Technical Report 3

Mechanical Systems
Existing Conditions Report

The Salvation Army Ray & Joan Kroc Corps Community Center of Salem Oregon

Mathias Kehoe
Mechanical Option
Advisor: Stephen Treado
November 16, 2011

Table of Contents

Executive Summary

For the following report, an in-depth summary was performed on the mechanical system of The Salvation Army Ray & Joan Kroc Corps Community Center of Salem, Oregon. This report determines what comprises the current mechanical system and why this system was chosen. The report also evaluates the adequacy of the system at meeting the building's loads and how efficiently it uses energy. An overall summary of the system will be included at the end of the report.

A number of different design considerations played major roles early on in the design process. The Kroc Center contains very energy intensive spaces; and the mechanical system had to meet the building's loads despite a limited budget. High indoor design temperatures and a lot of exterior glazing led to high heating loads requiring large pieces of mechanical equipment. The large equipment used up much of the budget, so only a few energy saving techniques could be used. A large plus of the Kroc Center's design was the lack of mechanical floor space. Almost all of the equipment was placed on the roof of the one-story building, eliminating the need for mechanical shafts.

The scheduled ventilation rates for the Kroc Center far exceed ASHRAE's minimum requirements and provide excellent indoor air quality especially in the pool areas. The cooling load calculations that were performed were very close to the scheduled cooling loads, but the calculated heating loads are significantly lower. The big difference in heating loads could be explained many different ways and will be examined in more detail later in this report. The ventilation and building load calculations meet the demands of the building but offer opportunities for energy savings.

The mechanical system in the Kroc Center is fairly simple. Fourteen primary air handlers condition the air inside the building. Boilers provide hot water to the pools and two of the air handlers. Two other air handling units have a heat pump to condition the air, and the other units use small natural gas burners. All of the units, except the two with heat pumps, use DX cooling systems. The mechanical system is simple but effective at meeting the needs of the building.

The design team tried to achieve LEED certification for the Kroc Center. Overall the building saved energy and should also earn most of the administrative credits. The mechanical system performed well on the LEED analysis, but LEED is not always the best test for determining the true quality of mechanical systems.

Design Considerations

Design Objectives and Requirements

The Kroc Corp Community Center of Salem Oregon is a one-story, 90,000 square foot community center containing a variety of spaces including a gymnasium, fitness center, chapel, commercial kitchen, and two natatoriums. The Kroc Center was designed to be a landmark in the community and provide a safe haven for children.

The design team's biggest areas of concern were the two natatoriums because they have large latent loads and high concentrations of contaminants coming off of the pools. To deal with those issues, each natatorium was given a dedicated air handling unit to prevent the spread of contaminants to other parts of the building. The other large spaces in the community center (gymnasium, fitness center, chapel, and kitchen) have individual air handling units designed to meet the unique requirements of each space. Offices, classrooms, and community spaces make up the remainder of the building; these spaces are conditioned by air handling units with VAV boxes that account for varying occupancy.

Influential Design Factors

Cost was the biggest limiting factor in the mechanical design. The Kroc Center was entirely funded by an endowment from the Salvation Army; so a tight budget was established very early in the design process. The building was designed to be a showpiece in the community, so a large portion of the budget was spent on the façade and architectural features. As a result, the mechanical system took a backseat. Some small steps were taken to increase the energy efficiency of the mechanical system, but energy savings was not the driving force in design. The design team chose the current system because of a lower first cost, even though the mechanical system will have a higher lifetime operation cost. The budget influenced the final decision, to scatter several air handling units scattered across the roof of the building, more than any other factor.

Outdoor and Indoor Design Conditions

The outdoor design temperatures are based on ASHRAE's 99.6% values for the city of Salem, Oregon. The temperature information is available in the ASHRAE Fundamentals handbook and was also listed in the design documents. The outdoor design temperatures are summarized in Table 1.

Outdoor Design Temperatures		
	DB	WB
Summer	92	67
Winter	21	-

TABLE 1 – Outdoor Design Temperatures

The interior design temperatures are also listed in the design documents and are all close to standard with the exception of the two natatoriums. The two natatoriums are kept at higher temperatures in both the winter and summer to keep the swimmers comfortable as they enter and exit the water. The temperatures are summarized in Table 2.

