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Building Audit
OSU Dixon Recreation Center
Corvallis, OR

Presented by Glumac

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Final – Incorporation of Energy Trust of Oregon review

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Disclaimer

The results of the energy analysis presented in this report shall not be construed to have absolute, predictive accuracy, representing the actual energy use of the building or its individual systems. All reasonable efforts have been taken to ensure the accuracy of the energy model inputs, including verifying that actual details correspond to the building as it is currently designed. The primary benefit of energy modeling is for comparison of alternative design options to determine their relative energy savings potential.

There are a number of factors that will cause the actual energy use of the building to diverge from the projected energy use of the model. Among these are: differences in building design relative to the building modeled; abnormal weather conditions; variations in schedules for equipment, systems, and occupancy; inconsistencies in the application of controls and operations strategies compared to those used in the model; the level of direct loads; and changes in connected loads and electricity and gas rates. In addition, the model results do not necessarily take into account all the energy uses of a facility or building site that would show up as loads on the utility meters.

Nevertheless, refinements of the energy model to reconcile all these differences, when these adjustments are made by a capable energy engineer, can yield model results that are more consistent with actual energy use.

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1. Executive Summary

1.1 INTENT

Summarized in this report are the results of the ASHRAE Level II Energy Audit performed for the Dixon Recreation Center, located on Oregon State University's campus in Corvallis, OR.

1.1 BUILDING OVERVIEW

This project includes a wide range of recreation spaces including a natatorium, gymnasiums, indoor climbing gym, racket ball courts, basketball courts, indoor running tracks, locker rooms, congregation/meeting space, and office/support spaces totaling approximately 150,000 square feet (sf). The building was initially constructed in the mid-1970s and has significant expansions in the early 1990s and 2000s making it what can be seen today. Future expansion is likely as the university grows. Mechanically, heating for the building is provided by the university's campus steam loop and limited cooling is provided by a local air-cooled chiller. A majority of the systems within Dixon Rec are built-up systems in the building are heating/ventilating only with economizer and heat recovery functionality. The building envelope is high mass brick providing a significant amount of thermal storage and temperature stability. Building controls are predominantly DDC and consistent with an installation from the early 2000s with some remaining pneumatic system and field devices from the 1990 expansion.

1.2 CURRENT PERFORMANCE

The following table is based on the average utility use of calendar years 2012, 2013, 2014.

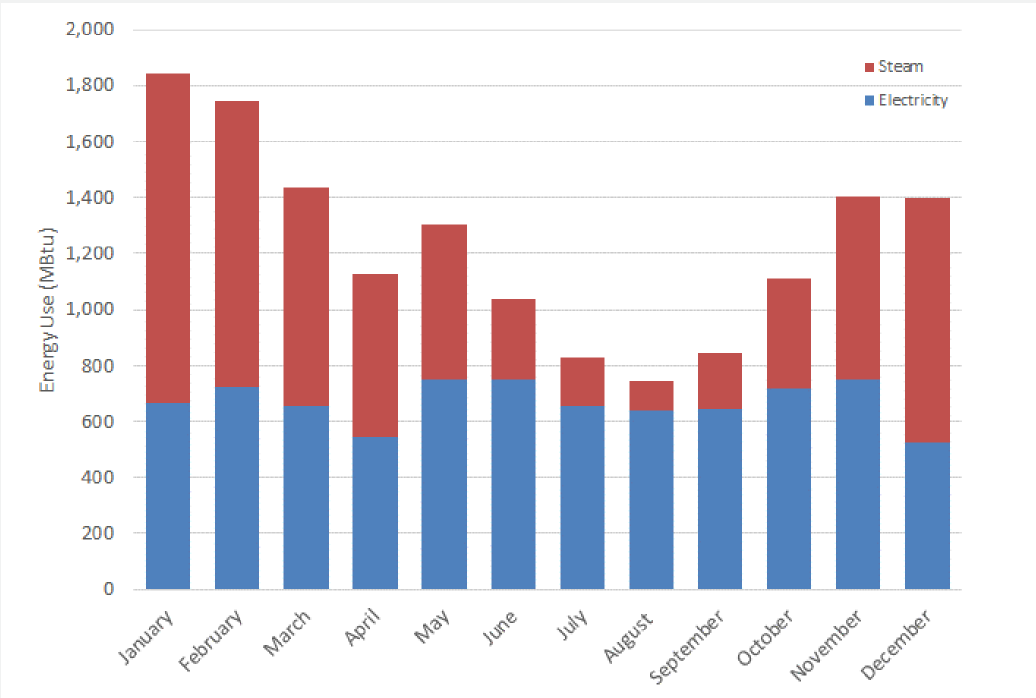

Table 1 – Energy Use Summary

The Dixon Recreation Center Energy Use Intensity (EUI) is 102.5 kbtu/sf-yr.

1.3 IMPROVEMENT OPPORTUNITIES AND RECOMMENDATIONS

Based on the findings of this report documented on the following pages, upgrading the building management system and tuning the controls for each system within the building, installation of air movement/ceiling fans, and upgrading lower and upper gym lighting systems has the greatest potential to cost effectively improve building performance and is Glumac's primary recommendation (Delivery Option 2). Together, these measures could save up to $56,180/year in operating costs with payback on investment within 6 years.

Annual Operating Cost	Building Area (sf)	Annual Electricity Usage (kWh)	Annual Steam Usage (lbs)	Annual Natural Gas Usage (Therms)	Annual Base EUI kBtu per sf	Annual CO_2 Emissions Tons
$307,845	150,000	2,344,249	5,929,067	3,000	102.5	2,143

EEM #		End Use Category	Electricity Savings (kWh/yr)	Steam Savings (lbs/yr)	Savings Beyond Energy ($/yr)	Operating Cost Savings ($/yr)	Operating Cost Savings (%)	Incremental First Cost	Potential Incentives	Simple Payback (yrs)
Preliminary Energy Conservation Measures for Consideration										
1	Building Management System Upgrade & Tuneup	HVAC	95,307	1,062,267	$10,400	$38,929	12.6%	$232,200	$38,700	5.0
2	Insulate steam and hot water piping in SF 2&3 fan room	Steam	0	93,233	$0	$1,818	0.6%	$12,791	$0	7.0
3	Variable Speed Control of HWP P2A & P2B, disable bypass on associated 3-way valves.	Pumps	9,600	0	$0	$787	0.3%	$14,000	$0	17.8
4	Replace/upgrade washing machines with high performance low water use units.	DHW	0	33,600	$0	$655	0.2%	$9,500	$0	14.5
5	Utilize ceiling fans and other air circulation devices throughout the building where possible	HVAC	55,968	212,453	$0	$8,732	2.8%	$78,000	$22,762	6.3
6	Air cooled chiller replacement	HVAC	18,236	0	$0	$1,495	0.5%	$168,000	$0	112.4
7	Upgrade lighting to LED technology for Upper and Lower Gyms including daylight control	Lighting	101,920	-84,981	$0	$6,700	2.2%	$68,600	$25,480	6.4
8	Remove lighting unnecessary from EM power, and implement daylight control and improved occupancy control to areas associated with the 2004 addition.	Lighting	46,143	-63,736	$7,800	$10,341	3.4%	$75,000	$11,536	6.1
9	Replace/Upgrade pool ventilation system	HVAC	41,575	467,397	$0	$12,523	4.1%	$160,000	$2,344	12.6
10	Optimize pumping power in pool filtration system	DHW	39,420	0	$0	$3,232	1.1%	$35,000	$0	10.8
11	Install Pool Blankets for unoccupied hours	DHW	0	380,520	-$3,650	$3,770	1.2%	$25,000	$3,242	5.8
12	Renewables - Solar Hot Water	Renewables	0	1,353,383	$0	$26,391	8.6%	$822,000	$246,600	21.8
13	Renewables - Photovoltaics	Renewables	221,651	0	$0	$18,175	5.9%	$818,000	$500,000	17.5

Table 2 – Energy Efficiency Metric

Note – Incentive values denoted in red have been reviewed and confirmed by the Energy Trust of Oregon's (ETO) existing building program under project number ETECPS1531433119. The remaining incentive opportunities listed above will need to be confirmed by the ETO Existing Building Programs lighting group should the owner wish to proceed with these measures. Glumac has used their experience with the program to estimate the value of these incentives for planning purposes.

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2. Project Delivery Recommendations

	EEM 1 Building Management System Upgrade & Tuneup	EEM 2 Insulate steam and hot water piping in SF 2&3 fan room	EEM 5 Utilize ceiling fans and other air circulation devices throughout the building where possible	EEM 7 Upgrade lighting to LED technology for Upper and Lower Gyms including daylight control	EEM 8 Remove lighting unnecessary from EM power, and implement daylight control and improved occupancy control to areas associated with the 2004 addition.	EEM 10 Optimize pumping power in pool filtration system	EEM 11 Install Pool Blankets for unoccupied hours	EEM 12 Renewables - Solar Hot Water	EEM 13 Renewables - Photovoltaics	Estimated Project Cost	Estimated Project Cost (Less Incentives)	Estimated Energy Savings	Simple Payback (yrs)
Soft + Hard Costs	$232,200	$12,791	$78,000	$68,600	$75,000	$35,000	$25,000	$822,000	$818,000				
Incentives Available	$38,700	$0	$22,762	$25,480	$11,536	$0	$3,242	$246,600	$500,000				
Adjusted Measure Cost	$193,500	$12,791	$55,238	$43,120	$63,464	$35,000	$21,758	$575,400	$318,000				
Energy Savings	$38,929	$1,818	$8,732	$6,700	$10,341	$3,232	$3,770	$26,391	$18,175				
Option - 1	X	X		X						$313,591	$249,411	$47,448	5.3
Option - 2 (Recommended)	X	X	X	X						$391,591	$304,649	$56,180	5.4
Option - 3	X	X	X	X	X	X	X			$526,591	$424,871	$73,523	5.8
Option - 4	X	X	X	X	X	X	X	X	X	$2,166,591	$1,318,271	$118,090	11.2

Table 3. Project Delivery Recommendations

Option 2 is our recommendation as it presents a manageable project size offering strong returns on investment. Option 3, pending review with natatorium management staff warrants consideration also.

3. Student Sustainability Coordination

This section of the report has been provided based on discussions with Student Sustainability coordinator Sean Walsh to provide useful metrics for performance that can be communicated with the student body beyond utility based operating costs information.

3.1 SAVINGS BEYOND ENERGY

The table below, documents the proposed energy efficiency measures using equivalencies based on carbon emissions. These equivalencies have been sourced from the Environmental Protection Agency (EPA).

	Annual Operating Cost	Annual Base EUI	Annual CO_2 Emissions	Electricity Rate ($/kWh)	Gas Rate ($/lb)	Electricity CO_2 (Tons/MWh)	Steam CO_2 (Tons/ 1000lbs)
		kBtu per sf	Tons				
	$307,845	102.5	2,143	$0.082	$0.0195	0.6851	0.09055

EEM #		Operating Cost Savings ($/yr)	Operating Cost Savings (%)	Site EUI Reduction		Additional Annual CO_2 Reduction		Emmissions Equivalencies			
				kBtu/sf-yr	% Reduction	Tons	% Reduction	Cars off the Road	Homes	Acres of Forrest	Railcars of Coal
Preliminary Energy Conservation Measures for Consideration											
1	Building Management System Upgrade & Tuneup	$38,929	12.6%	10.6	10.4%	161.48	7.5%	34.0	14.7	132.4	0.87
2	Insulate steam and hot water piping in SF 2&3 fan room	$1,818	0.6%	0.7	0.7%	8.44	0.4%	1.8	0.8	6.9	0.05
3	Variable Speed Control of HWP P2A & P2B, disable bypass on associated 3-way valves.	$787	0.3%	0.2	0.2%	6.58	0.3%	1.4	0.6	5.4	0.04
4	Replace/upgrade washing machines with high performance low water use units.	$655	0.2%	0.3	0.3%	3.04	0.1%	0.6	0.3	2.5	0.02
5	Utilize ceiling fans and other air circulation devices throughout the building where possible	$8,732	2.8%	3.0	2.9%	57.58	2.7%	12.1	5.2	47.2	0.31
6	Air cooled chiller replacement	$1,495	0.5%	0.4	0.4%	12.49	0.6%	2.6	1.1	10.2	0.07
7	Upgrade lighting to LED technology for Upper and Lower Gyms including daylight control	$6,700	2.2%	1.6	1.6%	62.13	2.9%	13.1	5.7	50.9	0.33
8	Remove lighting unnecessary from EM power, and implement daylight control and improved occupancy control to areas associated with the 2004 addition.	$10,341	3.4%	0.5	0.5%	25.84	1.2%	5.4	2.4	21.2	0.14
9	Replace/Upgrade pool ventilation system	$12,523	4.1%	4.7	4.6%	70.81	3.3%	14.9	6.5	58.0	0.38
10	Optimize pumping power in pool filtration system	$3,232	1.1%	0.9	0.9%	27.01	1.3%	5.7	2.5	22.1	0.14
11	Install Pool Blankets for unoccupied hours	$3,770	1.2%	3.0	3.0%	34.46	1.6%	7.3	3.1	28.2	0.18
12	Renewables - Solar Hot Water	$26,391	8.6%	10.8	10.5%	122.55	5.7%	25.8	11.2	100.4	0.66
13	Renewables - Photovoltaics	$18,175	5.9%	5.0	4.9%	151.86	7.1%	32.0	13.8	124.5	0.81

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4. Energy Use Analysis

4.1 ENERGY BENCHMARK DATA

Based on a review of the utility information Dixon Recreation Center has an EUI of 102.5 kBtu/sf. As the building includes a mix of uses including a Natatorium, where a majority of the energy is being used, there are limited buildings that energy use can be compared to. Using the building energy model, industry benchmarks, installed equipment and operational observations, the following energy end use breakdown has been developed. The building energy model has been calibrated to reflect this breakdown as a basis of comparison. Note that the project team believes that steam usage during summer and shoulder months is being underestimated, and has been adjusted accordingly from the utility information. This is discussed in detail in section 3.4 Steam Use Consumption.

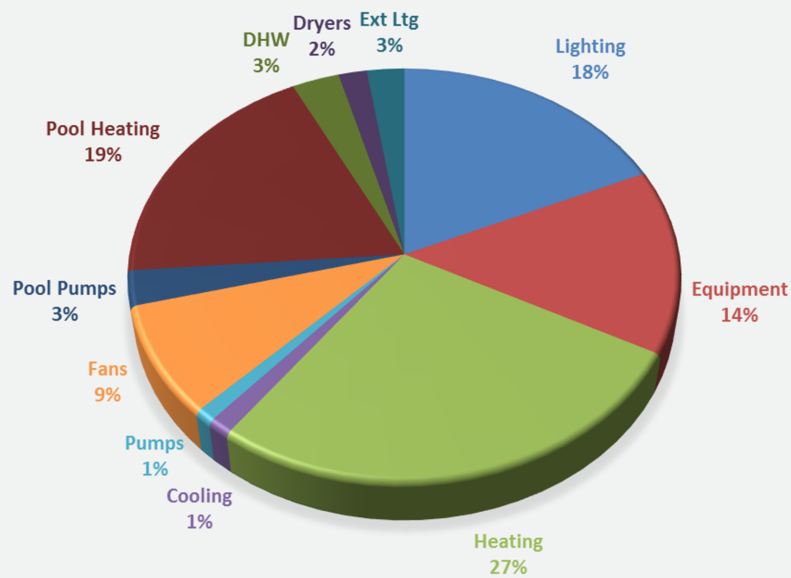

Figure 1. Building Energy End-Use Breakdown

4.2 ELECTRICTY CONSUMPTION

The following graph shows the electricity use for the prior three years. The electricity use for this building appears to follow a very consistent trend with only one significant anomaly that occurred June 2013. Based on utility bill information provided by OSU, the average annual electricity use for 2012, 2013, and 2014 is 2,344,249 kWh.

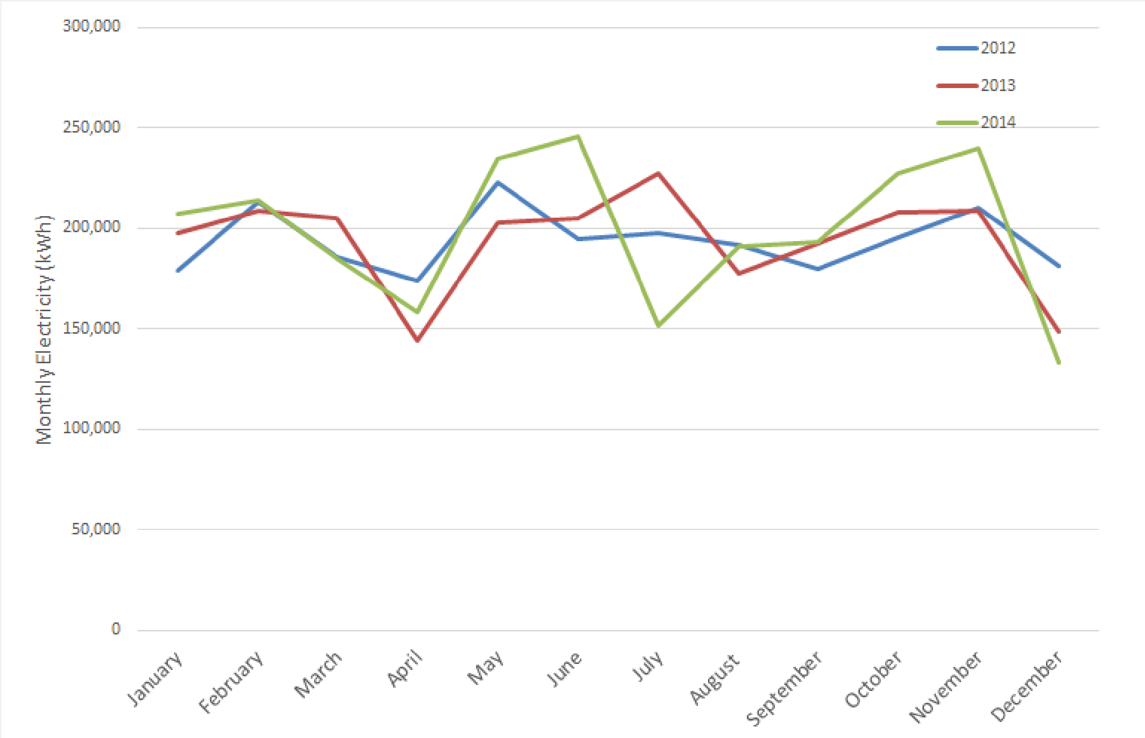

Figure 2 – Electricity Consumption Graph

4.3 NATURAL GAS CONSUMPTION

The only equipment using onsite natural gas are the dryers located in the laundry. According to facilities staff, the laundry performs approximately 6,000 loads annually and based on utility bills consistently uses approximately 3,000 therms per year.

