VETERANS MEMORIAL COLISEUM

ALLIANT ENERGY CENTER
RETROCOMMISSIONING REPORT

MADISON, WI

JANUARY 30, 2015

7475 Hubbard Ave, Suite 201 ● Middleton, WI 53562 ● 608.836.4488 ● Fax 608.836.4477 ● www.sustaineng.com

EXECUTIVE SUMMARY

Sustainable Engineering Group (SEG) was contracted by Dane County Alliant Energy Center to complete retrocommissioning investigation phase services at the Veterans Memorial Coliseum. Retrocommissioing (RCx) is a collaborative process between the RCx consultant and building staff that evaluates how building systems are operated and maintained, and then identifies ways to improve overall building performance including thermal comfort, energy performance, indoor air quality, and system functionality. The scope of work focused on the HVAC system, but also included domestic hot water and lighting.

Originally built in 1967 and renovated in 1996, the Coliseum is an event venue for sports, concerts, and entertainment productions. It is approximately 106,604 ft^2 and has a maximum capacity of 10,000 visitors. The facility can be set up for ice events and has a basketball court. The Coliseum previously hosted between 15-20 events per year, but now hosts a Hockey team with additional ice rink use.

Equipment Assessment
An equipment assessment was done for the major HVAC equipment in the building. The equipment age varies from original installation to 2014 when the steam coils were replaced. Though the equipment is currently running, expected life has been exceeded in many cases and failure of major equipment will be more common. The equipment has been generally well maintained over its lifespan.

Focus on Energy Retrocommissioning Project
This Retrocommissioing project is part of the Focus on Energy retrocommissioning incentive program. During the investigation phase we have identified short payback energy savings measures, upgrade/retrofit energy savings measures and facility improvement measures (not focused on energy savings). The measures include:

- Lighting control replacement
- Boiler tuning
- Ammonia chiller plant optimization
- AHU control sequence revision
- Steam Trap Repair

Short Payback Measures			
Projected Electric Savings		324,486	kWh
Projected Natural Gas Savings		7,845	therms
Cost Savings	$	45,138	
Cost of Measures	$	45,338	
Simple Payback		1.00	years
Capital Retrofits/Upgrades			
Projected Electric Savings		0	kWh
Projected Natural Gas Savings		24,924	therms
Cost Savings	$	16,896	
Cost of Measures	$	167,320	
Simple Payback		9.90	years

The short payback measures have a payback well below the 5 year target set for this project. Since the operating hours of the building depend on the event schedule, these paybacks are expected to scale linearly with building usage, for example the more hours the building is occupied, the shorter the payback for a measure will be. The next step of the RCx process is to review the measures and break them RCx implementation measures and future implementation measures based on Dane County's current project criteria. Incentives from Focus on Energy programs are available for all identified measures and help buy the payback of the measures down.

TABLE OF CONTENTS

RETOCOMMISSIONING PLAN

BUILDING INFORMATION

Originally built in 1967 and renovated in 1996, the Coliseum is an event venue for sports, concerts, and entertainment productions. It is approximately 106,604 ft^2 and has a maximum capacity of 10,000 visitors. The main floor of the facility can be set up for ice events and has a basketball court. The concourses around the main bowl can be used for trade show space. The last few years the Coliseum hosted between 15-20 events per year, and was vacant for a majority of the time in between. This year the Madison Capitols Hockey team is playing there season at the Coliseum and has increased the number of ice rink events held during the hockey season.

GOALS AND SCOPE OF THE RETROCOMMISSIONING PROJECT

The goals of this project are listed as follows:

1. Generate report of the condition of the current building equipment
2. Identify opportunities for cost effective reductions in energy consumption
3. Improve indoor conditions for building occupants
4. Document and refine operating and maintenance information and procedures
5. Help building staff and occupants understand the building systems better
6. Create a conditioning report for major mechanical systems in the building

Building systems included in the scope of this project are:

1. Heating, Ventilating and Air Conditioning (HVAC) Systems, including
    a. Air handling units
    b. Steam Boiler Heating System
    c. Chilled Water Cooling Systems
2. Lighting
3. Domestic Hot Water
4. Ice Making Refrigerant System

RETROCOMMISSIOING TEAM

Team Member	Organization	Title	Contact Info	RCx Involvement
Mark Clarke	Alliant Energy Center	Executive Director	608-267-3982 clarke@alliantenergycenter.com	Owner
William Franz	Alliant Energy Center	CFO	(608) 267-3985 franz@alliantenergycenter.com	Owner
Tim Weber	Alliant Energy Center	Steam Fitter	(608) 576-5139 timweber@countyofdane.com	Building Operations
Alex Harris	Sustainable Engineering Group, LLC	Energy Engineer	(608)836-4488x24 aharris@sustaineng.com	Commissioning Agent Lead
Mike Barnett	Sustainable Engineering Group, LLC	Project Engineer	(608)836-4488x19 mbarnett@sustaineng.com	Commissioning Agent Lead
Svein Morner	Sustainable Engineering Group, LLC	Principal Engineer	(608)836-4488x12 sjshulfer@shulferarchitects.com	Commissioning Agent Manager
Neil Howell	Focus on Energy	Energy Advisor	(715)720-2144 nhowell@cesa10.k12.wi.us	Focus on Energy Representative

RETROCOMMISSIOING ACTIVITIES

1. Audit Phase
    a. Gather utility data of facility (at least 12 months)
    b. Perform utility analysis and end use breakdown
    c. Develop retrocommissioning plan
    d. Gather building documentation
2. Investigation Phase
    a. Operator interview
    b. Create current facility requirements
    c. Document equipment list
    d. Conduct onsite assessment
    e. Perform functional and performance testing on building equipment
    f. Create energy efficiency measure (EEM list
    g. Sort EEMs into short payback and capital planning measures
    h. Select EEMs to be implemented as part of RCx project
3. Implementation Phase
    a. Finish any investigation activities or testing
    b. Implement short payback measures selected in the investigation phase
    c. Document building changes
4. Verification Phase
    a. Observe and trend changes in building performance
    b. Verify measures are performing as intended
    c. Update building documentation and current facility requirements
5. Persistence Phase
    a. Create ongoing commissioning process for facility
    b. Train staff on new procedures and ongoing commissioning process
    c. Verify implemented measures persist in future facility usage

PROJECT SCHEDULE

Project Stage	Dates
RCx Kickoff	August 2014
Investigation Phase	August 2014- January 2015
Implementation Phase	January 2015- May 2015
Verification Phase	May 2015
Persistence Phase	Summer 2015

UTILITY ENERGY-USE ANALYSIS

For the utility analysis, the three electric meters (E312770, E309862 and E312769) and two gas meters (G099384 and G050412) were studied. Our data analysis period started in January 2012 and ended in December 2014.

Energy Benchmarking for Veterans Memorial Coliseum, 2013					
Area [ft^2]	Energy Use Intensity - Site [$kBTU/ft^2/yr$]	Energy Use Intensity - Source [$kBTU/ft^2/yr$]	Energy Cost [$/yr]	Energy Cost Intensity [$/$ft^2$/yr]	Energy Star Score* (1-100)
106,604	121.3	206.2	$ 230,652	$ 2.16	NA*
***Note- Energy star score is unavailable for indoor arena building types. No other building types that a score was available for were close enough to the usage at the Coliseum to be relevant.**					

Since the start of the Capitols Hockey team season in October 2014, there has been an increase in usages of the energy systems at the Coliseum. The previous year's data will not accurately predict future usage for energy savings paybacks and comparison. For this reason we have estimated the new annual usage for the Coliseum based on data from October- December 2014 (below).

Energy Benchmarking for Veterans Memorial Coliseum, 2015 (Predicted)					
Area [ft^2]	Energy Use Intensity - Site [$kBTU/ft^2/yr$]	Energy Use Intensity - Source [$kBTU/ft^2/yr$]	Energy Cost [$/yr]	Energy Cost Intensity [$/$ft^2$/yr]	Energy Star Score* (1-100)
106,604	162.6	276.4	$ 312,887	$ 2.94	NA*
***Note- Energy star score is unavailable for indoor arena building types. No other building types that a score was available for were close enough to the usage at the Coliseum to be relevant.**					
****Note- This energy usage and cost is estimated based on the data we have from 2014 when the ice rink was maintained for Hockey games. It should give a better performance indicator for when Hockey is being played regularly at the Coliseum.**					

The predicated Energy Use Intensity (EUI) of the Veterans Memorial Coliseum is 162 kBtu/ft^2 in 2015. There is an estimated difference in annual utility cost before and after the Capitols hockey team started to play of $82,235 per year.

Energy Consumption Summary Predicted for 2015		
Electric (kW-hr)	Max Peak Demand (kW)	Natural Gas (Therms)
2,298,005	854	95,240

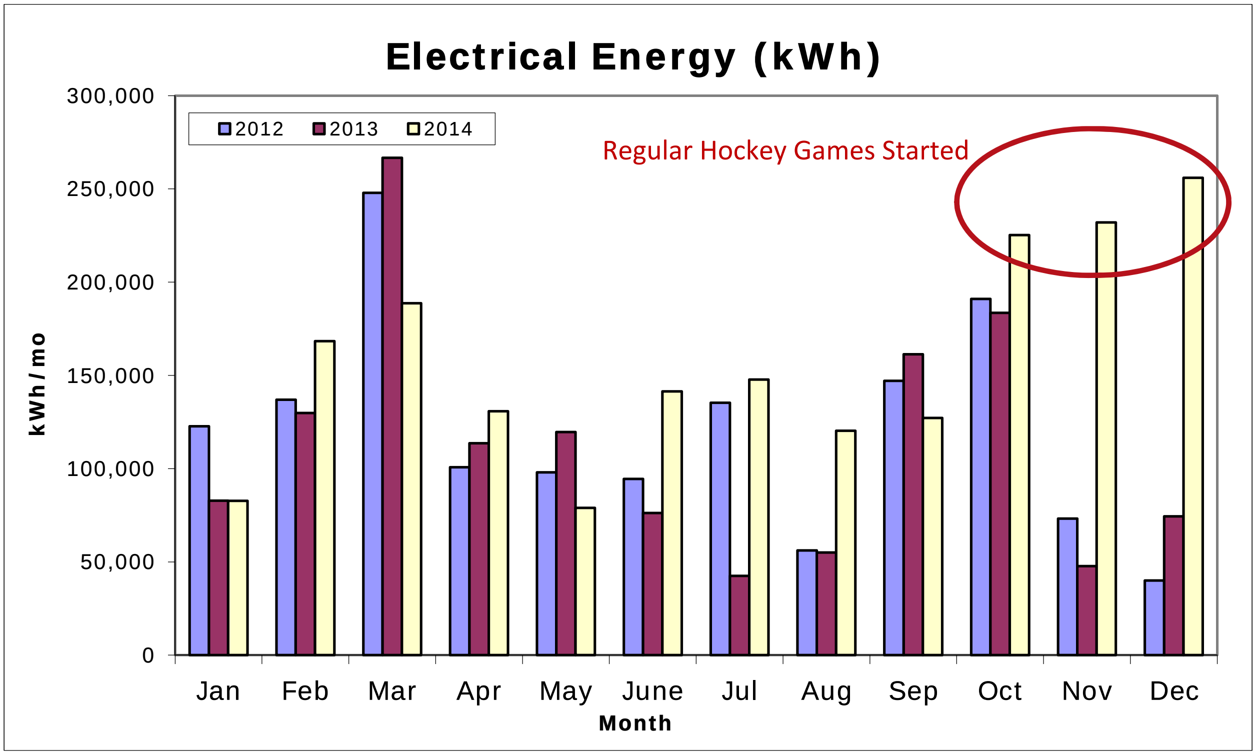

Figure 1- Electric Consumption History

Electric consumption looks very sporadic, following the events schedule of the facility. The increase in usage can be traced back to the E312770 meter that reports usage from the refrigeration equipment to make ice for the ice rink. The Spike in usage in March is likely due to making ice to the WIAA High School Hockey tournament held then. In 2014, with regular ice rink usage in the fall, the ice rink refrigeration meter has increased substantially, similar to increases seen when ice was made for the March Hockey tournament. September and October usage may be due to the World Dairy Expo held during that time.