Interior Design Temperatures		
Room	Summer	Winter
Child-Care	74	72
Gymnasium	76	68
Leisure Pool	85	85
Competition Pool	83	83
Data Rooms	78	74
All Other Spaces	74	68

TABLE 2 – Indoor Design Temperatures

Lost Usable Space

The Kroc Center has a minimum amount of floor space dedicated to mechanical systems. The design team took advantage of the fact that the building is one-story, so all of the air handlers are located on the roof of the building and duct down through the ceiling plenum. There is a small mechanical room on the south side of the building that houses the boilers that supply hot water to the pools and the air handlers. A small sprinkler room is located near the mechanical room and a pool support room is located adjacent to the competition pool. As you can see in Table 3 below, the area occupied by these three areas is very small compared to the rest of the building. These area totals do not include the electrical rooms or the plumbing access near the restrooms. The design team created a very efficient layout by minimizing the floor space of the mechanical spaces.

Mechanical Floor Space		
Room	Square Feet	% of Building
Mechanical	435	0.47%
Sprinkler	100	0.11%
Pool Support	1635	1.78%
Total:	2170	2.36%

TABLE 3 – Lost Usable Spaces

Energy Sources and Rates

The Kroc Center is located on a ten acre site in the city of Salem, Oregon, and has access to underground electricity and natural gas utilities. The utility rates were explained in more detail in Technical Report 2 but are summarized in Table 4 below. The electric demand and consumption rates are varied based on usage, but the natural gas cost is constant regardless of how much is consumed.

Utility Rates							
Electric Demand ($/kw)			Elec. Consumption ($/kwh)			Natural Gas ($/therm)	
First 50 kw	$0.00		First 3000 kwh	$0.0748		Constant	$1.2923
Over 50 kw	$6.11		Next 17,000 kwh	$0.0610			
			Over 20,000 kwh	$0.0464			

TABLE 4 – Utility Rates

Sizing Considerations

Design Ventilation Requirements

Minimum ventilation requirements were calculated in Technical Report 1 based on ASHRAE Standard 62.1; the calculated values were significantly lower than the designed ventilation rates. The design documents outline their design criteria for determining ventilation rates based on occupancy densities and higher ventilation rates per person. If the design team had kept the ventilation rates closer to ASHRAE standards, the design team could have reduced the amount of outdoor air supplied and potentially saved energy. The scheduled and design ventilation rates are shown below.

Unit	Description	Scheduled OA	ASHRAE Required OA
AHU 1	Competition Pool	10488	5818
AHU 2	Leisure Pool	8988	4735
FCU 1	Stage - North	880	648
FCU 2	Stage - South	880	647
RTU 1	North Office Wing	9610	8188
RTU 2	Office Wing	1640	1094
RTU 3	Chapel	4800	1795
RTU 4	Climbing Wall	2300	342
RTU 5	Gym - North	2800	2203
RTU 6	Gym - South	2800	2203
RTU 7	Aerobics	1230	1430
RTU 8	Fitness	1200	1005
RTU 9	Wet Multi-Purpose	1360	370
RTU 10	Locker Rooms	2750	1142

TABLE 5 – Ventilation Rates

Design Heating and Cooling Loads

Heating and cooling loads for the entire building were calculated in Technical Report 2. Information was taken from the design documents and entered into Trane Trace which determined the building loads and energy usage. Every room was modeled in Trace and grouped together to reflect the current mechanical system distribution. The loads calculated in Technical Report 2 were lower than the design loads of the current equipment, especially the heating loads. In the Kroc Center FCU-1 and FCU-2 both condition the stage area of the chapel, so they were modeled together as one unit. The same thing was done to RTU-5 and RTU-6 which condition the gymnasium.