The utility rate charged for natural gas is estimated to be $1.00/Therm. Current annual average cost for natural gas is estimated to be $3,000 annually.

4.4 STEAM CONSUMPTION

The following graph shows the steam use for the prior three years. The steam use for this building appears to follow a consistent trend driven largely by outside air temperature. Based on utility bill information provided by OSU, the average annual steam use for 2012, 2013, and 2014 is 5,929,067 lbs. For comparison with similar facilities, this is equivalent to approximately 68,006 Therms. Steam is generated by the campus co-generation plant with the steam generation as a secondary product from the source energy input (natural gas).

The project team believes that there could be issues surrounding the steam meters accuracy, especially around summer and shoulder season months with lower steam usage. The two key reasons for steam meters not measuring energy use correctly are;

1. Proximity to bends in piping being too close to the meter
2. The meter being oversized – Most meters are capable of turndown rates of 20:1 (5%), once a meter reaches minimum flow the steam medium transitions from turbulent to laminar and at that time the meter no longer is capable of reading steam usage accurately.

Taking into account most steam meters are oversized by as much as 50% to 100% and the meter is not in an ideal location, this realistically means that when heating falls below 15%-20% of peak winter heating demand readings could be questionable.

In order to account for this, the project team used theoretical methods to establish a more likely steam usage scenario during summer and shoulder months. This adjustment resulted in an estimated 650,000lbs of steam usage that is not currently being metered or billed for (valued at approximately $13,000/year)

The utility rate charged by the campus for steam is $0.0195/lb (equivalent rate of $1.70/Therm). Current annual average cost for steam is $115,617.

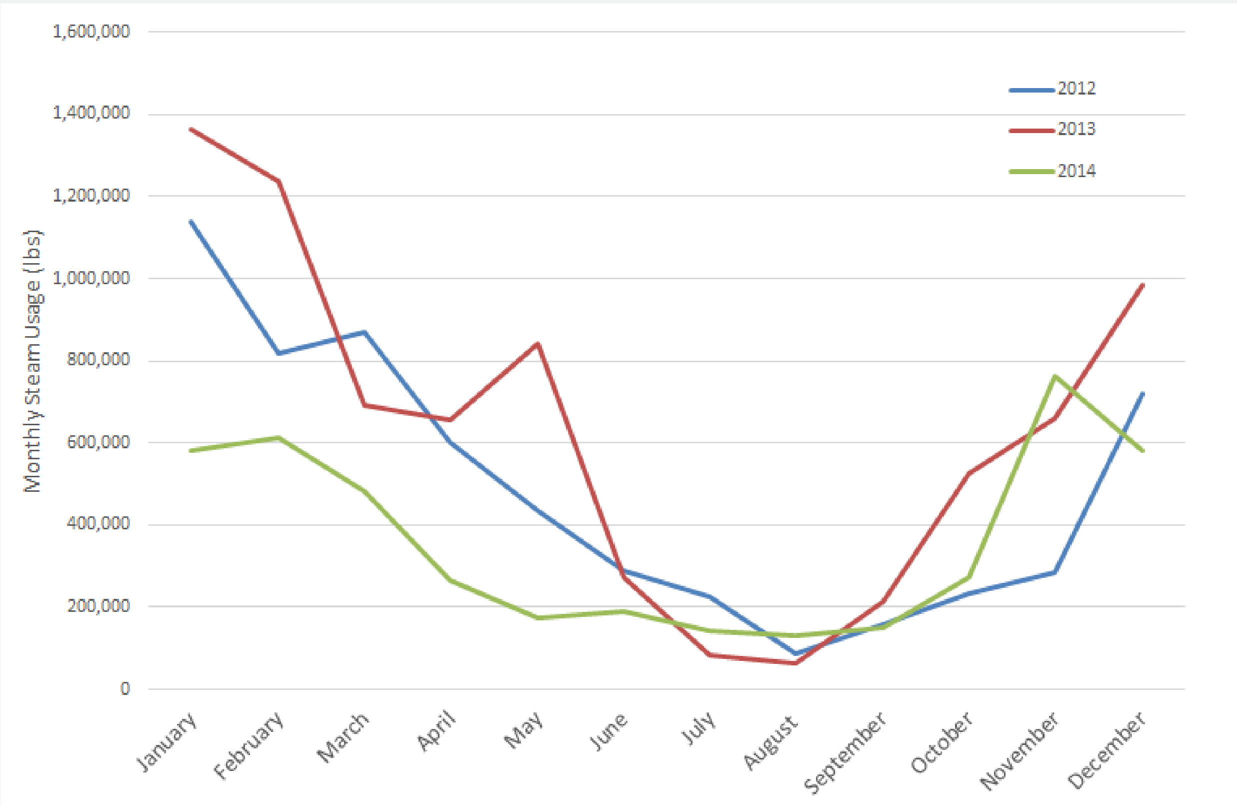

Figure 3 – Steam Consumption Graph

4.5 ENERGY USE

Based on utility bills the following energy use graph below has been generated.

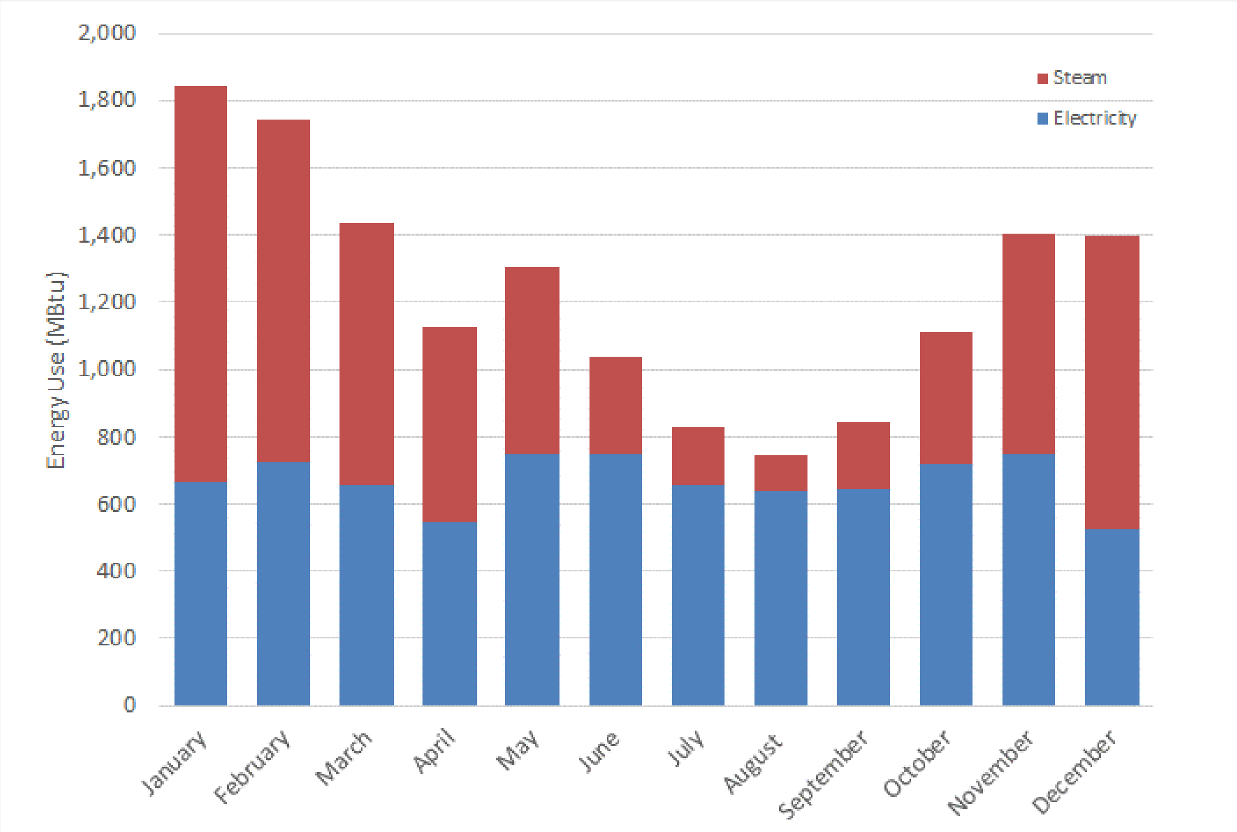

Figure 4 – Monthly Energy Use

4.6 ENERGY COST

Based on utility bills the following energy use graph has been generated. A summary of these costs follows this summary.

The utility rate charged by the campus for electricity is $0.053/kWh. It is anticipated that a market rate correction is expected shortly currently estimated at $0.082/kWh. Current annual average cost for electricity is $127,040 and based on the projected increased rate, similar electricity consumption could cost as much as $196,553.59, a 54% increase in operating costs..

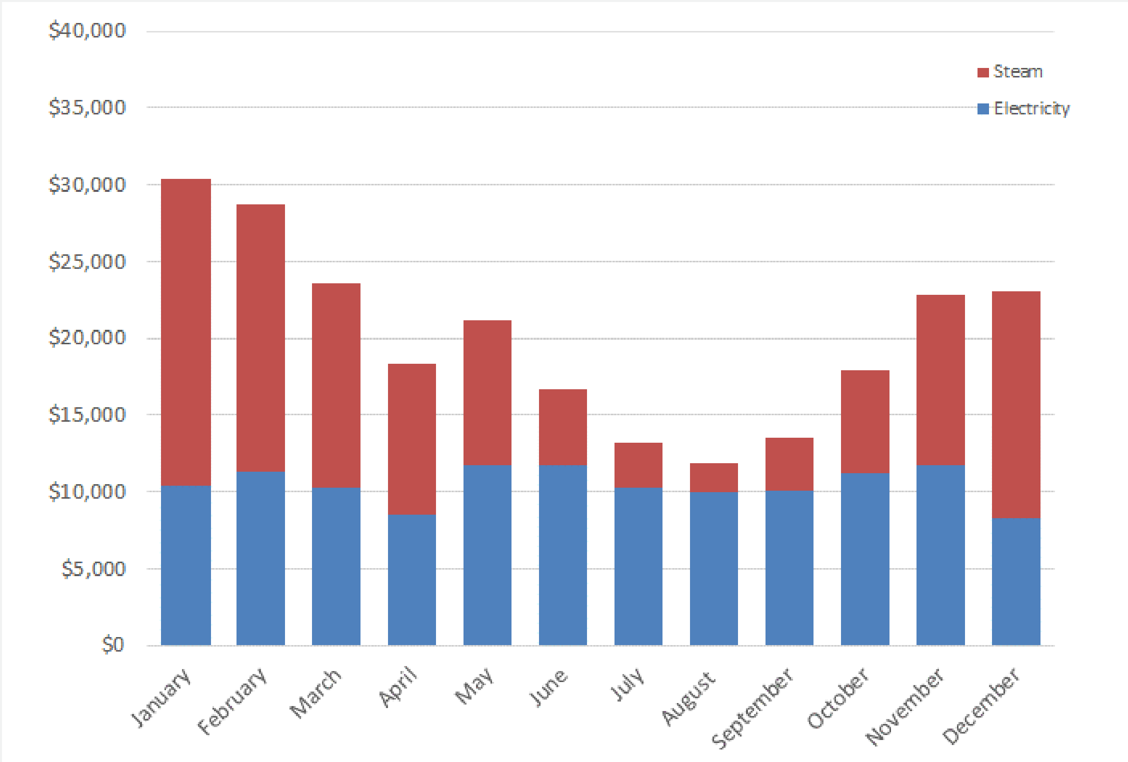

Figure 5 – Energy Cost Based on Today's Utility Rates

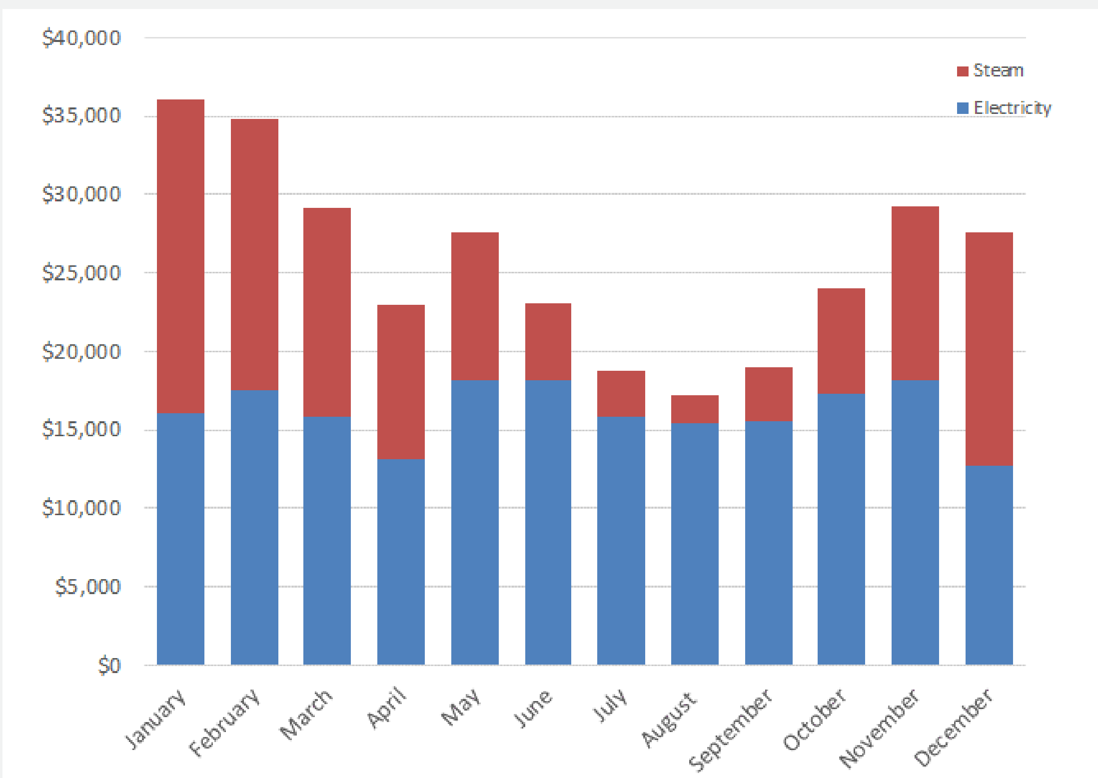

Figure 6 – Energy Cost Based on Future Utility Rates (Elec increase)

5. Energy Efficiency Measures (EEM's)

5.1 EEM 1: BUILDING MANAGEMENT SYSTEM UPGRADE & TUNEUP

5.1.1 EXISTING CONDITION

The building controls system last received a significant upgrade during the 2004 building additions. There are elements of legacy controls at the device level from the early 1970s and 1980 facility updates however all control is achieved through a common front end. Based on interviews with building operations staff, building walkthroughs, and review of the Building Management System (BMS) front end as outlined in Appendix B, the controls system is not providing an adequate level of feedback or controllability to the operator. Currently, a significant amount of time is spent by building operations staff troubleshooting the system day-to-day, manually resetting controllers and VFDs, and due to sensor calibration issues and devices not working correctly. This is resulting in significant energy is being lost through operation. The controllers for the Johnsons Control system are also obsolete making future maintenance potentially problematic (NC-5/6). The building currently does not utilize demand control ventilation, though there are CO_2 sensors installed to achieve this mode of operation in several areas.

5.1.2 PROPOSED MEASURE

Work for this measure includes;

1. Review Sequence of Operations and update based on modern control philosophy and opportunities.
2. Replace legacy device controls and sensors on AHUs 2, 4, & 5.
3. Replace device controls and sensors that have failed on remaining AHUs.
4. Replace pneumatic devices with DDC devices (primarily pool equipment).
5. Replace obsolete building controllers.
6. Replace unreliable, or uncontrolled Variable Speed Drives.
7. Upgrade building front end and building controls, Extent of work to include but not limited to;
    a. Update sequences of operation for building equipment.
    b. Update graphics to better reflect building equipment, operation, set points, and allow for user control and trending.
    c. Validation/Calibration of building sensor locations and outputs.
    d. Validation/Calibration of building control damper positions and actuation.
    e. Validation/Calibration of building terminal units
    f. Implementation of demand control ventilation (may require installation of new airflow measurement equipment and CO_2 sensors).
8. Retro-commissioning of updated systems.

5.1.3 OPINION OF COST

Note that costs are intended for initial measure assessment and do not include costs associated with OSU project management and delivery.

Opinion of Cost			
	Contractor	Consultant	Total
Item 1	$0	$9,000	$9,000
Items 2, 3, 4, 5, & 6	$91,000	$0	$91,000
Item 7	$45,000	$0	$45,000
Item 8	$10,000	$48,000	$58,000
Totals	$146,000	$57,000	$203,000
Total + 20% Contingency	**$175,200**	**$57,000**	**$232,200**

Table 4. EEM 1 Opinion of Cost

5.1.4 MEASURE PERFORMANCE

This measure is anticipated to save energy and time for operating staff. Based on calculations performed in the building energy model and estimates for staff time anticipated measure performance is as follows.

Measure Performance	
Modeled Annual Energy Cost Savings	$28,529
Facility Staff O&M* Annual Savings	$10,400
Opinion of Cost	$232,200
Estimated incentives	$23,827
Simple Payback (yrs)	5.4

Table 5. EEM 1 Measure Performance

5.2 EEM 2: INSULATE STEAM AND HOT WATER PIPING IN SF 2&3 FAN ROOM

5.2.1 EXISTING CONDITION

There is a significant amount of steam and hot water piping in the SF-2&3 fan room that is currently not insulated. During building walkthrough the room is very hot, which could be detrimental to electrical equipment in adjacent space and the performance of fan systems SF-2&3 since the room acts as a return air path. This waste heat is also being collected by the fans and distributed into the building as well as unnecessarily heating up the local thermal mass and radiating it into the floors above.

UPDATE – this measure was implemented prior to completion of this report and has been included for information purposes only.

5.2.2 PROPOSED MEASURE

Work for this measure includes;

1. Insulate exposed steam and hot water pipe work.

5.2.3 OPINION OF COST

Note that costs are intended for initial measure assessment and do not include costs associated with OSU project management and delivery.

Opinion of Cost			
	Contractor	Consultant	Total
Item 1	$12,971	$0	$12,971
Total	**$12,971**	**$0**	**$12,971**

Table 6. EEM 2 Opinion of Cost

5.2.4 MEASURE PERFORMANCE

This measure is anticipated to save energy and improve building comfort by reducing heat lost from exposed pipe work. Based on calculations performed anticipated measure performance is as follows.

