box Size**				**Design Minimum**		**Test Minimum**		
VAV	6				160		175		109%

min occupied has been changed from 100 to 160.

AT-F10-34 **Date Tested:** 4/29/2020

1	10263	CD	1224	425	387	-	--	443	104%
2	10263	CD	1224	425	393	-	--	382	90%
3	10263	CD	1224	425	382	-	--	392	92%
4	10263	CD	1224	425	400	-	--	395	93%
				1700				1612	95%
Box Type	**Box Size**				**Design Minimum**		**Test Minimum**		
VAV	14				450		481		107%

increase sp setpoint. Box was 100%open

AT-F10-42 **Date Tested:** 4/30/2020

1	10101	CD	1024	300	240	307	--	287	96%
2	10101	CD	1024	300	271	303	--	324	108%
				600				611	102%
Box Type	**Box Size**				**Design Minimum**		**Test Minimum**		
VAV	8				150		152		101%

SERIES FAN POWERED TEST SHEET

Job Name: Oncology Licensed Outpatient Clinic-10th Flr
Tested By: GLASS **Date:** 6/5/2020

Outlet Number	Room Number	Code	Size	Primary Air Design cfm	Fan Design cfm	First Test	Second Test	Final cfm		%
								Primary	Fan	

Tenth Floor

AT-F10-35 **Date Tested:** 5/1/20

1	10075	CD	824	--	250	257	252	--	235	94%
2	10075	CD	824	--	250	247	249	--	225	90%
3	10075	SD	48x2	--	143	81	141	--	155	108%
4	10075	SD	48x2	--	143	85	158	--	131	92%
5	10075	SD	48x2	--	143	83	130	--	156	109%
6	10075	SD	48x2	--	143	84	129	--	129	90%
7	10075	SD	48x2	--	143	77	130	--	128	90%
8	10075	SD	48x2	--	143	85	129	--	131	92%
9	10075	SD	48x2	--	143	86	131	--	133	93%
				1500	1501			1425	1423	95%
Box Type	**Box Size**	**Fan Speed:**		HIGH		**Design Minimum**		**Test Minimum**		
FPT	12	**Setting:**		--		310		290		94%

***AT-F10-36** **Date Tested:** 5/1/20

1	10074	SD	48x2	--	140	36		--	*	-
2	10000	SD	48x2	--	160	32		--	*	-
3	10000	SD	48x2	--	160	58		--	*	-
4	10000	SD	48x2	--	160	47		--	*	-
5	10000	SD	48x2	--	160	36		--	*	-
6	10001	SD	48x2	--	180	37		--	*	-
7	10001	SD	48x2	--	180	29		--	*	-
8	10001	SD	48x2	--	180	50		--	*	-
9	10001	SD	48x2	--	180	39		--	*	-
				1500	1500	364		1500	0	0%
Box Type	**Box Size**	**Fan Speed:**		HIGH		**Design Minimum**		**Test Minimum**		
FPT	12	**Setting:**		--		310		295		95%

*Fan is not running when enabled. Recorded airflow is primary air blowing through the fan compartment.

SERIES FAN POWERED TEST SHEET

Job Name: Oncology Licensed Outpatient Clinic-10th Flr
Tested By: GLASS **Date:** 6/5/2020

Outlet Number	Room Number	Code	Size	Primary Air Design cfm	Fan Design cfm	First Test	Second Test	Final cfm		%
								Primary	Fan	

Tenth Floor

***AT-F10-37** **Date Tested:** 5/1/20

1	10104	CD	624	--	50	39	-	--	*	-
2	10103	CD	624	--	50	29	-	--	*	-
3	10074	SD	48x2	--	140	50	-	--	*	-
4	10074	SD	48x2	--	140	48	-	--	*	-
5	10074	SD	48x2	--	140	42	-	--	*	-
6	10074	SD	48x2	--	140	53	-	--	*	-
7	10074	SD	48x2	--	140	63	-	--	*	-
8	10074	SD	48x2	--	140	75	-	--	*	-
9	10074	SD	48x2	--	140	56	-	--	*	-
10	10074	SD	48x2	--	140	66	-	--	*	-
11	10074	SD	48x2	--	140	77	-	--	*	-
12	10074	SD	48x2	--	140	71	-	--	*	-
				1500	1500			1500	0	0%
Box Type	**Box Size**	**Fan Speed:**		HIGH		**Design Minimum**		**Test Minimum**		
FPT	12	**Setting:**		--		310		290		94%

*Fan is not running when enabled. Recorded airflow is primary air blowing through the fan compartment.

AT-F10-38 **Date Tested:** 5/1/20

1	10218	CD	824	--	190	189	185	--	206	108%
2	10218	CD	824	--	190	292	180	--	179	94%
3	10218	SD	48x2	--	160	141	146	--	176	110%
4	10218	SD	48x2	--	160	114	154	--	175	109%
5	10218	SD	48x2	--	160	111	146	--	146	91%
6	10218	SD	48x2	--	160	149	147	--	164	103%
7	10218	SD	48x2	--	160	136	156	--	170	106%
8	10218	SD	48x2	--	160	129	144	--	169	106%
9	10218	SD	48x2	--	160	134	150	--	145	91%
				1500	1500			1500	1530	102%
Box Type	**Box Size**	**Fan Speed:**		HIGH		**Design Minimum**		**Test Minimum**		
FPT	12	**Setting:**		--		310		295		95%

SERIES FAN POWERED TEST SHEET

Job Name: Oncology Licensed Outpatient Clinic-10th Flr
Tested By: GLASS **Date:** 6/5/2020

Outlet Number	Room Number	Code	Size	Primary Air Design cfm	Fan Design cfm	First Test	Second Test	Final cfm		%
								Primary	Fan	

Tenth Floor

AT-F10-39 **Date Tested:** 4/28/20

1	10216	CD	824	--	190	218	206	--	204	107%
2	10216	CD	824	--	190	229	192	--	175	92%
3	10216	SD	48x2	--	160	156	156	--	158	99%
4	10216	SD	48x2	--	160	144	156	--	155	97%
5	10216	SD	48x2	--	160	156	169	--	175	109%
6	10216	SD	48x2	--	160	170	176	--	174	109%
7	10216	SD	48x2	--	160	173	155	--	152	95%
8	10216	SD	48x2	--	160	145	146	--	149	93%
9	10216	SD	48x2	--	160	148	144	--	146	91%
				1500	1500			1500	1488	99%
Box Type	**Box Size**	**Fan Speed:**		HIGH		**Design Minimum**		**Test Minimum**		
FPT	12	**Setting:**		--		310		300		97%

filter is missing bracket and is not held in place.

***AT-F10-40** **Date Tested:** 4/29/20

1	10216	CD	824	--	190	61	-	--	*	-
2	10216	CD	824	--	190	60	-	--	*	-
3	10216	SD	48x2	--	160	35	-	--	*	-
4	10216	SD	48x2	--	160	31	-	--	*	-
5	10216	SD	48x2	--	160	29	-	--	*	-
6	10216	SD	48x2	--	160	17	-	--	*	-
7	10216	SD	48x2	--	160	32	-	--	*	-
8	10216	SD	48x2	--	160	39	-	--	*	-
9	10216	SD	48x2	--	160	20	-	--	*	-
				1500	1500			1525	0	0%
Box Type	**Box Size**	**Fan Speed:**		HIGH		**Design Minimum**		**Test Minimum**		
FPT	12	**Setting:**		--		310		320		103%

*Fan does not actually run when enabled. Primary air calibrated.

SERIES FAN POWERED TEST SHEET

Job Name: Oncology Licensed Outpatient Clinic-10th Flr
Tested By: GLASS **Date:** 6/5/2020

Outlet Number	Room Number	Code	Size	Primary Air Design cfm	Fan Design cfm	First Test	Second Test	Final cfm		%
								Primary	Fan	

Tenth Floor

(1) AT-F10-41 **Date Tested:** 4/29/20

1	10216	SD	48x2	--	160	251	217	--	216	135%
2	10216	SD	48x2	--	160	220	214	--	205	128%
3	10216	SD	48x2	--	160	227	222	--	221	138%
4	10216	SD	48x2	--	160	199	216	--	213	133%
5	10216	SD	48x2	--	160	207	209	--	212	133%
6	10216	SD	48x2	--	160	190	210	--	215	134%
				1290	960			1275	1282	134%
Box Type	**Box Size**	**Fan Speed:**		LOW		**Design Minimum**		**Test Minimum**		
FPT	12	**Setting:**		--		310		325		105%

(1) Unit scheduled for 1500 cfm from the fan, but the outlet designs on M1.10 total 960 cfm. This unit is on the lowest speed setting and unable to reach design of 960. Primary air setpoint was adjusted to match fan airflow.

RELIEF FAN TEST SHEET

Job Name: Oncology Licensed Outpatient Clinic-10th Flr
Tested By: JACQUEMIN **Date Tested:** 6/5/2020

Fan Number	**(1) RF-1**		
Serving	10th Floor Relief		
Manufacturer	COOK		
Model Number	36XLWH		
Serial Number	019S983839-01/0022810		

	Design	Test	Design	Test	Design	Test
Total cfm	12500	-				
Suction Static Pressure	-	-				
Discharge Static Pressure	-	-				
Total Static Pressure	0.38	-				

Motor Sheave	--		
Diameter	3 1/2"		
Bore	1/2"		
Fan Sheave	--		
Diameter	7"		
Bore	1/2"		
Belts	2- A29		
Center Line Distance	7 1/4"		

Motor Name	BALDOR					
Horsepower	2	2				
Motor rpm	1725	-				
Phase	3					
Voltage	208	-				
		-				
		-				
Service Factor	1.15					
Amperage	6.1	-				
		-				
		-				
Fan rpm	692	-				
Fan Rotation	CCW	CCW				
Fan Speed	-					

Comments: (1)At the time of testing the relief fan was not running. We tried to enable it from the BAS system but it would not turn on.

FAN TEST SHEET

Job Name: Oncology Licensed Outpatient Clinic-10th Flr
Tested By: GLASS **Date:** 5/29/2020

Fan Number	**EF-F10**	**VF-1**	
Serving	10th Floor Exhaust	MECH/ELEC	
Manufacturer	COOK	NG	
Model Number	210 CPS	NG	
Serial Number	019S983839-01/0000701	NG	

	Design	**Test**	**Design**	**Test**	**Design**	**Test**
Total cfm	2,960	3,212	690	722		

Suction Static Pressure	-	-1.450	-	-0.047		
Discharge Static Pressure	-	0.180	-	0.300		
Total Static Pressure	1.00	1.630	0.13	0.347		

Motor Sheave	--	--	
Diameter	3 1/4"	DIRECT DRIVE	
Bore	1/2"	DIRECT DRIVE	
Fan Sheave	--	--	
Diameter	5"	DIRECT DRIVE	
Bore	1 3/8"	DIRECT DRIVE	
Belts	1- A47	DIRECT DRIVE	
Center Line Distance	18"	DIRECT DRIVE	

Motor Name	MARATHON		McMILLAN			
Horsepower	1	1	1/4	1/4		
Motor rpm	1725	1725	1625	1625		
Phase	3		1			
Voltage	208	211.2	115	162.2		
		211.4		-		
		211.8		-		
Service Factor	1.15		NV			
Amperage	4.1	4.0	3.9	3.6		
		4.1		-		
		4.1		-		
Frequency Hz	60		60			
Fan rpm	845	1025	NG	1625		
Fan Rotation	CW	CW	CCW	CCW		
Filters	NA		NA			
Fan Speed	60 Hz		60 Hz			

Comments:

RECTANGULAR DUCT TRAVERSE REPORT
EF-F10

Job Name: Oncology Licensed Outpatient Clinic-10th Flr
Tested By: GLASS **Date Tested:** 5/29/2020

DUCT		REQUIRED		ACTUAL	
℄ S.P. =	-1.30	FPM(M/S)=	1,184	FPM(M/S)=	1,285
AIR TEMP=	70.5	SCFM(SLS/S)=	- -	SCFM(SLS/S)=	- -
SIZE=	30 X 12	CFM(L/S)=	2,960	CFM(L/S)=	3,212
AREA=	2.50 Ft.^{2}				

DISTANCE FROM BOTTOM	POSITION	1	2	3	4	5	6	7	8	9	10	11	12	13
1.5	1	1492	1467	1450	1476	1424								
4.5	2	1496	1243	1141	1300	1423								
7.5	3	1303	1124	1123	987	1424								
10.5	4	1367	1161	1078	1057	1160								
	5													
	6													
	7													
	8													
	9													
	10													
	11													
	12													
	13													
DISTANCE FROM DUCT EDGE		3.0	9.0	15.0	21.0	27.0								
VELOCITY SUB-TOTALS		5658	4995	4792	4820	5431								

Remarks =

AIR INLET TEST SHEET

Job Name: Oncology Licensed Outpatient Clinic-10th Flr
Tested By: GLASS **Date:** 5/1/2020

Inlet Number	Room Number	Type	Size	Design cfm	First Test	Second Test	Final cfm	%	Notes
EF-F10									
1	10115	EG	8x6	75	68	71	76	101%	
2	10250	EG	12x12	150	133	137	141	94%	
3	10256	EG	12x12	140	152	141	131	94%	
4	10254	EG	12x12	140	129	127	141	101%	
5	10252	EG	12x12	140	122	139	117	84%	
6	10245A	EG	6x4	75	63	69	70	93%	
7	10245B	EG	12x24	450	488	426	447	99%	
8	10239	EG	36x18	510	562	495	511	100%	
9	10219	EG	8x6	75	51	68	70	93%	
10	10217	EG	8x6	75	37	68	51	68%	
11	NG	EG	12x24	75	88	72	88	117%	
12	10224	EG	8x6	75	44	69	75	100%	
13	10222	EG	8x6	75	89	80	80	107%	
14	10208	EG	8x6	75	23	77	69	92%	
15	10104	EG	12x24	385	372	348	321	83%	
16	10103	EG	12x24	360	236	325	292	81%	
				2875			2680	93%	
Pharmacy EF									
1	10209	EG	12x12	176	90	-	0		see remarks*
2	10209	EG	HOOD	NG	495	-	688	--	
				NG			688	--	

*valve was shut by maintenance to force the air into the hood for negative pressure reasons.

PRESSURIZED ROOM INVENTORY

Job Name: Oncology Licensed Outpatient Clinic-10th Flr **Date:** 5/8/2020
Tested By: GLASS

Room/Area	Room Type	Room Volume (cubic ft.)	Supply CFM	Fume Hood Exhaust CFM	Room Exhaust CFM	Design Air Changes/ Hr.	Actual Air Changes/ Hr.	Design Required Pressure Ralationship	Actual Required Pressure Ralationship	Pressure (in WC)	Year Constructed	Pass/Fail
10th Floor Pharmacy	PHARM	700	368	688	0	12	59.8	N	N	-0.209	--	P

RECTANGULAR DUCT TRAVERSE REPORT
LT-9 & LT-10 EXHAUST

Job Name: Oncology Licensed Outpatient Clinic-10th Flr

Tested By: GLASS **Date Tested:** 5/8/2020

DUCT		REQUIRED		ACTUAL	
℄ S.P. =	-2.50	FPM(M/S)=	-	FPM(M/S)=	826
AIR TEMP=	- -	SCFM(SLS/S)=	- -	SCFM(SLS/S)=	- -
SIZE=	12 X 10	CFM(L/S)=	NG	CFM(L/S)=	688
AREA=	0.83 Ft.^{2}				

DISTANCE FROM BOTTOM	POSITION	1	2	3	4	5	6	7	8	9	10	11	12	13
1.3	1	940	941	976	1010									
3.8	2	868	756	763	715									
6.3	3	854	850	785	757									
8.8	4	748	881	783	590									
	5													
	6													
	7													
	8													
	9													
	10													
	11													
	12													
	13													
DISTANCE FROM DUCT EDGE		1.5	4.5	7.5	10.5									
VELOCITY SUB-TOTALS		3410	3428	3307	3072									

Remarks =

DUCT TRAVERSE ZONE TOTAL SHEET

EF-4L

Job Name: Oncology Licensed Outpatient Clinic-10th Flr

Tested By: JACQUEMIN **Date:** 6/5/2020

SERVICE OR DESIGNATION	DUCT			DESIGN	PRELIM	ACTUAL	FINAL	FINAL %	FINAL
	TYPE	SIZE	AREA S.F.	CFM	CFM	Avg Velocity	CFM	of Design	S.P.
EF	RND	26"	3.69	NG	4815	1305	4815	NA	NA

This fan serves the pharmacy exhaust and exhaust hood in room 10209.

SCHEMATIC

Job Name: Oncology Licensed Outpatient Clinic-10th Flr

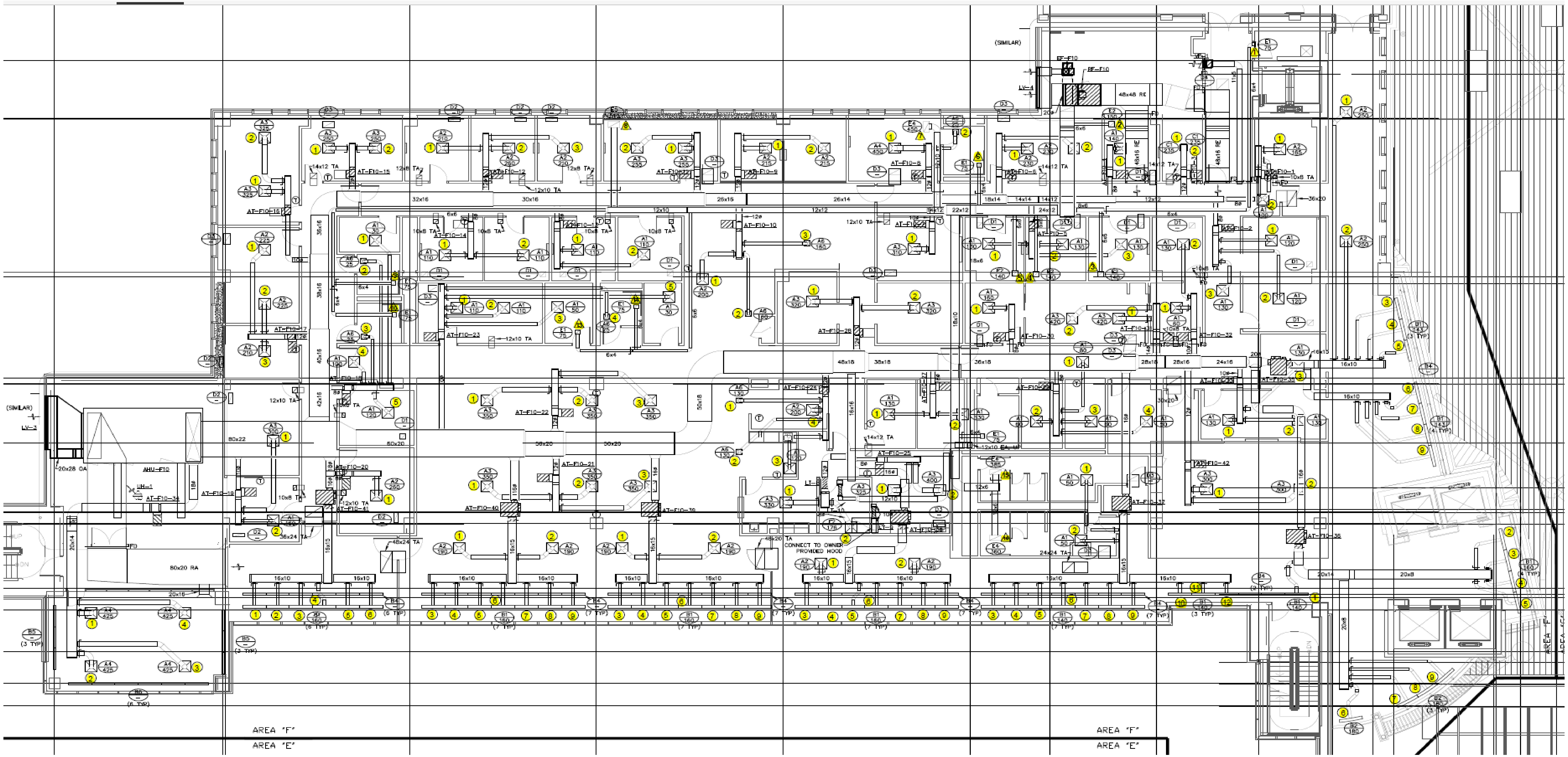


Table Of Contents

PROJECT: UHAT OUCP 4th & 9th Floor Reno Pre Read
LOCATION: ,
PROJECT #: 01-21xxxT

DATE: 2/21/2021
CONTACT: Levi Jacquemin
AUTHOR:

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Air Handling Unit

PROJECT:	UHAT OUCP 4th & 9th Floor Reno Pre Read	**DATE:**	2/21/2021
LOCATION:	,	**CONTACT:**	Levi Jacquemin
PROJECT #:	01-21xxxT	**AUTHOR:**	

SYSTEM/UNIT: AHU-F4

Tested By: Justin Rogers
Date: 2/19/2021

Unit Data

Unit Manufacturer	Climate Craft
Unit Model Number	CAH78x120E
Unit Serial Number	22250
Unit Discharge	Upblast
AHU-F4/SF Filter Bank	
Filter Manufacturer	NG
Filter Type	PLEATED
Filter Qty - S1	20
Filter Size - S1	20X24X4
AHU-F4/Supply Fan	
Fan Manufacturer	GREENHECK
Fan Model Number	40-QEP-3-II
Fan Serial Number	07J05129
Fan Design RPM	1238 RPM
Design Fan Rotation	CW
AHU-F4/CHW Coil	
Unit Manufacturer	CLIMATE CRAFT
Unit Model Number	CAH78x120E
Unit Serial Number	22250
Design Rows	8
Design Fins	6 /in.
Design Ent. Air DB	80.1 °F
Design Ent. Air WB	64.6 °F
Design Lvg. Air DB	53.7 °F
Design Lvg. Air WB	53.1 °F
Design Air ∆T	26.4 °F
Design Ent. Water Temp	44.0 °F
Design Lvg. Water Temp	NG °F
Design Water ∆T	NG °F
AHU-F4/HW Coil	
Unit Manufacturer	CLIMATE CRAFT
Unit Model Number	CAH78x120E
Unit Serial Number	22250
Design Rows	1
Design Fins	8 /in.
Design Ent. Air DB	34.0 °F
Design Lvg. Air DB	70.0 °F
Design Air ∆T	36.0 °F
Design Ent. Water Temp	180.0 °F
Design Lvg. Water Temp	NG °F
Design Water ∆T	NG °F

Test Data

Design Airflow	25000 CFM
Actual Airflow	25424 CFM
Design Min Outside Airflow	3850 CFM
Actual Min Outside Airflow	3570 CFM
Design Return Airflow	21150 CFM
Actual Return Airflow	21854 CFM
AHU-F4/Supply Fan	
Design Airflow	25000 CFM

Motor Data

AHU-F4/Supply Fan	
Motor Manufacturer	RELIANCE
Motor Frame	286T
Motor HP	30 HP
Motor RPM	1760 RPM
Motor Rated Volts	460 Volts
Motor Phase	3
Motor Hertz	60 Hz
Motor FL Amps	35.5 Amps
Motor Service Factor	1.15

Sheave Data

AHU-F4/Supply Fan	
Motor Sheave MFG	NG
Motor Sheave Model	NG
Motor Sheave Diam.	7 in.
Motor Sheave Bore	2 in.
Fan Sheave MFG	NV
Fan Sheave Model	NV
Fan Sheave Diam.	13 1/2 in.
Fan Sheave Bore	2 in.
Number of Belts	4
Belt Size	6L217G
Sheave Center Line	41.00 in.

Test Pressures

Design Total SP	NG in. wc
Actual Total SP	3.51 in. wc
External SP Design	2.40 in. wc
Suction SP	-1.87 in. wc
Discharge SP	1.49 in. wc
External SP Actual	3.27 in. wc
External Suction SP	-1.84 in. wc
External Discharge SP	1.43 in. wc
O/A Damper Position	5 %
R/A Damper Position	95 %

Air Test Data

AHU-F4/CHW Coil	
Design Airflow	25000 CFM
Actual Airflow	25424 CFM
Air Velocity Design	505 FPM
Air Velocity Actual	513 FPM
Actual Ent. Air DB Temp	99 Deg F
Actual Ent. Air WB Temp	70.5 °F
Actual Leav. Air DB Temp	59.2 Deg F
Actual Lvg. Air WB Temp	45.7 °F
Actual Air Temp ∆T	39.6 Deg F
Design Air Press. Drop In Wg	0.90 in. wg
Actual Air Press. Drop In Wg	0.38 in. wg
AHU-F4/HW Coil	

Air Handling Unit

PROJECT: UHAT OUCP 4th & 9th Floor Reno Pre Read
LOCATION: ,
PROJECT #: 01-21xxxT

DATE: 2/21/2021
CONTACT: Levi Jacquemin
AUTHOR:

SYSTEM/UNIT: AHU-F4

Tested By: Justin Rogers
Date: 2/19/2021

Test Data	
AHU-F4/Supply Fan	
Actual Airflow	25424 CFM
Design RPM	1760 RPM
Actual RPM	1760 RPM
Motor Volts T1-T2	477 Volts
Motor Amps T1	26.50 Amps
Actual Fan RPM	912 RPM
Actual Fan Rotation	CW

Air Test Data	
AHU-F4/HW Coil	
Design Airflow	10300 CFM
Air Velocity Design	650 FPM
Actual Ent. Air DB Temp	68 Deg F
Actual Leav. Air DB Temp	99.0 Deg F
Actual Air Temp ∆T	30.8 Deg F
Design Air Press. Drop In Wg	5.00 in. wg
Actual Air Press. Drop In Wg	0.35 in. wg

Water Test Data	
AHU-F4/CHW Coil	
Coil Inlet PSI Design	NG PSI
Coil Inlet PSI Actual	12.41 PSI
Coil Outlet PSI Design	NG PSI
Coil Outlet PSI Actual	6.67 PSI
Fluid Press. Drop PSI Design	4.33 PSI
Fluid Press. Drop PSI Actual	5.74 PSI
Actual Ent. Water Temp	52.0 Deg F
Actual Leav. Water Temp	63.0 Deg F
Water Delta T Actual	11.0 Deg F
Water Flow Design	90.0 GPM
Water Flow Actual	90.0 GPM
AHU-F4/HW Coil	
Coil Inlet PSI Design	NG PSI
Coil Inlet PSI Actual	8.54 PSI
Coil Outlet PSI Design	NG PSI
Coil Outlet PSI Actual	4.65 PSI
Fluid Press. Drop PSI Design	NG PSI
Fluid Press. Drop PSI Actual	3.89 PSI
Actual Ent. Water Temp	180.0 Deg F
Actual Leav. Water Temp	154.0 Deg F
Water Delta T Actual	26.0 Deg F
Water Flow Design	32.0 GPM
Water Flow Actual	32.0 GPM

Log:

AHU-F4	2/14/2021	Levi Jacquemin	Return ductwork is caving in when unit is fully ramped. OA Damper position does not match controls damper command position.
AHU-F4/Supply Fan	2/14/2021	Levi Jacquemin	With RA door open, mech room door open, and RA fire damper access open supply total was 27,652 CFM.

Air Handling Unit

PROJECT: UHAT OUCP 4th & 9th Floor Reno Pre Read
LOCATION: ,
PROJECT #: 01-21xxxT

DATE: 2/21/2021
CONTACT: Levi Jacquemin
AUTHOR:

SYSTEM/UNIT: AHU-F9

Tested By: Justin Rogers
Date: 2/19/2021

Unit Data	
Unit Manufacturer	Climate Craft
Unit Model Number	CAH78x120E
Unit Serial Number	22255
Unit Discharge	Upblast
AHU-F9/SF Filter Bank	
Filter Manufacturer	NG
Filter Type	Pleated
Filter Qty - S1	20
Filter Size - S1	20x24x4
AHU-F9/Supply Fan	
Fan Manufacturer	Greenheck
Fan Model Number	40-QEP-3-II
Fan Serial Number	NVIS
Fan Design RPM	1238 RPM
Design Fan Rotation	CW
AHU-F9/CHW Coil	
Unit Manufacturer	Climate Craft
Unit Model Number	CAH78x120E
Unit Serial Number	22255
Design Rows	8
Design Fins	6 /in.
Design Ent. Air DB	81.1 °F
Design Ent. Air WB	65.1 °F
Design Lvg. Air DB	53.6 °F
Design Lvg. Air WB	53.0 °F
Design Air ∆T	27.5 °F
Design Ent. Water Temp	44.0 °F
Design Lvg. Water Temp	NG °F
Design Water ∆T	NG °F
AHU-F9/HW Coil	
Unit Manufacturer	Climate Craft
Unit Model Number	CAH78x120E
Unit Serial Number	22255
Design Rows	1
Design Fins	8 /in.
Design Ent. Air DB	34.0 °F
Design Lvg. Air DB	70.0 °F
Design Air ∆T	36.0 °F
Design Ent. Water Temp	180.0 °F
Design Lvg. Water Temp	NG °F
Design Water ∆T	NG °F

Test Data	
Design Airflow	25000 CFM
Actual Airflow	23774 CFM
Design Min Outside Airflow	4310 CFM
Actual Min Outside Airflow	3350 CFM
Design Return Airflow	20690 CFM
Actual Return Airflow	20394 CFM
AHU-F9/Supply Fan	
Design Airflow	25000 CFM

Motor Data	
AHU-F9/Supply Fan	
Motor Manufacturer	Reliance Electric
Motor Frame	286T
Motor HP	30 HP
Motor RPM	1760 RPM
Motor Rated Volts	460 Volts
Motor Phase	3
Motor Hertz	60 Hz
Motor FL Amps	35.5 Amps
Motor Service Factor	1.15

Sheave Data	
AHU-F9/Supply Fan	
Motor Sheave MFG	NG
Motor Sheave Model	NG
Motor Sheave Diam.	7 in.
Motor Sheave Bore	2 in.
Fan Sheave MFG	N.VIS
Fan Sheave Model	N.VIS
Fan Sheave Diam.	13.5 in.
Fan Sheave Bore	2 in.
Number of Belts	4
Belt Size	6L217G
Sheave Center Line	41.00 in.