System Comparison						
Unit	Calculated		Scheduled		Percent Difference	
	Heating	Cooling	Heating	Cooling	Heating	Cooling
AHU-1	516.4	422.1	922	802.8	44%	47%
AHU-2	379.6	591.2	737	609.6	48%	3%
FCU-1	99.7	159	46.1	63.1	-8%	-26%
FCU-2			46.1	63.1		
RTU-1	454.2	702.5	697	763	35%	8%
RTU-2	91.3	182.7	284	208	68%	12%
RTU-3	102.7	217.5	410	240	75%	9%
RTU-4	18.8	27.9	284	192	93%	85%
RTU-5	309	476.9	284	202	46%	-18%
RTU-6			284	202		
RTU-7	76.3	182.2	104	60	27%	-204%
RTU-8	117.6	226.1	324	265	64%	15%
RTU-9	28.2	46.9	120	79	77%	41%
RTU-10	140.6	202.3	202	119	30%	-70%
Totals	2334.4	3437.3	4744.2	3868.6	51%	11%

TABLE 6 – Calculated Loads v. Scheduled Loads

There are several reasons to explain the discrepancies between the scheduled and calculated values. The outdoor winter design temperatures may be lower, which would explain why the heating system is so oversized while the cooling system is closer to design value. The numbers could also be skewed by different assumptions about building construction and glazing attributes. Another possibility is that the packaged units were sized to meet the cooling load, and were only available with the higher heating capacities. Additionally, when the design team sized the equipment they included safety factors to ensure that the equipment could meet the building loads.

Whatever the case, the scheduled building loads are higher than the design loads and provide another opportunity for energy savings.

Annual Energy Use

Using TRACE, the electrical consumption, electrical demand, and gas usage for the Kroc Center were determined on a month by month basis. Taking the utility rates mentioned in Table 4, the energy use was determined and assembled into Table 7 which shows a detailed cost breakdown. Actual utility bills for the Kroc Center were not available, but the energy analysis report performed by the mechanical engineer provided something reliable to compare these calculated results to.

The total energy cost value from Table 7 includes the building loads, but does not account for the energy required to heat the two pools. The energy analysis report performed by GLUMAC states that the total energy needed to heat the pools for an entire year was 1,060 MBtus. This heating load converts into 13,250 therms of natural gas and adds an additional $17,123 to the annual energy cost. The total energy cost including heating the pools is $141,404, which is significantly under GLUMAC's estimate of $191,208. The lower building loads that were found in the first part of this report may account for a large portion of the difference in the total energy calculations.

Energy Costs by Month and Type						
	EC (kwh)	ED (kw)	Gas (therms)	EC ($)	ED ($)	Gas ($)
January	80609	179	5930	$ 4,085	$ 788	$ 7,663
February	72895	183	4662	$ 3,727	$ 813	$ 6,025
March	82440	188	4418	$ 4,170	$ 843	$ 5,709
April	83299	220	2932	$ 4,209	$ 1,039	$ 3,789
May	104332	406	816	$ 5,185	$ 2,175	$ 1,055
June	119639	452	308	$ 5,896	$ 2,456	$ 398
July	152246	510	154	$ 7,409	$ 2,811	$ 199
August	145815	549	216	$ 7,110	$ 3,049	$ 279
September	115558	416	465	$ 5,706	$ 2,236	$ 601
October	94798	286	2064	$ 4,743	$ 1,442	$ 2,667
November	78229	180	5395	$ 3,974	$ 794	$ 6,972
December	78647	176	7352	$ 3,994	$ 770	$ 9,501

Costs:	$ 60,206	$ 19,216	$ 44,858
Total Energy Cost:	$ 124,281		

TABLE 7 – Energy Costs by Month

The energy cost for the Kroc Center was broken down into five major categories: Heating, Cooling, Lighting, Receptacles, and Pool energy use. When it is broken down, one can see that the energy costs for the Kroc Center are dominated by the heating and lighting loads. These two loads provide the biggest areas for potential energy savings. The lighting loads are high because of exterior lighting and the light intensive chapel, but the lighting was designed for aesthetics not energy savings. The heating load is surprisingly high, considering how much lower the calculated values were than the scheduled loads. The cost breakdown based on energy use is shown in Table 8.