Measure Performance	
Annual Energy Cost Savings	$1,818
Opinion of Cost	$12,971
Estimated incentives	$0
Simple Payback (yrs)	7.0

Table 7. EEM 2 Measure Performance

5.3 EEM 3: VARIABLE SPEED CONTROL OF HWP P2A & P2B, DISABLE BYPASS ON ASSOCIATED 3-WAY VALVES

5.3.1 EXISTING CONDITION

The building currently has constant speed pumping systems for hot and chilled water systems.

5.3.2 PROPOSED MEASURE

Work for this measure includes;

1. Install variable speed drives on hot water and chilled water systems and implement variable flow by disabling 3-way recirculation sections of these systems.

5.3.3 OPINION OF COST

Note that costs are intended for initial measure assessment and do not include costs associated with OSU project management and delivery.

Opinion of Cost			
	Contractor	Consultant	Total
Item 1	$14,000	$0	$14,000
Total	**$14,000**	**$0**	**$14,000**

Table 8. EEM 3 Opinion of Cost

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5.3.4 MEASURE PERFORMANCE

This measure is anticipated to reduce pumping energy. Based on calculations performed in the building energy model anticipated measure performance is as follows.

Measure Performance	
Annual Energy Cost Savings	$787
Opinion of Cost	$14,000
Estimated incentives	$0
Simple Payback (yrs)	17.8

Table 9. EEM 3 Measure Performance

5.4 EEM 4: REPLACE/UPGRADE WASHING MACHINES WITH HIGH PERFORMANCE LOW WATER USE UNITS

5.4.1 EXISTING CONDITION

The building currently has a system in place that reduces water use through cleaning methods and equipment tuning. Of the estimated

5.4.2 PROPOSED MEASURE

Work for this measure includes;

1. Replace existing washing machines with high performance low water use machines.

5.4.3 OPINION OF COST

Note that costs are intended for initial measure assessment and do not include costs associated with OSU project management and delivery.

Opinion of Cost			
	Contractor	Consultant	Total
Item 1	$9,500	$0	$9,500
Total	**$9,500**	**$0**	**$9,500**

Table 10. EEM 4 Opinion of Cost

5.4.4 MEASURE PERFORMANCE

This measure is anticipated to save energy through reduced domestic hot water requirements.

Measure Performance	
Annual Energy Cost Savings	$655
Opinion of Cost	$9,500
Estimated incentives	$0
Simple Payback (yrs)	14.5

Table 11. EEM 4 Measure Performance

5.4.5 BEHAVIOURAL OPPORTUNITIES

Working with facilities and the students, practices that involve reducing the amount of laundry generated will likely result in significant savings beyond replacement of equipment for newer. Based on preliminary calculations, a 25% reduction in the amount of laundry would result in approximately 750 Therms saved ($750 value) and a 38,800lbs steam saved ($755 value).

5.5 EEM 5: UTILIZE CEILING FANS AND OTHER AIR CIRCULATION DEVICES THROUGHOUT THE BUILDING, WHERE POSSIBLE

5.5.1 EXISTING CONDITION

Currently Dixon Recreation Center has installed ceiling fans in a workout room and it provides additional airflow to people working out for improved comfort. The Upper and Lower gyms experience a significant temperature difference between floors due to thermal stratification.

5.5.2 PROPOSED MEASURE

Work for this measure includes;

1. Install large blowers/ceiling fans in the Upper and Lower gyms.
2. Install fans in weights, multipurpose, and workout areas.
3. Install fans in Natatorium.

5.5.3 OPINION OF COST

Note that costs are intended for initial measure assessment and do not include costs associated with OSU project management and delivery.

Opinion of Cost			
	Contractor	Consultant	Total
Item 1	$18,000	$0	$18,000
Item 2	$15,000	$0	$15,000
Item 3	$20,000	$25,000	$45,000
Total	**$53,000**	**$25,000**	**$78,000**

Table 12. EEM 5 Opinion of Cost

5.5.4 MEASURE PERFORMANCE

The intent of this measure is twofold. In the high volume upper and lower gyms it is possible that warm air is stratifying high in the space and not making it to the occupied zone during colder months. The intent would be to use large fans/blowers to circulate this air into the occupied zone and improve the space's heating performance. Secondly, for the Upper and Lower gym and weights/multipurpose/workout areas proving ceiling fans/blowers is anticipated to allow occupants to achieve comfort at elevated temperatures based on the additional air circulation these systems will provide resulting in cooling and HVAC fan energy savings. Finally, by installing fans in the Natatorium it will be possible to achieve required pool surface air velocity without relying on the central air handling system. Consulting costs for a detailed study associated with this final measure has been included to ensure the system is designed appropriately.

Measure Performance	
Annual Energy Cost Savings	$8,732
Opinion of Cost	$78,000
Estimated incentives	$13,992
Simple Payback (yrs)	7.3

Table 13. EEM 5 Measure Performance

5.6 EEM 6: AIR COOLED CHILLER REPLACEMENT

5.6.1 EXISTING CONDITION

The currently utilizes a 140 Ton (approx.) chiller to provide cooling capacity to portions of the building. Please note that cooling is not provided to all areas of the building. Installed in 2004, this chiller likely has 5 to 10 years of service life remaining.

5.6.2 PROPOSED MEASURE

Work for this measure includes;

1. Replace chiller with high efficiency air-cooled chiller.

5.6.3 OPINION OF COST

Note that costs are intended for initial measure assessment and do not include costs associated with OSU project management and delivery.

Opinion of Cost			
	Contractor	Consultant	Total
Item 1	$168,000	$0	$168,000
Total	**$168,000**	**$0**	**$168,000**

Table 14. EEM 6 Opinion of Cost

5.6.4 MEASURE PERFORMANCE

This measure is anticipated to save cooling energy. Recently, air cooled chillers have incorporated high performance digital control compressors making replacement feasible for some applications.

Measure Performance	
Annual Energy Cost Savings	$1,495
Opinion of Cost	$168,000
Estimated incentives	$0
Simple Payback (yrs)	112.4

Table 15. EEM 6 Measure Performance

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5.6.5 FUTURE COOLING NEEDS FOR CONSIDERATION

There are several spaces within Dixon Recreation center where facilities would like to add cooling to improve occupant comfort. This includes the locker rooms and equipment issue. This load has been estimated at approximately 25-35 tons and would increase project cost by $100,000 to $150,000. It may also warrant consideration of a water-to-water heat pump that could be used for additional cooling and provide heating for the natatorium pools.

5.7 EEM 7: UPGRADE LIGHTING TO LED TECHNOLOGY FOR UPPER AND LOWER GYMS INCLUDING DAYLIGHT CONTROL

5.7.1 EXISTING CONDITION

The building currently had florescent lamps in the lower and upper gym areas with an installed power of approximately 30.5kW (98 x 310W/fixture). These lights are on for a majority of occupied hours.

5.7.2 PROPOSED MEASURE

Work for this measure includes;

1. Replace existing fixtures with LED fixture with an operating wattage of approximately 150W/fixture.
2. Installation to include the ability for daylight dimming control.

5.7.3 OPINION OF COST

Note that costs are intended for initial measure assessment and do not include costs associated with OSU project management and delivery.

Opinion of Cost			
	Contractor	Consultant	Total
Item 1	$49,000	$9,600	$58,600
Items 2	$10,000	$0	$10,000
Total	**$59,000**	**$9,600**	**$68,600**

Table 16. EEM 7 Opinion of Cost

5.7.4 MEASURE PERFORMANCE

This measure is anticipated to reduce lighting power requirements and save energy. Note that there is a small increase in the space heating requriment due to the high effieciency lighting which emits less heat energy andhas been accounted for in the results below.

Measure Performance	
Annual Energy Cost Savings	$38,929
Opinion of Cost	$68,600
Estimated incentives	$25,480
Simple Payback (yrs)	6.4

Table 17. EEM 7 Measure Performance

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5.8 EEM 8: REMOVE LIGHTING UNNECESSARY FROM EM POWER, AND IMPLEMENT DAYLIGHT CONTROL AND IMPROVED OCCUPANCY CONTROL TO AREAS ASSOCIATED WITH THE 2004 ADDITION.

5.8.1 EXISTING CONDITION

The lighting installation for 2004 is relatively high performance achieving an overall lighting power density in the 0.9 to 1.0 W/SF. Current control includes occupancy sensors in some areas. There is approximately 45,000 SF of improvements associated with this measure.

5.8.2 PROPOSED MEASURE

Work for this measure includes;

1. Installation of daylight controls and improved occupancy sensor controls through the scoped area.
2. Moving several lighting fixtures from emergency power to a circuit capable of turning off during unoccupied hours

5.8.3 OPINION OF COST

Note that costs are intended for initial measure assessment and do not include costs associated with OSU project management and delivery.

Opinion of Cost			
	Contractor	Consultant	Total
Item 1	$52,000	$11,000	$63,000
Items 2	$12,000	$0	$12,000
Total	**$64,000**	**$11,000**	**$75,000**

Table 18. EEM 8 Opinion of Cost

5.8.4 MEASURE PERFORMANCE

This measure is anticipated to save energy and time for operating staff. Facilities is currently spending up to 8 hours per week replacing lamps and ballasts in these areas. This is somewhat due to lighting systems approaching end of life based on time of installation. It is anticipated that this task will have a continued 3 hour per week effort associated with it. Based on calculations performed in the building energy model and estimates for staff time anticipated measure performance is as follows.

Measure Performance	
Annual Energy Cost Savings	$2,541
Facility Staff O&M* Annual Savings	$7,800
Opinion of Cost	$75,000
Estimated incentives	$11,536
Simple Payback (yrs)	6.1
* Based on 4 hours a week trouble shooting & $50/hr	

Table 19. EEM 8 Measure Performance

GLUMAC

5.9 EEM 9: REPLACE/UPGRADE POOL VENTILATION SYSTEM

5.9.1 EXISTING CONDITION

The building natatorium is currently served by the original air handling system, note that the system has had controls upgrades recently, however, is limited in its ability to reduce energy further as it does not utilize total energy wheels and relies on outdoor air to maintain relative humidity levels which adversely requires additional heating.

5.9.2 PROPOSED MEASURE

Work for this measure includes;

1. Rebuild existing natatorium air handing unit internals to reflect modern unit operation and controls. Replacing heat recovery section and allowing and enabling 100% air to move over the heat recovery coil.

5.9.3 OPINION OF COST

Note that costs are intended for initial measure assessment and do not include costs associated with OSU project management and delivery.

Opinion of Cost			
	Contractor	Consultant	Total
Item 1	$150,000	$10,000	$160,000
Total	**$150,000**	**$10,000**	**$160,000**

Table 20. EEM 9 Opinion of Cost

5.9.4 MEASURE PERFORMANCE

This measure is anticipated to save fan energy and heating energy for the natatorium HVAC unit. Though the simple payback is demonstrating a period longer then 10 years we believe working with the Energy Trust of Oregon and defining an alternative baseline comparison it would be possible to have this measure incentivized.

Measure Performance	
Annual Energy Cost Savings	$12,523
Opinion of Cost	$160,000
Estimated incentives	$10,394
Simple Payback (yrs)	11.9

Table 21. EEM 9 Measure Performance

5.9.5 UNIT REPLACEMENT OPTION

An alternate replacement unit for the natatorium was investigated to compare against the upgrade option described above. The location of the existing unit makes access for replacement challenging; the recommended approach would be to place the unit on the natatorium roof or adjacent structures pending structural verification. The unit could then leverage existing ductwork distribution for supply, and the return plenum box could be ducted to roof level to complete the system. The replacement option was based on Innovent's LASER series units, and based on the existing unit operating comfortably at 75% flow a 30,000CFM was selected.

This alternative is anticipated to save fan energy and heating energy for the natatorium HVAC unit.

Measure Performance	
Annual Energy Cost Savings	$15,028
Opinion of Cost	$450,000
Estimated incentives	$0
Simple Payback (yrs)	29.9

Table 22. EEM 9 Replacement Unit Alternate Measure Performance

5.10 EEM 10: OPTIMIZE PUMPING POWER IN POOL FILTRATION SYSTEM

5.10.1 EXISTING CONDITION

Estimated pumping energy for the proposed building has been calculated to be approximately 15kW operational.

5.10.2 PROPOSED MEASURE

Work for this measure includes;

1. Look at potential to update pump operation to set back during unoccupied hours and filtration options that would reduce pressure drop.

5.10.3 OPINION OF COST

Note that costs are intended for initial measure assessment and do not include costs associated with OSU project management and delivery.

Opinion of Cost			
	Contractor	Consultant	Total
Item 1	$35,000	$0	$35,000
Total	**$35,000**	**$0**	**$35,000**

Table 23. EEM 10 Opinion of Cost

5.10.4 MEASURE PERFORMANCE

This focuses on saving pumping energy within the natatorium pool filtration and circulation systems.

Measure Performance	
Annual Energy Cost Savings	$3,232
Opinion of Cost	$35,000
Estimated incentives	$9,855
Simple Payback (yrs)	7.8

Table 24. EEM 10 Measure Performance

5.11 EEM 11: INSTALL POOL BLANKETS FOR UNOCCUPIED HOURS

5.11.1 EXISTING CONDITION

Currently the pool does not have a cover installed.

5.11.2 PROPOSED MEASURE

Work for this measure includes;

1. Install a pool cover for unoccupied hours, note that the cover does not have to be thermally insulated it just needs to be capable of mitigating evaporation.

5.11.3 OPINION OF COST

Note that costs are intended for initial measure assessment and do not include costs associated with OSU project management and delivery.

Opinion of Cost			
	Contractor	Consultant	Total
Item 1	$25,000	$0	$25,000
Total	**$25,000**	**$0**	**$25,000**

Table 25. EEM 11 Opinion of Cost

5.11.4 MEASURE PERFORMANCE

This measure is anticipated to save energy by reducing pool heating. There will be an on going requirement to take the pool blankets on and off the pool which has been estimated at 2 student workers for 15 minutes at the start and end of the day.

Measure Performance	
Annual Energy Cost Savings	$7,420
Facility Staff O&M* Annual Savings	$3,650
Opinion of Cost	$25,000
Estimated incentives	$0
Simple Payback (yrs)	6.6

Table 26. EEM 11 Measure Performance

5.12 EEM 12: RENEWABLES – SOLAR HOT WATER

5.12.1 EXISTING CONDITION

Currently the facility does not have a solar hot water system

5.12.2 PROPOSED MEASURE

Work for this measure includes;

1. Install a solar hot water system to offset pool and domestic hot water requirements. Approx size of system 90 x 40SF flat plate collectors. This is based off the solar system designed by Interface in 2012

5.12.3 OPINION OF COST

Note that costs are intended for initial measure assessment and do not include costs associated with OSU project management and delivery.

Opinion of Cost			
	Contractor	Consultant	Total
Item 1	$810,000	$12,000	$822,000
Total	**$810,000**	**$12,000**	**$822,000**

Table 27. EEM 12 Opinion of Cost

5.12.4 MEASURE PERFORMANCE

This measure is anticipated to save energy by reducing pool heating and domestic hot water loads in the building. Note that incentives are tax credit based and are not applicable to all owners.

Measure Performance	
Annual Energy Cost Savings	$26,391
Opinion of Cost	$822,000
Estimated incentives	$246,600
Simple Payback (yrs)	21.8

Table 28. EEM 12 Measure Performance

5.13 EEM 13: RENEWABLES – PHOTOVOLTAICS

5.13.1 EXISTING CONDITION

Currently the facility does not have a PV system.

5.13.2 PROPOSED MEASURE

Work for this measure includes;

1. Install a photovoltaics system to offset building electrical use. Approximate size of system is estimated to be 200kW_{DC}.

5.13.3 OPINION OF COST

Note that costs are intended for initial measure assessment and do not include costs associated with OSU project management and delivery.

Opinion of Cost			
	Contractor	Consultant	Total
Item 1	$800,000	$18,000	$818,000
Total	**$800,000**	**$18,000**	**$818,000**

Table 29. EEM 13 Opinion of Cost

5.13.4 MEASURE PERFORMANCE

This measure is anticipated to offset building electrical use. Note that some of the incentives are tax credit based and are not applicable to all owners. For point of comparison to the solar hot water system above, a $400kW_{DC}$ system would be required to produce the same amount of energy as the solar hot water system as designed. The reason a $200kW_{DC}$ System was selected is to maximize incentives potential.

Measure Performance	
Annual Energy Cost Savings	$18,175
Opinion of Cost	$818,000
Estimated incentives	$500,000
Simple Payback (yrs)	17.5

Table 30. EEM 13 Measure Performance

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6. Results

For a discussion of these results and project construction recommendations please refer to Section 2 Project Delivery Recommendation.

Annual Operating Cost	Building Area (sf)	Annual Electricity Usage (kWh)	Annual Steam Usage (lbs)	Annual Natural Gas Usage (Therms)	Annual Base EUI kBtu per sf	Annual CO_2 Emissions Tons
$307,845	150,000	2,344,249	5,929,067	3,000	102.5	2,143

GLUMAC energy

EEM #		End Use Category	Electricity Savings (kWh/yr)	Steam Savings (lbs/yr)	Savings Beyond Energy ($/yr)	Operating Cost Savings ($/yr)	Operating Cost Savings (%)	Incremental First Cost	Potential Incentives	Simple Payback (yrs)
Preliminary Energy Conservation Measures for Consideration										
1	Building Management System Upgrade & Tuneup	HVAC	95,307	1,062,267	$10,400	$38,929	12.6%	$232,200	$38,700	5.0
2	Insulate steam and hot water piping in SF 2&3 fan room	Steam	0	93,233	$0	$1,818	0.6%	$12,791	$0	7.0
3	Variable Speed Control of HWP P2A & P2B, disable bypass on associated 3-way valves.	Pumps	9,600	0	$0	$787	0.3%	$14,000	$0	17.8
4	Replace/upgrade washing machines with high performance low water use units.	DHW	0	33,600	$0	$655	0.2%	$9,500	$0	14.5
5	Utilize ceiling fans and other air circulation devices throughout the building where possible	HVAC	55,968	212,453	$0	$8,732	2.8%	$78,000	$22,762	6.3
6	Air cooled chiller replacement	HVAC	18,236	0	$0	$1,495	0.5%	$168,000	$0	112.4
7	Upgrade lighting to LED technology for Upper and Lower Gyms including daylight control	Lighting	101,920	-84,981	$0	$6,700	2.2%	$68,600	$25,480	6.4
8	Remove lighting unnecessary from EM power, and implement daylight control and improved occupancy control to areas associated with the 2004 addition.	Lighting	46,143	-63,736	$7,800	$10,341	3.4%	$75,000	$11,536	6.1
9	Replace/Upgrade pool ventilation system	HVAC	41,575	467,397	$0	$12,523	4.1%	$160,000	$2,344	12.6
10	Optimize pumping power in pool filtration system	DHW	39,420	0	$0	$3,232	1.1%	$35,000	$0	10.8
11	Install Pool Blankets for unoccupied hours	DHW	0	380,520	-$3,650	$3,770	1.2%	$25,000	$3,242	5.8
12	Renewables - Solar Hot Water	Renewables	0	1,353,383	$0	$26,391	8.6%	$822,000	$246,600	21.8
13	Renewables - Photovoltaics	Renewables	221,651	0	$0	$18,175	5.9%	$818,000	$500,000	17.5

Appendix A: Building & Systems Information

A.1 LOCATION

The Dixon Recreation Center is located at 425 SW 26th St in Corvallis, OR. This is situated towards the center of Oregon State University's campus, just to the northeast of Reser Stadium. An image of the project site can be seen below.

