Consumers Energy
Existing Building Commissioning Report
Phase II – Systems Commissioning

Delta College

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October 15, 2010

Larry Ramseyer
Delta College
1961 Delta Road
University Center, MI 48710

RE: Existing Building Commissioning

Dear Larry Ramseyer,

The Consumers Energy Business Solutions team would like to thank you for your participation in Phase II of the Existing Building Commissioning Program. Commissioning has been identified as the most cost effective means of reducing energy costs, increasing equipment life, and improving occupant comfort for large commercial facilities. This study is continuing efforts towards controlling those costs.

The Existing Building Commissioning Program is one of many programs offered by Consumers Energy as part of our Consumers Energy Business Solutions program designed to help our customers implement energy efficiency measures in their facilities. Additional measures include incentives for energy efficient lighting retrofits, HVAC upgrades, and other equipment. This could include changes to processes and facilities that result in a net energy efficiency increase.

Please feel free to contact your account manager, or one of the energy advisors on the Consumers Energy Business Solutions team for more information on these opportunities.

We appreciate your interest in the Business Solutions Program and the energy efficiency efforts you are undertaking. If you have questions, please call the Business Solutions Team at 1-877-607-0737, or e-mail us at ConsumersEnergyBusinessSolutions@kema.com.

Sincerely,

The Consumers Energy Business Solutions Team
P.O. Box 1040
Okemos, MI 48805

EXISTING BUILDING COMMISSIONING REPORT
PHASE II – SYSTEMS COMMISSIONING

Consumers Energy Existing Building Commissioning Program

Delta College
University Center, Michigan

INTRODUCTION

Consumers Energy Business Solutions of Michigan provided Existing Building Commissioning (EBCx) Services. The pilot program will be used to determine the feasibility and cost effectiveness of a larger scale EBCx effort in the Consumers Energy territory.

The program is being broken down into three major phases:

1. Phase I – Operations and Maintenance Review: This phase establishes the current facilities requirements (CFR), evaluating schedules and setpoints, and identifying potential low and no cost facility improvement measures (FIMs). FIMs are focused on energy savings and improved facility performance.

2. Phase II – Systems Commissioning: This phase will include traditional commissioning activities including testing and diagnostics of the existing systems ability to meet the CFR and to further develop/quantify savings associated with energy savings facility improvement measures.

3. Phase III – Systems Optimization: This phase will focus on implementation of FIMs through capital improvements and introduction of new control strategies in order to bring existing systems to peak efficiency.

This report summarizes the findings for <u>Phase II</u> services provided by G/BA for Consumers Energy Business Solutions.

I. EXECUTIVE SUMMARY

Consumers Energy Business Solutions Existing Building Commissioning Pilot Program – Phase II had at its main goal to expand on Phase I energy savings findings by completing functional testing on selected heating and air conditioning equipment. Selection of systems to be tested was a collaborative process with Delta College operations personnel, Consumers Energy Business Solutions, and Grumman/Butkus Associates.

Testing of selected systems in lieu of all building systems enabled the pilot program dollars to spread further enabling a greater number of participants from Phase I screened candidates. Operations personnel participated in the testing process and it is planned that through this experience, Delta College would be able to carry the commissioning process forward to all systems of the building.

A. Building/Energy Information

The campus of Delta College located in University Center, Michigan (Saginaw area) includes multiple inter-connected building wings and the Consumers Energy Business Solutions Phase I/II existing building commissioning project focus was on the entire campus. The campus began construction in 1960 and multiple expansions have occurred through 2003. The campus is 932,812 gross square feet in size and consists of education and laboratory space. The tallest building of the campus is two stories.

The campus consumes energy at the rate of approximately 129,809 Btus/ft^2 per year (called the energy utilization index (EUI)) at the cost of approximately $1.39 per ft^2. Comparative data from the US Energy Information Administration for Commercial Buildings indicates that the average EUI in the education industry sector is 90,700 Btu/ft^2 per year or about a 30% reduction from what Delta College currently consumes. This suggests there may be opportunities for Delta College to take advantage in reducing energy consumption.

B. Facility Improvement Measure (FIM) Results

The following table indicates the FIMs that were identified as part of the Phase I/II commissioning process.

Table 1: Summary of Facility Improvement Measures

FIM	Description	Energy Savings ($)	Estimated Capital Cost ($)	Simple Payback (years)	Status/ Comments
1	Close Outside Air Dampers During Unoccupied AHU Start-up and during Morning Warm-up	$3,500-5,000	Negligible	<1	Partially complete [1]
2	Provide Morning Warm-up Optimal Start	$5,000-10,000	$1,000-5,000	<1	Partially complete [1]
3	Control AHU Preheat Coil Valves to Unoccupied Mixed Air Temperature Setpoints	$50-200	Negligible	<1	Partially complete [1]
4	Close Variable Air Volume Box Reheat Coil Valves when AHU is Off	$100-1,000	Negligible	<1	Open[3]
5	Close Outside Air Dampers on Gymnasium AHU-1 & 2 when AHU's are Off	$100-1,000	Negligible	<1	Completed
6	Lockout AHU Cooling Coil Control Valves during Morning Warm-up	$100-1,000	Negligible	<1	Completed
7	Reset AHU Mixed Air and Discharge Air Setpoints	$6,000-8,000	Negligible	<1	Open [1]
8	Reset Additional Variable Air Volume AHU Supply Air Static Pressure Setpoints	$1,500-1,750	Negligible	<1	Open [3]
9	Reduce Pool Filter Pump Operation A: Reduce Filter Pump Hours of Operation B: Reduce Filter Pump Speed During Unoccupied Hours	 $2,000-3,000 $4,000-7,000	 $1,000-2,000 $20,000-25,000	 <1 3-7	 Closed [4] Open [5]
10	Swimming Pool Cover	N/A	N/A	N/A	Closed [4]

11	Trim Pump Impellers A: Chiller-1 – CP-3 B: Chiller-2 – CP-5 & CP-6 C: East Courtyard Hot Water Radiation –CP-1 & CP-2 D: Pool Current and Slide Pump	 $4,000-6,000 $1,000-2,500 $500-1,500 $100-250	 $1,000-2,000 $2,000-4,000 $2,000-4,000 $2,000-4,000	 <1 1-4 2-8 8-40	 Open Open Open Open
12	Add Occupancy Sensors in Large Classrooms for Variable Air Volume Box Minimum Position Override Control	Varies	Varies	Varies	Open [6]
13	Greenhouse AHU-37 – Reconfigure AHU System to Include Return Air	$8,000-10,000	Varies	Varies	Open
14	Provide Control Valves for All Hot Water Unit Heaters	$75-150	$1,000-1,500	7-20	Open
15	High Efficiency Equipment Replacement	Varies	Varies	Varies	Closed [2]
16	Submetering	Varies	Varies	Varies	Open [5]
17	Eliminate Morning Warm-up Operation During Occupied Period	$100-500	Negligible	<1	Open
18	Correct Damper Control Signal Error	$100-500	Negligible	<1	Open
19	Reduce AHU-36 Heat Recovery Operation	$400-800	Negligible	<1	Open
20	Operate Secondary Chilled Water Pumps in Parallel	$300-500	$100-1,000	1-4	Open
21	Rebalance Chilled Water System	Varies	Varies	Varies	Open
22	Provide AHU Night Setup Cooling Control	Varies	Varies	Varies	Open
23	Provide VFDs for Hot Water Pumps	$5,000-7,000	$30,000-70,000	5-14	Open
24	Provide Lead/Lag Pumps for Ice System	$150-350	$15,000-20,000	>10	Open
25	Increase Chiller and Ice Storage Capacity	Varies	Varies	>10	Open
26	Increase Boiler Capacity	Varies	Varies	>10	Open

[1] Delta College (DC) has completed on a sample of units. Will complete rest of units during Phase II process.
[2] DC to review. No further investigation in Phase II by CE.
[3] DC has approved for implementation in Phase II
[4] Not accepted by DC
[5] Possible Phase III implementation
[6] Lighting occupancy sensors are currently being installed that could be utilized for VAV control in future.

Note that Consumers Energy Business Solutions and G/BA do not guarantee that proposals, bids or actual construction costs and stated energy savings will not vary from costs and savings contained herein.

If Delta College implements Facility Improvement Measures 1-8, 11a, and 17-20 the approximate annual savings is $21,000-36,000 with a capital cost of $2,100-8,000 providing a simple payback range of 1-5 months.

With the above listed measures implemented, Delta College could anticipate an overall reduction in utility consumption of 0.6-1.1%.

C. Operation and Maintenance Measures

The calculated energy savings for the O&M measures is the energy impact if the problem persisted for a full year and it is unknown how long the problems have existed; if the problem had started the day it was discovered and was corrected immediately there wouldn't actually be any change in the utility bills.

Energy savings have been calculated and listed for energy saving O&M measures but there are a few O&M measures which are causing poor space control or other issues which if corrected will actually result in more energy usage. The impact of correcting the O&M measures which result in more energy usage has not been included and will reduce overall savings.

Table 2: Energy Saving Operations and Maintenance Measures

O&M	Description	Energy Savings ($)	Estimated Capital Cost ($)	Simple Payback (years)	Status/ Comments
14	AHU-50 - Add Outside Air and Relief Damper Control	$800-1,200	$4,000-7,000	4-9	Open
21	Replace L Wing Differential Pressure Sensor	$2,500-3,500	$100-300	<1	Open

Note that Consumers Energy Business Solutions and G/BA do not guarantee that proposals, bids or actual construction costs and stated energy savings will not vary from costs and savings contained herein. O&M capital costs are assumptions, actual costs will vary greatly depending on the details of the problem and the actual method of resolution.

D. Suggested Implementation

It is suggested that all of the energy saving operation and maintenance (O&M) measures be addressed first because they have energy savings and may be negatively impacting other equipment in the building. Elimination of O&M issues will increase the success of other FIMs which modify setpoints and add resets and therefore the O&M issues should be resolved first. Then implement the FIMs identified with short simple paybacks of less than one year.

E. Extrapolation of Findings

The phase II commissioning process included functionally testing a sample of the equipment and if the remainder of the equipment was functionally tested it is expected that additional FIMs and O&M measures would be found and additional energy savings could be achieved. Including both short payback FIMs and O&Ms, it is anticipated that if all systems were tested the total savings identified would be about $37,000-63,000 with 0.05-0.2 year simple payback, and total energy cost reduction would be 1.8-3.1%. Given the potential for additional savings and for improving control additional functional testing is strongly recommended. In addition it is suggested that all equipment be tested to verify safeties and other alarming even if it is unlikely to have any implications on energy usage.

II. EXISTING BUILDING COMMISSIONING (EBCx) PROCESS OVERVIEW

A. The Building Commissioning Association defines Existing Building Commissioning (EBCx) as:

   1. Existing Building Commissioning is a systematic process for investigating, analyzing and optimizing the performance of building systems through identification and implementation of low/no cost and capital intensive Facility Improvement Measures (FIMs) and ensuring their continued performance.

B. The Existing Building Commissioning process assists in making the building systems perform interactively to meet the Current Facility Requirements (CFR) and provides the tools to support the continuous improvement of system performance over time.

C. The majority of existing buildings have not undergone any type of commissioning or quality assurance process. Additionally, over time the facility requirements change and the operational efficiencies of buildings tend to degrade. Because of these factors many buildings are performing well below their potential, use more energy than necessary and cost more to operate than they should. EBCx responds to an Owner's desire to improve building performance, solve comfort and operational problems and reduce operating costs.

D. Consumers Energy Business Solutions Existing Building Commissioning Pilot Program is in direct response to the above stated industry observations.

E. In whole building EBCx process, the purposes include:

   1. Verify that a facility and its systems meet the CFR.
   2. Improve building performance by saving energy and reducing operational costs.
   3. Identify and resolve building system operation, control and maintenance problems.
   4. Reduce or eliminate occupant complaints and increase tenant satisfaction
   5. Improve indoor environmental comfort and quality and reduce associated liability
   6. Document system operation
   7. Identify the Operations & Maintenance (O&M) personnel training needs and provide such training.
   8. Minimize operational risk and increase asset value
   9. Extend equipment life-cycle

10. Ensure the persistence of improvements over the building's life

F. Consumers Energy Business Solutions' Pilot Program certainly supports those concepts/purposes indicated above, but has narrowed the scope to include the following building systems:

1. HVAC Systems

2. Domestic hot water systems

3. Building controls/monitoring systems.

G. Also in the interest of ensuring the dollars allocated to the EBCx pilot program are efficiently utilized, the process is focusing on the identification of low/no cost energy conserving Facility Improvement Measurements.

H. To accomplish these goals of the pilot program, the program is employing a streamlined three phase EBCx process.

1. Phase I included screening facilities/owners and included identification of FIMs through 1-3 day site audits depending on the facility size.

2. Phase II is to be applied to those Phase I facilities that showed good FIM potential and the Owner was willing to commit dollars to implement low/no costs FIMs. Phase II will incorporate traditional functional testing as part of the EBCx process and will also include direct implementation of FIMs identified in Phase I that need no additional investigations.

3. Phase III will take Phase II facilities and employ capital improvement measures to further reduce energy consumption and to bring buildings to a higher level of operation to that realized in Phase II.

I. The Consumers Energy Business Solutions EBCx Pilot Program will employ a sampling of the building systems targeted for the program. With this approach it is hoped that the lessons learned while working with the operations/engineering staff within the facilities will be carried forward to the remaining systems of the facility by the same personnel that participated with Consumers Energy Business Solutions in the EBCx Pilot Program.

1. See Exhibit 5 for systems included for testing.

III. EXISTING BUILDING COMMISSIONING PLAN

A. The Existing Building Commissioning (EBCx) Plan is a living document developed and updated by the EBCx Provider (EBCxP) that outlines the organization, roles and responsibilities, schedule, allocation of resources and documentation requirements of the EBCx Process.

B. Existing Commissioning Team

1. The EBCx Team consists of individuals who through coordinated actions are responsible for implementing the EBCx Process.

2. See EBCx Team Directory (Exhibit 1) for a table listing the primary members of the EBCx Team (EBCxT).

C. EBCx Team Roles and Responsibilities

1. Owner/Facility Representative

a. The most significant role is to support the existing building commissioning team and provider's efforts to complete the work
b. Assign appropriate in-house staff to the project
c. Define the lines of communication between the team members
d. Work with the EBCx provider to establish the EBCx plan and how to best leverage existing resources to streamline the project and reduce costs
e. Support the EBCx provider by facilitating communication between the EBCx provider and other project team members as needed
f. Assign building operators to assist with as much of the EBCx commissioning process as possible to improve their understanding of the equipment and control strategies.

i. Personnel assigned should have direct knowledge of building energy consuming systems including, at minimum, the targeted systems.
ii. Personnel assigned should have knowledge of company standards and policies affecting the building systems infrastructure.

g. Assist with the performance of manual functional testing as needed
h. Gather building documentation

i. Perform appropriate preventive maintenance and EBCx generated checklist tasks prior to any diagnostic or functional testing.
j. Assist in installing and removing short-term diagnostic monitoring equipment
k. Gather trend information from the BMS as required
l. Inform the building occupants of the intended EBCx work as needed
m. Require and review progress reports and meeting minutes
n. Attend EBCx meetings when appropriate.

2. Existing Building Commissioning Provider (Consumers Energy Business Solutions)

a. Coordinate and direct EBCx activities during all phases of the project.
b. Identify what documentation, drawings, data, and other information will be required
c. Develop a building-specific EBCx plan
d. Develop agendas and facilitate all EBCx meetings
e. Subcontract test and balance contractor for possible air and water system testing
f. Submit progress reports and commissioning meeting notes to the project EBCxT
g. Perform on-site assessment of the present maintenance practices and operating strategies noting all possible deficiencies and improvements
h. Understand warranties and service contracts that are in place and how they can be leveraged on the project
i. Develop monitoring and testing plans
j. Perform short-term diagnostic monitoring, using BMS trend logging where appropriate
k. Develop, oversee, and document functional test procedures as needed
l. Develop "Master Lists" of facility improvements measures
m. Review with Owner all data gathered and master list of improvement measures identified prior to detailed calculations of savings and costs
n. Calculate the annual energy savings for each facility improvement measure (FIM) identified and the associated probable construction cost
o. Assist Owner in implementation of FIMs identified in Phase I that need no further investigation
p. Prepare EBCx Report describing the services performed, summarizing the results obtained and provide recommendation

prioritizing the most cost-effective improvements for implementation for the existing systems

q. Meet with Owner to review EBCx Report and to assist Owner in selection of FIMs identified in Phase II for implementation.

D. EBCx Scope of Work

1. Conduct a Phase II kickoff meeting with the Consumers Energy Business Solutions representative and the building Owner.

   a. Review the Phase I report and the identified facility improvement measures (FIMs)

   b. Look to establish agreement with building Owner that the FIMs identified are applicable for the building and the building Owner supports their further investigation or implementation.

2. Discuss with building Owner the direct implementation of selected FIMs identified in Phase I without further study. Consumers Energy Business Solutions to provide technical guidance and scope document for the building Owner to contract directly with those entities that will implement the specific FIM. Note that Consumers Energy Business Solutions technical guidance would be answering questions related to the interpretation or intent of FIMs to be implemented directly. In most cases, the building Owner would be contracting their control contractor to carry out implementation of measures.

3. Gather and review relevant EBCx systems existing documentation. Documentation to include:

   a. Drawings (MEP and architectural)

   b. Shop drawings

   c. Control system Documentation

      i. Obtain control system sequences of operation for EBCx systems.

      ii. Obtain shop drawings, system schematics, complete point list associated with DDC system pertaining to EBCx systems.

      iii. Identify existing available trend logs already created and others to be created to aid in analyzing system performance.

   d. Test and balance reports.

4. Develop EBCx Phase II plan with input from building Owner staff. EBCx plan to include the following at minimum:

   a. General building information and contacts (name, address, phone numbers, etc.)

   b. Project objectives

c. Building systems to be included in EBCx process
d. Project scope
e. Roles and responsibilities
f. Schedule (for primary tasks)
g. Documentation
h. Investigation scope and methods

5. Discuss EBCx Plan with building Owner engineering and operations personnel and agree to the EBCx Phase II Plan.

6. Develop written functional test procedures to further investigate FIMs identified in Phase I and to identify additional FIMs.

7. Test systems to determine sequence is operating as intended and evaluate sequence for the given application and possible modifications for energy savings. Testing to be completed on HVAC systems as agreed to by building Owner and Consumers Energy Business Solutions. Note that a sampling strategy will be utilized on equipment of the EBCx Systems determined by Consumers Energy Business Solutions with input from building Owner.

8. Data representative of actual facility operating status are necessary both to provide insight into the operation of equipment and to support engineering calculations that may form the basis for savings associated with FIMs. Collection of these operational perimeters will be done using the existing BMS, BMS trending, and handheld meters.

9. Based on the preceding data collected and testing completed prepare an updated master list of FIMs. This list will include low cost/no cost and capital improvement projects.

10. Review with building Owner all data gathered and master list of FIMs identified prior to engineering calculations of savings and costs (if applicable).

11. Calculate the annual energy savings (where applicable) for FIMs so identified.

12. Estimate the probable construction cost to implement each FIM and calculate simple payback of FIMs (where applicable).

    a. Note: Facility Improvement measures with greater than 2 year simple payback will be listed but no calculations/cost estimates will be completed.

13. Identify O&M staff training needs.

14. Identify documentation enhancement needs for the systems being included in the EBCx project.

15. Prepare a EBCx Report describing the services performed, summarizing the results obtained and recommendations.

16. Meet with building Owner to review the EBCx Report and to assist in selection of FIMs for implementation.

E. EBCx Project Deliverables

1. See EBCx Deliverables (Exhibit 3) for a table listing those deliverables that are to be provided as part of this EBCx project.

F. EBCx Meetings

1. An EBCx kick-off meeting will be held at the project site.

2. Additional EBCx meetings will be held periodically, scheduled by Owner or EBCxP to discuss progress and upcoming events.

G. EBCx Schedule

1. It is the role of EBCxP to prepare a schedule for the project for Owner review, comment and approval.

2. Look to Exhibit 4 for the schedule of project.

3. EBCxP shall update schedule periodically to reflect changes that have occurred during the course of the project.

IV. BUILDING DESCRIPTION/ENERGY DATA

The campus of Delta College located in University Center, Michigan (Saginaw area) includes multiple inter-connected building wings and the Consumers Energy Phase I existing building commissioning project focus was on the entire campus. The campus began construction in 1960 and multiple expansions have occurred through 2003. The campus is 932,812 gross square feet in size and consists of education and laboratory space. The tallest building of the campus is two stories.

All building wings are heated and/or air conditioned by air handling units. The heating for the campus is provided by three steam boilers (2 – 500BHP & 1 – 250 BHP) that are located in the powerhouse building. Steam is supplied to air handling heating coils for ventilation air heating. Steam is also supplied to hot water heat exchangers in most campus building wings to produce heating hot water. The heating hot water pumping systems for the building wings include either stand-alone or lead/standby hot water pumps, half of which are equipped with variable frequency drives. The heating hot water is distributed to perimeter radiation, reheat coils, and air handling heating coils. Air handling unit chilled water coil, hot water heating coil and steam heating coil control valves are two way. There are two water cooled centrifugal chillers (800 tons each) that serve the campus air handling unit cooling coils as well as build ice during off-peak electrical rate hours for chilled water cooling during peak electrical rate hours. One absorption chiller is used sparingly only during high cooling load conditions. Chiller cooling towers are also utilized for free cooling when the outdoor air conditions are suitable and the towers have variable speed fans.

The utility data presented in Table 1 below is for the entire campus that was included in the existing building commissioning process.

Table 2: Building Energy Data

2008-2009 Fiscal Year	Electric	Natural Gas	Totals
Usage	13,132,800 kWh	73,973 Mcf	-
Cost ($)	836,896	460,533	1,297,429
MMBtu	44,822	76,266	121,088
Btu/ft^2 – yr*	48,050	81,759	129,809
$/ft^2 – yr*	0.90	0.49	1.39

* Based on campus building area of 932,812 GSF

The current facility requirements (CFR) for the building were provided by Larry Ramseyer, Director of Facilities Management of Delta College. The CFR can be found in Exhibit 2 of this report.

V. FACILITY IMPROVEMENT MEASURES

This section of the report contains facility improvement measures (FIMs) that were identified through the existing building commissioning process. There is a brief narrative for each measure, energy savings projections, energy cost savings and probable capital costs to implement the short payback measures. The simple payback period is presented and is the capital cost divided by the energy savings. For each FIM, certain basic data was utilized and assumptions made to arrive at the projected savings. The basic data came primarily from field surveys, interviews with operations staff, record drawings, nameplate data, trend data analysis and functional performance testing. Note that implementation costs of FIMs do not include Owner project management personnel fees that may be applicable to the listed FIM.

Delta College has maintenance personnel capable of making both setpoint and programming modifications in the building automation system (BAS) and therefore the capital costs associated with any measure which strictly involves setpoint or easy to moderately complex programming modifications is listed as negligible because it is assumed this work will be performed by the College's on-site staff.

A sampling of the equipment was functionally tested, trended, and analyzed during phase II to find additional FIMs and O&M measures from that found in Phase I. The functional testing and analysis focused on energy usage and therefore safeties and alarming were not tested. AHU-1, 28, 32, 36, 39, and 45 were functionally tested. The chilled water plant was analyzed using trends and observed conditions but was not functionally tested due to electrical demand spikes and other problems which would occur if full testing was performed.

The majority of low and no cost facility improvement measures (FIMs) are associated with control changes and many of the FIMs strictly involve setpoint changes. In the interest of quickly addressing a complaint or problem setpoints can easily be changed by anyone on the maintenance staff and never changed back. *Changes to setpoints can have a significant impact on energy usage and therefore it is very important that some form of change control be implemented to track changes and ensure that any modifications are properly documented along with the rationale for these changes.*

FIM 1 (PH-I): Close Outside Air Dampers During Unoccupied AHU Start-up and during Morning Warm-up: All AHU's controlled by the American Auto-Matrix control system have their outdoor air dampers open during unoccupied AHU setback and/or setup operation and during early startup for morning warm-up. These AHU's also do not have true morning warm-up sequence as they are all started at an operator selected time prior to occupancy. This applies to a total of 25 AHU's. It is suggested that these AHU's be reprogrammed to keep the outside air dampers closed during unoccupied setback/setup startup and be reprogrammed with a true morning warm-up cycle.

(PH-II): This FIM has been implemented on some of the AHUs but the controls are sending the incorrect signal to the dampers which is resulting in the outside air damper being partially open both during unoccupied shutdown and when the air handling units turn on to provide unoccupied heating/cooling. The issue was corrected when testing AHU-28 but it should be fixed on the other units as well.

Annual Energy Savings	(kWh/yr)	16,000-20,000
	(Mcf/yr)	200-300
	($)	$3,500-5,000
Capital Cost	($)	Negligible
Simple Payback	(yrs)	<1

FIM 2 (PH-I): Provide Morning Warm-up Optimal Start: The units controlled by the Trane control system have a morning warm-up cycle of a preset length regardless of how far the space is from setpoint. It is suggested that an optimal start sequence be provided which determines the duration of morning warm-up based on how far the spaces are from occupied temperature setpoints and adjusts these durations based on historical trends. The addition of a true morning warm-up cycle for the AHUs controlled by the Auto-Matrix control system is suggested as a separate measure and the new morning warm-up sequence for these units should also be provided with an optimal start.

Annual Energy Savings	(kWh/yr)	50,000-100,000
	($)	$5,000-10,000
Capital Cost	($)	$1,000-5,000
Simple Payback	(yrs)	<1

FIM 3 (PH-I): Control AHU Preheat Coil Valves to Unoccupied Mixed Air Temperature Setpoints: All AHU's controlled by the American Auto-Matrix BAS have their preheat coil control valves controlling to occupied discharge air temperature setpoints even when the AHU is off. This applies to a total of 26 AHU's. It is suggested that these AHU's be reprogrammed to control the preheat coil valves to a reduced mixed air temperature setpoint when the unit is off to minimize energy usage while still preventing freezing.

Annual Energy Savings	($)	$50-200
Capital Cost	($)	Negligible
Simple Payback	(yrs)	<1

FIM 4 (PH-I): Close Variable Air Volume Box Reheat Coil Valves when AHU is Off: All AHU's controlled by the American Auto-Matrix building automatic system have their variable air volume (VAV) box reheat coil control valves under control from occupied room air temperature setpoints even when the AHU is off. This applies to a total of 15 AHU's and 190 VAV boxes. It is suggested that these VAV box controllers be reprogrammed to close the reheat coil valves when the associated AHU is off.

Annual Energy Savings	($)	$100-1,000
Capital Cost	($)	Negligible
Simple Payback	(yrs)	<1

FIM 5(PH-I): Close Outside Air Dampers on Gymnasium AHU-1 & 2 when AHU's are Off: When AHU-1 & 2 are off, their outdoor air dampers remain open resulting in infiltration and forcing the heating coils to control to occupied discharge air temperature setpoints. It is suggested that these AHU's be reprogrammed to close their outdoor air dampers when their fans are off.

Annual Energy Savings	($)	$100-1,000
Capital Cost	($)	Negligible
Simple Payback	(yrs)	<1

FIM 6(PH-I): Lockout AHU Cooling Coil Control Valves during Morning Warm-up: Upon initial AHU startup for all AHU's controlled by the American Auto-Matrix control system, the outdoor dampers are held closed while the preheat coil valve is opened to warm the AHU plenum. During this time, the chilled water coil valve is under control to cool down the discharge air temperature resulting in energy waste. This applies to a total of 25 AHU's. It is suggested that these AHU's be reprogrammed to lock out the cooling coil valve control during morning warm-up.

Annual Energy Savings	($)	$100-1,000
Capital Cost	($)	Negligible
Simple Payback	(yrs)	<1

FIM 7(PH-I): Reset AHU Mixed Air and Discharge Air Setpoints: Many AHU's do not have their mixed air damper, preheat coil valve, cooling coil valve and reheat coil valve control loop setpoints being reset by room air temperature. This applies to a total of 76 control loops. Some of the air handling units only have some of the setpoints reset and therefore the unit may sometimes be heating or cooling unnecessarily to make up the difference between the setpoints. It is suggested that all of these control loop setpoints be reprogrammed to be reset by room air temperature.

Annual Energy Savings	(Mcf/yr)	600-800
	($)	$6,000-8,000
Capital Cost	($)	Negligible
Simple Payback	(yrs)	<1

FIM 8 (PH-I): Reset Additional Variable Air Volume AHU Supply Air Static Pressure Setpoints: Only some of the AHU's have their supply air static pressure control loop setpoints being reset by cumulative variable air volume (VAV) box airflow. A total of 10 AHU's do not have reset control. It is suggested that these static setpoints be reprogrammed to be reset by cumulative VAV box airflow similar to the other units if possible.

Annual Energy Savings	(kWh/yr)	15,000-17,500
	($)	$1,500-1,750
Capital Cost	($)	Negligible
Simple Payback	(yrs)	<1

FIM 9 (PH-I): Reduce Pool Filter Pump Operation: The pool filter pump operates continuously and it may be possible to reduce the hours of operation or the flow while still maintaining proper water quality.

A: Reduce Filter Pump Hours of Operation: The pool filter pump should be able to be shut off for some of the unoccupied hours if timeclock control was added. The below savings are representative of a 3 hour reduction per day but the actual shutdown duration should be determined by increasing and decreasing the shutdown duration while monitoring water quality to determine the maximum allowable shutdown.

Annual Energy Savings	(kWh/yr)	20,000-30,000
	($)	$2,000-3,000
Capital Cost	($)	$1,000-2,000
Simple Payback	(yrs)	<1

B: Reduce Filter Pump Speed During Unoccupied Hours: A more sophisticated method of saving pool filter pump energy would be to install a variable frequency drive on the filter pump and to reduce the pump speed during all unoccupied hours which would reduce pumping energy while still providing continuous circulation and water filtration. The actual unoccupied pump speed should be determined by increasing and decreasing the speed while monitoring water quality to determine the minimum allowable speed.

Annual Energy Savings	(kWh/yr)	40,000-70,000
	($)	$4,000-7,000
Capital Cost	($)	$20,000-25,000
Simple Payback	(yrs)	3-7

FIM 10 (PH-I): Swimming Pool Cover: The swimming pool does not have a cover. It is suggested that the feasibility of using a swimming pool cover be evaluated and that the cover be used to cover the swimming pool during unoccupied periods. **(PH-II):** Room temperature is approximately the same as the pool temperature and room temperature is not reset at night. Given the irregular pool shape and minimal temperature difference a pool cover will not be worthwhile.

FIM 11 (PH-I): Trim Pump Impellers: Multiple pumps were found with their balance valves partially closed. It is suggested that the impellers for these pumps be trimmed to provide the required water flow at a lower pressure head and that the balance valves be opened.

A: Chiller-1 – CP-3: Chilled water pump CP-3 was found with its balance valve 10% open.

Annual Energy Savings	(kWh/yr)	40,000-60,000
	($)	$4,000-6,000
Capital Cost	($)	$1,000-2,000
Simple Payback	(yrs)	<1

B: Chiller-2 – CP-5 & CP-6: Chilled water pump CP-5 and condenser water pump CP-6 were found with their balance valves 20% open and 50% open, respectively.

Annual Energy Savings	(kWh/yr)	10,000-25,000
	($)	$1,000-2,500
Capital Cost	($)	$2,000-4,000
Simple Payback	(yrs)	1-4

C: East Courtyard Hot Water Radiation –CP-1 & CP-2: Hot water pumps CP-1 and CP-2 were found with their balance valves 30% open.

Annual Energy Savings	(kWh/yr)	5,000-15,000
	($)	$500-1,500
Capital Cost	($)	$2,000-4,000
Simple Payback	(yrs)	2-8

D: Pool Current and Slide Pump: Pool current and slide pumps were found with their balance valves 50% open and 40% open, respectively.

Annual Energy Savings	(kWh/yr)	1,000-2,500
	($)	$100-250
Capital Cost	($)	$2,000-4,000
Simple Payback	(yrs)	8-40

FIM 12 (PH-I): Add Occupancy Sensors in Large Classrooms for Variable Air Volume Box Minimum Position Override Control: The variable air volume (VAV) boxes serving the rooms use a timeclock to determine occupancy but there are likely many times throughout the day when the spaces are actually unoccupied but the VAV box continues to provide the occupied minimum airflow. The addition of occupancy sensors to detect the actual occupancy of the room and reducing the VAV box minimum damper position when the space is unoccupied will save both fan and reheat energy. The savings and payback for this FIM will be best for large classrooms/conference rooms which are frequently unoccupied.

Annual Energy Savings	($)	Varies
Capital Cost	($)	Varies
Simple Payback	(yrs)	Varies

FIM 13(PH-I): Greenhouse AHU-37 – Reconfigure AHU System to Include Return Air: The existing greenhouse AHU is designed as 100% outside air but it does not appear that this is required. It is suggested that the unit be modified to include some return air. Savings are based on 100% outside air unit; currently an access door on the unit is being left open which is allowing some return air to be provided to the unit and therefore actual savings may be less.

Annual Energy Savings	(kWh/yr)	3,000-5,000
	(Mcf/yr)	700-1,000
	($)	$8,000-10,000
Capital Cost	($)	NI
Simple Payback	(yrs)	NI

FIM 14 (PH-I): Provide Control Valves for All Hot Water Unit Heaters: Currently all hot water unit heaters in mechanical rooms do not have control valves. Room temperature is controlled by cycling the unit heater fan on/off. When the room temperature is satisfied hot water still flows through the unit heater coil, potentially overheating the room. It is suggested that two way control valves be installed for each unit heater and controlled from the room.

Annual Energy Savings	($)	$75-150 (each)
Capital Cost	($)	$1,000-1,500 (each)
Simple Payback	(yrs)	7-20

FIM 15 (PH-I): High Efficiency Equipment Replacement: Some of the existing equipment is old and may be approaching the end of its useful life. When the equipment needs to be replaced it is suggested that higher efficiency equipment be installed. The incremental cost for higher efficiency equipment may have a very attractive payback for some of the systems.

FIM 16 (PH-I): Submetering: Submetering allows for additional monitoring of individual loads or groups of loads (i.e. HVAC equipment or office equipment). There is no direct payback for additional metering but the greater monitoring capability should result in a number of benefits if the energy usage is properly monitored and evaluated. Metering allows operating personnel to more easily determine when a system has a problem that is wasting energy and also makes it much easier to determine the effectiveness of any other energy conservation measures that have been performed.

FIM 17 (PH-II): Eliminate Morning Warm-up Operation During Occupied Period: For all Trane BAS controlled AHU's; the AHU's go into morning warm-up mode anytime during the unoccupied or occupied period if average space temperature is less than 68F. The preheat coil valve is controlled to maintain 128F discharge air temperature setpoint. Morning warm-up should not be functional during the occupied period. The unoccupied warm-up (night setback) space temperature setpoint of 68F is too high and should be readjusted to 60F to save energy.

Annual Energy Savings	($)	$100-500
Capital Cost	($)	Negligible
Simple Payback	(yrs)	<1

FIM 18 (PH-II): Correct Damper Control Signal Error: For all American Auto-Matrix (AAM) BAS controlled AHU's, the unoccupied mode control output for the OA/RA/Rlf dampers is at 0% but the outside and relief air damper actuators are receiving a 4.48VDC signal keeping them partially open. This issue (wiring problem) was corrected on AHU-28, but needs to be corrected for all other AAM BAS controlled AHUs.

