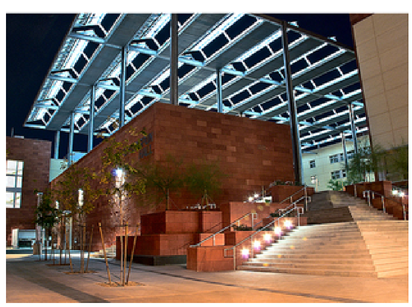
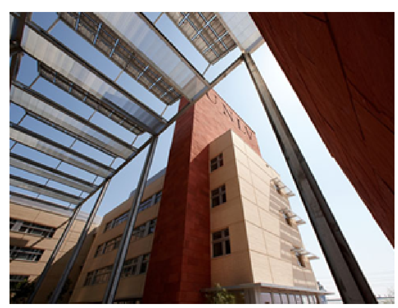
solar absorption and thermal storage application analysis

senior thesis final report





unlv greenspun hall
las vegas, nevada
mechanical
spring 2009

Prepared by: David Miller
Prepared for: Dr. James Freihaut

david miller

mechanical

greenspun hall
las vegas, nv

project information

project size.	122,000 sf
building height.	3-5 floors
construction dates.	fall 06' - fall 08'
construction cost.	$94 million
project delivery.	design-build

project team

architect.	hks architects
design architect.	robert a.m. stern architects
cm.	walter p. moore & assoc., inc
m.e.p. engineers	rg vanderweil engineers
structural engineers.	clark construction

architecture

a LEED silver modernist complex designed to minimize energy and water use while maximing natural lighting and indoor air quality. a louvered canopy of a photo-voltaic array reduces heat island affect and supplies energy to power roughly 30 percent of the building.

mechanical

(6) air handling units, 61,300 cfm total, and (2) 200 ton centrifugal chillers serve a system consisting of (22) Fan Coil Units, (6) computer room air-conditioning units, and an ellaborate system of chilled beams

structural

various sized spread footers along with strip footers. cast in place beams, slabs, and typical columns at 24x24. laterally braced steel framing in stairwells. shear walls located throughout. steel framing support photovoltaic canopy over central courtyard

electrical

(2) 480Y/277 3 phase 4 wire distribution panels at 800 amps. (1) 208Y/120 3 phase 4 wire distribution panel at 600 amps. all distribution panels and motor control centers located in main electrical room on 2nd floor

http://www.engr.psu.edu/ae/thesis/portfolios/2009/dmm5016/

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Acknowledgements

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Special Thanks to:	Bruce Nipp Fred Livingston, Steve Germano, and the rest of the Vanderweil Las Vegas office

1.0 Executive Summary

Greenspun Hall is a new LEED Gold certified building on the University of Nevada at Las Vegas' campus and just opened its doors to the public earlier this year. To maintain a comfortable environment, the building's architects and designers developed various features and components to help combat the extreme weather in this hot, arid valley. A 8,000 ft^2 photovoltaic array looms over the central courtyard to supply on site electricity and to reduce heat island effect. Louvers over windows, building materials, and the mechanical system also display sustainable and energy efficient design.

The mechanical system is an evaporative cooled system, utilizing *Marley* cooling towers, *Carrier* chillers, and *Climate Craft* air-handling units to meet the cooling load. The system uses a network of chilled beams to efficiently meet the demand while maintaining controllability. Overall, the system meets the designers design objectives: innovation and energy efficiency. However, several alternatives were proposed to improve the existing system.

Alternative 1 utilizes a large solar absorber array and back-up boilers to drive the generators of the absorption chillers, which would replace the current chillers in place. Such a system saves energy by having solar energy drive the system during periods of sunshine and decreases cost by reducing consumption and demand charges of electricity. The annual energy cost for this system is $15,130 and has a payback period of roughly 17 years.

The second solution, *Alternative 2*, implements the addition of chilled water storage to further shift the energy usage to non-peak periods and to reduce the number of solar absorbers needed to drive the absorption chilling process. Annual energy cost was calculated to be $17,645 and has a payback of roughly 25 years.

Alternative 3 uses the same chillers as the existing system, however adds thermal storage to the load loop to shift energy costs. Two different loading strategies were used to size the storage tank. The first discharges for the 12 hour period of increased electricity charges and the second discharges for the 6 hours of maximum electricity charge. In both situations, the storage system was only utilized for the 4 summer months due to the low cost of electricity in the other months. Both strategies had no payback period because the annual operating costs exceeded the existing system. This system would not save any energy either, thus was rejected as a solution.