Figure 7 - Image of Project Site

A.2 WEATHER

Weather in Corvallis, OR falls under climate zone 4C (mixed, marine) according to the American Society of Heating, Ventilation, and Air-Conditioning (ASHRAE) 90.1-2007 Energy Standard for Buildings Except Low-Rise Residential Buildings. This standard is regularly used in the building industry to validate energy performance. Typical weather for Corvallis, OR has the following conditions:

Heating Degree Days (65): 4,923

Cooling Degree Days (50): 2,051

Heating Design Temperature: 17°F

Cooling Design Temperatures: 92°F / 67°F (DB/WB)

A.3 FLOOR PLANS

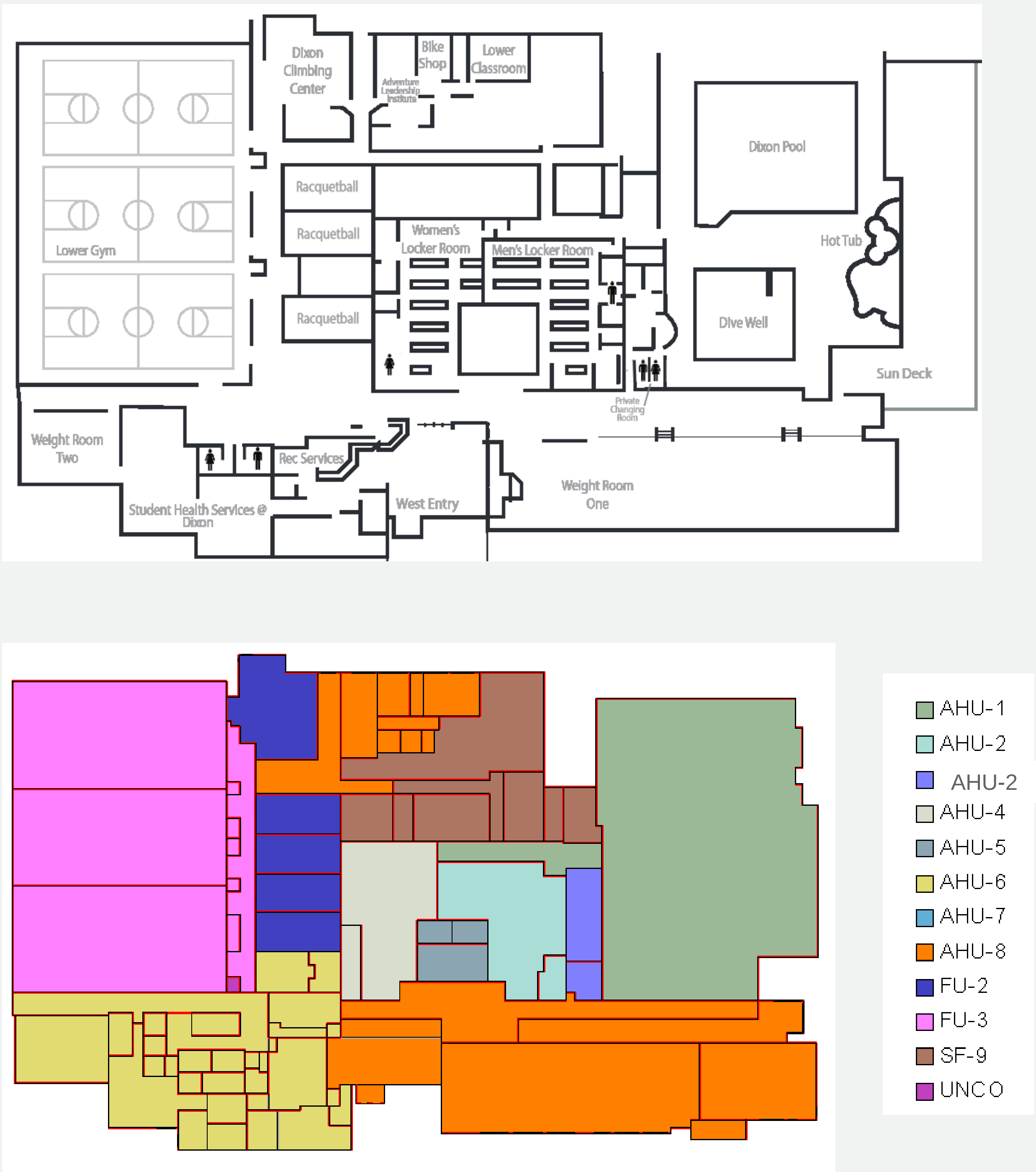


Figure 8 – First Floor Usage & HVAC Systems Map

Figure 9 – Second Floor Usage & HVAC Systems Map

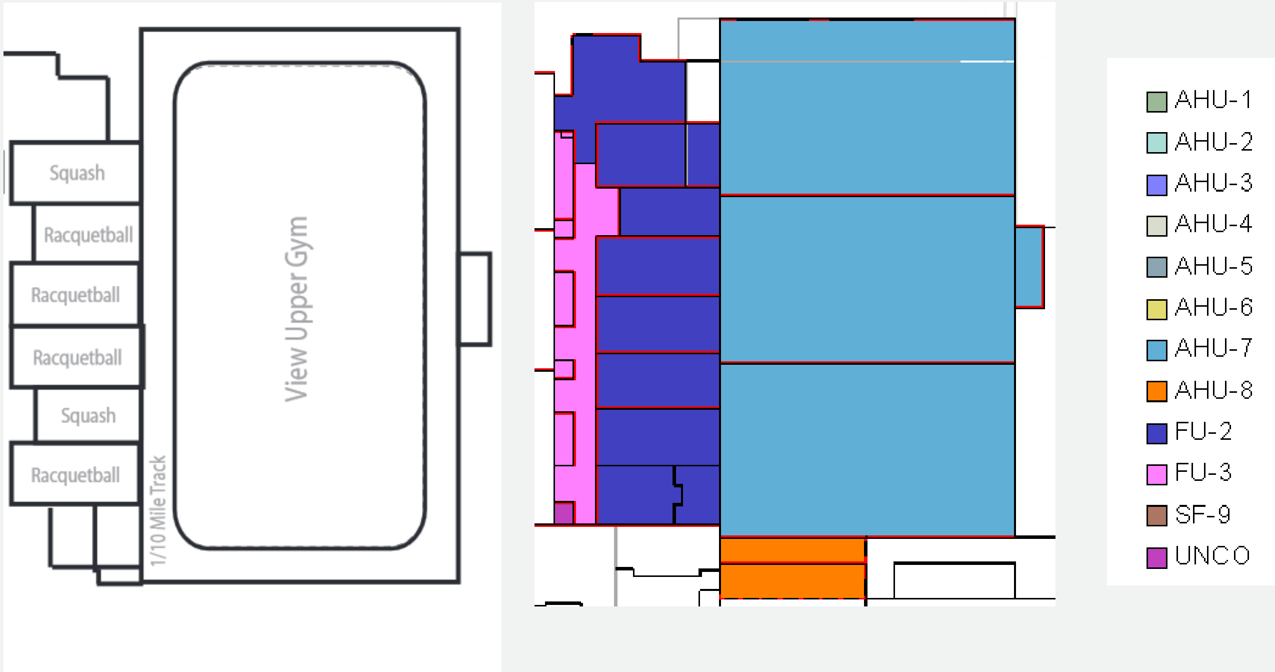


Figure 10 – Third Floor Usage & Systems Map

A.4 BUILDING OCCUPANCY

The facility is hard working for the students and can see as many as 6,000+ Students a day during peak times. In general, the following table represents hours of operation for key areas of the building

Hours of Operation			
	Monday to Friday	Saturday	Sunday
General Recreation	6am to 12am 6am to 8pm	9am to 10pm 9am to 4pm	10am to 12am 10am to 4pm
Climbing Center	4pm to 10pm 4pm to 10pm	Closed Closed	Closed Closed
Dixon Café	7am to 10pm 6am to 8pm	11am to 8pm Closed	11am to 8pm Closed
Dixon Pool	6am to 10pm 6am to 8pm	10am to 8pm 10am to 4pm	10am to 10pm 10am to 4pm

Regular Hours
Summer Term / Break

Table 31 – Hours of Operation

Using the card access scanning system students use to energy the building it was possible to get a better picture for how the facility was being used throughout the year, and throughout a typical day. One year of card access information was reviewed in order to inform the energy savings calculations and energy modeling efforts, from this information 3 key usage profiles were generated and characterize building usage, Spring/Winter break, Fall/Winter/Spring term, and Summer term. This information has been presented graphically on the following pages.

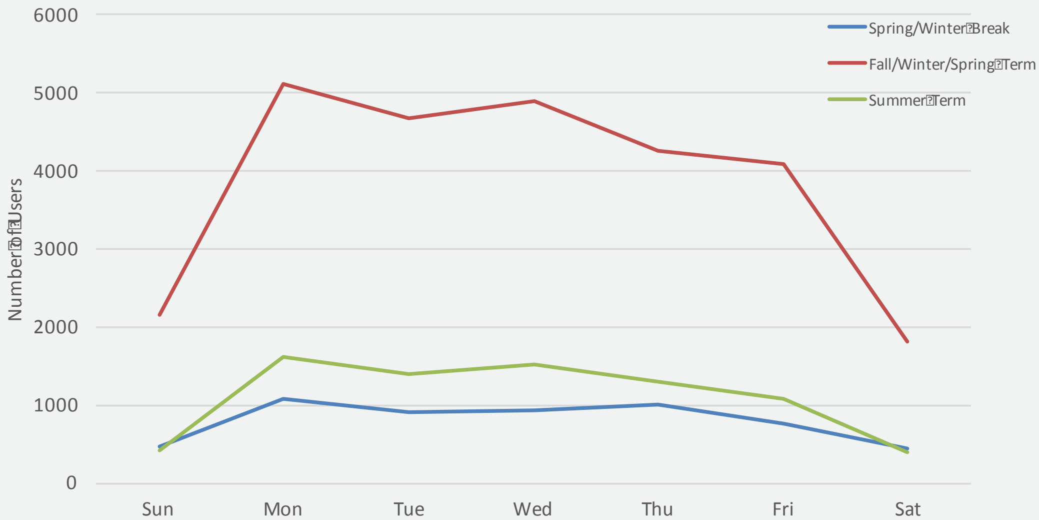


Figure 11 – Weekly Usage Profiles

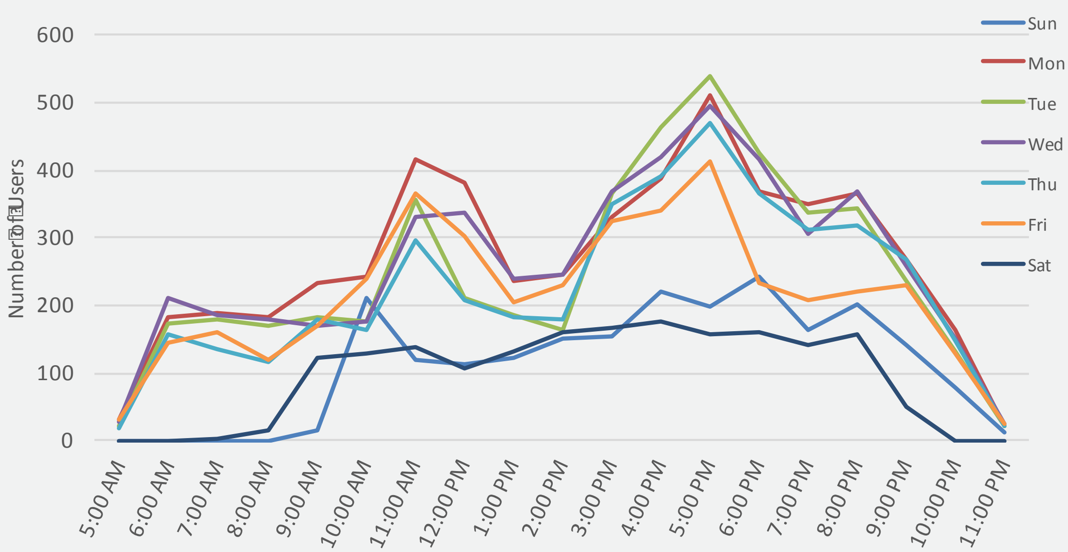


Figure 12 – Typical Term Daily Usage Profile

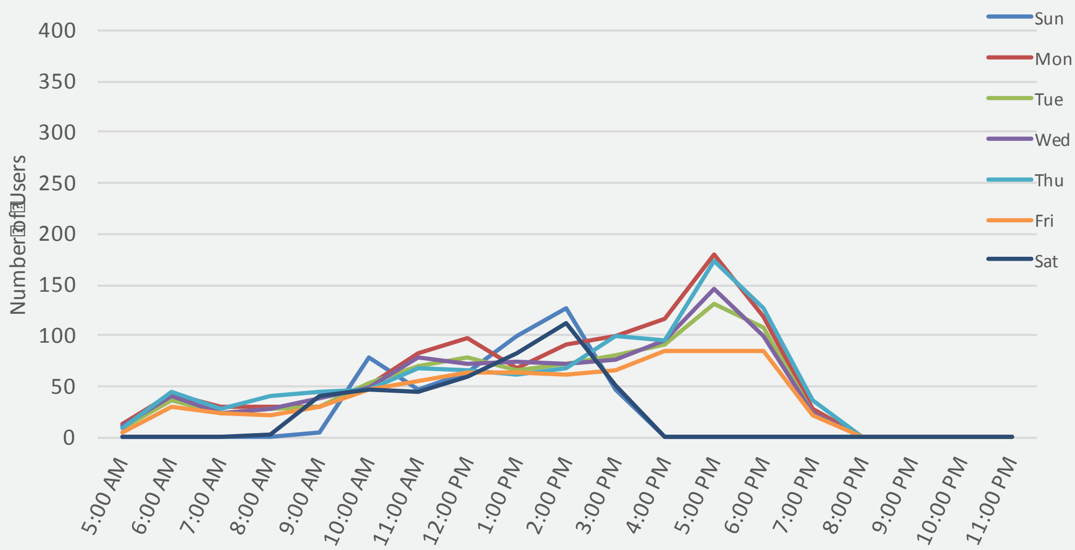


Figure 13 – Summer Term Daily Usage Profile

Figure 14 – Winter/Spring Break Daily Usage Profile

A.5 SYSTEMS OVERVIEW

A.5.1 ENVELOPE

Review of architectural drawings indicates the envelope has good insulation and building mass. Descriptions of exterior surface components are as follow:

- Roof: 2” Rigid Insulation Above and Below Deck, R-20 (U-0.048)
- Walls: 2.5” Rigid Insulation interior of 8”-10” brick wall, R-12.5 (U-0.059)
- Windows: Double pane w/ aluminum frames, non-thermally broken (U-0.75, SHGC-0.70)

A.5.2 AIR HANDLING UNITS

AHU-1 serving the Natatorium. It consists of a supply fan and return fan with full economizer capability as well as a heat recovery unit (HRU-3) to pre-condition the supply air. The fans are equipped with VFD’s which currently operate at fixed speeds scheduled through time of day programming. HRU-3 is provided with control dampers on the OSA and exhaust ducts in addition to the separate OSA and exhaust ducts with control dampers (to bypass the HRU). The heating coil is steam and modulates via a 1/3, 2/3 valve configuration. No cooling coil is provided. There are 2 airflow stations. One is on the OSA duct that is part of HRU-3 and the other is on the supply air duct. Currently the SA airflow station appears inoperable with a reading of 0 CFM. The OSA airflow station should also be checked for accuracy.

AHU-2 and AHU-4 serving the Men’s and Women’s Locker Rooms (respectively). They consist of a 100% supply fan and 100% exhaust fan with a heat recovery units to pre-condition the supply air. The fans are constant volume. The heating coil is steam and modulates via a single control valve. No cooling coil is provided. There is a single damper on the OSA duct of each unit.

AHU-5 serving the Main Issue area. It consists of a supply fan with full economizer capability. The fan is constant volume. The heating coil is steam and modulates via a single control valve. No cooling coil is provided.

AHU-6 serving the Administration Area. It consists of a supply fan and return fan with full economizer capability. The fan incorporates a natural ventilation mode with exhaust dampers directly from the space to outside. The fans are equipped with VFD’s. The supply fan VFD modulates fan speed to maintain the Supply duct static pressure setpoint. The return fan VFD modulates fan speed to maintain the building static pressure setpoint. The OSA intake has 2 separate control dampers; one is a dedicated OSA minimum duct with an airflow station. In addition to the economizer dampers, there is an isolation damper on both the supply and return ducts. The heating coil is steam and modulates via a single control valve. A cooling coil is provided and controlled by a single modulating valve. A separate BAS graphic indicates that this unit also incorporates Heat Recovery via HRU-3 but there are no points associated with the graphic to determine or evaluate operation. AHU-6 feeds 22 Variable Air Volume Terminal Units with re-heat coils.

AHU-7 serving the New Gymnasium. It consists of a supply fan with economizer capability. The fan incorporates a natural ventilation mode with exhaust dampers directly from the space to outside. The natural ventilation mode is currently controlled by time of day scheduling and would provide more stable control if incorporated into the temperature control programming. The OSA intake has 2 separate control dampers; one is a dedicated OSA minimum duct with an airflow station. In addition to the economizer and ventilation dampers, there is an isolation damper on the supply duct. The heating coil is steam and modulates via a single control valve.