Annual Energy Savings	($)	$100-500
Capital Cost	($)	Negligible
Simple Payback	(yrs)	<1

FIM 19 (PH-II): Reduce AHU-36 Heat Recovery Operation: The heat recovery pump for AHU-36 runs whenever the outside air temperature is greater than 5F above or below the current average room temperature. The discharge air temperature setpoint is reset based on average room temperature, so when the spaces are heavily loaded and the outside air temperature is between 55F and 70F the heat recovery is likely running unnecessarily. During these conditions the heat recovery will be adding excess heat to the air that the cooling coil has to remove which wastes cooling energy as well as the heat recovery pump energy. It is suggested that additional control logic be provided which prevents the heat recovery pump from running when both the outside air temperature is above the discharge air temperature (DAT) setpoint and the DAT setpoint is below the average room temperature.

Annual Energy Savings	(kWh/yr)	4,000-8,000
	($)	$400-800
Capital Cost	($)	Negligible
Simple Payback	(yrs)	<1

FIM 20 (PH-II): Operate Secondary Chilled Water Pumps in Parallel: The secondary chilled water pumps are large pumps which operate in lead/standby with one pump modulating while the other pump is off. There are a number of valves and other piping specialties for each of the pumps and these valves have a pressure drop which increases greatly at higher flows. It is suggested that the pumps both be modulated together to satisfy setpoint instead of having just one pump operate because this should reduce the total pressure drop and save energy. The pumps are controlled by a standalone Bell and Gossett controller and therefore this modification may not easily be able to be performed by on-site personnel.

Annual Energy Savings	(kWh/yr)	3,000-5,000
	($)	$300-500
Capital Cost	($)	$100-1000
Simple Payback	(yrs)	1-4

FIM 21 (PH-II): Rebalance Chilled Water System: The chiller plant has been in place for 16 years but no chilled water system test and balance reports could be found. It is suggested that a full balance of the chilled water system be performed to ensure the flows are properly balanced and if any balance problems are found they should be corrected to save energy and improve control.

FIM 22 (PH-II): Provide AHU Night Setup Cooling Control: Currently the air handling units that shut down during the unoccupied period do not restart until the occupied period begins (no cooling optimum start is provided). The spaces are very warm on Monday mornings during the summer so the required load exceeds the centrifugal chiller capacity so the less efficient absorber sometimes has to be run. An additional problem on summer Monday mornings is that the load in the space is so great that the secondary chilled water flow exceeds the primary water flow which results in mixing and an increase in secondary loop supply temperature. This increase in secondary temperature causes the chilled water coil performance to degrade, which in turn causes the control valves to open more to demand more flow, which in turn causes ever increasing flow in the secondary loop and even warmer supply water temperatures. Due to the high demand and mixing issues the spaces sometimes do not achieve setpoint before the building is occupied which can make them uncomfortable for the occupants. This cyclical problem is resolved when ice burn is initiated due to the low chilled water supply temperature but this speeds up the ice burn process and makes it more difficult to get through the peak hours without running out of ice. It is suggested that the addition of night setup cooling control be provided at least on the weekends which would turn on the air handling units if the spaces got too hot. The setup control should be programmed in a way that minimizes the impact on the ice build process either by only allowing the AHUs to operate during hours when ice building isn’t occurring or by ensuring only 1 or 2 air handling units is allowed to turn on for setup operation at a time. Setup control will help reduce the Monday morning cooling demand, reduce/eliminate chilled water mixing, lengthen the duration of the ice burn, and prevent the spaces from being too hot in the morning.

FIM 23 (PH-II): Provide VFDs for Hot Water Pumps: There are many hot water pumps that have no variable frequency drives (VFDs) applied to them. Per site personnel these systems consist entirely of 2-way valves and do not have bypass control, suggesting that savings could be realized if VFDs were installed. The calculated savings is representative of installing VFDs on all of the systems which have 5 or 7.5HP pumps; if smaller pumps were included it would increase savings but the payback would be longer. Capital cost and payback will vary depending on whether VFDs are provided on one or both of the pumps in each pair. During periods of low load most or all of the control valves could be closed which could result in deadheading of the pumps and adding VFDs would reduce this problem and therefore could also result in reduced maintenance costs.

Annual Energy Savings	(kWh/yr)	50,000-70,000
	($)	$5,000-7,000
Capital Cost	($)	$30,000-70,000
Simple Payback	(yrs)	5-14

FIM 24 (PH-II): Provide Lead/Lag Pumps for Ice System: Pump CP-9 operates during ice build and ice melt modes to pump water through the ice storage system. The pump speed is controlled with a variable speed drive (VFD) but sometimes during ice burn the pump is at minimum speed and the pump is still providing too much flow. Excessive flow through CP-9 causes very cold secondary chilled water temperatures which wastes energy and reduces the duration of ice burn. In addition it was observed that the balance valve for CP-9 was almost entirely closed which was likely done to reduce the flow but this results in excess energy usage. It is suggested that a second, smaller pump be provided in parallel with CP-9 which would operate instead of CP-9 during periods of low load to eliminate overpumping and reduce energy usage.

Annual Energy Savings	(kWh/yr)	1,500-3,500
	($)	$150-350
Capital Cost	($)	$15,000-20,000
Simple Payback	(yrs)	>10

FIM 2 (PH-II): Increase Chiller and Ice Storage Capacity: The existing chiller plant very seldom runs out of ice but this is sometimes accomplished by running one chiller in demand limiting mode during ice melt instead of strictly using ice. If the ice is not totally depleted the ice storage capacity and the chiller sizing is relatively well matched so to increase ice ability both the chiller and storage capacity would need to be upsized. Replacing the absorber with a larger centrifugal chiller would be especially beneficial because it would both increase capacity and increase the chiller efficiency.

FIM 23 (PH-II): Increase Boiler Capacity: The campus boiler capacity is insufficient so AHU's are started at fixed times in the morning but spaced out to prevent instantaneous high boiler load. Some AHU's are started as early as 5:30 am whether they need to or not to heat their spaces to occupied temperature before the occupied period begins. Some AHU's achieve occupied space temperature hours before occupancy and then shutdown until the occupied period begins. These spaces may not be at occupied temperature when the occupied period begins as they do not restart if the space temperature falls before occupancy. Additional boiler capacity is needed to efficiently provide AHU morning warm-up.

VI. OPERATION AND MAINTENANCE RECOMMENDATIONS

1. **A Wing - Replace missing HWS gauge for one of the HX2 HW pumps. (PH-I)**

   (PH-II): The pipe has an empty well and is not missing a gauge and therefore there is no problem.

2. **F Wing - Repair leaking HE3 HW pump (PH-I).**

   (PH-II): Leak has been repaired.

3. **L Wing - Repair heat exchanger gaskets to eliminate water leaks. (PH-I)**

   (PH-II): Leak has been repaired.

4. **L Wing - Replace non-functioning heat exchanger pump discharge pressure gauge. (PH-I)**

   (PH-II): Gauge has been replaced.

5. **S Wing – HWS thermometer reads 225F while HWR thermometer reads 165F - replace HWS thermometer. (PH-I)**

   (PH-II): Thermometer has been replaced.

6. **AHU-3 - Replace supply fan motor with a larger HP motor to prevent motor overload condition. (PH-I)**

7. **AHU-11 & 12 - Need new software to look at control program, parameters & setpoints. (PH-I)**

8. **AHU-22 - Clean dirty cooling coil. (PH-I)**

   (PH-II): Coil has been cleaned.

9. **AHU-26 - Replace non-functioning mixed air temperature sensor. (PH-I)**

   (PH-II): Sensor has been replaced.

10. **AHU-29 - Clean dirty heating coil. (PH-I)**

    (PH-II): Coil has been cleaned.

11. **AHU-29 - Add missing supply fan inlet vane control to the BAS graphic. (PH-I)**

    (PH-II): Graphic has been updated.

12. **AHU-43 - Replace missing outdoor air damper blade seals. (PH-I)**

13. **AHU-50 - Reconnect outdoor air damper actuator control. (PH-I)**

14. **AHU-50 - Add missing outdoor air and relief air damper control to the building automatic system graphic. (PH-I)**

    (PH-II): Control programming for controlling the dampers is also missing. The current damper arrangement includes a relief damper on the downstream side of the supply fan and a supply air damper. This arrangement won't work well and the system should be modified to include a return and relief damper upstream of the supply fan instead to allow the system to economize. Savings will be achieved if both O&M 13 and 14 are completed.

Annual Energy Savings	(kWh/yr)	8,000-12,000
	($)	$800-1,200
Capital Cost	($)	$4,000-7,000
Simple Payback	(yrs)	4-9

15. **CT-2 & 3 - Repair water leak in basin at seam. (PH-I)**

    (PH-II): Leak has been repaired.

16. **CT-3 - Repair water leak in basin at low water probe. (PH-I)**

    (PH-II): Leak has been repaired.

17. **Greenhouse AHU-37 – Adjust Heating Coil Integral Face And Bypass Damper to Close Off Tight (PH-I):** With the AHU heating coil face and bypass damper commanded to 100% bypass, the dampers leak enough to raise the discharge air temperature several degrees and overheat the space. The College currently keeps an AHU access door to the mixing box open to introduce cooler mechanical room air into the AHU to help prevent overheating of the discharge air temperature. It is suggested that the face and bypass damper be adjusted, repaired or replaced to eliminate overheating the discharge air temperature to the space.

    (PH-II): Damper has been adjusted as much as possible.

18. **Auto Labs AHU-38, 40 & Welding Lab AHU-42 – Provide Steam Preheat Coil with Face and Bypass Dampers to Prevent Freezing of Coil (PH-I):** These 100% outdoor air AHU's have been shutting down on freezestat alarms. The College currently keeps an AHU access door to the mixing box open to introduce warmer mechanical room air into the AHU to help prevent cold air from tripping the freezestats. It is suggested that face and bypass dampers be installed on the steam preheat coils with a control sequence to protect the coils from freezing and to eliminate the freezestat AHU shutdown alarms.

    (PH-II): Return air has been added to AHU-38 and 40. AHU-42 will have face and bypass added.

19. **L Wing – Move Hot Water Supply and Return Temperature Sensors Closer to Heat Exchanger (PH-I):** Currently, hot water supply and return temperature sensors are located near one of the three hot water branch loops that serve the L Wing and not near the heat exchanger. Due to the sensor locations, there is an excessive time lag in the control loop for controlling the heat exchanger steam control valve. The hot water supply temperature leaving the heat exchanger will over shoot the control setpoint by the time the hot water reaches the hot water supply temperature sensor. The hot water return temperature sensor is also located in one of the branch loops and does not sense a common hot water return temperature to the heat exchanger. It is suggested that the hot water supply and return temperature sensors be relocated close to the heat exchanger and the steam control valve control loop retuned for more accurate control of the hot water supply and to provide accurate sensing of the hot water return.

    (PH-II): Sensor has been relocated.

20. **L Wing – Add Hot Water Branch Loop Bypass Valves to Maintain Circulation (PH-I):** There are three hot water branch loops serving the L-Wing. Each branch loop has heating coils with two way control valves. When all zone control valves close off, flow is stopped in the hot water branch piping and the hot water supply eventually cools down before a zone requires hot water again. It is suggested that two way bypass valves be installed at the end of the three loops to maintain water flow through each hot water branch loop even during no zone demand periods. The bypass valves should be controlled from hot water loop differential pressure.

    (PH-II): Delta may consider this modification in the future.

21. **Replace L-Wing Heat Exchanger Differential Pressure Sensor (PH-II):** The differential pressure sensor for the L-Wing heat exchanger was observed to be reading 3 psi during the summer despite the pump running at full speed. It appears that the sensor is bad and forcing the pump to run faster than necessary which is wasting energy. The sensor should be replaced or recalibrated.

Annual Energy Savings	(kWh/yr)	25,000-35,000
	($)	$2,500-3,500
Capital Cost	($)	$100-300
Simple Payback	(yrs)	<1

22. **Adjust AHU-1 Outside and Relief Dampers to Allow Full Closure (PH-II)**

23. **Modify AHU-28 Damper Control Range (PH-II):** The outside air, return air and relief air damper actuator range is 2-10VDC but the actual control signal range is 0-10VDC which is causing the dampers to not provide any outside air during non-economizer operation and not provide proper ventilation. The output signal control range should be changed to match the actuator control range but it should be noted that this will cause an increase in energy usage.

24. **Adjust AHU-28 Damper Actuator to Allow Full Economizer Operation (PH-II):** The outside air, return air and relief air dampers for AHU-28 were observed to not open/close completely during economizer mode due to slipping of the actuator which prevented full economizer operation. The actuator should be adjusted to allow the unit to operate at 100% outside air when required.

25. **Replace AHU-28 Preheat Sensor (PH-II):** The preheat sensor was observed to be reading approximately 3F low. The sensor should be replaced or recalibrated.

26. **Replace Powerhouse Outside Air Temperature Sensor (PH-II):** The powerhouse outside air sensor was observed to be reading 2.5-3.5F higher than campus weather station and Saginaw National Weather service. The sensor location should be evaluated and the sensor should be replaced, relocated or recalibrated as required.

27. **Re-anchor Slipping AHU-32 Return Damper Blade to Shaft.**

28. **Re-anchor Slipping AHU-32 Face and Bypass Damper Section**

29. **Adjust AHU-36 Face and Bypass Dampers to Allow Them to Stroke Fully Opened and Closed.**

30. **Recalibrate Chilled Water Temperature and Flow Meters (PH-II):** The chilled water turbine flow meters and temperature sensors used to calculated the chilled water tonnage being used were observed to read 2000 tons when two 800 ton chiller were not even fully loaded. The sensors should be recalibrated to ensure accurate tonnage values are being calculated.

31. **Provide Economizer Deadband (PH-II):** During trending it was observed that there were times when AHU-1 and AHU-28 were quickly cycling between economizer and non-economizer operation. This problem only occurs when the outside air temperature is near the return air temperature so no impact to the discharge air control was observed. It is suggested that a deadband be provided for economizer control on all units to prevent the dampers from quickly cycling.

32. **Start AHUs at Minimum Speed (PH-II):** During trending it was observed that the supply fans for AHU-28 and AHU-45 initially started at full speed which sometimes resulted in the duct pressure exceeding setpoint for 5-30 minutes. It is suggested that the controls be modified to start the fan at minimum speed to prevent overpressurization. It is suggested that any other units with similar controls be modified as well.

33. **Start AHU Chilled Water Valves Fully Closed (PH-II):** During trending it was observed that AHU-1 chilled water valve started fully open but it quickly went back to a normal position with proper control. It is suggested that the controls be modified to start the air handling unit with the cooling coil valve initially closed to prevent overcooling. This issue was only observed on AHU-1 but it is suggested that any other units with similar controls be modified as well.

34. **Provide Controls to Prevent Simultaneous Heating and Cooling (PH-II):** During trending AHU-1, 28, 39 and 45 all had short time periods where both the heating and cooling valve appeared to be commanded open. For AHU-1, 28 and 39 it wasn't apparent if simultaneous heating and cooling was actually occurring but for AHU-45 temperatures did indicate that both coils were active simultaneously. Some of the other units already have heating locked out during summer operation but it is suggested that all units be controlled in a manner which will prevent simultaneous heating and cooling.

35. **Fix AHU-39 Cooling Control (PH-II):** During trending it was observed that the cooling coil valve frequently didn't open even if the discharge air temperature was above setpoint when the discharge air temperature setpoint was 55F. This problem was not observed to occur when the setpoint was 70F. The cause of this problem should be determined and the controls should be adjusted.

36. **Verify AHU-39 Sensors/Valves/Dampers are Operating Properly (PH-II):** During trending it was observed that there were times when the unit was in full economizer mode but the discharge air temperature was almost 10F above the outside air temperature. This is a larger temperature rise than would be expected from fan heat so it should be verified that the dampers, valves and sensors are all operating properly. This unit was functionally tested but nothing was observed that would explain this issue.

37. **ReduceAHU-39 Unoccupied Cycling (PH-II):** During trending it appeared the fan for AHU-39 was relatively quickly cycling on and off during unoccupied hours. This cycling should be reduced by creating a larger deadband for room temperature setpoint or increasing minimum on/off runtime setpoints.

38. **Provide System Bypass Valves on Constant Volume HW Systems:** There are nine (9) hot water heat exchanger system piping systems that have constant volume hot water pumps and two-way zone coil control valves. If all two-way zone coil control valves close off, the hot water pump is dead-headed and produces no flow. Each constant volume hot water system should have a system bypass control valve installed to prevent pump dead-heading.

39. **Trane BAS Trending is Insufficient:** The Trane BAS does not have the capacity to gather and save a sufficient number of trended points to provide adequate trouble-shooting value. It is suggested that Delta College investigate upgrading Trane software/hardware to improve BAS trending capability.

40. **Need Improved Documentation of BAS Sequences of Operation:** The current BAS programmed sequences of operation are not accurately kept up to date in written form. All BAS control programming needs to be analyzed and re-written in paragraph form including all detail of setpoints, differentials, setpoint reset schedules, time delays, point references, control loops, permanent overrides, alarm setpoints, alarm diffentials, failure reset needed, etc.

EXHIBIT 1

EXISTING BUILDING COMMISSIONING (EBCx) TEAM DIRECTORY

EBCx Team Directory

EXHIBIT 1
Delta College
University Center, Michigan
Existing Building Commissioning (EBCx) Team Directory

1. The EBCx Team consists of individuals who through coordinated actions are responsible for implementing the EBCx Process.

2. All team members work together to fulfill their EBCx responsibilities and to meet the objectives of the EBCx process.

3. The following table lists the primary members of the EBCx Team.

ENTITY	FIRM/ADDRESS	CONTACT(S)	PHONE/CELLULAR/FAX/EMAIL
Delta College	Delta College 1961 Delta Road University Center, MI 48710	Larry Ramseyer Director of Facilities Management	P 989-686-9234 C F 989-667-0620 E larryramsyeyer@delta.edu
Consumers Energy		Cheryl Sabias, Corporate Account Manager	P 989-791-5683 C 989-791-1156 F E
Consumers Energy Business Solutions	P.O. Box 1040 Okemos, MI 48805	John Nametz Senior Engineer	P 877-607-0737 C 248-255-6170 F 877-607-0738 E jnametz@franklinenergy.com

EBCx Team Directory – Continued

Commissioning Provider	Grumman/Butkus Associates 1011 N. Mayfair Road, Suite 300 Wauwatosa, WI 53226	Steven Riehle	P 414-476-8980 C 414-732-8983 F 414-476-2470 E smr@grummanbutkus.com
Commissioning Provider	Grumman/Butkus Associates 1011 N. Mayfair Road, Suite 300 Wauwatosa, WI 53226	William Kuzan	P 414-476-8980 C 414-732-8984 F 414-476-2470 E wek@grummanbutkus.com
Commissioning Provider	Grumman/Butkus Associates 700 Rayovac Drive, Suite 307 Madison, WI 53711.2479	Shawn Klose	P 608-278-1890 C 608-345-6913 F 608-278-1891 E spk@grummanbutkus.com
Commissioning Provider	Grumman/Butkus Associates 1011 N. Mayfair Road, Suite 300 Wauwatosa, WI 53226	Jeffrey Conner	P 414-476-8980 C 414-350-8980 F 414-476-2470 E jkc@grummanbutkus.com

EXHIBIT 2

CURRENT FACILITY REQUIREMENTS

1.0 PROJECT DESCRIPTION

A. Location: Delta College, University Center, Michigan
B. Year of Construction: 1960-1980, 1997, 2003
C. Size: 932,812 (net) sq ft
D. Type occupancy/use: Education with Labs
E. Number of Floors: 2

2.0 TEMPERATURE AND HUMIDITY CRITERIA

Functional Space	Criteria	Occupied		Unoccupied	
		Summer	Winter	Summer	Winter
Classrooms & Offices	Temperature (F)	75 official 74 average	68 official 72 average	80 or none	60
	Humidity (%RH)	None	None	None	None
Print Shop	Temperature (F)	75	68	80	60
	Humidity (%RH)	None	35-40	None	None
Data Center	Temperature (F)	72	68	NA	NA
	Humidity (%RH)	None	None	NA	NA
Swimming Pool	Temperature (F)	86	86	NA	NA
	Humidity (%RH)	50-55	50-55	NA	NA
Greenhouse	Temperature (F)	Varies depending upon requirements	Varies depending upon requirements	Varies depending upon requirements	Varies depending upon requirements
	Humidity (%RH)	None	Humidifier not used	None	None

3.0 VENTILATION AND FILTRATION CRITERIA

Functional Space	Outside Air CFM/person	Supply Air A/C Rate	Filtration Requirement
Automotive Labs	100% OA		

4.0 OCCUPANCY REQUIREMENTS

Functional Space/Area – Education - Summer

Day of Week	Morning Warm-Up	Occupied	Unoccupied
Weekday		6:30am-9:30pm	9:30pm-6:30am
Saturday		Varies based events	
Sunday		Varies based events	
Holiday		Varies based events	

Functional Space/Area – Education - Winter

Day of Week	Morning Warm-Up	Occupied	Unoccupied
Weekday		5:00am to 7:30am- 5:30pm to 10:30pm (Varies by space)	5:30pm to 10:30pm - 5:00am to 7:30am (Varies by space)
Saturday		Varies based events	
Sunday		Varies based events	
Holiday		Varies based events	

5.0 SYSTEM SETPOINTS

A. Chilled Water Supply Setpoint = 45F

B. Condenser Water Supply Setpoint

a. Freecool Setpoint = 39F
b. Ice Build Setpoint = 71F
c. Mech. Cooling Setpoint = 85F

C. Hot Water Supply Setpoints

System Tag	Supply Temperature Setpoint/Reset Range	Outdoor Air Temperature Reset Range	Reset (Yes/No)
HES-1 - Reheat Coils	130F-180F	70F-10F	Yes
HES-2 - Radiation	70F-180F	70F-10F	Yes
HX-1 - Science Wing - Reheat Coils	-210F		Yes
HX-2 - Library - Reheat Coils	-210F		Yes
HE - B Wing - Reheat Coils	110F-185F	60F-0F	Yes
HE-1 - F Wing - West Booster Coils	120F-200F	70F-25F	Yes
HE-2 - F Wing - East Booster Coils	120F-195F	65F-0F	Yes
HE-3 - F Wing - Radiation	100F-175F	60F-0F	Yes
HE-1 - G Wing - AH-21 & Radiation	100F-190F		Yes
HE - H Wing	155F-195F	60F-10F	Yes
HE - J Wing	150F-190F	60F-10F	Yes
HE - K Wing	120F-200F	60F-10F	Yes
HE - L Wing	150F-190F	60F-30F	Yes
HE-1 - M Wing - Reheat Coils	131F-191F	60F-0F	Yes
HE-2 - M Wing - 2nd Flr Reheat Coils	160F	NA	No
HE - N Wing	150F-190F	60F-30F	Yes
HE - P Wing - AH's, Pool, Spa	180F	NA	No
HE-1 - S Wing - West Unit Ventilators	140F-190F	65F-15F	Yes
HE-2 - S Wing - East Booster Coils & Radiation	130F-180F	65F-15F	Yes

D. Water Loop System Static Setpoints

System Tag	Static Pressure Setpoint	Reset (Yes/No)
Secondary Chilled Water Pumps CP-		No

1,2		
Htg HW Pumps CP-1,2 – Reheat Coils	7.0 psig	No
Htg HW Pumps CP-1,2 – H Wing	10.0 psig	No
Htg HW Pumps CP-1,2 – J Wing	12.1 psig	No
Htg HW Pumps CP-1,2 – K Wing	7.5 psig	No
Htg HW Pumps CP-1,2 – L Wing	7.0 psig	No
Htg HW Pumps CP-1,2 – M Wing 2nd Flr	9.0 psig	No
Htg HW Pumps CP-1,2 – N Wing	7.0psig	No
Htg HW Pumps CP-1,2 – P Wing	5.0psig	No

E. Air Distribution System Static Setpoints

System Tag	Static Pressure Setpoint	Reset (Yes/No)
AH-3 - N Wing Commons & Lockers	2.0”w.c.	No
AH-4 - N Wing Classrooms	2.0”w.c.	No
AH-5 - A Wing 2nd Flr Classrooms	0.5-1.0”w.c.	Yes
AH-7 - N Wing Printshop	2.0”w.c.	No
AH-8 - N Wing Bookstore	1.0-2.0”w.c.	Yes
AH-9 - A Wing LL East Concourse No.	1.5-2.5”w.c.	Yes
AH-10 - H Wing LL East Concourse So.	1.5-2.5”w.c.	Yes
AH-11 - LL West Courtyard	1.0-2.0”w.c.	Yes
AH-12 - LL West Courtyard	1.0-2.0”w.c.	Yes
AH-14 - B Wing Admin. Offices	1.0-2.0”w.c.	Yes
AH-17 - J Wing Classrooms	1.6-2.6”w.c.	Yes
AH-20 - D Wing	2.0-3.0”w.c.	Yes
AH-25 - P Wing 2nd Flr RQTB Courts	1.0”w.c.	No
AH-28 - P Wing LL Mech. Offices	1.5-2.5”w.c.	Yes
AH-29 - M Wing	1.5”w.c.	No
AH-31 - A Wing Library	0.5-1.0”w.c.	Yes
AH-32 - A Wing West	1.0-2.0”w.c.	Yes
AH-33 - D Wing	1.0-2.0”w.c.	Yes
AH-34 - E Wing	1.5-2.5”w.c.	Yes
AH-35 - C Wing	1.5-2.5”w.c.	Yes
AH-36 - E Wing Science	2.0”w.c.	No
AH-37 - E Wing Greenhouse	RMT 72.5F	No
AH-41 - L Wing	0.9-1.9”w.c.	Yes
AH-42 - M Wing Welding Lab	2.0”w.c.	No
AH-43 - M Wing Construction Lab	0.2”w.c.	No
AH-44 - M Wing Classrooms	2.0”w.c.	No
AH-45 - Kitchen	1.2”w.c.	No
Cooling Tower CT-1 Fans	CDWS 82F	No
Cooling Tower CT-2 Fans	CDWS Freecool 39F Ice Build 71F Mech Cooling 85F	No
Cooling Tower CT-3 Fans	CDWS Freecool 39F Ice Build 71F Mech Cooling 85F	No

EXHIBIT 3

EBCx PROCESS DELIVERABLES

LIST OF PROJECT DELIVERABLES

Phase II

- Diagnostic and monitoring plan
- Trend logs/data
- Completed functional test forms
- Updated listing of deficiencies found and Facility Improvement Measures (FIMs) identified with narrative description
- Supporting energy savings calculations (if applicable) based on engineering estimates
- Probable construction cost (if applicable) for each FIM based on engineering estimates
- Project Meeting Minutes
- Project Progress Reports
- EBCx Phase II Report

EXHIBIT 4

EBCx SCHEDULE

PROJECT TIMELINES

Date: 09/21/10 updated

Phase II Consumers Energy EBCx Program Schedule - Delta College

WEEKS

Week	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37
Month	Apr		May					Jun				Jul				Aug					Sep				Oct				Nov					Dec			
Date	19	26	3	10	17	24	31	7	14	21	28	5	12	19	26	2	9	16	23	30	6	13	20	27	4	11	18	25	1	8	15	22	29	6	13	20	27

TASK NUMBER	TASK DESCRIPTION
1	Kickoff meeting
2	Update phase II scope of services based on kickoff meeting
3	Owner assembles/furnishes existing sequences for EBCx systems and updates information for current facility requirements
4	Finalize current faciltiy requirements document
5	Prepare EBCx Plan/ Report (1st Issue)
6	Review EBCx Plan/Report (1st Issue)with Owner/Consumers Energy (CE)
7	Develop functional test procedures for EBCx systems
8	Develop diagnostic and monitoring plan
9	Trend EBCx systems
10	Complete functional testing of EBCx systems
11	Verify EBCx system modifications completed by Owner after phase I report
12	Prepare updated list of FIMs
13	Review FIMs with Owner/CE
14	Complete energy saving/capital costs calculations on applicable FIMs
15	Identify O&M training needs
16	Identify documentation enhancements
17	Prepare Final EBCx Report
18	Meet with Owner/CE to review EBCx Report
	IMPLEMENTATION
	Phase I FIM Implementation
1	Identify FIMs for implemetation from phase I that need scope document
2	Receive frontend terms from Owner
3	Prepare scope document
4	Issue to Owner for pricing from Owner selected contractor
5	Obtain pricing proposal from contractor
6	Implement FIMs
7	GBA to complete followup FIM implementation verification
	Phase II FIM Implementation
1	Identify FIMs for implemetation from phase II that need scope document
2	Left blank intentionally
3	Prepare scope document
4	Issue to Owner for pricing from Owner selected contractor
5	Obtain pricing proposal from contractor
6	Implement FIMs
7	GBA to complete followup FIM implementation verification

EXHIBIT 5

EBCx SYSTEMS TO BE TESTED

EBCx SYSTEMS TO BE TESTED

1. Chiller Plant w CHW/CW pumps
2. Boiler Plant
3. HW Pumps
4. Steam to HW heat exchangers (2) (S Wing HX, L Wing HX)
5. AHU-1, 28, 32, 36, 39 and 45
6. AHU-18 and 22 will also be tested if budget allows

EXHIBIT 6

EQUIPMENT LISTING

HVAC System	Area Served	Supply Flow (cfm)	Supply Fan Motor (HP)	Return Fan Motor (HP)	Observed SF Speed %	Observed RF Speed %	Current Assumed Supply (cfm)	Current SF Assumed (BHP)	Current RF Assumed (BHP)	Controlled by BAS	VAV or CV	Min. OA % or Min. OA CFM or 100% OA	Min OA	Current OA Flow (cfm)	OCC time schedule	Economizer switchover method (at min. OA)	MAD Fixed MAT setpoint or MAT setpoint reset	Reclaim Coil VLV Fixed RCAT setpoint or RCAT setpoint reset	PHC VLV Fixed PHAT setpoint or PHAT setpoint reset	CHW VLV Fixed DAT setpoint or DAT setpoint reset	RHC VLV Fixed DAT setpoint or DAT setpoint reset	SA VFD Fixed SASP setpoint or SASP setpoint reset	Unocc HTG RMT setpoint	Unocc CLG RMT setpoint	OAD closed during Warmup	HC valves modulate when AH off	VAV RHC valves modulate when AH off	Exhaust Fan OCC mode	HVAC System	Comments
AIR HANDLING UNITS																														
AH-1	N Wing East side of Gym	24,000	25.0	10.0			24,000	20.0	8.0	AAM	VAV	45% min. OA	20%	4,800	TuWTh 1430-2130 Sa 1215-1530	OAT>RAT+2	55F	NA	55F	72F	70F	1.5"w.c.	<64F	NA	no	yes	NA		AH-1	OAD @ 45% open when fan is off. Has Night Purge cooling mode.
AH-2	N Wing West side of Gym	24,000	25.0	10.0			24,000	20.0	8.0	AAM	CV	45% min. OA	20%	4,800	only for special events	OAT>RAT+2	55F	NA	55F	72F	70F	NA	<64F	NA	no	yes	NA		AH-2	Has Night Purge cooling mode.
AH-3	N Wing Commons & Lockers	26,300	25.0	10.0	73%	100%	19,111	7.7	8.0	AAM	VAV	45% min. OA	20%	3,822	MTuWTh 630-2130 F 630-1930 Sa 730-1630 Su 1230-1800	OAT>RAT+2	55F	NA	NA	55F	53F	2.0"w.c.	<55F	NA	no	yes	yes		AH-3	SF needs larger motor - can only maintain 1.0"w.c
AH-4	N Wing Classrooms	7,140	10.0	3.0	82%	100%	5,831	4.4	2.4	AAM	VAV	45% min. OA	20%	1,166	M 730-2200 TuWTh 730-2100 F 830-1500	OAT>RAT+2	55F	NA	NA	57F	53F	2.0"w.c.	<55F	NA	no	yes	yes		AH-4	
AH-5	A Wing 2nd Flr Classrooms	20,000	25.0	*10.0*	48%	49%	9,667	2.3	0.9	Trane	VAV	1600 cfm	8%	1,600	MWTh 645-2130 Tu 630-2100 F 700-2059 Sa 800-1700	>70F	59F	NA	57F	53F-60F	NA	0.5"-1.0"w.c.	<64F	>85F	yes	no	no		AH-5	heating coil with face and bypass dampers
AH-6	G Wing Lecture Theater	13,000	10.0	5.0			13,000	8.0	4.0	AAM	CV	10% min. OA	10%	1,300	MTh 1330-1702 Tu 1030-1400 W 130-2200 ThF 515-2203 Sa 1130-2200 Su 1130 2000	OAT>RAT+2 OR OAT<20F OR OAT>70F	55F-70F	NA	NA	55F-70F	55F-80F	NA	<55F	>90F	no	yes	NA		AH-6	
AH-7	N Wing Printshop	8,000	7.5	3.0			*6,000*	2.5	1.0	AAM	VAV	30% min. OA	30%	1,800	24/7/365	OAH>RAH+1	55F	NA	53F	55F-60F	NA	2.0"w.c.	NA	NA	NA	NA	yes		AH-7	
AH-8	N Wing Bookstore	18,000	15.0	5.0	65%	62%	11,700	3.3	0.9	AAM	VAV	30% min. OA	30%	3,510	MTuWThF 630-1800 SaSu for special events	OAT>RAT+2	55F	NA	53F-61F	57F-62F	NA	1.0-2.0"w.c.	<55F	NA	no	yes	yes		AH-8	
AH-9	A Wing LL East Concourse No.	22,600	25.0	*10.0*	62%	100%	13,937	4.7	8.0	AAM	VAV	45% min. OA	20%	2,787	MTuWTh 635-2030 F 637-2130	OAT>RAT+2	55F	NA	58F	62F	NA	1.5-2.5"w.c.	<55F	NA	no	yes	yes		AH-9	
AH-10	H Wing LL East Concourse So.	21,625	25.0	10.0	67%	100%	14,417	5.9	8.0	AAM	VAV	4200 cfm	19%	4,200	MTuWTh 630-2100 F 630-1730	OAT>RAT+2	60F-65F	NA	58F-63F	62F-77F	NA	1.5-2.5"w.c.	<55F	NA	no	yes	yes		AH-10	
AH-11	LL West Courtyard	23,380	2.5	7.5	59%	40%	13,794	0.4	0.4	Trane	VAV	3403 cfm	15%	3,403	MTuWTh 644-1800 F 645-1600	>70F	56F	NA	56F	56F	NA	1.0-2.0"w.c.	Can't see setpoints	Can't see setpoints	yes	no	no		AH-11	DAT reset is unknown - need new software to look at program code.
AH-12	LL West Courtyard	11,230	15.0	5.0	47%	33%	5,278	1.2	0.1	Trane	VAV	1422 cfm	13%	1,422	MTuWTh 645-1800 F 700-1600	>70F	56F	NA	56F	56F	NA	1.0-2.0"w.c.	Can't see setpoints	Can't see setpoints	yes	no	no		AH-12	
AH-13	A Wing South Main Hall	6,600	5.0	3.0			6,600	4.0	2.4	AAM	CV	10% min. OA	10%	660	MTuWTh 705-2115 F 705-1645	OAH>RAH+1 OR OAT<10F OR OAT>70F	55F-70F	NA	NA	65F-83F	80F-95F	NA	<55F	NA	no	yes	NA		AH-13	
AH-14	B Wing Admin. Offices	12,500	15.0	*5.0*	75%	65%	9,375	5.1	1.1	Trane	VAV	1101 cfm	9%	1,101	M 600-1800 TuWTh 635-1800 F 700-1700	>70F	59F	NA	57F	50F-65F	NA	1.0-2.0"w.c.	<65F	>85F	yes	no	no		AH-14	heating coil with face and bypass dampers
AH-15	LL - A Wing, TV area	22,500	20.0	7.5			22,500	16.0	6.0	AAM	CV	45% min. OA	20%	4,500	24/7/365	OAH>RAH+1	48F-58F	NA	NA	55F-65F	85F-125F	NA	NA	NA	NA	NA	NA		AH-15	
AH-16	A Wing TV Studio	4,670	5.0	1.5			4,670	4.0	1.2	AAM	CV	10% min. OA	10%	467	24/7/365	OAH>RAH+1 or OAT<-15F or OAT>90F	47F-57F	NA	NA	55F-65F	70F-120F	NA	<55F	>72F	NA	NA	NA		AH-16	
AH-17	J Wing Classrooms	20,650	25.0	7.5			*15,488*	8.4	2.5	AAM	VAV	4200 cfm	20%	4,200	MTuWTh 645-2200 F 800-1459	OAT>RAT+2	55F-70F	NA	58F-73F	57F-62F	NA	1.6"-2.6"w.c.	<55F	>72F	no	yes	yes		AH-17	
AH-18	B Wing Admin. Offices	16,410	30.0	5.0			16,410	24.0	4.0	AAM	CV	55% min. OA	30%	4,923	MTuWThF 650-1730	OAH>RAH+1 or OAT<10F or OAT>70F	55F-65F	NA	NA	55F-70F	70F-120F	NA	<55F	>80F	no	yes	NA		AH-18	
AH-19	B Wing Data Ctr	6,000	10.0	5.0			6,000	8.0	4.0	AAM	CV	10% min. OA	10%	600	24/7/365	OAH>RAH+1 or OAT<-15F or OAT>72F	71F	NA	NA	73F	69F	NA	NA	NA	no	NA	NA		AH-19	heating/cooling controlled from space temperature
AH-20	D Wing	14,500	20.0	*7.5*	88%	83%	12,784	11.0	3.5	Trane	VAV	1664 cfm	11%	1,664	MTuWTh 700-1800 F 715-1600	>70F	59F	NA	57F	50F-63F	NA	2.0"-3.0"w.c.	<60F	>85F	yes	no	no		AH-20	heating coil with face and bypass dampers
AH-21	G Wing Offices	*8,000*	7.5	5.0			8,000	6.0	4.0	AAM	CV	10% min. OA	10%	800	MTuWTh 630-2130 F 650-1630	OAH>RAH+1 OR OAT<5F OR OAT>73F	55F-70F	NA	NA	58F-76F	NA	NA	<55F	>90F	no	yes	NA		AH-21	
AH-22	S Wing	50,000	75.0	50.0			50,000	60.0	40.0	AAM	CV	15% min. OA	15%	7,500	MTuWTh 635-2159 F 635-1700	OAH>RAH+1 OR OAT<4F OR OAT>64F	53F-63F	NA	NA	52F-67F	NA	NA	<55F	NA	no	yes	NA		AH-22	
AH-23	F Wing	*50,000*	75.0	40.0			50,000	60.0	32.0	AAM	CV	10% min. OA	10%	5,000	MTuWTh 645-2200 F 645-1700 SaSu 730-1630	OAH>RAH+1 OR OAT<5F OR OAT>72F	55F-70F	NA	NA	55F-70F	NA	NA	<55F	>90F	no	yes	NA		AH-23	
AH-24	F Wing	*50,000*	75.0	40.0			50,000	60.0	32.0		CV	10% min. OA	10%	5,000	MTuWTh 645-2200 F 645-1700	OAH>RAH+1 OR OAT<5F OR OAT>72F	55F	NA	NA	55F-70F	NA	NA	<55F	>90F	no	no	NA		AH-24	
AH-25	P Wing 2nd Flr RQTB Courts	28,000	40.0	15.0	100%	100%	28,000	32.0	12.0	AAM	VAV	45% min. OA	45%	12,600	MTuWTh 630-2030 F 630-1930 Sa 730-1630 Su 1200-1559	OAT>RAT+2	58F-60F	NA	56F	60F-65F	NA	1.0"w.c.	<55F	NA	no	yes	yes		AH-25	
AH-26	P Wing Hyper Gym	32,000	50.0	30.0			32,000	40.0	24.0	AAM	CV	45% min. OA	20%	6,400	only for special events	OAT>RAT+2	60F	NA	60F	72F	70F	NA	63F	NA	no	yes	NA		AH-26	Has Night Purge cooling mode.
AH-27	Swimming Pool	30,000	30.0	40.0			30,000	24.0	32.0	AAM	CV	15% min. OA	15%	4,500	24/7/365	OATDP>58F	RMTDP=65F	NA	RMT=88F	RMTDP=65F	RMT=88F	NA	NA	NA	NA	yes	NA	24/7/365	AH-27	