The first alternative could be selected to improve the existing system and might have a more favorable payback period of CO^2 credits were implemented and future energy costs increased. With that in mind, I would implement Alternative 1 to further display leadership in innovation and energy efficient design.

2.0 Project History

The University of Nevada at Las Vegas' new building on campus is Greenspun Hall which is now the home for the Greenspun college of urban affairs as well as many offices and classrooms. The prominent structure is located on the outskirts of the campus positioned to be a gateway from the city. Greenspun Hall represents a commitment and investment to the future through its sustainable design and architecture.

The project broke ground on January 24, 2007 and was officially dedicated on December 2, 2008. HKS Architects, Inc. in association with Robert A.M. Stern Architects designed the environmentally friendly, 122,000 ft^2 structure which houses numerous classrooms and offices, 6 conference rooms, 5 high-tech learning centers, 3384 ft^2 of television and performance studio, 3 radio studios, editing bays, operational centers, several laboratories, and a 190 seat auditorium. The building achieved a LEED Gold rating by diverting 75% of its construction wasted from landfills, using regionally produced low emitting building materials, and saving 15% on regulated energy through its implementation of a photovoltaic array.

The array is one of the most prominent features of the structure applied as a louvered canopy that covers the large central courtyard to reduce direct sunlight and heat island affect, while still allowing direct views to the sky and creating energy. The building joins a list of modernist complexes on UNLV's campus and strives to achieve a sense of collegiateness. The structure wraps around a common courtyard which along with wide stairways and hallways with alcoves support informal interaction between spaces. There are two visible parts of the building visible from the exterior which share a basement underneath the courtyard, which are 3 and 5 stories respectfully.

The building is generally fully operational; however the media center is not set to open until the summer of 2009. The aspiration of the designers and consultants for Greenspun Hall was to utilize their design objectives: energy efficiency and innovation to represent UNLV's leadership and investment for the future, and to ultimately achieve a LEED Gold Certification. Re-design objectives will basically be the same, but to make the building design more innovative to save energy.

3.0 Existing Conditions

3.1 Mechanical System

Mechanical Overview:

Energy efficiency and innovation were key in the design of Greenspun Hall's mechanical system. The building incorporates new technologies to efficiently achieve a comfortable indoor environment. Five air-handling units supply air to a system of chilled beams which are a novel concept that are an improvement of the typical VAV system while also maintaining the added controllability. Three of the air-handling units are 100% dedicated outdoor air and the other two mix the minimum outdoor air requirement intake with return air. The secondary system for the building consists of several fan coil units dispersed throughout the building, but mainly in the basement which supply cooling assistance for the summer loads. Energy effectiveness is improved through efficient mechanical equipment, such as pumps, chillers, and fans, as well as a flat-plate heat exchanger with a capacity of 300 MBH.

Mechanical components of the Greenspun Hall system are spread throughout, on, and around the building to improve efficiency and minimize loss of usable space. One air-handling unit and the heat exchanger are located on the mechanical mezzanine, other air handling units on the roof, chillers and boilers in their respective rooms, fan-coils in the plenum, and cooling towers in the service yard across the parking lot. Overall, the system does not interfere with the usage of the building in that the mechanical systems only occupy 4,839.75 square feet of the 122,000 square feet of usable space. This is less than 4% of the total square footage of the building's footprint. A break down of the lost usable space due to the mechanical systems is supplied in the chart below.

Table 3.1.1

Lost Usable Space	
Reason	Floor Area (ft^2)
Boiler Room	893.25
Chiller Room	1620.00
Mechanical Mezzanine	2016.00
Vertical Shafts	310.50