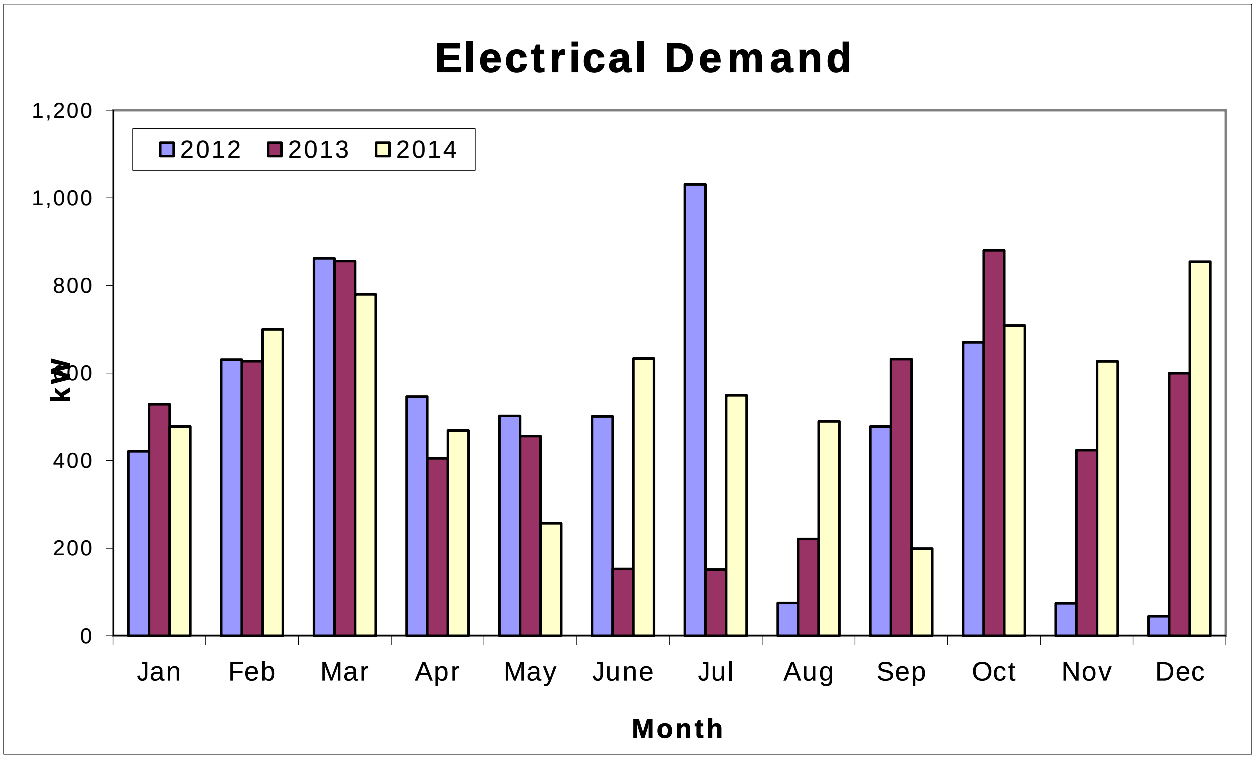

Figure 2- Monthly Peak Electric Demand

The demand profile for the building is a bit sporadic; most likely do the variety of events that are held at the Veterans Memorial Coliseum. Large events such as the WIAA Hockey Tournament and the World Dairy Expo show up again here on the demand trend for the facility.

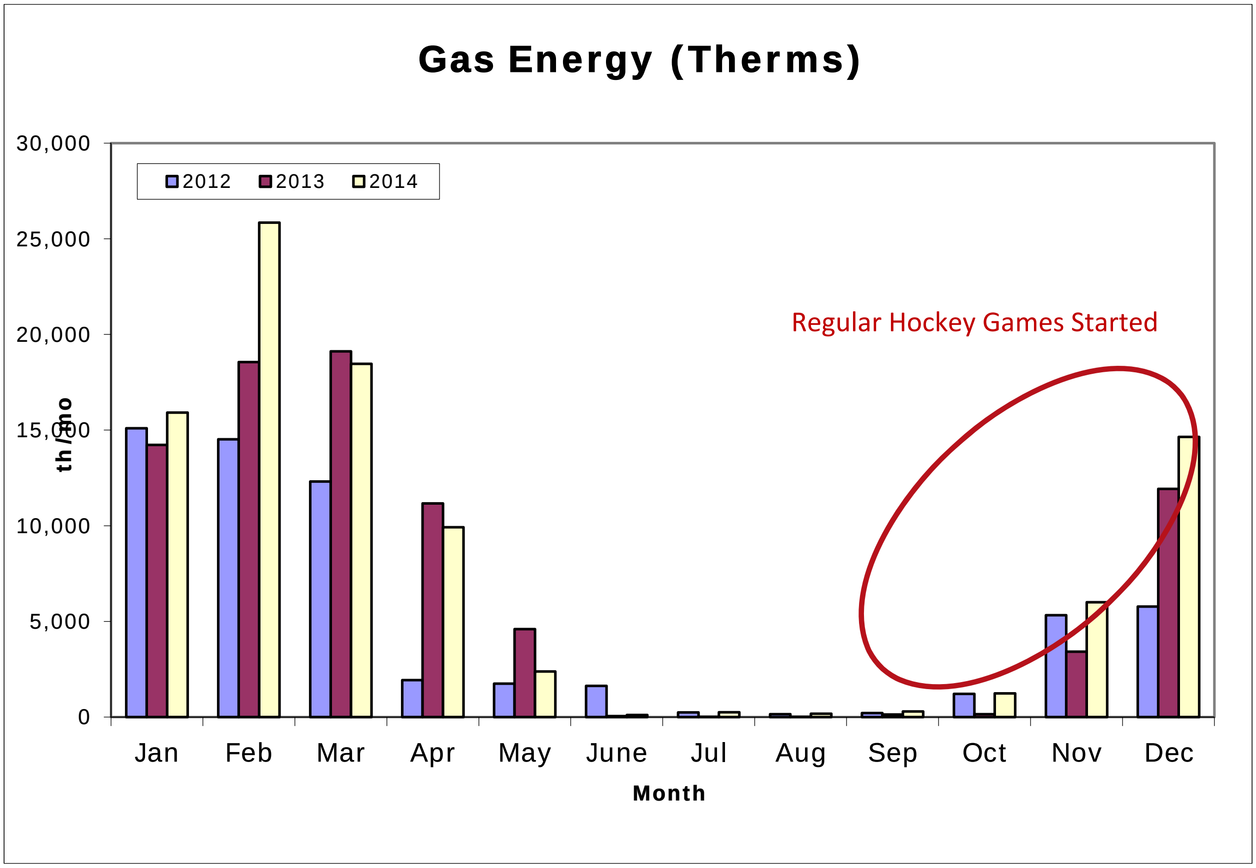

Figure 3- Natural Gas Consumption History

February of 2014 stand out as higher usage of natural gas, though per HDD March uses the most. This may be attributed to keeping the space temperature warm while the ice making equipment is running and rejecting heat for the WIAA Hockey Tournament.

It is interesting to note that the Hockey season start in 2014 only had a small increase on the gas usage in Oct, Nov, or Dec (unlike the large increase in electric usage). This may point to other heating loads that are the cause of most of the gas usage, possibly the building perimeter heating.

15 minute demand data was analyzed for the two electric meters using ECAM excel software. Since the electric usage was so varied throughout the year, month and week, the analysis was not conclusive as to energy usage patterns.

EQUIPMENT ASSESMENT

This retrocommissioning project includes a detailed look at the condition of the HVAC equipment, but also summarizes the current domestic hot water and lighting systems. The HVAC equipment at the Coliseum building is a mix of original 1967 equipment, and equipment that has been replaced on an as needed basis. General maintenance looks good and most equipment is working.

AIR DISTRIBUTION SYSTEM

The main bowl of the Coliseum is served by four large constant volume AHUs, each serving a fourth of the arena. Other spaces in the building, such as restrooms and concession stands, are served by exhaust fans that pull air from the general space. The large AHUs have original fans, dampers, cooling coils, and pneumatic control actuators, with replacement steam coils, motors, and some digital control actuators.

Figure 4- Example AHU fan, motor and belt drive

Each AHU consists of a 125 hp supply fan motor powering the supply fan. Air is distributed along the ceiling of the Coliseum roof line and pulled through the return grills at the arena floor level. There are return fans beneath the seating areas that move air under the concourse and back to the AHU rooms. There are outside air dampers that mix with return air before passing over the filters, steam coils, and cooling coils respectively. There are 8 high ceiling exhaust fans that remove air from the building from the top of the dome.


Figure 5- Example older cooling coil and new steam coil

Figure 6- Pneumatic actuators that have been disconnected and replaced with digital

Figure 7- Example of water in return air path

One issue noted was the return air tunnel/chase is also used as a sump pit for draining water. These return chases were observed with standing water in them and sump pump installed to remove the water with float control. This is a potential indoor air quality issue, and is addressed in our additional finding section at the end of the report.

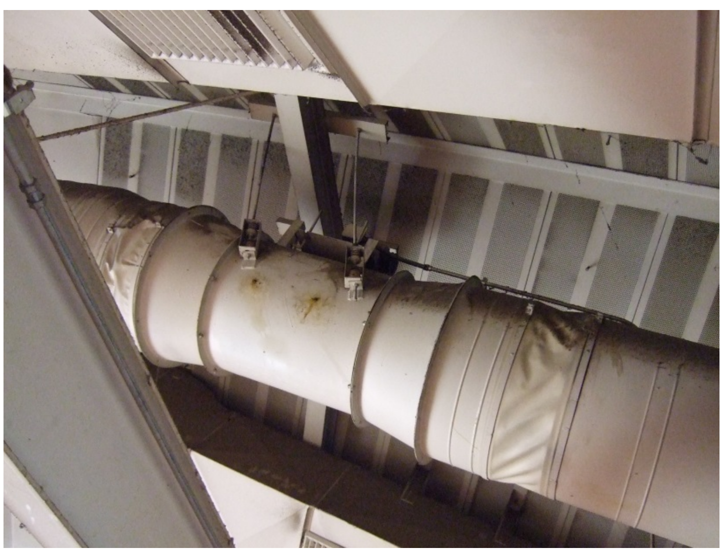

Figure 8- Example exhaust fans in ceiling above seating area

There are 8 exhaust fans that pull air from the upper dome to the exterior of the building. These are the only relief path for outside air introduced through the four central AHUs.