HVAC System	Area Served	Supply Flow (cfm)	Supply Fan Motor (HP)	Return Fan Motor (HP)	Observed SF Speed %	Observed RF Speed %	Current Assumed Supply (cfm)	Current SF Assumed (BHP)	Current RF Assumed (BHP)	Controlled by BAS	VAV or CV	Min. OA % or Min. OA CFM or 100% OA	Min OA	Current OA Flow (cfm)	OCC time schedule	Economizer switchover method (at min. OA)	MAD Fixed MAT setpoint or MAT setpoint reset	Reclaim Coil VLV Fixed RCAT setpoint or RCAT setpoint reset	PHC VLV Fixed PHAT setpoint or PHAT setpoint reset	CHW VLV Fixed DAT setpoint or DAT setpoint reset	RHC VLV Fixed DAT setpoint or DAT setpoint reset	SA VFD Fixed SASP setpoint or SASP setpoint reset	Unocc HTG RMT setpoint	Unocc CLG RMT setpoint	OAD closed during Warmup	HC valves modulate when AH off	VAV RHC valves modulate when AH off	Exhaust Fan OCC mode	HVAC System	Comments
AH-28	P Wing LL Mech. Offices	50,000	75.0	25.0	78%	75%	39,083	28.7	8.4	AAM	VAV	45% min. OA	20%	7,817	MTuWTh 600-2030 F 600-1930 Sa 730-1630 Su 1200-1800	OAT>RAT+2	60F	NA	58F-68F	62F	NA	1.5"-2.5"w.c.	<55F	NA	no	yes	yes		AH-28	
AH-29	M Wing	12,400	10.0	5.0			*9,300*	3.4	1.7	AAM	VAV	10% min. OA	10%	930	MWTh 700-2130 Tu 815-2200	OAH>RAH+1 OR OAT<40F OR OAT>65F	55F-70F	NA	57F-82F	70F-80F	NA	1.5"w.c.	<60F	NA	no	yes	yes		AH-29	SF with inlet vanes
AH-30	N Wing Security Area	2,600	2.0	1.0			2,600	1.6	0.8	AAM	CV	10% min. OA	10%	260	MTuWThFSa 630-2259 Su 1030-1900	OAH>RAH+1 OR OAT<10F OR OAT>73F	47F-67F	NA	NA	55F-65F	72F-122F	NA	<60F	NA	no	yes	NA		AH-30	
AH-31	A Wing Library	39,000	50.0	*20.0*	48%	48%	18,850	4.5	1.8	Trane	VAV	1600 cfm	4%	1,600	MTuWTh 630-2200 F 645-1600 Sa 900-1400 Su 1200-1730	>50F	59F	NA	57F	55F-53F	NA	0.5"-1.0"w.c.	<55F	NA	yes	no	no		AH-31	heating coil with face and bypass dampers
AH-32	A Wing West	39,000	50.0	*20.0*	77%	62%	29,900	18.0	3.8	Trane	VAV	3437 cfm	9%	3,437	MTuWTh 630-2100 F 645-1600 Sa 900-1400 Su 1200-1730	>70F	59F	NA	57F	55F-65F	NA	1.0-2.0"w.c.	<55F	NA	yes	no	no		AH-32	heating coil with face and bypass dampers
AH-33	D Wing	10,000	15.0	*5.0*	55%	35%	5,500	2.0	0.2	Trane	VAV	1402 cfm	14%	1,402	MTu 635-2200 WTh 640-2100 F 700-1600	>70F	59F	NA	57F	55F-65F	NA	1.0-2.0"w.c.	<55F	NA	yes	no	no		AH-33	heating coil with face and bypass dampers
AH-34	E Wing	28,000	50.0	*20.0*	77%	57%	21,467	18.0	2.9	Trane	VAV	1795 cfm	6%	1,795	MTuWTh 640-2130 F 700-1630	>70F	59F	NA	57F	55F-73F	NA	1.5"-2.5"w.c.	<64F	>85F	yes	no	no		AH-34	heating coil with face and bypass dampers
AH-35	C Wing	28,000	50.0	*20.0*	83%	72%	23,333	23.1	5.9	Trane	VAV	1111 cfm	4%	1,111	MTuWTh 640-2200 F 700-1700 Sa 900-1700	>70F	59F	NA	57F	55F-65F	NA	1.5"-2.5"w.c.	<64F	>85F	yes	no	no		AH-35	heating coil with face and bypass dampers
AH-36	E Wing Science	40,000	60.0	0.0	65%		26,000	13.2	0.0	Trane	VAV	100% OA	100%	26,000	24/7/365	NA	NA	NA	DATSP-2	53-69F	NA	2.0"w.c.	NA	NA	NA	NA	no	EF1 on 24/7 EF-2 Standby	AH-36	heating coil with face and bypass dampers
AH-37	E Wing Greenhouse	10,000	15.0	0.0	61%		6,083	2.7	0.0	Trane	VAV	100% OA	100%	6,083	24/7/365	NA	NA	NA	60.5F	64.5F	NA	RMT 72.5F	NA	NA	NA	NA	no	EF-4,5,6 run based upon SF speed	AH-37	
AH-38	M Wing North Auto Lab	12,100	15.0	0.0			12,100	12.0	0.0	AAM	CV	100% OA	100%	12,100	24/7/365	NA	NA	75F	62F-113F	75F	70F	NA	NA	NA	NA	NA	NA	EF on 24/7	AH-38	CHW coil not used
AH-39	M Wing Process Control	7,050	10.0	5.0			7,050	8.0	4.0	AAM	CV	45% min. OA	20%	1,410	MTuTh 715-2000 W 730-1530 F 745-1630	OAT>RAT+2	60F	NA	58F	62F	NA	NA	<50F	NA	no	yes	NA		AH-39	
AH-40	M Wing South Auto Lab	14,100	15.0	40.0		82%	14,100	12.0	32.0	AAM	CV	100% OA	100%	14,100	24/7/365	NA	NA	75F	55F-106F	78F	71F	NA	NA	NA	NA	NA	NA	EF on 24/7	AH-40	
AH-41	L Wing	13,500	25.0	7.5	72%	100%	9,698	7.4	6.0	AAM	VAV	45% min. OA	20%	1,940	MTuTh 715-2200 W 630-2115 F 730-1630	OAT>RAT+2	60F	NA	58F	62F	NA	0.9"-1.9"w.c.	<55F	NA	no	yes	yes		AH-41	
AH-42	M Wing Welding Lab	16,500	30.0	0.0	68%		11,220	7.5	0.0	AAM	VAV	100% OA	100%	11,220	24/7/365	NA	NA	NA	55F	83F	NA	2.0"w.c.	NA	NA	NA	NA	yes	EF-1,2,3,4 are manual on/off	AH-42	
AH-43	M Wing Construction Lab	11,000	10.0	5.0			*8,250*	3.4	1.7	AAM	VAV	45% min. OA	20%	1,650	W 830-1630 F 830-1400	OAT>RAT+2	65F	NA	63F	67F	NA	0.2"w.c.	<55F	NA	no	yes	yes		AH-43	
AH-44	M Wing Classrooms	14,000	25.0	7.5	100%	67%	14,000	20.0	1.8	AAM	VAV	45% min. OA	20%	2,800	MTuWTh 635-2230 F 630-1700	OAT>RAT+2	62F	NA	60F-70F	64F	NA	2.0"w.c.	<55F	NA	no	yes	yes		AH-44	
AH-45	Kitchen	28,450	*30.0*	0.0	92%		26,079	18.5	0.0	AAM	VAV	100% OA	100%	26,079	runs when one or more EF's are running	NA	NA	NA	55F	65F	NA	1.2"w.c.	NA	NA	NA	yes	yes	EF-1,3,6,7 are manual on/off	AH-45	
AH-50	Battery Room for UPS	1,600		0			1,600			AAM	CV	0% min. OA	0%	0	RMT>64F	NA	NA	NA	NA	78F Rm	NA	NA	NA	NA	NA	NA	NA		AH-50	OAD is closed - don't know why

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HVAC System	Area Served	Type	Fan Motor (HP)	VAV or CV	Comments
Exhaust Fans					
EF-1	AHU-36	Centrifugal		CV	Glycol coil heat recovery
EF-2	AHU-36	Centrifugal		CV	Glycol coil heat recovery
EF-1	Greenhouse	Propeller	1/3	CV	
EF-2	Greenhouse	Propeller	1/3	CV	
EF-3	Greenhouse	Propeller	1/3	CV	
EF-1	Power House - Boiler Plant	Mushroom	2	CV	Pulls tunnel air into powerhouse for combustion air.
EF-2	Power House - Boiler Plant	Mushroom	2	CV	Pulls tunnel air into powerhouse for combustion air.
EF-3	Power House - Boiler Plant	Mushroom	2	CV	Pulls tunnel air into powerhouse for combustion air.
EF-4	Power House - Chemical Rm	Mushroom	1/4	CV	
EF-5	Power House - Restroom	Mushroom	1/4	CV	
EF-6	Power House - Elec Rm	Mushroom	1/2	CV	Thermostat controlled
EF-7	Power House - Chiller Gen Exhaust	Mushroom	1/4	CV	
EF-8	Power House - Chiller Purge	Mushroom	3/4	CV	
WEF-1	Welding Hoods	Mushroom	3	CV	Turns on with hoods
WEF-2	Welding Hoods	Mushroom	3	CV	Turns on with hoods
WEF-3	Welding Hoods	Mushroom	3	CV	Turns on with hoods
WEF-4	Welding Hoods	Mushroom	3	CV	Turns on with hoods
WEF-5	Acetylene Storage	Mushroom	1/4	CV	
WEF-6	Acetylene Storage	Mushroom	1/4	CV	
EAHU-38	AHU-38		7.5	VAV	Glycol coil heat recovery
EAHU-40	AHU-40		5	VAV	Glycol coil heat recovery
COE-1	Monoxavent EAHU-40 Area	Centrifugal		CV	CV with bypass
COE-2	Monoxavent EAHU-38 Area	Centrifugal		CV	CV with bypass
EF-1	Restroom/Lockers		2	CV	Info based on P&N Schedules
EF-2	Restroom/Lockers		2	CV	Info based on P&N Schedules
EF-3	Pool Chemical Room		1/2	CV	Info based on P&N Schedules
EF-4	Laundry		2	CV	Info based on P&N Schedules
EF-5	Paint Room		2	Cv	Info based on P&N Schedules
EF-6	Kitchen Hood		5	CV	Info based on P&N Schedules
EF-7	Kitchen Hood		7.5	CV	Info based on P&N Schedules
EF-8	Pizza Oven		5	CV	Info based on P&N Schedules
EF-9	Dishwasher		2	CV	Info based on P&N Schedules
EF-10	Print Shop		5	CV	Info based on P&N Schedules
EF-11	Restroom			CV	Info based on P&N Schedules
EF-12	Kitchen Grill			CV	
EF-1	Finishing		1/4	CV	Info based on L&M Schedules
EF-2	Janitor's Closet		1/6	CV	Info based on L&M Schedules
EF-3	Electrical Rm		3	CV	Info based on L&M Schedules
EF-4	Brazing		1/4	CV	Info based on L&M Schedules
EF-5	Wax Melt		1/6	CV	Info based on L&M Schedules
EF-6	Control Lab 2		2	CV	Info based on L&M Schedules

HVAC System	Area Served	Type	Fan Motor (HP)	VAV or CV	Comments
EF-7	Control Lab 1		3	CV	Info based on L&M Schedules
EF-8	Comms		1/60	CV	Info based on L&M Schedules
EF-9	Comms		1/60	CV	Info based on L&M Schedules
EF-10	Restroom		1/4	CV	Info based on L&M Schedules
EF-11	Flammable Storage		1/60	CV	Info based on L&M Schedules
EF-38	Control Lab 2		7.5	CV	Info based on L&M Schedules
EF-40	Control Lab 1		7.5	CV	Info based on L&M Schedules

HVAC System	Area Served	Controlled by BAS	Lead HWP Enable	Lag HWP Enable	Steam Vlv Fixed HWST setpoint or HWST setpoint reset	HWP VFD Fixed HWDP setpoint or HWDP setpoint reset	Comments
HEAT EXCHANGERS							
HES-1	Reheat Coils	Trane	OAT<75F	Lead Failure	130F-180F OAT 70F-10F	7.0 PSI	HWP's with VFD's
HES-2	Radiation	Trane	OAT<75F	Lead Failure	70F-180F OAT 70F-10F	NA	
HX-1	Science Wing - Reheat Coils	Trane	24/7/365	Lead Failure	XXXF-210F	NA	
HX-2	Library - Reheat Coils	Trane	24/7/365	Lead Failure	XXXF-210F	NA	
HE	B Wing - Reheat Coils	AAM	OAT<53F	NA	110F-185F OAT 60F-0F	NA	
HE-1	F Wing - West Booster Coils	AAM	OAT<86F	NA	120F-200F OAT 70F-25F	NA	
HE-2	F Wing - East Booster Coils	AAM	OAT<76F	NA	120F-195F OAT 65F-0F	NA	
HE-3	F Wing - Radiation	AAM	OAT<58F	NA	100F-175F OAT 60F-0F	NA	
HE-1	G Wing - AH-21 & Radiation	AAM	OAT<63F	NA	100F-190F	NA	
HE	H Wing	AAM	OAT<88F	Lead Failure	155F-195F OAT 60F-10F	10.0 PSI	HWP's with VFD's
HE	J Wing	AAM	OAT<71F	Lead Failure	150F-190F OAT 60F-10F	12.1 PSI	HWP's with VFD's
HE	K Wing	AAM	OAT<73F	Lead Failure	120F-200F OAT 60F-10F	7.5 PSI	HWP's with VFD's
HE	L Wing	AAM	OAT<97F	Lead Failure	150F-190F OAT 60F-30F	7.0 PSI	HWP's with VFD's
HE-1	M Wing - Reheat Coils	AAM	OAT<83F	NA	131F-191F OAT 60F-0F	NA	
HE-2	M Wing - 2nd Flr Reheat Coils	AAM	OAT<88F	Lead Failure	160F	9.0 PSI	HWP's with VFD's
HE	N Wing	AAM	OAT<97F	Lead Failure	150F-190F OAT 60F-30F	7.0 PSI	HWP's with VFD's
HE	P Wing - AH's, Pool, Spa	AAM	24/7/365	Lead Failure	180F	5.0 PSI	HWP's with VFD's
HE-1	S Wing - West Unit Ventilators	AAM	OAT<83F	NA	140F-190F OAT 65F-15F	NA	
HE-2	S Wing - East Booster Coils & Radiation	AAM	OAT<87F	NA	130F-180F OAT 65F-15F	NA	
	Pool Heater		NA	NA	85F	NA	
	Pool Heater		NA	NA	85F	NA	
	Spa Heater		NA	NA	104F	NA	

HVAC System	Type	Capacity (Boiler HP)	Manufacture Date	Manufacturer	Model Number	Comments
BOILERS						
B-2	Steam	250	1996	Johnston	PFTA250-4LHG15CS	90.2% Efficient
B-3	Steam	500	1996	Johnston	PFTA500-4LHG150S	93% Efficient
B-4	Steam	500	1996	Johnston	PFTA500-4LHG150S	93% Efficient

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HVAC System	Description	Controlled by BAS	Also Used for Ice Building	Also Used for Free Cooling	Control Setpoint	Tonnage	Motor (HP)	Comments
CHILLERS								
CH-1	Absorption Chiller	Trane	no	no	45F CHWS	350	N/A	
CH-2	Centrifugal Chiller	Trane	yes	yes	45F CHWS	800	N/A	
CH-3	Centrifugal Chiller	Trane	yes	yes	45F CHWS	800	N/A	
COOLING TOWERS								
CT-1	CH-1 Cooling Tower	Trane	no	no	Mech Cooling 85F CDWS	350	2@15	with VFD
CT-2	CH-2 Cooling Tower	Trane	yes	yes	Freecool 39F CDWS Ice Build 71F CDWS Mech Cooling 85F CDWS	800	2@25	with VFD
CT-3	CH-3 Cooling Tower	Trane	yes	yes	Freecool 39F CDWS Ice Build 71F CDWS Mech Cooling 85F CDWS	800	2@25	with VFD

HVAC System	Description	Controlled by BAS	Also Used for Ice Building	Also Used for Free Cooling	Control Setpoint	Pump Motor (HP)	Design Flow (gpm)	Design Head (FtH2O)	Comments
CHILLED WATER PUMPS									
CP-1	Secondary CHW Pump	Trane	yes	yes	Standalone Controls	100	3000	90	with VFD
CP-2	Secondary CHW Pump	Trane	yes	yes	Standalone Controls	100	3000	90	with VFD
CP-3	CH-1 CHW Pump	Trane	no	no	interlocked with chiller	15	850	50	
CP-5	CH-2 CHW Pump	Trane	yes	yes	interlocked with chiller	25	1320	45	
CP-7	CH-3 CHW Pump	Trane	yes	yes	interlocked with chiller	25	1320	45	
CP-9	Ice Build Pump	Trane	Yes	no	enabled for ice build	75	2640	70	
CONDENSER WATER PUMPS									
CP-2	CH-1 CDW Pump	Trane	no	no	interlocked with chiller	25	1275	55	Physically labeled CP-4
CP-4	CH-2 CDW Pump	Trane	yes	yes	interlocked with chiller	60	2400	65	Physically labeled CP-6
CP-6	CH-3 CDW Pump	Trane	yes	yes	interlocked with chiller	60	3400	65	Physically labeled CP-8

HVAC System	Serves	Pump Motor (HP)	Design Flow (gpm)	Design Head (FtH2O)	Constant or VFD	Comments
HOT WATER PUMPS						
P HP-1	AHU-27 & P Reheat	7.5	250	70	VFD	
P HP-2	AHU-27 & P Reheat	7.5	250	70	VFD	
F HP-1	F Reheats	2	100	40	Constant	
F HP-2	F Reheats	1.5	95	30	Constant	
F HP-3	F Perim Baseboard	1.5	50	30	Constant	
L HP-1	L Wing	7.5	225	70	Constant	
L HP-2	L Wing	7.5	225	70	Constant	
A HP-1	A Reheat Coils	3	120	40	VFD	
A HP-2	A Reheat Coils	3	120	40	VFD	
J HP-1	J Reheat Coils	1.5	87	35	VFD	
J HP-2	J Reheat Coils	1.5	87	35	VFD	
M HP-1	M Wing	7.5	210	80	VFD	
M HP-2	M Wing	7.5	210	80	VFD	
HE5-2 A	E Courtyard Perim Baseboard	7.5	150	78	Constant	Balance valve 70% closed
HE5-2 B	E Courtyard Perim Baseboard	7.5	150	78	Constant	Balance valve 70% closed
E P-1	C,D, E & Connector Reheats	5	125	65	Constant	
E P-2	C,D, E & Connector Reheats	5	125	65	Constant	
P-1	Greenhouse In Floor Radiant	92W			Constant	
P-2	Greenhouse In Floor Radiant	92W			Constant	
HE5-1 A	Reheats for 11 & 12	3			VFD	
HE5-1 B	Reheats for 11 & 12	3			VFD	
P-1	S Wing Reheat				Constant	Taco pump, illegible nameplate
S Perim Pump	Baseboard and Cabinet UHs	2			Constant	
A HP-1	A & Front B Wing Reheat & BB	5	125	65	Constant	
A HP-2	A & Front B Wing Reheat & BB	5	125	65	Constant	
	AHU-29 & Reheat Coils	2	115	40	Constant	
POOL PUMPS						
	Spa jets	15			Constant	Controlled by 15 min timer
	Spa jets	7.5	210		Constant	Controlled by 15 min timer
	Activity	7.5			Constant	Manual control
	Current	15			Constant	Manual control
	Slide	10			Constant	Manual control
	Pool Filter	40			Constant	On continuously
	Ozone	20	535	110	Constant	Timeclock controlled
MISCELLANEOUS PUMPS						
Cond Pump 1	Boiler Condensate	1/2			Constant	
Cond Pump 2	Boiler Condensate	1/2			Constant	
	Boiler Feed Pump	15			Constant	
	Boiler Feed Pump	15			Constant	
	Boiler Feed Pump	15			Constant	
	Condensate Receiver Pump	5			Constant	
	Condensate Receiver Pump	5			Constant	

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System	Area Served	Controlled by BAS	Water Pump Enable	Steam Vlv Fixed HWST setpoint or HWST setpoint reset	Compressor on/off setpoints	Comments
MISCELLANEOUS CONTROL						
Dom Wtr Tower	Domestic Cold Water	No	Manual start, Auto stop started 6-7 days/wk	NA	NA	pump runs until shut off by tower level switch
Dom HW Tanks - Powerhouse	Domestic Hot Water	No	24/7/365	120F	NA	steam heats 55F water to 120F
Dom HW Tanks - F Wing	Domestic Hot Water	No	manual off (doesn't run)	120F	NA	steam heats 55F water to 120F
Dom HW Tanks - M Wing	Domestic Hot Water	No	24/7/365	120F	NA	steam heats 55F water to 120F
Dom HW Tanks - S Wing	Domestic Hot Water	No	24/7/365	120F	NA	steam heats 55F water to 120F
Steam Heated Hot Water	Food Service	No	NA	145F	NA	steam heats 120F water to 145F
Air Compressors	Labs, Shops, Art Dept.	Trane	NA	NA	ON<110PSI OFF>130PSI	three compressors - one runs at a time - lead rotated once per week

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Area Served	Controlled by BAS	OCC time schedule	Comments
INTERIOR LIGHTING			
A Wing Toilets	Trane	MTuWTh 645-2130 F 630-1600	
B Wing & B Wing Toilets	Trane	MTuWTh 646-2000 F 700-1700	
B Wing Corridors, Toilet EF	AAM	MTuWTh 730-1730 F 730-1659	
C Wing Corridor & Toilets	Trane	MTuWTh 700-2245 F 700-1700	
D Wing Toilets, Atrium & Science	Trane	MTuWTh 700-2230 F 700-1700	
D Wing Courtyard & Office	Trane	MTuWTh 650-1800	
E Wing Corridors & Toilets	Trane	MTuWTh 630-2215 F 630-1700	
F Wing Tlt Rm EF's/Lites & Corridors	AAM	MTuWThF 630-2215 SaSu 800-1630	
G Wing Tlt Rm EF's/Lites & Corridors	AAM	MTuWTh 630-2300 F 630-1700	
G Wing Library	Trane	MTuWTh 700-2200 F 700-1600 Sa 945-1410 Su 1250-1740	
H Wing Corriodr	AAM	MTuWTh 630-2300 F 630-1659 Sa 945-1410 Su 1250-1740	
J Wing Corriodr	AAM	MTuWTh 630-2259 F 630-1700	
K Wing Tlt Rm EF's/Lites & Corridor	AAM	MTuWThF 630-2300 Sa 730-1300	
L Wing Tlt Rm EF's/Lites	AAM	MTuWThF 555-2300	
M Wing Corridor	AAM	MTuWThF 630-2300	
N Wing Corridor	AAM	MTuWThF 630-2259	
N Wing LL Maint Corridor	AAM	MTuWThF 630-2159	
P Wing Corriodrs	AAM	MTuWThFSaSu 530-2300	
S Wing - Several Zones	AAM	MTuWThF 630-2300	
S Connector	Trane	MTuWTh 700-2230 F 700-1700 SaSu 800-1600	
Main Corridors	AAM	MTuWThF 600-2259	
Lower Level	AAM	MTuWThFSaSu 600-2300	
East Main Concourse	AAM	MTuWThF 600-2259	
1st Flr NE Concourse & Stair	AAM	MTuWThF 600-2259	
Main SW Corridor	AAM	MTuWThF 600-2259	
EXTERIOR LIGHTING			
B Wing Ext Soffit	AAM	on = light level <45cnd	
H Wing Ext Canopy	AAM	MTuWTh 500-2259 FSaSu 600-2159 on = light level <15cnd	
J Wing Ext Lighting	AAM	MTuWThF 630-1659 on = light level <15cnd	

Area Served	Controlled by BAS	OCC time schedule	Comments
M Wing Ext Lighting	AAM	on = light level <15cnd	
Main Roadway	AAM	MTuWThF 600-2300 on = light level <15cnd	
Delta Drive	AAM	MTuWThF 600-2300 on = light level <15cnd	
South Campus Drive	AAM	MTuWThF 600-2300 on = light level <15cnd	
Powerhouse Pole & Horseshoe roadway	AAM	MTuWThF 600-2200 on = light level <15cnd	
Far West Parking	AAM	not scheduled	
West Parking	AAM	not scheduled	
East Parking	AAM	MTuWThF 600-2300 on = light level <15cnd	
East Parking - G Wing	AAM	MTuWThF 600-2230 on = light level <15cnd	
SouthEast Parking	AAM	MTuWThF 700-2259 on = light level <15cnd	
SouthWest Parking	AAM	MTuWThF 700-2300 on = light level <15cnd	

EXHIBIT 7

ENERGY DATA

FY: **2009-10**
SITE: **MAIN CAMPUS**
UTILITY: **ELECTRICAL**
ACCOUNT: **01-7782-2450**
UTILITY CO: **Consumers Energy**
FILE NAME: **electric/mackinaw_main campus/0809**

BEGIN DATE	END DATE	AMOUNT	Y.T.D. AMOUNT	BEGIN READ	END READ	HIST. MAX KW	CURRENT MAX KW	KWH	Y.T.D. KWH	BILLING DEMAND	POWER FACTOR	AMT/ KWH	EDUCATION CREDITS	NOTES
07/01/09	07/31/10	84,468.14	84,468.14	24254	24601	3425	2980	1110400	1110400	2273	0.86	0.07607	9,987.65	
08/01/09	08/31/09	98,257.79	182,725.93	24601	24974	3425	3049	1193600	2304000	3011	0.86	0.082321	10,719.41	
09/01/09	09/30/09	74,822.60	257,548.53	24974	25362	3379	3379	1241600	3545600	2627	0.87	0.060263	11,209.27	
10/01/09	10/31/09	67,651.59	325,200.12	25362	25719	3379	2465	1142400	4688000	2319	0.88	0.059219	10,276.66	
11/01/09	11/30/09	59,137.26	384,337.38	25719	26044	3379	2381	1040000	5728000	2273	0.88	0.056863	13,517.18	
12/01/09	12/31/09	53,019.24	437,356.62	26044	26345	3379	2266	963200	6691200	2266	0.89	0.055045	22,008.12	
01/01/10	01/31/10	56,959.91	494,316.53	26345	26659	3379	2227	1004800	7696000	2196	0.9	0.056688	22,979.54	
02/01/10	02/28/10	56,503.45	550,819.98	26659	26956	3379	2227	950400	8646400	2227	0.9	0.059452	21,629.64	
03/01/10	03/31/10	67,591.19	618,411.17	26956	27295	3379	2703	1084800	9731200	2258	0.89	0.062308	24,608.29	
04/01/10	04/30/10	61,493.66	679,904.83	27295	27642	3379	2527	1110400	10841600	2281	0.88	0.05538	25,068.75	
05/01/10	05/31/10	72,769.66	752,674.49	27642	27691	3379	2949	1088000	11929600	2327	0.85	0.066884	24,663.37	
6/1/2010	06/30/10	84,221.54	836,896.03	230	606	3379	3133	1203200	13132800	2481	0.86	0.069998	27,154.82	
		$ 836,896.03						**13,132,800**				**0.063726**	**223,822.70**	

FISCAL YEAR: **2009-10**

SITE: DELTA COLLEGE - MAIN CAMPUS
6263 S Machinaw RD
UNIVERSITY CENTER, MI 48710

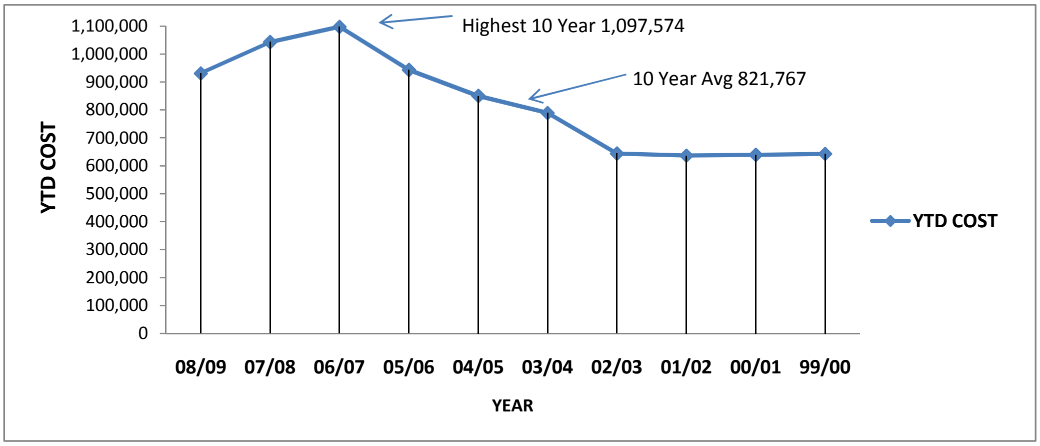
UTILITY: GAS
DELTA ACCT: **01-7782-2451**
UTILITY CO: CONSUMERS ENERGY
UTILITY ACCT: 15 18 00 8505 00 0
FILE NAME: GAS\site invoicing\gas\6263 Mackinaw Rd main campus\0809

		SOURCE AMOUNT										
FROM	TO	TRANSPORT GAS	CONSUMERS ENERGY	COMBINED COST	YTD TOTAL COST	BEGIN	END	BTU	MCF	YTD MCF	COST PER MCF	YTD COST PER MCF
1-Jul-2009	30-Jul-2009	$17,278.80	$3,764.28	$21,043.08	$21,043.08	87131	90478	3387	3347	3347	$6.29	$6.29
31-Jul-2009	28-Aug-2009	$12,872.40	$3,247.02	$16,119.42	$37,162.50	90478	93293	2849	2815	6162	$5.73	$6.03
29-Aug-2009	29-Sep-2009	$13,892.34	$4,231.97	$18,124.31	$55,286.81	93293	97121	3897	3828	9990	$4.73	$5.53
30-Sep-2009	29-Oct-2009	$29,729.00	$6,494.50	$36,223.50	$91,510.31	97121	103276	6260	6155	16145	$5.89	$5.67
30-Oct-2009	25-Nov-2009	$29,983.80	$6,483.34	$36,467.14	$127,977.45	103276	109202	6027	5926	22071	$6.15	$5.80
25-Nov-2009	30-Dec-2009	$53,526.30	$12,199.46	$65,725.76	$193,703.21	109202	119734	10701	10532	32603	$6.24	$5.94
30-Dec-2009	29-Jan-2010	$59,534.02	$13,398.45	$72,932.47	$266,635.68	119734	130537	10976	10803	43406	$6.75	$6.14
30-Jan-2010	25-Feb-2010	$42,485.00	$10,603.43	$53,088.43	$319,724.11	130537	139631	9267	9094	52500	$5.84	$6.09
26-Feb-2010	30-Mar-2010	$41,354.00	$9,945.26	$51,299.26	$371,023.37	139631	148132	8637	8501	61001	$6.03	$6.08
31-Mar-2010	29-Apr-2010	$24,749.40	$6,129.42	$30,878.82	$401,902.19	148132	153195	5119	5063	66064	$6.10	$6.08
30-Apr-2010	27-May-2010	$25,379.14	$4,967.48	$30,346.62	$432,248.81	153195	157282	4259	4087	70151	$7.43	$6.16
28-May-2010	30-Jun-2010	*$23,733.56*	$4,550.26	$28,283.82	$460,532.63	157282	161104	4145	3822	73973	$7.40	$6.23
				$460,532.63					**73973**			

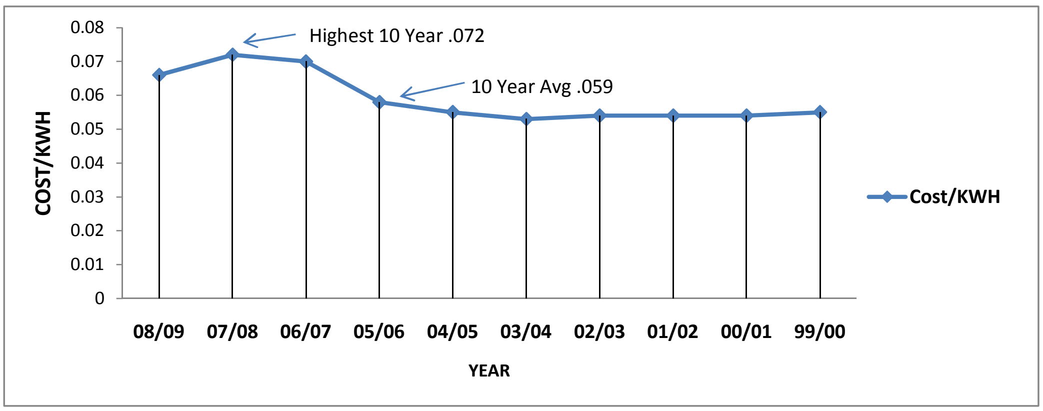
May transport cost is extrapolated.