Test Pressures	
Design Total SP	NG in. wc
Actual Total SP	2.36 in. wc
External SP Design	2.00 in. wc
Suction SP	-1.36 in. wc
Discharge SP	1.00 in. wc
External SP Actual	2.84 in. wc
External Suction SP	-1.94 in. wc
External Discharge SP	0.9 in. wc
O/A Damper Position	5 %
R/A Damper Position	95 %

Air Test Data	
AHU-F9/CHW Coil	
Design Airflow	25000 CFM
Air Velocity Design	505 FPM
Actual Ent. Air DB Temp	83 Deg F
Actual Ent. Air WB Temp	53.2 °F
Actual Leav. Air DB Temp	56.7 Deg F
Actual Lvg. Air WB Temp	40.8 °F
Actual Air Temp ∆T	26.0 Deg F
Design Air Press. Drop In Wg	0.90 in. wg
Actual Air Press. Drop In Wg	0.36 in. wg
AHU-F9/HW Coil	
Design Airflow	7500 CFM
Air Velocity Design	650 FPM

Air Handling Unit

PROJECT: UHAT OUCP 4th & 9th Floor Reno Pre Read
LOCATION: ,
PROJECT #: 01-21xxxT

DATE: 2/21/2021
CONTACT: Levi Jacquemin
AUTHOR:

SYSTEM/UNIT: AHU-F9

Tested By: Justin Rogers
Date: 2/19/2021

Test Data	
AHU-F9/Supply Fan	
Design RPM	1760 RPM
Actual RPM	1760 RPM
Motor Volts T1-T2	477/477/477 Volts
Motor Amps T1	28/28/28 Amps
Actual Fan RPM	894 RPM
Actual Fan Rotation	cw

Air Test Data	
AHU-F9/HW Coil	
Actual Ent. Air DB Temp	68 Deg F
Actual Leav. Air DB Temp	72.1 Deg F
Actual Air Temp ∆T	4.0 Deg F
Design Air Press. Drop In Wg	5.00 in. wg
Actual Air Press. Drop In Wg	0.40 in. wg

Water Test Data	
AHU-F9/CHW Coil	
Coil Inlet PSI Design	NG PSI
Coil Inlet PSI Actual	INA PSI
Coil Outlet PSI Design	NG PSI
Coil Outlet PSI Actual	29.35 PSI
Fluid Press. Drop PSI Design	NG PSI
Fluid Press. Drop PSI Actual	INA PSI
Actual Ent. Water Temp	53.0 Deg F
Actual Leav. Water Temp	65.0 Deg F
Water Delta T Actual	12.0 Deg F
Water Flow Design	96.0 GPM
Water Flow Actual	96.00(18psi) GPM
AHU-F9/HW Coil	
Coil Inlet PSI Design	NG PSI
Coil Inlet PSI Actual	37.25 PSI
Coil Outlet PSI Design	NG PSI
Coil Outlet PSI Actual	34.00 PSI
Fluid Press. Drop PSI Design	NG PSI
Fluid Press. Drop PSI Actual	3.25 PSI
Actual Ent. Water Temp	144.0 Deg F
Actual Leav. Water Temp	124.0 Deg F
Water Delta T Actual	20.0 Deg F
Water Flow Design	32.0 GPM
Water Flow Actual	32(15.5psi) GPM

Log:

AHU-F9	2/14/2021	Levi Jacquemin	CHW supply test port blocked by ball valve. Unit OA Damper command does not match actual position.

Fan Unit

PROJECT:	UHAT OUCP 4th & 9th Floor Reno Pre Read	**DATE:**	2/21/2021
LOCATION:	,	**CONTACT:**	Levi Jacquemin
PROJECT #:	01-21xxxT	**AUTHOR:**	

SYSTEM/UNIT: EF-F4

Tested By: Justin Rogers
Date: 2/19/2021

Unit Data	
Fan Manufacturer	Cook
Fan Model Number	210 CPS
Fan Serial Number	019s983839-01/0006801
Fan Design RPM	1050 RPM

Test Data	
Design Airflow	3940 CFM
Actual Airflow	3661 CFM
Actual Fan RPM	1177 RPM
Design RPM	not given RPM
Actual RPM	1177 RPM
Motor Volts T1-T2	206 Volts
Motor Amps T1	7.50 Amps
Suction SP	-1.170 in. wc
Discharge SP	0.320 in. wc
Design ESP	0.900 in. wc
Actual ESP	1.490 in. wc

Motor Data	
Rated Airflow Capacity	3940 CFM
Motor Manufacturer	Baldor
Motor Frame	182T
Motor HP	1 1/2 HP
Motor RPM	1765 RPM
Motor Rated Volts	208 Volts
Motor Phase	3
Motor Hertz	60 Hz
Motor FL Amps	9.70 Amps
Motor Service Factor	1.15

Sheave Data	
Motor Sheave MFG	Not Listed
Motor Sheave Model	Not Listed
Motor Sheave Diam.	4.25 in.
Motor Sheave Bore	1 1/8 in.
Fan Sheave MFG	Not Listed
Fan Sheave Model	AK61
Fan Sheave Diam.	6 in.
Fan Sheave Bore	1 7/16 in.
Number of Belts	1
Belt Size	AX47
Sheave Center Line	17.5 in.

Fan Unit

PROJECT:	UHAT OUCP 4th & 9th Floor Reno Pre Read	**DATE:**	2/21/2021
LOCATION:	,	**CONTACT:**	Levi Jacquemin
PROJECT #:	01-21xxxT	**AUTHOR:**	

SYSTEM/UNIT: EF-F9

Tested By: Justin Rogers
Date: 2/19/2021

Unit Data	
Fan Manufacturer	Cook
Fan Model Number	165CPS
Fan Serial Number	019S983839-01/0018801
Fan Design RPM	1000 RPM

Test Data	
Design Airflow	1640 CFM
Actual Airflow	1544 CFM
Actual Fan RPM	1231 RPM
Design RPM	NOT GIVEN RPM
Actual RPM	1231 RPM
Motor Volts T1-T2	206 Volts
Motor Amps T1	2.80 Amps
Suction SP	-1.110 in. wc
Discharge SP	0.210 in. wc
Design ESP	0.800 in. wc
Actual ESP	1.320 in. wc

Motor Data	
Rated Airflow Capacity	1640 CFM
Motor Manufacturer	Marathon
Motor Frame	56
Motor HP	3/4 HP
Motor RPM	1725 RPM
Motor Rated Volts	208 Volts
Motor Phase	3
Motor Hertz	60 Hz
Motor FL Amps	3.20 Amps
Motor Service Factor	1.25

Sheave Data	
Motor Sheave MFG	Not Listed
Motor Sheave Model	Not Listed
Motor Sheave Diam.	3.25 in.
Motor Sheave Bore	5/8 in.
Fan Sheave MFG	Not Listed
Fan Sheave Model	Not Listed
Fan Sheave Diam.	4.5 in.
Fan Sheave Bore	1 in.
Number of Belts	1
Belt Size	A36
Sheave Center Line	13.25 in.

Fan Unit

PROJECT:	UHAT OUCP 4th & 9th Floor Reno Pre Read	**DATE:**	2/21/2021
LOCATION:	,	**CONTACT:**	Levi Jacquemin
PROJECT #:	01-21xxxT	**AUTHOR:**	

SYSTEM/UNIT: Relief Fan-F4

Tested By: Justin Rogers
Date: 2/19/2021

Unit Data	
Fan Manufacturer	Cook
Fan Model Number	360 XLWH
Fan Serial Number	019s983839-01/0022811
Fan Design RPM	780 RPM

Test Data	
Design Airflow	12500 CFM
Actual Airflow	9505 CFM
Actual Fan RPM	670 RPM
Design RPM	NG RPM
Actual RPM	670 RPM
Motor Volts T1-T2	235 Volts
Motor Amps T1	6.90 Amps
Suction SP	-0.240 in. wc
Discharge SP	0.080 in. wc
Design ESP	0.380 in. wc
Actual ESP	0.320 in. wc

Motor Data	
Rated Airflow Capacity	12500 CFM
Motor Manufacturer	Baldor
Motor Frame	145T
Motor HP	2 HP
Motor RPM	1725 RPM
Motor Rated Volts	208 Volts
Motor Phase	3
Motor Hertz	60 Hz
Motor FL Amps	6.10 Amps
Motor Service Factor	1.15

Sheave Data	
Motor Sheave MFG	NG
Motor Sheave Model	NG
Motor Sheave Diam.	3.5 in.
Motor Sheave Bore	7/8 in.
Fan Sheave MFG	NG
Fan Sheave Model	2AK74N
Fan Sheave Diam.	7.5 in.
Fan Sheave Bore	1 in.
Number of Belts	2
Belt Size	6a141
Sheave Center Line	7 in.

Log:

Relief Fan-F4	2/15/2021	Levi Jacquemin	Prop fan on this unit is hitting fan shroud. Unit was traversed on both inlet trucks. Both traverses were in good locations.

Fan Unit

PROJECT: UHAT OUCP 4th & 9th Floor Reno Pre Read
LOCATION: ,
PROJECT #: 01-21xxxT

DATE: 2/21/2021
CONTACT: Levi Jacquemin
AUTHOR:

SYSTEM/UNIT: Relief Fan-F9

Tested By: Justin Rogers
Date: 2/19/2021

Unit Data

Fan Manufacturer	Cook
Fan Model Number	360XLWH
Fan Serial Number	019S983839-01
Fan Design RPM	780 RPM

Test Data

Design Airflow	12500 CFM
Actual Airflow	10930 CFM
Actual Fan RPM	687 RPM
Design RPM	NG RPM
Actual RPM	687 RPM
Motor Volts T1-T2	232 Volts
Motor Amps T1	6.70 Amps
Suction SP	-0.350 in. wc
Discharge SP	0.060 in. wc
Design ESP	0.380 in. wc
Actual ESP	0.410 in. wc

Motor Data

Rated Airflow Capacity	12500 CFM
Motor Manufacturer	Baldor
Motor Frame	145T
Motor HP	2 HP
Motor RPM	1725 RPM
Motor Rated Volts	208 Volts
Motor Phase	3
Motor Hertz	60 Hz
Motor FL Amps	6.10 Amps
Motor Service Factor	1.15

Sheave Data

Motor Sheave MFG	Not Listed
Motor Sheave Model	Not Listed
Motor Sheave Diam.	3.5 in.
Motor Sheave Bore	7/8 in.
Fan Sheave MFG	Not Listed
Fan Sheave Model	Not Listed
Fan Sheave Diam.	7.5 in.
Fan Sheave Bore	1 in.
Number of Belts	2
Belt Size	A29
Sheave Center Line	7.5 in.

Air Handling Unit

PROJECT: OUCP Terracon Cx
LOCATION: ,
PROJECT #: 01-21-402

DATE: 3/22/2021
CONTACT: Levi Jacquemin
AUTHOR:

SYSTEM/UNIT: AHU-F0

Tested By: Frederick Ogburn
Date: 3/15/2021

Unit Data

Unit Manufacturer	ClimateCraft
Unit Model Number	CAH66X90E
Unit Serial Number	22247
Unit Discharge	Upblast
AHU-F0/SF Filter Bank	
Filter Manufacturer	NG
Filter Type	Pleated
Filter Qty - S1	12
Filter Size - S1	20x24x4
AHU-F0/Supply Fan	
Fan Design RPM	1250 RPM
Design Fan Rotation	CCW

Test Data

Design Airflow	15000 CFM
Actual Airflow	15589 CFM
Design Min Outside Airflow	5680 CFM
Design Return Airflow	9320 CFM
AHU-F0/Supply Fan	
Design Airflow	15000 CFM
Actual Airflow	15589 CFM
Design RPM	1750 RPM
Actual RPM	1750 RPM
Motor Volts T1-T2	474 Volts
Motor Amps T1	18.80 Amps
Actual Fan RPM	922 RPM
Actual Fan Rotation	CW

Motor Data

AHU-F0/Supply Fan	
Motor Manufacturer	Reliance Electric
Motor Frame	256T
Motor HP	20 HP
Motor RPM	1750 RPM
Motor Rated Volts	460 Volts
Motor Phase	3
Motor Hertz	60 Hz
Motor FL Amps	24 Amps
Motor Service Factor	NG

Test Pressures

Actual Total SP	3.14 in. wc
External SP Design	2.20 in. wc
Suction SP	1.80 in. wc
Discharge SP	1.34 in. wc
External SP Actual	1.63 in. wc
External Suction SP	-0.93 in. wc
External Discharge SP	0.7 in. wc

Air Test Data

AHU-F0/CHW Coil	
Design Airflow	15000 CFM
Air Velocity Design	500 FPM
Actual Ent. Air DB Temp	84 Deg F
Actual Ent. Air WB Temp	59.9 °F
Actual Leav. Air DB Temp	56.4 Deg F
Actual Lvg. Air WB Temp	47.2 °F
Actual Air Temp ∆T	27.6 Deg F
Design Air Press. Drop In Wg	1.00 in. wg
Actual Air Press. Drop In Wg	0.46 in. wg
AHU-F0/HW Coil	
Design Airflow	5680 CFM
Air Velocity Design	650 FPM
Actual Ent. Air DB Temp	68 Deg F
Actual Leav. Air DB Temp	70.7 Deg F
Actual Air Temp ∆T	2.7 Deg F
Design Air Press. Drop In Wg	5.00 in. wg
Actual Air Press. Drop In Wg	0.52 in. wg

Water Test Data

AHU-F0/CHW Coil	
Coil Inlet PSI Actual	104.00 PSI
Coil Outlet PSI Actual	81.32 PSI
Fluid Press. Drop PSI Design	4.33 PSI
Fluid Press. Drop PSI Actual	22.68 PSI
Actual Ent. Water Temp	41.0 Deg F
Actual Leav. Water Temp	59.0 Deg F
Water Delta T Actual	18.0 Deg F
Water Flow Design	80.0 GPM
Water Flow Actual	80.0 GPM

Air Handling Unit

PROJECT:	OUCP Terracon Cx	**DATE:**	3/22/2021
LOCATION:	,	**CONTACT:**	Levi Jacquemin
PROJECT #:	01-21-402	**AUTHOR:**	

SYSTEM/UNIT: AHU-F0

Tested By: Frederick Ogburn
Date: 3/15/2021

Water Test Data	
AHU-F0/HW Coil	
Coil Inlet PSI Actual	121.52 PSI
Coil Outlet PSI Actual	74.33 PSI
Fluid Press. Drop PSI Actual	47.19 PSI
Actual Ent. Water Temp	115.0 Deg F
Actual Leav. Water Temp	104.0 Deg F
Water Delta T Actual	11.0 Deg F
Water Flow Design	40.0 GPM
Water Flow Actual	40.0 GPM

Air Handling Unit

PROJECT: OUCP Terracon Cx
LOCATION: ,
PROJECT #: 01-21-402

DATE: 3/22/2021
CONTACT: Levi Jacquemin
AUTHOR:

SYSTEM/UNIT: AHU-F02

Tested By: Frederick Ogburn
Date: 3/15/2021

Unit Data	
Unit Manufacturer	ClimateCraft
Unit Model Number	CAH78x120E
Unit Serial Number	22248
Unit Discharge	Upblast
AHU-F02/SF Filter Bank	
Filter Manufacturer	NG
Filter Type	Pleated
Filter Qty - S1	20
Filter Size - S1	20x24x4
AHU-F02/Supply Fan	
Fan Design RPM	1238 RPM
Design Fan Rotation	CW

Test Data	
Design Airflow	25000 CFM
Actual Airflow	25116 CFM
Design Min Outside Airflow	4000 CFM
Design Return Airflow	21000 CFM
AHU-F02/Supply Fan	
Design Airflow	25000 CFM
Actual Airflow	25116 CFM
Design RPM	1760 RPM
Actual RPM	1760 RPM
Motor Volts T1-T2	473 Volts
Motor Amps T1	33.20 Amps
Actual Fan RPM	912 RPM
Actual Fan Rotation	CW

Motor Data	
AHU-F02/Supply Fan	
Motor Manufacturer	Reliance Electric
Motor Frame	286T
Motor HP	30 HP
Motor RPM	1760 RPM
Motor Rated Volts	460 Volts
Motor Phase	3
Motor Hertz	60 Hz
Motor FL Amps	35.5 Amps
Motor Service Factor	1.15

Test Pressures	
Actual Total SP	3.48 in. wc
External SP Design	2.00 in. wc
Suction SP	1.37 in. wc
Discharge SP	2.11 in. wc
External SP Actual	3.30 in. wc
External Suction SP	-1.3 in. wc
External Discharge SP	2 in. wc

Air Test Data	
AHU-F02/CHW Coil	
Design Airflow	25000 CFM
Air Velocity Design	505 FPM
Actual Ent. Air DB Temp	81 Deg F
Actual Ent. Air WB Temp	58.2 °F
Actual Leav. Air DB Temp	57.7 Deg F
Actual Lvg. Air WB Temp	47.3 °F
Actual Air Temp ∆T	23.4 Deg F
Design Air Press. Drop In Wg	0.90 in. wg
Actual Air Press. Drop In Wg	0.39 in. wg
AHU-F02/HW Coil	
Design Airflow	7500 CFM
Air Velocity Design	650 FPM
Actual Ent. Air DB Temp	72 Deg F
Actual Leav. Air DB Temp	81.1 Deg F
Actual Air Temp ∆T	9.6 Deg F
Design Air Press. Drop In Wg	5.00 in. wg
Actual Air Press. Drop In Wg	0.27 in. wg

Water Test Data	
AHU-F02/CHW Coil	
Coil Inlet PSI Actual	INA due to valve handle being over port PSI
Coil Outlet PSI Actual	72.30 PSI
Fluid Press. Drop PSI Design	5.20 PSI
Actual Ent. Water Temp	47.0 Deg F
Actual Leav. Water Temp	60.0 Deg F
Water Delta T Actual	13.0 Deg F
Water Flow Design	96.0 GPM
Water Flow Actual	96.0 GPM

Air Handling Unit

PROJECT: OUCP Terracon Cx
LOCATION: ,
PROJECT #: 01-21-402

DATE: 3/22/2021
CONTACT: Levi Jacquemin
AUTHOR:

SYSTEM/UNIT: AHU-F02

Tested By: Frederick Ogburn
Date: 3/15/2021

Water Test Data	
AHU-F02/HW Coil	
Coil Inlet PSI Actual	109.34 PSI
Fluid Press. Drop PSI Actual	6.20 PSI
Actual Ent. Water Temp	112.0 Deg F
Actual Leav. Water Temp	102.0 Deg F
Water Delta T Actual	10.0 Deg F
Water Flow Design	36.0 GPM
Water Flow Actual	36.0 GPM

Air Handling Unit

PROJECT: OUCP Terracon Cx
LOCATION: ,
PROJECT #: 01-21-402

DATE: 3/22/2021
CONTACT: Levi Jacquemin
AUTHOR:

SYSTEM/UNIT: AHU-F03

Tested By: Frederick Ogburn
Date: 3/15/2021

Unit Data

Unit Manufacturer	ClimateCraft
Unit Model Number	CAH78x120E
Unit Serial Number	22249
Unit Discharge	Upblast
AHU-F03/SF Filter Bank	
Filter Manufacturer	NG
Filter Type	Pleated
Filter Qty - S1	20
Filter Size - S1	20x24x4
AHU-F03/Supply Fan	
Fan Design RPM	1238 RPM
Design Fan Rotation	CW

Test Data

Design Airflow	25000 CFM
Actual Airflow	27490 CFM
Design Min Outside Airflow	4625 CFM
Design Return Airflow	20375 CFM
AHU-F03/Supply Fan	
Design Airflow	25000 CFM
Actual Airflow	27490 CFM
Design RPM	1760 RPM
Actual RPM	1756 RPM
Motor Volts T1-T2	472 Volts
Motor Amps T1	35.30 Amps
Actual Fan RPM	908 RPM
Actual Fan Rotation	CW

Motor Data

AHU-F03/Supply Fan	
Motor Manufacturer	Reliance Electric
Motor Frame	286T
Motor HP	30 HP
Motor RPM	1760 RPM
Motor Rated Volts	460 Volts
Motor Phase	3
Motor Hertz	60 Hz
Motor FL Amps	35.5 Amps
Motor Service Factor	1.15

Test Pressures

Actual Total SP	3.26 in. wc
External SP Design	2.00 in. wc
Suction SP	1.83 in. wc
Discharge SP	1.43 in. wc
External SP Actual	3.34 in. wc
External Suction SP	-2.07 in. wc
External Discharge SP	1.27 in. wc

Air Test Data

AHU-F03/CHW Coil	
Design Airflow	25000 CFM
Air Velocity Design	505 FPM
Actual Ent. Air DB Temp	79 Deg F
Actual Ent. Air WB Temp	57.9 °F
Actual Leav. Air DB Temp	59.7 Deg F
Actual Lvg. Air WB Temp	49.1 °F
Actual Air Temp ∆T	19.3 Deg F
Design Air Press. Drop In Wg	0.90 in. wg
Actual Air Press. Drop In Wg	0.40 in. wg
AHU-F03/HW Coil	
Design Airflow	9200 CFM
Air Velocity Design	650 FPM
Actual Ent. Air DB Temp	70 Deg F
Actual Leav. Air DB Temp	77.3 Deg F
Actual Air Temp ∆T	7.4 Deg F
Design Air Press. Drop In Wg	5.00 in. wg
Actual Air Press. Drop In Wg	0.44 in. wg

Water Test Data

AHU-F03/CHW Coil	
Coil Inlet PSI Actual	INA due to valve handle being over port PSI
Coil Outlet PSI Actual	64.35 PSI
Fluid Press. Drop PSI Design	5.20 PSI
Actual Ent. Water Temp	45.0 Deg F
Actual Leav. Water Temp	50.0 Deg F
Water Delta T Actual	5.0 Deg F
Water Flow Design	94.0 GPM
Water Flow Actual	94.0 GPM

Air Handling Unit

PROJECT: OUCP Terracon Cx
LOCATION: ,
PROJECT #: 01-21-402

DATE: 3/22/2021
CONTACT: Levi Jacquemin
AUTHOR:

SYSTEM/UNIT: AHU-F03

Tested By: Frederick Ogburn
Date: 3/15/2021

Water Test Data	
AHU-F03/HW Coil	
Coil Inlet PSI Actual	106.33 PSI
Coil Outlet PSI Actual	102.66 PSI
Fluid Press. Drop PSI Actual	3.67 PSI
Actual Ent. Water Temp	120.0 Deg F
Actual Leav. Water Temp	106.0 Deg F
Water Delta T Actual	14.0 Deg F
Water Flow Design	28.0 GPM
Water Flow Actual	28.0 GPM

Air Handling Unit

PROJECT:	OUCP Terracon Cx	**DATE:**	3/22/2021
LOCATION:	,	**CONTACT:**	Levi Jacquemin
PROJECT #:	01-21-402	**AUTHOR:**	

SYSTEM/UNIT: AHU-F05

Tested By: Frederick Ogburn
Date: 3/15/2021

Unit Data	
Unit Manufacturer	ClimateCraft
Unit Model Number	CAH78x120E
Unit Serial Number	22251
Unit Discharge	Upblast
AHU-F05/SF Filter Bank	
Filter Manufacturer	NG
Filter Type	Pleated
Filter Qty - S1	20
Filter Size - S1	20x24x4
AHU-F05/Supply Fan	
Fan Design RPM	1238 RPM
Design Fan Rotation	CW

Test Data	
Design Airflow	25000 CFM
Actual Airflow	25601 CFM
Design Min Outside Airflow	4405 CFM
Design Return Airflow	20595 CFM
AHU-F05/Supply Fan	
Design Airflow	25000 CFM
Actual Airflow	25601 CFM
Design RPM	1760 RPM
Actual RPM	1758 RPM
Motor Volts T1-T2	473 Volts
Motor Amps T1	28.80 Amps
Actual Fan RPM	912 RPM
Actual Fan Rotation	CW

Motor Data	
AHU-F05/Supply Fan	
Motor Manufacturer	Reliance Electric
Motor Frame	286T
Motor HP	30 HP
Motor RPM	1760 RPM
Motor Rated Volts	460 Volts
Motor Phase	3
Motor Hertz	60 Hz
Motor FL Amps	35.5 Amps
Motor Service Factor	1.15

Test Pressures	
Actual Total SP	2.51 in. wc
External SP Design	2.00 in. wc
Suction SP	1.41 in. wc
Discharge SP	1.10 in. wc
External SP Actual	1.99 in. wc
External Suction SP	-1.27 in. wc
External Discharge SP	0.72 in. wc

Air Test Data	
AHU-F05/CHW Coil	
Actual Ent. Air DB Temp	79 Deg F
Actual Ent. Air WB Temp	57.8 °F
Actual Leav. Air DB Temp	54.0 Deg F
Actual Lvg. Air WB Temp	46.1 °F
Actual Air Temp ∆T	25.0 Deg F
Actual Air Press. Drop In Wg	0.31 in. wg
AHU-F05/HW Coil	
Actual Ent. Air DB Temp	68 Deg F
Actual Leav. Air DB Temp	73.4 Deg F
Actual Air Temp ∆T	5.1 Deg F
Actual Air Press. Drop In Wg	0.30 in. wg

Water Test Data	
AHU-F05/CHW Coil	
Coil Inlet PSI Actual	74.96 PSI
Coil Outlet PSI Actual	55.04 PSI
Fluid Press. Drop PSI Actual	19.92 PSI
Actual Ent. Water Temp	35.0 Deg F
Actual Leav. Water Temp	38.0 Deg F
Water Delta T Actual	3.0 Deg F
Water Flow Design	98.0 GPM
Water Flow Actual	98.0 GPM
AHU-F05/HW Coil	
Coil Inlet PSI Actual	96.86 PSI
Coil Outlet PSI Actual	88.57 PSI
Fluid Press. Drop PSI Actual	8.29 PSI
Actual Ent. Water Temp	135.0 Deg F
Actual Leav. Water Temp	120.0 Deg F
Water Delta T Actual	15.0 Deg F

Air Handling Unit

PROJECT:	OUCP Terracon Cx	**DATE:**	3/22/2021
LOCATION:	,	**CONTACT:**	Levi Jacquemin
PROJECT #:	01-21-402	**AUTHOR:**	

SYSTEM/UNIT: AHU-F05

Tested By: Frederick Ogburn
Date: 3/15/2021

Water Test Data	
AHU-F05/HW Coil	
Water Flow Design	36.0 GPM
Water Flow Actual	36.0 GPM

Air Handling Unit

PROJECT:	OUCP Terracon Cx	**DATE:**	3/22/2021
LOCATION:	,	**CONTACT:**	Levi Jacquemin
PROJECT #:	01-21-402	**AUTHOR:**	

SYSTEM/UNIT: AHU-F06

Tested By: Frederick Ogburn
Date: 3/15/2021

Unit Data	
Unit Manufacturer	ClimateCraft
Unit Model Number	CAH78x120E
Unit Serial Number	22252
Unit Discharge	Upblast
AHU-F06/SF Filter Bank	
Filter Manufacturer	NG
Filter Type	Pleated
Filter Qty - S1	20
Filter Size - S1	20x24x4
AHU-F06/Supply Fan	
Fan Design RPM	1238 RPM
Design Fan Rotation	CW

Test Data	
Design Airflow	25000 CFM
Actual Airflow	28077 CFM
Design Min Outside Airflow	4550 CFM
Design Return Airflow	20450 CFM
AHU-F06/Supply Fan	
Design Airflow	25000 CFM
Design RPM	1760 RPM
Actual RPM	1750 RPM
Motor Volts T1-T2	474 Volts
Motor Amps T1	32.40 Amps
Actual Fan RPM	902 RPM
Actual Fan Rotation	CW

Motor Data	
AHU-F06/Supply Fan	
Motor Manufacturer	Reliance Electric
Motor Frame	286T
Motor HP	30 HP
Motor RPM	1760 RPM
Motor Rated Volts	460 Volts
Motor Phase	3
Motor Hertz	60 Hz
Motor FL Amps	35.5 Amps
Motor Service Factor	1.15

Test Pressures	
Actual Total SP	3.31 in. wc
External SP Design	2.00 in. wc
Suction SP	1.87 in. wc
Discharge SP	1.44 in. wc
External SP Actual	3.13 in. wc
External Suction SP	-2.04 in. wc
External Discharge SP	1.09 in. wc

Air Test Data	
AHU-F06/CHW Coil	
Actual Ent. Air DB Temp	79 Deg F
Actual Ent. Air WB Temp	58.0 °F
Actual Leav. Air DB Temp	59.0 Deg F
Actual Lvg. Air WB Temp	48.6 °F
Actual Air Temp ∆T	20.1 Deg F
Actual Air Press. Drop In Wg	0.43 in. wg
AHU-F06/HW Coil	
Actual Ent. Air DB Temp	70 Deg F
Actual Leav. Air DB Temp	74.1 Deg F
Actual Air Temp ∆T	4.3 Deg F
Actual Air Press. Drop In Wg	0.33 in. wg

Water Test Data	
AHU-F06/CHW Coil	
Coil Inlet PSI Actual	INA due to valve handle being over port PSI
Coil Outlet PSI Actual	46.96 PSI
Actual Ent. Water Temp	48.0 Deg F
Actual Leav. Water Temp	61.0 Deg F
Water Delta T Actual	13.0 Deg F
Water Flow Design	96.0 GPM
Water Flow Actual	96.0 GPM
AHU-F06/HW Coil	
Coil Inlet PSI Actual	88.15 PSI
Coil Outlet PSI Actual	8.63 PSI
Fluid Press. Drop PSI Actual	4.52 PSI
Actual Ent. Water Temp	114.0 Deg F
Actual Leav. Water Temp	104.0 Deg F
Water Delta T Actual	10.0 Deg F
Water Flow Design	32.0 GPM

Air Handling Unit

PROJECT: OUCP Terracon Cx
LOCATION: ,
PROJECT #: 01-21-402

DATE: 3/22/2021
CONTACT: Levi Jacquemin
AUTHOR:

SYSTEM/UNIT: AHU-F06

Tested By: Frederick Ogburn
Date: 3/15/2021

Water Test Data	
AHU-F06/HW Coil	
Water Flow Actual	32.0 GPM

Air Handling Unit

PROJECT: OUCP Terracon Cx
LOCATION: ,
PROJECT #: 01-21-402

DATE: 3/22/2021
CONTACT: Levi Jacquemin
AUTHOR:

SYSTEM/UNIT: AHU-F07

Tested By: Frederick Ogburn
Date: 3/15/2021

Unit Data	
Unit Manufacturer	ClimateCraft
Unit Model Number	CAH78x120E
Unit Serial Number	22253
Unit Discharge	Upblast
AHU-F07/SF Filter Bank	
Filter Manufacturer	NG
Filter Type	Pleated
Filter Qty - S1	20
Filter Size - S1	20x24x4
AHU-F07/Supply Fan	
Fan Design RPM	1238 RPM
Design Fan Rotation	CW