Figure 9- Two supply diffusers and exhaust fan in between

Figure 10- Example rooftop exhaust fan

Several exhaust fans were noted throughout the facility serving the restrooms, ticketing offices, and concession stands.

Table 1- Air Side HVAC Equipment

Equipment	Location	Serves	Supply Flow Rate [cfm]	Heating Coil Type	Cooling Coil Type	Installed Date	Remaining Lifespan [yrs]
AHU 1	Basement Level	North East Arena	Unknown	Steam Coil	CW Coil	1967	0 years*
AHU 2	Basement Level	South East Arena	Unknown	Steam Coil	CW Coil	1967	0 years*
AHU 3	Basement Level	South West Arena	Unknown	Steam Coil	CW Coil	1967	0 years*
AHU 4	Basement Level	North West Arena	Unknown	Steam Coil	CW Coil	1967	0 years*
EF 1	Arena Ceiling	1/8 Arena	Unknown	-	-	1967	0 years*
EF 2	Arena Ceiling	1/8 Arena	Unknown	-	-	1967	0 years*
EF 3	Arena Ceiling	1/8 Arena	Unknown	-	-	1967	0 years*
EF 4	Arena Ceiling	1/8 Arena	Unknown	-	-	1967	0 years*
EF 5	Arena Ceiling	1/8 Arena	Unknown	-	-	1967	0 years*
EF 6	Arena Ceiling	1/8 Arena	Unknown	-	-	1967	0 years*
EF 7	Arena Ceiling	1/8 Arena	Unknown	-	-	1967	0 years*
EF 8	Arena Ceiling	1/8 Arena	Unknown	-	-	1967	0 years*

**0 years of equipment life left does not mean equipment is not running, rather it has exceeded the expected replacement age of the equipment type. Failure of components will become more common and maintenance may exceed replacement cost in the future.*

HEATING PLANT

The heating plant consists of two original 1967 Kewanee steam boilers. These two boilers have had new linkageless burners installed on them in 2013.

Figure 11- Steam boilers with new burners and controls

Figure 12- Boiler feedwater tank and feedwater pumps

Perimeter Heating

Perimeter and entry way areas of the coliseum are heated by a mix of steam fan coil units, steam unit heaters and hot water in floor heating. The perimeter heating systems are not part of the BAS and run based on their own local thermostats and setpoints.

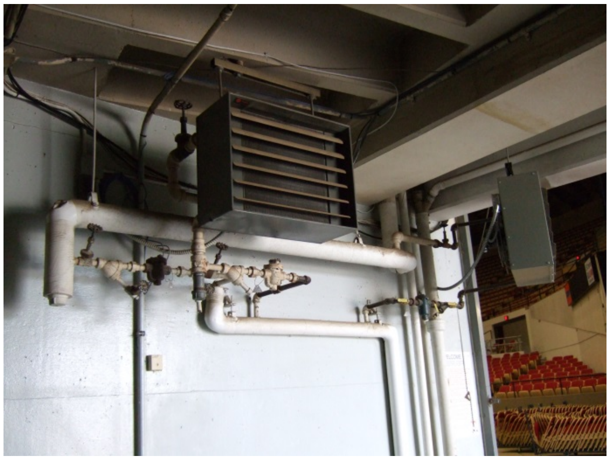

Figure 13- Example steam fan coil unit at service entrance to main floor

Figure 14- Entryway steam unit heater with thermostat controlling steam valve

Figure 15- Hot water pump and steam control valve for one of the in floor heating loops serving the East entrance

Table 2- Heating Plant Equipment

Equipment	Location	Serves	Type	Size	Estimated Efficiency	Date Installed	Remaining Lifespan [yrs]
Boiler 1	Mech Room	Whole building	Steam	6300 Mbh	80%	1967	10 years
Boiler 2	Mech Room	Whole building	Steam	6300 Mbh	80%	1967	10 years
Feedwater Pump 1	Mech Room	Boilers	Centrifugal	2 hp	-	1967	0 years*
Feedwater Pump 2	Mech Room	Boilers	Centrifugal	2 hp	-	1967	0 years*
Feedwater Pump 3	Mech Room	Boilers	Centrifugal	2 hp	-	1967	0 years*
**0 years of equipment life left does not mean equipment is not running, rather it has exceeded the expected replacement age of the equipment type. Failure of components will become more common and maintenance may exceed replacement cost in the future.*							

COOLING SYSTEM

The cooling plant consists of 2 chillers, one Carrier water cooled chiller and an ammonia refrigeration system (discussed as part of the ice making equipment section). The ammonia system can be used to cool the AHU cooling loop or the ice rink cooling loop. The Carrier chiller is connected to the AHU cooling loop, but rarely used, as not many events require mechanical cooling at the Coliseum. The Carrier chiller was installed in 1992, and has a capacity of 465 tons.

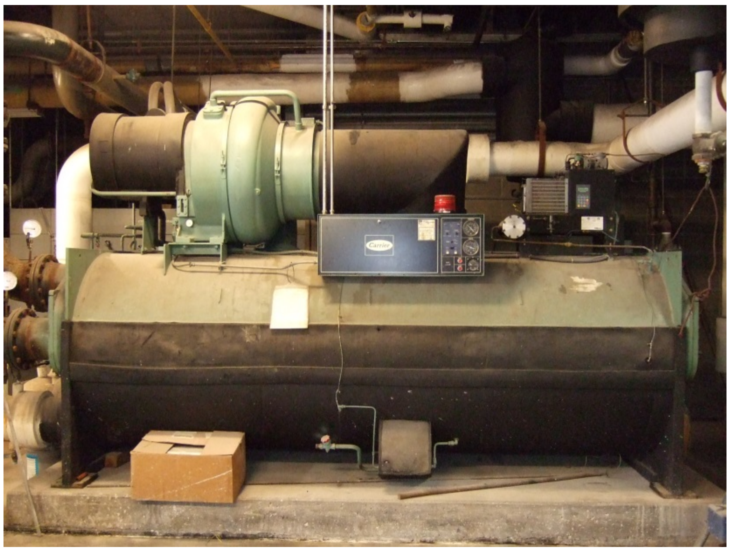

Figure 16- Carrier chiller serving AHU cooling loop

There are two cooling towers on the roof of the mechanical room. One serves the carrier chiller condenser water loop and the other serves the ammonia chiller. This carrier chiller cooling tower design uses the bottom of the cooling tower as a sump. It was noted that a lot of water scale had built up in the bottom of this cooling tower sump, and staff do not currently treat the condenser water for scaling.

Figure 17- Cooling tower for Carrier chiller on roof of mechanical building

Figure 18- Scale build-up in the bottom if the cooling tower sump

Table 3- AHU Cooling Equipment

Equipment	Location	Serves	Size	Refrigerant Type	Estimated Efficiency	Date Installed	Remaining Lifespan [yrs]
Water Chiller	Mech Room	AHUs	465 tons	R11	12 EER	1991	2 years
Cooling Tower	Above Mech Room	Water Chiller	-	-	-	1991	0 years*
Condenser Water Pump	Mech Room	Water Chiller	20 hp	-	-	1991	2 years
Primary Loop Pump	Mech Room	Water Chiller	20 hp	-	-	1991	2 years
**0 years of equipment life left does not mean equipment is not running, rather it has exceeded the expected replacement age of the equipment type. Failure of components will become more common and maintenance may exceed replacement cost in the future.*							

Figure 19- Piping run for cooling and heating between the mechanical room and the Coliseum building

ICE MAKING REFRIGERANT PLANT

Below is a summary of the equipment installed at the Alliant Energy Center that is directly associated with the ammonia refrigeration system.

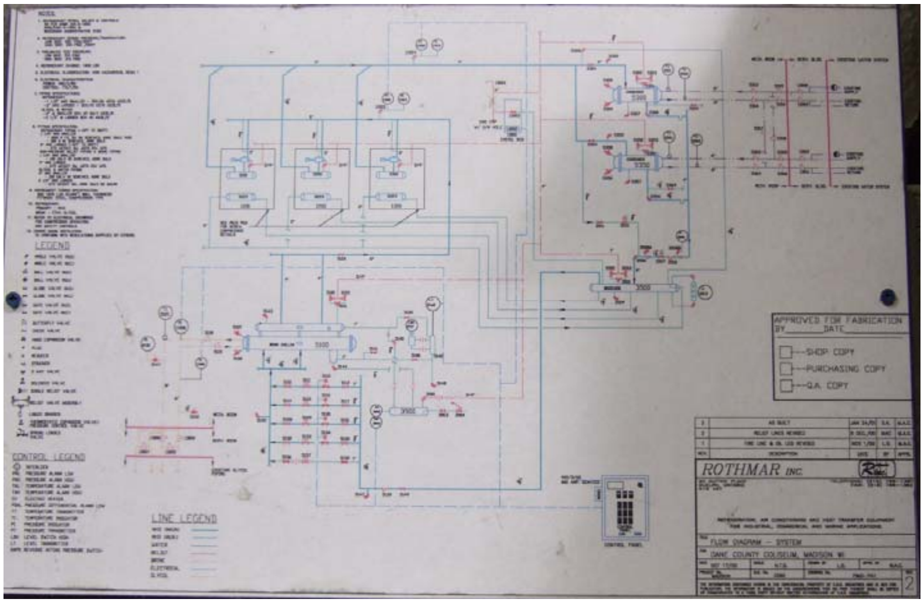

Figure 20- P&ID diagram of compressor layout

Figure 21- Three screw compressors for the ammonia refrigeration

Figure 22- Evaporator, condensers and high pressure/thermosiphon receiver for ammonia chiller

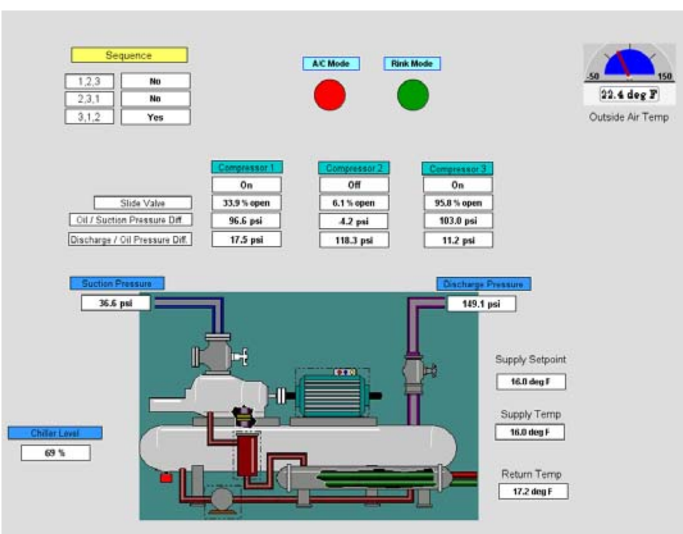

Figure 23- Chiller control graphic

The ammonia chiller has two separate condenser water loops, each with their own condenser loop cooling tower, pump, sump and heat exchanger.