* Meter rollover

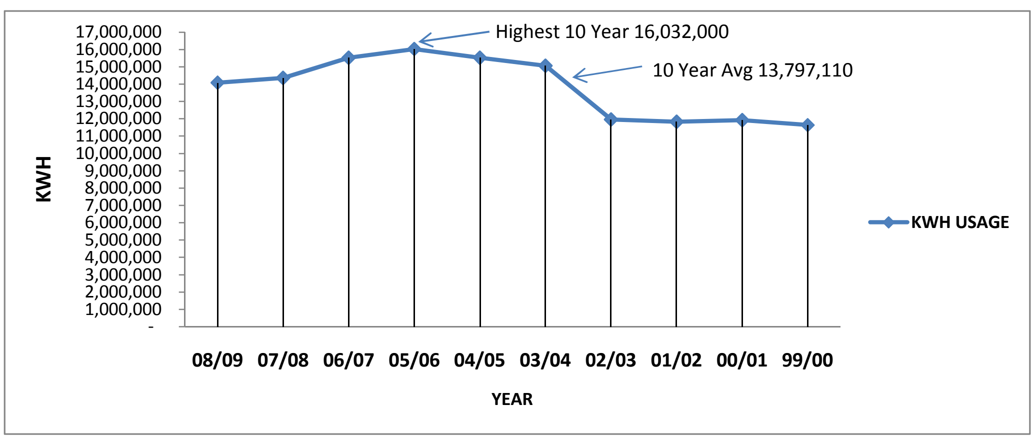
Year	YTD COST
08/09	931,190.48
07/08	1,043,270.59
06/07	1,097,574.14
05/06	943,137.38
04/05	850,024.41
03/04	789,213.67
02/03	644,215.62
01/02	636,673.73
00/01	639,659.14
99/00	642,713.72
AVG	**821,767.29**



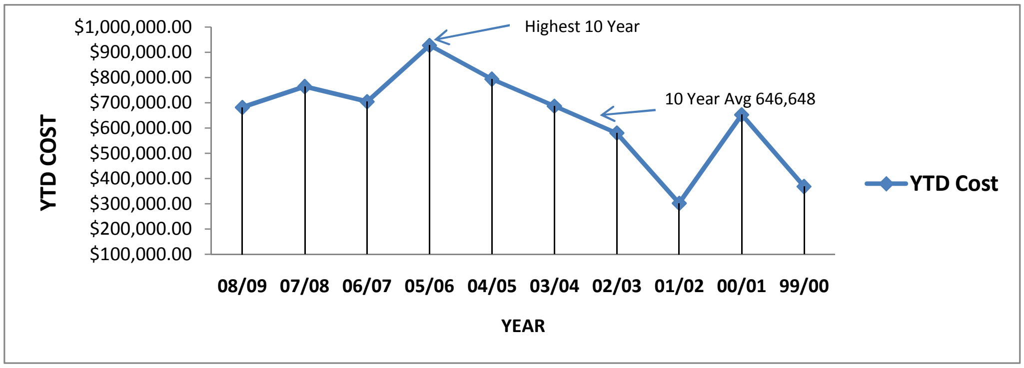
Year	Cost/KWH
08/09	0.066
07/08	0.072
06/07	0.070
05/06	0.058
04/05	0.055
03/04	0.053
02/03	0.054
01/02	0.054
00/01	0.054
99/00	0.055
AVG	**0.0591**



Year	KWH USAGE
08/09	14,080,000
07/08	14,358,400
06/07	15,529,600
05/06	16,032,000
04/05	15,532,700
03/04	15,068,800
02/03	11,968,000
01/02	11,830,400
00/01	11,929,600
99/00	11,641,600
AVG	**13,797,110**



Year	YTD Cost
08/09	682,230.09
07/08	764,877.35
06/07	705,270.57
05/06	928,009.73
04/05	794,016.28
03/04	687,473.73
02/03	580,427.92
01/02	302,117.24
00/01	653,069.58
99/00	368,993.62
AVG	**646,648.61**



Year	Cost/MCF
08/09	8.00
07/08	9.32
06/07	8.40
05/06	11.36
04/05	8.10
03/04	6.26
02/03	6.30
01/02	3.95
00/01	7.04
99/00	3.93
AVG	**7.27**

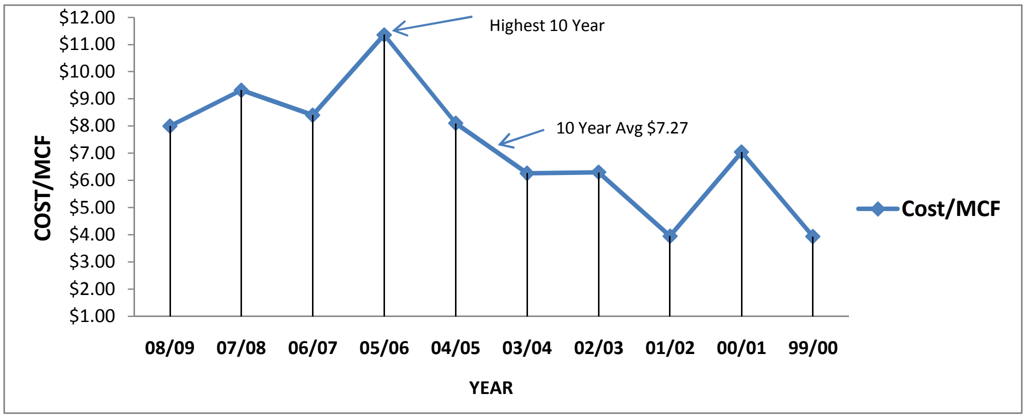


EXHIBIT 8

DIAGNOSTICS, MONITORING, AND TEST PLAN

DIAGNOSTICS, MONITORING, and TEST PLAN

1. Given scope of project, only a portion of the systems of the building will be functionally tested by G/BA with onsite personnel. It is hoped that onsite personnel will carry the testing forward to other systems not included in the scope of work. Systems to be tested were established in the Phase II EBCx kickoff meeting.
2. Existing sequences of operation for systems to be tested to be provided by Owner to G/BA.
3. G/BA to develop test procedures for systems selected in EBCx Phase II kickoff meeting to be functionally tested.
4. G/BA to provide listing of trends to be setup by onsite personnel utilizing the existing building management system.
5. Review trends to determine if anything stands out as inappropriate or there are savings opportunities for the system being monitored.
6. If necessary, request the Owner's control contractor to assist with testing and trending of systems being tested.
7. Given that only a portion of the AHU systems are being tested, it is hoped that similar findings may be applied/extrapolated to other similar AHU systems not tested.
8. Chiller plant and boiler plant evaluations will occur through trending and field data gathering. No testing of these systems is planned given their size and impact to the facility.
9. Temperature, humidity data from the BMS and manual amp readings will be utilized to aid in supporting energy savings/performance improvement measures identified.
10. All diagnostics will be through functional performance testing by G/BA with the assistance of Owner onsite personnel, field observations, and trending of specific systems utilizing the existing BMS. No data loggers or outside test and balance agency will be utilized for the Phase II investigation phase.

EXHIBIT 9

OPERATION AND MAINTENANCE OBSERVATIONS

Operation and Maintenance Observations

Building owners, managers, and operation personnel can save significant energy annually by implementing O&M best practices. As seen from section VI of this report, O&M measures identified in a sampling of systems suggest there is significant savings annually in these measures.

To help the building owner, managers, and operations staff a series of O&M Best Practice Reports, free to the public, were developed with funding by the U.S. EPA and U.S. DOE. A listing of these reports can be seen below, and five of the six reports can be obtained by going to the EnergyStar website address as indicated below:

http://www.energystar.gov/index.cfm?c=business.bus_om_reports

The reports at this website are:

1. Fifteen O&M Best Practices for Energy-Efficient Buildings
2. Operation and Maintenance Service Contracts: Guidelines for Obtaining Best-Practice Contracts for Commercial Buildings
3. Portable Data Loggers-Diagnostic Monitoring Tools for Energy-Efficient Building Operation
4. O&M Assessments: Enhancing Energy-Efficient Building Operations.
5. Putting the "O" Back in O&M: Best Practices in Preventive Operations, Tracking, and Scheduling

The sixth report is as indicated below and can be obtained at the website indicated.

6. Energy Management Systems-A Practical Guide

http://www.peci.org/documents/PECI_PracticalGuide1_0302.pdf

The purpose behind the development of this series of reports was to help owners, managers, and operation personnel increase energy efficiency, improve occupant comfort, and reduce operating expenses through low cost operating improvements. These reports are suggested reading and certainly would also contribute to the training/education of all that read the documents.

Site Observations

1. There are many O&M issues which can occur that do not cause complaints immediately or at all and can go undiscovered for a long time. These less obvious problems can sometimes have significant energy implications as can be seen by some of the listed O&M measures in section VI of this report. It is recommended that someone already on staff or someone new be given the time and responsibility of searching out problems in lieu of reacting when found due to complaints or other reactive methods. The additional cost to have someone take proactive steps to find problems, it is believed,

will be outweighed by the energy savings achieved by finding and resolving the issues.

EXHIBIT 10

BAS WORKSTATION OBSERVATIONS

Building Automatic System (BAS) Workstation Observations

1. See detailed operation and maintenance (O&M) measures listed in section VI of the report for specific issues.

2. The majority of low and no cost facility improvement measures (FIMs) are associated with control changes and many of the FIMs strictly involve setpoint changes. In the interest of quickly addressing a complaint or problem setpoints can easily be changed by anyone on the maintenance staff and never changed back. *Changes to setpoints can have a significant impact on energy usage and therefore it is very important that some form of change control be implemented to track changes and ensure that any modifications are properly documented along with the rationale for these changes.*

3. Additional training for the operations personnel on the control system is recommended because the better they understand the system the more easily they will find and solve problems.

5. It is suggested that operations staff create a table or reference list of all the building's adjustable settings to help them monitor and maintain the proper settings. In addition, the operations staff should answer the following questions when assessing how settings and setpoints may have changed over time:

   a. Have occupancy patterns or space layouts changed? Are HVAC and lighting still zoned to efficiently serve the spaces?

   b. Have temporary occupancy schedules been returned to original settings?

   c. Have altered equipment schedules or lockouts been returned to original settings?

   d. Is equipment short-cycling?

   e. Are timeclocks checked monthly to ensure proper operation?

   f. Are seasonally-changed setpoints regularly examined to ensure proper adjustment?

   g. Have any changes in room furniture or equipment adversely affected thermostat function? (Check thermostat settings or other controls that occupants can access.)

   h. Are new tenants educated in the proper use and function of thermostats and lighting controls?

6. A reference list of operational parameters can help building managers augment an existing preventive maintenance program by introducing a focus on operation. Operations personnel should periodically revisit various building settings to determine whether they have been changed to incorrect values or whether there is a need to change the desired value.

EXHIBIT 11

FACILITY IMPROVEMENT MEASURES (FIMs) AND OPERATION AND MAINTENANCE (O&M) SAVINGS CALCULATIONS/CAPITAL COST ESTIMATES

SAVINGS CALCULATIONS

Utility Info

Blended Electricity =	0.101	$/kWh	EIA Michigan Value
Heating =	0.965	$/therm	EIA Michigan Value
Chiller Plant Efficiency =	1.207	kW/ton	Value provided by FOE for generic chiller plant operation
Cooling =	0.121907	$/ton-hr	
Boiler Efficiency =	93%		Actual efficiency is 90.3-93%

FIM 1: Close OAD During Morning Warmup

Morning Warmup Duration =	390	hours	Assumes 1.5 hrs/day 5 days a week (some operate on weekends, conservative)
Total Current SF Flow =	438,777	cfm	Includes AHU-1,3-4,6,8-10,13,17-18,21-26,28-30,39,43,44. Uses witnessed VFD speed
Total Current OA Flow =	83,535	cfm	
Average % OA =	19.04%		
Electrical Savings (if 8760) =	417088	kWh	See Quattro, for 8760 operation
Gas Savings (if 8760) =	54,356	therms	See Quattro, for 8760 operation
Electrical Savings =	18,569	kWh	
Gas Savings =	2,420	therms	
Total Savings =	$4,211		Excludes reheat savings during economizer operation.
Capital Cost =	Negligible		Strictly requires setpoint/programming modifications

FIM 2: Provide Morning Warmup Optimal Start

Total Current Fan Power =	743.7	BHP	Assumes max BHP=80%hp & current VFD speed is avg speed & cubed power relationship
Reduction in Morning Warmup =	130	hours	Assumes 0.5 hrs/day 5 days a week reduction in morning warmup.
Electrical Savings =	72,121	kWh	
Total Savings =	$7,284	per year	
Capital Cost =	$1,000-5,000		Strictly involves programming changes. May require outside programming.

FIM 3: Control AHU Preheat Coil Valves to Unocc MAT Setpts

Savings =	$50-200	per year	Assumption, savings will be low
Capital Cost =	Negligible		Strictly requires setpoint/programming modifications

FIM 4: Close VAV Box Reheat Coil Valves when AHU is Off

Savings =	$100-1000	per year	Assumption
Capital Cost =	Negligible		Strictly requires setpoint/programming modifications

FIM 5: Close OAD on Gym AHU-1 &2 when AHUs are Off

Savings =	$100-1000	per year	Assumption
Capital Cost =	Negligible		Strictly requires setpoint/programming modifications

FIM 6: Lockout AHU CC Control Valves During Morning Warm-up

Savings =	$100-1000	per year	Assumption
Capital Cost =	Negligible		Strictly requires setpoint/programming modifications

FIM 7: Reset AHU MAT & DAT — Neglect savings for units which have only some setpoints reset (conservative)

AHU Flow for DAT SP @ 55-60	44,015	cfm	Current flow for units with constant setpoint between 55 & 60
AHU Flow for DAT SP @ 62	69,768	cfm	Current flow for units with DAT SP=62
Reheat Reduction for 55-60 DAT =	5	F	Actual reset will likely be 10F (conservative)
Reheat Reduction for 62 DAT =	2	F	Actual reset will likely be larger (conservative)
Hours at Increased DAT =	1,445	hours	Assume all hours OAT<40 & occupied. Assume 15hrs/weekday occupied
Reheat Savings =	6,063	therms	
Total Savings =	$5,851	per year	
Capital Cost =	Negligible		Strictly requires setpoint/programming modifications

FIM 8: Reset VAV Static Press SP

Current BHP =	113	BHP	AHU-3,4,7,25,29,36,42-45. Assumes current VFD speed is avg & cubed relation to power
Power Reduction =	5%		Assume average of 0.2" static reduction & TSP = 4"
Hours of Operation =	3900	hours	Assume 15hrs/weekday occupied.
Savings =	16,369	kWh	
Total Savings =	$1,653		
Capital Cost =	Negligible		Strictly requires setpoint/programming modifications

FIM 13: Greenhouse AHU - Add Recirculation

Current Flow =	6,083	cfm	Based on observed VFD speed
New OA Flow =	2,000	cfm	Assumption
Heating Savings =	8,758	therms	
Cooling Savings =	4,208	kWh	
Total Savings =	$8,876	per year	

FIM 14: Provide Control Valves for All Hot Water Unit Heaters

Savings =	$75-150	per year	Assumption based on calculations on previous studies
Capital Cost =	$1000-1500		Assumption based on calculations on previous studies

FIM 11: Trim Impellers

FIM 11A: Chiller 1 - CP-3

Motor HP =	15	HP	
Motor Power =	12	BHP	Assume BHP = 80%HP
Design Flow =	850	gpm	
Design Pressure =	50	Ft H2O	
Balance Valve Position =	10%	open	
Assumed Valve Size =	8	"	
Current Valve Pressure Drop =	27	Ft H2O	
New Valve Pressure Drop =	1.80	Ft H2O	
Pressure Savings =	25.20	Ft H2O	
Hours of Operation =	8760	hours	
Savings =	52,980	kWh	
Total Savings =	$5,351	per year	

FIM 11B: Chiller 2 - CP-5 & 6

CP-5

Motor HP =	25	HP	
Motor Power =	20	BHP	Assume BHP = 80%HP
Design Flow =	1320	gpm	
Design Pressure =	45	Ft H2O	
Balance Valve Position =	20%	open	
Assumed Valve Size =	10	"	8" would be reasonable but assume 10" to be conservative
Current Valve Pressure Drop =	8	Ft H2O	
New Valve Pressure Drop =	1.40	Ft H2O	
Pressure Savings =	6.60	Ft H2O	
Hours of Operation =	4380	hours	Assume runs 50% of the time.
Savings =	12848	kWh	
Total Savings =	$1,298	per year	

CP-6

Motor HP =	60	HP	
Motor Power =	48	BHP	Assume BHP = 80%HP
Design Flow =	2400	gpm	
Design Pressure =	65	Ft H2O	
Balance Valve Position =	50%	open	
Assumed Valve Size =	10	"	
Current Valve Pressure Drop =	3	Ft H2O	
New Valve Pressure Drop =	1.60	Ft H2O	
Pressure Savings =	1.80	Ft H2O	
Hours of Operation =	2920	hours	Assume runs 30% of the time (doesn't run during ice melt)
Savings =	3,881	kWh	
Total Savings =	$392	per year	

CP-5 & 6 Total

Savings =	16,729	kWh	
Total Savings =	$1,690	per year	

FIM 11C: East Courtyard HW P-1&2

Motor HP =	7.5	HP	Assume 1 pump on
Motor Power =	6	BHP	Assume BHP = 80%HP
Design Flow =	150	gpm	
Design Pressure =	78	Ft H2O	

Balance Valve Position =	30%	open	
Valve Size =	3	"	Field surveyed
Current Valve Pressure Drop =	17	Ft H2O	
New Valve Pressure Drop =	1.60	Ft H2O	
Pressure Savings =	15.40	Ft H2O	
Hours of Operation =	7708	hours	OAT<75
Savings =	9,131	kWh	
Total Savings =	$922	per year	

<u>FIM 11D: Pool Current & Slide Pumps</u>

<u>Current Pump</u>

Motor HP =	15		
Motor Power =	12	BHP	Assume BHP = 80%HP
Balance Valve Position =	50%	open	
Pressure Savings =	5%		Assumption, actual design pressure unknown
Hours of Operation =	1716	hours	
Savings =	1,030	kWh	
Total Savings =	$104	per year	

<u>Slide Pump</u>

Motor HP =	10		
Motor Power =	8	BHP	Assume BHP = 80%HP
Balance Valve Position =	40%	open	
Pressure Savings =	5%		Assumption, actual design pressure unknown
Hours of Operation =	1716	hours	
Savings =	686	kWh	
Total Savings =	$69	per year	
Total Savings	1,716	kWh	
Total Savings	$173	per year	
Capital Cost =	$1000-2000	per pump	Based on typical impeller trim costs

<u>FIM 9A: Reduce Filter Pump Hours of Operation</u>

Pump Power =	40	HP	
Pump Power =	32	BHP	
Shutdown Hours =	1095	hours	3 hrs/day
Savings =	26,140	kWh	
Savings =	$2,640	per year	
Capital Cost =	$1000-2000		Strictly requires addition of timeclock control

<u>FIM 9B: Reduce Filter Pump Speed During Unoccupied</u>

Unoccupied Hours =	4158	hours	Use same schedule as ozone pump
Unoccupied Speed =	60%		Assumption
Unoccupied Power Savings =	72%		
Additional Energy During Occ =	10,766	kWh	Assumes 9.8% VFD inefficiency at full speed
Energy Saved During Unocc =	71,666	kWh	
Savings =	60,899	kWh	
Savings =	$6,151		

Capital Cost

1 @ 60HP Motor =	$3,500
1 @ 60HP VFD =	$12,500
Wiring, Conduit, Etc. =	$1,250
Controls =	$3,000
Total Cost =	$20,250
Total w/ Engineering & Mgment =	$22,275

<u>FIM 17: Eliminate Morning Warm-up Operation During Occ Period</u>

Savings =	$100-500	per year	Assumption
Capital Cost =	Negligible		Strictly requires setpoint/programming modifications

<u>FIM 18: Correct Damper Control Signal Error</u>

Savings =	$100-500	per year	Assumption

Capital Cost =	Negligible		Strictly requires setpoint/programming modifications

FIM 19: Reduce AHU-36 HRC Operation

Avg AHU-36 Flow =	26,000	cfm	Assumption based on winter observed, likely conservative.
Exhaust Temperature =	74	F	Assumed
Cooling DAT Setpt (for savings) =	55	F	Assumed. No real savings when DATSP is higher.
Hours in Cooling =	25%		Assumption. Associated with hours when Rm Temp = 74 or higher
OAT Bin 55-60 Avg OAT =	57.5	F	
OAT Bin 60-65 Avg OAT =	62.5	F	
OAT Bin 65-70 Avg OAT =	67.5	F	
HRC Effectiveness =	40%		Assumed, low efficiency is conservative assumption
HRC DAT @ 55-60 OAT =	64	F	
HRC DAT @ 60-65 OAT =	67	F	
HRC DAT @ 65-70 OAT =	70	F	
Excess Cooling Reqd @55-60 =	186,186	Btu/h	
Excess Cooling Reqd @60-65 =	129,766	Btu/h	
Excess Cooling Reqd @65-70 =	73,346	Btu/h	
Hours 55-60 OAT =	604	hours	Includes all hours, not just hrs in cooling
Hours 60-65 OAT =	700	hours	Includes all hours, not just hrs in cooling
Hours 65-70 OAT =	759	hours	Includes all hours, not just hrs in cooling
Excess Cooling Reqd =	5,395	Ton-hrs	
Cooling Savings =	6,512	kWh	
Pump Size =	1	HP	Assumption
Pump Savings =	308	kWh	Assumes BHP = 80%HP
Total Electrical Savings =	6,820	kWh	
Savings =	$689	per year	
Capital Cost =	Negligible		Strictly requires setpoint/programming modifications

FIM 20: Operate Secondary Chilled Water Pumps in Parallel

Pump Power =	100	HP	Each
Average Pump Power =	32	BHP	Assumes BHP = 80%HP, Avg Power = 40%
Hours of Operation =	8760	hours	Pumps operate continuously
Expected Savings =	2%		Assumption
Savings =	4,182	kWh	
Savings =	$422	per year	
Capital Cost =	$100-1000		Standalone B&G Controller, will likely require outside assistance.

FIM 24: Provide Lead/Lag Pump for Ice System

CP-9 Power =	75	HP	
CP-9 Average Load =	30	BHP	Assumes BHP = 80%HP, Avg Power = 50%
Weeks of Operation =	30.3	weeks	Assumes ice making occurs 7 months out of the year
Ice Make Hours =	1,062	hours	Assumes 7 hours/day, 5 days a week
Ice Burn Hours =	1,213	hours	Assumes 8 hours/day, 5 days a week
Overpumping Hours =	303	hours	Assumes overpump 25% of ice burn hours
Balance Valve Power Savings =	5%		Assumption, @ design flow/head a 10" closed valve ≈ 18% of press drop
Overpumping Power Savings =	1%		Assumption
Total Energy Savings =	2614	kWh	Doesn't include savings associated with improved ice melt usage
Savings =	$264		
Capital Cost			
15HP Base Mounted Pump =	$6,000		
Piping/Specialties =	$2,000		
Controls =	$3,000		
VFD =	$4,000		
Electrical =	$1,000		
Total Construction Cost =	$16,000		
Total including Engineering =	$17,600		Assumes engineering equals 10% of construction cost.

FIM 23: Provide VFDs for HW Pumps

L HP-1 & 2 =	7.5	HP	
Hours of Operation =	8742	hours	Enabled when OAT <97F
Current Power =	39,129	kWh/yr	Assumes BHP = 80%HP

HE5-2 /B =	7.5	HP	
Hours of Operation =	7708	hours	Enabled when OAT<75
Current Power =	34,501	kWh/yr	Assumes BHP = 80%HP
E P-1/2 =	5	HP	
Hours of Operation =	6268	hours	Assume enabled when OAT<65
Current Power =	18,704	kWh/yr	Assumes BHP = 80%HP
A HP-1/2 =	5		
Hours of Operation =	4964	hours	Appears to be enabled when OAT<55
Current Power =	14,813	kWh/yr	Assumes BHP = 80%HP
Total Current Power =	107,146	kWh/yr	
Power Reduction =	58.4%		Assumes heavy load profile and includes VFD inefficiency.
Power Savings =	62,574	kWh/yr	
Savings =	$6,320	per year	Excludes balance valve savings
Capital Cost	Assume only lead pump has VFD installed.		
2 @ 7.5HP Motor =	$1,500		Means
2 @ 5HP Motor =	$1,350		Means
2 @ 7.5HP VFD =	$6,000		Means
2 @ 5HP VFD =	$5,000		Means
Wiring, Conduit, Etc. =	$5,000		
Controls =	$12,000		
Total Cost =	$30,850		
Total w/ Engineering & Mngt =	$33,935		Cost for single VFD per pair, cost will double for providing for both pumps

<u>O&M 21: Replace L-Wing HE DP Sensor</u>

Pump Power =	7.5	HP	Only 1 pump runs at a time.
Pump Power =	6	BHP	Assume BHP = 80%HP
Observed Winter Speed =	47%		28 Hz Observed 11/23/09
Observed Winter Power =	1.3	BHP	Assumes squared speed/power relationship (conservative).
Hours of Operation =	8760	hrs	Operates continuously.
Savings =	30,671	kWh	Summer observed at 100% speed & still well below setpt.
Savings =	$3,098	per year	
Capital Cost =	$100-300		Assumption, strictly involves sensor replacement/recalibration.

<u>O&M 14: Add AHU-50 Outside Air and Relief Damper Control</u>

AHU-50 Airflow =	1,600	cfm	
Room Setpt =	78	F	
Avg DAT =	68	F	Assumption
Economizer Enable Setpoint =	60	F	Assumption, conservatively below avg DAT.
Economizer Hours =	5568	hours	Hours OAT<econ setpt
Savings =	9,722	kWh	
Savings =	$982	per year	
Capital Cost			
Demolition =	$500		
2 Dampers =	$500		
Ductwork =	$1,500		
Controls =	$3,000		
Total Cost =	$5,500		

Bin		DB	WB	Btu/lb	Gr/lb	1-8	8-16	16-24	Total
95	99	97.5	76	38.6	96.4	0	6	0	6
90	94	92.5	74	37.87	99.5	0	52	6	58
85	89	87.5	72	35.92	95	1	132	32	165
80	84	82.5	70	33.49	87.3	11	225	88	324
75	79	77.5	67	31.33	81.3	68	260	159	487
70	74	72.5	64	29.29	76.1	176	262	243	681
65	69	67.5	61	27.44	72.1	270	220	269	759
60	64	62.5	57	24.17	59	280	176	244	700
55	59	57.5	52	21.35	48.6	233	160	211	604
50	54	52.5	47	18.83	40.2	222	163	196	581
45	49	47.5	43	16.68	34.2	212	164	189	565
40	44	42.5	38	14.41	27.3	194	181	197	572
35	39	37.5	34	12.59	23.3	243	237	245	725
30	34	32.5	30	10.88	20	319	251	299	869
25	29	27.5	25	8.91	15	227	160	202	589
20	24	22.5	21	7.3	12.4	154	100	117	371
15	19	17.5	16	5.71	9.9	98	60	73	231
10	14	12.5	11	4.1	7.2	69	43	52	164
5	9	7.5	6	2.57	5	44	30	41	115
0	4	2.5	1	1.11	3.4	40	18	31	89
-5	-1	-2.5	-3	-0.09	3.4	27	9	17	53
-10	-6	-7.5	-8	-1.38	2.8	17	3	7	27
-15	-11	-12.5	-13	-2.58	2.8	8	1	2	11
-20	-16	-17.5	-17	-3.88	2.1	2	0	0	2

100% OA Heating	100% OA Cooling	33% OA Heating	33% OA Cooling
	215		106
	1,762		919
	4,118		2,318
	6,328		3,972
	6,869		5,099
1,966			
5,043			
7,969			
11,171			
18,092			
26,400		1,131	
21,089		1,821	
15,296		1,811	
10,777		1,541	
8,541		1,388	
6,613		1,179	
5,601		1,072	
3,623		733	
1,992		422	
871		192	
169		38	
145,215	19,291	11,330	12,414

OA heating/cooling results are in Btu/cfm for 8760 operation.
OA cooling neglects dehumidification savings.

Delta Savings Summary

FIM/ O&M	#	Phase	Description	Min Savings	Max Savings	Min Cost	Max Cost	Min Payback	Max Payback	Min Gas Savings	Max Gas Savings	Min Elec Savings	Max Elec Savings
FIM	1	1	Close OAD During Unocc AHU Start-up & Warmup	$3,500	$5,000	$0	$0	0.0	0.0	2,000	3,000	16,000	20,000
FIM	2	1	Provide Morning Warmup Optimal Start	$5,000	$10,000	$1,000	$5,000	0.1	1.0	0	0	50,000	100,000
FIM	3	1	Control Preheat Coil Valves to Unocc MAT Setpt	$50	$200	$0	$0	0.0	0.0	26	104	248	990
FIM	4	1	Close VAV Reheat Coil Valves when AHU is Off	$100	$1,000	$0	$0	0.0	0.0	52	518	495	4,950
FIM	5	1	Close OADs on Gym AHU-1/2 when AHUs are off	$100	$1,000	$0	$0	0.0	0.0	52	518	495	4,950
FIM	6	1	Lockout AHU CC Control Valves During Warmup	$100	$1,000	$0	$0	0.0	0.0	0	0	990	9,901
FIM	7	1	Reset AHU MAT & DAT Setpts	$6,000	$8,000	$0	$0	0.0	0.0	0	0	6,000	8,000
FIM	8	1	Reset VAV AHU SASP Setpts	$1,500	$1,750	$0	$0	0.0	0.0	0	0	15,000	17,500
FIM	9a	1	Reduce Pool Filter Hours of Operation	$2,000	$3,000	$1,000	$2,000	0.3	1.0	0	0	20,000	30,000
FIM	9b	1	Reduce Filter Pump Speed During Unocc Hours	$4,000	$7,000	$20,000	$25,000	2.9	6.3	0	0	40,000	70,000
FIM	10	1	Swimming Pool Cover										
FIM	11a	1	Trim CP-3	$4,000	$6,000	$1,000	$2,000	0.2	0.5	0	0	40,000	60,000
FIM	11b	1	Trim CP-5&6	$1,000	$2,500	$2,000	$4,000	0.8	4.0	0	0	10,000	25,000
FIM	11c	1	Trim East Courtyard CP-1&2	$500	$1,500	$2,000	$4,000	1.3	8.0	0	0	5,000	15,000
FIM	11d	1	Trim Pool Current & Slide Pump	$100	$250	$2,000	$4,000	8.0	40.0	0	0	1,000	2,500
FIM	12	1	Add Occ Sensors to Large Classrooms for VAV										
FIM	13	1	Greenhouse AHU-37 - Reconfigure for Return	$8,000	$10,000					7,000	10,000	3,000	5,000
FIM	14	1	Provide CVs on all Hot Water Unit Heaters	$75	$150	$1,000	$1,500	6.7	20.0	39	78	371	743
FIM	15	1	High Efficiency Equipment Replacement										
FIM	16	1	Submetering										
FIM	17	2	Eliminate Morning Warmup During Occ	$100	$500	$0	$0	0.0	0.0	52	259	495	2,475
FIM	18	2	Correct Damper Control Signal Error	$100	$500	$0	$0	0.0	0.0	52	259	495	2,475
FIM	19	2	AHU-36 Heat Recovery Pump Control Error	$400	$800	$0	$0	0.0	0.0	0	0	4,000	8,000
FIM	20	2	Operate Secondary Chilled Water Pumps in Parallel	$300	$500	$100	$1,000	0.2	3.3	0	0	3,000	5,000
FIM	21	2	Rebalance CHW System										
FIM	22	2	Provide AHU Night Setup Cooling Control										
FIM	23	2	Provide VFDs for HW Pumps	$5,000	$7,000	$30,000	$70,000	4.3	14.0	0	0	50,000	70,000
FIM	24	2	Provide Lead/Lag Pumps for Ice System	$150	$350	$15,000	$20,000	42.9	133.3	0	0	1,500	3,500
FIM	25	2	Increase Chiller and Ice Storage Capacity										
FIM	26	2	Increase Boiler Capacity										
O&M	14	1	AHU-50 Add OAD & RAD Control	$800	$1,200	$4,000	$7,000	3.3	8.8	0	0	8,000	12,000
O&M	21	2	Replace L Wing Differential	$2,500	$3,500	$100	$300	0.0	0.1	0	0	25,000	35,000

Phase 1 Short Payback/O&M Total =	$20,350	$33,950	$2,000	$7,000		
Phase 2 Short Payback/O&M Total =	$3,400	$5,800	$200	$1,300		
Anticipated Short Payback/O&M Savings for Completing Func Testing =	$13,600	$23,200	$800	$5,200		
Currently Identified Short Payback/O&M Total =	$23,750	$39,750	$2,200	$8,300		
Anticipated Short Payback/O&M Total with Full Testing =	$37,350	$62,950	$3,000	$13,500	0.05	0.21

Present Utility Cost =	$2,040,252		(Uses EIA Utility Rates)
Present Utility Usage =	121,014,436		Thousand BTU
Identified Short Payback/O&M Total Savings =	1.2%	1.9%	
Anticipated Short Payback/O&M Total Savings with Full Testing =	1.8%	3.1%	

FIMs 1-8, 11a, 17-20 Total Cost Savings =	$21,250	$36,250	$2,100	$8,000	0.06	0.22
FIMs 1-8, 11a, 17-20 Total Cost Savings =	1.0%	1.8%				
FIMs 1-8, 11a, 17-20 kBtu Savings =	691,640	1,299,403				
FIMs 1-8, 11a, 17-20 kBtu Savings =	0.6%	1.1%				

EXHIBIT 12

TREND LOG ANALYSIS/ABNORMALITIES

Trend Log Analysis/Abnormalities

Trends for four of the air handling units being functionally tested were set up with a sampling rate of every 5 minutes and were reviewed to determine if any abnormalities were observed which should be addressed with a potential FIM or O&M measure. See FIM and O&M descriptions for recommendations associated with the below analysis.

The chiller plant was not functionally tested and instead was evaluated by performing additional field observations, analysis of observed conditions, and interviews with operators. Chiller trends will be reviewed once they have been completed.