Test Data	
Design Airflow	25000 CFM
Actual Airflow	28252 CFM
Design Min Outside Airflow	4710 CFM
Design Return Airflow	20290 CFM
AHU-F07/Supply Fan	
Design Airflow	25000 CFM
Actual Airflow	28252 CFM
Design RPM	1760 RPM
Actual RPM	1758 RPM
Motor Volts T1-T2	474 Volts
Motor Amps T1	28.90 Amps
Actual Fan RPM	910 RPM
Actual Fan Rotation	CW

Motor Data	
AHU-F07/Supply Fan	
Motor Manufacturer	Reliance Electric
Motor Frame	286T
Motor HP	30 HP
Motor RPM	1760 RPM
Motor Rated Volts	460 Volts
Motor Phase	3
Motor Hertz	60 Hz
Motor FL Amps	35.5 Amps
Motor Service Factor	1.15

Test Pressures	
Actual Total SP	0.38 in. wc
External SP Design	2.00 in. wc
Suction SP	1.34 in. wc
Discharge SP	0.96 in. wc
External SP Actual	2.70 in. wc
External Suction SP	-2.06 in. wc
External Discharge SP	0.64 in. wc

Air Test Data	
AHU-F07/CHW Coil	
Actual Ent. Air DB Temp	81 Deg F
Actual Ent. Air WB Temp	59.1 °F
Actual Leav. Air DB Temp	56.5 Deg F
Actual Lvg. Air WB Temp	47.8 °F
Actual Air Temp ∆T	24.4 Deg F
Actual Air Press. Drop In Wg	0.38 in. wg
AHU-F07/HW Coil	
Actual Ent. Air DB Temp	72 Deg F
Actual Leav. Air DB Temp	75.2 Deg F
Actual Air Temp ∆T	3.4 Deg F
Actual Air Press. Drop In Wg	0.42 in. wg

Water Test Data	
AHU-F07/CHW Coil	
Coil Inlet PSI Actual	INA due to valve handle being over port PSI
Coil Outlet PSI Actual	41.92 PSI
Actual Ent. Water Temp	47.0 Deg F
Actual Leav. Water Temp	58.0 Deg F
Water Delta T Actual	11.0 Deg F
Water Flow Design	96.0 GPM
Water Flow Actual	96.0 GPM
AHU-F07/HW Coil	
Coil Inlet PSI Actual	83.24 PSI
Coil Outlet PSI Actual	78.91 PSI
Fluid Press. Drop PSI Actual	4.33 PSI
Actual Ent. Water Temp	113.0 Deg F
Actual Leav. Water Temp	106.0 Deg F
Water Delta T Actual	7.0 Deg F
Water Flow Design	32.0 GPM

Air Handling Unit

PROJECT:	OUCP Terracon Cx	**DATE:**	3/22/2021
LOCATION:	,	**CONTACT:**	Levi Jacquemin
PROJECT #:	01-21-402	**AUTHOR:**	

SYSTEM/UNIT: AHU-F07

Tested By: Frederick Ogburn
Date: 3/15/2021

Water Test Data	
AHU-F07/HW Coil	
Water Flow Actual	32.0 GPM

Air Handling Unit

PROJECT:	OUCP Terracon Cx	**DATE:**	3/22/2021
LOCATION:	,	**CONTACT:**	Levi Jacquemin
PROJECT #:	01-21-402	**AUTHOR:**	

SYSTEM/UNIT: AHU-F08

Tested By: Frederick Ogburn
Date: 3/4/2021

Unit Data

Unit Manufacturer	ClimateCraft
Unit Model Number	CAH78x120E
Unit Serial Number	22254
Unit Discharge	Upblast
AHU-F08/SF Filter Bank	
Filter Manufacturer	NG
Filter Type	Pleated
Filter Qty - S1	20
Filter Size - S1	20x24x4
AHU-F08/Supply Fan	
Fan Manufacturer	GREENHECK
Fan Model Number	40-QEP-3-11
Fan Serial Number	07J05120
Fan Design RPM	1238 RPM
Design Fan Rotation	CW
AHU-F08/CHW Coil	
Unit Manufacturer	NG
Unit Model Number	NG
Unit Serial Number	NG
Design Rows	NG
Design Fins	NG /in.
Design Ent. Air DB	NG °F
Design Ent. Air WB	NG °F
Design Lvg. Air DB	NG °F
Design Lvg. Air WB	NG °F
Design Air ΔT	NG °F
Design Ent. Water Temp	NG °F
Design Lvg. Water Temp	NG °F
Design Water ΔT	NG °F
AHU-F08/HW Coil	
Unit Manufacturer	FLOW DESIGN INC
Unit Model Number	YR200
Unit Serial Number	NG
Design Rows	NG
Design Fins	NG /in.
Design Ent. Air DB	NG °F
Design Ent. Air WB	NG °F
Design Lvg. Air DB	NG °F
Design Lvg. Air WB	NG °F
Design Air ΔT	NG °F
Design Ent. Water Temp	NG °F
Design Lvg. Water Temp	NG °F
Design Water ΔT	NG °F

Test Data

Design Airflow	25000 CFM
Actual Airflow	26451 CFM
Design Min Outside Airflow	5015 CFM
Design Return Airflow	19985 CFM
AHU-F08/Supply Fan	
Design Airflow	25000 CFM

Motor Data

AHU-F08/Supply Fan	
Motor Manufacturer	Reliance Electric
Motor Frame	286T
Motor HP	30 HP
Motor RPM	1760 RPM
Motor Rated Volts	460 Volts
Motor Phase	3
Motor Hertz	60 Hz
Motor FL Amps	35.5 Amps
Motor Service Factor	1.15

Sheave Data

AHU-F08/Supply Fan	
Motor Sheave MFG	NG
Motor Sheave Model	NG
Motor Sheave Diam.	7 in.
Motor Sheave Bore	2 in.
Fan Sheave MFG	NG
Fan Sheave Model	NG
Fan Sheave Diam.	13 1/2 in.
Fan Sheave Bore	2 in.
Number of Belts	4
Belt Size	6L217G
Sheave Center Line	41.00 in.

Test Pressures

Design Total SP	NG in. wc
Actual Total SP	4.41 in. wc
External SP Design	2.00 in. wc
Suction SP	2.45 in. wc
Discharge SP	1.96 in. wc
External SP Actual	3.51 in. wc
External Suction SP	-1.88 in. wc
External Discharge SP	1.63 in. wc
O/A Damper Position	40 %
R/A Damper Position	60 %

Air Test Data

AHU-F08/CHW Coil	
Design Airflow	NG CFM
Air Velocity Design	NG FPM
Actual Ent. Air DB Temp	79 Deg F
Actual Ent. Air WB Temp	57.4 °F
Actual Leav. Air DB Temp	71.0 Deg F
Actual Lvg. Air WB Temp	53.8 °F
Actual Air Temp ΔT	8.2 Deg F
Design Air Press. Drop In Wg	NG in. wg
Actual Air Press. Drop In Wg	0.49 in. wg
AHU-F08/HW Coil	
Design Airflow	NG CFM
Air Velocity Design	NG FPM

Air Handling Unit

PROJECT: OUCP Terracon Cx
LOCATION: ,
PROJECT #: 01-21-402

DATE: 3/22/2021
CONTACT: Levi Jacquemin
AUTHOR:

SYSTEM/UNIT: AHU-F08

Tested By: Frederick Ogburn
Date: 3/4/2021

Test Data	
AHU-F08/Supply Fan	
Actual Airflow	26451 CFM
Design RPM	1760 RPM
Actual RPM	1760 RPM
Motor Volts T1-T2	477 Volts
Motor Amps T1	38.20 Amps
Actual Fan RPM	913 RPM
Actual Fan Rotation	CW

Air Test Data	
AHU-F08/HW Coil	
Actual Ent. Air DB Temp	68 Deg F
Actual Ent. Air WB Temp	52.8 °F
Actual Leav. Air DB Temp	73.4 Deg F
Actual Lvg. Air WB Temp	55.0 °F
Actual Air Temp ∆T	5.0 Deg F
Design Air Press. Drop In Wg	NG in. wg
Actual Air Press. Drop In Wg	0.54 in. wg

Water Test Data	
AHU-F08/CHW Coil	
Coil Inlet PSI Design	NG PSI
Coil Inlet PSI Actual	52.73 PSI
Coil Outlet PSI Design	NG PSI
Coil Outlet PSI Actual	43.90 PSI
Fluid Press. Drop PSI Design	NG PSI
Fluid Press. Drop PSI Actual	8.83 PSI
Actual Ent. Water Temp	47.0 Deg F
Actual Leav. Water Temp	60.0 Deg F
Water Delta T Actual	13.0 Deg F
Water Flow Design	96.0 GPM
Water Flow Actual	96.0 GPM
AHU-F08/HW Coil	
Coil Inlet PSI Design	NG PSI
Coil Inlet PSI Actual	60.39 PSI
Coil Outlet PSI Design	NG PSI
Coil Outlet PSI Actual	57.01 PSI
Fluid Press. Drop PSI Design	NG PSI
Fluid Press. Drop PSI Actual	3.38 PSI
Actual Ent. Water Temp	119.0 Deg F
Actual Leav. Water Temp	109.0 Deg F
Water Delta T Actual	10.0 Deg F
Water Flow Design	32.0 GPM
Water Flow Actual	32.0 GPM

Air Handling Unit

PROJECT: OUCP Terracon Cx
LOCATION: ,
PROJECT #: 01-21-402

DATE: 3/22/2021
CONTACT: Levi Jacquemin
AUTHOR:

SYSTEM/UNIT: AHU-F10

Tested By: Blaine Phillips
Date: 3/16/2021

Unit Data	
Unit Manufacturer	ClimateCraft
Unit Model Number	CAH78x120E
Unit Serial Number	22256
Unit Discharge	Upblast
AHU-F10/SF Filter Bank	
Filter Manufacturer	NG
Filter Type	Pleated
Filter Qty - S1	20
Filter Size - S1	20x24x4
AHU-F10/Supply Fan	
Fan Design RPM	1236 RPM
Design Fan Rotation	CW

Test Data	
Design Airflow	25000 CFM
Actual Airflow	65% Fan speed CFM
Design Min Outside Airflow	3800 CFM
Design Return Airflow	21200 CFM

Motor Data	
AHU-F10/Supply Fan	
Motor Manufacturer	Reliance Electric
Motor Frame	286T
Motor HP	30 HP
Motor RPM	1760 RPM
Motor Rated Volts	460 Volts
Motor Phase	3
Motor Hertz	60 Hz
Motor FL Amps	35.5 Amps
Motor Service Factor	1.15

Test Pressures	
External SP Design	2.00 in. wc

Air Test Data	
AHU-F10/CHW Coil	
Actual Ent. Air DB Temp	81 Deg F
Actual Ent. Air WB Temp	64.9 °F
Actual Leav. Air DB Temp	60.7 Deg F
Actual Lvg. Air WB Temp	53.6 °F
Actual Air Temp ∆T	20.3 Deg F
AHU-F10/HW Coil	
Actual Ent. Air DB Temp	71 Deg F
Actual Leav. Air DB Temp	81.0 Deg F
Actual Air Temp ∆T	9.6 Deg F

Water Test Data	
AHU-F10/CHW Coil	
Coil Inlet PSI Actual	INA due to valve handle being over port PSI
Coil Outlet PSI Actual	37.30 PSI
Actual Ent. Water Temp	44.0 Deg F
Actual Leav. Water Temp	56.0 Deg F
Water Delta T Actual	12.0 Deg F
Water Flow Design	96.0 GPM
Water Flow Actual	96.0 GPM
AHU-F10/HW Coil	
Coil Inlet PSI Actual	35.76 PSI
Coil Outlet PSI Actual	17.74 PSI
Fluid Press. Drop PSI Actual	18.18 PSI
Actual Ent. Water Temp	114.0 Deg F
Actual Leav. Water Temp	104.0 Deg F
Water Delta T Actual	10.0 Deg F
Water Flow Design	32.0 GPM
Water Flow Actual	32.0 GPM

Air Handling Unit

PROJECT: OUCP Terracon Cx
LOCATION: ,
PROJECT #: 01-21-402

DATE: 3/22/2021
CONTACT: Levi Jacquemin
AUTHOR:

SYSTEM/UNIT: AHU-F11

Tested By: Frederick Ogburn
Date: 3/4/2021

Unit Data	
Unit Manufacturer	ClimateCraft
Unit Model Number	CAH78x120E
Unit Serial Number	22257
Unit Discharge	Upblast
AHU-F11/SF Filter Bank	
Filter Manufacturer	NG
Filter Type	Pleated
Filter Qty - S1	20
Filter Size - S1	20x24x4
AHU-F11/Supply Fan	
Fan Manufacturer	GREENHECK
Fan Model Number	40-QEP-3-11
Fan Serial Number	07J05122
Fan Design RPM	1238 RPM
Design Fan Rotation	CW
AHU-F11/HW Coil	
Unit Manufacturer	FLOW DESIGN
Unit Model Number	YR200

Test Data	
Design Airflow	25000 CFM
Actual Airflow	22500 CFM
Design Min Outside Airflow	4000 CFM
Design Return Airflow	21000 CFM
AHU-F11/Supply Fan	
Design Airflow	25000 CFM
Actual Airflow	22500 CFM
Design RPM	1760 RPM
Actual RPM	1760 RPM
Motor Volts T1-T2	475 Volts
Motor Amps T1	27.40 Amps
Actual Fan RPM	913 RPM
Actual Fan Rotation	CW

Motor Data	
AHU-F11/Supply Fan	
Motor Manufacturer	Reliance Electric
Motor Frame	286T
Motor HP	30 HP
Motor RPM	1760 RPM
Motor Rated Volts	460 Volts
Motor Phase	3
Motor Hertz	60 Hz
Motor FL Amps	1.15 Amps

Sheave Data	
AHU-F11/Supply Fan	
Motor Sheave MFG	NG
Motor Sheave Model	NG
Motor Sheave Diam.	7 in.
Motor Sheave Bore	2 in.
Fan Sheave MFG	NG
Fan Sheave Model	NG
Fan Sheave Diam.	13 1/2 in.
Fan Sheave Bore	2 in.
Number of Belts	4
Belt Size	6L217G
Sheave Center Line	41.00 in.

Test Pressures	
External SP Design	2.00 in. wc
Suction SP	1.81 in. wc
Discharge SP	1.46 in. wc
External SP Actual	2.53 in. wc
External Suction SP	-1.28 in. wc
External Discharge SP	1.25 in. wc
O/A Damper Position	0 %
R/A Damper Position	100 %

Air Test Data	
AHU-F11/CHW Coil	
Actual Ent. Air DB Temp	82 Deg F
Actual Ent. Air WB Temp	58.4 °F
Actual Leav. Air DB Temp	67.7 Deg F
Actual Lvg. Air WB Temp	52.2 °F
Actual Air Temp ∆T	14.0 Deg F
Actual Air Press. Drop In Wg	0.35 in. wg
AHU-F11/HW Coil	
Actual Ent. Air DB Temp	71 Deg F
Actual Ent. Air WB Temp	54.1 °F
Actual Leav. Air DB Temp	73.2 Deg F
Actual Lvg. Air WB Temp	54.8 °F
Actual Air Temp ∆T	2.5 Deg F
Actual Air Press. Drop In Wg	0.24 in. wg

Air Handling Unit

PROJECT: OUCP Terracon Cx
LOCATION: ,
PROJECT #: 01-21-402

DATE: 3/22/2021
CONTACT: Levi Jacquemin
AUTHOR:

SYSTEM/UNIT: AHU-F11

Tested By: Frederick Ogburn
Date: 3/4/2021

Water Test Data	
AHU-F11/CHW Coil	
Coil Inlet PSI Actual	42.49 PSI
Coil Outlet PSI Actual	34.42 PSI
Fluid Press. Drop PSI Actual	8.06 PSI
Actual Ent. Water Temp	48.0 Deg F
Actual Leav. Water Temp	60.0 Deg F
Water Delta T Actual	12.0 Deg F
Water Flow Design	96.0 GPM
Water Flow Actual	96.0 GPM
AHU-F11/HW Coil	
Coil Inlet PSI Actual	44.00 PSI
Coil Outlet PSI Actual	39.72 PSI
Fluid Press. Drop PSI Actual	4.29 PSI
Actual Ent. Water Temp	114.0 Deg F
Actual Leav. Water Temp	102.0 Deg F
Water Delta T Actual	12.0 Deg F
Water Flow Design	32.0 GPM
Water Flow Actual	32.0 GPM

Air Handling Unit

PROJECT: OUCP Terracon Cx
LOCATION: ,
PROJECT #: 01-21-402

DATE: 3/22/2021
CONTACT: Levi Jacquemin
AUTHOR:

SYSTEM/UNIT: AHU-F12

Tested By: Greg Higgins
Date: 3/16/2021

Unit Data	
Unit Manufacturer	ClimateCraft
Unit Model Number	CAH78x120E
Unit Serial Number	22258
Unit Discharge	Upblast
AHU-F12/SF Filter Bank	
Filter Manufacturer	NG
Filter Type	Pleated
Filter Qty - S1	20
Filter Size - S1	20x24x4
AHU-F12/Supply Fan	
Fan Manufacturer	GREENHECK
Fan Model Number	40-QEP-3-11
Fan Serial Number	07J05121
Fan Design RPM	1238 RPM
Design Fan Rotation	CW

Test Data	
Design Airflow	25000 CFM
Actual Airflow	27402 CFM
Design Min Outside Airflow	4300 CFM
Design Return Airflow	20700 CFM
AHU-F12/Supply Fan	
Design Airflow	25000 CFM
Actual Airflow	27402 CFM
Design RPM	1760 RPM
Actual RPM	1761 RPM
Motor Volts T1-T2	481 Volts
Motor Amps T1	30.10 Amps
Actual Fan RPM	987 RPM
Actual Fan Rotation	CW

Motor Data	
AHU-F12/Supply Fan	
Motor Manufacturer	Reliance Electric
Motor Frame	286T
Motor HP	30 HP
Motor RPM	1760 RPM
Motor Rated Volts	460 Volts
Motor Phase	3
Motor Hertz	60 Hz
Motor FL Amps	35.5 Amps
Motor Service Factor	1.15

Sheave Data	
AHU-F12/Supply Fan	
Motor Sheave MFG	NG
Motor Sheave Model	NG
Motor Sheave Diam.	8 1/2 in.
Motor Sheave Bore	1 7/8 in.
Fan Sheave MFG	NG
Fan Sheave Model	NG
Fan Sheave Diam.	16 in.
Fan Sheave Bore	2 1/4 in.
Number of Belts	3
Belt Size	3GWJ4
Sheave Center Line	41 1/4 in.

Test Pressures	
Actual Total SP	3.89 in. wc
External SP Design	2.00 in. wc
Suction SP	-1.98 in. wc
Discharge SP	1.91 in. wc
External SP Actual	2.70 in. wc
External Suction SP	-1.6 in. wc
External Discharge SP	1.1 in. wc

Air Test Data	
AHU-F12/CHW Coil	
Design Airflow	25000 CFM
Actual Airflow	27402 CFM
Actual Ent. Air DB Temp	81 Deg F
Actual Ent. Air WB Temp	64.2 °F
Actual Leav. Air DB Temp	56.4 Deg F
Actual Lvg. Air WB Temp	50.4 °F
Actual Air Temp ∆T	24.6 Deg F
Actual Air Press. Drop In Wg	0.40 in. wg
AHU-F12/HW Coil	
Design Airflow	25000 CFM
Actual Airflow	27402 CFM
Actual Ent. Air DB Temp	69 Deg F
Actual Ent. Air WB Temp	57.1 °F
Actual Leav. Air DB Temp	80.7 Deg F
Actual Lvg. Air WB Temp	64.2 °F

Air Handling Unit

PROJECT: OUCP Terracon Cx
LOCATION: ,
PROJECT #: 01-21-402

DATE: 3/22/2021
CONTACT: Levi Jacquemin
AUTHOR:

SYSTEM/UNIT: AHU-F12

Tested By: Greg Higgins
Date: 3/16/2021

Air Test Data	
AHU-F12/HW Coil	
Actual Air Temp ∆T	11.7 Deg F
Actual Air Press. Drop In Wg	0.03 in. wg

Water Test Data	
AHU-F12/CHW Coil	
Coil Inlet PSI Actual	INA due to valve handle being over port PSI
Coil Outlet PSI Actual	29.60 PSI
Actual Ent. Water Temp	52.0 Deg F
Actual Leav. Water Temp	58.9 Deg F
Water Delta T Actual	6.9 Deg F
Water Flow Design	96.0 GPM
Water Flow Actual	96.0 GPM
AHU-F12/HW Coil	
Coil Inlet PSI Actual	56.93 PSI
Coil Outlet PSI Actual	53.03 PSI
Fluid Press. Drop PSI Actual	3.90 PSI
Actual Ent. Water Temp	119.5 Deg F
Actual Leav. Water Temp	107.5 Deg F
Water Delta T Actual	12.0 Deg F
Water Flow Design	32.0 GPM
Water Flow Actual	32.0 GPM

Air Handling Unit

PROJECT: OUCP Terracon Cx
LOCATION: ,
PROJECT #: 01-21-402

DATE: 3/22/2021
CONTACT: Levi Jacquemin
AUTHOR:

SYSTEM/UNIT: AHU-F14

Tested By: Blaine Phillips
Date: 3/16/2021

Unit Data	
Unit Manufacturer	ClimateCraft
Unit Model Number	CAH78X120E
Unit Serial Number	22395
Unit Discharge	Vertical
AHU-F14/SF Filter Bank	
Filter Manufacturer	NG
Filter Type	pleated
Filter Qty - S1	20
Filter Size - S1	20x24x4
AHU-F14/Supply Fan	
Fan Manufacturer	GREENHECK
Fan Model Number	40-QEP-3-11
Fan Serial Number	11186431 0803
Fan Design RPM	1238 RPM
Design Fan Rotation	CW

Test Data	
Design Airflow	25000 CFM
Actual Airflow	30145 CFM
Design Min Outside Airflow	4300 CFM
Design Return Airflow	20700 CFM
AHU-F14/Supply Fan	
Design Airflow	25000 CFM
Actual Airflow	30145 CFM
Design RPM	1760 RPM
Actual RPM	1757 RPM
Motor Volts T1-T2	475 Volts
Motor Amps T1	31.00 Amps
Actual Fan RPM	912 RPM
Actual Fan Rotation	CW

Motor Data	
AHU-F14/Supply Fan	
Motor Manufacturer	Marathon
Motor Frame	286T
Motor HP	30 HP
Motor RPM	1768 RPM
Motor Rated Volts	460 Volts
Motor Phase	3
Motor Hertz	60 Hz
Motor FL Amps	37 Amps
Motor Service Factor	1.15

Sheave Data	
AHU-F14/Supply Fan	
Motor Sheave MFG	INA
Motor Sheave Model	INA
Motor Sheave Diam.	INA in.
Motor Sheave Bore	INA in.
Fan Sheave MFG	INA
Fan Sheave Model	INA
Fan Sheave Diam.	INA in.
Fan Sheave Bore	INA in.
Number of Belts	3
Belt Size	B-118
Sheave Center Line	INA in.

Test Pressures	
Actual Total SP	3.99 in. wc
External SP Design	2.00 in. wc
Suction SP	-1.79 in. wc
Discharge SP	2.20 in. wc
External SP Actual	2.51 in. wc
External Suction SP	-1.4 in. wc
External Discharge SP	1.11 in. wc

Air Test Data	
AHU-F14/CHW Coil	
Actual Ent. Air DB Temp	79 Deg F
Actual Ent. Air WB Temp	62.2 °F
Actual Leav. Air DB Temp	52.0 Deg F
Actual Lvg. Air WB Temp	46.1 °F
Actual Air Temp ∆T	27.0 Deg F
Actual Air Press. Drop In Wg	0.40 in. wg
AHU-F14/HW Coil	
Actual Ent. Air DB Temp	71 Deg F
Actual Ent. Air WB Temp	57.3 °F
Actual Leav. Air DB Temp	78.9 Deg F
Actual Lvg. Air WB Temp	62.2 °F
Actual Air Temp ∆T	7.9 Deg F
Actual Air Press. Drop In Wg	0.02 in. wg

Air Handling Unit

PROJECT:	OUCP Terracon Cx	**DATE:**	3/22/2021
LOCATION:	,	**CONTACT:**	Levi Jacquemin
PROJECT #:	01-21-402	**AUTHOR:**	

SYSTEM/UNIT: AHU-F14

Tested By: Blaine Phillips
Date: 3/16/2021

Water Test Data	
AHU-F14/CHW Coil	
Coil Inlet PSI Actual	INA due to valve handle being over port PSI
Coil Outlet PSI Actual	10.76 PSI
Actual Ent. Water Temp	49.0 Deg F
Actual Leav. Water Temp	60.0 Deg F
Water Delta T Actual	11.0 Deg F
Water Flow Design	96.0 GPM
Water Flow Actual	96.0 GPM
AHU-F14/HW Coil	
Coil Inlet PSI Actual	49.63 PSI
Coil Outlet PSI Actual	3.67 PSI
Fluid Press. Drop PSI Actual	46.03 PSI
Actual Ent. Water Temp	137.3 Deg F
Actual Leav. Water Temp	99.7 Deg F
Water Delta T Actual	37.6 Deg F
Water Flow Design	32.0 GPM
Water Flow Actual	NG GPM

Log:

AHU-F14/Supply Fan	3/16/2021	Greg Higgins	Unable to remove Shroud from the motor and fan due to stripped and/or frozen screws.

PUMP TEST SHEET

Job Name: SAMIS, ATRIUM, TCH PUMPS
Tested By: JACQUEMIN/HIGGINS/OGBURN **Date:** 12/2/2020

PUMP DATA

Pump Number	CHWP-1	CHWP-2	CHWP-3
Manufacturer	ARMSTRONG	ARMSTRONG	ARMSTRONG
Model Number	DE4200H 0511-040.0	6X5X11.5 4030	6X5X11.5 4030
Serial Number	832908	589164	589183
Impeller Size	11.5	11.5	11.5
Rpm	NG	1800	1800
Specified gpm	1200	1200	700
Specified Head	95	95	94

MOTOR DATA

	Design	Test	Design	Test	Design	Test
Motor Name	BROOK CROMPTON		ARMSTRONG		ARMSTRONG	
Horsepower	40	40	40	40	30	30
Motor rpm	1765		1780		1780	
Phase	3		3		3	
Voltage	460	448	460		460	INA
		-				-
		-				-
Service Factor	1.25		1.15		1.15	
Amperage	45.0	30.0	45.3		33.5	INA
		-				-
		-				-

TEST RESULTS – CLOSE OFF

Suction Pressure (PSI)	-	-	-
Discharge Pressure (PSI)	-	-	-
Differential Pressure (PSI)	-	-	-
Head (Feet)	-	-	-

TEST RESULTS - RUNNING

Suction Pressure (PSI)	82.7		78.1
Discharge Pressure (PSI)	138.9		120.8
Differential Pressure (PSI)	56.2		42.7
Head (Feet)	129.7		98.5
Final gpm	800.0		1175.0
HZ	60.0		60.0

Comments: LAG PUMPS WERE NOT TURNED ON AND ARE MARKED IN YELLOW. IF AMPS AND VOLTS ARE MARKED AS INA THE DRIVE WOULD NOT SHOW THE CURRENT AND WE COULD NOT GAIN ACCESS INSIDE THE DRIVE TO GET A READING.

PUMP TEST SHEET

Job Name: SAMIS, ATRIUM, TCH PUMPS
Tested By: JACQUEMIN/HIGGINS/OGBURN **Date:** 12/2/2020

PUMP DATA

Pump Number	**HWP-1**	**HWP-2**	**HWP-3**
Manufacturer	ARMSTRONG	ARMSTRONG	ARMSTRONG
Model Number	6X5X11.5	6X5X11.5 4030	6x5x11.5 4030
Serial Number	739747	743105	589187
Impeller Size	11.5	11.5	11.5
Rpm	NG	NG	1800
Specified gpm	1100	1100	400
Specified Head	85	85	94

MOTOR DATA

	Design	**Test**	**Design**	**Test**	**Design**	**Test**
Motor Name	ARMSTRONG		ARMSTRONG		WEG	
Horsepower	40	40	40	40	20	20
Motor rpm	1780		1780		1765	
Phase	3		3		3	
Voltage	460	INA	460		460	481
		INA				
		INA				
Service Factor	1.15		1.15		1.15	
Amperage	45.3	INA	45.3		24.1	25.8
		INA				
		INA				

TEST RESULTS – CLOSE OFF

Suction Pressure (PSI)	-	-	-
Discharge Pressure (PSI)	-	-	-
Differential Pressure (PSI)	-	-	-
Head (Feet)	-	-	-

TEST RESULTS - RUNNING

Suction Pressure (PSI)	82.2		65.7
Discharge Pressure (PSI)	131.1		73.5
Differential Pressure (PSI)	48.9		7.8
Head (Feet)	112.8		18.0
Final gpm	875.0		CANNOT BE DETERMINED
HZ	60.0		60.0

Comments: HWP-3 HAS WRITTEN LABEL AS HWP-4 (PUMP RUNNING BACKWARDS) LAG PUMPS WERE NOT TURNED ON AND ARE MARKED WITH YELLOW

APPENDIX G
OU PHYSICIANS BUILDING REPORT

MECHANICAL CONSULTING SERVICES

Building Infrastructure Testing Report

OU Physicians Building at 825 NE 10th Street

Oklahoma City, Oklahoma 73104

April 12, 2021

Project No. FA20P031

Prepared For:

University Hospitals Authority and Trust (UHAT)
Nathan Miller
940 NE 13th Street
Oklahoma City, Oklahoma 73104

Prepared by:

Terracon Consultants, Inc.
4701 N. Stiles Avenue
Oklahoma City, Oklahoma 73105

Terracon

April 12, 2021

Mr. Nathan Miller
Building Systems Manager
University Hospital Authority & Trust
940 NE 13th Street
Oklahoma City, Oklahoma 73104
P: 405-271-4962 x44199
E: Nathan-Miller@uhat.org

Reference: **UHAT**
Building Infrastructure Testing & Retro-Commissioning
OU Physicians Building
825 NE 10th Street
Oklahoma City, Oklahoma 73104
Project No. FA20P031

Mr. Miller:

Terracon Consultants, Inc. (Terracon) is pleased to submit this Mechanical Consulting Services Report of our Building Infrastructure Testing for the OU Physicians Building at 825 NE 10th Street in Oklahoma City, Oklahoma. This work was performed in general accordance with the scope of services outlined in the Terracon Company Proposal for Building Infrastructure Testing & Retro-Commissioning Services dated December 19, 2019 as identified in the scope section of this Report.