AHU-8 serving the Fitness and Multipurpose Areas. It consists of a supply fan and return fan with full economizer capability. The fan incorporates a natural ventilation mode with exhaust dampers directly from the space to outside. The fans are equipped with VFD’s. The supply fan VFD modulates fan speed to maintain the Supply duct static pressure setpoint. Currently the supply fan is operating at 80% and only achieving 0.7”w.c. (35% of the 2.0”w.c. setpoint). The return fan VFD modulates fan speed to maintain the building static pressure setpoint. The OSA intake has 2 separate control dampers; one is a dedicated OSA minimum duct with an airflow station. In addition to the economizer dampers, there is an isolation damper on both the supply and return ducts. The heating coil is hot water and modulates via a single control valve. A cooling coil is provided and controlled by a single modulating valve. A separate BAS graphic indicates that this unit also incorporates Heat Recovery via HRU-4 but there are no points associated with the graphic to determine or evaluate operation. AHU-8 feeds 22 Variable Air Volume Terminal Units with re-heat coils.

AHU-9 serving the Storage and Chemical Room. It consists of a supply fan and return fan with full economizer capability. The fans are constant volume. No heating or cooling coils are provided at the unit. There are Electric Duct Heaters serving four separate zones. Currently the BAS graphic indicates that the return fan is being commanded on but is not running.

FU-2 serving the Racquetball Court and Rock Wall. The supply fan has a VFD which is running at 100% but only achieving a supply duct pressure of 0.43”w.c. with a setpoint of 0.8”w.c.. There is a return air damper and the OSA intake has 2 separate control dampers; one is a dedicated OSA minimum duct. The BAS graphics indicate an airflow station but there is no point associated to display a value. Currently the heating coil valve is commanded to 0% in operator priority. A separate Exhaust fan EF-7 also serves this space.

FU-3 serving the Old Gym. The supply fan has a VFD which is running at 100% but indicating supply airflow 819.5 CFM but the OSA minimum setpoint is 1000 CFM. There is a return air damper and the OSA intake has 2 separate control dampers; one is a dedicated OSA minimum duct. The BAS graphics indicate a minimum OSA airflow station but it is reading 4.7 CFM. The supply duct has three branches, each with a Heating coil. Currently the Heating coil valves are commanded to 0% in operator priority. A separate Return fan RF-1 also serves this space and is operating at 100% and the building pressure indicates it is 0.6”w.c.. The setpoint is 0.1”w.c..

A.5.7 INTERIOR LIGHTING SYSTEMS

In general, the lighting power densities and controls are typical for a building of this era. That said have of the lights are on emergency ballasts hence potentially operate more then is required.

A.5.8 EXTERIOR LIGHTING SYSTEMS

Confirm extent of exterior lighting that is connected to the Dixon meter.

A.5.9 PLUG LOADS

Plug loads are a very minor component of energy use for an recreation building. Most of the building area is comprised of active space, plug loads have been taken into account however have not been considered a major energy driver.

A.5.10 DOMESTIC HOT WATER

Domestic hot water (DHW) is provided to the building by steam converter. In addition to this there is a gas connection to the washing machines which is a minor load on the building.

A.5.11 RENEWABLE ENERGY

The building does not currently have renewable energy sources installed

APPENDIX B: BUILDING AUTOMATION SYSTEM REVIEW

Dixon Recreation operations staff granted Glumac Commissioning access to the front end of the building automation system to perform a review geared at establishing the level of control the system has over the building building. This was performed at a high level and should not be construed as an in depth review, however based on the number of discrepancies found within the system the team has a low level of confidence in the system's ability to serve the facility in its current state.

B.1 SYSTEM OBSERVATIONS & DEFICIENCIES

Performed morning of May 15th, 2015 approximate outdoor air temperature 56ºF

AHU-1 – Natatorium

- Supply airflow sensor was not operational at the time of investigation.
- The system was capable of recovering heat from the 82ºF relief air, however much of this benefit was lost due to mixing with outdoor air after the heat recovery coil. This may be due to size limitations of the Heat Recovery Unit.
- Fan speed control appears to be done through scheduler, SF @ 70% from 5:am to 11pm then 5 %, RF @ 100% 5am to 11pm then 5%.
- It was unclear what was controlling the OA and EA Heat Recovery Unit bypass dampers as the EA and OA mixing damper was closed.

AHU-2 – Men's Locker Room

- Heat recovery coil appears to be achieving 10ºF temperature rise.
- Exhaust fan shown as off during operating hours.
- Graphic does not have a command status for exhaust fan.
- HR-DA-T @ 68.5°F Heating valve at 100%, DAT drops to 60.7°F indicating significant calibration issues or heat radiating from coil resulting deficient user feedback from the system.

AHU-4 – Women's Locker Room

- Heat recovery coil appears to be achieving 10ºF temperature rise.
- Graphic does not have a command status for exhaust fan
- Temperature rise across supply fan is excessive at 3ºF and may be the result of sensor calibration issue or hot water leaking through the valve.

AHU – 5 Main Issue

- Graphic indicates economizer is "on" however temperature sensors within the unit indicate the unit is likely operating in 100% return and not economizing resulting in space being significantly above set point.

AHU – 6 New Admin Area

- Unit does not appear to be economizing correctly or graphics are incorrect. Exhaust air and return air dampers are shown open at the same time with the chilled water valve 100% open and DAT at 62.1ºF with OAT at 56ºF. This is not a logical operating scenario.
- SA temperature set point is not shown on graphic.
- It is difficult to decipher if air from HRU 3 is being utilized or the system is economizing.

AHU – 7 New Gymnasium

- Return air sensor temperature is not a practical value.
- CO_2 sensors are not reading correctly.
- Minimum OA sensor value and location is unclear.

AHU – 8 Fitness Area and Multipurpose

- Fan speed is 80% with DA static pressure below setpoint, which shows the fan is not responding to the system's needs.
- Check damper positions.

AHU – 9 Storage and Chem Room

- Setpoints not shown on the graphic.
- Return fan status indicated fan commanded on but not running.

FU – 2 Racquetball Court and Rock Wall

- Zone temperature is providing an impossible value
- Unit is operating with 100% OSA (56.5ºF) and DAT is climbing ≈12°F with heating valve closed which is an impossible scenario.
- Fan speed is operating at 100% but the DAT-Static is ½ of setpoint

FU – 3 Old Gym

- System is using 100% OSA and the DAT is indicating a temperature rise of 8.5ºF which is an impossible scenario.
- Return fan indicating off with command on and VFD speed commanded 100%.

Chilled Water System

- Chiller command is on and the pump is running however, the supply and return chilled water temperatures are the same indicating the chiller is not operating.

Heat Recovery Units

- Graphic is incomplete, show's nothing to give the user an idea of how/if the system is operating.

Pool Heat Exchanges

- This system appears to controlling to setpoint.

Hot Water System and Heat Exchangers

- System is controlling to setpoint however there appears to be little temperature differential between supply and return lines. Good opportunity for variable control.

Racquetball Courts, Rock Gym

- Controller appears to have failed.

VAV Boxes 1st Floor East

- TU8-107 Damper is 100% and CFM is below scheduled minimum value (review TAB report?) and not achieving temperature setpoint.
- TU8-108 Damper is 100% and CFM is below scheduled minimum value (review TAB report?) and not achieving temperature setpoint.
- TU8-109 Damper should not read 130.4% open and short of minimum flow of 200.
- TU8-110 Damper is 100% and CFM is below scheduled minimum value.
- TU8-111 controller is failed or not communicating.
- TU8-112 Damper is 100% and CFM is below scheduled minimum value and cooling max CFM is needed, as space is 5.8°F above setpoint.

VAV Boxes 1st Floor West

- TU6-103, damper overridden and airflow is at heating/minimum. Release damper to provide cooling CFM so setpoint can be met.
- TU6-104, damper overridden.
- TU6-105, damper overridden and at max design CFM but not achieving setpoint.

- TU6-106, TU-6-107, TU8-101A, TU8-104, damper at 100% but showing 0 CFM.
- TU6-108, TU8-110, TU8-102, TU8-103, TU8-105, damper at 100% but CFM shows well below design min.
- TU8-106, controller is failed or not communicating with the front-end.

VAV Boxes 2nd Floor West

- TU6-201, HW valve at 100% and not achieving setpoint. Damper is controlling to scheduled airflow of 2000 CFM.
- TU6-202, TU6-203, TU6-211, TU8-201, TU8-204, Dampers are 100% but below scheduled minimum airflow.
- TU6-204, Should be in heating mode but airflow is at scheduled cooling max and HW valve is closed.
- TU8-206, 3.7°F above setpoint. Damper is at -10.2% open?? Airflow well below cooling max design flow of 2150 CFM.
- TU8-207, damper position is failed or not communicating with the front-end.
- TU8-208, 3.1°F above setpoint. Damper is at 100% but airflow well below cooling max design flow of 1750 CFM.
- TU8-209, 3.8°F above setpoint. Cooling design flow max. CFM is being achieved.

Night Flush

- Operation confirmed through trending correctly based on 1 day observed.