Energy Costs per Use			
Element	Cost	$/SF	% of Total
Lighting	$ 34,093	$ 0.37	24%
Heating	$ 63,267	$ 0.69	45%
Cooling	$ 16,910	$ 0.18	12%
Receptacles	$ 5,116	$ 0.06	4%
Pool	$ 17,123	-	12%

TABLE 8 – Energy Cost by Use

Description of Current Mechanical System

Major Equipment Summary

Fourteen packaged rooftop units supply the majority of air to the Kroc Center. The pieces of equipment and the areas of the building that they serve are summarized in Table 9 below. Also including in the chart are the scheduled heating and cooling loads given in the design documents.

Unit	Areas Served	Scheduled (MBH)	
		Heating	Cooling
AHU-1	Competition Pool	922	802.8
AHU-2	Leisure Pool	737	609.6
FCU-1	Platform - North	46.1	63.1
FCU-2	Platform - South	46.1	63.1
RTU-1	North Office Wing	697	763
RTU-2	Office Wing	284	208
RTU-3	Chapel	410	240
RTU-4	Climbing Wall	284	192
RTU-5	Gym - North	284	202
RTU-6	Gym - South	284	202
RTU-7	Aerobics Room	104	60
RTU-8	Fitness Center	324	265
RTU-9	Wet Multi-Purpose Room	120	79
RTU-10	Locker Rooms	202	119

TABLE 9 – Major Equipment Summary

System Descriptions

AHU-1 and AHU-2

The two large air handlers condition the competition pool and leisure pools respectively. Though slightly different sizes, the two units operate the exact same way. First, the return air from the building is pulled by the return fan into the air handling unit and through a sound trap. A fraction of the return air is exhausted and passes through a heat exchanger to help precondition the entering outside air. The outside air and remainder of the return air mix and pass through the cooling and heating coils. The cooling coil is a DX system with the compressor, evaporator, and expansion valve housed in the air handling unit. The heating coil uses hot water supplied from the boilers in the mechanical room to heat the air. After passing through the coils, the supply air flows through a filter and into the supply fan. The supply fan sends the air through another sound trap before it leaves the unit. The supply air then travels through the supply air ducts and is distributed into the space. Figure 1 below is a simple schematic of the two large air handling units.