AHU-1

1. There are periods where the unit is quickly cycling from economizer to non-economizer operation. The resulting discharge air temperature fluctuations appear to be a maximum of 1F so there is likely no significant energy impact.
2. The unit sometimes turns on with the cooling coil valve mostly open but it quickly goes back to normal position.
3. There are times when both the CHW and PHW valves appear to be commanded open. There is no clear impact to the discharge air temperature; valves may not both actually be open.

AHU-28

1. There are periods where the unit is quickly cycling from economizer to non-economizer operation. A discharge air temperature fluctuation of 5F was observed at one time but there is still likely no significant energy impact.
2. The VFD appears to start at 100% speed which is sometimes resulting in overpressurization for 5-30 minutes. This problem only appears to existing during the first half of the trending period.
3. There are times when both the CHW and HW valves appear to be commanded open. There is no clear impact to the discharge air temperature; valves may not both actually be open.

AHU-39

1. There was one short time when both the CHW and HW valves appear to be commanded open. There is no clear impact to the discharge air temperature; valves may not both actually be open.
2. The outside air damper position is sometimes listed as 450. It is unclear what this means.
3. When the discharge air temperature (DAT) setpoint was 70F there were times when the DAT was above setpoint but the chilled water valve did not open. This problem did not occur when the DAT setpoint was 55F and it was confirmed that the cooling coil can operate simultaneously with the economizer both during functional testing and it was also observed in the trends when the DAT setpoint was 55F.

4. The discharge air temperature is surprisingly high during full economizer when the chilled water valve wasn't open. During some periods the DAT was almost 10F above the outside air temperature which is a greater temperature difference than would be expected just from fan heat.
5. There were times when the fan was relatively quickly cycling on and off during unoccupied hours.

AHU-45

1. The VFD appears to start at 100% speed which is sometimes resulting in overpressurization for 5-30 minutes.
2. There are times when both the CHW and HW valves appear to be commanded open. The heating coil is overshooting and the cooling coil is making up for it so energy is being wasted but this only occurs for approximately 15 minutes at a time, and usually just at startup.

Abridged versions of the trends are attached which show the issues discussed above.

AHU-1

Date & Time	OAT	OA DMPR POS	MAIN SPC SP	RET TMP	M/A TMP	DSCHG TMP	SUP FAN VFD %	COOLNG VLV POS	PRE HT VLV POS	LOW SPC TMP	UNIT STATIC "H20
5/5/2010 19:41	70.9	100	60	73.2	67	61.6	87.1	34.3	0	68.8	1.6
5/5/2010 19:46	71.5	45	60	73.1	70.7	63.1	85.4	38.1	0	68.7	1.8
5/5/2010 19:51	71.1	100	60	73	70.6	62.8	84.6	40.6	0	68.7	1.44
5/5/2010 19:56	71.6	45	60	73.1	70.4	61.5	83.7	37.6	0	68.8	1.72
5/5/2010 20:01	71.3	45	60	73	70.9	62.3	82.8	38.5	0	68.7	1.67
5/5/2010 20:06	71	100	60	73	69.2	62.1	83.2	37.3	0	68.8	1.28

5/13/2010 5:56	48.3	0	60	70.5	65	74.1	100	0	0	62.6	0
5/13/2010 6:01	48.4	88.1	5	71.3	68.4	71.8	99.1	72.5	0	63.9	2.01
5/13/2010 6:06	48.4	90	60	73.9	58.7	55.9	97.3	35	15.5	64.7	1.85
5/13/2010 6:11	48.6	88.3	60	74	58.6	60	95.4	28	14.3	65.5	1.84
5/13/2010 6:16	48.6	87.5	60	73.8	59.1	61.7	93.3	27.5	14	66.1	1.85
5/13/2010 6:21	48.6	87.4	60	73.7	59.2	61.6	91.6	26	14	66.6	1.78
5/13/2010 6:26	48.6	87.2	60	73.7	59	61.6	90.2	24.6	14	66.9	1.72
5/13/2010 6:31	48.6	87.2	60	73.7	59.3	61.6	89.2	22.3	14	67.3	1.65
5/13/2010 6:36	48.7	87.2	60	73.7	59.9	62	88.9	22.3	10.8	67.7	1.56
5/13/2010 6:41	48.7	87.2	60	73.8	59.7	61.5	88.3	20.3	11.5	68	1.64
5/13/2010 6:46	48.7	87.2	60	73.7	59.3	60.9	87.8	15.1	11.5	68.3	1.59
5/13/2010 6:51	48.7	87.2	60	73.6	59.2	60.6	87.4	9.3	11.5	68.5	1.56
5/13/2010 6:56	48.8	87.2	60	73.5	59.1	60.6	87.1	3.3	11.5	68.7	1.54
5/13/2010 7:01	48.8	87.1	60	73.4	59.1	60.5	87	0	11.5	68.7	1.53
5/13/2010 7:06	48.8	87.1	60	73.4	59.1	60.3	87	0	11.5	68.9	1.53
5/13/2010 7:11	48.8	87.1	60	73.3	59.2	60.4	86.7	0	7.6	69.3	1.55
5/13/2010 7:16	48.8	86.6	60	73.4	59.2	60.4	86.6	0	4.5	69.4	1.53
5/13/2010 7:21	48.8	86.6	60	73.4	59.4	60.4	86.6	0	0	69.7	1.53

5/14/2010 5:56	51.4	90.7	60	75.2	71.7	80	100	97.1	0	70.1	1.74
5/14/2010 6:01	51.3	94.9	60	75.5	58.5	54.3	98.6	49	3.8	70.6	1.74
5/14/2010 6:06	51.2	91.7	60	75	57.4	57.3	96.7	30.3	6	69.8	1.87
5/14/2010 6:11	51.1	89.7	60	74.4	58.9	61.7	94.2	30.5	0	70.6	1.91

AHU-28

Date & Time	OA HUM	OAT	D/A TMP	R/A TMP	M/A TMP	O/A DMPR	MAIN SP	SUP FAN VFD	COOL VLV	HEAT VLV	LOW ZONE TMP	STAT "H2O
5/4/2010 5:56	67	51.9	80.4	76.7	72	0	60	100	0	0	68.6	0
5/4/2010 6:01	66	51.6	78.9	76.7	72.5	90.8	60	99.6	93.6	0	69.5	1.81
5/4/2010 6:06	68	51.5	52.5	75.8	55.3	90.9	60	99.5	34.8	15.8	69.9	1.6
5/4/2010 6:11	67	51.3	60.1	75	58.6	87.8	60	97.9	29	9.1	69.6	1.82
5/4/2010 6:16	67	51.5	61.8	74.4	59.6	87.9	60	96	29.3	1.6	69.2	1.83
5/4/2010 6:21	66	51.4	61.8	74.1	59.6	87.9	60	94.3	28	0	68.7	1.76
5/4/2010 6:26	67	51.2	61.8	74	59.5	87.9	60	93.1	27.6	0	69.6	1.7
5/4/2010 6:31	66	50.6	61.7	73.9	59.5	87.9	60	92.3	26.8	0	70	1.62
5/4/2010 6:36	68	50.2	61.9	73.8	60.7	87.9	60	92.2	27.1	0	69	1.47

5/5/2010 19:41	29	70.2	61.6	73.2	67	100	60	87.1	34.3	0	68.8	1.6
5/5/2010 19:46	26	71.7	63.1	73.1	70.7	45	60	85.4	38.1	0	68.7	1.8
5/5/2010 19:51	26	71	62.8	73	70.6	100	60	84.6	40.6	0	68.7	1.44
5/5/2010 19:56	26	71.4	61.5	73.1	70.4	45	60	83.7	37.6	0	68.8	1.72
5/5/2010 20:01	25	71.4	62.3	73	70.9	45	60	82.8	38.5	0	68.7	1.67
5/5/2010 20:06	27	71	62.1	73	69.2	100	60	83.2	37.3	0	68.8	1.28

5/7/2010 5:51	60	47.8	77.1	73.2	65.2	0	60	100	0	0	70.1	0
5/7/2010 5:56	60	47.7	74.7	73.3	66.6	87.8	60	99	77.5	0	0	2.61
5/7/2010 6:01	60	47.7	54.1	74.5	58.5	90.7	60	94.8	29.8	11.1	70.1	2.14
5/7/2010 6:06	60	47.6	59.5	74.3	57.9	88.2	60	91.6	21.3	10	69.1	2
5/7/2010 6:11	60	47.6	60.6	74.1	59.1	87	60	89.2	16.1	10.6	67	1.87
5/7/2010 6:16	60	47.5	60.8	73.9	59.3	87	60	87.5	11	11.5	67.3	1.77
5/7/2010 6:21	60	47.5	60.8	73.9	59.2	87	60	86.2	5.8	11.5	67.5	1.71
5/7/2010 6:26	60	47.4	60.6	73.7	59.4	86.7	60	85.3	0.3	8.5	69.3	1.63
5/7/2010 6:31	60	47.4	60.7	73.6	59.6	86.7	60	84.7	0	4.1	69.3	1.59
5/7/2010 6:36	60	47.3	61.6	73.5	60.7	86.7	60	84.8	0	0	69.3	1.51

AHU-39

Date & Time	OAT	HEAT VLV	O/A DMPR	COOL VLV	MAIN SP	D/A TMP	R/A TMP	FAN ON/OFF
5/3/2010 16:03	75.2	0	100	0	70	78.1	75.9	1
5/3/2010 16:08	75	0	100	0	70	78.8	76.3	1
5/3/2010 16:13	75.3	0	100	0	70	79	76.5	1
5/3/2010 16:18	74.8	0	100	0	70	79.2	76.6	1
5/3/2010 16:23	74.6	0	100	0	70	79.3	76.7	1
5/3/2010 16:28	74.5	0	100	0	70	79.4	76.8	1
5/3/2010 16:33	75.2	0	100	0	70	79.4	76.9	1
5/3/2010 16:38	74.4	0	100	0	70	79.5	77	1
5/3/2010 16:43	75.2	0	100	0	70	79.6	77.1	1
5/3/2010 16:48	75.4	0	100	0	70	79.7	77.2	1
5/3/2010 16:53	75	0	100	0	70	79.8	77.2	1
5/3/2010 16:58	75.1	0	100	0	70	79.8	77.3	1
5/3/2010 19:33	70.8	0	100	0	70	79.8	77.5	1
5/3/2010 19:38	70.6	0	100	0	70	79.8	77.4	1
5/3/2010 19:43	70.4	0	100	0	70	79.8	77.4	1
5/3/2010 19:48	70.4	0	100	0	70	79.7	77.4	1
5/3/2010 19:53	70.5	0	100	0	70	79.7	77.4	1
5/3/2010 19:58	71	0	100	0	70	79.6	77.3	1
5/3/2010 20:03	71.2	0	100	0	70	79.6	77.3	1
5/3/2010 20:08	72	0	100	0	70	79.6	77.2	1
5/3/2010 20:13	72.1	0	100	0	70	79.5	77.2	1
5/4/2010 15:08	72.6	0	10	0	70	73.7	74.7	1
5/4/2010 15:13	72.9	0	450	0	70	73.9	74.7	1
5/4/2010 15:18	73.1	0	450	0	70	74.1	74.7	1
5/4/2010 15:23	73.1	0	450	0	70	73.9	74.8	1
5/4/2010 15:28	72.8	0	10	0	70	74	74.9	1
5/23/2010 21:18	80.8	0	0	0	70	82.4	82.1	0
5/23/2010 21:23	80.2	0	100	0	70	83	82.1	1
5/23/2010 21:28	79.9	0	0	0	70	81.4	82.5	0
5/23/2010 21:33	79.6	0	100	0	70	82.3	82.2	1
5/23/2010 21:38	79.2	0	0	0	70	80.6	82.5	0
5/23/2010 21:43	79	0	100	0	70	81.1	82.4	1
5/23/2010 21:48	78.9	0	0	0	70	80.1	82.3	0
5/23/2010 21:53	78.7	0	0	0	70	80.7	82.9	0
5/23/2010 21:58	78.6	0	100	0	70	81.4	82.1	1
5/23/2010 22:03	78.7	0	0	0	70	80.3	82.5	0
5/28/2010 18:23	80	0	100	0	55	87.2	84.9	1
5/28/2010 18:28	79.9	0	100	0	55	87.3	85	1
5/28/2010 18:33	79.9	0	100	0	55	87.3	85	1
5/28/2010 18:38	79.9	0	100	0	55	87.3	84.9	1
5/28/2010 18:43	79.6	0	100	0	55	87.2	84.9	1

5/28/2010 18:48	79.6	0	100	0	55	87.3	84.9	1
5/28/2010 18:53	79.7	0	100	0	55	87.2	84.9	1
5/28/2010 18:58	79.6	0	100	0	55	87.3	85	1
5/28/2010 19:03	79.8	0	100	0	55	87.3	85	1
5/28/2010 19:08	79.7	0	100	0	55	87.3	84.9	1
5/28/2010 19:13	79.6	0	100	0	55	87.3	84.9	1

6/7/2010 6:58	51.6	0	0	0	55	78.1	76.9	1
6/7/2010 7:03	52	0	97.4	100	55	60.9	76.9	1
6/7/2010 7:08	52.7	1.2	87.2	70.3	55	50.9	76.3	1
6/7/2010 7:13	52.8	2	87.2	44	55	50.8	75.2	1
6/7/2010 7:18	52.9	0	87.2	36.8	55	55.6	74.2	1

AHU-45

Date & Time	OAT	D/A TMP	STATIC "H2O	BTWN HEAT & COOL COILS	HEAT COIL	COOL COIL	FAN VFD
5/5/2010 5:36	62.3	80.6	0	78.4	0	100	100
5/5/2010 5:41	62.2	52.9	1.65	75.4	5.1	66.1	94.5
5/5/2010 5:46	62.1	59.4	1.54	77.8	3.9	35.7	88.3
5/5/2010 5:51	62.1	64.7	1.17	65.4	0	30.1	88.2
5/5/2010 5:56	62.2	65.5	1.18	65	0	32.8	88.2

5/6/2010 5:31	49	50.9	1.41	57.8	6.8	74.2	99
5/6/2010 5:36	48.8	57.9	1.41	79.5	19.3	36.6	95.6
5/6/2010 5:41	48.7	58.7	1.35	55.1	4.8	14.8	93.1
5/6/2010 5:46	49.2	59	1.3	54.5	7	0	91.4
5/6/2010 5:51	49.2	59.2	1.27	55.5	6.1	0	90.3
5/6/2010 5:56	49.1	59.3	1.24	55.3	5.7	0	89.8
5/6/2010 6:01	49.3	59.4	1.24	55.5	5.2	0	89.7
5/6/2010 6:06	49.3	59.5	1.24	54.7	5.2	0	89.5
5/6/2010 6:11	49	59.1	1.24	54.4	8.5	0	89.4
5/6/2010 6:16	48.6	59	1.24	55.2	7.4	0	89.4
5/6/2010 6:21	48.4	59.4	1.22	54	4.3	0	88.8
5/6/2010 6:26	48.3	69.8	1.43	61.1	0	9	85.7
5/6/2010 6:31	48.4	71.1	1.31	56	0	31.8	83.3
5/6/2010 6:36	48.3	65.6	1.29	55.6	0	40.1	81.7
5/6/2010 6:41	48.4	64.3	1.26	53.8	13.7	36.4	80.5
5/6/2010 6:46	48.5	64	1.13	63.4	0	28.5	81.6
5/6/2010 6:51	49.1	56.7	1	54.5	14.2	6.1	85
5/6/2010 6:56	49.3	58.3	1.06	55	12.2	0	87.4

5/13/2010 7:01	48.8	65.7	1.16	66.7	0	100	100
5/13/2010 7:06	48.8	52.1	1.43	54.9	17.9	47.8	95.7
5/13/2010 7:11	48.8	57.9	1.33	55	13.3	23.2	93.2
5/13/2010 7:16	48.8	60.8	1.28	55.1	13.1	10.5	91.6
5/13/2010 7:21	48.8	61.6	1.27	54.3	12.9	0	90.4
5/13/2010 7:26	48.8	60.9	1.24	54.2	13.8	0	89.9

EXHIBIT 13

FUNCTIONAL TESTING

HVAC Functional Testing SIGN-OFF
Signatures below indicate completion and acceptance of the test procedures described in this document.

Firm	Representative	Function	Signature	Date
Commissioning Authority Grumman/Butkus Assoc.	STEVE RUEHLE	Witness	[signature]	7/15/10
Owner's Representative	RICH COLVIN	Witness	[signature]	7/15/10

System Description:
AHU-1 is a constant volume air handling unit with supply fan, steam heating coil, chilled water cooling coil, hot water reheat coil, filters, economizer and return fan.

Tools Required to conduct Functional Testing Procedures (provided by installing contractor unless otherwise noted):

	Digital duct thermometer/humidity sensor
	Infrared thermometer
	Tools for modifying or overriding economizer control
	Multimeter
	Ladder

located: N300 mech Rm.
serves: East side of N wing Gym

Functional Test Date 7·14·10

Test Procedure Step	Expected Response	Witnessed Response Y=Yes, N=No or Enter Comment	Notes (see below)	Pass (P) Fail (F)
Note: Throughout test ensure that equipment and spaces are still maintaining setpoint well enough to prevent any complaints.				

Notes:

Functional Performance Test

Air Handling Unit

AHU-1

	Test Procedure Step	Expected Response	Witnessed Response Y=Yes, N=No or Enter Comment	Notes (see below)	Pass (P) Fail (F)
1	**Pre-Test measured conditions** Record initial system conditions	NA Nite purge {	Per BMS: DAT = 71.8 F Cooling Coil DAT = — F MAT = 66.8 F Room Temp = 81 F OAT = 70.7 F RAT 79.8 Per Infrared or Duct/Pipe Thermometer: AHU DAT = _____F Cooling Coil DAT = _____F Heating Coil DAT = _____F MAT = _____F RAT = _____F AHU CHWS = _____F AHU CHWR = _____F AHU HWS = _____F AHU HWR = _____F		P
2	**Pre-Test control setpoints** Record initial setpts.	Room Temp Setpt = (unspecified) Max CC DAT Setpt = 65F Min CC DAT Setpt = 55F Max MAT Setpt = 65F Min MAT Setpt = 55F Max Preheat Setpt = 65F Min Preheat Setpt = 55F Economizer Enable Setpt = RAT+2 Economizer Disable Setpt = (unspecified) Unocc Space Setpt = 64F Unocc Cabinet Heating Setpt = (unspecified) Season = (manual) Operating Schedule = T-T 1430-2130 Sa 1215-1530	Room Temp Setpt = _____F Max CC DAT Setpt = _____F Min CC DAT Setpt = _____F Max MAT Setpt = _____F Min MAT Setpt = _____F Max Preheat Setpt = _____F Min Preheat Setpt = _____F Economizer Enable Setpt = _____F Economizer Disable Setpt = _____F Unocc Space Setpt = 65 F – winter Unocc Cabinet Heating Setpt = _____F Season = __________ Operating Schedule = nite purge = 72F Rm setpt		P

Notes: Nite purge – 100% OA, lockout preheat (setpt 35F), lockout cc (setpt 72F), reheat enabled (65F setpt) cool space to 72F then shutoff AHU.
manual enable/disable

	Test Procedure Step	Expected Response	Witnessed Response Y=Yes, N=No or Enter Comment	Notes (see below)	Pass (P) Fail (F)
3	**Occupied Operation Verification** – re: scheduled events				
3a	Mechanical Cooling Verification Adjust economizer setpoint or create a simulated condition of the OAT > economizer setpoint Decrease room temp setpt until AHU setpts are at minimum. 64F reset up to [illegible] Room Temp Setpt = ___F MAD setpt = 54F preheat setpt = 55F CC setpt = 72 F ② reheat setpt = 70 mah setpt = 70F reset range RmT 70F 60F ① no reset	Supply and return fans are on	Y		P
		Chilled water valve is partially open [illegible]	CHW Valve = [illegible] % open		P
		Heating coil valves are fully closed	1/3 HC Valve = 0 %open 2/3 HC Valve = 0 %open		P
		Reheat coil valve is fully closed	RHC Valve = 0 %open		P
		OA Damper is at minimum operating position	OAD = 45 %open (BMS) OAD = _____%open (visual)		P
		RA Damper is at maximum operating position	RAD = 55 %open (BMS) RAD = _____%open (visual)		P
		EA Damper is at minimum operating position	EAD = 45 %open (BMS) EAD = _____%open (visual)		P
		CC DAT Setpt = Min CC DAT Setpt MAT Setpt = Min MAT Setpt Preheat Setpt = Min Preheat Setpt 76F Start	CC DAT Setpt = 72 F MAT Setpt = 55 F Preheat Setpt = 55 F		P
		DAT = CC DAT Setpt	DAT = 73 F and falling		P
3b	Economizer Operation Verification Adjust economizer enable setpoint or create a simulated condition of the OAT< economizer setpoint Room Temp Setpt = _____F MAT setpt = 77F MAT = 72.7F MAT = 72.9F+	Supply and return fans are on	Y		P
		Chilled water valve is closed (if OAT<MAT Setpt) Chilled water valve is partially open (if OAT>MAT Setpt)	CHW Valve = 0 % open		P
		Heating coil valves are fully closed (unless OAT is very low)	1/3 HC Valve = 0 %open 2/3 HC Valve = 0 %open		P
		Reheat coil valve is fully closed	RHC Valve = 0 %open		P
		OA Damper opens further	OAD = [illegible] %open (BMS) 84 OAD = _____%open (visual)		P
		RA Damper closes further	RAD = [illegible] %open (BMS) 16 RAD = _____%open (visual)		P
		EA Damper opens further	EAD = [illegible] %open (BMS) 84 EAD = _____%open (visual)		P

Notes:

① Arch changed MAD control MAT setpt reset schedule reset range from 30F to 10F 54-64F MAT over 70-60F Rmt range

② Cooling schedule is always "unscheduled" so no CHW cooling provided clg scheduled only for graduation.

	Test Procedure Step	Expected Response	Witnessed Response Y=Yes, N=No or Enter Comment	Notes (see below)	Pass (P) Fail (F)
	OAT > RAT+2 override MAT to 65F	CC DAT Setpt = Min CC DAT Setpt MAT Setpt = Min MAT Setpt Preheat Setpt = Min Preheat Setpt	CC DAT Setpt = 72 F MAT Setpt = 54 F Preheat Setpt = 55 F		P
		DAT = CC DAT Setpt	DAT = ___F		/
3c	<u>Economizer Reset Verification</u> Adjust economizer disable setpoint or create a simulated condition of OAT > economizer setpoint. OAT = 72.1	Chilled water valve is partially open	CHW Valve = 0 % open		P
		OA Damper is at minimum operating position	OAD = 45 %open		P
		DAT = CC DAT Setpt	DAT = ___F		
3d	<u>Increased DAT Setpt Initiation</u> Increase room temp setpt gradually until DAT setpts are at maximum but reheat coil has not yet initiated. Room Temp Setpt = _____F	Supply and return fans are on	Y		P
		Chilled water valve closes further	CHW Valve = 0 % open		P
		Heating coil valves are closed (unless OAT is very low)			/
		Reheat coil valve is fully closed			/
		OA Damper is at minimum operating position	OAD = _____%open		/
		CC DAT Setpt = Max CC DAT Setpt MAT Setpt = Max MAT Setpt Preheat Setpt = Max Preheat Setpt	CC DAT Setpt = _____F MAT Setpt = _____F Preheat Setpt = _____F		/
		DAT = CC DAT Setpt	DAT = ____F		/
3e	<u>Reheat Initiation</u> Increase room temp setpt to 5F above current room temp. Room Temp Setpt = _____F	Supply and return fans are on	Y		P
		Chilled water valve position does not change	CHW Valve = 0 % open		P
		Heating coil valves positions do not change	1/3 HC Valve = _____%open 2/3 HC Valve = _____%open		/
		Reheat coil valve is modulating	RHC Valve = _____%open		/
		OA Damper is at minimum operating position	OAD = 45 %open		P

X — OAD/Rlf Dprs need to be readjusted so they close tight.

Notes: Economizer - OAT < RAT+2
enable -
disable - OAT > RAT+2) Rich corrected programming OAT to not look at DAT vs OAT but rather RAT vs OAT

Exist method would keep OAD 100% open even when CHW CC operation is enabled.

	Test Procedure Step	Expected Response	Witnessed Response Y=Yes, N=No or Enter Comment	Notes (see below)	Pass (P) Fail (F)
		CC DAT Setpt = Max CC DAT Setpt MAT Setpt = Max MAT Setpt Preheat Setpt = Max Preheat Setpt	CC DAT Setpt = _____F MAT Setpt = _____F Preheat Setpt = _____F		
		CC DAT = CC DAT Setpt	CC DAT = _____F		
		Reheat DAT > CC DAT	Reheat DAT = _____F		
3f	Reheat Shutdown and Preheat Initiation Decrease room temp setpt to current room temp. Manually override preheat setpt to 5F above current MAT. Room Temp Setpt = _____F Preheat Setpt = _____F	1/3 HC valve is modulating	1/3 HC Valve = _____%open		
		2/3 HC valve is closed	2/3 HC Valve = _____%open		
		Reheat coil valve is fully closed	RHC Valve = _____%open		
		Heating Coil DAT = Preheat Setpt	Heating Coil DAT = _____F		
3g	Increased Preheat Initiation Increase preheat setpt gradually until both heating coil valves are open. Preheat Setpt = _____F	1/3 HC valve is fully open	1/3 HC Valve = _____%open		
		2/3 HC valve is modulating	2/3 HC Valve = _____%open		
		Heating Coil DAT = Preheat Setpt	Heating Coil DAT = _____F		
3h	Return setpts to initial setpoints. Return preheat setpt to automatic control.	Room Temp Setpt = (unspecified) Economizer Enable Setpt = RAT+2	Room Temp Setpt = _____F Economizer Enable Setpt = _____F		
4	**Unoccupied Operation Verification**				
4a	Unoccupied Shutdown Verification Set system to unoccupied time. Turn off economizer by lowering economizer enable setpt to 5F below current OAT.	Supply and return fans are off	Y		P
		Chilled water valve is closed	Y		P
		Heating coil valves are closed	Y		P
		Reheat coil valve is closed	Y		P
		OA & EA Dampers are closed	OAD = 0 %open (BMS) OAD = _____%open (visual) EAD = 0 %open (BMS) EAD = _____%open (visual)		P
		RA Damper is open	RAD = 100 %open (BMS) RAD = _____%open (visual)		P

Notes:

	Test Procedure Step	Expected Response	Witnessed Response Y=Yes, N=No or Enter Comment	Notes (see below)	Pass (P) Fail (F)
4b	<u>Unoccupied Heating Initiation</u> Increase unoccupied heating setpt to 2F above current room temp. Unoccupied Heating Setpt = _____F normal rm set pt = 65F preheat setpt = 55 cc setpt = 172F reheat setpt = 60 main setpt 70F	Supply and return fans are on			
		Chilled water valve is closed	CHW Valve = 0 % open		P
		Heating coil valve is modulating to satisfy setpt	1/3 HC Valve = _____%open 2/3 HC Valve = 22 + %open		P
		Reheat coil valve is modulating to satisfy setpt	RHC Valve = 0 %open		P
		OA & EA Dampers are closed	OAD = 0 %open (BMS) OAD = _____%open (visual) EAD = 0 %open (BMS) EAD = _____%open (visual)		P
		RA Damper is open	RAD = 100 %open (BMS) RAD = _____%open (visual)		P
		Preheat setpt > Occ Preheat setpt Reheat Setpt > Occ Reheat Setpt	Preheat Setpt = _____F Reheat Setpt = _____F		
		Heating Coil DAT = Preheat Setpt	Heating Coil DAT = _____F		
		Reheat Coil DAT = Reheat Coil Setpt	Reheat Coil DAT = _____F		
		DAT = DAT Setpt	DAT = _____F		
4c	<u>Unoccupied Heating Shutdown</u> Decrease unoccupied heating setpt to initial setpt. Unoccupied Heating Setpt = 65 F	Supply and return fans are off	Y		P
4d	<u>Morning Warmup Initiation</u> Initiate morning warmup by adjusting timeclock and space temperature/setpts as required. Set season to winter.	Supply and return fans are on		①	
		Chilled water valve is closed	CHW Valve = _____% open		
		Heating coil valve is modulating to satisfy setpt	1/3 HC Valve = _____%open 2/3 HC Valve = _____%open		
		Reheat coil valve is modulating to satisfy setpt	RHC Valve = _____%open		
		OA & EA Dampers are closed	OAD = _____%open (BMS) OAD = _____%open (visual) EAD = _____%open (BMS) EAD = _____%open (visual)		
		RA Damper is open	RAD = _____%open (BMS) RAD = _____%open (visual)		

Notes: ① Not needed - not used. - not tested

	Test Procedure Step	Expected Response	Witnessed Response Y=Yes, N=No or Enter Comment	Notes (see below)	Pass (P) Fail (F)
		Preheat setpt > Occ Preheat setpt Reheat Setpt > Occ Reheat Setpt	Preheat Setpt = _____F Reheat Setpt = _____F	(1)	
		Heating Coil DAT = Preheat Setpt	Heating Coil DAT = _____F	↓	
		Reheat Coil DAT = Reheat Coil Setpt	Reheat Coil DAT = _____F		
		DAT = DAT Setpt	DAT = _____F		
4e	<u>Morning Warmup Wait Initiation</u> Modify setpts to simulate the warmup setpt being satisfied and the initiation of the wait state.	Supply and return fans are off			
		Chilled water valve is closed			
		Heating coil valves are closed			
		Reheat coil valve is closed			
		OA & EA Dampers are closed	OAD = _____%open EAD = _____%open		
		RA Damper is open	RAD = _____%open		
4f	Return setpts to initial setpts. Return timeclock/schedule to normal operation.	Room Temp Setpt = (unspecified) Unocc Space Setpt = 64F Unocc Cabinet Heating Setpt = (unspecified) Season = (manual) Operating Schedule = T-T 1430-2130 Sa 1215-1530	Room Temp Setpt = _____F Unocc Space Setpt = _____F Unocc Cabinet Heating Setpt = _____F Season = ___________ Operating Schedule =	↓	
	END OF TEST				

Functional test procedure was created for testing portions of sequence most likely to have impact on energy usage. The following items were not tested:

1. Freezestat Operation
2. Unoccupied Cabinet Heating Operation
3. Fan Failure Operation
4. Night Purge
5. Smoke Detector
6. Filter Alarm
7.

Notes: (1) Not needed - not used - not tested

HVAC Functional Testing SIGN-OFF
Signatures below indicate completion and acceptance of the test procedures described in this document.

Firm	Representative	Function	Signature	Date
Commissioning Authority Grumman/Butkus Assoc.	STEVE RIEHLE	Witness	[signature]	7/15/10
Owner's Representative	RICH COLVIN	Witness	[signature]	7/15/10

System Description:
AHU-28 is a variable volume air handling unit with supply fan, return fan, chilled water cooling, steam heating, filters, and economizer.

Tools Required to conduct Functional Testing Procedures (provided by installing contractor unless otherwise noted):

Located - LL Mech Rm P wing
Serves - LL Mech offices
- 1st Flr offices, classroom, fitness ctr. P wing

	Digital duct thermometer sensor
	Infrared thermometer
	Tools for modifying or overriding economizer control
	Multimeter
	Ladder

Functional Test Date 7-12-10 / 7.13.10

Test Procedure Step	Expected Response	Witnessed Response Y=Yes, N=No or Enter Comment	Notes (see below)	Pass (P) Fail (F)
Note: Throughout test ensure that equipment and spaces are still maintaining setpoint well enough to prevent any complaints.				

Notes:

	Test Procedure Step	Expected Response	Witnessed Response Y=Yes, N=No or Enter Comment	Notes (see below)	Pass (P) Fail (F)
1	**Pre-Test measured conditions** Record initial system conditions	NA OAD= 10%	Per BMS: DAT = [struck through] 57.5 F Preheat DAT = 67.2 F MAT = 74.6 F RAT = 75.5 F Duct Static = 1.3 "w.c. SA Flow = 34.8K cfm RA Flow = 50.5K cfm OA Flow = NA cfm SF Speed = 100 % RF Speed = 100 % OAT = 78.5 F Per Infrared or Duct/Pipe Thermometer: AHU DAT = [struck through] ? F Cooling Coil DAT = 57.9 F Heating Coil DAT = — F MAT = 75.5 F RAT = ____ F AHU CHWS = 47 F AHU CHWR = 56 F	Preheat DAT – mounted too close to CC? NO strapped to HC. Sensor is in error reads 2-3F low cold coil	P

OA/RA/RLF dpr actuators are 2-10V DC but 0-100% output signal is 0-10VDC. Need to modify output signal to be 0-100% at 2-10VDC

Energy waste when needing full economizer and RA dpr is not fully closed.

Also dprs don't drive full stroke of dpr blade (95%)

Notes: OA not fully open
RA not fully closed

Functional Performance Test
Air Handling Unit
AHU-28

	Test Procedure Step	Expected Response	Witnessed Response Y=Yes, N=No or Enter Comment	Notes (see below)	Pass (P) Fail (F)
2	**Pre-Test control setpoints** Record initial setpts. Morning Warmup occ PH stpt +20F	DAT Setpt = 62F MAT Setpt = 60F Preheat Min Setpt = 58F Preheat Max Setpt = 68F Preheat Min Reset Room Temp = 76F Preheat Max Reset Room Temp = 68F Unocc Heat DAT Setpt = 100F Unocc Heating Setpt = 55F Economizer Enable Setpt = RAT+2 Economizer Disable Setpt = (unspecified) Min OA Damper Position = 45% 4400 cfm Min OA Flow Setpt= (varies) Min Duct Static Setpt = 1.5"w.c. 1.0 Max Duct Static Setpt = 2.5"w.c. SF & RF Flow Offset = (based on exhaust flow) 2.0 Operating Schedule = M-Th: 600-2030 F: 600-1930 Sa: 730-1630 Sun: 1200-1800	DAT Setpt = 57 F MAT Setpt = 55 F Preheat Min Setpt = 53 F Preheat Max Setpt = 63 F Preheat Min Reset Room Temp = ___ F 76 Preheat Max Reset Room Temp = ___ F 68 Unocc Heat DAT Setpt = ___F Occ stpt +20F Unocc Heating Setpt = 55 F Economizer Enable Setpt = ___F • OAT < RAT+2 Economizer Disable Setpt = ___F OAT > RAT+2 Min OA Damper Position = 45 % Min OA Flow Setpt = NA cfm Min Duct Static Setpt = ___"w.c. 90% Box flow Max Duct Static Setpt = ___"w.c. 100% Boxflow Duct Static Setpt = 1.0 "w.c. SF & RF Flow Offset = NA cfm Same signal to SF VFD & RF VFD Operating Schedule =	— Not used	P
3	**Cooling Operation Verification**				
3a	**Mechanical Cooling Verification** Adjust economizer setpoint or create a simulated condition of the OAT > economizer setpoint.	Supply and return fans are on	SF Speed = 100 % RF Speed = 100 %		P
		Chilled water valve is partially open	CHW Valve = 49 % open		P
		Steam valves are fully closed	1/3 Valve = 0 % open 2/3 Valve = 0 % open		P
		OA Damper is at minimum position	OAD = 10 %open (BMS) OAD = 0 %open (visual)		P
		RA Damper is at maximum operating position	RAD = 90 %open (BMS) RAD = 100 %open (visual)		P

Notes: PHC controlled to 55F PHAT when AHU is off. Same for all KAM AHU's.