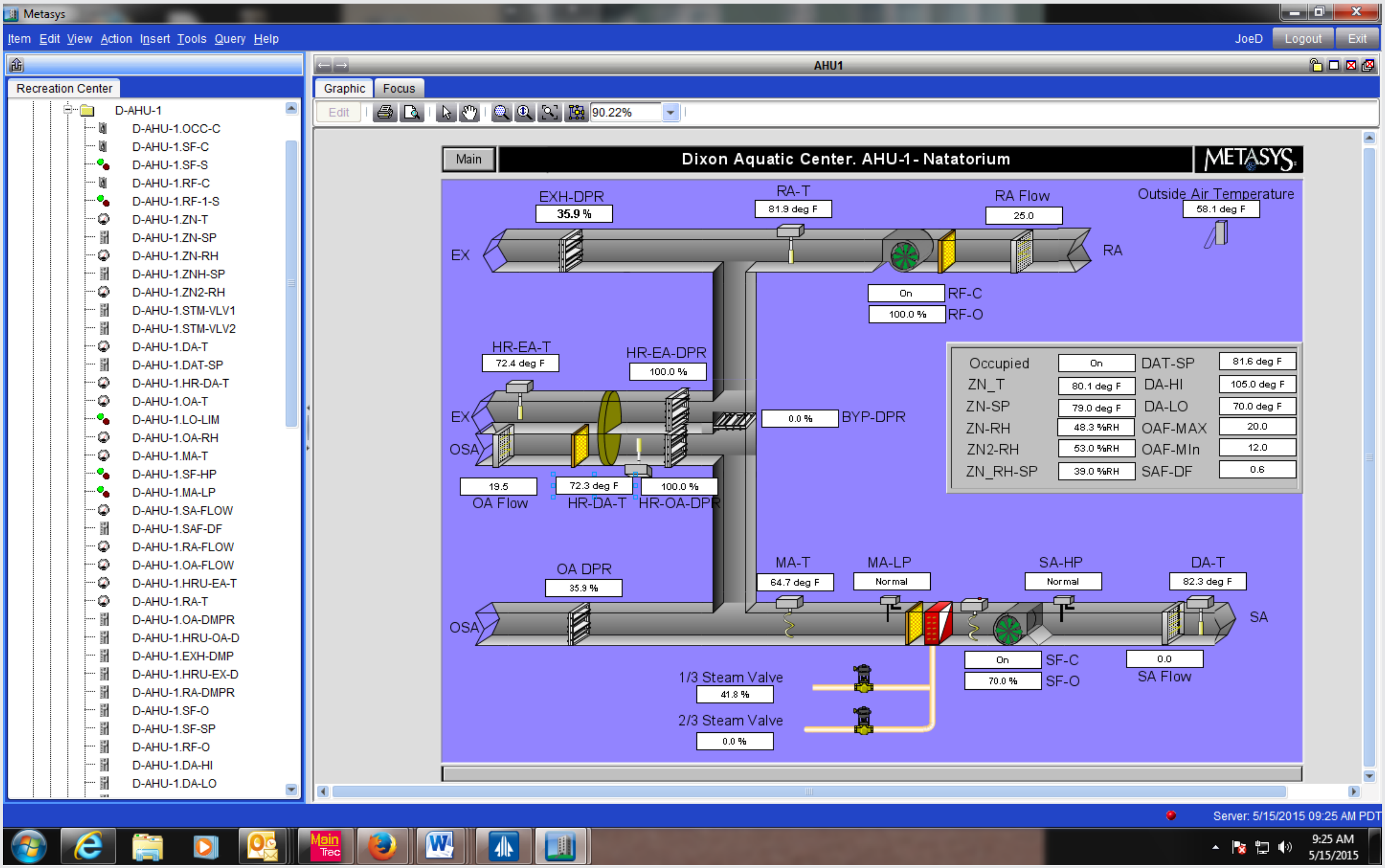


Figure 15 – AHU-1 - Natatorium

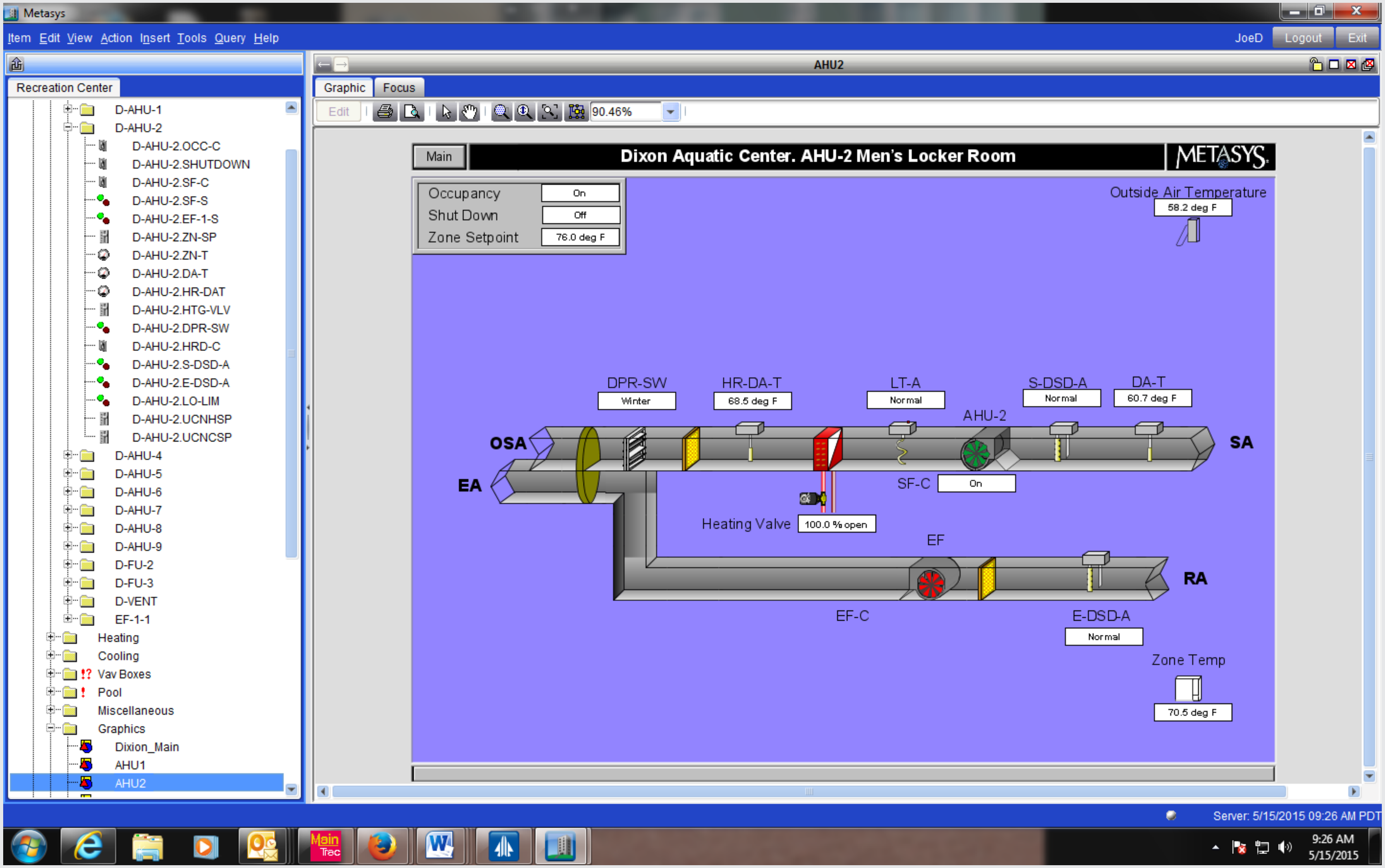


Figure 16 – AHU-2 – Men's Locker Room

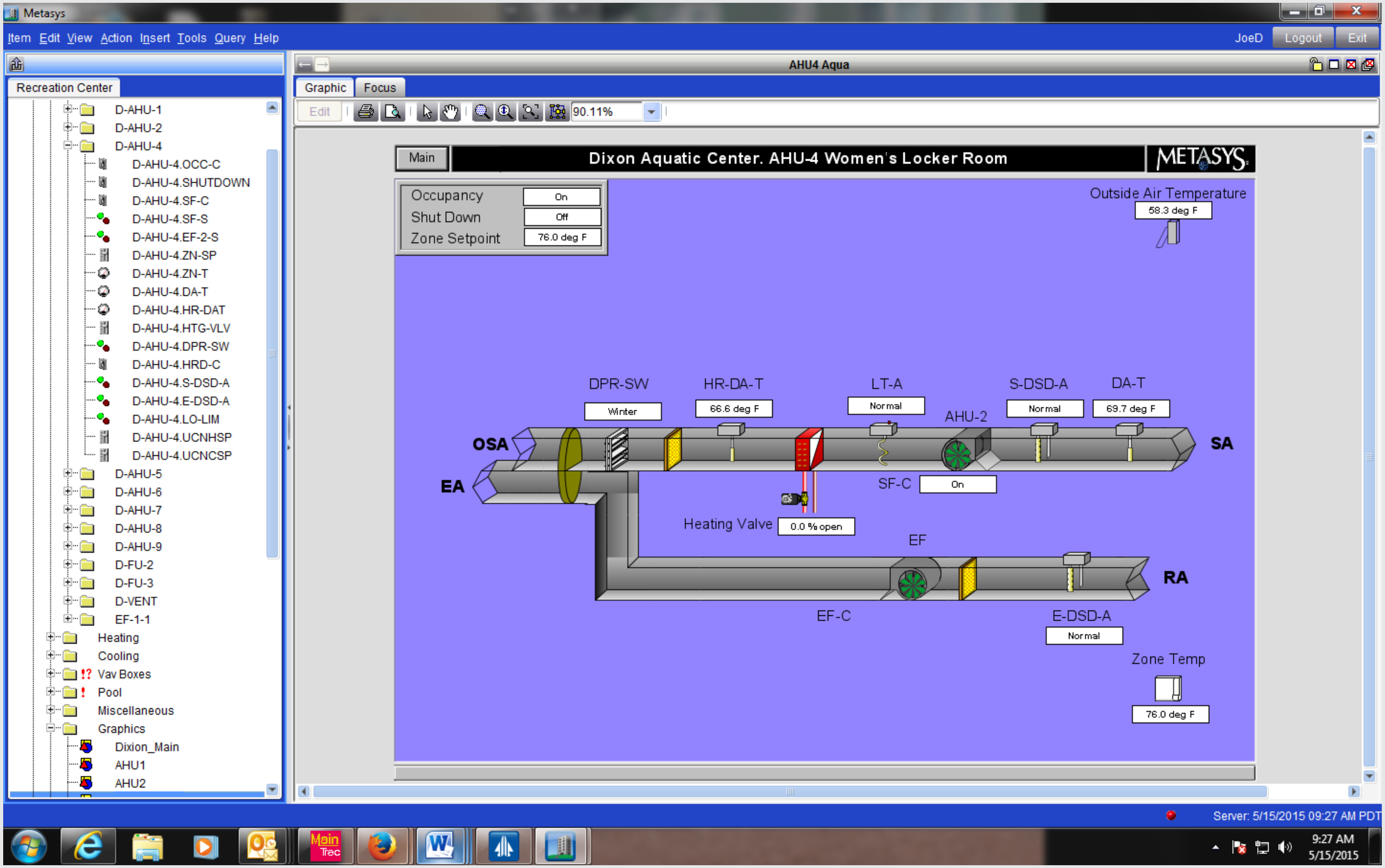


Figure 17 – AHU-4 – Women's Locker Room

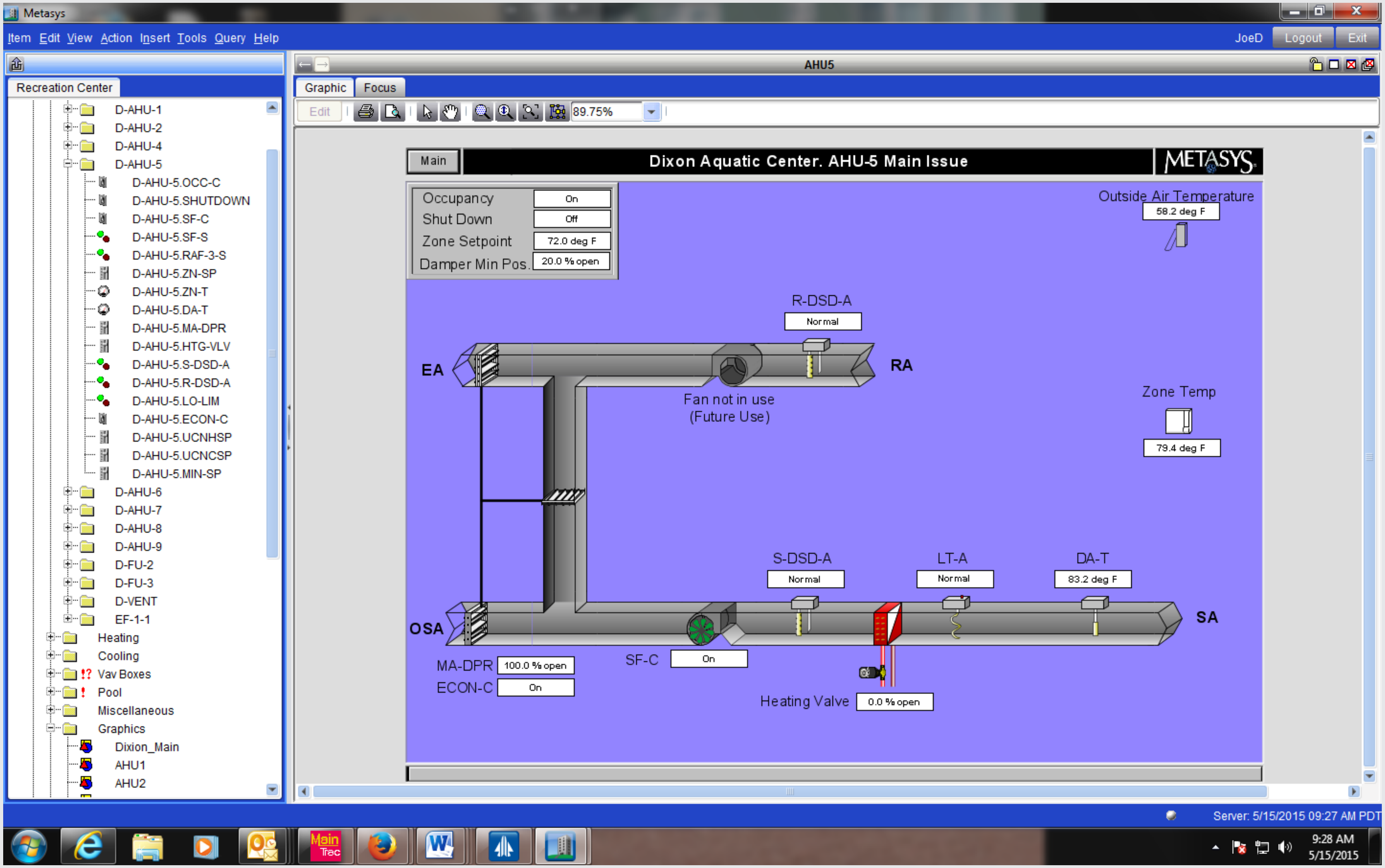


Figure 18 – AHU-5 – Main Issue

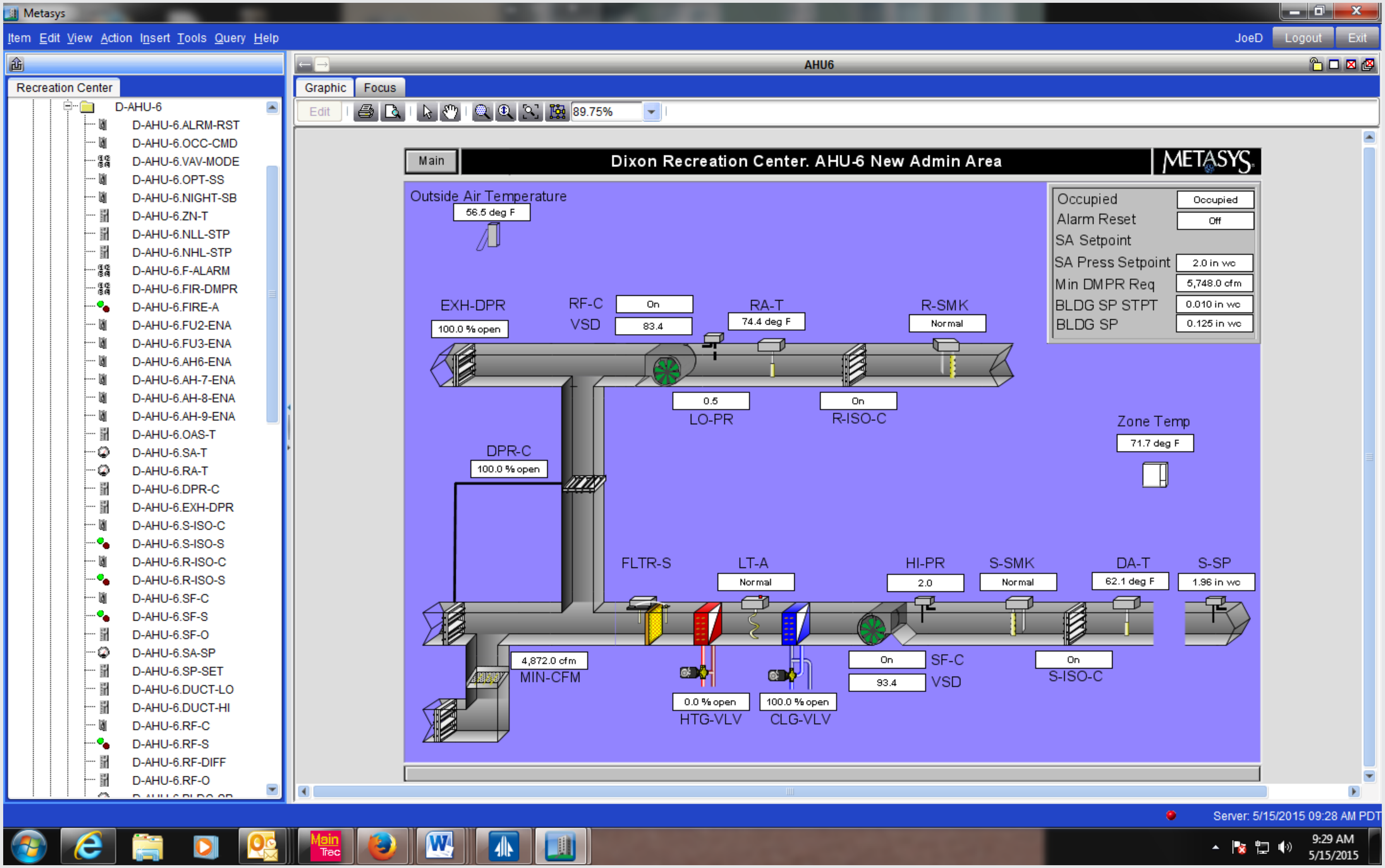


Figure 19 – AHU-6 – New Admin Area

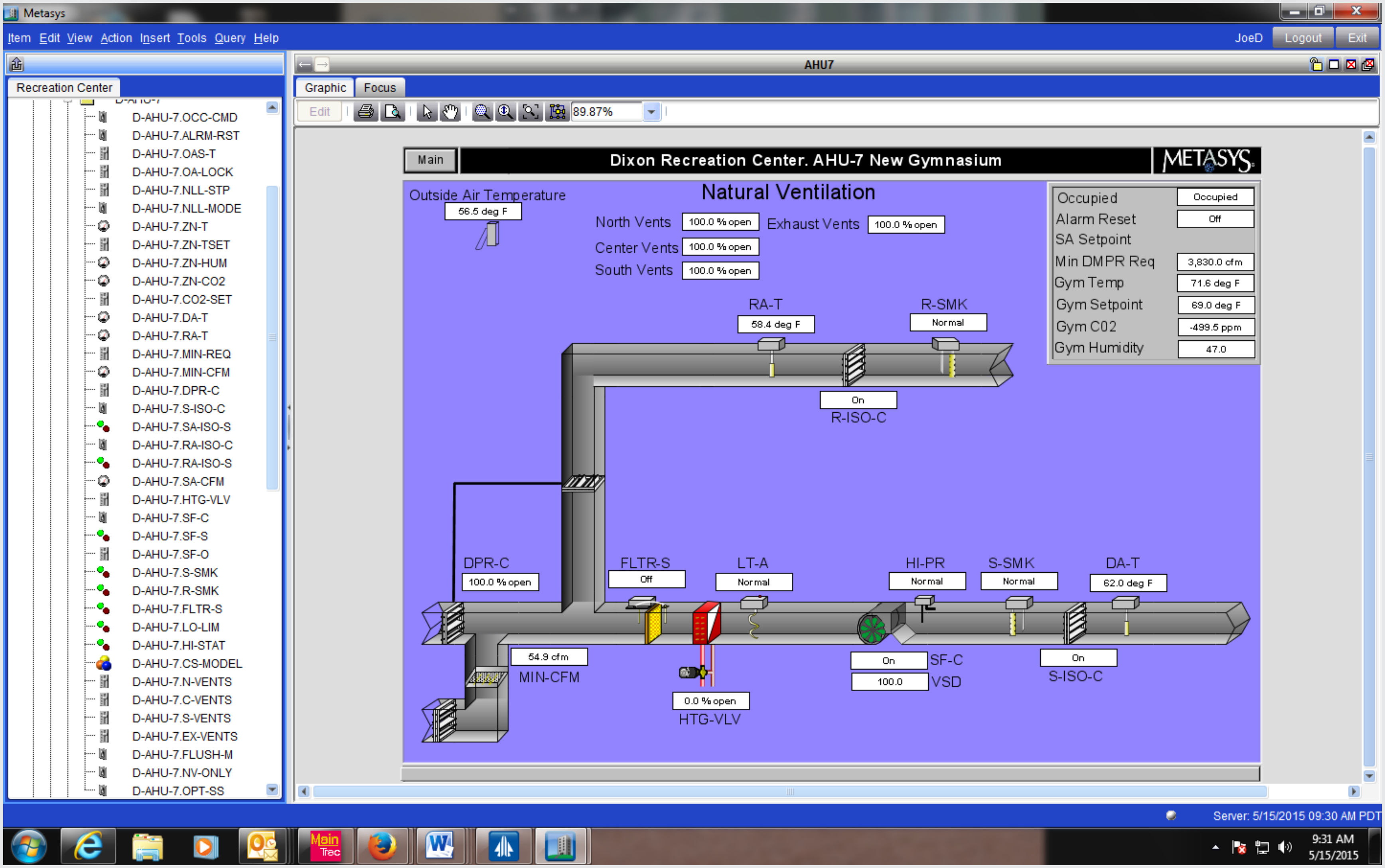


Figure 20 – AHU-7 – New Gymnasium

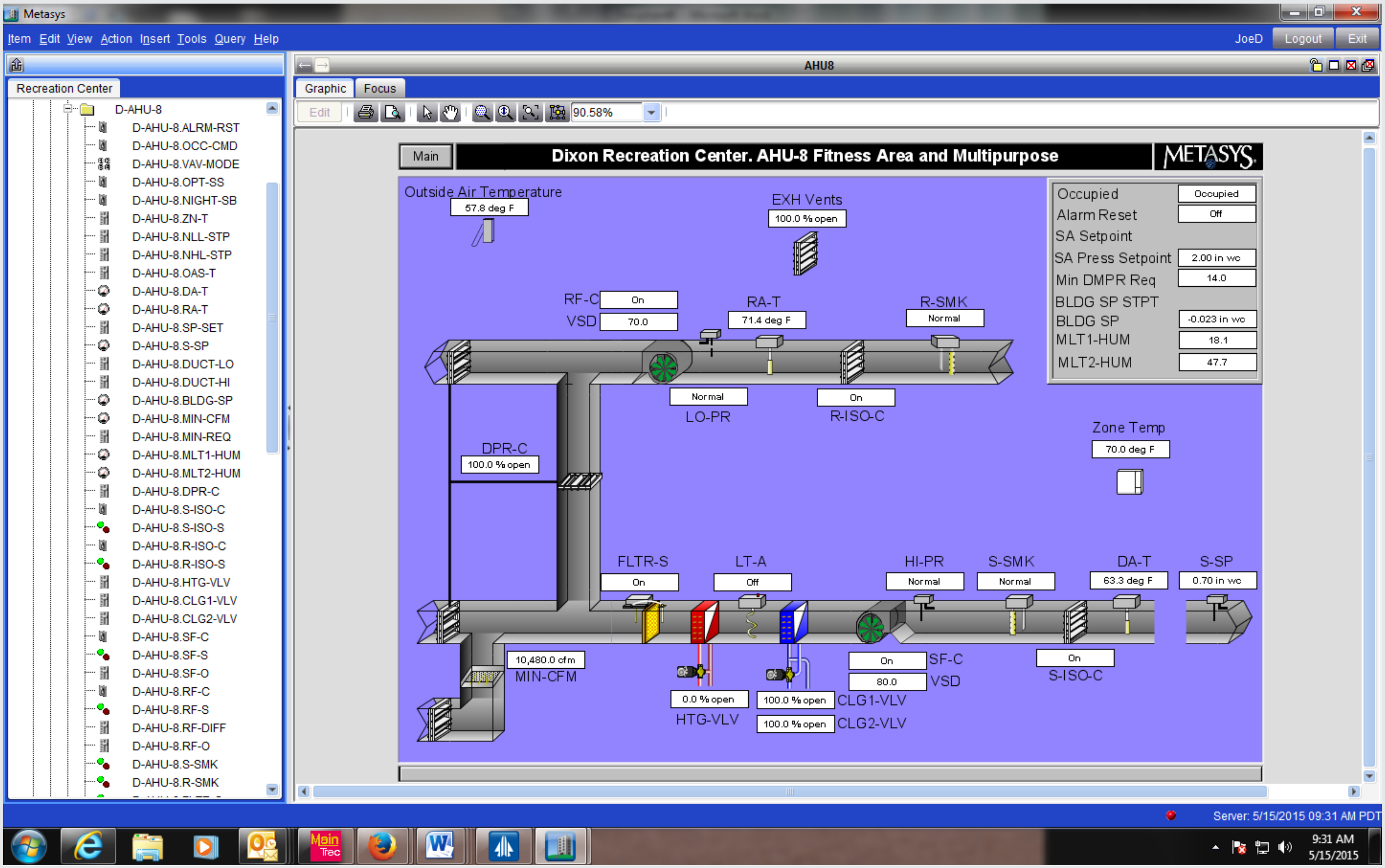


Figure 21 – AHU-8 – Fitness Area and Multipurpose

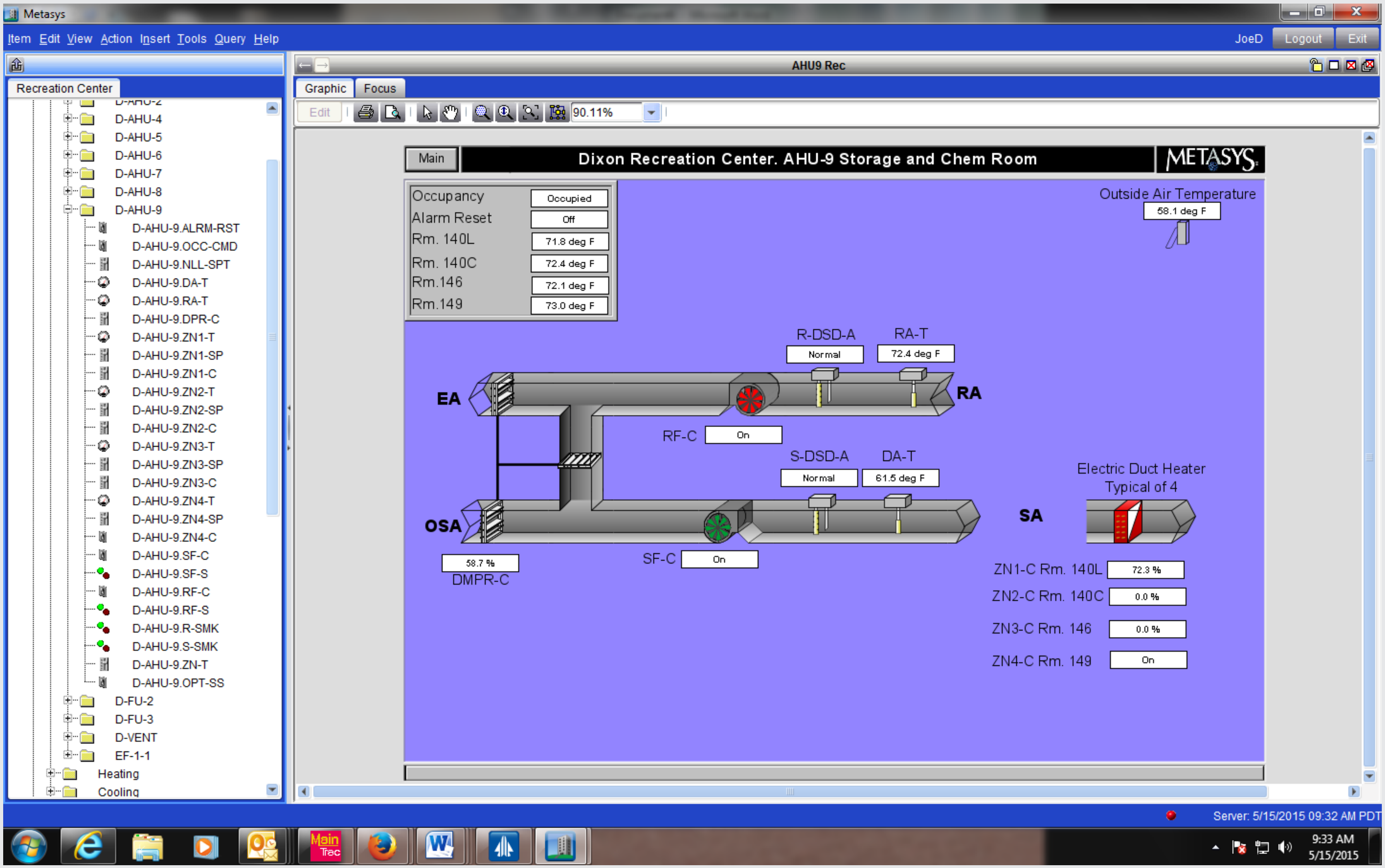


Figure 22 – AHU-9 – Storage and Chem Room

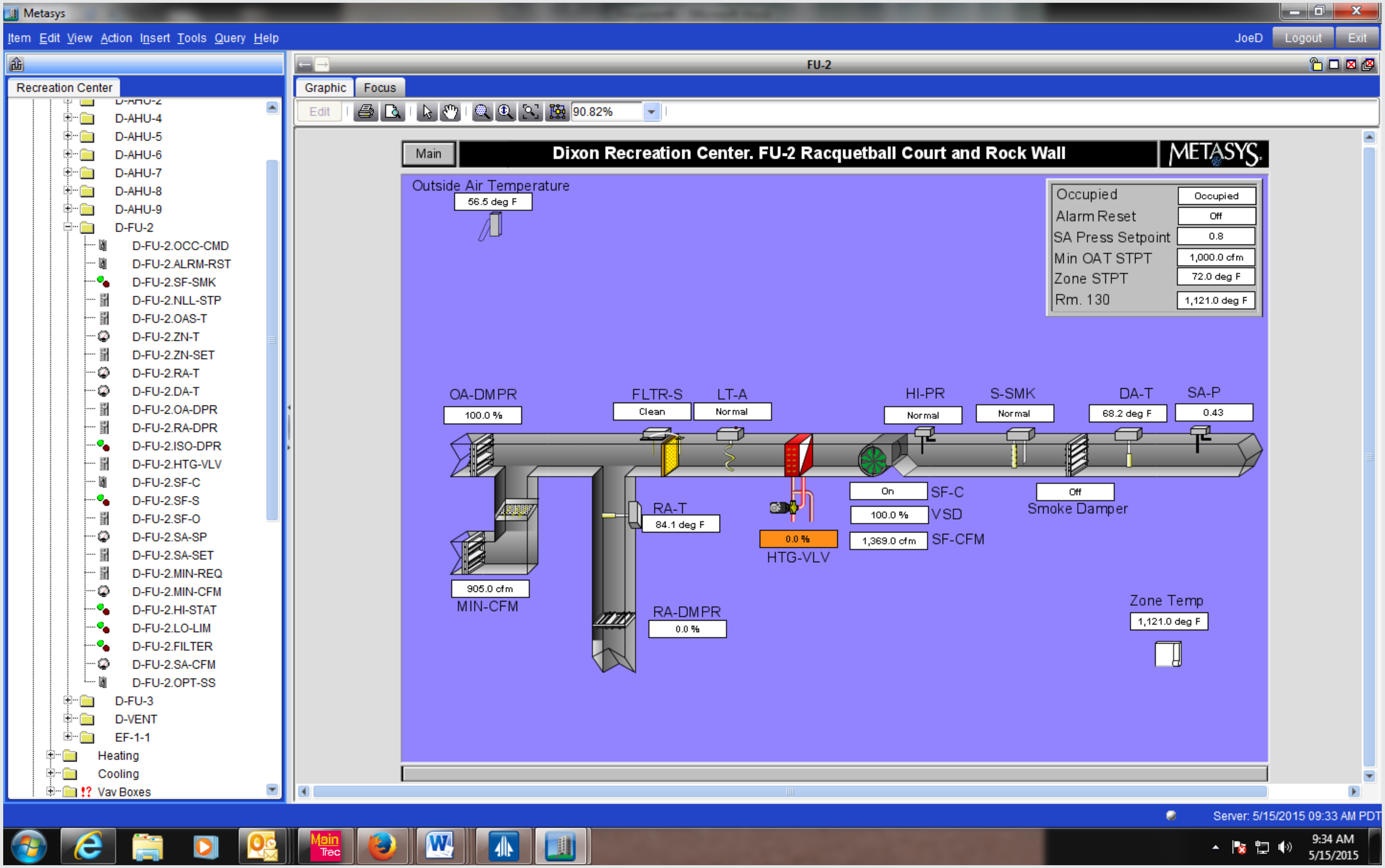


Figure 23 – FU-2 – Racquetball Court and Rock Wall

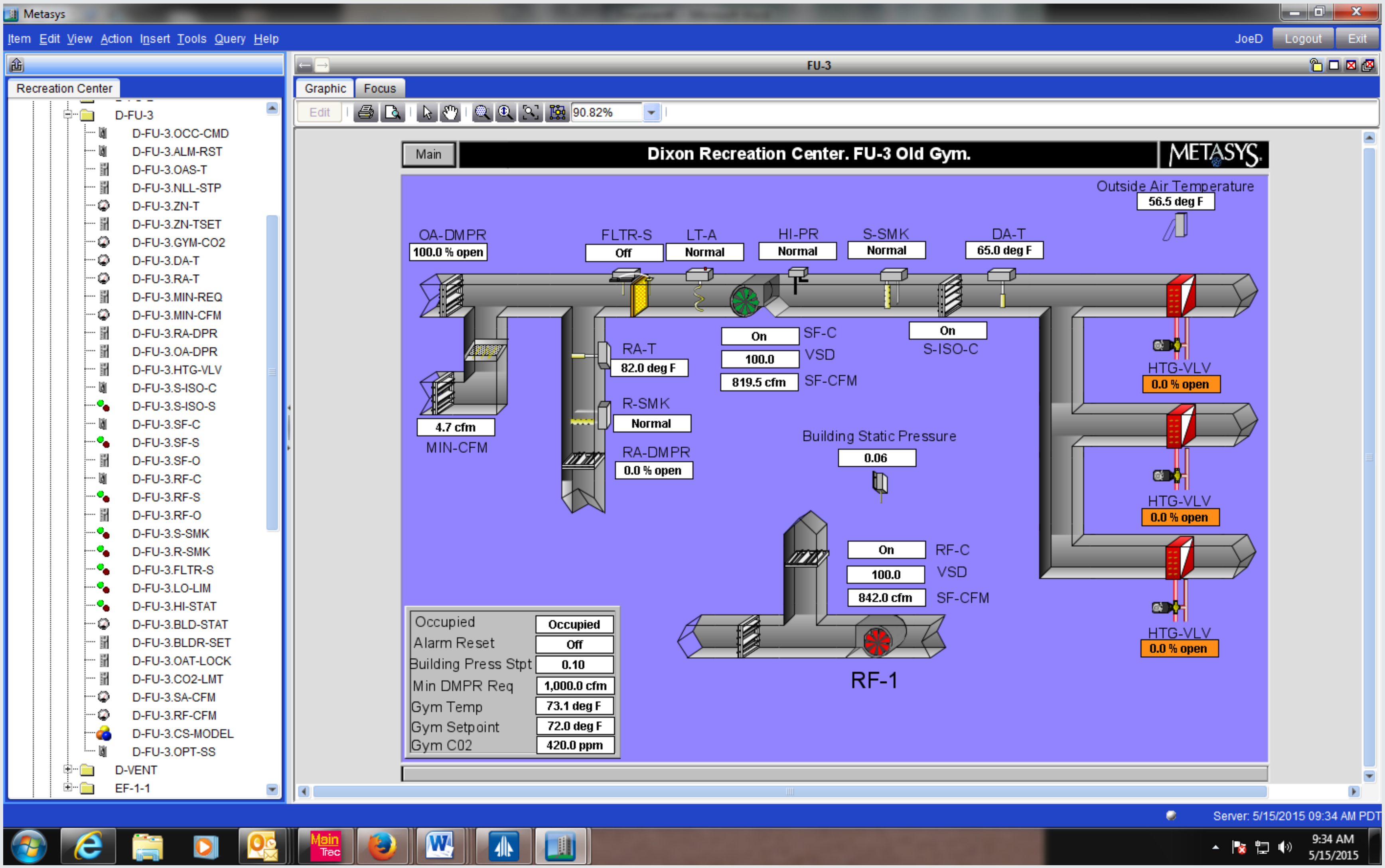


Figure 24 – FU-3 – Old Gym

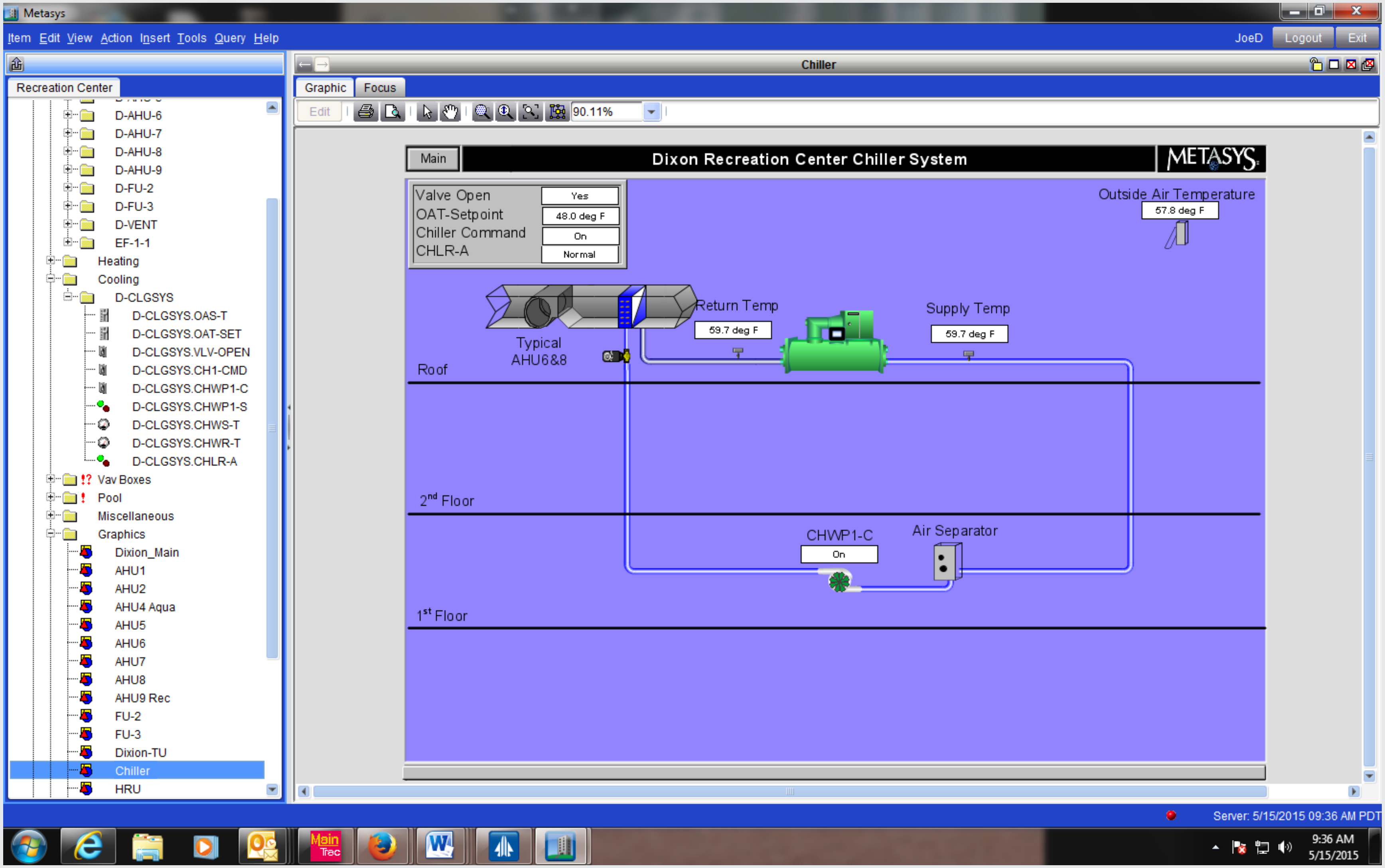


Figure 25 – Chiller System

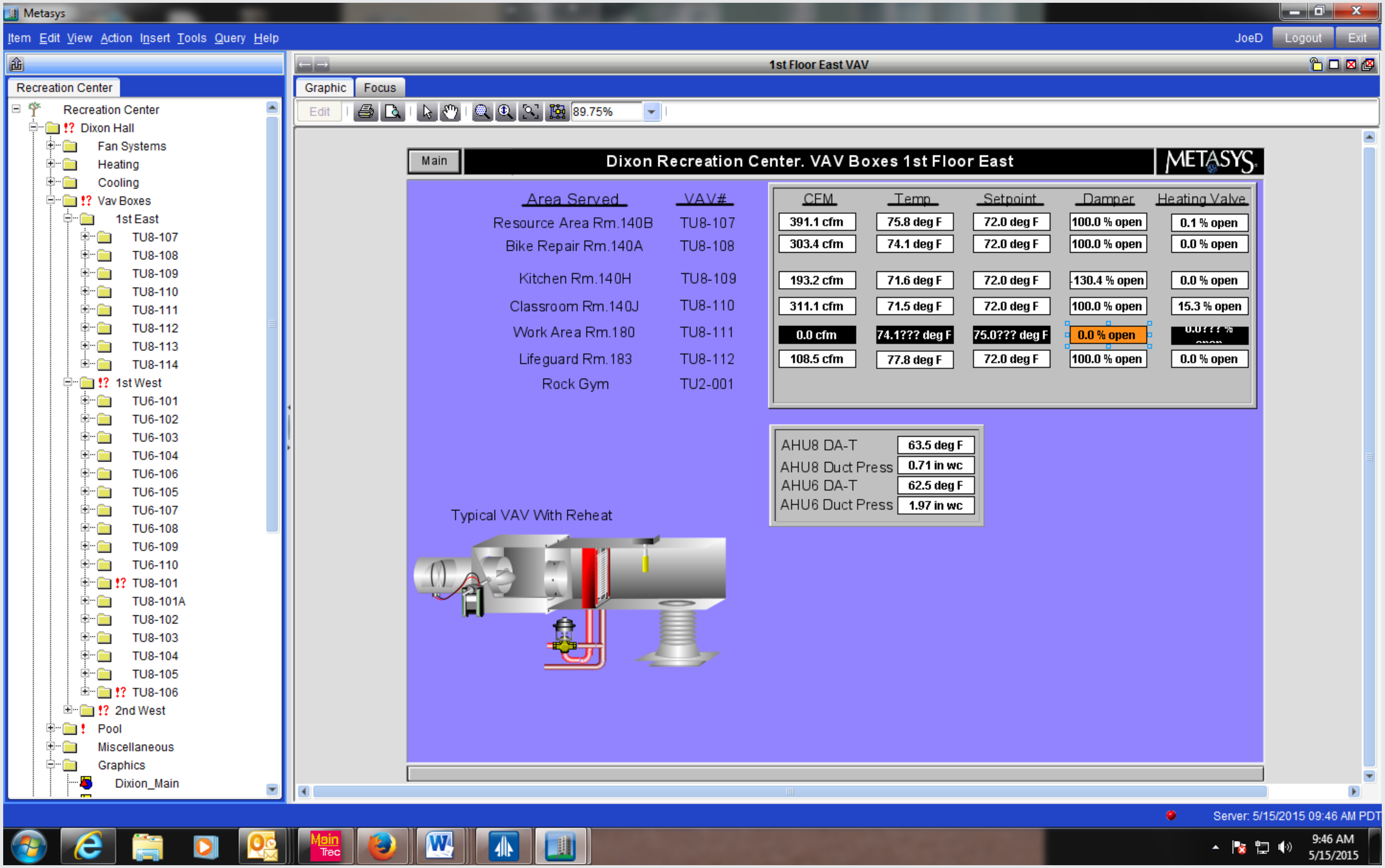


Figure 26 – VAV Boxes 1st Floor East

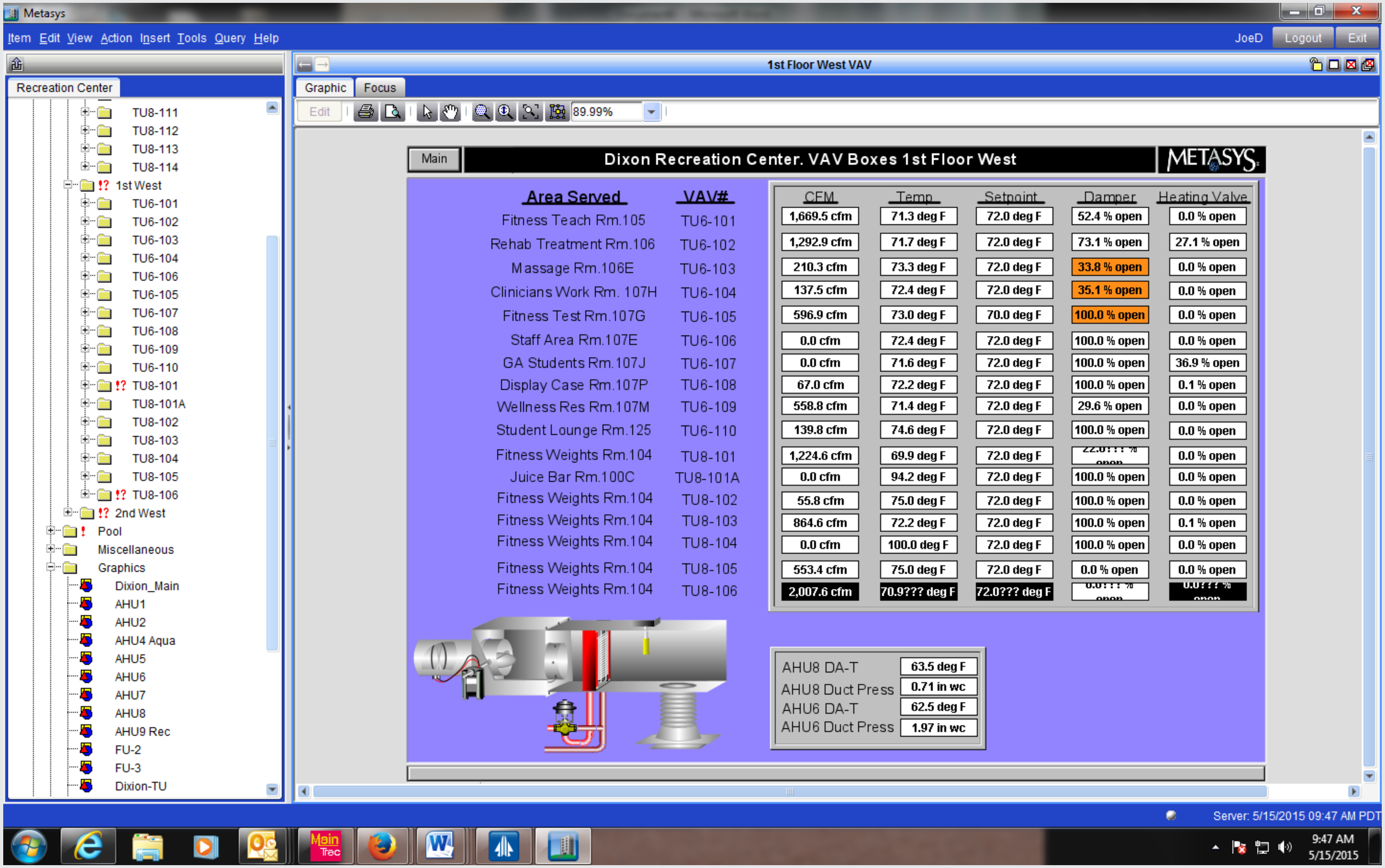
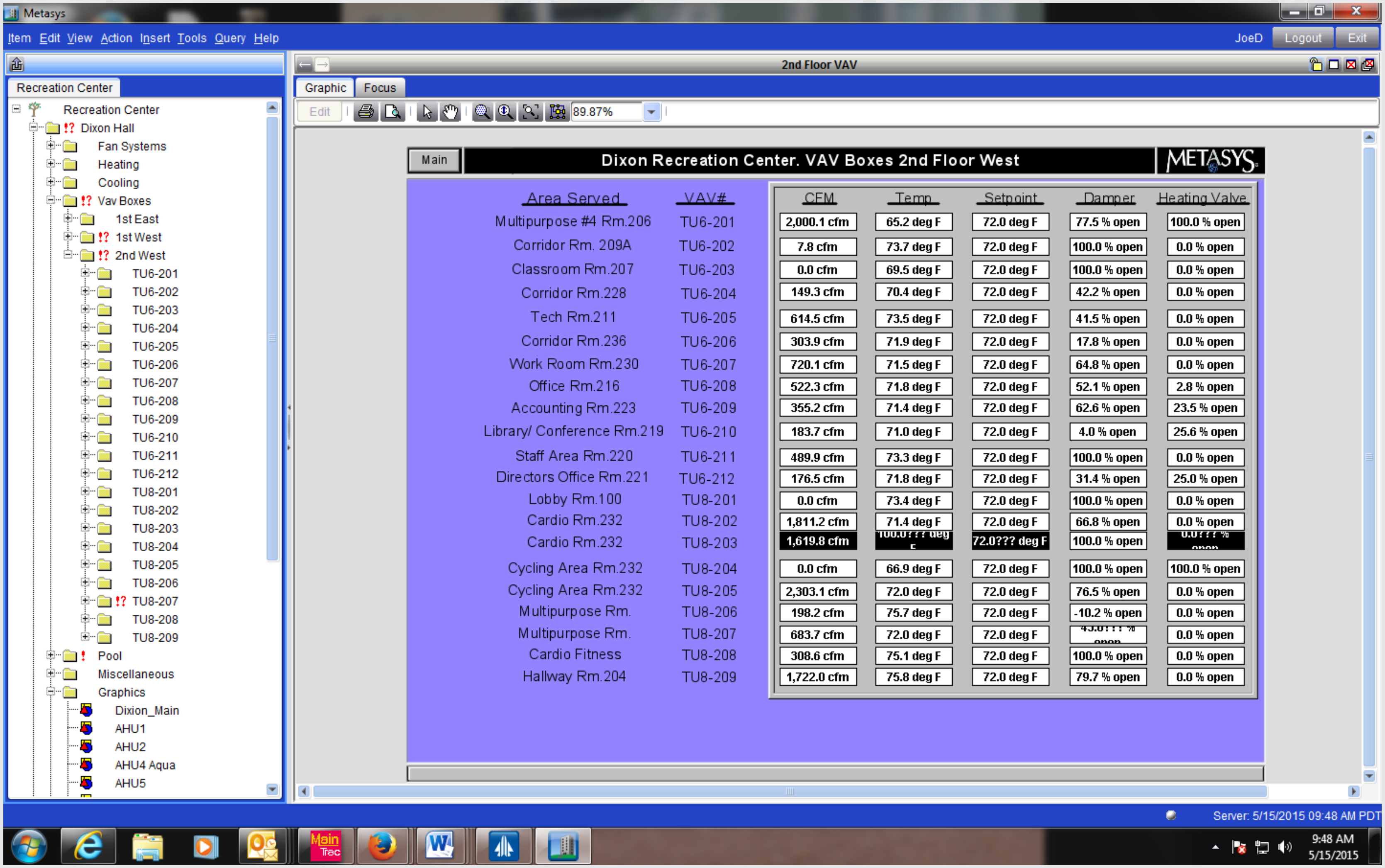


Figure 27 – VAV Boxes 1st Floor West



Area Served	VAV#	CFM	Temp	Setpoint	Damper	Heating Valve
Multipurpose #4 Rm.206	TU6-201	2,000.1 cfm	65.2 deg F	72.0 deg F	77.5 % open	100.0 % open
Corridor Rm. 209A	TU6-202	7.8 cfm	73.7 deg F	72.0 deg F	100.0 % open	0.0 % open
Classroom Rm.207	TU6-203	0.0 cfm	69.5 deg F	72.0 deg F	100.0 % open	0.0 % open
Corridor Rm.228	TU6-204	149.3 cfm	70.4 deg F	72.0 deg F	42.2 % open	0.0 % open
Tech Rm.211	TU6-205	614.5 cfm	73.5 deg F	72.0 deg F	41.5 % open	0.0 % open
Corridor Rm.236	TU6-206	303.9 cfm	71.9 deg F	72.0 deg F	17.8 % open	0.0 % open
Work Room Rm.230	TU6-207	720.1 cfm	71.5 deg F	72.0 deg F	64.8 % open	0.0 % open