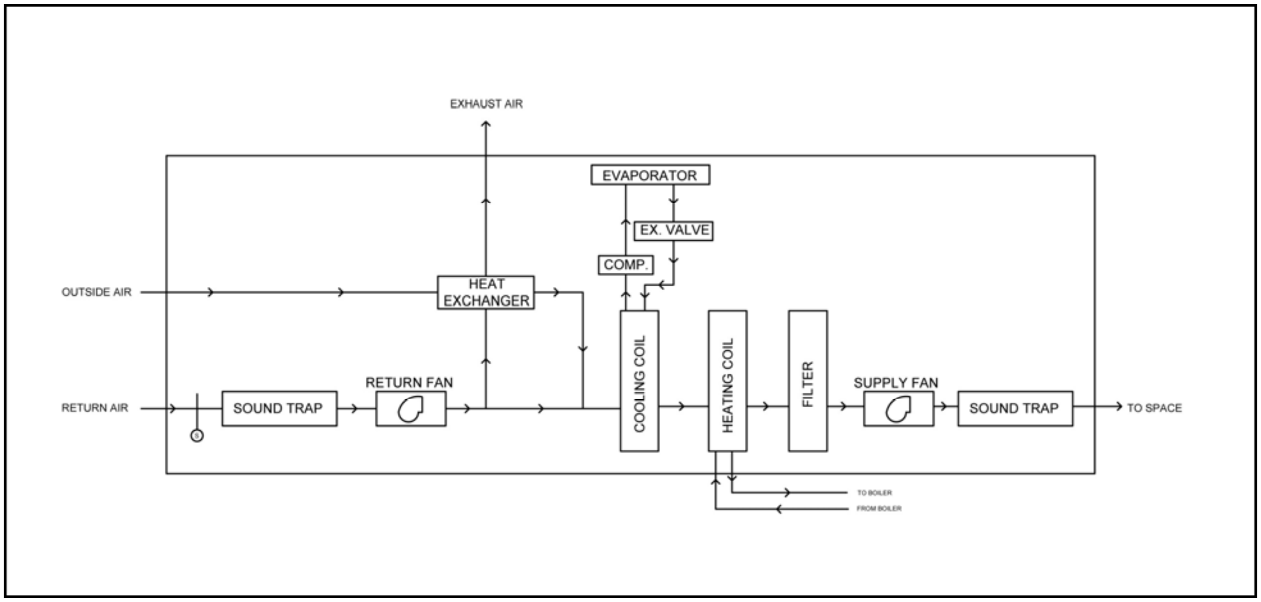

FIGURE 1 – AHU Schematic

Rooftop Units

There are ten packaged rooftop units that supply air to the remainder of the spaces in the Kroc Center. The RTU's are very similar with only small differences between them; so only a typical RTU will be explained. All of the rooftop units have economizers that use more outside air to condition the space when the outside air is at the desired temperatures. The economizers are each capable of producing up to 100 percent outside air. The return air enters the air handler from the bottom of the unit and passes through a sound trap before entering the economizer section of the unit. Once the correct mixture of return and outside air is achieved, the air passes through the cooling coil and the heat exchanger. The cooling coil is a DX unit, the same as what is in AHU-1 and AHU-2. The rooftop units, however, use a heat exchanger instead of a heating coil. A small natural gas burner is located in the unit which heats air that passes through the heat exchanger and conditions the supply air. After passing through the heat exchanger, the air flows through a filter, supply fan, and sound trap before leaving the unit. RTU-1, RTU-2, and RTU-10 have variable frequency drives (VFDs) on the supply fans, because the loads they condition can fluctuate greatly throughout a day. The supply air from these three units travels through VAV boxes with reheat coils before entering the spaces they are conditioning. The other rooftop units have constant speed fans and do not use VAV boxes.

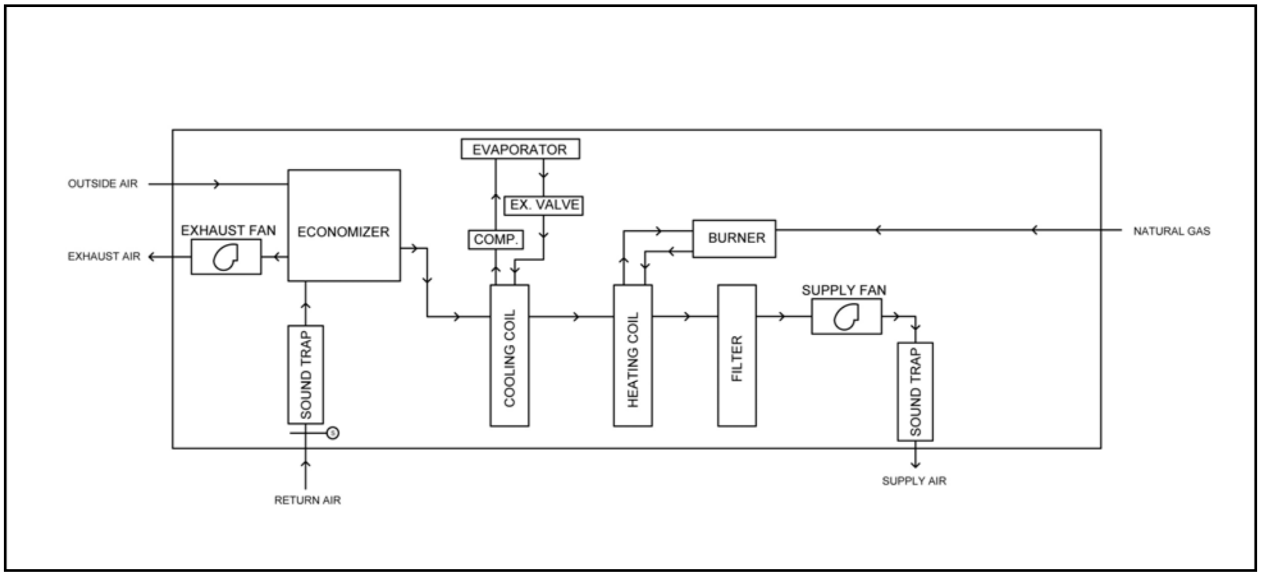

FIGURE 2 – RTU Schematic

Fan Coil Units

Two small fan coil units supply air to the stage area of the chapel. The fan coil units use outdoor heat pumps to supply the heating and cooling necessary to condition the space. The FCU's are constant volume systems and do not have economizers. The space they condition is connected to the chapel, so the air handling unit that conditions the chapel can vary its supply air to properly condition the entire section of the building. The fan coil units and the outdoor heat pumps are mounted on the roof of the stage.