	Test Procedure Step	Expected Response	Witnessed Response Y=Yes, N=No or Enter Comment	Notes (see below)	Pass (P) Fail (F)
	Stpt = 57.5F Stpt = 1.5"	EA Damper is at minimum operating position	EAD = 10 %open (BMS) EAD = 0 %open (visual)		P
		MAT > DAT	MAT = 73 F		P
		DAT = DAT Setpt	DAT = 57.6 F		P
		Duct Static = Duct Static Setpt	Duct Static = 1.5 "w.c.		P
		OA Flow = Min OA Flow Setpt	OA Flow = NA cfm		✓
		Supply Flow – Return Flow = SF & RF Flow Offset	SF VFDsp = RF VFDsp		P
3b	Decrease Increased Mechanical Cooling Verification Decrease DAT Setpt 5F. DAT Setpt = 66 F CHWV = 59% DAT 59F setpt = 58F	Chilled water valve opens further closes	CHW Valve = 50 % open closing		P
		DAT = DAT Setpt	DAT = 61 F rising		P
3c	Economizer Operation Verification Adjust economizer enable setpoint or create a simulated condition of the OAT< economizer setpoint enable Econ = OAT < RAT+2 OAT = 69.4F – on power house RAT = 74.5F [illegible] MAD setpt 55F MAT = 67.0 measured MAT = 68.1 Low space T = 70.0F	Supply and return fans are on	SF Speed = 100 % RF Speed = 100 %		P
		Chilled water valve is closed (if OAT<MAT Setpt) Chilled water valve is partially open (if OAT>MAT Setpt)	CHW Valve = [illegible] % open 94.5		P
		Steam valves are fully closed	1/3 Valve = 0 % open 2/3 Valve = 0 % open		P
		OA Damper opens further	OAD = 100 %open (BMS) OAD = 95 %open (visual)	dpr actuators need adjustment	P
		RA Damper closes further	RAD = 0 %open (BMS) RAD = 5 %open (visual)		P
		EA Damper opens further	EAD = 100 %open (BMS) EAD = 95 %open (visual)		P
		MAT = MAT Sept (if OAT<MAT Setpt) MAT = OAT (if OAT>MAT Setpt)	MAT = 67.4 F		P
		DAT = DAT Setpt = 57.4	DAT = 57.8 F		P
		Duct Static = Duct Static Setpt = 1.0	Duct Static = 1.1 "w.c.		P
		OA Flow increases	OA Flow = NA cfm		–
		Supply Flow – Return Flow = SF & RF Flow Offset	100% = 100%		P

Notes:

OAT sensor on powerhouse wall (Sage 1) 69.4F – needs high
National weather Saginaw OAT 66F (75%)
Campus weather station OAT 67°F
at 100% OA MAT reads 67F

Functional Performance Test
Air Handling Unit
AHU-28

	Test Procedure Step	Expected Response	Witnessed Response Y=Yes, N=No or Enter Comment	Notes (see below)	Pass (P) Fail (F)
3d	Economizer Reset Verification Adjust economizer disable setpoint or create a simulated condition of OAT > economizer setpoint.	Chilled water valve is partially open	CHW Valve = 86 % open	(visual)	P
		OA Damper is at minimum position	OAD = 45 %open (signal) 5% open		P
		DAT = DAT Setpt	DAT = 55 F		P
3f	Return setpts to initial setpoints.	DAT Setpt = 62F Economizer Enable Setpt = RAT+2 Economizer Disable Setpt = (unspecified)	DAT Setpt = 55 F Economizer Enable Setpt = ___F OAT < RAT+2 Economizer Disable Setpt = ___F OAT > RAT+2		P
4	**Preheating Operation Verification**				
4a	Min Preheating Initiation Decrease preheat room reset setpts to 5F below current low room temp. Preheat Min Reset Room Temp = 76 F Preheat Max Reset Room Temp = 68 F MAT = 73 RmT = 69	Chilled water valve is modulating to satisfy DAT setpt	CHW Valve = 53 % open		P
		Smaller steam valve is modulating or closed Larger steam valve is closed	1/3 Valve = 0 % open 2/3 Valve = 0 % open		P
		Preheat DAT = Preheat Min Setpt 60F	67°F		P
		Preheat DAT = Preheat Setpt	Preheat DAT = 67 F no heat needed		P
		DAT = DAT Setpt	DAT = 57 F cc operation		P
4b	Max Preheating Initiation Increase preheat room reset setpts to 5F above current low room temp. Preheat Min Reset Room Temp = ___F Preheat Max Reset Room Temp = ___F	Chilled water valve is modulating to satisfy DAT setpt	CHW Valve = ___% open		
		Smaller steam valve is modulating or closed Larger steam valve is closed	1/3 Valve = ___% open 2/3 Valve = ___% open		
		Preheat DAT = Preheat Max Setpt			
		Preheat DAT = Preheat Setpt	Preheat DAT = ___F		
		DAT = DAT Setpt	DAT = ___F		
4c	Increased Heating Initiation Gradually increase preheat max setpt until small steam valve is fully open and larger steam valve is modulating. Preheat Max Setpt = 80 F (forced to:)	Chilled water valve is modulating to satisfy DAT setpt	CHW Valve = 0 % open		P
		Smaller steam valve is fully open Larger steam valve is modulating	1/3 Valve = 20+ % open (opening) 2/3 Valve = 0 % open		P
		Preheat DAT = Preheat Setpt	Preheat DAT = 69+ F rising		P
		DAT = DAT Setpt	DAT = 69 F + rising		P

Notes:

	Test Procedure Step	Expected Response	Witnessed Response Y=Yes, N=No or Enter Comment	Notes (see below)	Pass (P) Fail (F)
4d	Return setpts to initial setpts	Preheat Min Setpt = 58F Preheat Max Setpt = 68F Preheat Max Reset Room Temp = 68F	Preheat Min Setpt = 53 F Preheat Max Setpt = 63 F Preheat Max Reset Room Temp = 68 F		P
5	**Fan Speed Control Verification**				
5a	Increased Fan Speed Initiation Shut off economizer by adjusting economizer setpoints if economizer is active. Manually override ~~maximum box position~~ or flow input to 100%. Wait for duct static pressure setpt to reset up to maximum setpt. Required ~~Maximum Box Position~~ = ~~100~~ % flow 90	Supply fan speed increases	SF Speed = 92 % rising		P
		Return fan speed increases	RF Speed = 87 % rising		P
		Duct static pressure setpt = Max duct static pressure	Duct static pressure setpt = 2.0 "w.c.		P
		Duct static pressure = Duct static pressure setpt	Duct static pressure = 1.6 "w.c. rising		P
		DAT = DAT Setpt	DAT = 57 F		P
		OA Flow = Min OA Flow Setpt	OA Flow = NA cfm		—
		Supply flow minus return flow = SF & RF Flow Offset	SF Flow = NA cfm RF Flow = NA cfm		—
5b	Decreased Fan Speed Initiation Manually override maximum box position input or flow input to 5% below reset setpt. Wait for duct static pressure setpt to reset down to minimum setpt. Required ~~Maximum Box Position~~ = ~~[illegible]~~ % flow " ~~[illegible]~~ SP = 1.6" 106%	Supply fan speed decreases	SF Speed = 89 % falling		P
		Return fan speed decreases	RF Speed = 85 % falling		P
		Duct static pressure setpt = Min duct static pressure	Duct static pressure setpt = 1.0 "w.c.		P
		Duct static pressure = Duct static pressure setpt	Duct static pressure = 1.4 "w.c. falling		P
		DAT = DAT Setpt	DAT = 57 F		P
		OA Flow = Min OA Flow Setpt	OA Flow = NA cfm		—
		Supply flow minus return flow = SF & RF Flow Offset	SF Flow = NA cfm RF Flow = NA cfm		—
5c	Return setpoint to initial setpoints. Return maximum box position/flow control to automatic operation.	Economizer Enable Setpt = RAT + 2 Economizer Disable Setpt = (unspecified)	Economizer Enable Setpt = ___F OAT < RAT+2 Economizer Disable Setpt = ___F OAT > RAT+2		P
6	**Unoccupied Operation Verification**				
6a	Unoccupied Shutdown Verification Set system to unoccupied time. changed time schedule	Supply and return fans are off	✓		P
		Chilled water valve is closed	✓		P
		Heating coil valves are closed	✓		P

Notes:

	Test Procedure Step	Expected Response	Witnessed Response Y=Yes, N=No or Enter Comment	Notes (see below)	Pass (P) Fail (F)
		OA & EA Dampers are closed (5) (5)	OAD = 0 %open (BMS) OAD = 20 %open (visual) EAD = 0 %open (BMS) EAD = 20 %open (visual)	①	P
		RA Damper is open (95 100)	RAD = 100 %open (BMS) RAD = 80 %open (visual)	①	P
6b	<u>Unoccupied Heating Initiation</u> Increase unoccupied heating setpt to 2F above current room temp. Unoccupied Heating Setpt = 80 F low space temp = 69F	Supply and return fans are on	Y		P
		Chilled water valve is closed	CHW Valve = 0 % open		P
		Heating coil valve(s) are partially open	1/3 Valve = 47 % open 2/3 Valve = ___ % open rising	HC setpt = 20F higher than occ setpt	
		OA & EA Dampers are at ~~minimum position~~ Closed (0) (0)	OAD = 0 %open (BMS) OAD = 20 %open (visual) EAD = 0 %open (BMS) EAD = 20 %open (visual)	①	P
		RA Damper is at maximum position (100)	RAD = 100 %open (BMS) RAD = 80 %open (visual)	①	P
		DAT = Unocc Heat DAT Setpt = 85.7F	DAT = 77 F + rising		P
6c	<u>Unoccupied Heating Shutdown</u> Decrease unoccupied heating setpt to initial setpt. Unoccupied Heating Setpt = 55 F	Supply and return fans are off	Y		P
6d	<u>Morning Warmup Initiation</u> Initiate morning warmup by adjusting timeclock and space temperature/setpts as required. (PHAT) PHAT setpt forced to occ PHAT stpt +20F. AHU runs to satisfy Rm occ setpt @ 72F @ lowest pnt	Supply and return fans are on		Rich needs to fix not working correctly yet	
		Chilled water valve is closed	CHW Valve = ___ % open		
		Heating coil valve(s) are partially open	1/3 Valve = ___ % open 2/3 Valve = ___ % open		
		OA & EA Dampers are at minimum position	OAD = ___ %open (BMS) OAD = ___ %open (visual) EAD = ___ %open (BMS) EAD = ___ %open (visual)		
		RA Damper is at maximum position	RAD = ___ %open (BMS) RAD = ___ %open (visual)		
		DAT = Unocc Heat DAT Setpt	DAT = ___ F		

Notes:

① Damper control needs to be resolved – output command ~~signal~~ issued was 0% but output signal was @ 4.48VDC LS parameter was at 45

will be issue with other AHUs.

⇒ ~~Rich changed unocc dpr parameters to resolve issue~~

Functional Performance Test
Air Handling Unit
AHU-28

	Test Procedure Step	Expected Response	Witnessed Response Y=Yes, N=No or Enter Comment	Notes (see below)	Pass (P) Fail (F)
6e	<u>Morning Warmup Completion Initiation</u> Modify setpts to simulate the warmup setpt being satisfied which should put the unit into regular, occupied operation.	Supply and return fans are on		①	
		DAT = DAT Setpt	DAT = ____F		
6f	Return setpts to initial setpts. Return timeclock/schedule to normal operation.	Unocc Heating Setpt = 55F	Unocc Heating Setpt = _____F		
	END OF TEST				

Functional test procedure was created for testing portions of sequence most likely to have impact on energy usage. The following items were not tested:

1. Freezestat Operation
2. Fan shutdown and failure operation
3. High static pressure alarm operation
4. Smoke detector operation
5. Min OA Calculation Verification (to be verified with trending)
6. Smoke damper operation
7. VFD bypass operation
8. Morning cooldown operation (if present)
9. Unoccupied cabinet heating

① When Non occ setpt is reached, AHU stops & waits for occ period before restarting.

Notes: Need to disable zone RHC valve control when unoccupied & AHU is off. need to Close RHC valves.

HVAC Functional Testing SIGN-OFF

Signatures below indicate completion and acceptance of the test procedures described in this document.

Firm	Representative	Function	Signature	Date
Commissioning Authority Grumman/Butkus Assoc.	STEVE RIEHLE	Witness	[signature]	7/15/10
Owner's Representative	RICH COLVIN	Witness	[signature]	7/15/10

System Description:
AHU-32 is a variable volume air handling unit with supply fan, return fan, chilled water cooling, steam heating with face and bypass, filters, and economizer.

Tools Required to conduct Functional Testing Procedures (provided by installing contractor unless otherwise noted):

	Digital duct thermometer sensor
	Infrared thermometer
	Tools for modifying or overriding economizer control
	Multimeter
	Ladder

located: AO tunnel

serves: A wing west

Functional Test Date 7/14/10

Test Procedure Step	Expected Response	Witnessed Response Y=Yes, N=No or Enter Comment	Notes (see below)	Pass (P) Fail (F)
Note: Throughout test ensure that equipment and spaces are still maintaining setpoint well enough to prevent any complaints.				

Notes:

	Test Procedure Step	Expected Response	Witnessed Response Y=Yes, N=No or Enter Comment	Notes (see below)	Pass (P) Fail (F)
1	**Pre-Test measured conditions** Record initial system conditions	NA	Per BMS: DAT = 56.8 F Preheat DAT = _____F MAT = 76 F RAT = 74 F Duct Static = 1.8 "w.c. SA Flow = NA cfm RA Flow = 26376 cfm OA Flow = 3289 cfm SF Speed = 89.8 % RF Speed = 74.8 % OAT = 82.5 F Per Infrared or Duct/Pipe Thermometer: AHU DAT = _____F Cooling Coil DAT = _____F Heating Coil DAT = _____F MAT = _____F RAT = _____F AHU CHWS = _____F AHU CHWR = _____F		P

Pickup todo:

Notes: SF graphic for fan status looking at wrong point. SF shows on when fan is off. Rich fixed this.

Functional Performance Test
Air Handling Unit
AHU-32

	Test Procedure Step	Expected Response	Witnessed Response Y=Yes, N=No or Enter Comment	Notes (see below)	Pass (P) Fail (F)
2	**Pre-Test control setpoints** Record initial setpts. *ECON STPT = DATSP* *COOLSTPT = ECONSTPT+2* *HTSTPT = ECONSTPT − 2* *55 + (73 - Ave RmT T) * 3 = DATSP* *DATSP (55F min, 65F max*	Max DAT Reset Setpt = 65F Min DAT Reset Setpt = 55F Max OAT Reset Setpt = (unspecified) Min OAT Reset Setpt = (unspecified) MAT Setpt = 59F Preheat Setpt = 57F Unocc Heat DAT Setpt = (unspecified) Unocc Heating Setpt = 55F Unocc Cooling Setpt = 85F Economizer Enable Setpt = ~~OA Enthalpy<RA Enthalpy~~ Economizer Disable Setpt = (unspecified) Min OA Flow Setpt= (varies) Min Duct Static Setpt = 1.0"w.c. Max Duct Static Setpt = 2.0"w.c. SF & RF Flow Offset = (based on exhaust flow) Face/Bypass OAT Setpt = 3F Operating Schedule = M-Th: 630-2100 F: 645-1600 Sa: 900-1400 Sun: 1200-1730	Max DAT Reset Setpt = *65* F Min DAT Reset Setpt = *55* F ~~Max OAT Reset Setpt = — F~~ ~~Min OAT Reset Setpt = — F~~ MAT Setpt = ____F Preheat Setpt = ____F Unocc Heat DAT Setpt = *128* F Unocc Heating Setpt = *68* F ~~Unocc Cooling Setpt = — F~~ Economizer Enable Setpt = ____F *OAT < 67F* Economizer Disable Setpt = ____F *OAT > 70F* Min OA Flow Setpt = _____cfm Min Duct Static Setpt = *0.2* "w.c. Max Duct Static Setpt = *1.8* "w.c. SF & RF Flow Offset = ____cfm *RF = SF − 15%* Face/Bypass OAT Setpt = ____F Operating Schedule =		*P*
3	**Cooling Operation Verification**				
3a	Max Reset Cooling Verification Adjust economizer setpoints or create a simulated condition of the OAT > economizer setpoint. Increase OAT reset setpoints to above current OAT. Max OAT Reset Setpt = ____F Min OAT Reset Setpt = ____F	Supply and return fans are on	SF Speed = *100* % RF Speed = *85* %		*P*
		Chilled water valve is partially open	CHW Valve = *80* % open		*P*
		Steam valves are fully closed	1/3 Valve = *0* % open 2/3 Valve = *0* % open		*P*
		OA Damper is at minimum position	OAD = *37* %open (BMS) OAD = ____%open (visual)		*P*
		RA Damper is at maximum operating position	RAD = *63* %open (BMS) RAD = ____%open (visual)		*P*

Notes: *Can go into MWU any time of Day - runs AHU when Ave RmT < 68F ← too high!*
- need to be OCCUPIED or night setback mode - VAV boxes
- AHU is on
- PHC controlled to 128F DAT
- SFVFD — controlled to SASP
- RFVFD = SFVFD control signal minus 15%

	Test Procedure Step	Expected Response	Witnessed Response Y=Yes, N=No or Enter Comment	Notes (see below)	Pass (P) Fail (F)
		EA Damper is at minimum operating position	EAD = 37 %open (BMS) EAD = _____%open (visual)		P
		MAT > DAT	MAT = 75 F		P
		DAT Setpt = Max DAT Reset Setpt	DAT Setpt = 63 F		P
		DAT = DAT Setpt	DAT = 58 F		P
		Duct Static = Duct Static Setpt	Duct Static = 1.8 "w.c.		P
		OA Flow = Min OA Flow Setpt	OA Flow = 3361 cfm		P
		Supply Flow – Return Flow = SF & RF Flow Offset	1598		P
3b	Medium Reset Cooling Verification Modify min and max OAT reset setpts so that current OAT is halfway between the two setpoints. Max OAT Reset Setpt = _____F Min OAT Reset Setpt = _____F	Chilled water valve opens further	CHW Valve = _____% open (DNT)		/
		DAT Setpt = (Max DAT Reset Setpt + Min DAT Reset Setpt)/2	DAT Setpt = _____F (DNT)		/
		DAT = DAT Setpt	DAT = ____F (DNT)		/
3c	Min Reset Cooling Verification Decrease OAT reset setpoints to below current OAT. Min OAT Reset Setpt = _____F	Chilled water valve opens further	CHW Valve = 100 % open		P
		DAT Setpt = Min DAT Reset Setpt	DAT Setpt = 55 F		P
		DAT = DAT Setpt	DAT = 60.5 F	①	P
3d	Economizer Operation Verification Adjust economizer enable setpoint or create a simulated condition of the OAT< economizer setpoint	Supply and return fans are on	SF Speed = _____% RF Speed = _____%	②	P
		Chilled water valve is closed (if OAT<MAT Setpt) Chilled water valve is partially open (if OAT>MAT Setpt)	CHW Valve = 100 % open		P
		Steam valves are fully closed	1/3 Valve = 0 % open 2/3 Valve = 0 % open		P
		OA Damper opens further	OAD = _____%open (BMS) OAD = _____%open (visual)	visually saw 0%, 50% & 100% open OAD / RAD	
		RA Damper closes further	RAD = _____%open (BMS) RAD = _____%open (visual)		
		EA Damper opens further	EAD = _____%open (BMS) EAD = _____%open (visual)		

Notes:

① recovering from MWU test

② one blade of RAD needs to be screwed to its shaft

Test Procedure Step		Expected Response	Witnessed Response Y=Yes, N=No or Enter Comment	Notes (see below)	Pass (P) Fail (F)
		MAT = MAT Sept (if OAT<MAT Setpt) MAT = OAT (if OAT>MAT Setpt)	MAT = _____F		✓
		DAT = DAT Setpt	DAT = ____F		✓
		Duct Static = Duct Static Setpt	Duct Static = _____"w.c.		✓
		OA Flow increases	OA Flow = _____cfm		✓
		Supply Flow – Return Flow = SF & RF Flow Offset			✓
3e	Economizer Reset Verification Adjust economizer disable setpoint or create a simulated condition of OAT > economizer setpoint.	Chilled water valve is partially open	CHW Valve = 100 % open		P
		OA Damper is at minimum position	OAD = ~~40~~ %open 37		P
		DAT = DAT Setpt	DAT = 60 F		P
3f	Return setpts to initial setpoints.	Max OAT Reset Setpt = (unspecified)	Max OAT Reset Setpt = _____F	see setpt sheet	
		Min OAT Reset Setpt = (unspecified)	Min OAT Reset Setpt = _____F		
		Economizer Enable Setpt = RAT+2	Economizer Enable Setpt = ____F		
		Economizer Disable Setpt = (unspecified)	Economizer Disable Setpt = _____F		
4	Preheating Operation Verification				
4a	Heating Initiation Increase preheat setpt to 5F above current MAT. Decrease face/bypass setpt to be below current OAT (if not already). Preheat Setpt = _____F	Supply and return fans are on	Y		P
		Chilled water ~~valve is modulating to~~ satisfy DAT setpt	CHW Valve = 0 % open		P
		Smaller steam valve is modulating Larger steam valve is closed	1/3 Valve = 15 % open 2/3 Valve = ✓ % open		P
		Face/Bypass damper is in full face	Face Damper = 100 %open		P
		Preheat DAT = Preheat Setpt	Preheat DAT = 60 F		P
		DAT = DAT Setpt	DAT = 60 F		P
		Duct Static = Duct Static Setpt	Duct Static = 1.3 "w.c.		P

Notes:

Functional Performance Test
Air Handling Unit
AHU-32

	Test Procedure Step	Expected Response	Witnessed Response Y=Yes, N=No or Enter Comment	Notes (see below)	Pass (P) Fail (F)
4b	Increased Heating Initiation Gradually increase preheat setpt until larger steam valve starts modulating. Preheat Setpt = _____F	Chilled water valve is modulating to satisfy DAT setpt	CHW Valve = 0 % open		✓
		Smaller steam valve is fully open Larger steam valve is modulating	1/3 Valve = _____% open 2/3 Valve = _____% open	DAT	✓
		Preheat DAT = Preheat Setpt	Preheat DAT = _____F		✓
		Face/Bypass damper is in full face	Face Damper = ____%open		✓
		DAT = DAT Setpt	DAT = ____F		✓
		Duct Static = Duct Static Setpt	Duct Static = _____"w.c.		✓
4c	Face/Bypass Initiation Increase face/bypass setpt to 5F above current OAT. Face/Bypass OAT Setpt = _____F	Supply and return fans are on			
		Chilled water valve is modulating to satisfy DAT setpt	CHW Valve = _____% open	① space warm	
		Both steam valves are fully open	1/3 Valve = _____% open 2/3 Valve = _____% open	rich has been	
		Face/Bypass damper is modulating	Face Damper = ____%open	F&BP operate	
		Preheat DAT = Preheat Setpt	Preheat DAT = _____F	DAT	✓
		DAT = DAT Setpt	DAT = ____F		
		Duct Static = Duct Static Setpt	Duct Static = _____"w.c.		
4d	Heating Shutdown Decrease preheat setpt to 5F below current MAT.	Steam valves are closed	1/3 Valve = 0 % open 2/3 Valve = _____% open		P
		DAT = DAT Setpt	DAT = 60 F still clg		P
4e	Return setpts to initial setpts	Preheat Setpt = 57F Face/Bypass OAT Setpt = 3F	Preheat Setpt = _ F as determined Face/Bypass OAT Setpt = 3 F	by ave pt T DATSP reset	P
5	**Fan Speed Control Verification**				
5a	Increased Fan Speed Initiation Shut off economizer by adjusting economizer setpoints if economizer is active. Manually override maximum box position or flow input to 100%. Wait for duct static pressure setpt to reset up to maximum setpt.	Supply fan speed increases	SF Speed = 100 %		P
		Return fan speed increases	RF Speed = 85 %		P
		Duct static pressure setpt = Max duct static pressure	Duct static pressure setpt = 1.8 "w.c.		P
		Duct static pressure = Duct static pressure setpt	Duct static pressure = 1.2 "w.c. rising		P

Notes:

CHWV = 100% DAT 60.2F
RAT 77.4F

① F&BP jackshaft needs repair – 2 of 3 sections not moving

Functional Performance Test
Air Handling Unit
AHU-32

	Test Procedure Step	Expected Response	Witnessed Response Y=Yes, N=No or Enter Comment	Notes (see below)	Pass (P) Fail (F)
	Maximum Box Position = 100 %	DAT = DAT Setpt	DAT = 60.? F set pt:	55F	P
		OA Flow = Min OA Flow Setpt	OA Flow = 3366 cfm		P
		Supply flow minus return flow = SF & RF Flow Offset	SF Flow = _____cfm RF Flow = 34000 cfm		P
5b	Decreased Fan Speed Initiation Manually override maximum box position input or flow input to 5% below reset setpt. Wait for duct static pressure setpt to reset down to minimum setpt. Maximum Box Position = _____%	Supply fan speed decreases	SF Speed = _____%		-
		Return fan speed decreases	RF Speed = _____%		-
		Duct static pressure setpt = Min duct static pressure	Duct static pressure setpt = _____"w.c.		/
		Duct static pressure = Duct static pressure setpt	Duct static pressure = _____"w.c.		/
		DAT = DAT Setpt	DAT = ____F		/
		OA Flow = Min OA Flow Setpt	OA Flow = _____cfm		/
		Supply flow minus return flow = SF & RF Flow Offset	SF Flow = _____cfm RF Flow = _____cfm		- FB
5c	Return setpoint to initial setpoints. Return maximum box position to initial normal, automatic control.	Economizer Enable Setpt = RAT + 2 Economizer Disable Setpt = (unspecified)	Economizer Enable Setpt = ____F OAT < RAT+2 Economizer Disable Setpt = _____F OAT > RAT+2		P
6	**Unoccupied Operation Verification**				
6a	Unoccupied Shutdown Verification Set system to unoccupied time.	Supply and return fans are off	Y		P
		Chilled water valve is closed	Y		P
		Heating coil valves are closed	Y		P
		OA & EA Dampers are closed	OAD = 0 %open (BMS) OAD = _____%open (visual) EAD = 0 %open (BMS) EAD = _____%open (visual)		P
		RA Damper is open	RAD = 100 %open (BMS) RAD = _____%open (visual)		P
6b	Unoccupied Heating Initiation Increase unoccupied heating setpt to 2F above current room temp. Unoccupied Heating Setpt = 68 F	Supply and return fans are on	Y		P
		Chilled water valve is closed	CHW Valve = 0 % open		P
		Heating coil valve(s) are partially open	1/3 Valve = 100 % open 2/3 Valve = 100 % open		P

override = Ave Rmt 65F

trip setpt is < 68F

Notes:

	Test Procedure Step	Expected Response	Witnessed Response Y=Yes, N=No or Enter Comment	Notes (see below)	Pass (P) Fail (F)
		OA & EA Dampers are at minimum position 0	OAD = 0 %open (BMS) OAD = _____%open (visual) EAD = 0 %open (BMS) EAD = _____%open (visual)		P
		RA Damper is at maximum position	RAD = 100 %open (BMS) RAD = _____%open (visual)		P
		DAT = Unocc Heat DAT Setpt	DAT = ___F Full heat	w/ PHAT setpt of 128F	P
		Duct static pressure = Duct static pressure setpt	Duct static pressure = 0.8 "w.c. All VAV boxes forced to 100% open		P
6c	Unoccupied Heating Shutdown Decrease unoccupied heating setpt to initial setpt. Unoccupied Heating Setpt = 68 F	Supply and return fans are off	Y		P
6d	Unoccupied Cooling Initiation Decrease unoccupied cooling setpt to 5F below current room temp. Unoccupied Cooling Setpt = _____F	Supply and return fans are on			–
		Chilled water valve is modulating	CHW Valve = _____% open		–
		Heating coil valves are closed			–
		OA & EA Dampers are at minimum position	OAD = _____%open EAD = _____%open	NA	–
		RA Damper is at maximum position	RAD = _____%open		–
		DAT = DAT Setpt	DAT = _____F		–
		Duct static pressure = Duct static pressure setpt	Duct static pressure = _____"w.c.		–
6e	Unoccupied Cooling Shutdown Increase unoccupied cooling setpt to initial setpt. Unoccupied Cooling Setpt = _____F	Supply and return fans are off		NA	–
6f	Morning Warmup Initiation Initiate morning warmup by adjusting timeclock and space temperature/setpts as required.	Supply and return fans are on			
		Chilled water valve is closed	CHW Valve = _____% open		
		Heating coil valve(s) are partially open	1/3 Valve = _____% open 2/3 Valve = _____% open	(1)	
		OA & EA Dampers are at minimum position	OAD = _____%open (BMS) OAD = _____%open (visual) EAD = _____%open (BMS) EAD = _____%open (visual)		

Notes:

(1) Same seq. as nightsetback but only during the occ period

Test Procedure Step		Expected Response	Witnessed Response Y=Yes, N=No or Enter Comment	Notes (see below)	Pass (P) Fail (F)
		RA Damper is at maximum position	RAD = _____%open (BMS) RAD = _____%open (visual)		
		DAT = Unocc Heat DAT Setpt	DAT = _____F		
6g	<u>Morning Warmup Completion Initiation</u>	Supply and return fans are on		①	
	Modify setpts to simulate the warmup setpt being satisfied which should put the unit into regular, occupied operation.	DAT = DAT Setpt	DAT = ____F		
6h	Return setpts to initial setpts. Return timeclock/schedule to normal operation.	Unocc Heating Setpt = 55F	Unocc Heating Setpt = _____F		
END OF TEST					

Functional test procedure was created for testing portions of sequence most likely to have impact on energy usage. The following items were not tested:

1. Freezestat Operation
2. Fan shutdown and failure operation
3. High static pressure alarm operation
4. Smoke detector operation
5. Min OA Calculation Verification (to be verified with trending)
6. Smoke damper operation
7. VFD bypass operation
8. Morning cooldown operation (if present)
9. Unoccupied cabinet heating

cabinet freeze protection
- when MAT < 45F
- when AHU SF is off
- runs RF @ 35% speed.

Notes:

① Same as night setback but only during the occ period.

HVAC Functional Testing SIGN-OFF

Signatures below indicate completion and acceptance of the test procedures described in this document.

Firm	Representative	Function	Signature	Date
Commissioning Authority Grumman/Butkus Assoc.	STEVE RUEHLE	Witness	[signature]	7/15/10
Owner's Representative	RICH COLVIN	Witness	[signature]	7/15/10

System Description:
AHU-36 is a 100% outside air variable volume air handling unit with supply fan, chilled water cooling, steam heating with face and bypass, and heat recovery.

Tools Required to conduct Functional Testing Procedures (provided by installing contractor unless otherwise noted):

	Digital duct thermometer sensor
	Infrared thermometer
	Tools for modifying or overriding economizer control
	Multimeter
	Ladder

Located: LL D wing - funnel S cience wing

Serves: E wing Science Labs

Functional Test Date 7·13·10 / 7·14·10

Test Procedure Step	Expected Response	Witnessed Response Y=Yes, N=No or Enter Comment	Notes (see below)	Pass (P) Fail (F)
Note: Throughout test ensure that equipment and spaces are still maintaining setpoint well enough to prevent any complaints.				

Notes:

	Test Procedure Step	Expected Response	Witnessed Response Y=Yes, N=No or Enter Comment	Notes (see below)	Pass (P) Fail (F)
1	**Pre-Test measured conditions** Record initial system conditions 24/7 AHU-36 operation w/ one EF face/bypass dpr is clamshell type	NA	Per BMS: DAT = ~~[illegible]~~ 59.3 F Avg Room Temp = 68.0 F Duct Static = 2.1 "w.c. SF Speed = 74 % OAT = 78.7 F Per Infrared or Duct/Pipe Thermometer: AHU DAT = _____F Cooling Coil DAT = _____F Heating Coil DAT = _____F Recover Coil DAT = _____F Exhaust Air Temp (upstream of heat recovery) = _____F AHU CHWS = _____F AHU CHWR = _____F		P
2	**Pre-Test control setpoints** Record initial setpts. DATSP 74 - Ave temp = X 53 + (X * 3) = DATSP within limits of 53F-69F SASP setpt. is fixed 74F adjustable only in program code	Max DAT Reset Setpt = 69F Min DAT Reset Setpt = 53F Max Avg Rm Temp Reset Setpt = (unspecified) Min Avg Rm Temp Reset Setpt = (unspecified) Preheat Setpt = 55F Face/Bypass OAT Setpt = 20F Duct Static Setpt = 2.0"w.c. Heat Recovery Setpt = Rm Temp 5F or greater from OAT or less OK Operating Schedule = Continuous	Max DAT Reset Setpt = 69 F Min DAT Reset Setpt = 53 F Max Avg Rm Temp Reset Setpt = ____F Min Avg Rm Temp Reset Setpt = ____F Preheat Setpt = ____F coolsetpt - 2.0F Face/Bypass OAT Setpt = 20 F Duct Static Setpt = 2.0 "w.c. - Fixed. Heat Recovery Setpt = HR pump on when AHU is on - no control Operating Schedule = continuous ~~[illegible] DAT setpt = 57.0F~~		P

~~Cool setpt~~ = DATSP
Heat setpt = ~~Cool setpt - 2.0F~~
coolsetpt = Heatstpt + 2F (1)

Notes: (1) Rich corrected the cool setpt to use calc'd DATSP in lieu of keypad setpoint input which was 57F with Rm temp of 68F, Coolsetpt should be 7[illegible]F and not 57F. That has been used.