Office Rm.216	TU6-208	522.3 cfm	71.8 deg F	72.0 deg F	52.1 % open	2.8 % open
Accounting Rm.223	TU6-209	355.2 cfm	71.4 deg F	72.0 deg F	62.6 % open	23.5 % open
Library/ Conference Rm.219	TU6-210	183.7 cfm	71.0 deg F	72.0 deg F	4.0 % open	25.6 % open
Staff Area Rm.220	TU6-211	489.9 cfm	73.3 deg F	72.0 deg F	100.0 % open	0.0 % open
Directors Office Rm.221	TU6-212	176.5 cfm	71.8 deg F	72.0 deg F	31.4 % open	25.0 % open
Lobby Rm.100	TU8-201	0.0 cfm	73.4 deg F	72.0 deg F	100.0 % open	0.0 % open
Cardio Rm.232	TU8-202	1,811.2 cfm	71.4 deg F	72.0 deg F	66.8 % open	0.0 % open
Cardio Rm.232	TU8-203	1,619.8 cfm	100.0??? deg F	72.0??? deg F	100.0 % open	0.0??? % open
Cycling Area Rm.232	TU8-204	0.0 cfm	66.9 deg F	72.0 deg F	100.0 % open	100.0 % open
Cycling Area Rm.232	TU8-205	2,303.1 cfm	72.0 deg F	72.0 deg F	76.5 % open	0.0 % open
Multipurpose Rm.	TU8-206	198.2 cfm	75.7 deg F	72.0 deg F	-10.2 % open	0.0 % open
Multipurpose Rm.	TU8-207	683.7 cfm	72.0 deg F	72.0 deg F	45.0??? % open	0.0 % open
Cardio Fitness	TU8-208	308.6 cfm	75.1 deg F	72.0 deg F	100.0 % open	0.0 % open
Hallway Rm.204	TU8-209	1,722.0 cfm	75.8 deg F	72.0 deg F	79.7 % open	0.0 % open

Figure 28 – VAV Boxes 2nd Floor West

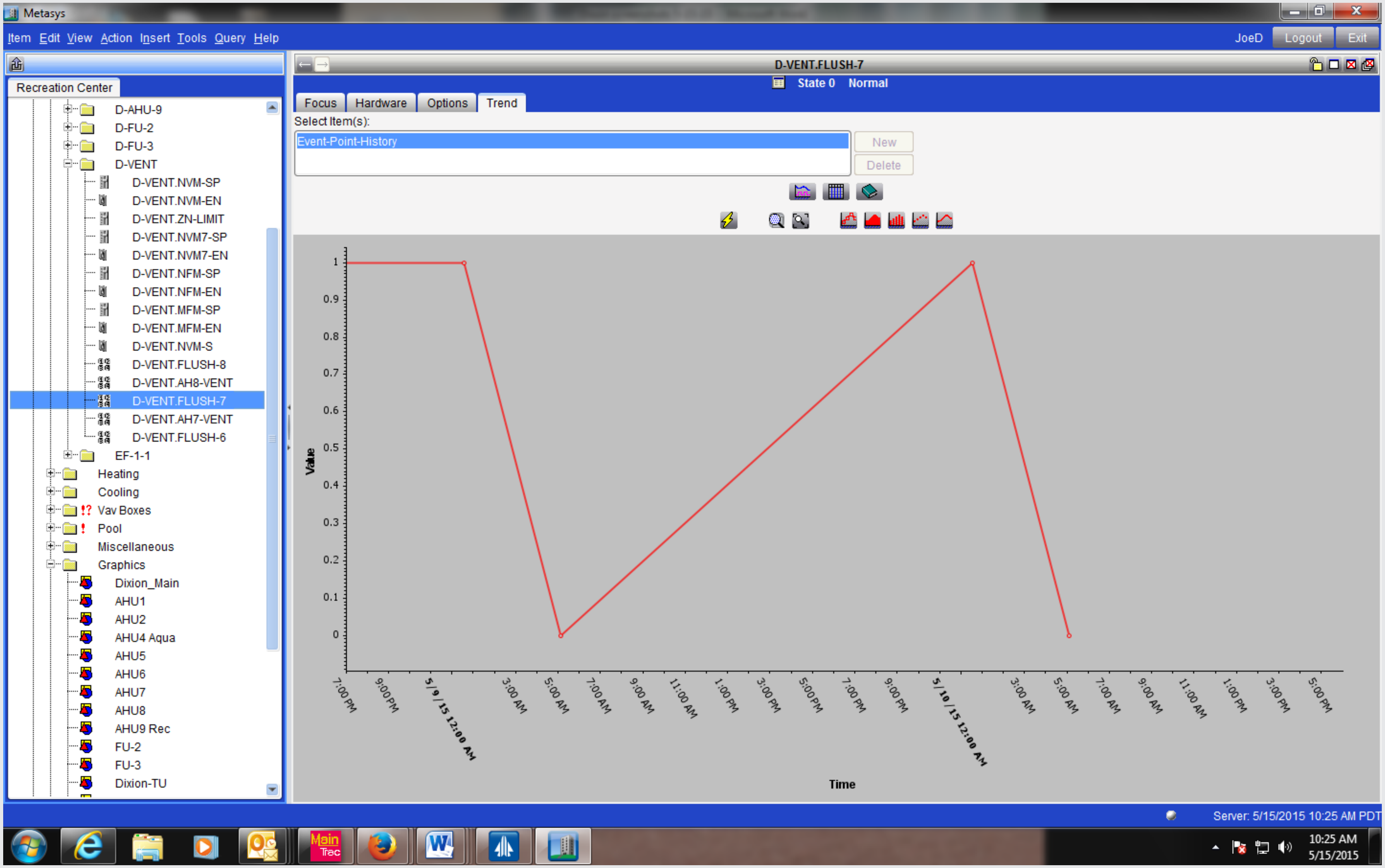


Figure 29 – AHU-7 Night Flush

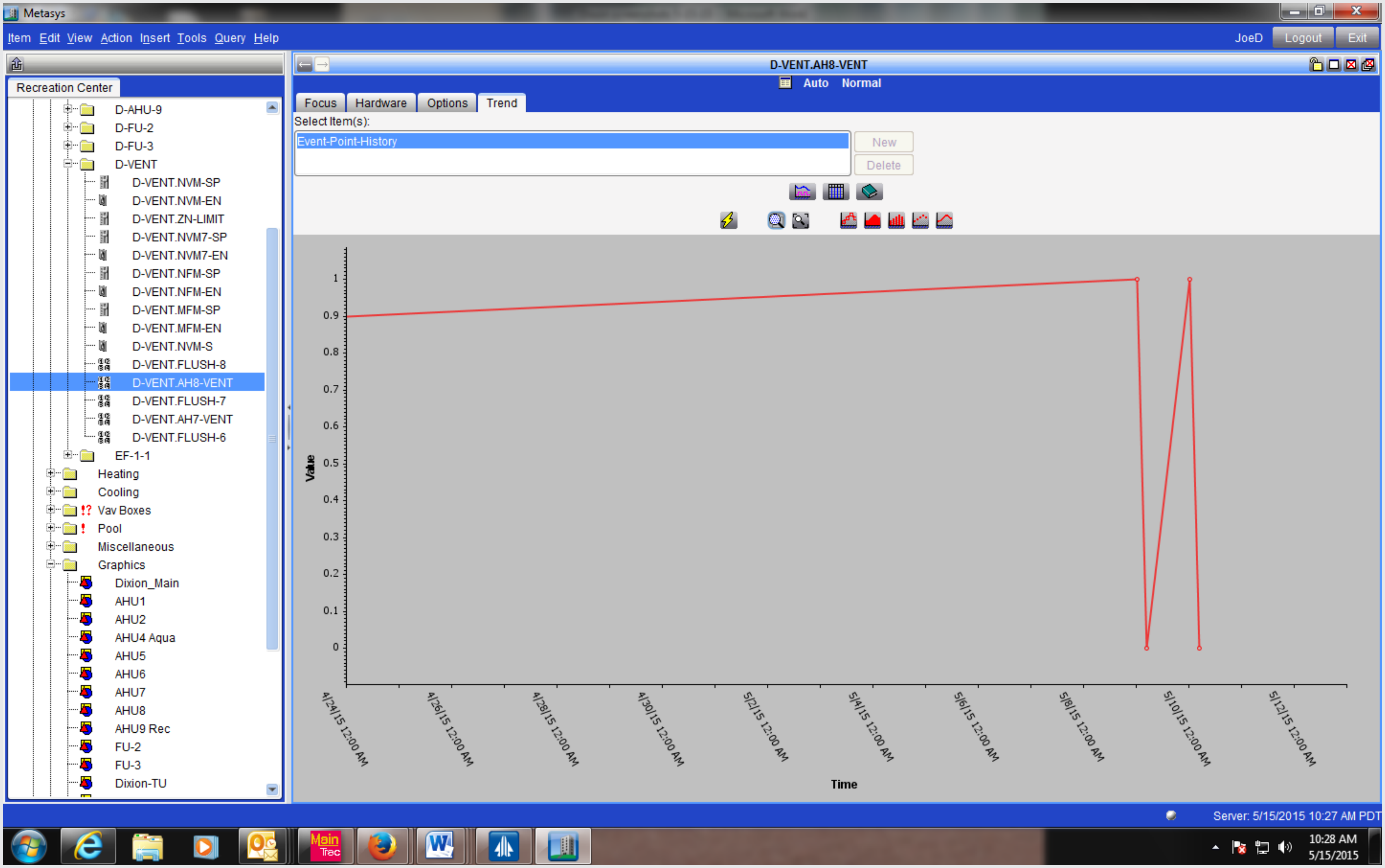


Figure 30 – AHU-8 Night Flush

Appendix C: Review Of Previous Studies

C.1 DIXON RECREATION CENTER NATATORIUM RETRO-COMMISSION REPORT

A retro-commissioning effort for the Dixon Recreation Center Natatorium was completed by Systems West Engineers on June 5, 2008.

C.1.1 KEY FINDINGS & RECOMMENDATIONS

- Replace energy recovery exhaust air damper.
  - It is our understanding that this work has been completed and was successful in achieving the intent of the measure.
- Replace existing pneumatic damper and valve actuators with electronic actuators.
  - It is our understanding that this work has not been completed.
- Diagnose and repair energy recovery system.
  - It is our understanding that this work has not been completed.
- Isolate existing bypass damper between mixed air section and exhaust air duct.
  - It is our understanding that this work has not been completed.
- Calibrate existing control device.
  - It is our understanding that this work has not been completed.
- Relocated return air temperature sensor to provide a better representation of the actual return are temperature.
  - It is our understanding that this work has not been completed.
- Modify control sequence of operation to improve temperature and humidity control and ventilation. This will include the addition of several field mounted control devices.
  - It is our understanding that this work has not been completed.
- Install variable frequency drives on the supply and exhaust fans to allow the fans to reduce speed during unoccupied hours and low occupancy times and increase speed during high occupancy times.
  - It is our understanding that this work has been completed and was successful in achieving the intent of the measure.
- Modify existing air distribution ductwork in natatorium to improve airflow.
  - It is our understanding that this work has been completed and was successful in achieving the intent of the measure.
- Rebalance the natatorium air distribution system
  - It is our understanding that this work has been completed and was successful in achieving the intent of the measure.
- Install variable frequency drives on the lap pool circulation pumps