Figure 24- Two cooling towers serve the ammonia chiller condenser loops

There was several water leaks observed on the two water towers in use. While this increases the amount of make-up water needed, the real problem is the ice buildup in the freezing temperatures from the leaks.

Figure 25- Example of water leaks that have formed significant ice on the cooling tower in winter

Table 4- Ammonia Refrigeration Equipment Table

Compressor	Model Number	Motor	Date Installed	Remaining Lifespan
Compressor 1 (Kobelco)	13LV (GB Series)	Lincoln SD2P125TS61Y	2000	20 year
Compressor 2 (Kobelco)	13LV (GB Series)	Lincoln SD2P125TS61Y	2000	20 year
Compressor 3 (Kobelco)	13LV (GB Series)	GEA R125360T3G404TS	2000	20 year
Condenser (x2)	CA 20180 200	-	2000	20 year
Evaporator/Oil Cooler	RA-24180-509	-	2000	20 year
Chil-con TSOC (26 TR)	TSOC-026-05084	-	2000	20 year
Oil Separator	-	-	2000	20 year
Cooling Towers				
Baltimore Air Coil	3424 (3000 series)	Hi/Low Speed	1997	3 Years
Baltimore Air Coil	3424 (3000 series)	Hi/Low Speed	1997	3 Years
Glycol Pump	Unknown	Allis Chalmers 60 HP	1968	0 Years
**0 years of equipment life left does not mean equipment is not running, rather it has exceeded the expected replacement age of the equipment type. Failure of components will become more common and maintenance may exceed replacement cost in the future.*				

The bulk of this equipment was installed in 2000 time period. The major exception is the glycol pump which is original to the 1967 system.

Operational History

Over the past several years, the ammonia system was run only for the WIAA state boys and girls hockey tournaments held in March. Total operational time was limited to 2 weeks, unless another event was scheduled. In all cases, the ice would be built for the event and then removed upon completion. This provided very little runtime on the compressors and other equipment. Therefore, very little operational history is available.

The ammonia system can also be used to provide chilled glycol to the 4 air handlers in the facility for space conditioning. To the knowledge of the staff interviewed, this has not been performed in the recent past either.

Current Operation

With the recent addition of the Madison Capitols hockey team, the ammonia system will be used to maintain an ice surface for the entire hockey season. The season began in late September and wraps up in mid-April. A contract exists for the Capitols to play for 5 years.

The ice surface is maintained at 18°F and a thickness of 1 to 1.5 inches. Normal ice surface temperature (IST) for a hockey facility is in the range of 20F to 22F but the facility must maintain the lower temperature to re-freeze the ice after ice resurfacing between periods.

The compressors are controlled via the glycol return temperature. The compressors normally run at a suction pressure of 37 psia (8F) and a discharge pressure of 155 psia (81F). The glycol is cooled in a shell and tube heat exchange with liquid feed being controlled by 4 separate feed solenoids and associated hand expansion valves. One of them is marked “AHU” and is thought to be set to a higher pressure to provide warmer glycol when the unit is being used to condition the air instead of building/maintaining an ice surface.

The ice arena sees only mild use for the Capitols games and a few practices. During standby, the compressor sequencing is shown in **Error! Reference source not found.**. When in use, the load increases to nearly 2 full compressors.

	Run Status	Slide Valve Position	Suction Pressure	Discharge Pressure
Compressor 1	On	9.9% open	37 psia	155 psia
Compressor 2	Off	-	-	-
Compressor 3	On	94.4% open	37 psia	155 psia

Figure 26- Typical conditions of screw compressors

System Condition

As part of the walk through, the investigators were asked to provide an opinion of the current condition of the system. This was not a formal Mechanical Integrity audit as outlined by IIAR (International Institute of Ammonia Refrigeration) or required under OSHA’s PSM program (29 CFR 1910.119 (j)). Rather this is an opinion based on a cursory visual observation.

The external condition of the system showed signs of aging. There were several locations, especially valve bodies that suffered a surface level of corrosion or worse. Likewise, there were multiple indications of moisture intrusion under the insulation system that could lead to corrosion under insulation.

Corrosion under insulation is one of the leading failures of ammonia refrigeration systems. The insulation systems are designed to keep moisture out but when they are compromised, the insulation system works well to hold water against the carbon steel piping and vessels. Several breaks, gaps and other openings were found in the insulation system along with signs that corrosion is occurring under the insulation.

Steps should be taken to remove the insulation, clean up the corrosion and properly re-insulate the system. This should include coating the insulated pipe and vessels with paint or another suitable coating. Additionally, visible corrosion on un-insulated portions of the system should be addressed.

Figure 27. Broken PVC jacket allowing moisture to enter the insulation system.

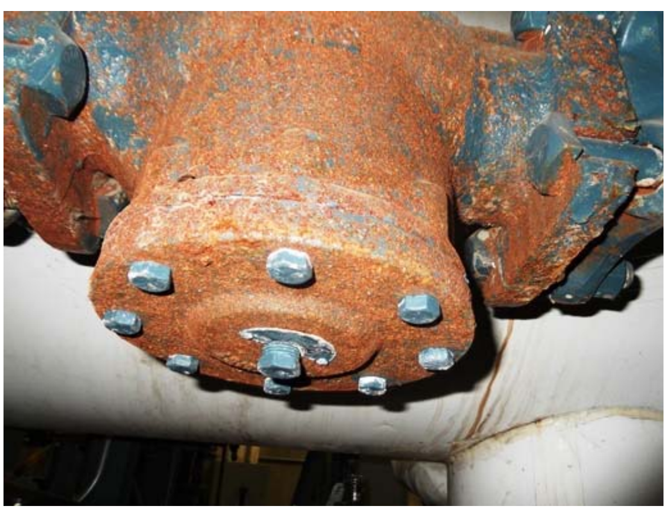

Figure 28. Valve body exhibiting corrosion over a significant portion of its surface.

DOMESTIC WATER HEATING

The domestic hot water heaters at the Coliseum were replaced in 2010 with 3 Bock tank water heaters. There is a circulation pump that keeps the hot water loop warm and is controlled by the Johnson Controls HVAC system.

Figure 29- Domestic hot water heaters

Figure 30- Domestic hot water circulation pump

Table 5- Domestic Hot Water Equipment

Equipment	Location	Type	Storage Capacity	Heat Capacity	Serves	Installed Date	Remaining Lifespan [yrs]
Heater 1	Mech Room	Storage Gas	95 gal	300 Mbh	All facility	2010	15 years
Heater 2	Mech Room	Storage Gas	95 gal	300 Mbh	All facility	2010	15 years
Heater 3	Mech Room	Storage Gas	95 gal	300 Mbh	All facility	2010	15 years
Circ Pump	Mech Room	In Line	N/A	1 hp	All facility	2010	15 years

LIGHTING

Interior Lighting

The Arena area is lit by high bay T8 linear fluorescent lighting. This lighting was retrofitted recently and looks to be well maintained. Several lighting options are available with the different linear fluorescent circuit controls.

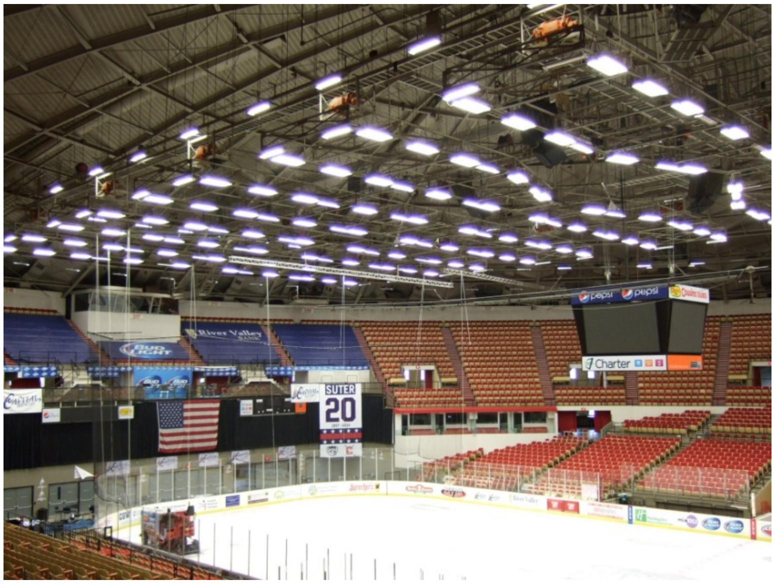

Figure 31- Arena lighting during ice resurfacing

The three levels of concourses outside of the area are mostly lit by linear fluorescent T8 fixtures as well.

Figure 32- Linear florescent T8 fixtures in lower concourse

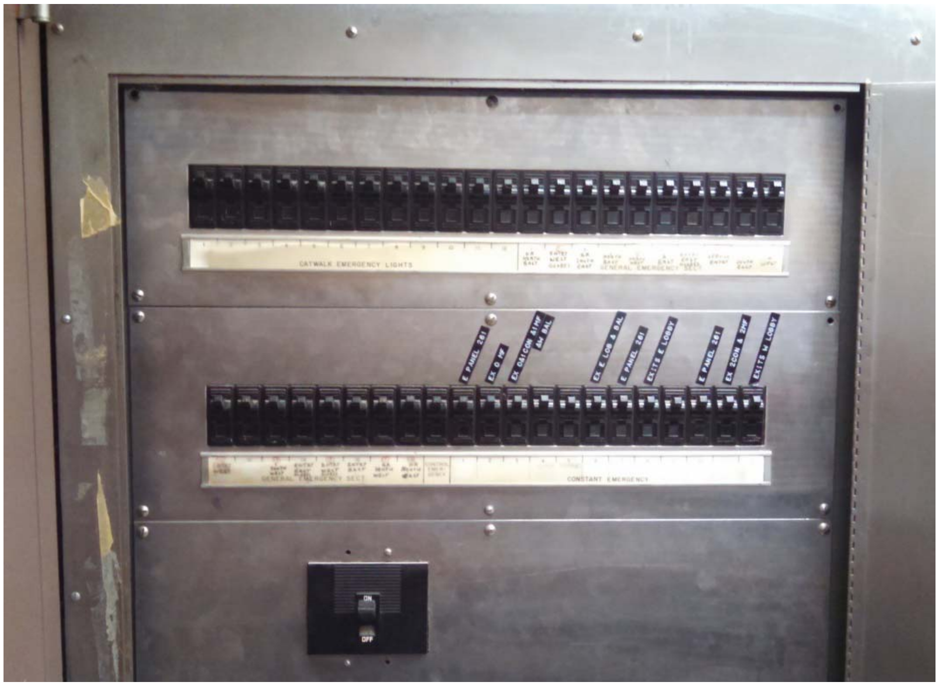

Figure 33- Emergency circuit switch panel

Figure 34- Restrooms and maintenance closets have been fitted with occupancy sensors

Exterior Lighting

There are flood lights mounted on the concourse roof that light the coliseum walls. There are also several walkway lighting fixtures around the entrances of the facility.

Figure 35- Example flood lights and walkway lights

Figure 36- Building lighting at night

BUILDING ENVELOPE

The building envelope appears to have been updated since original 1967 construction, but little has been done to improve its energy efficiency. Double pane glazing has been installed in windows and doors, but wall panels are still poorly insulated. Increasing the insulation and cutting down on air leakage usually has a mid-long term payback and will not be considered in this report, but should be included in any long term (>5 years) facility plans.