Functional Performance Test
Air Handling Unit
AHU-36

	Test Procedure Step	Expected Response	Witnessed Response Y=Yes, N=No or Enter Comment	Notes (see below)	Pass (P) Fail (F)
3	**Cooling Operation Verification**				
3a	Max Reset Cooling Verification Increase avg room temp reset setpoints to above current OAT. Max Avg Rm Temp Reset Setpt = _____F Min Avg Rm Temp Reset Setpt = _____F Note: During cooling operation steps decrease DAT setpts if OAT is too low for cooling to be required if freezing is not a concern. DATSP = 53F Cool setpt = 55F	Supply fan is on	SF Speed = 74.1 %		P
		Chilled water valve is partially open (if OAT>DAT Setpt)	CHW Valve = 62 % open		P
		Steam valve is fully closed	Steam Valve = 0 % open		P
		Steam coil dampers are in full face	Y		P
		Heat recovery system is on	Y		P
		EF-1 is on	Y		P
		EF-2 is off	Y		P
		DAT = DAT Setpt	DAT = 57 F		P
		Duct Static = Duct Static Setpt	Duct Static = 2.1 "w.c.		P
3b	Medium Reset Cooling Verification Modify min and max rm temp reset setpts so that current avg room temp is halfway between the two setpoints. Max Avg Rm Temp Reset Setpt = _____F Min Avg Rm Temp Reset Setpt = _____F	Chilled water valve opens further	CHW Valve = 30 % open	closing	P
		DAT Setpt = (Max DAT Reset Setpt + Min DAT Reset Setpt)/2	DAT Setpt = 69 F cool setpt = 71		P
		DAT = DAT Setpt	DAT = 59 F		P
3c	Min Reset Cooling Verification Decrease rm temp reset setpoints to below current OAT. Min Avg Rm Temp Reset Setpt = _____F	Chilled water valve opens further	CHW Valve = 0 % open		P
		DAT Setpt = Min DAT Reset Setpt	DAT Setpt = 69 F cool stpt = 71F		P
		DAT = DAT Setpt	DAT = 67 F		P
		Duct Static = Duct Static Setpt	Duct Static = 2.0 "w.c.		P
3f	Return setpts to initial setpoints.	Max DAT Reset Setpt = 69F Min DAT Reset Setpt = 53F Max Avg Rm Temp Reset Setpt = (unspecified) Min Avg Rm Temp Reset Setpt = (unspecified)	Max DAT Reset Setpt = _____F Min DAT Reset Setpt = _____F Max Avg Rm Temp Reset Setpt = _____F Min Avg Rm Temp Reset Setpt = _____F	✓	P
4	**Preheating Operation Verification**				
4a	Heating Initiation htstpt = 69F Increase preheat setpt to 15F above current OAT. Decrease preheat OAT setpt to 5F	Supply fan is on	SF Speed = 74 %		P
		Steam valve is modulating	Steam Valve = 14 % open	closing	P
		Steam coil dampers are in full face	Y		P

Notes: DAT = 69.5

Functional Performance Test
Air Handling Unit
AHU-36

	Test Procedure Step	Expected Response	Witnessed Response Y=Yes, N=No or Enter Comment	Notes (see below)	Pass (P) Fail (F)
	below current OAT (if not already below OAT). Preheat Setpt = _____F Face/Bypass OAT Setpt = _____F	EF-1 is on	Y		P
		EF-2 is off	Y		P
		Heating Coil DAT = Preheat Setpt	Heating Coil DAT = 69.5 F		P
		DAT = DAT Setpt	DAT = ___F same sensor		P
		Duct Static = Duct Static Setpt	Duct Static = 2.0 "w.c.		P
4b	Face/Bypass Initiation Increase preheat OAT setpt to 5F above current OAT. Face/Bypass OAT Setpt = _____F FBP enabled <20F OAT	Supply fan is on	SF Speed = _____%	(1)	
		Steam valve is fully open	Steam Valve = _____% open	Rick has verified FBP modulation	
		Steam coil face/bypass dampers are modulating	Face Damper = _____%open		
		EF-1 is on			
		EF-2 is off			
		Heating Coil DAT = Preheat Setpt	Heating Coil DAT = _____F		
		DAT = DAT Setpt	DAT = ____F		
		Duct Static = Duct Static Setpt	Duct Static = _____"w.c.		
4c	Heating Shutdown Decrease preheat setpt to 5F below current OAT.	Steam valve is fully closed	Steam Valve = 0 % open		P
		Steam coil dampers are in full face	Y		P
		DAT = DAT Setpt	DAT = 69 F		P
4d	Return setpts to initial setpts	Preheat Setpt = 55F Face/Bypass OAT Setpt = 20F	Preheat Setpt = 69 F Face/Bypass OAT Setpt = 20 F		P
5	Fan Speed Control Verification				
5a	Increased Fan Speed Initiation Increase duct static setpt to 0.25" above current setpoint. Duct Static Setpt = _____"w.c.	Supply fan speed increases	SF Speed = _____%	works great, hugs setpt.	P
		Duct static pressure = Duct static pressure setpt	Duct static pressure = _____"w.c.		
		DAT = DAT Setpt	DAT = ____F		
5b	Decreased Fan Speed Initiation Decrease duct static setpt to 0.5" below previous setpoint (0.25" below initial) Duct Static Setpt = _____"w.c.	Supply fan speed decreases	SF Speed = _____%		
		DAT = DAT Setpt	DAT = ____F		
		Duct static pressure = Duct static pressure setpt	Duct static pressure = _____"w.c.		
5c	Return setpoint to initial setpoints.	Duct Static Setpt = 2.0"w.c.	Duct Static Setpt = 2.0 "w.c.		
6	Heat Recovery Operation Verification				

Notes: (1) F&BP linkages need adjustment (wing coil) dampers don't move totally closed or totally open.

Test Procedure Step		Expected Response	Witnessed Response Y=Yes, N=No or Enter Comment	Notes (see below)	Pass (P) Fail (F)
6a	<u>Heat Recovery Initiation</u> Override OAT or Room temp input to simulate a room temperature 10F above current OAT.	Heat recovery pump is on	OAT = 79.7 > 68.7+5 = 73.7 Y	(1)	P
		DAT = DAT Setpt	DAT = ___F HR loop = 74.9F		P
6b	<u>Heat Recovery Shutdown</u> Override OAT or Room temp input to simulate a room temperature equal to current OAT.	Heat recovery pump is off	Y	(2)	P
		DAT = DAT Setpt	~~DAT = ___F~~		[illegible]
6c	Return OAT and room temperature to normal, automatic control.	N/A	Y		P
END OF TEST					

Functional test procedure was created for testing portions of sequence most likely to have impact on energy usage. The following items were not tested:

1. Freezestat Operation
2. Fan shutdown and failure operation
3. Unoccupied operation (unit is on continuously)
4. Exhaust fan standby operation

68 - 5 = 63

AveRnt - 5F

if OAT < 63F = pump on

Ave Rnt + 5F

68.7 + 5 = 73.7

if OAT > 73.7F = pump on

otherwise pump off

Energy savings ↓ now HR pump will be off when OAT & AveRnt are within ±5F.

(2) program logic also looks at AHU fan status for HR pump on/off - but code looks at fan status OR OAT vs AveRnt and not fan status AND OAT vs AveRnt AND fan status.

← Rich changed code to AND

Notes:

(1) Rich added HR pump status to graphic

Functional Performance Test
Air Handling Unit
AHU-39

HVAC Functional Testing SIGN-OFF
Signatures below indicate completion and acceptance of the test procedures described in this document.

Firm	Representative	Function	Signature	Date
Commissioning Authority Grumman/Butkus Assoc.	STEVE RIEHLE	Witness	[signature]	7/15/10
Owner's Representative	RICH COLVIN	Witness	[signature]	7/15/10

System Description:
AHU-39 is a constant volume air handling unit with supply fan, return fan, chilled water cooling, steam heating, filters, and economizer.

Tools Required to conduct Functional Testing Procedures (provided by installing contractor unless otherwise noted):

	Digital duct thermometer sensor
	Infrared thermometer
	Tools for modifying or overriding economizer control
	Multimeter
	Ladder

Located: M wing 2nd Flr
Serves: L wing 1st Flr Process control Lab

Functional Test Date 7.13.10

	Test Procedure Step	Expected Response	Witnessed Response Y=Yes, N=No or Enter Comment	Notes (see below)	Pass (P) Fail (F)
Note: Throughout test ensure that equipment and spaces are still maintaining setpoint well enough to prevent any complaints.					
1	**Pre-Test measured conditions** Record initial system conditions	NA	Per BMS: DAT = 56 F Preheat DAT = 75.9 F MAT = 75.8 F RAT = 74.5 F OAT = 79.4 F Per Infrared or Duct/Pipe Thermometer: AHU DAT = _____F Cooling Coil DAT = _____F Heating Coil DAT = _____F MAT = 77 F RAT = 76.5 F AHU CHWS = 47 F AHU CHWR = 57 F		P

Notes:

Functional Performance Test

Air Handling Unit
AHU-39

	Test Procedure Step	Expected Response	Witnessed Response Y=Yes, N=No or Enter Comment	Notes (see below)	Pass (P) Fail (F)
2	**Pre-Test control setpoints** Record initial setpts.	DAT Setpt = 60F MAT Setpt = 60F Preheat Setpt = 58F Unocc Heat DAT Setpt = (unspecified) Unocc Heating Setpt = (unspecified) Economizer Enable Setpt = RAT+2 Economizer Disable Setpt = (unspecified) Min OA Damper Position = 45% Operating Schedule = M, Tu, Th: 715-2000 W: 730-1530 F: 745-1630	DAT Setpt = 57 F 70 MAT Setpt = 60 F Forced Preheat Setpt = 53 F - No reset Unocc Heat DAT Setpt = 73 F occ+20F Unocc Heating Setpt = 55 F Economizer Enable Setpt = ___F OAT < RAT+2 Economizer Disable Setpt = ___F OAT > RAT+2 Operating Schedule = Min. OAD = 45%	Rset 0 73 ×10	P
3	**Cooling Operation Verification**				
3a	Mechanical Cooling Verification Adjust economizer setpoint or create a simulated condition of the OAT > economizer setpoint. DAT setpt = 57°F	Supply and return fans are on	✓		P
		Chilled water valve is partially open	CHW Valve = 96 % open		P
		OA Damper is at minimum position	OAD = 45 %open (BMS) OAD = 5 %open (visual)	②	F
		RA Damper is at maximum operating position	RAD = 55 %open (BMS) RAD = 95 %open (visual)	②	F
		EA Damper is at minimum operating position	EAD = 45 %open (BMS) EAD = 5 %open (visual)	②	F
		MAT > DAT	MAT = 75 F		P
		DAT = DAT Setpt	DAT = 56.9 F		P
3b	~~Increased~~ Decreased Mechanical Cooling Verification ~~Decrease~~ In DAT Setpt 5F. DAT Setpt = 64 F	Chilled water valve ~~opens further~~ closes	CHW Valve = 83 % open & closing		P
		DAT = DAT Setpt	DAT = 58 F + rising	①	F
3c	Economizer Operation Verification Adjust economizer enable setpoint or create a simulated condition of the OAT< economizer setpoint	Supply and return fans are on	Y		P
		Chilled water valve is closed (if OAT<MAT Setpt) Chilled water valve is partially open (if OAT>MAT Setpt)	CHW Valve = 95 % open		P
		Steam valve is fully closed	Steam Valve = 0 % open		P

Notes:

RF will start during unocc when MAT < 45F to prevent freezing coil.

① Rich is modifying program so heat is locked out during summer mode

② Rich to fix

Functional Performance Test
Air Handling Unit
AHU-39

Test Procedure Step		Expected Response	Witnessed Response Y=Yes, N=No or Enter Comment	Notes (see below)	Pass (P) Fail (F)
		OA Damper opens further	OAD = 100 %open (BMS) OAD = 100 %open (visual)		P
		RA Damper closes further	RAD = 0 %open (BMS) RAD = 0 %open (visual)		P
		EA Damper opens further	EAD = 100 %open (BMS) EAD = 100 %open (visual)		P
		MAT = MAT Sept (if OAT<MAT Setpt) MAT = OAT (if OAT>MAT Setpt)	MAT = 77 F OAT = 80F		P
		DAT = DAT Setpt	DAT = 57 F		P
3d	<u>Economizer Reset Verification</u> Adjust economizer disable setpoint or create a simulated condition of OAT > economizer setpoint.	Chilled water valve is partially open	CHW Valve = 95 % open		P
		OA Damper is at minimum position	OAD = 45 %open		P
		DAT = DAT Setpt	DAT = 57 F		P
3f	Return setpts to initial setpoints.	DAT Setpt = 60F Economizer Enable Setpt = RAT+2 Economizer Disable Setpt = (unspecified)	DAT Setpt = 57 F Economizer Enable Setpt = ___F OAT < RAT+2 Economizer Disable Setpt = ___F OAT > RAT+2		P
4	<u>**Preheating Operation Verification**</u>				
4a	<u>Preheating Shutdown</u> Decrease preheat setpt to 5F below current MAT (if not already below MAT). Preheat Setpt = _____F	Chilled water valve is modulating to satisfy DAT setpt	CHW Valve = 95 % open		P
		Steam valve is closed	Steam Valve = 0 %open		P
		Preheat DAT > Preheat Setpt	Preheat DAT = 75 F		P
		DAT = DAT Setpt	DAT = 57 F		P
4b	<u>Preheating Initiation</u> Increase preheat setpt to 5F above current MAT. Preheat Setpt = 99 F MAT = 76.4	Chilled water valve is ~~modulating to satisfy DAT setpt~~ closed	CHW Valve = 0 % open		P
		Smaller steam valve is modulating Larger steam valve is closed	1/3 Valve = ____% open + 2/3 Valve = 20 % open rising		P
		Preheat DAT = Preheat Setpt	Preheat DAT = 80 F + rising		P
		DAT = DAT Setpt	DAT = 59 F + rising CC still cold w/ valve @ 0%		P

Notes:

	Test Procedure Step	Expected Response	Witnessed Response Y=Yes, N=No or Enter Comment	Notes (see below)	Pass (P) Fail (F)
4c	Increased Heating Initiation Gradually increase preheat setpt until small steam valve is fully open and larger steam valve is modulating. Preheat Setpt = 99 F	Chilled water valve is modulating to satisfy DAT setpt ✓ Closed	CHW Valve = 0 % open		P
		Smaller steam valve is fully open Larger steam valve is modulating	1/3 Valve = — % open 2/3 Valve = 25 % open + rising		P
		Preheat DAT = Preheat Setpt	Preheat DAT = 80 F ↑		P
		DAT = DAT Setpt	DAT = 60 F ↑		P
4d	Return setpts to initial setpts	Preheat Setpt = 58F	Preheat Setpt = 53 F		P
5	**Unoccupied Operation Verification**				
5a	Unoccupied Shutdown Verification Set system to unoccupied time.	Supply and return fans are off	Y		P
		Chilled water valve is closed	Y		P
		Heating coil valves are closed	Y		P
		OA & EA Dampers are closed	OAD = 0 %open (BMS) OAD = 0 %open (visual) EAD = 0 %open (BMS) EAD = 0 %open (visual)		P
		RA Damper is open	RAD = 100 %open (BMS) RAD = 100 %open (visual)		P
5b	Unoccupied Heating Initiation Increase unoccupied heating setpt to 2F above current room temp. Unoccupied Heating Setpt = 95 F LRmT = 75.6	Supply and return fans are on	Y		P
		Chilled water valve is closed	CHW Valve = 0 % open		P
		Heating coil valve(s) are partially open	1/3 Valve = 10+ % open 2/3 Valve = 10 % open	opening ①	P
		OA & EA Dampers are at minimum position	OAD = 0 %open (BMS) OAD = 0 %open (visual) EAD = 0 %open (BMS) EAD = 0 %open (visual)		P
		RA Damper is at maximum position	RAD = 100 %open (BMS) RAD = 100 %open (visual)		P
		DAT = Unocc Heat DAT Setpt = ~~53F~~ 84F	DAT = 76 F	①	P

Notes:

① PHC setpoint did not change to OCC PHAT stpt + 20F. still was 53F. Rich will change.
PHC valve did not open.
Rich fixed this. now +20F added to PHAT stpt. and displays

Functional Performance Test
Air Handling Unit
AHU-39

	Test Procedure Step	Expected Response	Witnessed Response Y=Yes, N=No or Enter Comment	Notes (see below)	Pass (P) Fail (F)
5c	Unoccupied Heating Shutdown Decrease unoccupied heating setpt to initial setpt. Unoccupied Heating Setpt = 55 F	Supply and return fans are off	Y		P
5d	Morning Warmup Initiation Initiate morning warmup by adjusting timeclock and space temperature/setpts as required.	Supply and return fans are on		① DNT	
		Chilled water valve is closed	CHW Valve = _____% open		
		Heating coil valve(s) are partially open	1/3 Valve = _____% open 2/3 Valve = _____% open		
		OA & EA Dampers are at minimum position	OAD = _____%open (BMS) OAD = _____%open (visual) EAD = _____%open (BMS) EAD = _____%open (visual)		
		RA Damper is at maximum position	RAD = _____%open (BMS) RAD = _____%open (visual)		
		DAT = Unocc Heat DAT Setpt	DAT = _____F		
5e	Morning Warmup Completion Initiation Modify setpts to simulate the warmup setpt being satisfied which should put the unit into regular, occupied operation.	Supply and return fans are on			
		DAT = DAT Setpt	DAT = ____F		
5f	Return setpts to initial setpts. Return timeclock/schedule to normal operation.	Unocc Heating Setpt = 55F	Unocc Heating Setpt = _____F		
	END OF TEST				

Functional test procedure was created for testing portions of sequence most likely to have impact on energy usage. The following items were not tested:

1. Freezestat Operation
2. Fan shutdown and failure operation
3. Smoke detector operation
4. Morning cooldown operation (if present)
5. Unoccupied cabinet heating

Notes: ① Same issue as AHU-28 - Arch to revise programming. See AHU-28 FTP.

Functional Performance Test
Air Handling Unit
AHU-45

HVAC Functional Testing SIGN-OFF

Signatures below indicate completion and acceptance of the test procedures described in this document.

Firm	Representative	Function	Signature	Date
Commissioning Authority Grumman/Butkus Assoc.	STEVE RIEHLE	Witness	[signature]	7/15/10
Owner's Representative	RICH COLVIN	Witness	[signature]	7/15/10

System Description:

AHU-45 is a 100% outside air variable volume air handling unit with supply fan, chilled water cooling, and steam heating.

Tools Required to conduct Functional Testing Procedures (provided by installing contractor unless otherwise noted):

	Digital duct thermometer sensor
	Infrared thermometer
	Tools for modifying or overriding economizer control
	Multimeter
	Ladder

Located – LL Mech Rm

Serves – LL Kitchen

Functional Test Date 7·13·10 [signature]

	Test Procedure Step	Expected Response	Witnessed Response Y=Yes, N=No or Enter Comment	Notes (see below)	Pass (P) Fail (F)
Note: Throughout test ensure that equipment and spaces are still maintaining setpoint well enough to prevent any complaints.					
1	**Pre-Test measured conditions** Record initial system conditions	NA	Per BMS: DAT = 105 F Duct Static = 1.2 "w.c. SF Speed = ____% OAT = 80.9 F Per Infrared or Duct/Pipe Thermometer: AHU DAT = ____F Cooling Coil DAT = ____F Heating Coil DAT = ____F AHU CHWS = ____F AHU CHWR = ____F		P

Notes:

	Test Procedure Step	Expected Response	Witnessed Response Y=Yes, N=No or Enter Comment	Notes (see below)	Pass (P) Fail (F)
2	**Pre-Test control setpoints** Record initial setpts.	Cooling DAT Setpt = 65F Heating DAT Setpt = 55F Duct Static Setpt = 1.2"w.c. Unoccupied Cabinet Temp Setpt = 55F	Cooling DAT Setpt = 65 F Heating DAT Setpt = 55 F (PHAT) Duct Static Setpt = 1.2 "w.c. Unoccupied Cabinet Temp Setpt = 55 F		P
3	**Heating/Cooling Operation Verification**				
3a	Cooling Initiation Turn EF-1 on. Turn EF-3, 6, 7 off. Decrease cooling and heating setpts to 5F below current OAT. Cooling DAT Setpt = 65 F Heating DAT Setpt = 55 F (PHAT)	Supply fan is on	SF Speed = 97 % and falling		P
		Chilled water valve is partially open	CHW Valve = 60 % open and closing		P
		Steam valve is fully closed	Steam Valve = 0 % open		P
		Outside air damper is open	Y	①	P
		DAT = Cooling DAT Setpt	DAT = 60 F + rising		P
		Duct Static = Duct Static Setpt = 1.2	Duct Static = 1.2 "w.c. and falling		P
		EF-1 is on	Y		P
		EF-3, 6, 7 are off	Y		P
3b	Deadband Initiation Increase cooling setpt to 5F above current OAT. Cooling DAT Setpt = 81 F OAT = 81	Supply fan is on	SF Speed = 97 % falling		P
		Chilled water valve is fully closed	CHW Valve = 0 % open		P
		Steam valve is fully closed	Steam Valve = 0 % open		P
		DAT = OAT	DAT = 69 F + rising		P
		Duct Static = Duct Static Setpt	Duct Static = 1.3 "w.c.		P
3c	Heating Initiation Increase heating setpt to 5F above current OAT. Heating DAT Setpt = 88 F lowest of PHAT & DAT sensors	Supply fan is on	SF Speed = 97 %		P
		Chilled water valve is fully closed	CHW Valve = 0 % open		P
		Steam valve is partially open	Steam Valve = 32 % open + opening		P
		DAT = OAT	DAT = 85 F + rising		P
		Duct Static = Duct Static Setpt	Duct Static = 1.3 "w.c.		P
3f	Return setpts to initial setpoints.	Cooling DAT Setpt = 65F Heating DAT Setpt = 55F	Cooling DAT Setpt = 65 F Heating DAT Setpt = 55 F		P
4	**Fan Speed Control Verification**				
4a	Increased Fan Speed Initiation Turn EF-1 on. Turn EF-3, 6, 7 off. Increase duct static setpt to 0.25" above current setpoint. Duct Static Setpt = 1.4 "w.c.	Supply fan speed increases	SF Speed = 97 %		P
		Duct static pressure = Duct static pressure setpt	Duct static pressure = 1.4 "w.c.		P
		DAT = DAT Setpt	DAT = 65 F		P

Notes:

① OAD has end switch to permit SF to run

	Test Procedure Step	Expected Response	Witnessed Response Y=Yes, N=No or Enter Comment	Notes (see below)	Pass (P) Fail (F)
4b	Decreased Fan Speed Initiation Decrease duct static setpt to 0.5" below previous setpoint (0.25" below initial) Duct Static Setpt = 1.2"w.c.	Supply fan speed decreases	SF Speed = 94 %		P
		Duct static pressure = Duct static pressure setpt	Duct static pressure = 1.3 "w.c. falling		P
		DAT = DAT Setpt	DAT = 65 F		P
4c	Increased Exhaust Initiation Turn EF-3, 6, 7 on.	Supply fan speed stays the same or decreases slightly	SF Speed = 93 %		P
		Duct static pressure = Duct static pressure setpt	Duct static pressure = 1.2 "w.c.		P
		DAT = DAT Setpt	DAT = 65 F		P
4d	Return setpoint to initial setpoints.	Duct Static Setpt = 1.2"w.c.	Duct Static Setpt = 1.2 "w.c.		P
5	Unoccupied Operation Verification				
5a	Unoccupied Initiation Turn EF-1,3,6,7 are off.	Supply fan is off	Y		P
		Outside air damper is closed	Y		P
		Steam valve is closed	Y		P
5b	Cabinet Temp Control Initiation Increase unoccupied cabinet temp setpt to 5F above current cabinet temp. Unoccupied Cabinet Temp Setpt = 35 F PHAT normally 55F PHAT setpt.	Supply fan is off	Y		P
		Outside air damper is closed	Y		P
		Steam valve is modulating open	Steam Valve = 100 % open	(1)	P
		Cabinet temp increases 72F	Cabinet Temp = 84 F + rising		P
5c	Return setpts to initial setpts and fans to original control positions.	Unoccupied Cabinet Temp Setpt = 55F	Unoccupied Cabinet Temp Setpt = 35 F		P
	END OF TEST				

on DAT < 38F

Functional test procedure was created for testing portions of sequence most likely to have impact on energy usage. The following items were not tested:

1. Freezestat Operation
2. Fan shutdown and failure operation

(2) ~~Rich will check the 4 VAV boxes interlocked with kidney? not reading flow.~~ if AHU is on & stop SF.

(1) Will also operate pre-freeze if this is auto reset.

- SA VAV boxes have a minimum position when their respective EF is off

- smallest EF on will run AHU SF @ speed to maintain 1.2" sp. Rich needs to check if this is possible with AHU.

Notes:

* can SA VAV RHC valves be closed when AHU is off? RHC flow is only a small part of total HW loop flow so should not impact min. HW flow.

HVAC Functional Testing SIGN-OFF

Signatures below indicate completion and acceptance of the test procedures described in this document.

Firm	Representative	Function	Signature	Date
Commissioning Authority Grumman/Butkus Assoc.	STEVE RIEHLE	Witness	[signature]	7/15/10
Owner's Representative	RICH COLVIN	Witness	[signature]	7/15/10

System Description:
The hot water converters are served by the steam system and produce hot water for various usages. This is a generic test form for testing converters and applies to heat exchanger HE-_____ and pump(s) P-__________.

The heat exchanger serves the following equipment: Pwing HE

Tools Required to conduct Functional Testing Procedures

☐	Multimeter
☐	Ladder
☐	Infrared thermometer

located: LL Pwing mech Rm
serves: Pwing RHC AHU-27, 29 (AHU 25, 28)
swim pool AHU-25, 26, 28

Functional Test Date 7-14-10

	Test Procedure Step	Expected Response	Witnessed Response Y=Yes, N=No or Enter Comment	Notes (see below)	Pass (P) Fail (F)
	Note: Be prepared to raise the space temperature setpoints to cause a real load on the heating system if required. Throughout test ensure that equipment and spaces are still maintaining setpoint well enough to prevent any complaints.				
1	**Pre-Test measured conditions** Record initial temperatures and pressures. Note: Use infrared thermometer to measure uninsulated pipe temperature directly downstream of steam traps to check for leaks.	N/A	HWS = 179 F HWR = 167 F Steam Press = _____psi Condensate Temp = _____F OAT = 86 F	created p today	
2	**Pre-Test control setpoints** Record initial setpts as found Amt to reset 0 F begin reset 30F OAT End reset 100F OAT	N/A part of OA lockout High OAT lockout = 99F runs continuously	Max HWS Reset Setpt = _____F Min HWS Reset Setpt = _____F Max HWS Reset OAT Setpt = _____F Min HWS Reset OAT Setpt = _____F Calculated HWS Setpt = 180 F FIXED	① base setpt 140F ② amt of reset = 40F OAT range 60F → 40F	P

Notes: ① HWS temp not reset because it serves swim pool AHU-27
② Rich setup HWS setpt reset on stm control output parameters – He will add to the graphics screen to replace the OA lockout cells.

	Test Procedure Step	Expected Response	Witnessed Response Y=Yes, N=No or Enter Comment	Notes (see below)	Pass (P) Fail (F)
3	**HE Temperature Control Verification**				
3a	Max HW Reset Initiation Increase reset OAT setpts to 5F above current OAT. Max HWS Reset OAT Setpt = _____F Min HWS Reset OAT Setpt = _____F	Steam valve(s) opens further	1 Valve = 20 % ___Valve = ___%		P
		HWS = Max HWS Reset Setpt 180F	HWS = 179 F		P
3b	Midpoint HW Reset Initiation Modify reset OAT setpts so that OAT is halfway between min and max. Max HWS Reset OAT Setpt = _____F Min HWS Reset OAT Setpt = _____F	Steam valve(s) close further	____Valve = ____% ____Valve = ____%	not checked	–
		HWS = (Max HWS Reset Setpt + Min HWS Reset Setpt)/2	HWS = ____F		–
3c	Min HW Reset Initiation Decrease reset OAT setpts to 5F below current OAT. Max HWS Reset OAT Setpt = _____F Min HWS Reset OAT Setpt = _____F	Steam valve(s) close further	1 Valve = 11.4% closing ___Valve = ___%		P
		HWS = Min HWS Reset Setpt	HWS = 144 F HWS sp = 140F		P
3d	Return setpts to initial setpts.	Varies	Max HWS Reset OAT Setpt = ____F Min HWS Reset OAT Setpt = ____F	see reset schedule	P
	END OF TEST				

Functional test procedure was created for testing portions of sequence most likely to have impact on energy usage. The following items were not tested:

1. Pump Failure and Alarming
2. OAT Lockout (not present for most HEs)

5# DP setpt
5# press reading
65% PmpB speed.

Notes:

Functional Performance Test
Converter

HVAC Functional Testing SIGN-OFF
Signatures below indicate completion and acceptance of the test procedures described in this document.

Firm	Representative	Function	Signature	Date
Commissioning Authority Grumman/Butkus Assoc.	STEVE RIEHLE	Witness	[signature]	7/15/10
Owner's Representative	RICH COLWIN	Witness	[signature]	7/15/10

System Description:
The hot water converters are served by the steam system and produce hot water for various usages. This is a generic test form for testing converters and applies to heat exchanger HE-_____ and pump(s) P-_________.

The heat exchanger serves the following equipment: C WING REHEAT COILS [scribbled out] East

Tools Required to conduct Functional Testing Procedures

	Multimeter
	Ladder
	Infrared thermometer

Functional Test Date 7-14-10

	Test Procedure Step	Expected Response	Witnessed Response Y=Yes, N=No or Enter Comment	Notes (see below)	Pass (P) Fail (F)
Note: Be prepared to raise the space temperature setpoints to cause a real load on the heating system if required. Throughout test ensure that equipment and spaces are still maintaining setpoint well enough to prevent any complaints.					
1	**Pre-Test measured conditions** Record initial temperatures and pressures. Note: Use infrared thermometer to measure uninsulated pipe temperature directly downstream of steam traps to check for leaks.	N/A	HWS = 130.5 F HWR = _____F Steam Press = _____psi Condensate Temp = _____F OAT = 87 F		P
2	**Pre-Test control setpoints** Record initial setpts OA lockout 790.0F	N/A	Max HWS Reset Setpt = 180 F Min HWS Reset Setpt = 130 F Max HWS Reset OAT Setpt = ~~30~~ 150 F Min HWS Reset OAT Setpt = ~~180~~ 65 F Calculated HWS Setpt = 130 F		P

Notes:

	Test Procedure Step	Expected Response	Witnessed Response Y=Yes, N=No or Enter Comment	Notes (see below)	Pass (P) Fail (F)
3	**HE Temperature Control Verification**				
3a	Max HW Reset Initiation Increase reset OAT setpts to 5F above current OAT. Max HWS Reset OAT Setpt = _____F Min HWS Reset OAT Setpt = _____F	Steam valve(s) opens further	_____Valve = _____% _____Valve = _____%	DNT	
		HWS = Max HWS Reset Setpt	HWS = _____F		
3b	Midpoint HW Reset Initiation Modify reset OAT setpts so that OAT is halfway between min and max. Max HWS Reset OAT Setpt = _____F Min HWS Reset OAT Setpt = _____F	Steam valve(s) close further	_____Valve = 50 % open _____Valve = _____%	works well	P
		HWS = (Max HWS Reset Setpt + Min HWS Reset Setpt)/2 140F setpt.	HWS = 128 F		
3c	Min HW Reset Initiation Decrease reset OAT setpts to 5F below current OAT. Max HWS Reset OAT Setpt = _____F Min HWS Reset OAT Setpt = _____F	Steam valve(s) close further	_____Valve = 12 % OPEN _____Valve = _____%		P
		HWS = Min HWS Reset Setpt 130F	HWS = 128 F		P
3d	Return setpts to initial setpts.	Varies	Max HWS Reset OAT Setpt = 15.0 F Min HWS Reset OAT Setpt = 65.0 F		P
	END OF TEST				

Functional test procedure was created for testing portions of sequence most likely to have impact on energy usage. The following items were not tested:

1. Pump Failure and Alarming
2. OAT Lockout (not present for most HEs)

one CV pump - w/o bypass control valve

Notes:

EXHIBIT 14

COMMISSIONING MEETING MINUTES

Grumman/Butkus Associates
1011 N. Mayfair Rd., Suite 300
Wauwatosa, WI 53226
(414) 476-8980
FAX (414) 476-2470

Date of Meeting Minutes	4/29/2010

Commissioning Meeting Minutes

Project:		Meeting Date:	4/29/2010
FES - Delta College	Consumers Energy Phase II RCx Program	Location:	Delta College
Saginaw, MI			
GBA 10127			

Attended	Copied	Personnel	
x	x	John Nametz	FE
x	x	Jeff Jump	Delta
x	x	Rich Colvin	Delta
x	x	Larry Ramseyer	Delta
x	x	Anthony Khalil	Delta
x	x	Matthew Sullivan	Delta
x	x	Ken Ritter	Delta
x	x	Tom Kienbaum	Delta
x	x	Jim Witucki	Delta
x	x	Linda Petee	Delta
x	x	Jeff Conner	GBA
x	x	Shawn Klose	GBA

The following outlines the writer's understanding of the meeting. If there are any discrepancies, corrections or additions, please notify the writer within the next five working days.