The purpose of this Report is to render our findings, field notes, and recommendations related to our site visits at the above referenced location.

This document includes background information, observations, findings, and recommendations pertaining to the operations of the heating, ventilation, and air conditioning (HVAC) at the site.

Terracon appreciates the opportunity to be of service to you on this project. If you have any questions regarding this report, please do not hesitate to contact us.

Sincerely,

Terracon Consultants, Inc.

Erik Gonzalez, P.E. (TX), CEM
Senior Engineer
Facilities Services

Jeffrey A. Miller, P.E. (OK)
Senior Principal/Senior Engineer
Facilities Services

Terracon Consultants, Inc. 4701 N. Stiles Avenue Oklahoma City, Oklahoma 73105
P (405) 525-0453 terracon.com

Geotechnical ■ Environmental ■ Construction Materials ■ Facilities

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PROJECT OBJECTIVE

The purpose of the Building Infrastructure Testing (BIT) services is to conduct limited visual observations and engineering diagnostics of the HVAC systems. With the observations and measurements taken, a retro-commissioning plan is developed with recommended energy conservation opportunities that will help reduce the operating costs of the building without compromising comfort for the building occupants.

Terracon's representatives, Mr. Saeed Foroughi, Mr. John Harmon, E.I.T., Mr. Kim Morris QCxP, and Mr. Erik Gonzalez, P.E. (TX), CEM conducted site visits on May 12 – May 14, 2020 and May 25, 2020 at the OUP Building in order to obtain visual and diagnostic information and measurements for the HVAC systems. During the site visits, visual observations were made to note general operating conditions of the HVAC systems. In addition, diagnostic measurements were taken for the air distribution of the five VAV AHUs and associated chilled water and hot water coils, chilled water distribution pumps, and hot water distribution pump. Measurements recorded were compared to the design documents and EMCS sensor measurements for air flow and water flow characteristics using the software workstation. Observations were made from readily accessible areas and did not include substantial dismantling of components of the building and HVAC equipment, including walls and closed ceilings. With the observations and measurements, Terracon developed energy conservation opportunity recommendations for improvements to the HVAC systems.

DOCUMENTS AND INFORMATION REVIEWED

Terracon was provided with design documentation for the subject building, utility data for chilled water, steam, and electricity, tariff sheets that breakdown the cost of each utility service, and network access to the *AutomatedLogic Corporation* (*ALC*) *WebCTRL v7.0* energy management control system. The following items were reviewed while performing this assessment:

Document	Source
UPMG Medical Office Building Architectural and MEP Design Record Drawings — REES ASSOCIATES, dated February 08, 2002	Client Provided
Utility Bill Data for Terracon.xlsx – e-mailed to Terracon on February 28, 2020	Client Provided
Utility Service Tariff Sheets for OUHSC and OGE services provided to UHAT – e-mailed to Terracon on March 3, 2020	Client Provided

BUILDING DESCRIPTION AND ENERGY USE BASELINE

The subject property is a five-story medical office building with a mechanical penthouse above the fifth floor and totals approximately 189,525-square feet. The building was designed in 2000, with construction completed in 2001. The HVAC systems were designed to operate with distributed chilled water and distributed steam from a Central Plant associated with the University of Oklahoma Health Sciences Center (OUHSC) at a remote location in downtown Oklahoma City.

The HVAC systems include two chilled water pumps, one heating hot water pump, one domestic water pump, and two steam-to-hot water heat exchangers that provide distributed hot water for the HVAC systems and domestic hot water within the building. In addition, there are five variable air volume (VAV) air handling units (AHUs), one constant volume AHU, twelve fan coil units, three water cooled packaged direct expansion (DX) computer room air conditioning (CRAC) units, two centralized return fans, nine exhaust fans, 181 VAV terminal units with hot water reheat, and seven constant volume terminal units with hot water reheat. All major equipment is controlled and monitored with an *ALC* energy management control system (EMCS). The majority of the *ALC* controllers (hardware) and the *WebCTRL* (software) were installed to replace the original *InvenSys/Seibe* controls in approximately 2012.

Table 1: General Building Information

Attributes	***OUP***
Property Manager	*ONECall*
Year Opened	2001
Enclosed Square Feet	189,525
Floors	5
Annual Metered kWh Consumption (2019)	2,746,800* (89% OUP & 11% RAD)
Annual Metered Peak kW Demand	781* (89% OUP & 11% RAD)
Annual Electric $	$164,316* (89% OUP & 11% RAD)
Annual CHW Ton-hrs Consumed (2019)	751,836
Annual Peak Demand Tons	319.70
Average Monthly CHW Temp. Diff. (ºF)	13.559
Annual CHW $	$123,788
Annual Steam klbs Consumed (2019)	5,017
Annual Steam Demand lbs/hr	2,530
Annual Steam Condensate Return (%)	95%
Annual Steam Cost $	$36,141
kWh/sqft	14.5
Peak W/sqft	4.12
Electrical Load Factor	40.1%
CHW Ton-hrs/sqft	4.06
Steam kBtu/sqft	32.4
Electrical EUI (kBtu/sqft)	50.6
CHW EUI (kBtu/sqft)	48.7
Total EUI (kBtu/sqft)	123.3*
Annual Utility Spend	$324,245
ECI ($/SqFt)	$1.62*
FCI Score	2019 (100) 2021 (100)
Operating Schedule	M-Sat 5am-10pm
Occupied Hours	M-F 5am-5pm 1st Floor Sat 7am-5pm
EMCS - Energy Management Control System	*ALC - WebCTRL*
Cooling Systems	Chilled Water
Heating Systems	Hot Water
Air Distribution	SZ & VAV with VAV TB's
Outside Air / Ventilation	OA is ducted directly to AHU’s

*Electric consumption was estimated based on the calculated ratio between OU Physicians building sqft versus the overall sqft (OU Physicians and Radiation Therapy) served by the electric meter at the OU Physicians building.

To measure the building's energy utilization and current level of efficiency, two Energy Performance Indicators were calculated in this Report as follows:

Energy Utilization Intensity

The Energy Utilization Intensity (EUI) depicts the total annual energy consumption per square foot of building space, and is expressed in "British Thermal Units" (BTUs). To calculate the EUI, the annual consumption of electricity, steam, and chilled water are first converted to equivalent kBTU consumption via the following formulas:

Total Annual Energy Usage = Total Annual Electrical Energy Usage + Total Annual Steam Energy Usage + Total Annual Chilled Water Energy Usage converted to units of kBTUs/year.

Total Annual Electrical Energy Usage
[Total kWh /yr.] x [3.412 kBTUs/kWh] = __________ kBTUs / yr.

Total Annual Steam Energy Usage
[Total klbs /yr.] x [1,196 kBTUs/klbs] = __________ kBTUs / yr.

Total Annual Chilled Water Energy Usage
[Total Ton/hr /yr.] x [12 kBTUs/hr/Ton/hr] = __________ kBTUs / yr.

The total kBTUs are then divided by the building area.

EUI = [Total annual kBTUs] divided by [Total square feet]

The EUI was compared to the average energy utilization published in the 2012 Commercial Building Energy Consumption Survey (CBECS).

Energy Cost Index

The Energy Cost Index (ECI) depicts the total annual energy cost per square foot building space. To calculate the ECI, the annual costs of electricity, steam, and chilled water are divided by the total square footage of the leased space:

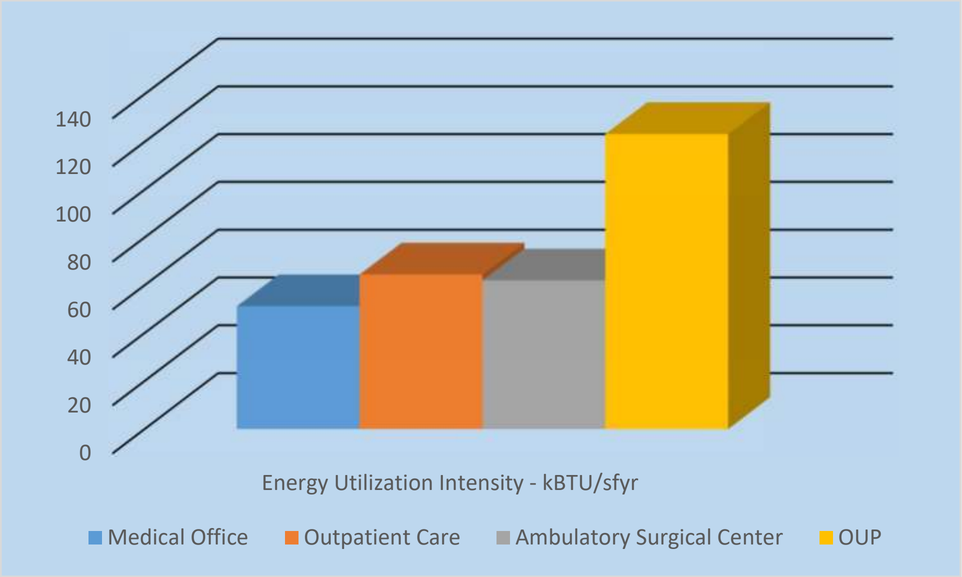
ECI = [Total Energy Cost] divided by [Total square feet]

The ECI was calculated and compared to the statistical average energy cost index published in the 2012 Commercial Building Energy Consumption Survey (CBECS).

The EUI and ECI may be used to compare the facility's approximate usage and cost to other similar facilities in the area. Although the comparisons will not provide specific reasons for unusual operation, they serve as indicators that opportunities may exist by more efficiently operating energy consuming systems.

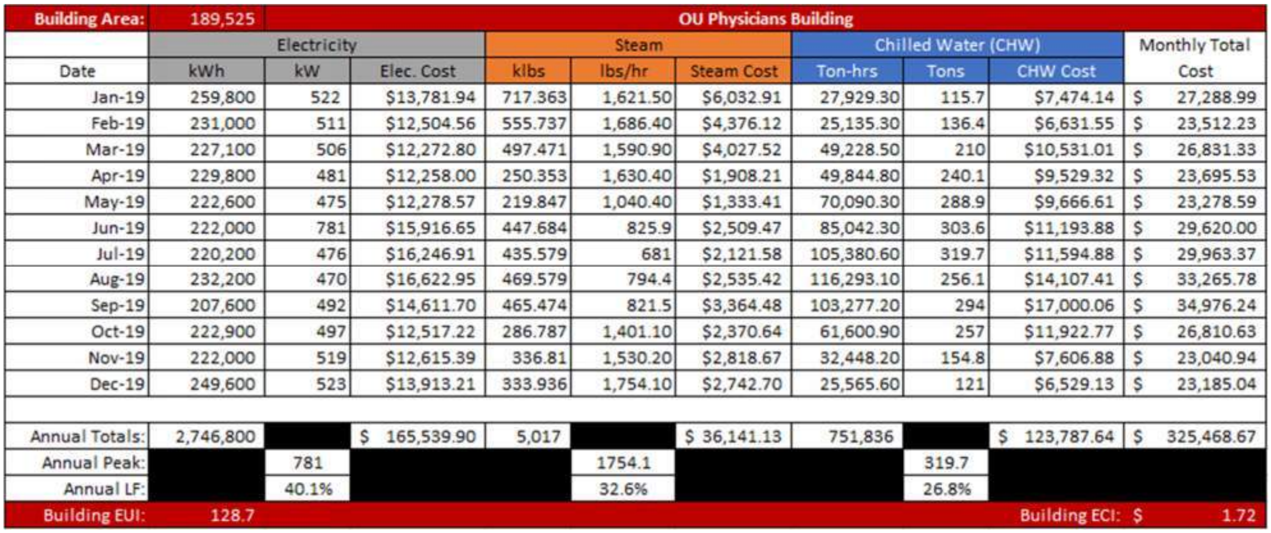
Referring to the 2012 Commercial Building Energy Consumption Survey (CBECS), compiled by the United States Department of Energy, we find the following ranges of comparison with the subject building. The CBECS survey results were based on a national statistical average of a total of 9,941-million square feet reported. The subject site is located within the southwestern section of the United States.

- CBECS utility cost and energy utilization comparison of the EUI and ECI indicates that OUP has a **moderately high EUI and ECI** compared to similar facilities in the healthcare category.



OU Health Sciences Center (OUHSC) and Oklahoma Gas and Electric (OGE) are the main energy utility providers for the building. Terracon has analyzed the energy consumption for the building and determined the Energy Usage Index (EUI) is 123.3 kBtu/SQFT and the Energy Cost Index (ECI) is $1.62/SQFT. The annual energy consumption ratio shows that electricity accounts for approximately 36% of total energy consumption, chilled water accounts for approximately 38% of total energy consumption, and steam accounts for the remaining 26% of total energy consumption. Annually, electricity accounts for approximately 48% of the total energy cost, chilled water accounts for approximately 40% of the total energy cost, and steam accounts for the remaining 12% of total energy cost. The annual cost ratios are most likely significantly disproportionate from the annual consumption ratios due to ratcheting costs associated with the electrical demand. In June 2019, the building experienced an actual 15-minute demand interval of 781 kW that will be responsible for a portion of the billed demand costs for the following 12 months.

Table 2 – 2019 Energy Baseline



Building Area:	189,525	OU Physicians Building								
	Electricity			Steam			Chilled Water (CHW)			Monthly Total Cost
Date	kWh	kW	Elec. Cost	klbs	lbs/hr	Steam Cost	Ton-hrs	Tons	CHW Cost	
Jan-19	259,800	522	$13,781.94	717.363	1,621.50	$6,032.91	27,929.30	115.7	$7,474.14	$ 27,288.99
Feb-19	231,000	511	$12,504.56	555.737	1,686.40	$4,376.12	25,135.30	136.4	$6,631.55	$ 23,512.23
Mar-19	227,100	506	$12,272.80	497.471	1,590.90	$4,027.52	49,228.50	210	$10,531.01	$ 26,831.33
Apr-19	229,800	481	$12,258.00	250.353	1,630.40	$1,908.21	49,844.80	240.1	$9,529.32	$ 23,695.53
May-19	222,600	475	$12,278.57	219.847	1,040.40	$1,333.41	70,090.30	288.9	$9,666.61	$ 23,278.59
Jun-19	222,000	781	$15,916.65	447.684	825.9	$2,509.47	85,042.30	303.6	$11,193.88	$ 29,620.00
Jul-19	220,200	476	$16,246.91	435.579	681	$2,121.58	105,380.60	319.7	$11,594.88	$ 29,963.37
Aug-19	232,200	470	$16,622.95	469.579	794.4	$2,535.42	116,293.10	256.1	$14,107.41	$ 33,265.78
Sep-19	207,600	492	$14,611.70	465.474	821.5	$3,364.48	103,277.20	294	$17,000.06	$ 34,976.24
Oct-19	222,900	497	$12,517.22	286.787	1,401.10	$2,370.64	61,600.90	257	$11,922.77	$ 26,810.63
Nov-19	222,000	519	$12,615.39	336.81	1,530.20	$2,818.67	32,448.20	154.8	$7,606.88	$ 23,040.94
Dec-19	249,600	523	$13,913.21	333.936	1,754.10	$2,742.70	25,565.60	121	$6,529.13	$ 23,185.04
Annual Totals:	2,746,800		$ 165,539.90	5,017		$ 36,141.13	751,836		$ 123,787.64	$ 325,468.67
Annual Peak:		781			1754.1			319.7		
Annual LF:		40.1%			32.6%			26.8%		
Building EUI:	128.7								Building ECI:	$ 1.72

Chart 1 – Energy Ratio

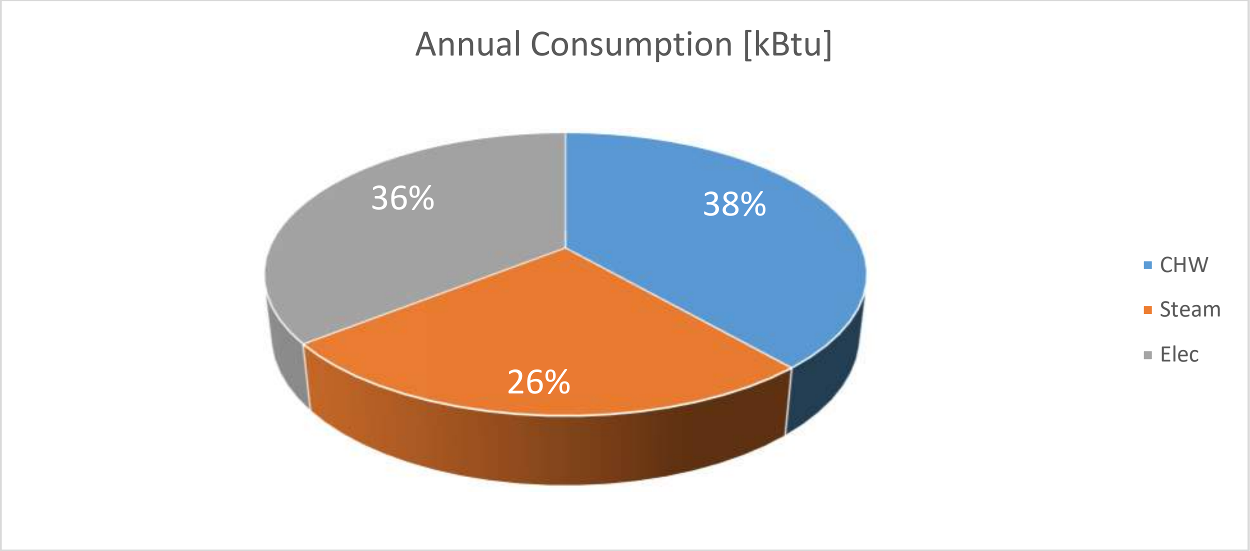
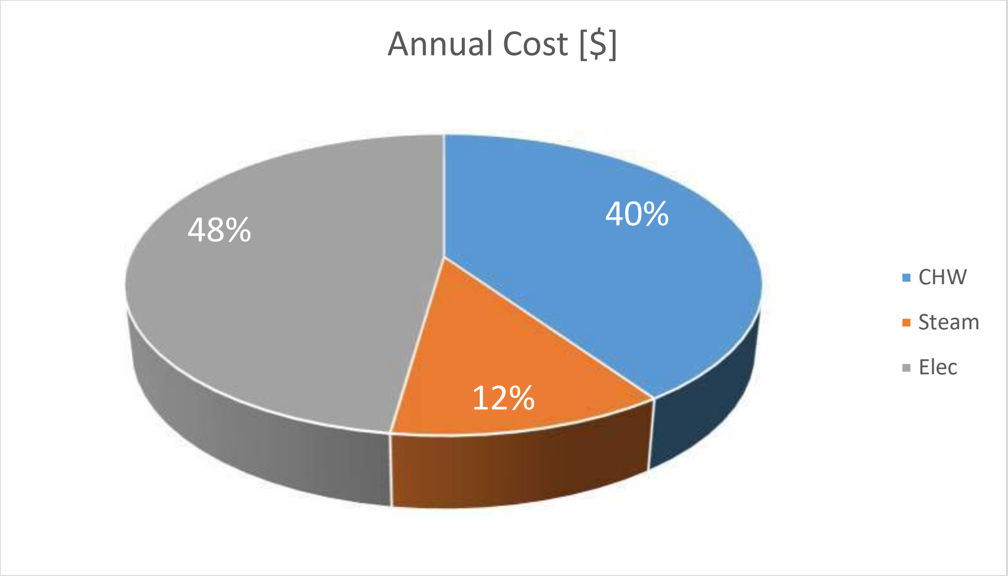


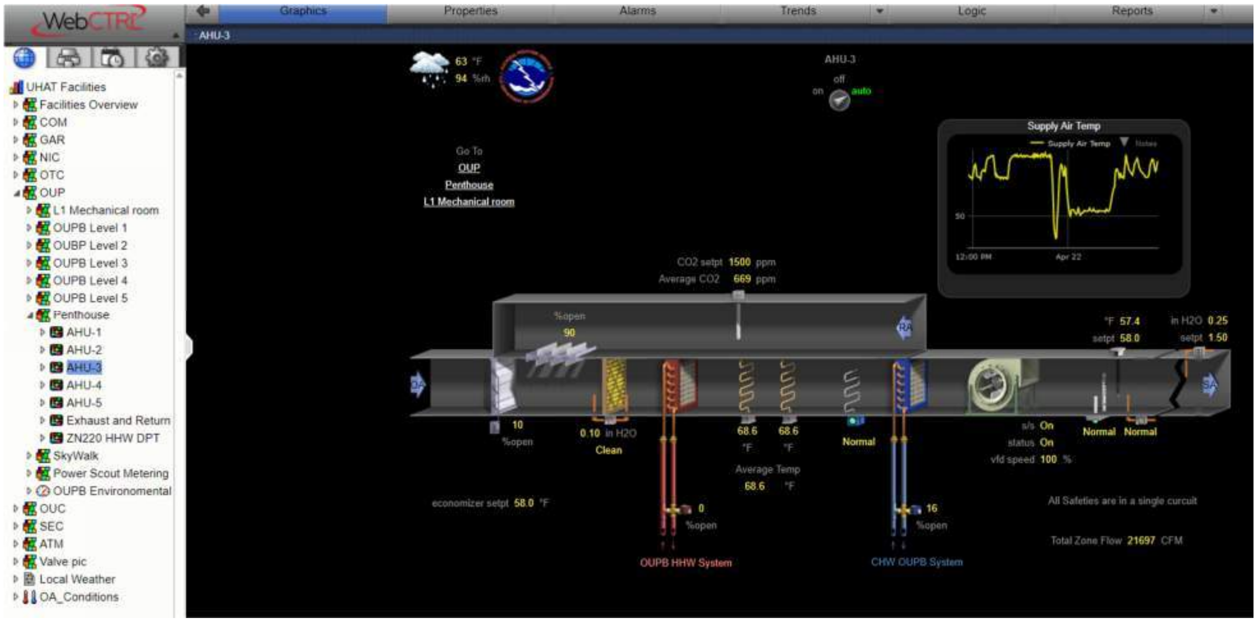
Chart 2 – Energy Cost Ratio



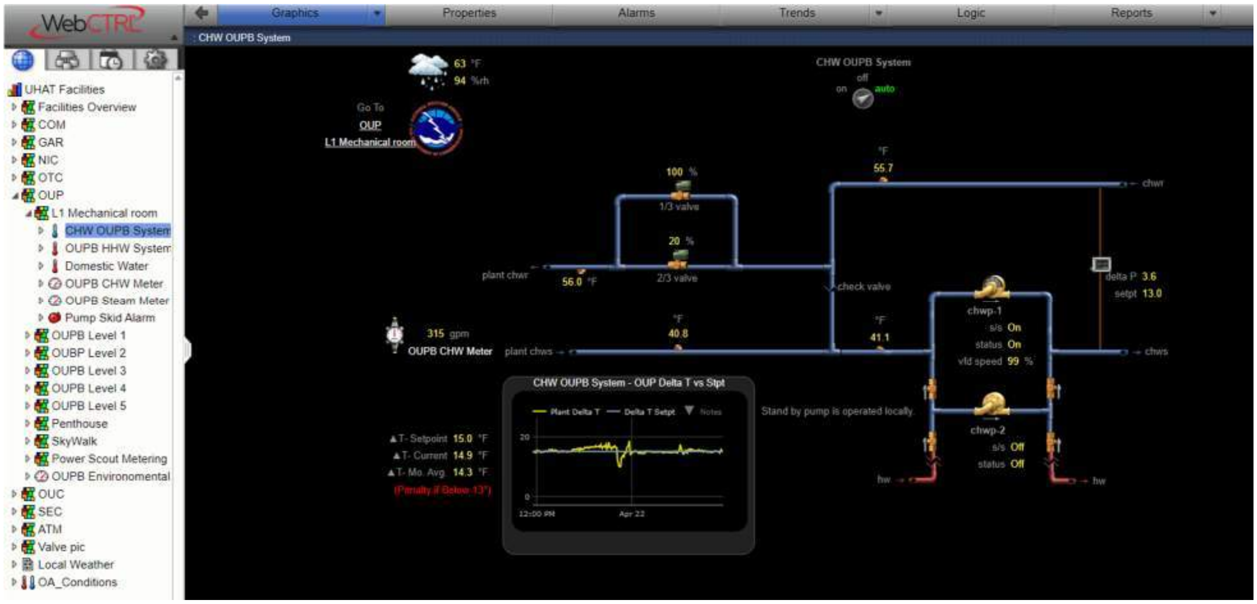
HVAC SYSTEM OBSERVATIONS

During the investigation and pre-task planning portion of this project, Terracon observed a variety of issues that prompted Terracon to investigate further:

The *ALC WebCTRL* EMCS indicated that AHU-3, AHU-4, and AHU-5 were all having issues maintaining static pressure setpoints (1.5” w.g.) when the fan speed of each of the three supply air fans were operating at 100%. The total zone flow monitoring point on the EMCS at the time of observation showed approximately 22,000 CFM of air flow being read by all the VAV terminal units. AHU-3, AHU-4, and AHU-5 are all designed for a maximum air flow of 40,000 CFM. With such a discrepancy between the design requirements and what was read by the EMCS, Terracon had independent air flow measurements recorded by a test, adjustment, and balancing (TAB) company to verify the actual performance of all AHU’s in the building.



Terracon also observed conditions where the chilled water meter readings did not appear to be reasonable based on the chilled water pump speed and valve positions (percent open) of the 1/3 and 2/3 valves.



The EMCS indicated that the two return fans and four exhaust fans for the building were created a negative building air pressure condition. Information about the performance of the return fans was not indicated on the design drawings provided. A negative building air pressure effect, if significant enough, can cause unconditioned air to infiltrate the building envelope and place unnecessary heating and cooling loads on the building HVAC systems.

Exhaust and Return Fans

63 °F
94 %rh

Exhaust Fans
Occupied until 10:00 PM

Exhaust Fan 1
Cmd On

Exhaust Fan 2
Cmd On

Exhaust Fan 3
Cmd On

Speed limited to 85%
Remove text when fan is repaired
South RF-2
s/s On
status On
vfd speed 85 %

North RF-1
s/s On
status On
vfd speed 100 %

RF-2 Chase static pressure
actual -0.95 in H2O
setpoint -0.01 in H2O

Penthouse Static Pressure
actual 0.00 in H2O
setpoint 0.00 °F

Fans will control to SP if Penthouse falls negative

RF-1 Chase static pressure
actual -0.50 in H2O
setpoint -0.01 in H2O

During the site visits, the Terracon team made the following observations:

1. Terracon observed that the south return air fan is out of balance with the supply fans for the air handling units and is manually set to only operate at 87% of maximum speed.
2. The two return air fans appear to be operating uncontrolled and are in need of air balancing to properly operate with the supply fans of the AHUs.
3. Terracon observed both AHU #3 and AHU #5 have variable frequency drives (VFD's) that are not functioning and in need of repair or replacement.
4. The VFD for the chilled water pumps is not properly functioning and in need of repair or replacement.
5. The relief dampers in the penthouse mechanical room have been damaged or removed and in need of repair or replacement.
6. CO2 sensors responsible for demand ventilation control (outside air requirements) for each AHU are in need of calibration or replacement. There are five sensors, one for each floor, installed in the south return air chase. In addition, relocation of the CO2 sensors near the return dampers for the AHUs may provide benefit as well.
7. The two chilled water valves (1/3 flow & 2/3 flow) configuration for each AHU is in need of an updated sequence of operation adjustment. No known sequence is being utilized.
8. VAV terminal units associated with AHU #1 may not be properly calibrated for air flow or supply air may be getting diverted to areas of the building where air flow is not being measured, such as the plenum above the drop ceiling of the first floor. The AHU appears to indicate that less air is available to the VAV terminal units.
9. UHAT meters (only used to monitor chilled water and steam provided by OUHSC, not the utility meters) are in need of calibration to provide accurate readings.
10. A variety of the EMCS hardware (controllers, sensors, etc.) upgrades and associated software updates may be needed based on the age of the equipment.

BUILDING INFRASTRUCTURE TESTING

Terracon investigated the discrepancy between the design requirements in the drawings provided and the EMCS readings with an independent air flow instrument. The AHU air flow parameters at AHU-1, AHU-2, AHU-3, AHU-4, and AHU-5 were all measured in a traverse pattern grid that is in accordance with industry TAB standards for HVAC systems.

In addition to supply air flow measurements, Terracon also verified the following:

1. Supply air temperature being distributed to the VAV terminal boxes
2. Entering and leaving water temperatures for each hot water and chilled water coil
3. Entering and leaving water pressures for each hot water and chilled water coil
4. Entering and leaving air pressure for each hot water and chilled water coil section
5. External air pressure (suction and discharge) for each AHU supply fan.

All measurements were taken independent to the EMCS to verify accuracy of the parameters being read by the *ALC webCTRL* system. The accuracy of the measurements are necessary to validate the HVAC systems are meeting the equipment's design performance requirements.