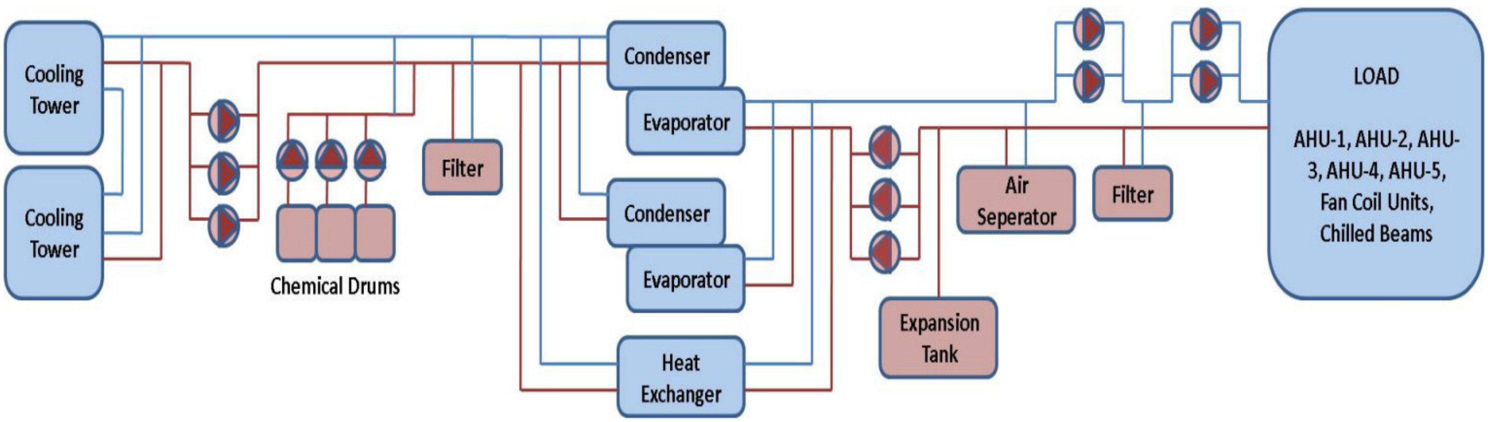
System Description:

The chilled water system for UNLV Greenspun Hall is a primary/secondary system which consists of a heat rejection loop and load loop. Air is supplied through five air handling units, four of which are roof top units, and three of which are 100% dedicated outdoor air. Air is first filtered through 2” pre-filters and then through pleated MERV-13 rated filters before pre-conditioning through the coils in the air handlers, where the air dry bulb temperature is reduced from roughly 100 F to 50 F. It is then distributed to the various zones, where chilled beams can supply further cooling if necessary to meet the load by the same supply of chilled water that the cooling coils in the air handlers used for pre-conditioning.

After being distributed to each of the various zones and spaces, air is then collected in the plenum. In the case of a zone needing additional cooling not sufficiently met by the primary system, the secondary system of fan coil units circulate the air over their respective cooling coils and supply it back to that particular zone. Most of the plenum air is delivered back to the air handlers through hallway plenum return and vertical shafts.

The chilled water system for UNLV Greenspun Hall consists of a heat rejection loop (primary) and a load loop (secondary). This system is known as a primary/secondary system with major equipment shown on the diagram below. This system operates in one of two modes: chiller or heat exchanger. During chiller mode, both chillers are enabled whenever the outdoor air web bulb temperature exceeds the set point. These are equipped with variable speed drives to maintain maximum efficiency.

Figure 3.1.1



UNLV Greenspun Hall’s mechanical system has two Carrier 19XR centrifugal chillers and one 300 MBH Plate Heat Exchanger which supply chilled water to the air handling units, chilled beams, and fan coil units. This is accomplished by circulating condenser water through the heat rejection loop through which the chillers supply cooling to the chilled water loop to circulate back to the loads via sets of primary and secondary pumps.

Condenser water is circulated by the pumps, from the chiller to the cooling towers, where heat is rejected through evaporation. The cooler condenser water is then re-circulated back to the chillers. Each open-celled cooling tower has its own basin filter and is chemically treated to reduce the chance of contamination. The load loop utilizes an air separator, filter, and expansion tank to complete the circuit back to the chillers. The table below summarizes all major equipment of the chilled water system.

Table 3.1.2

Cooling Tower Schedule								
			Summer			Fan		
Unit	No. of Cells	Tons/Cell	GPM/Cell	EWT/LWT	EAT (WB)	CFM	HP	Weight
CT-1	2	200	600	95/85	78	69,390	10	23,400
CT-2	2	200	600	95/85	78	69,390	10	23,400

Heat Exchanger Schedule					
		Hot Side		Cold Side	
Unit	Capacity	EWT/LWT	GPM	EWT/LWT	GPM
PHX-1	300.6	64/54	600	52/57	1,200