Hot Water Distribution

Three natural gas boilers are located in the mechanical room on the southern side of the Kroc Center. These boilers supply hot water to AHU-1, AHU-2, and the heat exchangers that heat the two pools. Figure 3 below is a schematic that clearly describes the layout of the hot water system.

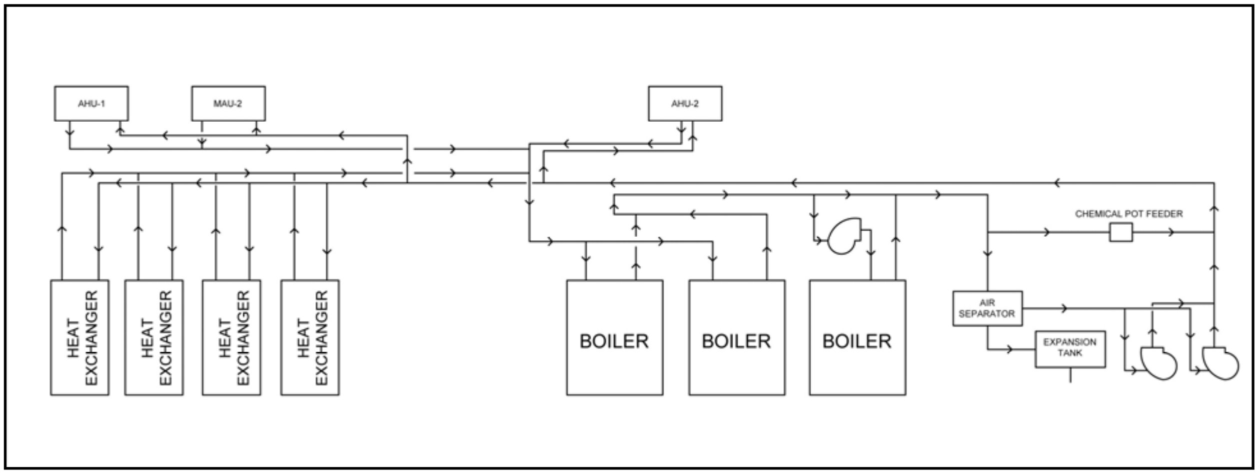

FIGURE 3 – How Water Schematic

Mechanical System First Cost

The current mechanical system was chosen to reduce first costs and only employed minor energy savings. The total cost of the mechanical system was just under $3,319,000, which is equal to $36.08 per square foot. The cost of the entire building was roughly $33.2 million, so the mechanical system makes up almost exactly ten percent of the total construction cost.

LEED Evaluation

The design team on the Kroc Center designed the building to reach LEED Gold certification. A detailed breakdown of the LEED analysis was not available, but an analysis of the mechanical efficiency was. Two sections of LEED v2.2 are based on the performance of the mechanical system of the building: Energy & Atmosphere, and Indoor Environmental Quality. All the LEED credits that have been achieved or that could be achieved will be evaluated.

EA Prerequisite 1: Fundamental Commissioning of the Building Energy Systems

This credit calls for commissioning to ensure that the system is correctly installed. The commissioning required is fairly standard and is specified in the design documents.

EA Prerequisite 2: Minimum Energy Performance

To meet this prerequisite the building must comply with ASHRAE Standard 90.1 As determined in Technical Report 1, the Kroc Center complies with Standard 90.1.

EA Prerequisite 3: Fundamental Refrigerant Management

This prerequisite states that the mechanical systems cannot use refrigerants that contain CFCs. The Kroc Center specifies that the mechanical equipment must use R-410A and R-407C refrigerants.