The following information was measured:

AHU#1

Total Supply Air [CFM]	Supply Air Temperature [ºF]	Entering Heating Coil Temperature [ºF]	Leaving Heating Coil Temperature [ºF]	Entering Cooling Coil Temperature [ºF]	Leaving Cooling Coil Temperature [ºF]
44,539	61.6	113.3	97.7	-	57.5

Heating Coil Delta Air Pressure [in H_2O]	Cooling Coil Delta Air Pressure [in H_2O]	Heating Coil Delta Water Pressure [psig]	Cooling Coil Delta Water Pressure [psig]	Total Fan Static Pressure [in H_2O]
1.02*	1.02*	0.4	0.33^	2.91

AHU#2

Total Supply Air [CFM]	Supply Air Temperature [ºF]	Entering Heating Coil Temperature [ºF]	Leaving Heating Coil Temperature [ºF]	Entering Cooling Coil Temperature [ºF]	Leaving Cooling Coil Temperature [ºF]
35,229	69.3	-	-	41.0	51.7

Heating Coil Delta Air Pressure [in H_2O]	Cooling Coil Delta Air Pressure [in H_2O]	Heating Coil Delta Water Pressure [psig]	Cooling Coil Delta Water Pressure [psig]	Total Fan Static Pressure [in H_2O]
0.81*	0.81*	-	2.0	2.60

AHU#3

Total Supply Air [CFM]	Supply Air Temperature [ºF]	Entering Heating Coil Temperature [ºF]	Leaving Heating Coil Temperature [ºF]	Entering Cooling Coil Temperature [ºF]	Leaving Cooling Coil Temperature [ºF]
37,804	58.4	114.6	105.6	41.3	57.4

Heating Coil Delta Air Pressure [in H_2O]	Cooling Coil Delta Air Pressure [in H_2O]	Heating Coil Delta Water Pressure [psig]	Cooling Coil Delta Water Pressure [psig]	Total Fan Static Pressure [in H_2O]
1.16*	1.16*	1.2	1.6	2.87

AHU#4

Total Supply Air [CFM]	Supply Air Temperature [ºF]	Entering Heating Coil Temperature [ºF]	Leaving Heating Coil Temperature [ºF]	Entering Cooling Coil Temperature [ºF]	Leaving Cooling Coil Temperature [ºF]
37,513	61.9	116.9	95.5	48.1	57.0

Heating Coil Delta Air Pressure [in H_2O]	Cooling Coil Delta Air Pressure [in H_2O]	Heating Coil Delta Water Pressure [psig]	Cooling Coil Delta Water Pressure [psig]	Total Fan Static Pressure [in H_2O]
0.96*	0.96*	0.1	1.8	2.05

AHU#5

Total Supply Air [CFM]	Supply Air Temperature [ºF]	Entering Heating Coil Temperature [ºF]	Leaving Heating Coil Temperature [ºF]	Entering Cooling Coil Temperature [ºF]	Leaving Cooling Coil Temperature [ºF]
39,814	73.0	116.8	107.6	40.7	47.7

Heating Coil Delta Air Pressure [in H_2O]	Cooling Coil Delta Air Pressure [in H_2O]	Heating Coil Delta Water Pressure [psig]	Cooling Coil Delta Water Pressure [psig]	Total Fan Static Pressure [in H_2O]
1.02*	1.02*	1.3	1.5	2.51

* = Pressure Drop is across both coils because access between hot water and chilled water coils was difficult for measurements.

^ = Pressure Drop is across autoflow valve because no other testing ports were identified.

During testing, the Terracon team made the following observations:

1. The hot water valve associated with AHU #2 was not properly functioning and prevented measurements from being taken.
2. One of the building chilled water pumps was not operating properly due to a faulty VFD.

ENERGY CONSERVATION OPPORTUNITIES (ECOs) AND RECOMMENDATIONS

In order to effectively evaluate existing systems and deficiencies, and to provide recommended measures, various methods and actions were considered. Considerations include:

- Analysis of existing construction drawings and as-built documentation.
- Analysis of utility bills.
- Conversations with the UHAT personnel regarding HVAC system configuration, controls, and existing trouble spots.
- Collection of information and data from *ALC webCTRL* interface to gather set points, operating conditions, identify anomalies, etc.
- Site surveys and investigations.
- Profiled mechanical equipment (e.g. pumps, chillers, air handling units) affected by the ECO's so that accurate calculations of savings could be produced.
- For weather dependent systems, bin temperature analysis is to be used to calculate baseline and post-installation consumption.
- For weather independent systems, time-of-use methods were used to calculate baseline and post-installation consumption.

Energy conservation opportunities (ECOs) have been listed on the basis of cost, potential benefit and, most importantly, Owner approval.

ECO Master List

Table 3: Master List

Measure #	Equipment or System	Description of Finding	Recommended Improvement
M1.1	Central Plant	Chilled water pump has a faulty VFD. Faulty VFD prevents the chilled water system from operating at speed associated with building load.	Replace existing faulty VFD with new ABB VFD. Update: VFD was replaced on 08/12/20 with Yaskawa VFD.
M1.2	Central Plant	Chilled water meter on the EMCS appears to be reading lower than design (310 GPM at 100% flow with only 1/3 valve operating).	Install new calibrated electromagnetic water meter and have chilled water pumps adjusted and balanced to design parameters.
M2.1	Return Air	Relief dampers for the return air fan system in the in the penthouse appear to be damaged and removed in some areas. When the return air fans are shut down or running at a low enough speed, this provides an opportunity for unconditioned air to infiltrate the penthouse and cause additional heating and cooling loads to be placed on the AHUs that are not necessary.	Repair and replace missing dampers with the same style and type. Update: Repairs are scheduled for completion by 09/01/20.
M2.2	Return Air	Differential pressure sensors for the two return air fans are older and may not be functioning properly. Without a properly functioning sensor, the VFDs for each fan will not have the means to properly modulate fan speed.	Replace differential pressure sensors with new sensors. Also, consider relocating existing sensor on the south end of the building if shaft door to access return air fan is left open for extended periods.
M2.3	Return Air	VFDs for both return air fans appear to be set at a fixed speed and operating without any automation.	Replace existing faulty VFDs with new ABB VFD for each return air fan, program, schedule, balance, and commission return fans to operate with differential pressure sensors. Note that

Measure #	Equipment or System	Description of Finding	Recommended Improvement
			relief dampers in the penthouse should be repaired prior to commissioning.
M3.1	AHU #3	VFD for supply air fan does not appear to modulate speed. ONECall made Terracon aware than this VFD was scheduled for replacement soon.	Replace existing faulty VFD with new ABB VFD. Update: VFD was replaced on 08/14/20 with Yaskawa VFD.
M3.2	AHU #3	CO2 sensor is beyond expected useful service life. CO2 sensors are notorious for calibration issues.	Replace or recalibrate existing CO2 sensor. In addition, CO2 sensor should be relocated closer to the AHU return air damper location for more precise operation of the demand ventilation control sequence.
M3.3	AHU #3	There does not appear a sequence of operation to determine how 1/3 and 2/3 chilled water valves for AHU are to operate.	Update AHU sequence of operation to operate 1/3 valve during low load conditions (winter) and 2/3 valve during moderate load conditions (spring and fall). Both valves are currently operating together to the best of Terracon's knowledge, which is only ideal during higher load conditions (summer).
M4.1	AHU #5	VFD for supply air fan does not appear to modulate speed. ONECall made Terracon aware than this VFD was scheduled for replacement soon.	Replace existing faulty VFD with new ABB VFD. Update: VFD was replaced on 08/14/20 with Yaskawa VFD.
M4.2	AHU #5	CO2 sensor is beyond expected useful service life. CO2 sensors are notorious for calibration issues.	Replace or recalibrate existing CO2 sensor. In addition, CO2 sensor should be relocated closer to the AHU return air damper location for more precise operation of the demand ventilation control sequence.
M4.3	AHU #5	There does not appear a sequence of operation to determine how 1/3 and 2/3 chilled water valves for AHU are to operate.	Update AHU sequence of operation to operate 1/3 valve during low load conditions (winter) and 2/3 valve during moderate load conditions (spring and fall). Both valves

Measure #	Equipment or System	Description of Finding	Recommended Improvement
			are currently operating together to the best of Terracon's knowledge, which is only ideal during higher load conditions (summer).
M5.1	AHU #1	CO2 sensor is beyond expected useful service life. CO2 sensors are notorious for calibration issues.	Replace or recalibrate existing CO2 sensor. In addition, CO2 sensor should be relocated closer to the AHU return air damper location for more precise operation of the demand ventilation control sequence.
M5.2	AHU #1	There does not appear a sequence of operation to determine how 1/3 and 2/3 chilled water valves for AHU are to operate.	Update AHU sequence of operation to operate 1/3 valve during low load conditions (winter) and 2/3 valve during moderate load conditions (spring and fall). Both valves are currently operating together to the best of Terracon's knowledge, which is only ideal during higher load conditions (summer).
M6.1	AHU #2	CO2 sensor is beyond expected useful service life. CO2 sensors are notorious for calibration issues.	Replace or recalibrate existing CO2 sensor. In addition, CO2 sensor should be relocated closer to the AHU return air damper location for more precise operation of the demand ventilation control sequence.
M6.2	AHU #2	There does not appear a sequence of operation to determine how 1/3 and 2/3 chilled water valves for AHU are to operate.	Update AHU sequence of operation to operate 1/3 valve during low load conditions (winter) and 2/3 valve during moderate load conditions (spring and fall). Both valves are currently operating together to the best of Terracon's knowledge, which is only ideal during higher load conditions (summer).

Measure #	Equipment or System	Description of Finding	Recommended Improvement
M6.3	AHU #2	Hot water valve does not appear to be operating properly and prevented hot water coil measurements during testing.	Replace existing hot water valve assembly with new hot water valve assembly. Select new valve Cv based on design conditions.
M7.1	AHU #2A	CO2 sensor is beyond expected useful service life. CO2 sensors are notorious for calibration issues.	Replace or recalibrate existing CO2 sensor. In addition, CO2 sensor should be relocated closer to the AHU return air damper location for more precise operation of the demand ventilation control sequence.
M7.2	AHU #2A	There does not appear a sequence of operation to determine how 1/3 and 2/3 chilled water valves for AHU are to operate.	Update AHU sequence of operation to operate 1/3 valve during low load conditions (winter) and 2/3 valve during moderate load conditions (spring and fall). Both valves are currently operating together to the best of Terracon's knowledge, which is only ideal during higher load conditions (summer).
M8.1	EMCS – Penthouse	Many of the existing controllers, sensors (temperature and pressure sensors), and other end devices (current transducers, relays, etc.) that appear to be properly functioning now are near or beyond expected useful service life.	Replace existing retrofitted controllers with upgraded controllers for all AHUs, EFs, and RFs. While replacing controllers, replace sensors and other end devices that are near or beyond expected useful service life.
M8.2	EMCS – 1st Floor	During testing, the total zone flow indicated on the EMCS was significantly different than the total supply flow measured for AHU #1. It is possible Many of the existing sensors (temperature sensors) and other end devices (valve actuators, relays, etc.) that appear to be properly functioning now are near or beyond expected useful service life.	Recalibrate flow sensors (K-values), upgrade temperature sensors and other end devices with a phased approach (floor-by-floor).
M8.3	EMCS – 2nd Floor	During testing, the total zone flow indicated on the EMCS was significantly different than the total supply flow measured for AHU #2.	Recalibrate flow sensors (K-values), upgrade temperature sensors and other end devices with a phased approach (floor-

Measure #	Equipment or System	Description of Finding	Recommended Improvement
		It is possible Many of the existing sensors (temperature sensors) and other end devices (valve actuators, relays, etc.) that appear to be properly functioning now are near or beyond expected useful service life.	by-floor).
M8.4	EMCS – 3rd Floor	During testing, the total zone flow indicated on the EMCS was significantly different than the total supply flow measured for AHU #3. It is possible Many of the existing sensors (temperature sensors) and other end devices (valve actuators, relays, etc.) that appear to be properly functioning now are near or beyond expected useful service life.	Recalibrate flow sensors (K-values), upgrade temperature sensors and other end devices with a phased approach (floor-by-floor).
M8.5	EMCS – 4th Floor	During testing, the total zone flow indicated on the EMCS was significantly different than the total supply flow measured for AHU #4. It is possible Many of the existing sensors (temperature sensors) and other end devices (valve actuators, relays, etc.) that appear to be properly functioning now are near or beyond expected useful service life.	Recalibrate flow sensors (K-values), upgrade temperature sensors and other end devices with a phased approach (floor-by-floor).
M8.6	EMCS – 5th Floor	During testing, the total zone flow indicated on the EMCS was significantly different than the total supply flow measured for AHU #5. It is possible Many of the existing sensors (temperature sensors) and other end devices (valve actuators, relays, etc.) that appear to be properly functioning now are near or beyond expected useful service life.	Recalibrate flow sensors (K-values), upgrade temperature sensors and other end devices with a phased approach (floor-by-floor).

LIMITATIONS

The field observations, tests, findings, and recommendations presented in this report are based upon the information provided to Terracon by the client, UHAT, and observations and field notes collected at the time of our site visits. While additional conditions may exist that could alter our recommendations, we feel that reasonable means have been made to fairly and accurately evaluate the existing conditions of these systems. This report is limited to Terracon's observations of the interior and exterior of the facility. Some of the observations were limited due to obstructions and access to areas of the systems and facility. Although our observations were made with normal care and diligence, it is likely that not all existing conditions were documented. The general intent was to identify representative conditions and provide recommendations based on general findings.

This report has been prepared for the exclusive use of UHAT for specific application to the project discussed and has been prepared in accordance with generally accepted engineering practices using the standard of care and skill currently exercised by professional engineers practicing in this area, for a project of similar scope and nature. No warranties, either expressed or implied, are intended or made. In the event that information described in this document which was provided by others is incorrect, or if additional information becomes available, the recommendations contained in this report shall not be considered valid unless Terracon reviews the information and either verifies or modifies the recommendations of this report in writing.

APPENDIX A
Photographs

Photo #1 AHU-1

Photo #2 AHU-2

Photo #3 AHU-3

Photo #4 AHU-4

Photo #5 AHU-5

Photo #6 Typical return air damper with motorized damper control.

Photo#7 Typical split return air actuator below with outside damper actuator above

Photo #8 Heat exchanger for steam to hot water conversion.

Photo #9 Typical 3-way hot water valve.

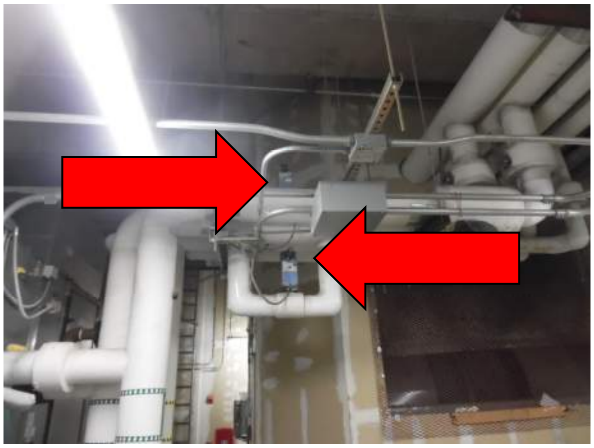


Photo #10 Split chilled water valves and actuators with 1/3 and 2/3 service capacities.

Photo #11 Dual chilled water pumps.

Photo #12 Defective chilled water VFD

Photo #13 Return air fans 1 of 2.

Photo #14 Common return air chase for all five floors.

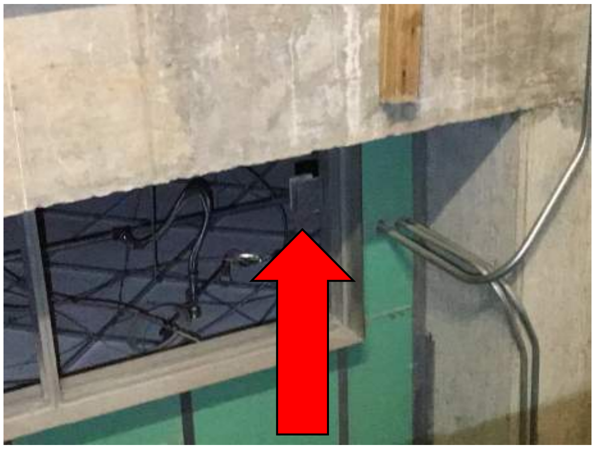


Photo #15 CO2 sensors are in the return air duct at each floor entering the chase.

Photo #16 The gravity relief dampers need repair and or replacement.

Photo #17 Typical retrofitted ALC controller for AHU.

Photo #18 Retrofitted ALC controller for RFs and EFs.

APPENDIX B
Test and Balancing Report

es2 engineered systems & energy solutions, inc.

13401 N. Santa Fe Avenue
Oklahoma City, Oklahoma 73114
Phone: (405) 528-4500

CERTIFIED TEST, ADJUST, AND BALANCE REPORT

Date: May 13, 2020

Project: OUPB Cx Assessment

Address: Oklahoma City

ES2 project number 01-20-405

The data presented in this report is an exact record of the system performance and was obtained in accordance with NEBB standard procedures. Any variances from design quantities, which exceed NEBB tolerances, are noted throughout this report.

The air distribution systems and hydronic distribution systems have been tested and balanced and final adjustments have been made in accordance with NEBB "Procedural Standards for Testing-Adjusting-Balancing of Environmental Systems" and the project specifications.

Submitted and Certified by:

David M. Halcomb

NEBB Certified Test and Balance Supervisor

Engineered Systems & Energy Solutions, Inc.
NEBB Certification Number is: 3426

DAVID M. HALCOMB
CERTIFICATION
3426
Exp. 3/31/22

Non Standard Abbreviations Used for Reporting

CCW	- Counter Clockwise
CD	- Ceiling Diffuser
CW	- Clockwise
DD	- Direct Drive
EG	- Exhaust Grille
INA	- Inaccessible
LD	- Linear Diffuser
NA	- Not Applicable
NG	- Not Given
NL	- Not Listed
NM	- Not Measured
NS	- Not Specified
NTS	- No Test Site
NV	- Not Visible
OA	- Outside Air
OTA	- Open To Atmosphere
PD	- Pressure Drop
RG	- Return Grille
SD	- Supply Diffuser
SP	- Static Pressure
SWD	- Sidewall Diffuser
TA	- Throw Away

Table of Contents

Job Name: OUPB Cx Assessment

Instruments

Job Name: OUPB Cx Assessment

Category	Instrument	Mfr.	Mdl #	Serial #	Last Cal'd	Next Due
Air	Air Data Multimeter	Shortridge	ADM-860	M93293	7/29/2019	7/29/2020
Electrical	Amp, volt meter True RMS	UEI	DL389	180601421	9/10/2019	9/10/2020
Tachometer	Digital Tachometer	Extech	461920	150103258	9/10/2019	9/10/2020
Temperature	Module / Probe	Evergreen Telemetry	RM-T-1 / PR-T-2	2000159 / 1900233	3/9/2020	3/9/2021
Water	Water Meter	Shortridge	HDM 250	W14080	4/14/2020	4/14/2021

AIR APPARATUS TEST SHEET

Job Name: OUPB Cx Assessment
Tested By: GLASS **Date:** 5/12/2020

DESIGN DATA :

Manufacturer =		**Model No. =**	
Type =		**Serial No. =**	
Outside Air cfm =			
Total Scheduled cfm =	50,000	**Grille Design Schedule cfm =**	
Fan rpm =			
Total Static Pressure =		**External Static Pressure =**	
Fan Rotation =			

MOTOR DESIGN DATA

Horsepower =	**Voltage =**	**Phase =**	**Rpm =**

AIR TEST DATA

Total cfm by Traverse Readings =	44,539	**Total cfm by Grille Readings =**	NM
Outside Air =	NM	**Return Air =**	NM

TEMPERATURE TEST DATA

Outside Air Temperature =	NM	**Supply Air Temp Sensor =**	61.6
Mixed Air Temperature =	NM	**Supply Air Temp Measured =**	61.6

PRESSURE TEST DATA

Fan Suction Static Pressure =		-1.45	
Fan Discharge Static Pressure =		1.46	
Total Static Pressure =			2.91
External Suction Static Pressure =		OPEN	
External Discharge Static Pressure =		1.46	
External Static Pressure =			1.46
Cooling Coil ΔS.P. =	1.02*	**Heating Coil ΔS.P. =**	1.02*
Pre Filters ΔS.P. =	0.10	**Final Filters ΔS.P. =**	NA

MOTOR TEST DATA

Motor Manufacturer / Frame =					
HP =	**Volts/Ph/Hertz =**	**Act. Voltage =**			
Full Load Amps =		**Act. Amps =**			
Service Factor =					
Motor Design rpm =		**Act motor rpm =**			

FAN TEST DATA

Motor Sheave Diameter =		**Motor Sheave Bore =**	
Fan Sheave Diameter =		**Fan Sheave Bore =**	
Adjustable Sheave Dia. =		**Centerline Distance =**	
Fan rpm =		**Fan Rotation =**	
Frequency Hz=	60		
Belts =			
Pre Filters =			
Final Filters =			

Comments: *PRESSURE DROP IS ACROSS BOTH COILS TOGETHER.

ROUND DUCT TRAVERSE REPORT
AHU-1

Job Name: OUPB Cx Assessment
Tested By: GLASS **Date:** 5/12/2020

DUCT		REQUIRED		ACTUAL	
℄ S.P. =	1.08"	FPM(M/S)=	2548	FPM(M/S)=	2269
AIR TEMP=	65	SCFM(SLS/S)=	- -	SCFM(SLS/S)=	- -
SIZE=	60	CFM(L/S)=	50000	CFM(L/S)=	44539
AREA=	19.63 Ft^2				

Distance From Edge	
1.54	2308
4.90	2174
8.79	2254
13.57	2458
20.51	2769
39.49	2637
46.43	2489
51.21	2512
55.10	2594
58.46	2739

Distance From Edge	1.54	4.90	8.79	13.57	20.51	39.49	46.43	51.21	55.10	58.46
	0	432	1681	2640	2889	2648	2560	2567	2594	2433

Vert. Subtotal	24934
Horiz. Subtotal	20444
Total	45378
No. of Points	20
Average	2269

Comments:

AIR APPARATUS TEST SHEET

Job Name: OUPB Cx Assessment
Tested By: GLASS **Date:** 5/13/2020

DESIGN DATA :

Manufacturer =		**Model No. =**	
Type =		**Serial No. =**	
Outside Air cfm =			
Total Scheduled cfm =	40,000	**Grille Design Schedule cfm =**	
Fan rpm =			
Total Static Pressure =		**External Static Pressure =**	
Fan Rotation =			

MOTOR DESIGN DATA

Horsepower =	**Voltage =**	**Phase =**	**Rpm =**

AIR TEST DATA

Total cfm by Traverse Readings =	35,229	**Total cfm by Grille Readings =**	NM
Outside Air =	NM	**Return Air =**	NM

TEMPERATURE TEST DATA

Outside Air Temperature =	NM	**Supply Air Temp Sensor =**	69.3
Mixed Air Temperature =	NM	**Supply Air Temp Measured =**	69.3

PRESSURE TEST DATA

Fan Suction Static Pressure =		-1.23	
Fan Discharge Static Pressure =		1.37	
	Total Static Pressure =		2.60
External Suction Static Pressure =		OPEN	
External Discharge Static Pressure =		1.37	
	External Static Pressure =		1.37
Cooling Coil ΔS.P. =	0.81*	**Heating Coil ΔS.P. =**	.81*
Pre Filters ΔS.P. =	0.11	**Final Filters ΔS.P. =**	NA

MOTOR TEST DATA

Motor Manufacturer / Frame =					
HP =	**Volts/Ph/Hertz =**	**Act. Voltage =**			
Full Load Amps =		**Act. Amps =**			
Service Factor =					
Motor Design rpm =		**Act motor rpm =**			

FAN TEST DATA

Motor Sheave Diameter =	**Motor Sheave Bore =**
Fan Sheave Diameter =	**Fan Sheave Bore =**
Adjustable Sheave Dia. =	**Centerline Distance =**
Fan rpm =	**Fan Rotation =**
Frequency Hz=	
Belts =	
Pre Filters =	
Final Filters =	

Comments: *PRESSURE DROP IS ACROSS BOTH COILS TOGETHER.

ROUND DUCT TRAVERSE REPORT
AHU-2

Job Name: OUPB Cx Assessment
Tested By: GLASS
Date: 5/13/2020

DUCT		REQUIRED		ACTUAL	
℄ S.P. =	1.16"	FPM(M/S)=	2714	FPM(M/S)=	2390
AIR TEMP=	69.2	SCFM(SLS/S)=	- -	SCFM(SLS/S)=	- -
SIZE=	52	CFM(L/S)=	40000	CFM(L/S)=	35229
AREA=	14.74 Ft^2				

Distance From Edge		
1.34	2066	2736
4.25	2251	2915
7.62	2194	2862
11.76	1862	2826
17.78	1991	2582
34.22	2594	2068
40.24	2694	2019
44.38	2786	1911
47.75	2774	1892
50.66	2752	2024

Vert. Subtotal	23964
Horiz. Subtotal	23835
Total	47799
No. of Points	20
Average	2390

Comments:

AIR APPARATUS TEST SHEET

Job Name: OUPB Cx Assessment
Tested By: GLASS **Date:** 5/12/2020

DESIGN DATA :

Manufacturer =		**Model No. =**	
Type =		**Serial No. =**	
Outside Air cfm =			
Total Scheduled cfm =	40,000	**Grille Design Schedule cfm =**	
Fan rpm =			
Total Static Pressure =		**External Static Pressure =**	
Fan Rotation =			

MOTOR DESIGN DATA

Horsepower =	**Voltage =**	**Phase =**	**Rpm =**

AIR TEST DATA

Total cfm by Traverse Readings =	37,804	**Total cfm by Grille Readings =**	NM
Outside Air =	NM	**Return Air =**	NM

TEMPERATURE TEST DATA

Outside Air Temperature =		**Supply Air Temp Sensor =**	57.6
Mixed Air Temperature =		**Supply Air Temp Measured =**	58.4

PRESSURE TEST DATA

Fan Suction Static Pressure =		-1.52	
Fan Discharge Static Pressure =		1.35	
Total Static Pressure =			2.87
External Suction Static Pressure =		OPEN	
External Discharge Static Pressure =		1.35	
External Static Pressure =			1.35
Cooling Coil ΔS.P. =	1.16*	**Heating Coil ΔS.P. =**	1.16*
Pre Filters ΔS.P. =	0.03	**Final Filters ΔS.P. =**	NM

MOTOR TEST DATA

Motor Manufacturer / Frame =					
HP =	**Volts/Ph/Hertz =**	**Act. Voltage =**			
Full Load Amps =		**Act. Amps =**			
Service Factor =					
Motor Design rpm =		**Act motor rpm =**			

FAN TEST DATA

Motor Sheave Diameter =	**Motor Sheave Bore =**
Fan Sheave Diameter =	**Fan Sheave Bore =**
Adjustable Sheave Dia. =	**Centerline Distance =**
Fan rpm =	**Fan Rotation =**
Frequency Hz=	
Belts =	
Pre Filters =	
Final Filters =	

Comments: *PRESSURE DROP IS ACROSS BOTH COILS TOGETHER.

ROUND DUCT TRAVERSE REPORT
AHU-3

Job Name: OUPB Cx Assessment
Tested By: GLASS
Date: 5/12/2020

DUCT		REQUIRED		ACTUAL	
℄ S.P. =	.85"	FPM(M/S)=	2714	FPM(M/S)=	2565
AIR TEMP=	58.4	SCFM(SLS/S)=	- -	SCFM(SLS/S)=	- -
SIZE=	52	CFM(L/S)=	40000	CFM(L/S)=	37804
AREA=	14.74 Ft^2				

Distance From Edge	
1.34	3300
4.25	3340
7.62	3042
11.76	3206
17.78	3120
34.22	2539
40.24	2270
44.38	2319
47.75	2568
50.66	2490

Distance From Edge	1.34	4.25	7.62	11.76	17.78	34.22	40.24	44.38	47.75	50.66
	1130	1326	1599	1621	1941	3119	2811	3177	3222	3153

Vert. Subtotal	28194
Horiz. Subtotal	23099
Total	51293
No. of Points	20
Average	2565

Comments:

AIR APPARATUS TEST SHEET

Job Name: OUPB Cx Assessment
Tested By: GLASS **Date:** 5/13/2020

DESIGN DATA :

Manufacturer =		**Model No. =**	
Type =		**Serial No. =**	
Outside Air cfm =			
Total Scheduled cfm =	40,000	**Grille Design Schedule cfm =**	
Fan rpm =			
Total Static Pressure =		**External Static Pressure =**	
Fan Rotation =			

MOTOR DESIGN DATA

Horsepower =	**Voltage =**	**Phase =**	**Rpm =**

AIR TEST DATA

Total cfm by Traverse Readings =	37,513	**Total cfm by Grille Readings =**	NM
Outside Air =	NM	**Return Air =**	NM

TEMPERATURE TEST DATA

Outside Air Temperature =	NM	**Supply Air Temp Sensor =**	62.9
Mixed Air Temperature =	NM	**Supply Air Temp Measured =**	61.9

PRESSURE TEST DATA

Fan Suction Static Pressure =		-1.28	
Fan Discharge Static Pressure =		0.77	
	Total Static Pressure =		2.05
External Suction Static Pressure =		OPEN	
External Discharge Static Pressure =		0.77	
	External Static Pressure =		0.77
Cooling Coil ΔS.P. =	0.96*	**Heating Coil ΔS.P. =**	.96*
Pre Filters ΔS.P. =	0.07	**Final Filters ΔS.P. =**	NA

MOTOR TEST DATA

Motor Manufacturer / Frame =					
HP =	**Volts/Ph/Hertz =**	**Act. Voltage =**			
Full Load Amps =		**Act. Amps =**			
Service Factor =					
Motor Design rpm =		**Act motor rpm =**			

FAN TEST DATA

Motor Sheave Diameter =	**Motor Sheave Bore =**
Fan Sheave Diameter =	**Fan Sheave Bore =**
Adjustable Sheave Dia. =	**Centerline Distance =**
Fan rpm =	**Fan Rotation =**
Frequency Hz=	
Belts =	
Pre Filters =	
Final Filters =	

Comments: *PRESSURE DROP IS ACROSS BOTH COILS TOGETHER.