Item	Description	Status	Item Date	Who
1	Delta is planning to have an institution wide energy management program with a much larger scope that also includes subjects such as marketing and education. This retrocommissioning process will be a portion of the overall plan.	N/A	4/29/2010	N/A
2	Maintenance personnel are interested in using sensors for continuous steam trap leak monitoring. This is a capital type improvement which may have the potential of being included as part of Consumers Energy Retro-Commissioning Program Phase 3.	N/A	4/29/2010	N/A
3	G/BA will be given contractor badges if needed but access will typically be provided by maintenance personnel.	N/A	4/29/2010	N/A
4	The G/BA portion of the commissioning process is targeting low and no-cost measures which typically are control changes. Measures which require substantial capital will not be targeted but will still be included in the report and should be considered by Delta separately or as part of phase 3. Measures may also be eligible for various CE incentives which would help offset the implementation cost.	N/A	4/29/2010	N/A
5	Monthly commissioning progress reports will be provided.	Open	4/29/2010	GBA
6	Preliminary commissioning schedule will be provided to Delta for their review.	Open	4/29/2010	GBA
7	Persistence of modifications is critical. G/BA will work closely with on-site personnel to ensure "buy-in" on all of the modifications. Delta will want to ensure modifications are maintained and not overridden.	Open	4/29/2010	Delta
8	Delta is currently working on a variety of projects including both lighting retrofits and the addition of occupancy sensors for lighting control.	N/A	4/29/2010	N/A
9	The automotive lab AHUs are being converted to include some recirculation air.	N/A	4/29/2010	N/A
10	Design/Shop Drawing/As-Built sequences of operation are typically available. As-built sequences of operation will be provided by Delta to G/BA for all systems being functionally tested.	Open	4/29/2010	Delta
11	Delta is contemplating new chiller plant upgrades and the addition of demand control ventilation to the gymnasium AHUs.	N/A	4/29/2010	N/A
12	On-site staff are capable of performing setpoint and programming changes but a separate control contractor may be required to perform the modifications if on-site staff do not have adequate time to perform. G/BA will create scope documents as required for Delta to solicit bids from contractors.	N/A	4/29/2010	N/A
13	G/BA will functionally test a sample of the various system types. It is suggested that all systems eventually be tested but this is not within the scope of the current project.	N/A	4/29/2010	N/A
14	The following systems will be functionally tested with G/BA: AHU-32 (Trane VAV), AHU-36 (Trane MAU), AHU-45 (AAM Kitchen MAU), AHU-39 (CV AAM), AHU-1 (CV AAM Gym), AHU-28 (AAM VAV), S Wing Heating HX, L Wing Heating HX, boiler plant and chiller plant. AHU-22 (CV AAM) and AHU-18 (AAM Dual Duct) will be performed if budget allows.	Open	4/29/2010	GBA & Delta
15	The systems functionally tested with G/BA should be trended for a full week with intervals of 5 minutes. All available points associated with the system should be trended with the exception of points such as the filter switches.	Open	4/29/2010	Delta
16	Operation and Maintenance issues should be resolved if possible before functionally testing the equipment. See O&M comments below for additional information.	Open	4/29/2010	Delta
17	The following is a listing of the current status of the individual O&M items:		4/29/2010	Delta
	1. A Wing - Replace Missing HWS Gauge: Will be completed.	Open		
	2. F Wing - Repair Leaking HE3 HW Pump: Completed	Closed		
	3. L Wing - Repair Heat Exchanger Leaks: Completed	Closed		
	4. L Wing - Replace HX Pump Pressure Gauge: Will be completed.	Open		
	5. S Wing - Replace HWS Thermometer - Will be Completed.	Open		
	6. AHU-3 - Replace SF Motor: May be fixed eventually.	Open		
	7. AHU-11 & 12 - Need New Software: Unsure on issue/resolution	Open		
	8. AHU-22 - Clean Dirty Cooling Coil: Will verify and complete if not already performed.	Open		
	9. AHU-26 - Replace MAT Sensor: Completed	Closed		
	10. AHU-29 - Clean Dirty Heating Coil: Completed	Closed		
	11. AHU-29 - Add Missing Inlet Vane BAS Graphic: Believe has been completed.	Closed		
	12. AHU-43 - Replace OA Damper Blade Seals: Will verify and complete if not already performed.	Open		
	13. AHU-50 - Reconnect OA Damper Actuator: Will investigate reason for disconnection.	Open		
	14. AHU-50 - Add Missing OA & Relief Air Graphic to BAS: Will be completed if item 13 is completed.	Open		
	15. CT-2 & 3 - Repair Water Leak at Seam: Completed.	Closed		
	16. CT-3 - Repair Leak at Probe: Completed.	Closed		
	17. Greenhouse AHU-37 - Adjust F/B Damper: Have adjusted as much as possible.	Closed		
	18. Auto Lab AHUs - Add F/B Dampers: AHU-38 & 40 are getting modified to include return. AHU-42 will have F/B added.	Closed		

	19. L Wing - Move HWS/R Sensors: Completed	Closed		
	20. L Wing - Add HW Bypass Valves: May consider in the future	Open		
18	The following is a listing of the current status of the individual FIMs:			GBA & Delta
	1. Close OA Dampers During Morning Warmup: Have completed on sample units; works well. Will complete on remaining units during commissioning.	Open		
	2. Provide Morning Warm-Up Optimal Start: Trane has default program included which can be enabled. Automatrix doesn't have default program. Considering using Trane's program for those units and creating a custom program for the Automatrix units which starts the units up earlier and puts them in standby once they have reached setpoint to spread out the load on the boiler plant. Sequence has been created by Delta and will be submitted to GBA for review.	Open		
	3. Control AHU Preheat Coil to Unocc MAT Setpoints: Have completed on sample units; works well. Will complete on remaining units during commissioning.	Open		
	4. Close VAV Box Reheats when AHU is Off: Willing to attempt.	Open		
	5. Close OAD on Gym AHU-1, 2 when AHUs are Off: Completed and also performed on AHU-26.	Closed		
	6. Lockout AHU CC Control Valves During Morning Warmup: Have completed on sample units; works well. Will complete on remaining units during commissioning.	Open		
	7. Reset AHU Mixed Air and Discharge Air Setpoints: Have completed on sample units; works well. Will complete on remaining units during commissioning.	Open		
	8. Reset VAV AHU Static Pressure Setpoints: Willing to attempt.	Open		
	9 - A: Reduce Filter Pump Hours of Operation: Problems would occur with surge tank overflowing and chlorine sensor startup time. Not feasible.	Closed		
	9 - B: Reduce Filter Pump Speed During Unoccupied Hours: Willing to consider, could be part of Phase 3.	Open		
	10. Swimming Pool Cover: Not much heat is put into pool by heat exchanger, most of the heat is coming from the air. Might be more relevant if unoccupied room temperature setpoint was employed. May be more appropriate for spa.	Open		
	11. Trim Pump Impellers: Would be more interested in using VFDs instead of trimming impellers due to flexibility. 11A may not be necessary because modifications are being considered to chiller plant. Would like to investigate further.	Open		
	12. Add Occupancy Sensors for VAV Control: Lighting occupancy sensors are currently being installed that could be utilized for VAV control in the future. Incentives should be available for both the lighting and VAV control.	Open		
	13. Greenhouse AHU-37 - Reconfigure System to Include Return Air: Willing to consider in future.	Open		
	14. Provide Control Valves for Unit Heaters: Issue is also present on most of the steam unit heaters. Longer payback may make the modification hard to justify.	Open		
	15. High Efficiency Equipment Replace: FIM is a general consideration during future improvements.	Closed		
	16. Submetering: Delta is interested in submetering. Submetering has a variety of benefits including simplifying the investigation of any changes in utility usage, real time trending which allows for quicker responses to problems, and additional accountability for the individual areas within the campus. Submetering could be included as part of Phase 3.	Open		
	Other: Would like to consider vending machine occupancy control, a $50 incentive is available per machine. Would like to investigate demand control exhaust for the kitchen hoods (Melink). Would like to investigate demand control ventilation and CO2 control.	Open		
	Next Meeting: Not yet scheduled			

EXHIBIT 15

BCA BEST PRACTICES IN COMMISSIONING EXISTING BUILDINGS

Best Practices in Commissioning Existing Buildings
Building Commissioning Association

EXECUTIVE SUMMARY

The Building Commissioning Association (BCA) defines Existing Building Commissioning (EBCx) as: ***"…a systematic process for investigating, analyzing, and optimizing the performance of building systems through the identification and implementation of low/no cost and capital intensive Facility Improvement Measures and ensuring their continued performance. The goal of EBCx is to make building systems perform interactively to meet the Current Facility Requirements and provide the tools to support the continuous improvement of system performance over time. The term EBCx is intended to be a comprehensive term defining a process that encompasses the more narrowly focused process variations such as retro-commissioning, re-commissioning and ongoing commissioning that are commonly used in the industry."***

The BCA is committed to defining what the Best Practices are in the "Existing Building Commissioning Industry" through the provision of a document that details practical solutions, facilitates the implementation of EBCx Best Practices improvements over time and assists in the standardization of the commissioning industry. The term ***Best Practice*** generally refers to the best possible way of doing something, taking the most successful elements from many different sources and combining them to create the ultimate process or approach. This document looks in detail at these issues and helps understand and discuss why they are Best Practices for continuous quality improvement across the commissioning industry. In order to meet our commitment to be the leading authority and clearinghouse for the commissioning industry, the BCA is implementing an evaluation strategy to ensure appropriate and effective evaluation of all commissioning standards and guidelines at all levels. Recognizing that each project might require a different approach depending on the circumstances, the BCA emphasizes that the list of Best Practices should not be understood as mandates. Subsequent to finalizing this document, the Public and members of the BCA Board and Chapters have been asked to comment and make suggestions. The "Best Practices", therefore, is presented by BCA as a document that presents a positive contribution to the Existing Building Commissioning Industry as a whole.

This document defines the qualities and characteristics of best commissioning practices in order to promote those practices in the market. The definition of Best Practices creates a benchmark against which the market can gauge quality and professionalism, and which the BCA can use to objectively evaluate other commissioning initiatives, including our own. These Best Practices criteria will allow the BCA to compare/contrast commissioning processes, guidelines, training curriculum, certifications, etc. BCA best practices criteria were developed from sources such as the California Commissioning Collaborative guide for Existing Buildings, the Building Commissioning Hand Book by the Building Commissioning Association, NEBB National Environmental Balancing Bureau (NEBB) retro-commissioning process, Associated Air Balance Council Commissioning Group (ACG) Commissioning Guidelines, ASHRAE Guideline 0-2005, input from ASHRAE GPC 1.2, and SMACNA, among others. This report also draws extensively upon years of real world experience of the sub committee from managing a wide array of EBCx projects.

The BCA is comprised of Principal Members who are owners, engineers, architects, contractors, providers and users of commissioning services in their day-to-day operations. The members represent a broad cross-section of interests and are associated with many sectors of the facilities and construction community.

The BCA Best Practices process is intended to communicate initiatives that are innovative, sound, and represent generally accepted standards. The processes and practices identified in this document are referred to as Best Practices. These Best Practices have been proven through experience and implementation and as a process would be beneficial for others involved in the EBCx process to use. Best Practices are a cornerstone of effective and efficient operation.

For best results the EBCx investigation process includes the Owner's maintenance and operations personnel, the Owner's occupant representative(s) (building manager, school principal, department head, etc.), the building automation system (BAS) maintenance contractor, and other contracted service personnel (if any), and the Commissioning Authority.

As the commissioning industry continues to mature and the professionals in this segment of the industry continue to gain experience and innovate, the list of Best Practices set forth here will very likely be refined and improved. These Best Practices are intended to promote quality, consistency, efficiency and flexibility in the EBCx industry.

Accordingly, suggestions from other related industry and commissioning organizations are invited.

The Best Practices Task Force acknowledges the thoughtful and essential contributions made by the members of BCA in providing invaluable input and comment on the various drafts as we worked to complete this document since spring 2006.

1. SCOPE OF COMMISSIONING ACTIVITY	
1.1 Definition and Purpose of Existing Building Commissioning	
1.1.1	Existing Building Commissioning is a systematic process for investigating, analyzing, and optimizing the performance of building systems through the identification and implementation of low/no cost and capital intensive Facility Improvement Measures (FIMs) and ensuring their continued performance. The Existing Building Commissioning process assists in making the building systems perform interactively to meet the Current Facility Requirements (CFR) and provides the tools to support the continuous improvement of system performance over time. The term Existing Building Commissioning is intended to be a comprehensive term and process that encompasses the more narrowly focused process variations such as retro-commissioning, re-commissioning and ongoing commissioning that are commonly used in the industry.
1.1.2	The majority of existing buildings have not undergone any type of commissioning or quality assurance process. Additionally, over time the facility requirements change and the operational efficiencies of buildings tend to degrade. Because of these factors many buildings are performing well below their potential, use more energy than necessary and cost more to operate than they should. EBCx responds to an Owner's desire to improve building performance, solve comfort and operational problems and reduce operating costs. The purpose of existing building commissioning is as follows: - Verify that a facility and its systems meet the CFR - Improve building performance by saving energy and reducing operational costs - Identify and resolve building system operation, control and maintenance problems - Reduce or eliminate occupant complaints and increase tenant satisfaction - Improve indoor environmental comfort and quality and reduce associated liability - Document system operation - Identify the Operations & Maintenance (O&M) personnel training needs and provide such training - Minimize operational risk and increase asset value - Extend equipment life-cycle - Ensure the persistence of improvements over the building's life - Assist in achieving LEED for Existing Buildings http://www.usgbc.org/LEED - Improve the building's ENERGY STAR rating http://www.energystar.gov/

1.1.3	EBCx promotes operations and maintenance and building performance excellence, but requires the involvement of all stakeholders, including senior management, engineering, O&M personnel, contractors, vendors and facility users/occupants. The commissioning process is not a one time event, but rather an ongoing activity that continues throughout the life-cycle of a facility. This document identifies distinct and sequential phases to the EBCx process; however, it is important to recognize that the commissioning process is an iterative process that may repeat or loop back to previously completed phases over time. The basic phases and the goals of each phase of the EBCx process are as follows: - <u>Planning Phase</u>: Development of the EBCx goals, facility requirements, and a commissioning plan. - <u>Investigation Phase</u>: Field inspections, data gathering, testing and analysis to accurately assess system performance and identify improvement opportunities. - <u>Implementation Phase</u>: The desired facility improvements are completed and the results and performance are verified. - <u>Turnover Phase</u>: The systematic transition from a commissioning activity and the Commissioning Team to standard operating practice and the O&M team. - <u>Persistence Phase</u>: Implementation of systems and tools to support both the persistence of benefits and continuous performance improvement over time.
1.2 Commissioning Authority (CxA)	
1.2.1	The Commissioning Authority (CxA) is the entity that leads, plans, schedules and coordinates the commissioning process and makes recommendations to the Owner regarding Facility Improvement Measures and assists in verifying their continued performance over time.
1.2.2	The CxA is an objective, independent advocate of the Owner who leads, plans, and coordinates the Commissioning Team and commissioning process. Ideally, the CxA will be independent of the O&M team, without specific operational responsibilities, maintenance tasks or project responsibilities. The use of a 3rd party “outsider” can be beneficial in that a fresh perspective is brought to the commissioning process that can challenge traditional O&M practices, infuse new enthusiasm, technical expertise and human resources into the process which will ultimately enhance the benefits achieved by the process. The CxA can be an independent consultant or a qualified employee of the Owner.
1.2.3	If the CxA is an independent consultant and the CxA’s firm is responsible for operational/maintenance duties, has other project responsibilities or is not under direct contract to the Owner, a conflict of interest may exist. Wherever this occurs, the CxA shall disclose, in writing, the nature of the conflict and the means by which the conflict shall be managed.

1.2.4	In addition to having good written and verbal communication skills, the CxA has current engineering knowledge and extensive recent hands-on field experience regarding: building systems commissioning, the physical principles of building systems performance, building systems start-up, balancing and adjusting, testing, troubleshooting, operations, maintenance procedures, building design and construction process.
1.3 Systems Included in Commissioning Process	
1.3.1	EBCx is a “whole-building” or “total building” process in which building systems and their interactions are tested and verified to suit current requirements. This integrated approach maximizes positive results and helps to ensure that the building is operated safely, efficiently, and meets the CFR. Although limiting the commissioning scope to focus on a single system (i.e. HVAC systems) or singular objective/goal (i.e. save energy) is a practice in the industry, this narrowing of scope is not likely to produce a building that operates best overall.
1.3.2	The following are several common building systems that could be included in the EBCx Plan (as applicable). However, this list is not all encompassing and each facility should be evaluated to determine what other specialized systems or system integrations should be included. - HVAC&R Systems - Building Assembly (Envelope, Interior, Paths of Egress, etc.) - Conveying Systems (Elevators and Escalators) - Protective Systems (Fire Suppression, Lightning Protection, etc.) - Plumbing Systems (Water Distribution, Sanitary/Storm Water, etc.) - Electrical Systems (Power Distribution, Lighting, etc.) - Communication Systems (Telecom, Sound, Video, etc.) - Alarm Systems (Fault Detection, Security, Leak Detection, etc.)

2. PLANNING PHASE	
The objectives of the Planning Phase are to develop/confirm the Owner's needs and requirements for the facility and document through the development of a CFR document and to develop an EBCx Plan to define the commissioning process for the facility. If a 3rd party consultant will be utilized as the CxA for the project, the Contract with the consultant would be prepared and executed based upon the Owner's CFR and the required scope of services.	
2.1	Define Roles and Responsibilities - The roles and responsibilities of all EBCx participants and the EBCx Plan should be defined during this phase. Clear documentation of the CFR, which defines the Owner's operational needs and requirements, should be completed prior to concluding this phase of the process.
2.2	Define Scope of Work, Schedule and CFR - If a 3rd party consultant is utilized as the CxA, a clearly defined scope of work, schedule and CFR need to be understood, documented and agreed upon as part of the agreement and EBCx Provider's contract. The roles of all the commissioning participants should be defined in the agreement. Based upon the size of the specific facility(s) and the scope of services the duration of the Cx contract may vary from just a few weeks to several years.
2.3	Define EBCx Goals – Clear goals and objectives for the commissioning process should be developed to focus the team and to provide guidance in the planning effort which culminates with the EBCx Plan.
2.4	Define the CFR - The process should start with a review of, and if required, an update to the CFR which defines the current operational needs and requirements of the building. For buildings that undertook the new building commissioning process the CFR is the evolution of the Owner's Project Requirements (OPR) established during the original commissioning process. The EBCx Plan shall adequately address the CFR in sufficient detail to allow for the documentation of and verification that those requirements are being met. If the building has had its usage changed from the original design, or if a current CFR does not exist, the Owner, with assistance from the Commissioning Authority, should develop a detailed CFR. Items such as temperature, humidity, operating hours, filtration, sound, vibration, and/or specialty needs must be discussed and agreed upon in the CFR. The CFR should note any integrated requirements such as controls, Fire & Life Safety, Personnel Training, Warranty review, Service Contract review, Security Systems, etc.
2.5	Preliminary Building Benchmarking - Perform preliminary building benchmarking of readily available data to quantitatively measure overall building performance. This preliminary benchmarking can help uncover potential opportunities and can be used as a baseline to measure future performance improvements during the commissioning process.
2.6	Review Existing Building Documentation - Review existing building documentation, such as building plans and specifications, O&M Manuals, maintenance documentation records, etc. This review helps to increase an understanding of the building, but the primary focus is to determine the availability of documentation for the EBCx Investigation process.
2.7	Interview Key O&M Personnel - Interview key O&M personnel to learn from their extensive knowledge and experiences from working in the building on a daily basis.
2.8	Perform a Cursory Walk-Through - Perform a cursory walk-through of all major spaces to gain an understanding of the types of spaces, condition of spaces, occupancy levels, lighting and controls and prevalence of information technology related infrastructure and equipment.

2.9	Develop EBCx Plan - Develop an EBCx Plan that documents goals, roles, responsibilities, the EBCx process, communication protocols, major activities and tasks and the overall EBCx project schedule. It is important that the Plan give thoughtful consideration to the level of involvement of all Stakeholders and how communication with key Owner constituencies will be handled to ensure consensus and success. The Plan is a working document that evolves throughout the commissioning process.
2.10	Develop a Customized Building Operation Plan - Develop a customized Building Operation Plan which identifies specific building, system/equipment level and zoning level operational strategies, set points and schedules which will support the operational needs and the CFR.

3. INVESTIGATION PHASE	
The objective of the Investigation Phase is to conduct the site investigation to compare the actual building conditions and system performance with the Owner's current operational needs and requirements defined by the CFR. This phase concludes with the completion and review of a Master List of Findings that identifies Facility Improvement Measures (FIMs) that upon implementation will improve building and system performance to meet the CFR, reduce energy and O&M costs and/or improve the indoor environmental quality.	
3.1	Commissioning Coordination – During the Investigation Phase (and throughout the entire commissioning process) the Commissioning Team should meet periodically to discuss Commissioning status, system performance, and issues identified. Stakeholder participation in these status meetings is critical to solicit additional input and build consensus, as well as to help address any simple repairs or adjustments that need to be made during this phase.
3.2	Documentation Review - Review building drawings and documentation to understand the building energy usage, initial basis of design and evaluate the system integration. The review process includes the evaluation of all old and new drawings, specifications, Test and Balance Reports, Operations & Maintenance Manuals (typically related to mechanical, electrical and controls), and any past Commissioning Reports.
3.3	Site Review/Survey - Conduct a thorough and detailed building walk through (maintenance staff participation is highly desirable) to evaluate the issues identified in the Planning Phase and observed during the drawing and documentation review. Important facility information not found during the Documentation Review may need to be recreated during the site survey (i.e. TAB analysis to determine current air/water flows, or if sequences of operation are unavailable, perform functional performance testing to determine how systems operate). During this step additional issues which are not captured through the Documentation Review should be noted.
3.4	Building Occupant Interviews – Interview the Owner's maintenance personnel, utility personnel, occupants, and other relevant parties to understand the current needs and issues related to system operations and maintenance. A formal interview process is recommended to systematically assist in understanding potential issues and problems, uncover potential improvement opportunities, confirm the CFR and to develop consensus on the commissioning process goals.
3.5	Facility Performance Analysis and Performance Baseline Establishment – Collect and analyze available energy, non-energy and other system performance data to establish baseline benchmarks for facility performance. Available facility performance baseline data may include utility billing data, sub-metering data, work orders, comfort complaint logs, indoor air quality parameters, occupant satisfaction survey results, BAS trend data and/or stand alone data logger data.
3.6	Systems Diagnostic Monitoring – Develop a diagnostic monitoring plan and then perform comprehensive system diagnostic monitoring. Diagnostic monitoring methods can include BAS trending, portable data logger trending, and energy and weather data collection. The collected data is analyzed to identify issues and improvement opportunities and highlight particular problems that may require more rigorous and focused investigation. Analyzing the diagnostic monitoring data can assist in determining if the system is meeting the CFR.

3.7	Test Development - Develop Test Procedures for the systems identified in the project scope. Test plans typically focus on confirming that the system performance is meeting the performance requirements of the Owner set forth in the CFR.
3.8	System Testing - Perform system testing to evaluate the building systems performance. In addition, any anomalies or issues identified in earlier Investigation Phase steps should be considered for further evaluation during system testing to determine root causes and possible solutions. It is recommended that the testing process include the verification and calibration of critical sensors. Typically, critical sensors are those sensors which are essential to the effective and efficient operation of the building systems.
3.9	If appropriate and agreed upon by the Commissioning Team, perform simple repairs or improvements identified during the Investigation Phase monitoring and testing. The EBCx process is intended to be an iterative and flexible process, therefore, some implementation may occur during the Investigation Phase and conversely further investigation may occur during the Implementation Phase.
3.10	Master List of Findings - Create a Master List of Findings that identifies possible FIMs based on the findings from the steps above. The following information on each FIM is desirable so that the Owner has sufficient information to make an informed decision when selecting the FIMs for implementation: 1) Description of Finding, 2) The Solution/ Measure Description; 3) Benefits; 4) Drawbacks/Risks; 5) Implementation Cost; 6) Savings (details on the estimated electrical, fossil and demand energy savings may be desired); 7) Payback and Return on Investment (ROI) analysis; and 8) Commissioning Team recommendation for implementation. Frequently, only rough budgetary implementation cost estimates are included in the Master List during the Investigation Phase with firm contractor quotes being obtained during the Implementation Phase, once specific measures have been selected for implementation. The rigor of the energy saving calculation methodology utilized to estimate energy savings can vary significantly. Factors that impact calculation methodology rigor may include utility program requirements if applicable, owner expectations, and the level of investment required for measure implementation.
3.11	Performance Assurance **-** Evaluate methods of measuring system performance and verifying proper implementation to demonstrate the success of the FIMs implemented. Each measure should have a verification methodology appropriate to the size and complexity of the measure. The identified verification methodology is then incorporated into a Measurement and Verification (M&V) Plan. The M&V plan is intended to provide a comprehensive protocol to verify the performance of the measure/system and confirm that the predicted energy savings have been achieved upon the completion of implementation. Ongoing BAS trending, portable data loggers, spot measurements, and functional testing may be utilized pre and/or post implementation as part of the M&V process.

4. IMPLEMENTATION PHASE	
The intent of the Implementation Phase is to implement the Facility Improvement Measures (FIMs) that are selected from the Master List of Findings and to verify that the predicted results and system performance are achieved.	
4.1	Analyze, Prioritize and Select Facility Improvement Measures - The Implementation Phase begins with the analysis, prioritization and selection of FIMs for implementation. The Owner, with any necessary support from the Commissioning Team, evaluates and prioritizes the measures that have been recommended for implementation by the Commissioning Team. The final selection of measures for implementation and implementation timing is frequently influenced by many factors, including ROI and simple payback, budgetary constraints, anticipated facility impacts, future capital plans, available implementation resources, etc.
4.2	Prepare an Implementation Plan - Upon measure selection, the Commissioning Team prepares an Implementation Plan to guide the implementation process and provide details on steps to be followed to complete the implementation of the selected Facility Improvement Measures. This plan typically indicates which improvements will be made during the Implementation Phase and which ones will be deferred with a timetable for planned implementation as capital improvement projects, with the ultimate goal of having the systems perform efficiently to meet the CFR.
4.3	Implement Selected FIMs – As defined by the Implementation Plan, the selected improvements to the systems and operations are undertaken and completed.
4.4	Verify Successful FIM Implementation – Testing or re-testing is performed on modified or upgraded systems to demonstrate that the improvements are successful. Plans are also made for the future testing of the deferred capital improvement projects identified. If testing does not show that the improvements were successful, further modifications or refinements to the upgrades should be made to achieve acceptable results.
4.5	Execute the Measurement and Verification (M&V) plan – Implement the M&V Plan developed during the Investigation Phase to evaluate project success and final energy savings as a result of the project.
4.6	Plan for Ongoing Commissioning – Plans are made to continue elements of the commissioning verification process on an ongoing basis to help the improvements to persist over time. Certain steps may be repeated at regular intervals to facilitate this.

5.	TURNOVER PHASE
The intent of the Turnover Phase is to ensure a smooth hand off and transition from the commissioning process/team to the personnel responsible for operating and maintaining the building over its life-cycle (the O&M personnel). Successful transitions ensure that all necessary documentation, knowledge and systems are provided to the O&M personnel, that the O&M personnel demonstrate the effective use of these tools, and that the implemented improvements become a part of the standard operating practice so that the CFR is met and the positive results persist into the future.	
5.1	Update O&M Manuals and As- Built Documentation - Update O&M manuals and as- built documentation as required. If the Owner has acceptable, up-to-date O&M manuals, then O&M manuals only need to be modified to include any changes to equipment or operations that were made as part of the EBCx project. If existing manuals are not adequate to support effective O&M of the existing equipment, the Owner should consider including a task in the EBCx scope to improve them.
5.2	Develop Final Report & Update Documentation - The final report is a record of the EBCx activities and measures that were implemented for the Owner and will become an important document for the building and an invaluable resource to current and future building operators.
5.3	Compile or Update a Systems Manual - Compile or update a Systems Manual as required by the CFR. A systems manual is a compilation of important building documentation such as the CFR, systems description, a narrative description of the Sequence of Operation and the Final report. The system manual will greatly enhance the building personnel's ability to operate the building effectively. The systems manual should include the following information: - Index - Construction record documents, specifications, submittals - A list of recommended operational record keeping procedures - Ongoing optimization guidance - EBCx report - CFR - Basis of design - O & M manuals - Training materials
5.4	Establish a Plan for Operational Sustainability, Ongoing Commissioning and Continuous Improvement - A plan for operational sustainability and ongoing commissioning is developed during this process to ensure the persistence of results and continuous improvement, and is a key deliverable of the Turnover Phase. The plan will provide the building personnel with detailed instructions, systems and tools for strategic operational, monitoring and maintenance tasks that help maintain the commissioning process performance benefits and support continuous improvement. The plan may include recommendations and instructions related to: establishment and monitoring of energy and non-energy facility performance benchmarks, energy tracking, preventive and/or predictive maintenance, BAS trending, training, and procedures for updating CFR and other documentation.

5.5	Develop Training Plan - Develop Training Plan, provide training and plan for future training. The Owner's building operating personnel should be part of the Commissioning Team and be involved in all phases of the EBCx process to understand the findings, changes and improvements stemming from the commissioning process. Training should be pervasive throughout the commissioning process. The Turnover Phase provides an excellent opportunity to provide focused training on the EBCx process, the associated FIMs implemented, system optimization techniques and strategies for persistence and continuous improvement. Establish a Training Plan for future training based upon the current training needs, estimated future needs (including "refresher" training), and training for continuous improvement of skills.
5.6	Hold a Lessons Learned Meeting - Hold a Lessons Learned Meeting with the Owner's building operating personnel and other Commissioning Team members. This can help the operating personnel in maintaining the performance benefits for EBCx and can increase their knowledge, expanding their ability to identify and address improvement measures in the buildings in which they work.

6.	PERSISTENCE PHASE
The intent of the Persistence Phase is to ensure that all the Facility Improvement Measures continue to perform properly over their life cycle and that systems and tools are provided and employed to facilitate the continuous improvement of facility performance to meet the Current Facility Requirements.	
6.1	Implement the Plan for Operational Sustainability and Ongoing Commissioning - Implement the plan for operational sustainability and ongoing commissioning developed as a result of the commissioning process to support the goal of continuously improving facility performance.
6.2	Benchmark the Building Energy Use - Continue to benchmark the building energy use to compare to other similar buildings and to the original building prior to implementing the EBCx process. This is a way for Owners to assess how their building is performing compared to peer buildings. Establish annual benchmark score improvement goals and consider recognition/rewards for goal achievement to encourage continuous improvement efforts. ENERGY STAR Portfolio Manager is a frequently used and nationally recognized building energy benchmarking tool among others. https://www.energystar.gov/istar/pmpam/
6.3	Monitor and Track Energy Use - Track energy use to monitor changes on an ongoing basis. Utility tracking records a building's energy use over time and helps the operating personnel understand the building's consumption patterns. Track energy consumption and cost regularly by analyzing utility bills and consider implementing a "real time" energy tracking system. Increasingly User Interface Dashboards are being employed so that the operating personnel can observe on a "real time" basis key energy and operational parameters and continuously compare to previous day, previous month and previous year figures. Establish specific energy type (i.e. electricity, natural gas, etc.) and system level performance targets to help improve energy performance on a continuous basis.
6.4	Monitor and Track Non-Energy Building Performance Metrics - Monitor and track non-energy building performance metrics such as comfort calls, occupant satisfaction, indoor air quality parameters, etc. to assess building performance and compare to benchmarks established prior to and during the commissioning process.
6.5	Trend Key System Parameters - Trend key system parameters to detect problems early and assess system performance. Trend logging through the BAS is important for observing the performance of systems under various modes and operating conditions over time. Trending is also an important tool to ensure that the implemented facility improvement measures continue to perform properly.
6.6	Document Changes with an Operator's Log - Utilize an operator's log to keep a record of significant events such as equipment replacement, maintenance or testing, and problems and their resolution. If possible, the log should be kept electronically to allow for easy searching. CMMS (Computerized Maintenance Management System) software is commercially available to aid in this documentation and can be used as an asset maintenance scheduling and record system.

6.7	Implement Persistence Strategies with The BAS - Utilize the existing BAS software and graphical user interface to facilitate operator awareness and persistence of FIMs. Set up triggers to check for any variance within the FIMs. Ensure that any variance from the original intent of the FIMs is immediately recorded and incorporated into the O&M and work order generation procedures of the facility.
6.8	Consider Automated Fault Detection & Diagnostic (AFDD) Tools - Consider automated commissioning and continuous diagnostic tools that are integrated with the BAS to automatically detect faults and alert operators when faults are identified in sensors, valves, dampers and energy efficiency sequences.
6.9	Implement Personnel Training Plan - Implement personnel Training Plan and update Training Plan as required.
6.10	Implement the Commissioning Process Again (Re-Commission) - Implement the commissioning process again (Re-Commission) on a periodic basis. Conduct the re-commissioning either on a regular schedule (3 to 5 years is a frequently cited time frame), or if building performance degrades, or if the building occupancy or usage changes significantly.

ACKNOWLEDGEMENTS AND RESOURCES

1. "ACG Commissioning Guideline" by the Associated Air Balance Council Commissioning Group (ACG)
2. ASHRAE Guideline 0-2005 "The Commissioning Process" by the American Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc.
3. The Building Commissioning Hand Book by the Building Commissioning Association
4. "California Commissioning Guide: Existing Buildings" by the California Commissioning Collaborative (CA Cx)
5. "LEED-EB for Existing Buildings" Version 2.0 and "LEED for Existing Buildings: Operations & Maintenance" by the United States Green Building Council
6. NEBB National Environmental Balancing Bureau (NEBB) guide
7. SMACNA- Sheet Metal and Air Conditioning Contractors National Association, Inc.
8. "Strategies for Improving Persistence of Commissioning Benefits" by Hannah Friedman, Amanda Potter, and Tudi Haasl of Portland Energy Conservation, Inc. David Claridge, Texas A&M Energy Systems Laboratory

Existing Building Commissioning Definitions

1. **Automated Fault Detection & Diagnostic (AFDD) Tool:**

   Automated Fault Detection & Diagnostic Tools are programs that are integrated with the BAS to automatically detect faults or abnormalities in operation of systems and alert operators when these faults occur in sensors, valves, dampers and energy efficiency sequences.

2. **Benchmarking:**

   Benchmarking is the process of comparing a building's energy usage to other similar buildings and to the building itself prior to the retro-commissioning process. Developing standards and goals for energy management is a good way to motivate people to improve towards the goal of optimal energy performance. ENERGY STAR Portfolio Manager is a frequently used and nationally recognized building energy benchmarking tool, among others.

3. **Building Operation Plan:**

   A Building Operation Plan identifies specific building, system/equipment level and zoning level operational strategic set points and schedules which will support operational needs and the Current Facility Requirements (CFR).

4. **Commissioning Team[1]**

   The individuals who through coordinated actions are responsible for implementing the Commissioning Process.

5. **Computerized Maintenance Management System (CMMS):**

   An electronic version of an operator's log which keeps a record of significant events such as equipment replacement, maintenance, testing and problems along with their resolutions. Commercially available CMMS software is easily searchable and can be used as an asset maintenance scheduling and record system.

6. **Continuous Commissioning[SM]**

   A process variation of EBCx that the Texas A&M System Energy Systems Lab has developed. The Continuous Commissioning[SM] Process focuses on optimizing HVAC system operation and control for existing buildings through monitoring and engineering analysis of mechanical systems and occupant needs.

7. **Current Facility Requirements (CFR):**

Defines the Owner's current operational needs and requirements for a building. It typically includes items addressing temperature and humidity set points, operating hours, filtration, vibration, sound and/or specialty needs. The CFR should note any integrated requirements such as controls, fire and life safety, warranty review, service contract review and security systems.

8. **Dashboard, User Interface:**

User Interface Dashboards are "real time" systems that measure and display building performance metrics such as overall building comfort, energy use, operational and maintenance parameters to enable stakeholders to improve operational efficiency. After operational efficiency targets have been established for a building, the dashboard facilitates the process of monitoring ongoing performance against the previous day, month or year's metrics.

9. **Existing Building Commissioning (EBCx)**

EBCx is a systematic process for investigating, analyzing, and optimizing the performance of building systems through the identification and implementation of low/no cost and capital intensive Facility Improvement Measures and ensuring their continued performance. The EBCx process assists in making the building systems perform interactively to meet the CFR and provides the tools to support the continuous improvement of system performance over time.

10. **Existing Building Commissioning Plan (EBCx Plan)**

A document that outlines the organization, responsibilities, schedule, allocation of resources and documentation requirements of the EBCx process.

11. **Facility Improvement Measure (FIM):**

Alterations or revisions to systems or equipment planned to improve building and system performance, reduce Operations and Maintenance (O&M) costs and/or improve the indoor environmental quality as part of an EBCx process.

12. **Implementation Plan:**

A written document that details the prioritization and selection of FIMs for completion during the Implementation Phase.

13. **Lessons Learned Meeting:**

A meeting held during the Turnover Phase to discuss what went right and what went wrong during the EBCx process. Attendees include the Owner's building operating personnel and members of the Commissioning Team.

14. **Master List of Findings:**

The Master List of Findings is a document assembled at the end of the investigation phase of a retro-commissioning project. It serves as a preliminary budgeting tool and identifies possible Facility Improvement Measures (FIMs) to be included in the implementation phase to follow.

15. **Measurement and Verification (M&V) Plan:**

Measurement and Verification (M&V) Plan uses ongoing BAS trending, portable data loggers, spot measurements, and functional testing to measure the efficacy of each FIM and verify its proper implementation. It is intended to verify the performance of the measure/system and confirm that the predicted energy savings have been achieved upon the completion of implementation.

16. **Monitoring Based Commissioning:**

A process variation of EBCx, Monitoring Based Commissioning employs remote energy system metering with trend log capability to identify inefficiencies in energy system operations, facilitate diagnostics, document energy savings, and ensure persistence of savings through ongoing re-commissioning.

17. **Ongoing Commissioning:**

The application of commissioning related process activities on an ongoing or continuous basis to ensure that the CFR are being met and to support the continuous improvement of system performance. The Ongoing Commissioning Plan details how these activities and goals will be achieved.

18. **Operations and Maintenance (O&M) Manual:**

O&M manuals describe key components of each system or piece of equipment and explain how they should be operated and maintained for optimum performance.

19. Owner's Project Requirements (OPR):[1]

A written document that details the functional requirements of a project and the expectations of how it will function. These include project goals, measurable performance criteria, cost considerations, benchmarks, success criteria, and supporting information.

20. Re-Commissioning:

The periodic re-implementation of the commissioning process, either on a regularly occurring schedule (every 3 to 5 years is typical), or if building performance degrades, or if the building occupancy or usage changes significantly.

21. Retro-Commissioning(RCx):

The application of the commissioning process to an existing building that has not previously undergone the commissioning process. The primary focus of the RCx process for utility public benefit funded RCx projects is to reduce energy consumption and/or electrical demand.

22. Return on Investment (ROI):

The ratio of the money gained or lost on an investment relative to the cost of the investment. To calculate ROI, the benefit (return) of an investment is divided by the cost of the investment; the result is expressed as a percentage or a ratio.

ROI = (Gain from Investment - Cost of Investment) / Cost of Investment

23. Stakeholder, Commissioning Process

People or organizations that have a direct or indirect interest or stake in the commissioning process. Typical commissioning process stakeholders include: operations and maintenance personnel, facility users/occupants, senior management, maintenance or service contractors and related vendors.

24. Systems Manual: [1]

A system-focused composite document that includes the operation manual, maintenance manual, and additional information of use to the Owner during the Occupancy and Operations Phase.

25. Test Procedure: [1]

A written protocol that defines methods, personnel, and expectations for tests conducted on components, equipment, assemblies, systems, and interfaces among systems.

26. Training Plan: [1]

A written document that details the expectations, schedule, budget, and deliverables of Commissioning Process activities related to training of project operating and maintenance personnel, users, and occupants.

27. Turnover Phase

The phase of Retro-Commissioning where all necessary documentation and training are provided to the O&M personnel to ensure that they understand how to use the commissioning tools and make sure that positive results persist far into the future.

1. Definition from ASHRAE Guideline 0-2005, American Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc.,1791 Tullie Circle NE, Atlanta, GA 30329