EA Credit 1: Optimize Energy Performance

This credit gives one to ten points based on the energy performance of the mechanical system. A detailed energy analysis was performed by the mechanical engineer who determined that the current system would use 17.6% less energy than a baseline performance building. That amount of savings in a new building is enough to award three LEED points.

EA Credit 3: Enhanced Commissioning

This credit awards one point for making commissioning a more integral part of the design and construction of the building. Though it could not be determined if the design team pursued this credit, it is definitely attainable.

EA Credit 4: Enhanced Refrigerant Management

To receive this credit the refrigerant used in the mechanical system must reduce ozone depletion and minimize direct contributions to global warming. The primary refrigerant used in this mechanical system is R-410A which does not cause ozone depletion. It does carry a high global warming potential, but if installed correctly the refrigerant will not pose any significant environmental problems. The Kroc Center should be able to achieve this point.

EA Credit 5: Measurement and Verification

One point will be awarded if steps are taken to monitor the energy use for at least one year after it is initially occupied. It could not be determined whether or not any steps were taken to achieve this credit, but this credit could be achieved.

EQ Prerequisite 1: Minimum IAQ Performance

To meet this prerequisite the building must comply with sections 4 through 7 of ASHRAE Standard 62.1-2004. It was determined in Technical Report 1 that the Kroc Center completely complies with this standard, thus the prerequisite is met.

EQ Prerequisite 2: Environmental Tobacco Smoke Control

The Kroc Center is a community center that will be used primarily by children; smoking is prohibited on the Kroc Center's property. Therefore, the building complies.

EQ Credit 3.1: Construction IAQ Management Plan: During Construction
This credit calls for an indoor air quality plan to be developed and implemented during the construction and pre-occupancy phases of the building. A detailed plan is described in the project specifications so the building complies with this credit.

EQ Credit 3.2: Construction IAQ Management Plan: Before Occupancy
The specifications state the building is to be completely "flushed out" before it is occupied. The documentation for this task to be provided by the contractor and submitted to the mechanical engineer.

EQ Credit 6.2: Controllability of Systems: Thermal Control
The specifications state for the contractors to provide individual comfort controls for a minimum of 50% of the building occupants to enable adjustment to individual needs. This is in direct compliance with the LEED requirements, so this credit is achieved

EQ Credit 7.1: Thermal Comfort: Design
Steps were taken to show that the building complies with ASHRAE Standard 55-2004. This complies with the credit requirements, so the Kroc Center achieves this credit.

EQ Credit 7.2: Thermal Comfort: Verification
The specifications state that a thermal comfort survey is to be completed by the occupants between six and eighteen months after the building is occupied. This survey will ensure that the mechanical system is providing adequate thermal comfort levels.

Overall Evaluation of System

The mechanical system meets the ventilation and building load requirements of the Kroc Center. The use of VFDs on some of the air handlers and economizers help to reduce the energy use of the building. The current mechanical system is definitely capable of meeting the demands of the building, but the design team did not take that extra step to make the building even more energy efficient. Possibilities for improvement definitely exist, but they were likely ruled out because of higher first costs. Some of the equipment appears to be oversized, which provides a large area for potential energy savings. Several steps were specifically taken to achieve certain LEED points; but LEED points are not indicative of the overall performance of the mechanical system. The current mechanical system meets all the needs of the building and even provides some steps to save energy, but there are definitely possibilities for improvement.

References

ASHRAE. 2007, ANSI/ASHRAE, Standard 62.1-2007, Ventilation for Acceptable Indoor Air Quality. American Society of Heating Refrigeration and Air-Conditioning Engineers, Inc., Atlanta GA.

ASHRAE. 2007, ANSI/ASHRAE, Standard 90.1-2007, Energy Standard for Building Except Low-Rise Residential Buildings. American Society of Heating Refrigeration and Air-Conditioning Engineers, Inc., Atlanta GA.

Construction Documents and Project Specifications for The Salvation Army Ray & Joan Kroc Corps Community Center of Salem Oregon. Courtesy of BRS Architecture.

Final Report. Salem Kroc Center Recreational Building LEED Energy Analysis. GLUMAC International. 9 Jan. 2009.

Pay Application October 2009. LCG Pence Construction LLC.