ROUND DUCT TRAVERSE REPORT
AHU-4 (1 OF 2)

Job Name: OUPB Cx Assessment
Tested By: GLASS
Date: 5/13/2020

DUCT		REQUIRED		ACTUAL	
℄ S.P. =	0.83	FPM(M/S)=	2293	FPM(M/S)=	2320
AIR TEMP=	61.9	SCFM(SLS/S)=	- -	SCFM(SLS/S)=	- -
SIZE=	40	CFM(L/S)=	20000	CFM(L/S)=	20230
AREA=	8.72 Ft^2				

Distance From Edge	
1.03	2073
3.27	2580
5.86	2401
9.05	2458
13.68	2300
26.32	2458
30.95	2493
34.14	2494
36.73	2458
38.97	2333

Distance From Edge	1.03	3.27	5.86	9.05	13.68	26.32	30.95	34.14	36.73	38.97
	1642	1823	1914	1762	2058	2532	2607	2690	2756	2562

Vert. Subtotal	24048
Horiz. Subtotal	22346
Total	46394
No. of Points	20
Average	2320

Comments:

ROUND DUCT TRAVERSE REPORT
AHU-4 (2 OF 2)

Job Name: OUPB Cx Assessment
Tested By: GLASS
Date: 5/13/2020

DUCT		REQUIRED		ACTUAL	
℄ S.P. =	0.41	FPM(M/S)=	2293	FPM(M/S)=	1982
AIR TEMP=	61.9	SCFM(SLS/S)=	- -	SCFM(SLS/S)=	- -
SIZE=	40	CFM(L/S)=	20000	CFM(L/S)=	17283
AREA=	8.72 Ft^2				

Distance From Edge	
1.03	1558
3.27	1825
5.86	1886
9.05	2333
13.68	2643
26.32	2003
30.95	1939
34.14	1820
36.73	1922
38.97	1893

Distance From Edge	1.03	3.27	5.86	9.05	13.68	26.32	30.95	34.14	36.73	38.97
	1709	1841	2035	2136	2056	2886	2509	2441	1066	1140

Vert. Subtotal	19822
Horiz. Subtotal	19819
Total	39641
No. of Points	20
Average	1982

Comments:

AIR APPARATUS TEST SHEET

Job Name: OUPB Cx Assessment
Tested By: GLASS **Date:** 5/13/2020

DESIGN DATA :

Manufacturer =		**Model No. =**	
Type =		**Serial No. =**	
Outside Air cfm =			
Total Scheduled cfm =	40,000	**Grille Design Schedule cfm =**	
Fan rpm =			
Total Static Pressure =		**External Static Pressure =**	
Fan Rotation =			

MOTOR DESIGN DATA

Horsepower =	**Voltage =**	**Phase =**	**Rpm =**

AIR TEST DATA

Total cfm by Traverse Readings =	39,814	**Total cfm by Grille Readings =**	NM
Outside Air =	NM	**Return Air =**	NM

TEMPERATURE TEST DATA

Outside Air Temperature =	NM	**Supply Air Temp Sensor =**	72.9
Mixed Air Temperature =	NM	**Supply Air Temp Measured =**	73.0

PRESSURE TEST DATA

Fan Suction Static Pressure =		-1.37	
Fan Discharge Static Pressure =		1.14	
	Total Static Pressure =		2.51
External Suction Static Pressure =		OPEN	
External Discharge Static Pressure =		1.14	
	External Static Pressure =		1.14
Cooling Coil ΔS.P. =	1.02*	**Heating Coil ΔS.P. =**	1.02*
Pre Filters ΔS.P. =	0.08	**Final Filters ΔS.P. =**	NA

MOTOR TEST DATA

Motor Manufacturer / Frame =					
HP =	**Volts/Ph/Hertz =**	**Act. Voltage =**			
Full Load Amps =		**Act. Amps =**			
Service Factor =					
Motor Design rpm =		**Act motor rpm =**			

FAN TEST DATA

Motor Sheave Diameter =	**Motor Sheave Bore =**
Fan Sheave Diameter =	**Fan Sheave Bore =**
Adjustable Sheave Dia. =	**Centerline Distance =**
Fan rpm =	**Fan Rotation =**
Frequency Hz=	
Belts =	
Pre Filters =	
Final Filters =	

Comments: *PRESSURE DROP IS ACROSS BOTH COILS TOGETHER.

RECTANGULAR DUCT TRAVERSE REPORT
AHU-5 (1 OF 2)

Job Name: OUPB Cx Assessment
Tested By: GLASS **Date Tested:** 5/13/2020

DUCT		REQUIRED		ACTUAL	
℄ S.P. =	1.00"	FPM(M/S)=	1,875	FPM(M/S)=	1,868
AIR TEMP=	73.1	SCFM(SLS/S)=	- -	SCFM(SLS/S)=	- -
SIZE=	48 X 32	CFM(L/S)=	20,000	CFM(L/S)=	19,924
AREA=	10.67 Ft.^{2}				

DISTANCE FROM BOTTOM	POSITION	1	2	3	4	5	6	7	8	9	10	11	12	13
2.7	1	1112	1405	1856	1980	2175	2324	2346	2406					
8.0	2	1281	1293	1460	1564	1817	2056	2188	2409					
13.3	3	1162	1202	1294	1348	1668	1901	2096	2406					
18.7	4	1491	1360	1494	1588	1882	2039	2224	2515					
24.0	5	1491	1511	1648	1905	2060	2231	2338	2524					
29.3	6	1083	1735	2120	2190	2364	2434	2428	2255					
	7													
	8													
	9													
	10													
	11													
	12													
	13													
DISTANCE FROM DUCT EDGE		3.0	9.0	15.0	21.0	27.0	33.0	39.0	45.0					
VELOCITY SUB-TOTALS		7620	8506	9872	10575	11966	12985	13620	14515					

Comments:

RECTANGULAR DUCT TRAVERSE REPORT
AHU-5 (2 OF 2)

Job Name: OUPB Cx Assessment
Tested By: GLASS **Date Tested:** 5/13/2020

DUCT		REQUIRED		ACTUAL	
℄ S.P. =	.8"	FPM(M/S)=	1,893	FPM(M/S)=	1,883
AIR TEMP=	73.1	SCFM(SLS/S)=	- -	SCFM(SLS/S)=	- -
SIZE=	58.5 X 26	CFM(L/S)=	20,000	CFM(L/S)=	19,890
AREA=	10.56 Ft.^{2}				

DISTANCE FROM BOTTOM	POSITION	1	2	3	4	5	6	7	8	9	10	11	12	13
2.6	1	1942	1358	1369	1121	828	933	256	338	362	268			
7.8	2	2167	2139	2274	2035	2048	1802	2093	1466	1679	1432			
13.0	3	1888	1806	2206	2235	2200	2427	2527	2436	2727	2835			
18.2	4	1910	1721	1807	2013	2217	2217	2273	2386	2650	2590			
23.4	5	1745	1872	1816	1918	1990	2015	2297	2495	2663	2364			
	6													
	7													
	8													
	9													
	10													
	11													
	12													
	13													
DISTANCE FROM DUCT EDGE		2.9	8.8	14.6	20.5	26.3	32.2	38.0	43.9	49.7	55.6			
VELOCITY SUB-TOTALS		9652	8896	9472	9322	9283	9394	9446	9121	10081	9489			

Comments:

COIL APPARATUS TEST REPORT

Job Name: OUPB Cx Assessment
Tested By: JACQUEMIN **Date:** 6/16/2020

COIL DATA			
System Number	**AHU-1**	**AHU-2**	**AHU-3**
Location	PENTHOUSE	PENTHOUSE	PENTHOUSE
Coil Type	COOLING	COOLING	COOLING
No. Rows-Fins/ In.	NA	NA	NA
Manufacturer	NA	NA	NA
Model Number	NA	NA	NA
Serial Number	NA	NA	NA

Air Test Data	**DESIGN**	**ACTUAL**	**DESIGN**	**ACTUAL**	**DESIGN**	**ACTUAL**
Air Qty. CFM(l/s)	50,000	44,539	40,000	35,229	40,000	37,804
Air Vel. FPM (m/s)	NG	NM	NG	NM	NG	NM
Press. Drop In wg (Pa)	NG	NM	NG	NM	NG	NM
Out. Air DB/WB	-	-	-	-	-	-
Ret. Air DB/WB	-	-	-	-	-	-
Ent. Air DB/WB	NG	NM	NG	NM	NG	NM
Lvg. Air DB/WB	NG	NM	NG	NM	NG	NM
Air ΔT	NG	NM	NG	NM	NG	NM

Water Test Data	**DESIGN**	**ACTUAL**	**DESIGN**	**ACTUAL**	**DESIGN**	**ACTUAL**
Water Flow GPM (l/s)	NG	NM	NG	NM	NG	NM
Press. Drop PSI (kPa)	NG	*	NG	2.0	NG	1.6
Ent Water Temp.	NG	NA	NG	41.0	NG	41.3
Lvg. Water Temp.	NG	57.5	NG	51.7	NG	57.4
Water ΔT	NG	-	NG	10.7	NG	16.1

Refrigeration Test	**DESIGN**	**ACTUAL**	**DESIGN**	**ACTUAL**	**DESIGN**	**ACTUAL**
Exp. Valve/Refrig.	-	-	-	-	-	-
Refrig. Suction Press.	-	-	-	-	-	-
Refrig. Suction Temp.	-	-	-	-	-	-
Inlet Steam Press.	-	-	-	-	-	-

COMMENTS: *.33 PSI PRESSURE DROP ACROSS THE AUTOFLOW VALVE. THERE WERE NO OTHER TEST PORTS FOR CHW COIL DROP.
THE BUILDING CHILL WATER PUMP NOT WORKING CORRECTLY. CHW BEING FED FROM MAIN PLANT.

COIL APPARATUS TEST REPORT

Job Name: OUPB Cx Assessment
Tested By: JACQUEMIN **Date:** 6/16/2020

COIL DATA			
System Number	**AHU-4**	**AHU-5**	
Location	PENTHOUSE	PENTHOUSE	
Coil Type	COOLING	COOLING	
No. Rows-Fins/ In.	NA	NA	
Manufacturer	NA	NA	
Model Number	NA	NA	
Serial Number	NA	NA	

Air Test Data	DESIGN	ACTUAL	DESIGN	ACTUAL	DESIGN	ACTUAL
Air Qty. CFM(l/s)	40,000	37,513	40,000	39,814		
Air Vel. FPM (m/s)	NG	NM	NG	NM		
Press. Drop In wg (Pa)	NG	NM	NG	NM		
Out. Air DB/WB	-	-	-	-	-	-
Ret. Air DB/WB	-	-	-	-	-	-
Ent. Air DB/WB	NG	NM	NG	NM		
Lvg. Air DB/WB	NG	NM	NG	NM		
Air ΔT	NG	NM	NG	NM		

Water Test Data	DESIGN	ACTUAL	DESIGN	ACTUAL	DESIGN	ACTUAL
Water Flow GPM (l/s)	NG	NM	NG	NM		
Press. Drop PSI (kPa)	NG	1.8	NG	1.5		
Ent Water Temp.	NG	48.1	NG	40.7		
Lvg. Water Temp.	NG	57.0	NG	47.7		
Water ΔT	NG	8.9	NG	7.0		

Refrigeration Test	DESIGN	ACTUAL	DESIGN	ACTUAL	DESIGN	ACTUAL
Exp. Valve/Refrig.	-	-	-	-	-	-
Refrig. Suction Press.	-	-	-	-	-	-
Refrig. Suction Temp.	-	-	-	-	-	-
Inlet Steam Press.	-	-	-	-	-	-

COMMENTS:

COIL APPARATUS TEST REPORT

Job Name: OUPB Cx Assessment
Tested By: JACQUEMIN **Date:** 6/16/2020

COIL DATA			
System Number	**AHU-1**	**AHU-2**	**AHU-3**
Location	PENTHOUSE	PENTHOUSE	PENTHOUSE
Coil Type	HEATING	HEATING	HEATING
No. Rows-Fins/ In.	NA	NA	NA
Manufacturer	NA	NA	NA
Model Number	NA	NA	NA
Serial Number	NA	NA	NA

Air Test Data	DESIGN	ACTUAL	DESIGN	ACTUAL	DESIGN	ACTUAL
Air Qty. CFM(l/s)	50,000	44,539	40,000	35,229	40,000	37,804
Air Vel. FPM (m/s)	NG	NM	NG	NM	NG	NM
Press. Drop In wg (Pa)	NG	NM	NG	NM	NG	NM
Out. Air DB/WB	-	-	-	-	-	-
Ret. Air DB/WB	-	-	-	-	-	-
Ent. Air DB/WB	NG	NM	NG	NM	NG	NM
Lvg. Air DB/WB	NG	NM	NG	NM	NG	NM
Air ΔT	NG	NM	NG	NM	NG	NM

Water Test Data	DESIGN	ACTUAL	DESIGN	ACTUAL	DESIGN	ACTUAL
Water Flow GPM (l/s)	NG	NM	NG	NM	NG	NM
Press. Drop PSI (kPa)	NG	0.4	NG	NM	NG	1.2
Ent Water Temp.	NG	113.3	NG	NM	NG	114.6
Lvg. Water Temp.	NG	97.7	NG	NM	NG	105.6
Water ΔT	NG	15.6	NG	NM	NG	9.0

Refrigeration Test	DESIGN	ACTUAL	DESIGN	ACTUAL	DESIGN	ACTUAL
Exp. Valve/Refrig.	-	-	-	-	-	-
Refrig. Suction Press.	-	-	-	-	-	-
Refrig. Suction Temp.	-	-	-	-	-	-
Inlet Steam Press.	-	-	-	-	-	-

COMMENTS: AHU 2 HW VALVE NOT FUNCTIONING.
WHEN TESTING THE HEATING WATER ONLY THE AHU VALVES WERE OPENED. THE REST OF THE SYSTEM REMAINED IN AUTO.

COIL APPARATUS TEST REPORT

Job Name: OUPB Cx Assessment
Tested By: JACQUEMIN **Date:** 6/16/2020

COIL DATA			
System Number	**AHU-4**	**AHU-5**	
Location	PENTHOUSE	PENTHOUSE	
Coil Type	HEATING	HEATING	
No. Rows-Fins/ In.	NA	NA	
Manufacturer	NA	NA	
Model Number	NA	NA	
Serial Number	NA	NA	

Air Test Data	DESIGN	ACTUAL	DESIGN	ACTUAL	DESIGN	ACTUAL
Air Qty. CFM(l/s)	40,000	37,513	40,000	39,814		
Air Vel. FPM (m/s)	NG	NM	NG	NM		
Press. Drop In wg (Pa)	NG	NM	NG	NM		
Out. Air DB/WB	-	-	-	-	-	-
Ret. Air DB/WB	-	-	-	-	-	-
Ent. Air DB/WB	NG	NM	NG	NM		
Lvg. Air DB/WB	NG	NM	NG	NM		
Air ΔT	NG	NM	NG	NM		

Water Test Data	DESIGN	ACTUAL	DESIGN	ACTUAL	DESIGN	ACTUAL
Water Flow GPM (l/s)	NG	NM	NG	NM		
Press. Drop PSI (kPa)	NG	0.1	NG	1.3		
Ent Water Temp.	NG	116.9	NG	116.8		
Lvg. Water Temp.	NG	95.5	NG	107.6		
Water ΔT	NG	21.4	NG	9.2		

Refrigeration Test	DESIGN	ACTUAL	DESIGN	ACTUAL	DESIGN	ACTUAL
Exp. Valve/Refrig.	-	-	-	-	-	-
Refrig. Suction Press.	-	-	-	-	-	-
Refrig. Suction Temp.	-	-	-	-	-	-
Inlet Steam Press.	-	-	-	-	-	-

COMMENTS: WHEN TESTING THE HEATING WATER ONLY THE AHU VALVES WERE OPENED. THE REST OF THE SYSTEM REMAINED IN AUTO.

APPENDIX H
SAMIS EDUCATION CENTER REPORT

MECHANICAL CONSULTING SERVICES

Building Infrastructure Testing Report

Samis Education Center

Oklahoma City, Oklahoma

April 12, 2021

Project No. FA20P031

Prepared For:

University Hospitals Authority and Trust (UHAT)
940 NE 13th Street
Oklahoma City, Oklahoma 73104

Prepared by:

Terracon Consultants, Inc.
4701 N. Stiles Avenue
Oklahoma City, Oklahoma 73105

Terracon

April 12, 2021

Mr. Nathan Miller
Building Systems Manager
University Hospitals Authority & Trust
940 NE 13th Street
Oklahoma City, Oklahoma 73104
P: 405-271-4962 x44199
E: Nathan-Miller@uhat.org

Reference: **UHAT**
Building Infrastructure Testing
Samis Education Center
1200 Children's Avenue
Oklahoma City, Oklahoma 73104
Project No. FA20P031

Mr. Miller:

Terracon Consultants, Inc. (Terracon) is pleased to submit this Mechanical Consulting Services Report of our Building Infrastructure Testing for the Samis Education Center located at 1200 Children's Avenue in Oklahoma City, Oklahoma. This work was performed in general accordance with the scope of services outlined in Terracon's Proposal for Building Infrastructure Testing & Retro-Commissioning Services dated December 19, 2019 and authorized in February 2020 as identified in the scope section of this Report.

The purpose of this Report is to render our findings, field notes, and recommendations related to our site visits at the above referenced location.

This document includes background information, observations, findings, and recommendations pertaining to the operations of the heating, ventilation, and air conditioning (HVAC) at the site.

Terracon appreciates the opportunity to be of service to you on this project. If you have any questions regarding this report, please do not hesitate to contact us.

Sincerely,

Terracon Consultants, Inc.

Erik Gonzalez, P.E. (TX), CEM
Senior Engineer
Facilities Services

Jeffrey A. Miller, P.E. (OK)
Senior Principal/Senior Engineer
Facilities Services

Terracon Consultants, Inc. 4701 N. Stiles Avenue Oklahoma City, Oklahoma 73105
P (405) 525-0453 terracon.com

Geotechnical ■ Environmental ■ Construction Materials ■ Facilities

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PROJECT OBJECTIVE

The purpose of our Building Infrastructure Testing (BIT) services is to conduct limited visual observations and engineering diagnostics of the HVAC systems of the subject site. With the observations and measurements obtained, a retro-commissioning plan will be developed from recommended energy conservation opportunities in this report that, if enacted, will help improve performance and reduce the operating costs of the building without compromising comfort for the building occupants.

Terracon's representatives, Mr. John Harmon, E.I.T., Mr. Kim Morris QCxP, Mr. Erik Gonzalez, P.E. (TX), CEM, and Mr. Jonathan Curtin P.E. (TX) of Terracon, and our sub-consultant, Engineering Systems & Energy Solutions (ES2), conducted site visits on September 14 - 15, 2020 at the Samis Education Center in order to obtain visual and diagnostic information and field performance measurements for the HVAC systems. During the site visits, visual observations were made to note general operating conditions of the HVAC systems. In addition, diagnostic measurements were taken for the air distribution of the six AHUs, two chilled water pumps, and two hot water pumps comprising the HVAC systems. Measurements recorded were compared to the performance requirements contained in the design documents and EMCS sensor for air flow and water flow characteristics using the software workstation. Observations were made from readily accessible areas and did not include substantial dismantling of components of the building and HVAC equipment, including walls and closed ceilings. With the observations and measurements, Terracon developed energy conservation opportunities and recommendations for improvements to the HVAC systems.

DOCUMENTS AND INFORMATION REVIEWED

Terracon was provided with design documentation for the subject building, utility data for chilled water, steam, and electricity, tariff sheets that breakdown the cost of each utility service, and network access to the *AutomatedLogic Corporation* (*ALC*) *WebCTRL v7.0* energy management control system. The following items were reviewed while performing this assessment:

Document	Source
SAMIS EXTG DRAWINGS MEP — MILES ASSOCIATES, ZAHL-FORD, ZRHD, FLINTCO, dated April 24, 2012	Client Provided
Utility Bill Data for Terracon.xlsx – e-mailed to Terracon on February 28, 2020	Client Provided
Utility Service Tariff Sheets for OUHSC and OGE services provided to UHAT – e-mailed to Terracon on March 3, 2020	Client Provided

BUILDING DESCRIPTION AND ENERGY USE BASELINE

The subject property is a four-story medical education training building which totals approximately 56,276-square feet. The building was originally constructed around 2012. The HVAC systems were designed to operate with distributed chilled water and distributed hot water from the pumps and heat exchangers located in the basement of the OU Childrens Physician’s Building. The two chilled water pumps and two heating hot water pumps have dedicated loops to distributing chilled water and heating hot water to both the Atrium and Samis Education Center.

The HVAC systems within the building include six air handling units (AHUs), seven fan coil units (FCU), and two exhaust fans (EF). All major equipment is controlled and monitored with an *ALC* energy management control system (EMCS) *WebCTRL* (software). The controllers (hardware) were all observed to be *ALC* field controllers and were installed when the building was constructed in 2012.

Table 1: General Building Information

Attributes	***SEC***
Property Manager	***ONECall***
Year Opened	2012
Enclosed Square Feet	56,276
Floors	4
Annual Metered kWh Consumption (2019)	848,150*
Annual Metered Peak kW Demand	158.5
Annual Electric $	$50,826
Annual CHW Ton-hrs Consumed (2019)	337,288**
Annual Peak Demand Tons	181.3
Average Monthly CHW Temp. Diff. (ºF)	14.9
Annual CHW $	$49,260
Annual Steam klbs Consumed (2019)	2,358**
Annual Steam Demand lbs/hr	681.1
Annual Steam Condensate Return (%)	29%
Annual Steam Cost $	$18,428
kWh/sqft	15.1
Peak W/sqft	2.82
Electrical Load Factor	61.1%
CHW Ton-hrs/sqft	5.99
Steam kBtu/sqft	50.3
Electrical EUI (kBtu/sqft)	52.1
CHW EUI (kBtu/sqft)	71.1
Total EUI (kBtu/sqft)	173.5
Annual Utility Costs	$118,514
ECI ($/SqFt)	$2.11
FCI Score	2019 (100) 2021 (100)
Operating Schedule	M-F 7am-10pm
Occupied Hours	M-F 7am-6:30pm
EMCS - Energy Management Control System	*ALC - WebCTRL*
Cooling Systems	Chilled Water
Heating Systems	Hot Water
Air Distribution	Single Zone
Outside Air / Ventilation	OA is ducted directly to return air section of AHU's

*Electric consumption was estimated based on the calculated ratio of the Samis sqft to the overall sqft (Samis, Atrium, and OU Children's Physicians) served by the electric meter at the OU Children's Physicians building.

**Steam and chilled water consumption was estimated based on the calculated ratio of the Samis sqft to the the overall sqft (Samis and Atrium) served by the Atrium-Samis chilled water meter and Atrium-Sammis steam meter located at the OU Children's Physicians building.

To measure the building's energy utilization and current level of efficiency, two Energy Performance Indicators were calculated in this Report as follows:

Energy Utilization Intensity

The Energy Utilization Intensity (EUI) depicts the total annual energy consumption per square foot of building space, and is expressed in "British Thermal Units" (BTUs). To calculate the EUI, the annual consumption of electricity, steam, and chilled water are first converted to equivalent kBTU consumption via the following formulas:

Total Annual Energy Usage = Total Annual Electrical Energy Usage + Total Annual Steam Energy Usage + Total Annual Chilled Water Energy Usage converted to units of kBTUs/year.

Total Annual Electrical Energy Usage
[Total kWh /yr.] x [3.412 kBTUs/kWh] = __________ kBTUs / yr.

Total Annual Steam Energy Usage
[Total klbs /yr.] x [1,196 kBTUs/klbs] = __________ kBTUs / yr.

Total Annual Chilled Water Energy Usage
[Total Ton/hr /yr.] x [12 kBTUs/hr/Ton/hr] = __________ kBTUs / yr.

The total kBTUs are then divided by the building area.

EUI = [Total annual kBTUs] divided by [Total square feet]

The EUI was compared to the average energy utilization published in the 2012 Commercial Building Energy Consumption Survey (CBECS).

Energy Cost Index

The Energy Cost Index (ECI) depicts the total annual energy cost per square foot building space. To calculate the ECI, the annual costs of electricity, steam, and chilled water are divided by the total square footage of the leased space:

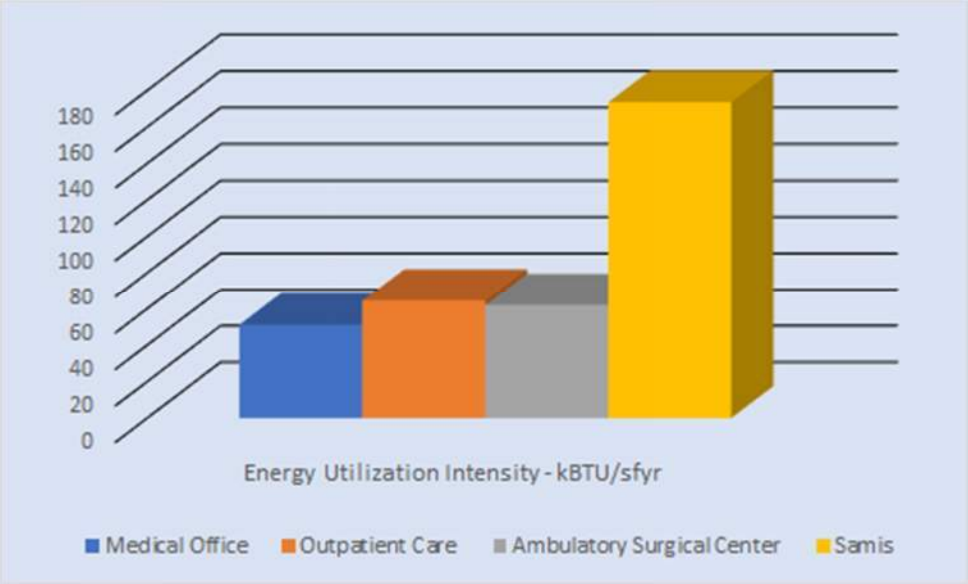
ECI = [Total Energy Cost] divided by [Total square feet]

The ECI was calculated and compared to the statistical average energy cost index published in the 2012 Commercial Building Energy Consumption Survey (CBECS).

The EUI and ECI may be used to compare the facility's approximate usage and cost to other similar facilities in the area. Although the comparisons will not provide specific reasons for unusual operation, they serve as indicators that opportunities may exist by more efficiently operating energy consuming systems.

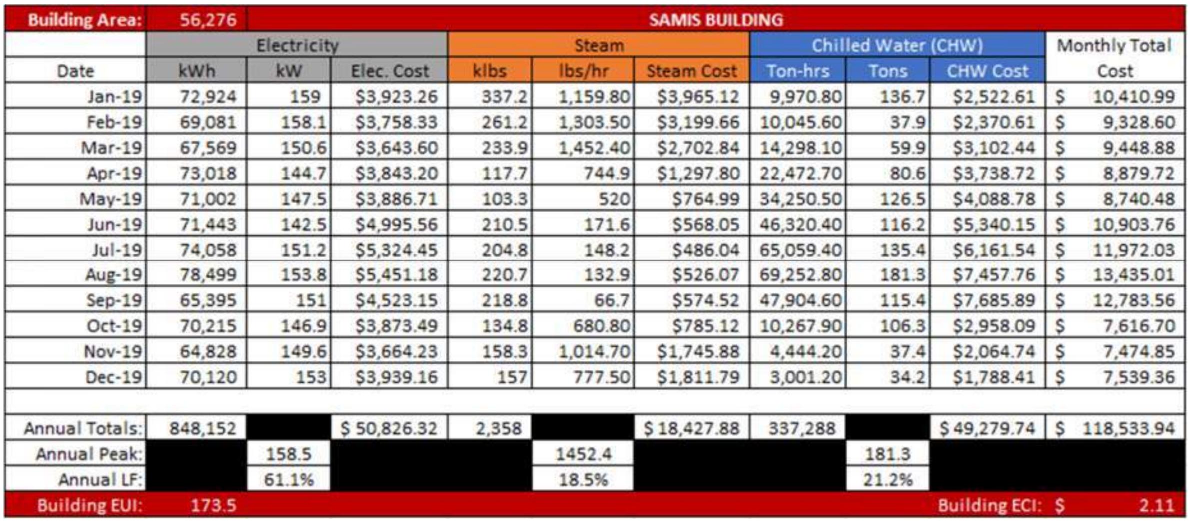
Referring to the 2012 Commercial Building Energy Consumption Survey (CBECS), compiled by the United States Department of Energy, we find the following ranges of comparison with the subject building. The CBECS survey results were based on a national statistical average of a total of 9,941-million square feet reported. The subject site is located within the southwestern section of the United States.

- CBECS utility cost and energy utilization comparison of the EUI and ECI indicates that Samis has a **moderately high EUI and ECI** compared to similar facilities in the healthcare category.



Oklahoma Gas and Electric (OGE) and OU Health Sciences Center (OUHSC) are the main energy utility providers for the building. Terracon has analyzed the energy consumption for the building and determined the Energy Usage Index (EUI) is approximately **173.5 kBtu/SQFT/yr** and the Energy Cost Index (ECI) is **$2.11/SQFT/yr**. The annual energy consumption ratio shows that electricity accounts for approximately 30% of total energy consumption, chilled water accounts for approximately 41% of total energy consumption, and steam accounts for the remaining 29% of total energy consumption. Annually, electricity accounts for approximately 15% of the total energy cost, chilled water accounts for approximately 42% of the total energy cost, and steam accounts for the remaining 43% of total energy cost. The annual cost ratios are mostly proportionate from the annual consumption ratios, with the steam cost ratio being much lower than the overall steam energy consumption ratio.