Figure 37- Upper concourse exterior wall

Figure 38- Concourse window detail

ENERGY EFFICIENCY MEASURES

ENERGY EFFICIENCY MEASURE MASTER LIST

The following list contains all of the energy savings findings that are part of the retrocommissioning investigation. They are sorted into short payback measures, and major upgrade/retrofit measures. Short payback measures are findings that had a simple payback of less than 3 years with an estimated cost of under $25,000 per measure. All of these measures are recommended to be implemented as part of the retrocommissioning implementation. Capital improvement measures have a payback longer than 3 years or an estimated cost of over $25,000. These are good projects to complete as the budget cycle allows. The next section describes other measures that do not have an energy savings payback associated with implementing them (or it is not possible to determine at this time). They are added to fix comfort or maintenance issues that were discovered as part of the retrocommissioning process.

The measure payback will scale with building usage for lighting and HVAC measures. The relationship should be close to linear, so if the building is used twice as much as it currently is, the payback for a lighting or HVAC measure will be twice as short.

Short Payback Measures		
Projected Electric Savings	324,486	kWh
Projected Natural Gas Savings	7,845	therms
Cost Savings	$ 45,138	
Cost of Measures	$ 45,338	
Simple Payback	1.00	years
Capital Retrofits/Upgrades		
Projected Electric Savings	0	kWh
Projected Natural Gas Savings	24,924	therms
Cost Savings	$ 16,896	
Cost of Measures	$ 167,320	
Simple Payback	9.90	years

EEM #	Equipment or System(s) Affected	Measure Title	Measure- Recommended Improvement	Annual Electric Savings (kWh)	Annual Gas Savings (therms)	Annual Utility Cost Savings	Additional Implementation Cost	Payback (years)	Estimated Focus Incentive*	Category
M01	Lighting Control	Install Lighting Control Panel	Replace with new lighting controls system, web based remote access for custom scheduling of events	193,556	0	$24,930	$21,920.00	0.88	$15,484.48	Short Payback
M02	Carrier Chiller	Chiller Oil Heater Shutdown	Shut down oil heater when chiller will not be used for a long time	7,760	0	$999	$450.00	0.45	$620.80	Short Payback
M03	Boilers	Boiler Staging and Modulation Tuning	Reduce lag boiler cut-in setpoint, tune burner response to steam load for one boiler	0	340	$235	$770.00	3.28	$169.97	Short Payback
M04	Boilers	Steam Trap Survey	Conduct steam trap survey and repair traps that are leaking	0	3,937	$2,716	$3,277.50	1.21	$585.00***	Short Payback
M05	AHU	AHU Heating Sequence	Investigate sequence to see if simultaneous heating and cooling exists	0	1,587	$1,095	$1,280.00	1.17	$793.50	Short Payback
M06	Ammonia Compressor	Ammonia Chiller Increase Suction Pressure by Glycol Temperature Reset	During the time when a game is not being played or the ice is in use, we recommend that the IST be reset to 22F. This 4F increase in ice surface temperature will allow the glycol leaving temperature to be reset from 16F to 20F and the corresponding suction temperature from 8F to 12F. Increase suction pressure when glycol temperature is reset	115,670	1,981	$8,307	$1,410.00	0.17	$10,244.10	Short Payback
M07	Ammonia Compressor	Ammonia Chiller Decrease Head Pressure	We recommend that operations reduce the head pressure setpoint in a slow, methodical manner. Increments of no more than 5 psi are recommended. After each pressure setpoint reduction, the system should be monitored for 1 to 2 weeks for any problems that arise.	7,500	0	$473	$1,220.00	2.58	$600.00	Short Payback

EEM #	Equipment or System(s) Affected	Measure Title	Measure- Recommended Improvement	Annual Electric Savings (kWh)	Annual Gas Savings (therms)	Annual Utility Cost Savings	Additional Implementation Cost	Payback (years)	Estimated Focus Incentive*	Category
M08	Ammonia Compressor	VFD on Ammonia Compressor	If operational changes do not allow lag compressor to turn off for a majority of the runtime, then a VFD could be installed to increase efficiency of lag compressor while lightly loaded.	101,314	0	$6,383	$15,010.00	2.35	$6,250.00	Short Payback
M09	Perimeter Heating	Perimeter Heating Controls	Replace with digital (wireless?) thermostats and link sequence with building schedule	0	3,345	$2,007	$9,320.00	4.64	$1,672.50	Major Retrofit or Upgrade
M10	Ammonia Condenser	Ice Making Heat Recovery	This warm water could be used in other areas such as heating the Zamboni melt pit or heating the Coliseum's air	0	21,579	$14,889	$113,000.00	7.59	$17,262.83	Major Retrofit or Upgrade

* This is the total available Focus on Energy incentive estimated based on successful completion of the retrocommissioning, prescriptive, or custom programs depending on measure type and savings.

** Custom and Prescriptive Incentive Programs

SHORT PAYBACK MEASURES

EEM #1- New Lighting Control Panel

Current lighting controls are set up to manually switch lighting circuits with the breaker and EM panels. This relies on staff to walk the building after hours and turn on or shut off lighting circuits as needed. This leads to inconsistency in lighting and many hours that lights are left on or more lights are turned on than necessary. A lighting control system similar to the exhibition hall that would centralize the lighting circuit control for remote scheduling, save energy and save staff time while ensuring the appropriate light level for the events. A new standalone panel or adding lighting controls to the current HVAC control system are both viable options.

Next Steps:

- Consult with electrician staff to develop plan to install lighting control panels for lighting circuits with remote network.
- If addition to HVAC control system is selected, hire controls contractor to integrate lighting circuit control points onto HVAC control head end.
- If standalone lighting control panel is selected, hire electrician to install lighting control panel with web based head end for remote access to lighting controls

Figure 39- Concourse lighting is controlled by a circuit breaker panel

EEM #2- Chiller Oil Heater Shutdown

Oil heater for the compressor oil on the Carrier chiller is currently running year round as chiller is left in standby mode. This could be shut down for a majority of the year as the chiller is rarely used and re-activation of the oil heater can be included in the chiller startup procedure.

Next Steps:

- Disable oil heater for chiller during shutdown
- Revise chiller startup procedure to include activation of oil heater

Figure 40- Oil temperature gage

EEM #3- Boiler Staging and Modulation Tuning

Current boiler control is set up so that the burner controllers are enabled based on a cut-in/cut-out setpoint, these are set so close that both boilers are firing for much of the time when only one boiler is needed to meet load. The burner modulation response is also too quick to correctly modulate in the low load conditions to keep the boilers from cycling. Testing and tuning of these two controls methods can be done to ensure that the boilers stage and modulate effectively to more efficiently meet the steam load.

Next steps:

- Work with local burner control and BAS to better integrate control and tune boiler response to meet load over a range of operating conditions.
- Hire controls contractor to tune burner response to load such that boiler cycling is reduced
- Trend boilers to verify that cycling and staging is correct

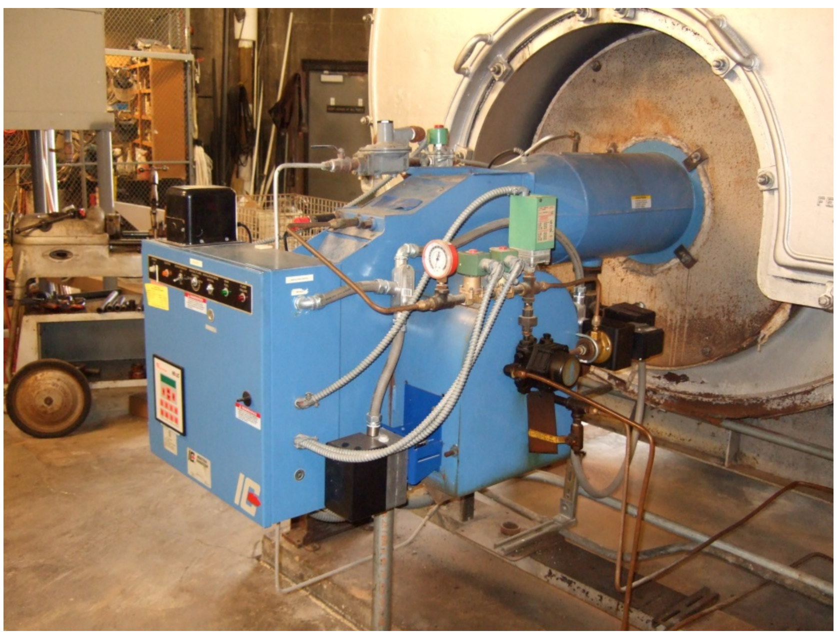

Figure 41-New Boiler Burner Controls

EEM #4- Steam Trap Survey

Steam trap survey was done in 2009 and found 10% of traps had failed across the 202 traps surveyed between the Exhibition Hall and the Coliseum. We have currently observing leaking stream and hot condensate return temps which may be a sign of steam trap failure or flash steam in condensate. This measure would complete a similar survey to the one that was done in 2009 looking for steam traps that have failed so they can be repaired.

Next steps:

- Hire steam trap survey contractor to conduct steam trap survey
- Repair or replace steam traps that have failed

Figure 42- Example steam trap for AHU steam heating coil

EEM #5- Main AHU Heating Sequence Revision

Sometimes one AHU has a different heating response than the others causing simultaneous heating and cooling of the 4 units that serve the Coliseum bowl. We suggest increasing the deadband for space temperature setpoint to +/- 1F. Ensure that AHUs heat and cool to the same sensor setpoint as not to supply hot and cold air simultaneously.

Next steps:

- Hire controls contractor to revise heating sequence for AHUs that serve bowl areas
- Verify comfort with new sequence in bowl areas
- Verify heating and cooling operation with trending data from BAS

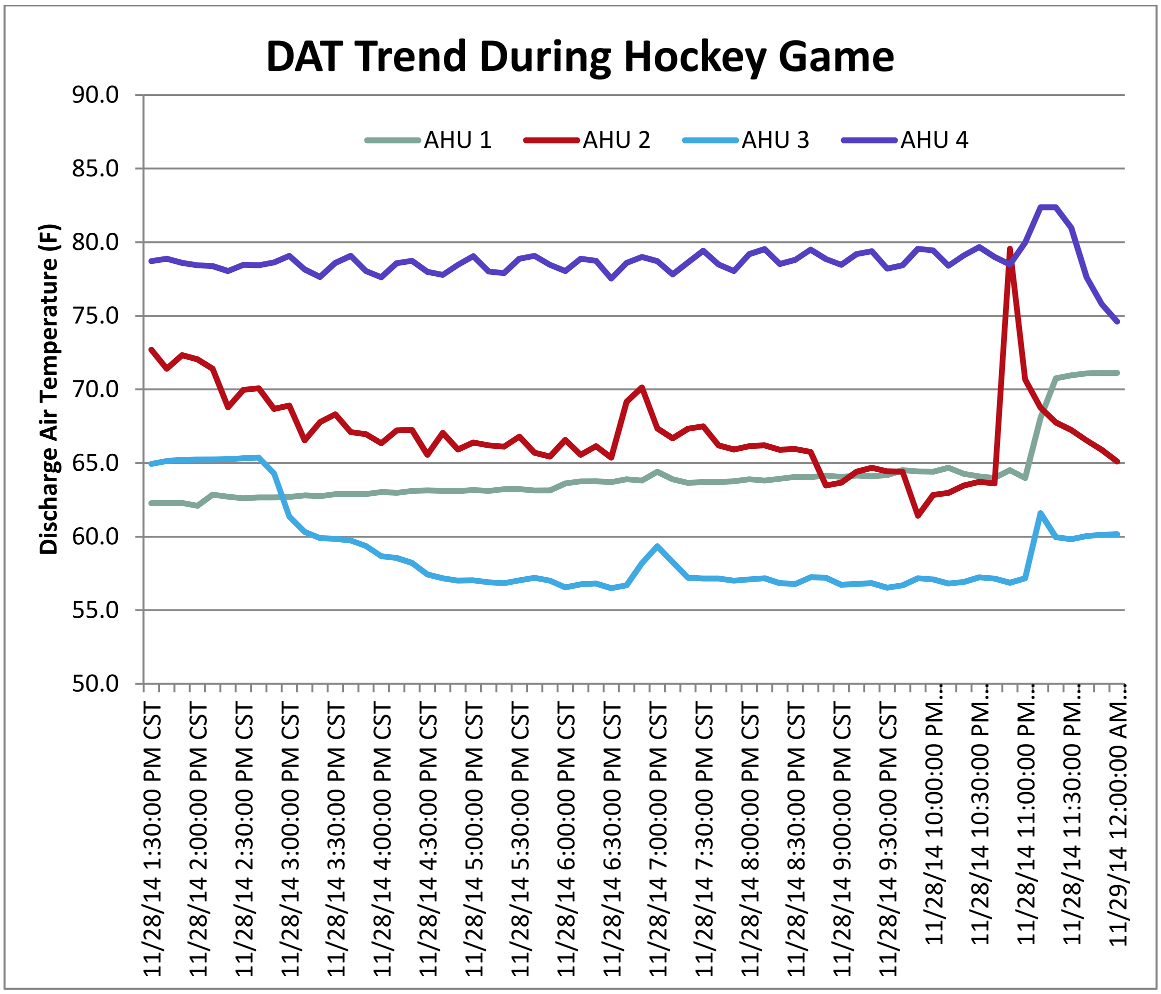

Figure 43- Trend during hockey game of AHU discharge temperatures

EEM #6- Glycol Temperature Reset

It was reported that the 18F IST (Ice Surface Temperature) was maintained to allow the ice to refreeze quickly after resurfacing between periods. Due to the nature of the facility, this may be necessary and unavoidable.

During the time when a game is not being played or the ice is in use, we recommend that the IST be reset to 22F. This 4F increase in ice surface temperature will allow the glycol leaving temperature to be reset from 16F to 20F and the corresponding suction temperature from 8F to 12F. The full benefits of this will be explained in the next section.

A glycol temperature reset will yield dramatic savings during the bulk of the ammonia refrigeration system's operational year.

When the suction pressure (temperature) of a compressor is increased, the overall efficiency (i.e. bhp/ton) is improved. The compressor gains considerable capacity and will only slightly increase the brake horsepower (bhp) necessary to drive the process. This will provide major benefits to the Alliant Energy Center refrigeration system.

In order to increase the suction pressure and corresponding temperature of the ammonia, a compromise must be made elsewhere in the system. An obvious compromise is to reset the glycol temperature higher when the ice is not being used. This will allow the suction to be increased during the majority of the season. Other methods to increase the heat transfer/decrease parasitic loads may be found by cleaning the tubes of the chiller or improving the pumping of the glycol either through a combination of a more efficient pump and/or a VFD installed on said pump.

It was reported that the 18F IST (Ice Surface Temperature) was maintained to allow the ice to refreeze quickly after resurfacing between periods. Due to the nature of the facility, this may be necessary and unavoidable but only when the ice is in use.

During the time when a game is not being played or the ice is in use for practice, we recommend that the IST be reset to 22F. This 4F increase in ice surface temperature will allow the glycol leaving temperature to be reset from 16F to 20F and the corresponding suction temperature from 8F to 12F. A glycol temperature reset will yield dramatic savings during the bulk of the ammonia refrigeration system's operational year both by a reduced load due to warmer ice and more efficient compression.

By resetting the suction pressure of the compressors up it means that at all times, except 2 hours prior to and during the games, the IST is reset to 22F, the glycol leaving temperature is reset to 20F and the suction temperature is reset to 12F. This corresponds to a pressure of around 40 psia for the suction. The results of this increase can be seen in .

Table 6. Compressor performance at 155 psia head pressure

	37 psia suction			40 psia suction			42 psia suction		
SV Pos.	Capacity	BHP	Motor kW	Capacity	BHP	Motor kW	Capacity	BHP	Motor kW
100%	71.5	84.2	69.8	77.2	86.1	71.4	81.4	86.2	71.5
90%	64.4	78.6	65.2	69.5	80.3	66.6	73.3	80.5	66.7
80%	57.2	72.2	59.8	61.8	93.8	77.7	65.1	73.8	61.2
70%	50.1	66.3	55.0	54.1	67.6	56.0	57.0	67.7	56.1
60%	42.9	60.8	50.4	46.3	62.0	51.4	48.9	61.9	51.3
50%	35.8	55.8	46.3	38.6	56.7	47.0	40.7	56.7	47.0
40%	28.6	51.2	42.4	30.9	52.0	43.1	32.6	51.9	43.0
30%	21.5	47.0	39.0	23.2	47.7	39.5	24.4	47.5	39.4
20%	14.3	43.3	35.9	15.4	43.8	36.3	16.3	43.6	36.1
10%	7.2	40.1	33.2	7.7	40.4	33.5	8.1	40.1	33.2

From **Error! Reference source not found.**, we know that Compressor 3 typically runs around 95% slide valve while Compressor 1 is mostly unloaded at 10% slide valve. This can help us determine our typical load when the ice is not in use:

Table 7. Compressor performance at "typical" no-game conditions

Compressor	Slide Valve	Capacity	BHP	kW
Compressor 1	10%	7.2 ton	40.1 bhp	33.2 kW
Compressor 2	0% (off)	0 ton	0 bhp	0 kW
Compressor 3	95%	68.0 ton	81.4 bhp	67.5 kW
Total		**75.2ton**	**121.5 bhp**	**100.7 kW**

We can see the total load is around 75 tons while using 121.5 bhp. This gives us an efficiency of 1.62 bhp/ton, which is about the same efficiency as an traditional air cooled HFC refrigerant chiller.

Compressor Sequencing Optimization – 22F Ice Surface Temperature

If the suction were to be raised to 40 psia (i.e. corresponding to an IST of 22F), the capacity of a single compressor at 100% slide valve is 77.2 tons using 86.1 bhp. At these conditions, we meet the entire load of the ice with a single compressor. By implementing other EEMs on the building (e.g. reduced lighting load, reduced air temperature, improved glycol pumping), we are fairly certain this load could be achieved and Compressor 1 could be shutdown at all times but when the ice is not in use. This improves the compressor overall efficiency to 1.12 bh/ton or an overall reduction of 35.4 bhp. This corresponds to a 29.3 kW reduction in demand and corresponding savings in kWh.

Compressor Sequencing Optimization – 24F Ice Surface Temperature

If we were to take it one step further and raise the IST to 24F, the savings would be even further improved as the suction pressure can now increase to 42 psia. We are not certain this warm of a temperature is possible, especially when the ice is in use, but supposing it is, any given compressor would have a full load capacity of 81.4 tons for 86.2 bhp at an efficiency of 1.06 bhp/ton. Going back to a load of 77.2 tons, a compressor at 95% slide valve would cover that load at a cost of 83.4 bhp or 69.1 kW. This is a savings of 31.6 kW off the original conditions. These numbers are summarized in .

Table 8. Summary of compressor performance when meeting non-game load

Suction Pressure	Number of Compressors	Total Capacity	Total Bhp	Total kW
37	2	75.2 ton	121.5 bhp	100.7 kW
40	1	77.2 ton	86.1 bhp	71.4 kW
			Total Savings	**29.3 kW**
42	1 (95% SV)	77.4ton	83.4bhp	69.1kW
			Total Savings	**31.6kW**

If this EEM is to be undertaken, it must be verified that the oil separators and motors are large enough. The higher capacity necessitates a higher mass flow rate and higher vapor velocity. This higher velocity makes oil separation more difficult. Likewise, the higher capacity will require a slightly larger motive force so the electric motor installed should be of sufficient size.

EEM #7- Decrease Ammonia System Head Pressure

Currently, the system is running at a head pressure of approximately 155 psia, though there is a fair amount of variance in that number. Trend data provided indicates a range of 138 psia up to 175.1 psia. The system utilizes thermosiphon oil cooling and does not have any thermal expansion valves or other reasons to keep an elevated head pressure to our knowledge.

The wide range of head pressure is confusing since the system has a water cooled condenser with a cooling tower. A closer tolerance should be able to be achieved.

We recommend that operations reduce the head pressure setpoint in a slow, methodical manner. Increments of no more than 5 psi are recommended. After each pressure setpoint reduction, the system should be monitored for 1 to 2 weeks for any problems that arise. If there are no problems, another incremental step should be taken. The compressor manufacturer should be consulted but a 10 psi reduction may be possible.

Table 9. Compressor performance at 37 psia suction pressure

	155 psia Discharge			145 psia Discharge		
SV Pos.	**Capacity**	**BHP**	**Motor kW**	**Capacity**	**BHP**	**Motor kW**
100%	71.5	84.2	69.8	72.6	80.6	66.8
90%	64.4	78.6	65.2	65.3	75.2	62.3
80%	57.2	72.2	59.8	58.1	69.1	57.3
70%	50.1	66.3	55.0	50.8	63.4	52.6
60%	42.9	60.8	50.4	43.6	58.1	48.2
50%	35.8	55.8	46.3	36.3	53.2	44.1
40%	28.6	51.2	42.4	29	48.7	40.4
30%	21.5	47.0	39.0	21.8	44.7	37.1
20%	14.3	43.3	35.9	14.5	41.1	34.1
10%	7.2	40.1	33.2	7.3	37.9	31.4

A drop of 10 psi in head pressure would increase the system capacity by about 1 ton per compressor and drop the motor power by 3.6 bhp. The full load compressor efficiency would improve from 1.18 bhp/ton to 1.11 bhp/ton. A moderate gain of about 6% energy savings.

If we were to use the data that will be presented in , then the efficiency would drop from 1.62 bhp/ton to 1.57 bhp/ton.

EEM #8- Variable Speed Control of Lag Ammonia Compressor

Current operation of ammonia refrigeration system leaves the lead compressor fully loaded and one lag compressor on lightly loaded (as described in measure 7). If measure7 is not implemented or is not effective at reducing the load so that only the lead compressor is on, then a VFD should be considered on the lag compressor for energy savings. This would improve the part load performance of this compressor and provide energy savings when the ice is not used.