Table 2 – 2019 Energy Use Baseline



Building Area:	56,276	SAMIS BUILDING								
	Electricity			Steam			Chilled Water (CHW)			Monthly Total Cost
Date	kWh	kW	Elec. Cost	klbs	lbs/hr	Steam Cost	Ton-hrs	Tons	CHW Cost	
Jan-19	72,924	159	$3,923.26	337.2	1,159.80	$3,965.12	9,970.80	136.7	$2,522.61	$ 10,410.99
Feb-19	69,081	158.1	$3,758.33	261.2	1,303.50	$3,199.66	10,045.60	37.9	$2,370.61	$ 9,328.60
Mar-19	67,569	150.6	$3,643.60	233.9	1,452.40	$2,702.84	14,298.10	59.9	$3,102.44	$ 9,448.88
Apr-19	73,018	144.7	$3,843.20	117.7	744.9	$1,297.80	22,472.70	80.6	$3,738.72	$ 8,879.72
May-19	71,002	147.5	$3,886.71	103.3	520	$764.99	34,250.50	126.5	$4,088.78	$ 8,740.48
Jun-19	71,443	142.5	$4,995.56	210.5	171.6	$568.05	46,320.40	116.2	$5,340.15	$ 10,903.76
Jul-19	74,058	151.2	$5,324.45	204.8	148.2	$486.04	65,059.40	135.4	$6,161.54	$ 11,972.03
Aug-19	78,499	153.8	$5,451.18	220.7	132.9	$526.07	69,252.80	181.3	$7,457.76	$ 13,435.01
Sep-19	65,395	151	$4,523.15	218.8	66.7	$574.52	47,904.60	115.4	$7,685.89	$ 12,783.56
Oct-19	70,215	146.9	$3,873.49	134.8	680.80	$785.12	10,267.90	106.3	$2,958.09	$ 7,616.70
Nov-19	64,828	149.6	$3,664.23	158.3	1,014.70	$1,745.88	4,444.20	37.4	$2,064.74	$ 7,474.85
Dec-19	70,120	153	$3,939.16	157	777.50	$1,811.79	3,001.20	34.2	$1,788.41	$ 7,539.36
Annual Totals:	848,152		$ 50,826.32	2,358		$ 18,427.88	337,288		$ 49,279.74	$ 118,533.94
Annual Peak:		158.5			1452.4			181.3		
Annual LF:		61.1%			18.5%			21.2%		
Building EUI:	173.5								Building ECI:	$ 2.11

Chart 1 – Energy Ratio

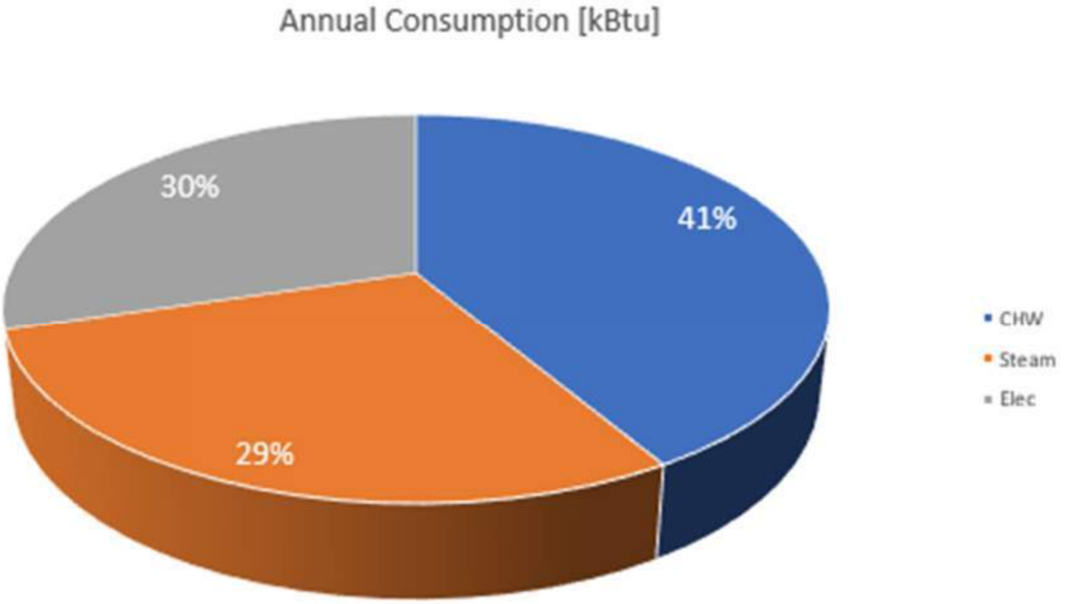
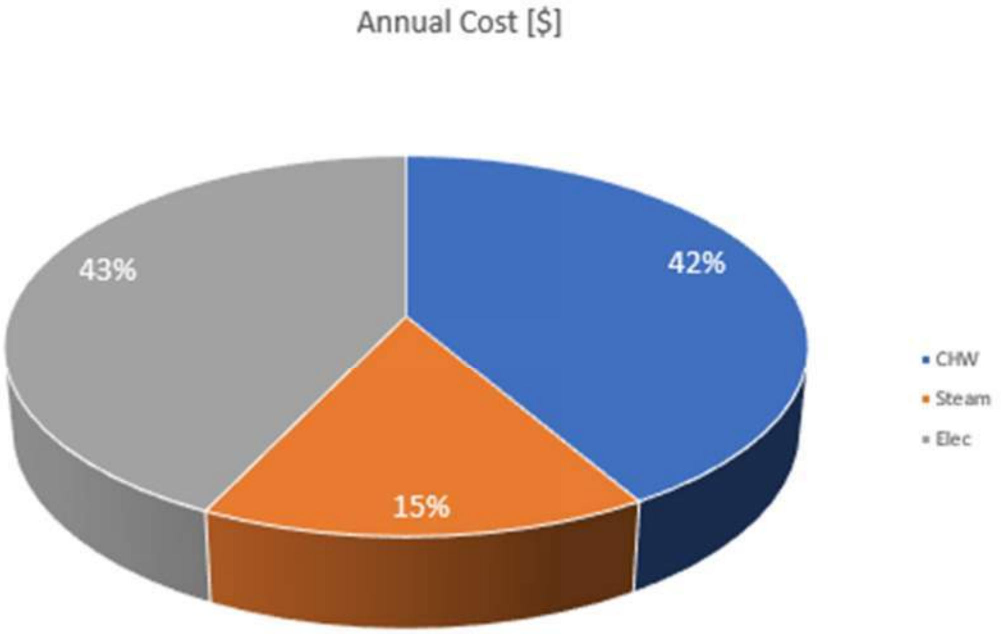


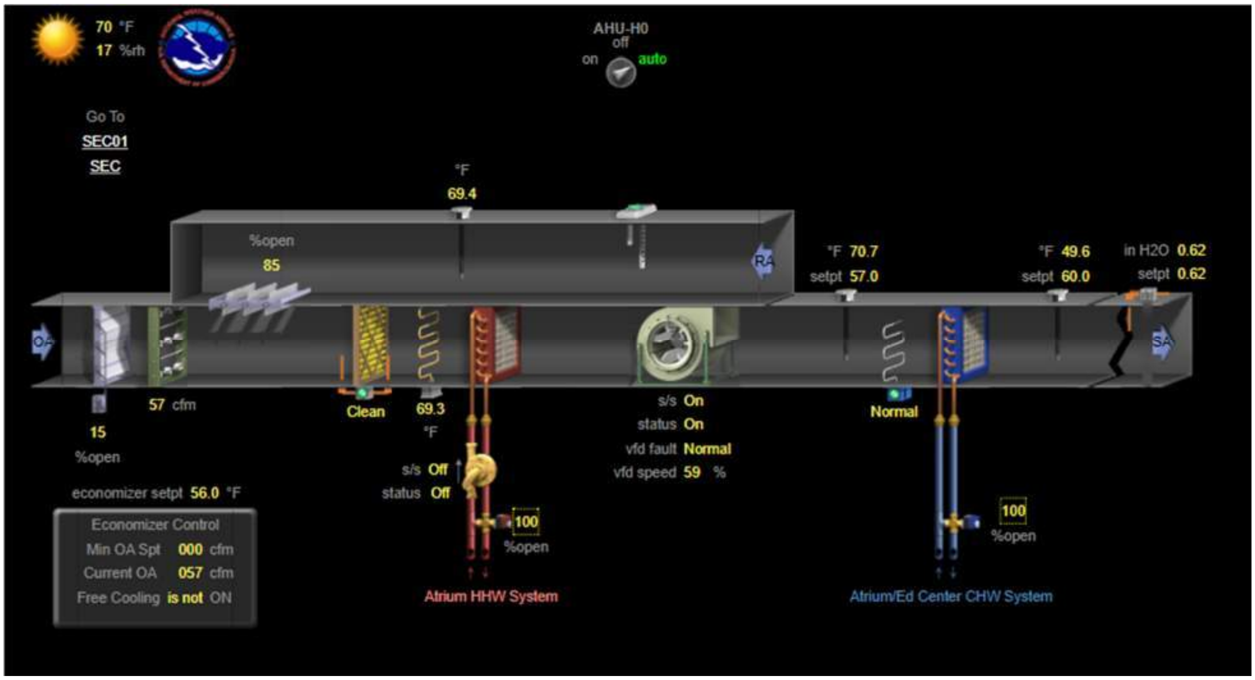
Chart 2 – Energy Cost Ratio


Annual Cost [$]
43%
42%
15%
CHW
Steam
Elec

HVAC SYSTEM OBSERVATIONS

During the site visits, Terracon and our sub-consultant made the following observations:

1. Terracon personnel viewed six air handling units (AHU-H0 thru AHU-H5) for the Samis Education Center.
2. AHU-H0 and AHU-H1 serve the basement and the 1st floor.
3. The hot water supply temperature needs to be programmed to reset according to outside air conditions.
4. The differential pressure sensor for the heating water is located on the 4th floor (10.8psi) and located in the Atrium Building.
5. The differential pressure sensor for the chill water loop is located on AGU-3 (15.2 psi) and is also located in the Atrium Building.
6. Two chilled water pumps with VFD's serve the Atrium and Samis buildings.
7. Two hot water pumps with VFD's serve the Atrium and Samis buildings.
8. Utility meters supplying chilled water and steam need to be calibrated and verified as calibrated and reading correctly.
9. Controls need calibration verification upon T&B work.
10. AHU Economizer cycle setpoints are set between 56 degrees and 70 degrees outside air temperatures to begin operation and need to be adjusted and confirmed as optimal setpoints.
11. The outside air and relief air airflow monitoring stations for each AHU are not readily serviceable, and BAS indicated flowrates appear low given damper positions. See BAS screenshots below.
12. The installed HHWP-3 and HHWP-4 do not match the design requirements.
13. HHWP4 is installed with reversed rotation.



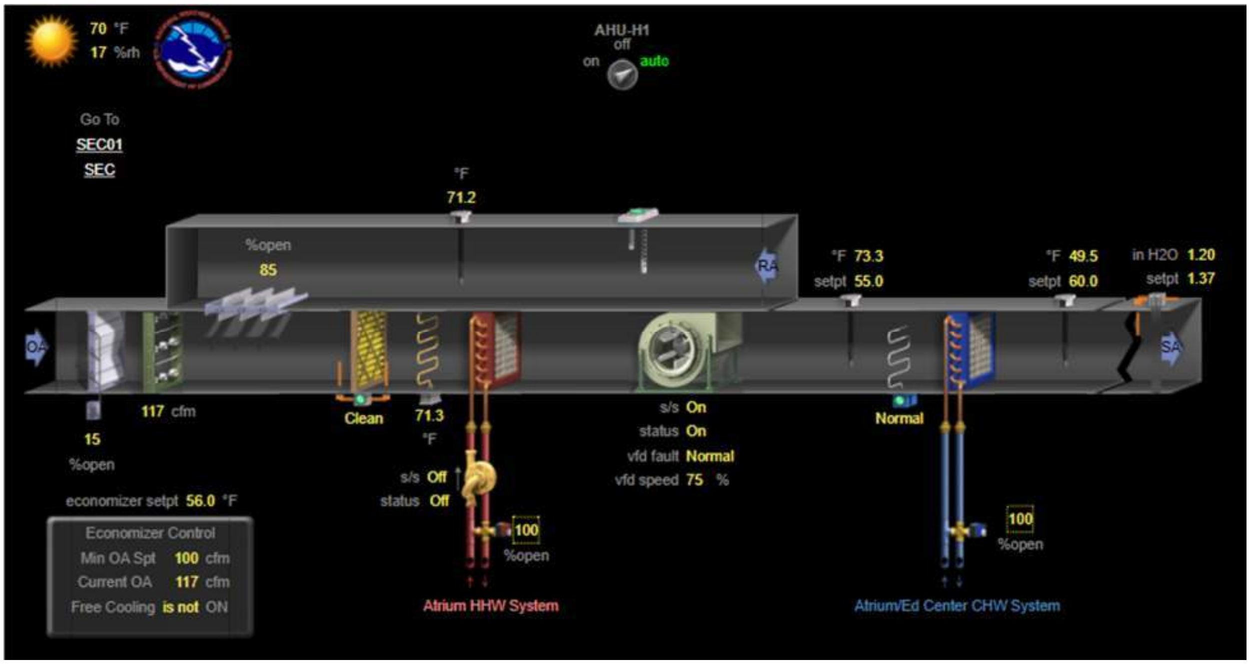
70 °F
17 %rh

AHU-H0
off
on auto

°F 69.4
%open 85
°F 70.7 setpt 57.0
°F 49.6 setpt 60.0
in H2O 0.62 setpt 0.62
57 cfm
15 %open
69.3 °F
s/s Off
status Off
s/s On
status On
vfd fault Normal
vfd speed 59 %
100 %open
100 %open
economizer setpt 56.0 °F

Economizer Control
Min OA Spt 000 cfm
Current OA 057 cfm
Free Cooling is not ON

AHU-H0



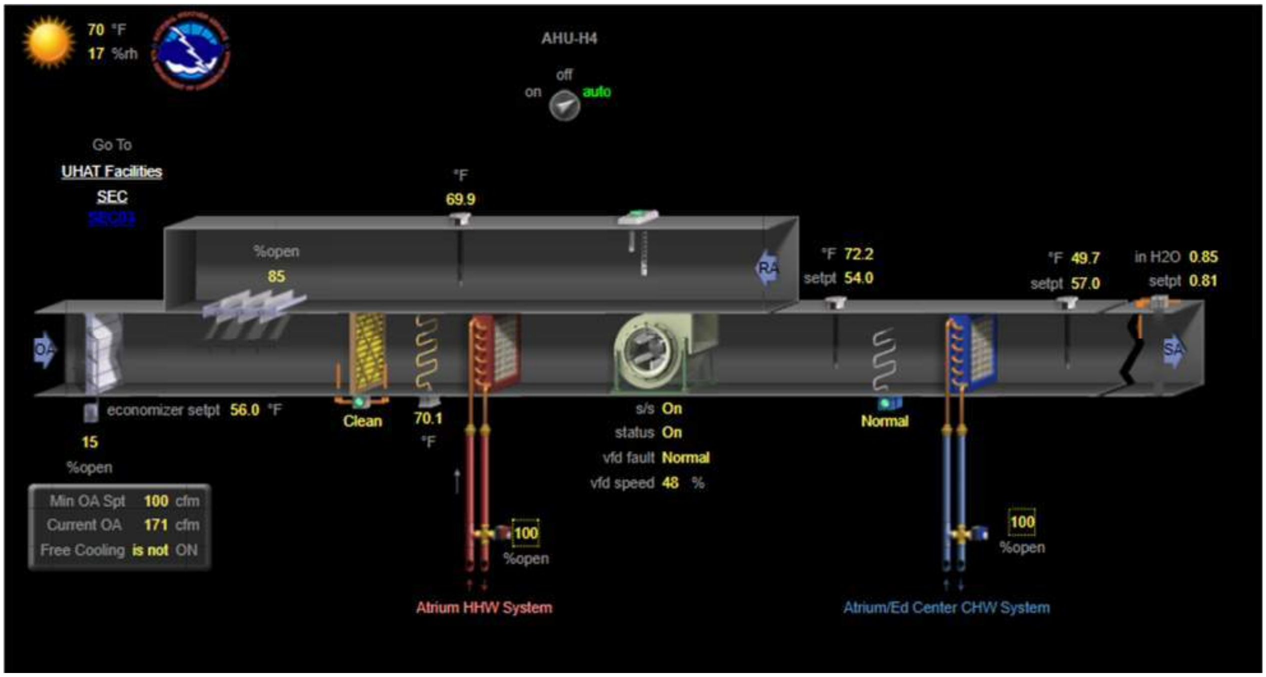
70 °F
17 %rh

AHU-H1
off
on auto

°F 71.2
%open 85
°F 73.3 setpt 55.0
°F 49.5 setpt 60.0
in H2O 1.20 setpt 1.37
117 cfm
15 %open
71.3 °F
s/s Off
status Off
s/s On
status On
vfd fault Normal
vfd speed 75 %
100 %open
100 %open
economizer setpt 56.0 °F

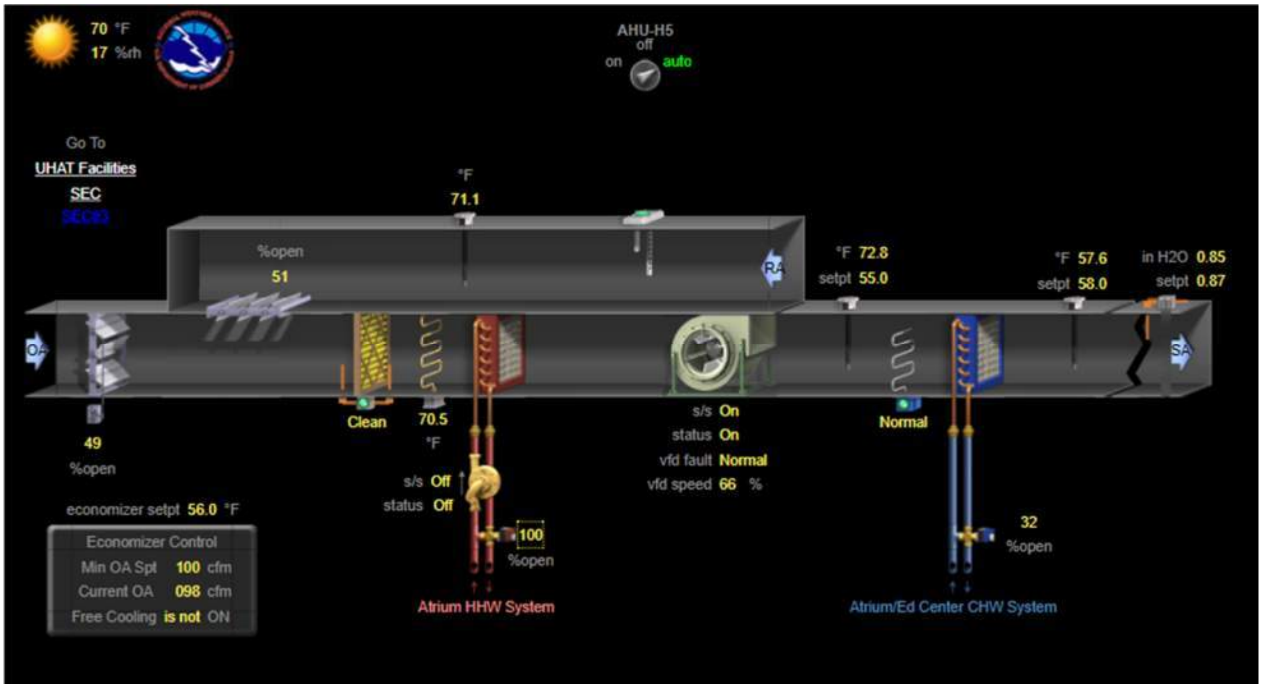
Economizer Control
Min OA Spt 100 cfm
Current OA 117 cfm
Free Cooling is not ON

AHU-H1



70 °F
17 %rh
°F 69.9
%open 85
°F 72.2
setpt 54.0
°F 49.7
setpt 57.0
in H2O 0.85
setpt 0.81
economizer setpt 56.0 °F
15 %open
70.1 °F
s/s On
status On
vfd fault Normal
vfd speed 48 %
100 %open
100 %open
Min OA Spt 100 cfm
Current OA 171 cfm
Free Cooling is not ON

AHU-H4



70 °F
17 %rh
°F 71.1
%open 51
°F 72.8
setpt 55.0
°F 57.6
setpt 58.0
in H2O 0.85
setpt 0.87
49 %open
70.5 °F
s/s Off
status Off
s/s On
status On
vfd fault Normal
vfd speed 66 %
100 %open
32 %open
economizer setpt 56.0 °F
Economizer Control
Min OA Spt 100 cfm
Current OA 098 cfm
Free Cooling is not ON

AHU-H5

BUILDING INFRASTRUCTURE TESTING

Terracon investigated discrepancies between the requirements in the design documentation provided and the EMCS readings with an independent air flow instrument provided by our subconsultant. The AHU air flow at AHU H0, AHU H1, AHU H2, AHU H3, AHU H4, and AHU H5 were all measured in a traverse pattern grid that is in accordance with industry TAB standards for HVAC systems.

In addition to supply air flow measurements, Terracon also parameters tested and verified the following:

1. Supply air temperature being distributed to the VAV terminal boxes
2. Entering and leaving water temperatures for each hot water and chilled water coil
3. Entering and leaving water pressures for each hot water and chilled water coil
4. Entering and leaving air pressure for each hot water and chilled water coil section
5. External static air pressure (suction and discharge) for each AHU supply fan.

All measurements were taken independent to the EMCS to verify accuracy of the parameters being read by the *ALC webCTRL* system. The accuracy of the measurements are necessary to validate that the HVAC systems are meeting the equipment's design performance requirements.

The following information was field measured:

AHU H0

Total Supply Air [CFM]	**Supply Air Temperature [ºF]**	**Entering Heating Water Temperature [ºF]**	**Leaving Heating Water Temperature [ºF]**	**Entering Chilled Water Temperature [ºF]**	**Leaving Chilled Water Temperature [ºF]**
14,600**	-	78.1	74.3	63.6	71.1

Heating Coil Delta Air Pressure [in H_2O]	**Cooling Coil Delta Air Pressure [in H_2O]**	**Heating Coil Delta Water Pressure [psig]**	**Cooling Coil Delta Water Pressure [psig]**	**Total Fan Static Pressure [in H_2O]**
0.1*	0.55	2.0	13.2	3.09

AHU H1

Total Supply Air [CFM]	Supply Air Temperature [ºF]	Entering Heating Water Temperature [ºF]	Leaving Heating Water Temperature [ºF]	Entering Chilled Water Temperature [ºF]	Leaving Chilled Water Temperature [ºF]
14,355**	-	78.1	74.1	63.5	70.1

Heating Coil Delta Air Pressure [in H_2O]	Cooling Coil Delta Air Pressure [in H_2O]	Heating Coil Delta Water Pressure [psig]	Cooling Coil Delta Water Pressure [psig]	Total Fan Static Pressure [in H_2O]
0.21*	0.29	2.0	14.5	3.13

AHU H2

Total Supply Air [CFM]	Supply Air Temperature [ºF]	Entering Heating Water Temperature [ºF]	Leaving Heating Water Temperature [ºF]	Entering Chilled Water Temperature [ºF]	Leaving Chilled Water Temperature [ºF]
3994**	-	118.2	110.9	56.2	50.1

Heating Coil Delta Air Pressure [in H_2O]	Cooling Coil Delta Air Pressure [in H_2O]	Heating Coil Delta Water Pressure [psig]	Cooling Coil Delta Water Pressure [psig]	Total Fan Static Pressure [in H_2O]
0.04*	0.10	3.0	2.5	0.40

AHU H3

Total Supply Air [CFM]	Supply Air Temperature [ºF]	Entering Heating Water Temperature [ºF]	Leaving Heating Water Temperature [ºF]	Entering Chilled Water Temperature [ºF]	Leaving Chilled WaterTemperature [ºF]
7680**	-	-	-	-	-

Heating Coil Delta Air Pressure [in H_2O]	Cooling Coil Delta Air Pressure [in H_2O]	Heating Coil Delta Water Pressure [psig]	Cooling Coil Delta Water Pressure [psig]	Total Fan Static Pressure [in H_2O]
0.10	0.16	3.5	5.2	.50

AHU H4

Total Supply Air [CFM]	Supply Air Temperature [ºF]	Entering Heating Water Temperature [ºF]	Leaving Heating Water Temperature [ºF]	Entering Chilled Water Temperature [ºF]	Leaving Chilled Water Temperature [ºF]
9367**	-	108.6	117.5	48.8	54.8

Heating Coil Delta Air Pressure [in H_2O]	Cooling Coil Delta Air Pressure [in H_2O]	Heating Coil Delta Water Pressure [psig]	Cooling Coil Delta Water Pressure [psig]	Total Fan Static Pressure [in H_2O]
.09	0.24	4.1	2.0	2.33

AHU H5

Total Supply Air [CFM]	Supply Air Temperature [ºF]	Entering Heating Water Temperature [ºF]	Leaving Heating Water Temperature [ºF]	Entering Chilled Water Temperature [ºF]	Leaving Chilled Water Temperature [ºF]
8,200**	-	119.8	109.0	50.1	59.1

Heating Coil Delta Air Pressure [in H_2O]	Cooling Coil Delta Air Pressure [in H_2O]	Heating Coil Delta Water Pressure [psig]	Cooling Coil Delta Water Pressure [psig]	Total Fan Static Pressure [in H_2O]
0.25*	0.18	9.0	6.0	3.07

CHWP 3

Final GPM	Head (Feet)	Suction Pressure (PSI)	Discharge Pressure (PSI)	Horsepower
1175.0	98.5	78.1	120.8	30

CHWP 4

Final GPM	Head (Feet)	Suction Pressure (PSI)	Discharge Pressure (PSI)	Horsepower
***	***	***	***	20

HHWP 3

Final GPM	Head (Feet)	Suction Pressure (PSI)	Discharge Pressure (PSI)	Horsepower
N/A	18	65.7	73.5	20

HHWP 4

Final GPM	Head (Feet)	Suction Pressure (PSI)	Discharge Pressure (PSI)	Horsepower
***	***	***	***	20

* = The delta p for HW Coil is across both the coil and pre filters, and vice versa.

^ = Measurement taken in return duct due to limited access around supply duct.

**= Airflow total for unit was determined by using face velocity across the coil.

***= Lag pumps were not turned on during testing per ES2

During testing, the Terracon team made the following observations:

1. The heating hot water coil for AHU-H4 was found to be piped in reverse.
2. VFD drive for AHU-H3 screen is damaged and is not accessible for manual control.

ENERGY CONSERVATION OPPORTUNITIES (ECOs) AND RECOMMENDATIONS

In order to effectively evaluate existing systems and deficiencies and to provide recommended measures, various methods and actions were considered. Considerations include:

- Analysis of existing construction drawings and as-built documentation.
- Analysis of utility bills.
- Conversations with the UHAT personnel regarding HVAC system configuration, controls, and existing trouble spots.
- Collection of information and data from *ALC webCTRL* interface to gather set points, operating conditions, identify anomalies, etc.
- Site surveys and investigations.
- Profiled mechanical equipment (e.g. pumps, chillers, air handling units) affected by the ECO's so that accurate calculations of savings could be produced.
- For weather dependent systems, bin temperature analysis is to be used to calculate baseline and post-installation consumption.
- For weather independent systems, time-of-use methods were used to calculate baseline and post-installation consumption.

Energy conservation opportunities (ECOs) have been listed on the basis of cost, potential benefit and, most importantly, Owner approval.

ECO Master List

Table 3: Master List

Measure #	Equipment or System	Description of Finding	Recommended Improvement
M1.1.1	HHWP-3	The pump was found to be mislabeled and running in reverse. Head pressure did not match design specification.	Reverse pump rotation and reevaluate pump selection for system efficiency.
M2.1.1	AHU-H0	The outside air and relief air flow monitoring stations for each AHU are not readily serviceable, and BAS indicated flowrates appeared low (unreliable) given damper positions. All AHUs were observed with measured OA flowrates per the airflow monitoring stations (AFMS) of less than 200 cfm, some less than 100 cfm	Provide service solution for AFMS; clean, recalibrate, provide access for continued maintenance.
M2.1.2	AHU-H0	The economizer setpoints for AHUs range from 56degF to 70degF. Typical range is 55 to 62 degF.	Functionality test economizer operation for all AHUs and optimize setpoints.
M2.1.3	AHU-H0	BAS programmed minimum outdoor airflow setpoint for all AHU systems (~100 cfm) is unreasonably low given minimum ventilation requirements.	Review minimum OA flow requirements, verify BAS programming of setpoint and setpoint modulation is consistent with building needs, and rebalance the ventilation systems to ensure adequate minimum ventilation and positive building pressurization.
M2.2.1	AHU-H1	The outside air and relief air flow monitoring stations for each AHU are not readily serviceable, and BAS indicated flowrates appeared low (unreliable) given damper positions. All AHUs were observed	Provide service solution for AFMS; clean, recalibrate, provide access for continued maintenance.

Measure #	Equipment or System	Description of Finding	Recommended Improvement
		with measured OA flowrates per the airflow monitoring stations (AFMS) of less than 200 cfm, some less than 100 cfm	
M2.2.2	AHU-H1	The economizer setpoints for AHUs range from 56degF to 70degF. Typical range is 55 to 62 degF.	Functionality test economizer operation for all AHUs and optimize setpoints.
M2.2.3	AHU-H1	BAS programmed minimum outdoor airflow setpoint for all AHU systems (~100 cfm) is unreasonably low given minimum ventilation requirements.	Review minimum OA flow requirements, verify BAS programming of setpoint and setpoint modulation is consistent with building needs, and rebalance the ventilation systems to ensure adequate minimum ventilation and positive building pressurization.
M2.3.1	AHU-H2	The outside air and relief air flow monitoring stations for each AHU are not readily serviceable, and BAS indicated flowrates appear low (unreliable) given damper positions. All AHUs were observed with measured OA flowrates per the airflow monitoring stations (AFMS) of less than 200 cfm, some less than 100 cfm	Provide service solution for AFMS; clean, recalibrate, provide access for continued maintenance.
M2.3.2	AHU-H2	The economizer setpoints for AHUs range from 56degF to 70degF.	Functionality test economizer operation for all AHUs and optimize setpoints.
M2.3.3	AHU-H2	BAS programmed minimum outdoor airflow setpoint for all AHU systems (~100 cfm) is unreasonably low given minimum ventilation requirements.	Review minimum OA flow requirements, verify BAS programming of setpoint and setpoint modulation is consistent with building needs, and rebalance the ventilation systems to ensure adequate minimum ventilation and positive building pressurization.

Measure #	**Equipment or System**	**Description of Finding**	**Recommended Improvement**
M2.4.1	AHU-H3	The outside air and relief air flow monitoring stations for each AHU are not readily serviceable, and BAS indicated flowrates appeared low (unreliable) given damper positions. All AHUs were observed with measured OA flowrates per the airflow monitoring stations (AFMS) of less than 200 cfm, some less than 100 cfm	Provide service solution for AFMS; clean, recalibrate, provide access for continued maintenance.
M2.4.2	AHU-H3	The economizer setpoints for AHUs range from 56degF to 70degF. Typical range is 55 to 62 degF.	Functionality test economizer operation for all AHUs and optimize setpoints.
M2.4.3	AHU-H3	BAS programmed minimum outdoor airflow setpoint for all AHU systems (~100 cfm) is unreasonably low given minimum ventilation requirements.	Review minimum OA flow requirements, verify BAS programming of setpoint and setpoint modulation is consistent with building needs, and rebalance the ventilation systems to ensure adequate minimum ventilation and positive building pressurization.
M2.4.4	AHU-H3	The VFD screen for AHU-H3 is damaged and requires replacement.	Repair VFD.
M2.5.1	AHU-H4	The outside air and relief air flow monitoring stations for each AHU are not readily serviceable, and BAS indicated flowrates appeared low (unreliable) given damper positions. All AHUs were observed with measured OA flowrates per the airflow monitoring stations (AFMS) of less than 200 cfm, some less than 100 cfm	Provide service solution for AFMS; clean, recalibrate, provide access for continued maintenance.
M2.5.2	AHU-H4	The economizer setpoints for AHUs range from 56degF to 70degF. Typical range is 55 to 62 degF.	Functionality test economizer operation for all AHUs and optimize setpoints.