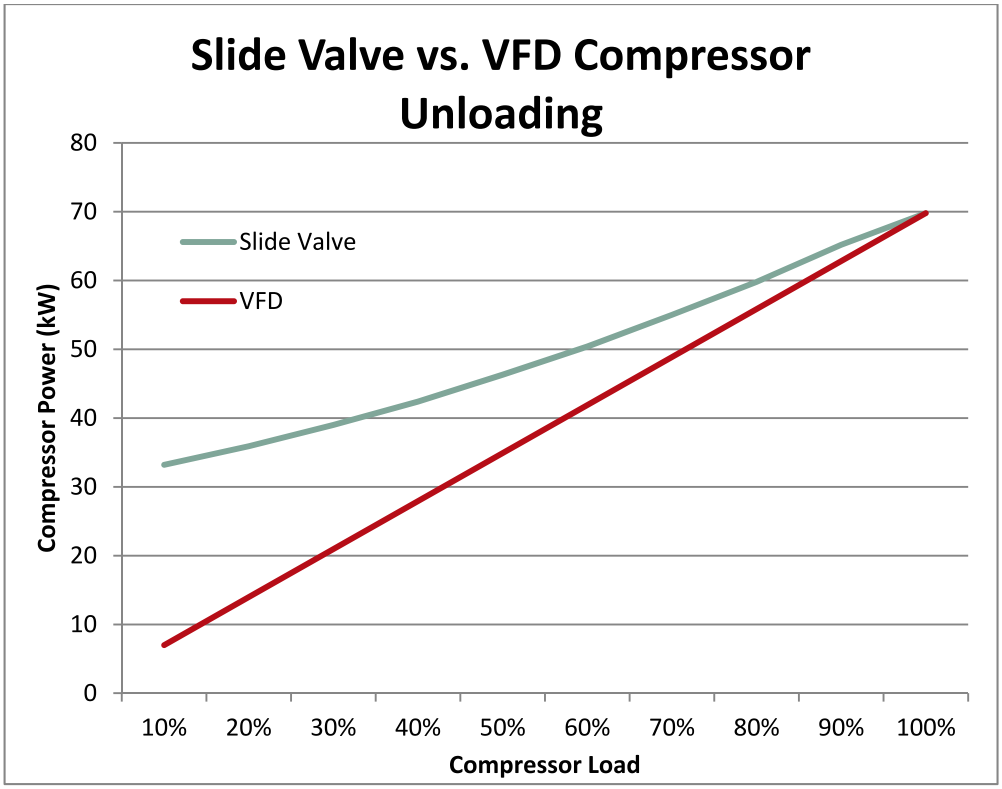

Figure 44- Comparison power consumption between slide valve and VFD control of compressors

EEM #9- Perimeter Heating Controls

Current perimeter heating is comprised of radiant floor heaters and unit heater that are controlled by stand alone pneumatic controls that do not have setback or communication with other HVAC controllers in the building. This means that while the bowl temperature is setback to 55F, the perimeter, entrances and concourses are still warmed to event desired temperatures. Since these areas have the most heating load on them in the cold months the energy savings is greater if these areas are also setback to a lower temperature than event levels.

The pneumatic controllers and steam control valves can be replaced with digital ones that can network with the existing BAS system. This would allow operations staff to schedule and set temperature much like the AHU areas.

Figure 45- Pneumatic thermostat on entryway unit heater

EEM #10- Ammonia Refrigeration Heat Recovery

The system as operated produces a steady stream of warm water. This warm water could be used in other areas such as heating the Zamboni melt pit or heating the Coliseum's air. As it stands, the steam system is used to warm the air inside the Coliseum. The bulk of that heat is not lost to the outdoors but rather it is absorbed by the ice and taken up by the refrigeration system. The refrigeration system then pushes the heat outside.

Further investigation is needed but it may be possible to use the water directly in the existing cooling coils located in the air handling units. If a temperature boost is needed, a water loop heat pump could be installed to provide that temperature lift.

The other option is to use the warm water to melt the ice removed during the resurfacing process. This low temperature water will provide sufficient capacity to melt the ice.

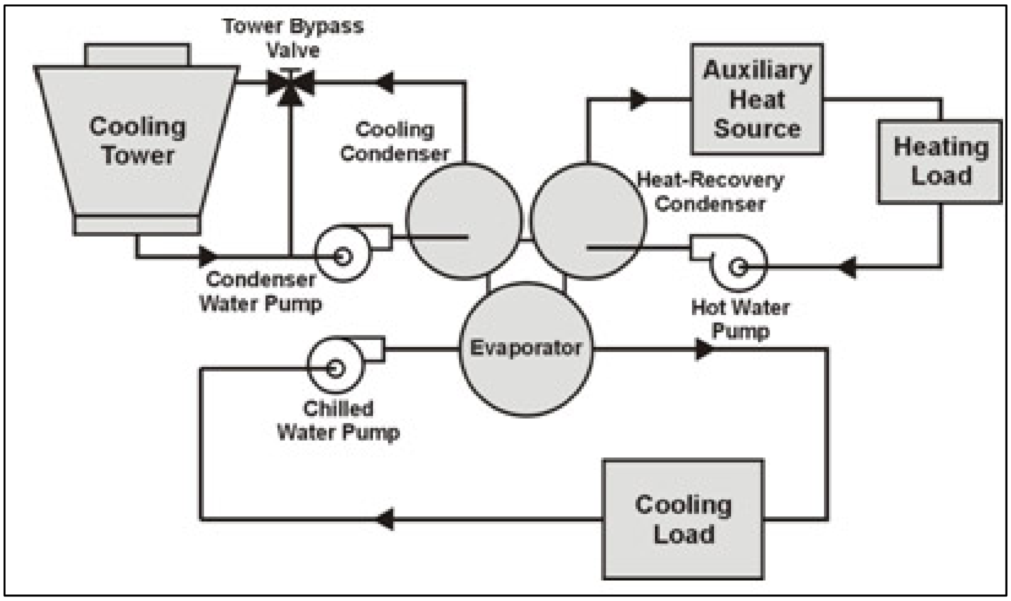

Figure 46- Example of chiller heat recovery configuration

ADDITIONAL FINDINGS

OVERVIEW

This section describes measures that were identified at the facility that do not directly affect the energy usage of the facility. These measures may have an effect on energy using equipment, and thus have energy and maintenance savings, but it is difficult to quantify through this analysis. For this reason they are termed facility improvement measures (FIMs).

FIM #	Equipment or System(s) Affected	Measure Title	Recommended Improvement	Benefits	Estimated Implementation Cost
M11	Ammonia System/ Chilled Glycol Loop	Ammonia Chiller System Check	Look for refrigeration capacity pinch points, such as heat exchanger surface fouling or the glycol pump	Energy savings, less equipment maintenance, increased equipment life	$5,000
M12	Ammonia Chiller	Ammonia Chiller Operator Training	In our experience a knowledgeable operator can have a drastic effect on the operation of the system. The training should be specific to the operation of ammonia refrigeration systems.	Increased safety, less equipment maintenance, increased equipment life	$2,600
M13	Ammonia Chiller	Add Fluid Cooler to Ammonia Condenser Loop	Install closed loop cooling tower (fluid cooler) in place or next to the current open loop tower to run in winter times.	No ice buildup on mechanical room, less equipment maintenance	$50,000
M14	AHUs	Return Air Ducting	Separate Return Air Path to AHUs from Facility Drainage	Indoor air quality	Unknown

FIM #11- Examine Ammonia System for Refrigeration Capacity Pinch Points

At this point, it is a gut feeling of the investigators that there are 1 or more points in the refrigeration system that is preventing the refrigeration system from operating at its peak efficiency. To fully ascertain if there is a problem, additional investigation would need to be performed. The alternative is to tackle these tasks on the merit of proper maintenance of the system regardless of potential energy efficiency or capacity improvements.

Clean heat exchange surfaces

This refrigeration system has three primary heat exchange surfaces that are subject to fouling, corrosion and other debris build up that can be easily cleaned: chiller tubes, condenser tubes, cooling tower. Normally, the effects of fouling would be noticed in a slow degradation of performance but due to the operational history of this system, it is uncertain how bad the problem is.

During the next shutdown, a professional cleaning of the glycol tubing inside the chiller barrel should be considered. Due to insulation, it is not clear if the evaporator vessel can be opened for cleaning or if this would involve opening a stamped vessel. If it is the latter case, then the option becomes more difficult and expensive. Therefore, further tests on the glycol system looking for signs of dirt, debris and corrosion should be conducted to determine if this is warranted.

Likewise, the water side of the water cooled condenser should be cleaned out. Debris from the cooling tower can be easily deposited in the tubing of the condenser where it degrades the unit's performance. They are outfitted with removable heads for cleaning.

Finally, the true condition of the cooling tower was difficult to determine due to ice buildup but it is rare that a cooling tower in the Madison area is not in need of scale removal.

Figure 47. Cooling tower used with the refrigeration system

Investigate the glycol pump

At this time very little is known about the glycol pump as an accurate manufacturer and model number was not obtained. The only known information is that the pump is original to the system (1967), it is the only pump on the glycol system and its maintenance history is murky. As with all equipment, a certain level of degradation is expected.

We recommend that during the off season, the insulation be removed from the pump and the pump's performance be verified against the manufacturer's original data. If the degradation is severe, it should be replaced.

Likewise, replacement of the motor with a high efficiency motor should be considered. This can lead to substantial energy savings.

Finally, the actual pumping requirements of the system should be investigated. What is the optimal mass flow rate through the chiller? What is the optimal flowrate and/or temperature difference across the glycol field under the ice? These questions should be answered to determine if there is the potential for energy or ice quality improvement. Likewise, the use of a VFD on the pump should be investigated.

Figure 48- Current pump for glycol rink loop

FIM #12-Operator Ammonia Refrigeration Training

The system is currently operated primarily by a single operator. While the operator has extensive experience in the halocarbon refrigeration industry, ammonia based systems operate considerably differently. In our experience a knowledgeable operator can have a drastic effect on the operation of the system. The training should be specific to the operation of ammonia refrigeration systems.

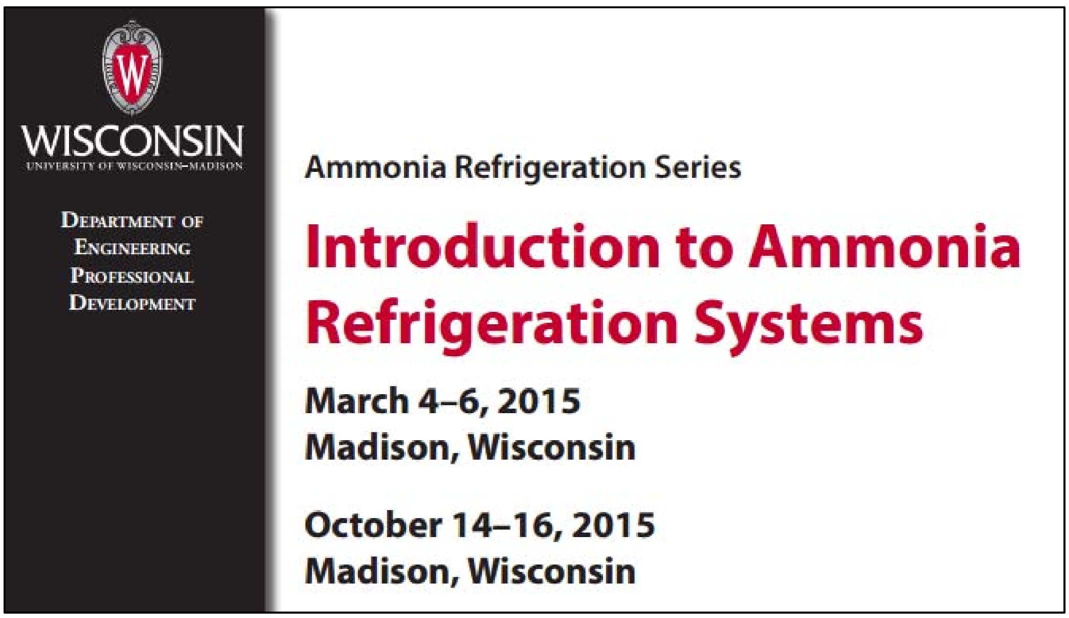

Figure 49- The UW Industrial Refrigeration Series has several classes located in Madison

FIM #13- Install Alternative Condensing Technology

As can be seen in the conditioning report, the use of a cooling tower for winter time heat rejection can lead to a number of problems revolving around ice formation. While this method can be used successfully, it is far from optimal.

Traditionally, ammonia refrigeration systems use an evaporative condenser to reject heat. This has the advantage of being able to use water to reduce the condensing temperature to near dewpoint temperatures like a cooling tower or it can run "dry" to reject heat without the worry of wintertime freeze-up. The downsides are that these units can be quite expensive and a reduction in efficiency.

We recommend to investigate the installation of a fluid cooler, which is basically a set of coils for the condenser water to run through that is exposed to outside air. This will allow the system operation to be easier and eliminate many of the icing problems. Since the system is only run in the wintertime, the heat rejection capacity will be sufficient. During times when extra capacity is needed by the refrigeration system for heat rejection (i.e. above freezing outdoor air temperatures) the cooling tower can be operated.

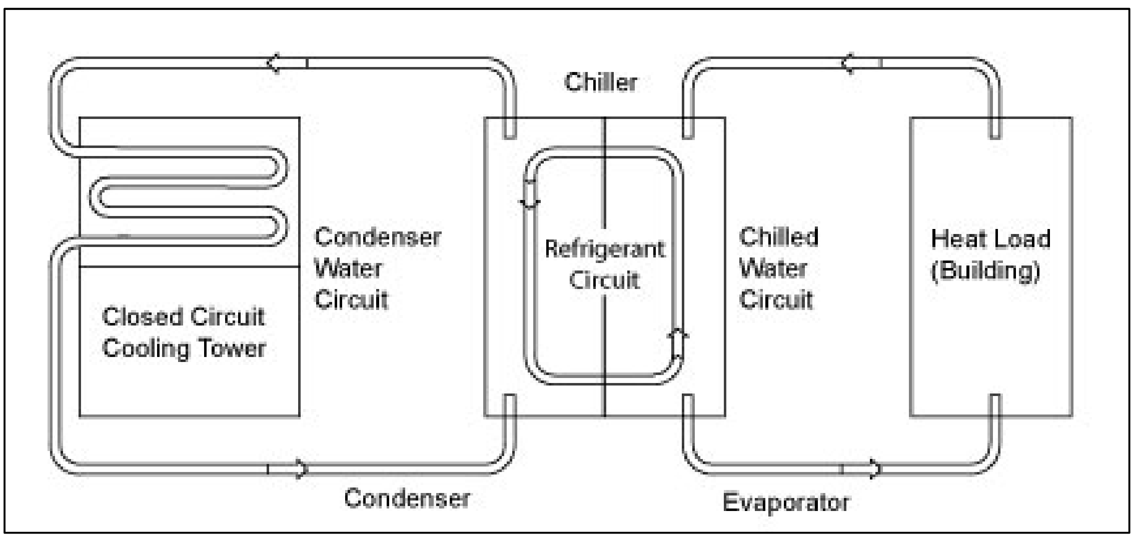

Figure 50- Schematic of fluid cooler (source: Baltimore Aircoil Company)

FIM #14- Separate Return Air Path to AHUs from Facility Drainage

During the equipment assessment it was noted that there was water in the return path for the 4 AHU that serve the coliseum bowl. This water is part of the drainage system for the structure and has a sump pump system to remove the water based on water level control. This could be an indoor air quality issue and can be remedied by separating the drain and air stream. Further investigation and design will need to be completed before this can be implemented and cost can be determined at that point.

Figure 51- Standing water in return air plenum

APPENDIX A- UTILITY HISTORY

		Natural Gas		Electricity			Total Site Energy			
	Month	Usage [Therms]	Cost [$]	Usage [kWh]	Cost [$]	Demand [kW]	Total Cost [$]	Total Energy [kBTU]	$kBTU/ft^2$	$\$/ft^2$
2012	Jan-12	15,097	8698	122,735	15400	421	$24,098	1,928,472	18.1	$0.23
	Feb-12	14,516	8027	136,980	16876	631	$24,904	1,918,976	18.0	$0.23
	Mar-12	12,308	6440	247,883	26062	862	$32,502	2,076,577	19.5	$0.30
	Apr-12	1,928	1128	100,749	20063	546	$21,191	536,556	5.0	$0.20
	May-12	1,747	866	97,997	13987	502	$14,853	509,066	4.8	$0.14
	Jun-12	1,632	824	94,520	14547	501	$15,370	485,702	4.6	$0.14
	Jul-12	238	299	135,366	25869	1031	$26,168	485,669	4.6	$0.25
	Aug-12	151	250	56,118	8344	75	$8,594	206,575	1.9	$0.08
	Sep-12	206	282	147,081	18694	478	$18,976	522,440	4.9	$0.18
	Oct-12	1,207	763	191,036	21744	670	$22,507	772,515	7.2	$0.21
	Nov-12	5,321	2715	73,254	7830	74	$10,545	782,043	7.3	$0.10
	Dec-12	5,771	3198	40,036	5209	45	$8,407	713,703	6.7	$0.08
2013	Jan-13	14,223	7524	82,786	13726	529	$21,250	1,704,766	16.0	$0.20
	Feb-13	18,552	9504	129,853	15577	627	$25,081	2,298,258	21.6	$0.24
	Mar-13	19,112	9746	266,641	27872	856	$37,618	2,820,979	26.5	$0.35
	Apr-13	11,170	6002	113,656	15990	405	$21,991	1,504,794	14.1	$0.21
	May-13	4,594	2720	119,603	16379	456	$19,099	867,485	8.1	$0.18
	Jun-13	47	223	76,216	9344	153	$9,566	264,749	2.5	$0.09
	Jul-13	14	178	42,504	7104	151	$7,282	146,424	1.4	$0.07
	Aug-13	17	185	55,052	9021	221	$9,206	189,537	1.8	$0.09
	Sep-13	136	262	161,294	20381	632	$20,643	563,935	5.3	$0.19
	Oct-13	153	245	183,584	25121	880	$25,366	641,689	6.0	$0.24
	Nov-13	3,415	1901	47,760	10352	424	$12,253	504,457	4.7	$0.11
	Dec-13	11,930	6675	74,387	14621	600	$21,296	1,446,808	13.6	$0.20
2014	Jan-14	15,918	9134	82,742	14753	478	$23,887	1,874,116	17.6	$0.22
	Feb-14	25,849	16538	168,365	18991	700	$35,528	3,159,361	29.6	$0.33
	Mar-14	18,462	14847	188,734	22621	780	$37,468	2,490,160	23.4	$0.35
	Apr-14	9,924	7728	130,767	15578	469	$23,306	1,438,577	13.5	$0.22
	May-14	2,379	1699	79,006	9184	257	$10,883	507,468	4.8	$0.10
	Jun-14	107	255	141,398	21063	633	$21,318	493,150	4.6	$0.20
	Jul-14	253	63	147,784	19964	549	$20,027	529,539	5.0	$0.19
	Aug-14	172	550	120,274	17649	490	$18,199	427,575	4.0	$0.17
	Sep-14	295	353	127,201	14673	199	$15,027	463,510	4.3	$0.14
	Oct-14	1,236	845	225,278	22249	708	$23,094	892,249	8.4	$0.22
	Nov-14	5,999	3463	232,004	20284	626	$23,747	1,391,498	13.1	$0.22
	Dec-14	14,646	8896	255,926	26972	854	$35,869	2,337,820	21.9	$0.34
Avg.	Month	**6,631**	**$3,973**	**130,460**	**$16,780**	**514**	**$20,753**	**1,108,255**	**10.4**	**$0.19**
Avg.	Year	**79,575**	**$47,675**	**1,565,523**	**$201,365**	**N/A**	**$249,040**	**13,299,066**	**125**	**$2.34**

APPENDIX B- CURRENT FACILITY REQUIREMENTS

Current Requirement	Typical For Building	Arena Bowl	Concourse
Heating Season Low Temp Set Point	68F	65F	70F
Cooling Season High Temp Set Point	70-74F	-	-
Humidification Requirements %RH	-	-	-
Pressure Relationship	-	-	-
Ventilation	scheduled min OA	-	-
Sound and Noise	-	-	-
Normal Occupancy Schedule	schedules with events	scheduled with events	-
After Hours Equipment Status	cycles to maintain setback	-	-
Lighting	-	-	-
Cleaning Schedules	at night	-	-

APPENDIX C- FUNCTIONAL PERFORMANCE TESTING LOG

		Remote Access Investigation			On-Site Investigation			
Equipment	**Location**	**Economizer Mode**	**Cooling Mode**	**Heating Mode**	**Dampers**	**Valves**	**Sensors**	**Issues Noted**
Main AHUs	Lower Concourse	X	X	X	X	X	X	
Exhaust Fans	Rooftop		X	X				
Cooling Towers	Mech Room Roof		X			X	X	
Chillers	Mech Room	X	X	X		X	X	
Boilers	Mech Room		X	X		X	X	

APPENDIX D- GREENHOUSE GAS EQUIVALENCY FOR ENERGY REDUCTION MEASURES

EEM #	Measure Title	Annual Electric Savings (kWh)	Annual Gas Savings (therms)	Annual Utility Cost Savings	CO2 Emission Reduction (lbs)*
M01	Install Lighting Control Panel	193,556	0	$24,930	290,334
M02	Chiller Oil Heater Shutdown	7,760	0	$999	11,640
M03	Boiler Staging and Modulation Tuning	0	340	$235	3,977
M04	Steam Trap Survey	0	3,937	$2,716	46,062
M05	AHU Heating Sequence	0	1,587	$1,095	18,568
M06	Ammonia Chiller Increase Suction Pressure by Glycol Temperature	115,670	1,981	$8,307	196,683
M07	Ammonia Chiller Decrease Head Pressure	7,500	0	$473	11,250
M08	VFD on Ammonia Compressor	101,314	0	$6,383	151,971
M09	Perimeter Heating Controls	0	3,345	$2,007	39,137
M10	Ice Making Heat Recovery	0	21,579	$14,889	252,469
		425,800	**32,768**	**$62,034**	**1,022,090**

**Based on EPA Greenhouse Gas Equivalency Calculator (1.5 lbs CO2 for kWh reduced and 11.7 lbs CO2 for therm reduced). http://www.epa.gov/cleanenergy/energy-resources/calculator.html*