Measure #	Equipment or System	Description of Finding	Recommended Improvement
M2.5.3	AHU-H4	BAS programmed minimum outdoor airflow setpoint for all AHU systems (~100 cfm) is unreasonably low given minimum ventilation requirements.	Review minimum OA flow requirements, verify BAS programming of setpoint and setpoint modulation is consistent with building needs, and rebalance the ventilation systems to ensure adequate minimum ventilation and positive building pressurization.
M2.5.4	AHU-H4	Heating hot water coil found to be piped incorrectly in reverse. This is likely to increase the risk of water hammer in the coil, and having a higher water flow through the upper portion of the coil which is less effective for the heat transfer rate.	Repipe HHW coil.
M2.6.1	AHU-H5	The outside air and relief air flow monitoring stations for each AHU are not readily serviceable, and BAS indicated flowrates appeared low (unreliable) given damper positions. All AHUs were observed with measured OA flowrates per the airflow monitoring stations (AFMS) of less than 200 cfm, some less than 100 cfm	Provide service solution for AFMS; clean, recalibrate, provide access for continued maintenance.
M2.6.2	AHU-H5	The economizer setpoints for AHUs range from 56degF to 70degF. Typical range is 55 to 62 degF.	Functionality test economizer operation for all AHUs and optimize setpoints.
M2.6.3	AHU-H5	BAS programmed minimum outdoor airflow setpoint for all AHU systems (~100 cfm) is unreasonably low given minimum ventilation requirements.	Review minimum OA flow requirements, verify BAS programming of setpoint and setpoint modulation is consistent with building needs, and rebalance the ventilation systems to ensure adequate minimum ventilation and positive building pressurization.

LIMITATIONS

The field observations, tests, findings, and recommendations presented in this report are based upon the information provided to Terracon by the client, UHAT, and observations and field notes collected at the time of our site visits. While additional conditions may exist that could alter our recommendations, we feel that reasonable means have been made to fairly and accurately evaluate the existing conditions of these systems. This report is limited to Terracon's observations of the interior and exterior of the facility. Some of the observations were limited due to obstructions and access to areas of the systems and facility. Although our observations were made with normal care and diligence, it is likely that not all existing conditions were documented. The general intent was to identify representative conditions and provide recommendations based on general findings.

This report has been prepared for the exclusive use of UHAT for specific application to the project discussed and has been prepared in accordance with generally accepted engineering practices using the standard of care and skill currently exercised by professional engineers practicing in this area, for a project of similar scope and nature. No warranties, either expressed or implied, are intended or made. In the event that information described in this document which was provided by others is incorrect, or if additional information becomes available, the recommendations contained in this report shall not be considered valid unless Terracon reviews the information and either verifies or modifies the recommendations of this report in writing.

APPENDIX A
Photographs

Photo #1 The Atrium serves as the gateway to the, SAMIS Education Center and OU Children's Hospital.

Photo #2 AHU-H0.

Photo #3 AHU-H1

Photo #4 AHU-H2

Photo #5 AHU-H3.

Photo #6 AHU-H4.

Photo#7 AHU-H5

Photo #8 Typical ALC controllers

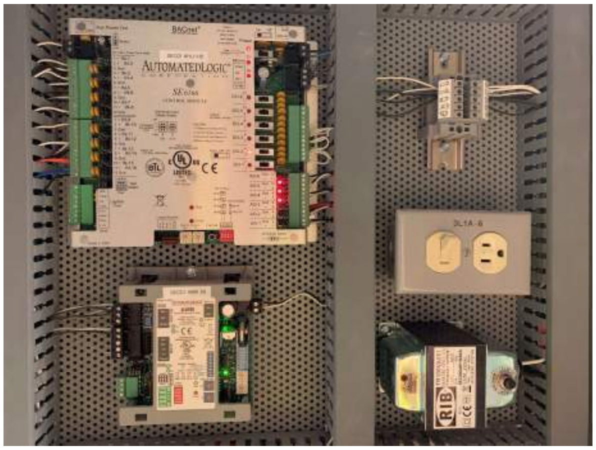


Photo #9 Typical ALC controllers for AHU -H5.

Photo #10 Lead/Lag hot water pumps which serve the Atrium and SAMIS.

Photo #11 Steam bundle heat exchanger serves two buildings from the basement mechanical room in the OU Childrens Physician's building.

Photo #12 Automated Logic graphics were reviewed for the SAMIS Education Center.

APPENDIX B
Test and Balancing Report

AIR APPARATUS TEST SHEET

Job Name: UHAT SAMMIS
Tested By: JACQUEMIN **Date:** 11/10/2020

DESIGN DATA :

Manufacturer =	TEMTROL	**Model No. =**	
Type =	AHU	**Serial No. =**	
Outside Air cfm =			
Total Scheduled cfm =	12,500	**Grille Design Schedule cfm =**	
Fan rpm =			
Total Static Pressure =		**External Static Pressure =**	2.30
Fan Rotation =			

MOTOR DESIGN DATA

Horsepower =	15	**Voltage =**	480	**Phase =**	3	**Rpm =**	

AIR TEST DATA

Total cfm by Traverse Readings =	14,600	**Total cfm by Grille Readings =**	
Outside Air =		**Return Air =**	

TEMPERATURE TEST DATA

Outside Air Temperature =	60DB/40WB	**Return Air Temperature =**	INA
Mixed Air Temperature =	70DB/58WB		

PRESSURE TEST DATA

Fan Suction Static Pressure =		-1.38	
Fan Discharge Static Pressure =		1.71	
	Total Static Pressure =		3.09
External Suction Static Pressure =		INA	
External Discharge Static Pressure =		INA	
	External Static Pressure =		NA
Cooling Coil ΔS.P. =	0.55	**Heating Coil ΔS.P. =**	0.10
Pre Filters ΔS.P. =	0.10	**Final Filters ΔS.P. =**	NA

MOTOR TEST DATA

Motor Manufacturer / Frame =		BALDOR/254T					
HP =	15	**Volts/Ph/Hertz =**	480/3/60	**Act. Voltage =**	468	468	468
Full Load Amps =			18.5	**Act. Amps =**	16.8	16.8	16.8
Service Factor =			1.15				
Motor Design rpm =			1765	**Act motor rpm =**		1768	

FAN TEST DATA

Motor Sheave Diameter =		**Motor Sheave Bore =**	
Fan Sheave Diameter =		**Fan Sheave Bore =**	
Adjustable Sheave Dia. =		**Centerline Distance =**	
Fan rpm =		**Fan Rotation =**	
Frequency Hz=	60		
Belts =			
Pre Filters =			
Final Filters =			

Comments: The delta p for HW Coil is across both the coil and pre filters, and vice versa. Airflow total for unit was determined by using face velocity across the coil.

AIR APPARATUS TEST SHEET

Job Name: UHAT SAMMIS
Tested By: JACQUEMIN **Date:** 11/10/2020

DESIGN DATA :

Manufacturer =	TEMTROL	**Model No. =**	
Type =	AHU	**Serial No. =**	
Outside Air cfm =			
Total Scheduled cfm =	14,500	**Grille Design Schedule cfm =**	
Fan rpm =			
Total Static Pressure =		**External Static Pressure =**	2.30
Fan Rotation =			

MOTOR DESIGN DATA

Horsepower =	15	**Voltage =**	480	**Phase =**	3	**Rpm =**	1765

AIR TEST DATA

Total cfm by Traverse Readings =	14355*	**Total cfm by Grille Readings =**	
Outside Air =		**Return Air =**	

TEMPERATURE TEST DATA

Outside Air Temperature =	60DB/40WB	**Return Air Temperature =**	INA
Mixed Air Temperature =	71.5DB/57.7WB		

PRESSURE TEST DATA

Fan Suction Static Pressure =		-0.73	
Fan Discharge Static Pressure =		2.40	
	Total Static Pressure =		3.13
External Suction Static Pressure =		INA	
External Discharge Static Pressure =		INA	
	External Static Pressure =		NA
Cooling Coil ΔS.P. =	0.29	**Heating Coil ΔS.P. =**	0.21
Pre Filters ΔS.P. =	0.21	**Final Filters ΔS.P. =**	NA

MOTOR TEST DATA

Motor Manufacturer / Frame =	BALDOR/254T						
HP =	15	**Volts/Ph/Hertz =**	480/3/60	**Act. Voltage =**	473	473	473
Full Load Amps =			18.5	**Act. Amps =**	14.1	14.1	14.1
Service Factor =			1.15				
Motor Design rpm =			1765	**Act motor rpm =**			1776

FAN TEST DATA

Motor Sheave Diameter =		**Motor Sheave Bore =**	
Fan Sheave Diameter =		**Fan Sheave Bore =**	
Adjustable Sheave Dia. =		**Centerline Distance =**	
Fan rpm =		**Fan Rotation =**	
Frequency Hz=	60		
Belts =			
Pre Filters =			
Final Filters =			

Comments: The delta p for HW Coil is across both the coil and pre filters, and vice versa. Airflow total for unit was determined by using face velocity across the coil.

AIR APPARATUS TEST SHEET

Job Name: UHAT SAMMIS
Tested By: JACQUEMIN **Date:** 11/10/2020

DESIGN DATA :

Manufacturer =	TEMTROL	**Model No. =**	
Type =	AHU	**Serial No. =**	
Outside Air cfm =			
Total Scheduled cfm =	6,400	**Grille Design Schedule cfm =**	
Fan rpm =			
Total Static Pressure =		**External Static Pressure =**	1.20
Fan Rotation =			

MOTOR DESIGN DATA

Horsepower =	7.5	**Voltage =**	480	**Phase =**	3	**Rpm =**	1770

AIR TEST DATA

Total cfm by Traverse Readings =	3994*	**Total cfm by Grille Readings =**	
Outside Air =		**Return Air =**	

TEMPERATURE TEST DATA

Outside Air Temperature =	55 / 40	**Return Air Temperature =**	INA
Mixed Air Temperature =	69.7 / 57		

PRESSURE TEST DATA

Fan Suction Static Pressure =		-0.14	
Fan Discharge Static Pressure =		0.26	
	Total Static Pressure =		0.40
External Suction Static Pressure =		INA	
External Discharge Static Pressure =		INA	
	External Static Pressure =		NA
Cooling Coil ΔS.P. =	0.10	**Heating Coil ΔS.P. =**	0.04
Pre Filters ΔS.P. =	0.04	**Final Filters ΔS.P. =**	NA

MOTOR TEST DATA

Motor Manufacturer / Frame =			BALDOR/213T				
HP =	7.5	**Volts/Ph/Hertz =**	480/360	**Act. Voltage =**	98	98	98
Full Load Amps =			9.4	**Act. Amps =**	2.8	2.8	2.8
Service Factor =			1.15				
Motor Design rpm =			1770	**Act motor rpm =**			717

FAN TEST DATA

Motor Sheave Diameter =		**Motor Sheave Bore =**	
Fan Sheave Diameter =		**Fan Sheave Bore =**	
Adjustable Sheave Dia. =		**Centerline Distance =**	
Fan rpm =		**Fan Rotation =**	
Frequency Hz=	24.4		
Belts =			
Pre Filters =			
Final Filters =			

Comments: The delta p for HW Coil is across both the coil and pre filters, and vice versa. Airflow total for unit was determined by using face velocity across the coil.

es2 engineered systems & energy solutions, inc.

AIR APPARATUS TEST SHEET

Job Name: UHAT SAMMIS
Tested By: JACQUEMIN **Date:** 11/10/2020

DESIGN DATA :

Manufacturer =	TEMTROL	**Model No. =**	
Type =	AHU	**Serial No. =**	
Outside Air cfm =			
Total Scheduled cfm =	9,600	**Grille Design Schedule cfm =**	
Fan rpm =			
Total Static Pressure =		**External Static Pressure =**	1.50
Fan Rotation =			

MOTOR DESIGN DATA

Horsepower =	10	**Voltage =**	480	**Phase =**	3	**Rpm =**	1760

AIR TEST DATA

Total cfm by Traverse Readings =	7680*	**Total cfm by Grille Readings =**	
Outside Air =		**Return Air =**	

TEMPERATURE TEST DATA

Outside Air Temperature =	55 / 40	**Return Air Temperature =**	INA
Mixed Air Temperature =	60.1/48.8		

PRESSURE TEST DATA

Fan Suction Static Pressure =		-0.22	
Fan Discharge Static Pressure =		0.28	
	Total Static Pressure =		0.50
External Suction Static Pressure =		INA	
External Discharge Static Pressure =		INA	
	External Static Pressure =		NA
Cooling Coil ΔS.P. =	0.16	**Heating Coil ΔS.P. =**	0.10
Pre Filters ΔS.P. =	0.10	**Final Filters ΔS.P. =**	NA

MOTOR TEST DATA

Motor Manufacturer / Frame =							
HP =	10	**Volts/Ph/Hertz =**	480/3/60	**Act. Voltage =**	*	*	*
Full Load Amps =			12.5	**Act. Amps =**	*	*	*
Service Factor =			1.15				
Motor Design rpm =			1760	**Act motor rpm =**			*

FAN TEST DATA

Motor Sheave Diameter =		**Motor Sheave Bore =**	
Fan Sheave Diameter =		**Fan Sheave Bore =**	
Adjustable Sheave Dia. =		**Centerline Distance =**	
Fan rpm =		**Fan Rotation =**	
Frequency Hz=	*		
Belts =			
Pre Filters =			
Final Filters =			

Comments: *The delta p for HW Coil is across both the coil and pre filters, and vice versa. Airflow total for unit was determined by using face velocity across the coil. The drive was busted at time of testing, was unable to chech running data.

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AIR APPARATUS TEST SHEET

Job Name: UHAT SAMMIS
Tested By: JACQUEMIN **Date:** 11/10/2020

DESIGN DATA :

Manufacturer =	TEMTROL	**Model No. =**	
Type =	AHU	**Serial No. =**	
Outside Air cfm =			
Total Scheduled cfm =	8,600	**Grille Design Schedule cfm =**	
Fan rpm =			
Total Static Pressure =		**External Static Pressure =**	2.50
Fan Rotation =			

MOTOR DESIGN DATA

Horsepower =	10	**Voltage =**	480	**Phase =**	3	**Rpm =**	1760

AIR TEST DATA

Total cfm by Traverse Readings =	9367*	**Total cfm by Grille Readings =**	
Outside Air =		**Return Air =**	

TEMPERATURE TEST DATA

Outside Air Temperature =	55 / 40	**Return Air Temperature =**	68.6 / 57.8
Mixed Air Temperature =	70.1 / 57		

PRESSURE TEST DATA

Fan Suction Static Pressure =		-0.41	
Fan Discharge Static Pressure =		1.92	
	Total Static Pressure =		2.33
External Suction Static Pressure =		-0.15	
External Discharge Static Pressure =		1.64	
	External Static Pressure =		1.79
Cooling Coil ΔS.P. =	0.24	**Heating Coil ΔS.P. =**	0.09
Pre Filters ΔS.P. =	0.09	**Final Filters ΔS.P. =**	NA

MOTOR TEST DATA

Motor Manufacturer / Frame =							
HP =	10	**Volts/Ph/Hertz =**	480/3/60	**Act. Voltage =**	361	361	361
Full Load Amps =			12.5	**Act. Amps =**	7.4	7.4	7.4
Service Factor =			1.15				
Motor Design rpm =			1760	**Act motor rpm =**			1331

FAN TEST DATA

Motor Sheave Diameter =		**Motor Sheave Bore =**	
Fan Sheave Diameter =		**Fan Sheave Bore =**	
Adjustable Sheave Dia. =		**Centerline Distance =**	
Fan rpm =		**Fan Rotation =**	
Frequency Hz=	44.7		
Belts =			
Pre Filters =			
Final Filters =			

Comments: The delta p for HW Coil is across both the coil and pre filters, and vice versa. Airflow total for unit was determined by using face velocity across the coil.

AIR APPARATUS TEST SHEET

Job Name: UHAT SAMMIS
Tested By: JACQUEMIN **Date:** 11/10/2020

DESIGN DATA :

Manufacturer =	TEMTROL	**Model No. =**	
Type =	AHU	**Serial No. =**	
Outside Air cfm =			
Total Scheduled cfm =	7,400	**Grille Design Schedule cfm =**	
Fan rpm =			
Total Static Pressure =		**External Static Pressure =**	2.30
Fan Rotation =			

MOTOR DESIGN DATA

Horsepower =	10	**Voltage =**	480	**Phase =**	3	**Rpm =**	1760

AIR TEST DATA

Total cfm by Traverse Readings =	8,200	**Total cfm by Grille Readings =**	
Outside Air =		**Return Air =**	

TEMPERATURE TEST DATA

Outside Air Temperature =	55 / 40	**Return Air Temperature =**	71.2 / 57
Mixed Air Temperature =	73.5 / 58.5		

PRESSURE TEST DATA

Fan Suction Static Pressure =		-0.93	
Fan Discharge Static Pressure =		2.14	
	Total Static Pressure =		3.07
External Suction Static Pressure =		-0.18	
External Discharge Static Pressure =			
	External Static Pressure =		
Cooling Coil ΔS.P. =	0.25	**Heating Coil ΔS.P. =**	0.18
Pre Filters ΔS.P. =	0.18	**Final Filters ΔS.P. =**	NA

MOTOR TEST DATA

Motor Manufacturer / Frame =		BALDOR/215T					
HP =	10	**Volts/Ph/Hertz =**	480/3/60	**Act. Voltage =**	475	475	475
Full Load Amps =			12.5	**Act. Amps =**	8.8	8.8	8.8
Service Factor =			1.15				
Motor Design rpm =			1760	**Act motor rpm =**			1758

FAN TEST DATA

Motor Sheave Diameter =		**Motor Sheave Bore =**	
Fan Sheave Diameter =		**Fan Sheave Bore =**	
Adjustable Sheave Dia. =		**Centerline Distance =**	
Fan rpm =		**Fan Rotation =**	
Frequency Hz=	59.5		
Belts =			
Pre Filters =			
Final Filters =			

Comments: The delta p for HW Coil is across both the coil and pre filters, and vice versa. Airflow total for unit was determined by using face velocity across the coil.

COIL APPARATUS TEST REPORT

Job Name: UHAT SAMIS Cx
Tested By: OGBURN **Date:** 11/17/2020

COIL DATA				
System Number	AHU-H0	AHU-H0	AHU-H1	AHU-
Location	1st Floor	1st Floor	1st Floor	1st Fl
Coil Type	CHW	HW	CHW	HW
No. Rows-Fins/ In.	NG	NG	NG	NG
Manufacturer	NG	NG	NG	NG
Model Number	NG	NG	NG	NG
Serial Number	NG	NG	NG	NG

Air Test Data	DESIGN	ACTUAL	DESIGN	ACTUAL	DESIGN	ACTUAL	DESIGN
Air Qty., CFM(l/s)	12500	-	12500	-	14500	-	14500
Air Vel. FPM (m/s)	500	-	650	-	505	-	680
Press. Drop In wg (Pa)	1.00	0.55	0.20	0.10	1.00	0.29	0.20
Out. Air DB/WB	-	-	-	-	-	-	-
Ret. Air DB/WB	-	-	-	-	-	-	-
Ent. Air DB/WB	NG	71.8/53.6	NG	70.2	NG	73.9/54.2	NG
Lvg. Air DB/WB	NG	49.3/42.1	NG	70.4	NG	49.7/41.6	NG
Air ΔT	NG	22.5/11.5	NG	0.2	NG	24.2/12.6	NG

Water Test Data	DESIGN	ACTUAL	DESIGN	ACTUAL	DESIGN	ACTUAL	DESIGN
Water Flow, GPM (l/s)	80.0	80.0	28.0	28.0	85.0	85.0	26.0
Press. Drop PSI (kPa)	2-32'	13.2	2-32'	2.0	2-32'	14.5	2-32'
Ent Water Temp.	NG	63.6	NG	78.1	NG	63.5	NG
Lvg. Water Temp.	NG	71.1	NG	74.3	NG	70.7	NG
Water ΔT	NG	7.5	NG	3.8	NG	7.2	NG

Refrigeration Test	DESIGN	ACTUAL	DESIGN	ACTUAL	DESIGN	ACTUAL	DESIGN
Exp. Valve/Refrig.	-	-	-	-	-	-	-
Refrig. Suction Press.	-	-	-	-	-	-	-
Refrig. Suction Temp.	-	-	-	-	-	-	-
Inlet Steam Press.	-	-	-	-	-	-	-

COMMENTS: Water temps were taken on outside of pipe.

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ACTUAL
-
-
0.21
-
-
70.2
72.6
2.4

ACTUAL
26.0
2.0
78.1
74.1
4.0

ACTUAL
-
-
-
-

COIL APPARATUS TEST REPORT

Job Name: UHAT SAMIS Cx
Tested By: OGBURN **Date:** 11/17/2020

COIL DATA				
System Number	AHU-H2	AHU-H2	AHU-H3	AHU-H3
Location	3rd Floor	3rd Floor	3rd Floor	3rd Floor
Coil Type	CHW	HW	CHW	HW
No. Rows-Fins/ In.	NG	NG	NG	NG
Manufacturer	NG	NG	NG	NG
Model Number	NG	NG	NG	NG
Serial Number	NG	NG	NG	NG

Air Test Data	DESIGN	ACTUAL	DESIGN	ACTUAL	DESIGN	ACTUAL	DESIGN	ACTUAL
Air Qty., CFM(l/s)	6400	-	6400	-	9600	-	9600	-
Air Vel. FPM (m/s)	500	-	650	-	500	-	500	-
Press. Drop In wg (Pa)	0.90	-	0.20	-	0.90	-	0.20	-
Out. Air DB/WB	-	-	-	-	-	-	-	-
Ret. Air DB/WB	-	-	-	-	-	-	-	-
Ent. Air DB/WB	NG		NG	81.0	NG		NG	
Lvg. Air DB/WB	NG		NG	82.1	NG		NG	
Air ΔT	NG		NG	1.1	NG		NG	

Water Test Data	DESIGN	ACTUAL	DESIGN	ACTUAL	DESIGN	ACTUAL	DESIGN	ACTUAL
Water Flow, GPM (l/s)	60.0	60.0	16.0	16.0	60.0	60.0	16.0	16.0
Press. Drop PSI (kPa)	2-32'	2.5	2-32'	3.0	2-32'	5.2	2-32'	3.5
Ent Water Temp.	NG	50.1	NG	118.2	NG	50.0	NG	122.4
Lvg. Water Temp.	NG	56.2	NG	110.9	NG	60.6	NG	115.4
Water ΔT	NG	6.1	NG	7.3	NG	10.6	NG	7.0

Refrigeration Test	DESIGN	ACTUAL	DESIGN	ACTUAL	DESIGN	ACTUAL	DESIGN	ACTUAL
Exp. Valve/Refrig.	-	-	-	-	-	-	-	-
Refrig. Suction Press.	-	-	-	-	-	-	-	-
Refrig. Suction Temp.	-	-	-	-	-	-	-	-
Inlet Steam Press.	-	-	-	-	-	-	-	-

COMMENTS:

COIL APPARATUS TEST REPORT

Job Name: UHAT SAMIS Cx
Tested By: OGBURN **Date:** 11/17/2020

COIL DATA				
System Number	AHU-H4	AHU-H4	AHU-H5	AHU-H5
Location	3rd Floor	3rd Floor	3rd Floor	3rd Floor
Coil Type	CHW	HW	CHW	HW
No. Rows-Fins/ In.	NG	NG	NG	NG
Manufacturer	NG	NG	NG	NG
Model Number	NG	NG	NG	NG
Serial Number	NG	NG	NG	NG

Air Test Data	DESIGN	ACTUAL	DESIGN	ACTUAL	DESIGN	ACTUAL	DESIGN	ACTUAL
Air Qty., CFM(l/s)	8600	-	8600	-	7400	-	7400	-
Air Vel. FPM (m/s)	505	-	500	-	505	-	650	-
Press. Drop In wg (Pa)	0.90	0.24	0.10	0.09	0.90	0.25	0.20	0.18
Out. Air DB/WB	-	-	-	-	-	-	-	-
Ret. Air DB/WB	-	-	-	-	-	-	-	-
Ent. Air DB/WB	NG	71.5/52.9	NG	70.7	NG	72.8/53.2	NG	70.9
Lvg. Air DB/WB	NG	48.9/41	NG	72.7	NG	56.8/45.1	NG	72.1
Air ΔT	NG	22.6/11.9	NG	2.0	NG	16/8.1	NG	1.2

Water Test Data	DESIGN	ACTUAL	DESIGN	ACTUAL	DESIGN	ACTUAL	DESIGN	ACTUAL
Water Flow, GPM (l/s)	80.0	80.0	12.0	12.0	80.0	80.0	12.0	12.0
Press. Drop PSI (kPa)	2-32'	2.0	2-32'	4.1	2-32'	6.0	2-32'	9.0
Ent Water Temp.	NG	48.8	NG	108.6	NG	50.1	NG	119.8
Lvg. Water Temp.	NG	54.8	NG	117.5	NG	59.1	NG	109.0
Water ΔT	NG	6.0	NG	8.9	NG	9.0	NG	10.8

Refrigeration Test	DESIGN	ACTUAL	DESIGN	ACTUAL	DESIGN	ACTUAL	DESIGN	ACTUAL
Exp. Valve/Refrig.	-	-	-	-	-	-	-	-
Refrig. Suction Press.	-	-	-	-	-	-	-	-
Refrig. Suction Temp.	-	-	-	-	-	-	-	-
Inlet Steam Press.	-	-	-	-	-	-	-	-

COMMENTS:

HW Coil on AHU-H4 has a hotter leaving temp than entering.

APPENDIX J
COMMUNICATION SPREADSHEET
LAST UPDATED - 03/22/2021

Update communication spreadsheet sent to UHAT for tracking purposes.

Building Name	Project Status: Data		Report Draft	Report Issued to Client	Completed	Scheduling Comments	Test Findings	Paragon Information Updated
	Collected	Not Collected	Date	Date	Yes / No			
ATM	2/9/2021		2/11/2021	2/17/2021	Yes	Data was scheduled to be collected on 10/13/20; rescheduled for 10/18/20; rescheduled for 10/28/20; rescheduled for 11/10/20; rescheduled for 11/17/20; started 11/18/20 with incomplete data sent on 11/30/20; rescheduled for 12/2/20; rescheduled for 12/9/20; rescheduled for 12/12/20 and incomplete reports sent to Terracon on 12/17/20; rescheduled for 02/04/21; completed data sent on 02/09/21.	Terracon noticed that air economizer setpoints were inconsistent for most AHUs. Setpoints varied from 45 degF to 70 degF. These operating setpoints can cause the building to be ventilated with excessive humidity during warmer days in the spring and fall seasons.	The information from this report has been entered in Paragon No update needed for FCI score
COM	2/9/2021		2/12/2021	2/17/2021	Yes	Data was scheduled to be collected on 10/13/20; rescheduled for 10/18/20; rescheduled for 10/28/20; rescheduled for 11/10/20; rescheduled for 11/17/20; started 11/20/20 with incomplete data sent on 11/30/20; rescheduled for 12/2/20; rescheduled for 12/9/20; rescheduled for 12/12/20; rescheduled for 02/04/21; completed data sent on 02/09/21.	Erik and Nathan to talk about the pump information and the associated work order - Discussion was completed and the work order remained in Paragon	The information from this report has been entered in Paragon No update needed for FCI score
MRI/OTC	Data collected Sent to Terracon 02/22		2/26/2021	3/5/2021	Yes	Data was scheduled to be collected on 12/12/20; rescheduled for 12/19/20; rescheduled for 02/05/21. Terracon to discuss manpower with ES2 moving forward - must be performed after hours (3pm or later) - Badge access cleared 02/10 - Data has been collected based on the conference call between ES2, Terracon, UHAT 02/19/21	Terracon is going need to review this with Nathan to go over everything that was found - The equipment condition ratings scores need to be updated to -Y and potentially R based on the data collected	Information will be entered into Paragon by 03/19/2021 FCI score was updated
NIC	02/22-03/01		3/11/2021	3/16/2021	Yes	Data scheduled to be collected 01/11/21; rescheduled - May run into some complications with collecting data - ES2 wants to factor that into the field work 02/22-03/01 Terracon received the information from ES2 - Erik is writing the report to be delivered on 03/16	Terracon found that AHU BM1, AHU 6N3, and AHU 5N1 did not match the original score issued in paragon	Information will be entered into Paragon by 03/26/2021
OUCP	02/19 (4th and 9th) 03/01-03/16		3/23/2021	3/26/2021	Yes	Appears that ES2 will be complete collecting data 02/19 for the 4th and 9th floors Remaining 12 units remaining on the remaining floors - ES2 plans to be back on site 03/04 to finishing collecting data - 7th, 12th floors complete (03/08) - Communication issues are causing delay (router) - ES2 looking at issue on 3/10 ES2 plans to be back onsite 03/15 to continue - Information collected and data sent to Terracon 03/18	Pump data collected 12/9/20 with ATM/SEC Pump data (same room);	Information will be entered into Paragon by 04/02/2021
SEC	12/9/2020		12/21/2020	12/24/2020	Yes	Data was scheduled to be collected on 10/13/20; rescheduled for 10/18/20; rescheduled for 10/28/20; rescheduled for 11/10/20; rescheduled for 11/17/20; started on 11/17/20 and incomplete data sent on 11/30/20; rescheduled for 12/2/20; rescheduled for 12/09/20 and complete data sent on 12/9/20.	Terracon found that HHWP-3 did not match the original score issued in paragon because of the operating performance for the pump does not match the design for the system and the equipment was operating in reverse.	The information from this report has been entered in Paragon
Garrison	6/25/2020		8/13/2020	8/13/2020	Yes	Field measurements began 06/02/20 and were completed 06/23/20.	Terracon found that AHU BG2, AHU 5G2, and AHU 5G3 did not match the original score issued in paragon because of excessive corrosion associated with the chilled water and hot water coils.	The information from this report has been entered in Paragon FCI score was updated
OUPB	6/18/2020		8/12/2020	8/12/2020	Yes	Field measurements began on 05/12/20 and were completed 06/16/20.	Terracon found that most of the equipment surveyed in the FCA matched our expectations; Terracon found that the some of the VFDs did not match the original score issued in paragon because the equipment was not properly operating and in need of replacements.	The information from this report has been entered in Paragon
Retro-Comissioning	Terracon was onsite 03/12			3/26/2021		Rx for Garrison building only - Terracon plans to have this portion of the scope of work by the final completion date of 03/26/2021 - Confirm Terracon badge access Terracon collected all available information while on-site (report to be issued 03/26) - The Level II ASHRAE audit is included in this deliverable. Terracon met 03/17 to discuss final steps on completion		