Air Handling Units										
			Motor			Cooling Coil				
Unit	Total CFM	Min. OA CFM	RPM	BHP	Motor HP	EAT (DB/WB)	LAT (DB/WB)	EWT/LWT	GPM	Total MBH
AHU-1	21,000	10,200	1,580	30.1	40	91/64.8	52.5/50.8	45/60.5	100	777.2
AHU-2	17,000	3,600	1,718	23.6	25	101/66	53.7/48.7	45/62.8	85	758
AHU-3	7,000	7,000	1,717	6.6	7.5	108/67	49.5/45.2	45/60.2	50	381
AHU-4	8,200	8,200	1,775	7.8	10	108/67	50.8/45.9	45/59.5	50	370
AHU-5	5,100	5,100	1,775	4.6	7.5	108/67	49.8/45.5	45/59.0	60	274.2

3.2 Structural System

The foundation of the structure consists of various sized spread footers along with strip footers. All beams, slabs, and columns are cast-in-place, normal weight concrete with typical columns at 24x24. Shear walls are located throughout the structure, mainly around vertical shafts and rises. All stair wells are laterally braced with steel framing. Steel framing supports the louvered photovoltaic canopy covering the central courtyard. The roof system is a non-composite 5” normal weight concrete slab on deck with 7 ft. joist spacing.

3.3 Electrical System

All electrical systems are served by the main electrical room located on the second floor. Two distribution panels are 480Y/277 3 phase 4 wire rated at 800 amps and one is 208Y/120 3 phase 4 wire rated at 600 amps. The lighting is primarily comprised of recessed fluorescent fixtures and is rated for 1.1 watts/ft^2. The photovoltaic array comprises 8,000 ft^2 over the central courtyard and can supply the building with roughly 50,000 KWhs of energy annually.

3.4 Site Conditions

The city of Las Vegas has an arid desert climate with extreme temperatures during the summer months. There is an abundant amount of sun all year round averaging about 300 days of sun a year. Daytime highs in the summer commonly exceed 100 degrees F with average nighttime lows in the 70's and 80's. Greenspun Hall architecture has accounted for this through the solar array along with overhands on south-facing glass which serve to block out direct sunlight, decreasing the amount of cooling load due to solar radiation. Hourly average temperature and solar radiation values for each month of the year are summarized in Appendix A. The following information are values found in ASHRAE Standard 90.1-2007 that summarize the buildings design conditions.

Table 3.4.1

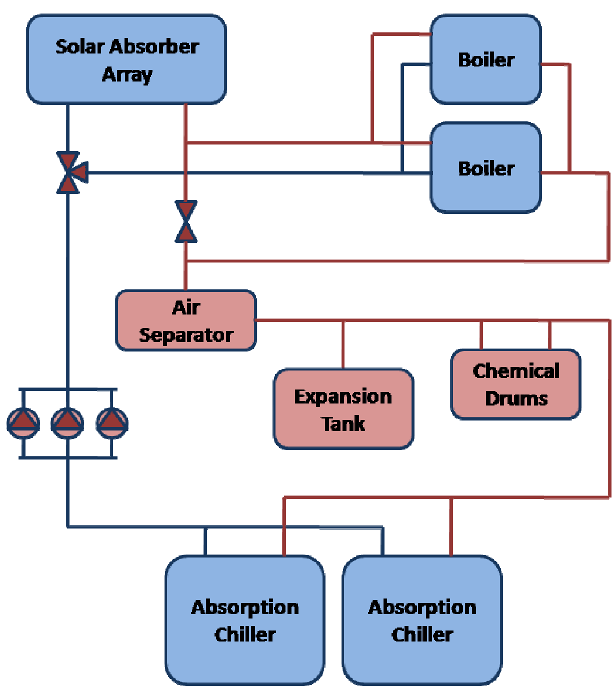
Outdoor Design Conditions	
Location	Las Vegas, Nevada
Climate Description	Warm Dry
Latitude	36.08 F
Longitude	115.17 F
Elevation	2,162 ft
Summer Design DB	106 F
Summer Design WB	66 F
Winter Design DB	27 F

4.0 Improving the System

The existing system is very innovative and efficient, fulfilling all of the design goals set forth. The use of efficient system equipment, such as the chillers and pumps, and harnessing an effective system design through an intricate system of chilled beams keeps the consumption of regulated energy low. Both existing chillers depend on electricity to meet the cooling loads. These loads are at their peak non-consequently at the same time the electric rates are at their highest. For this thesis, three new designs were analyzed and compared to the current design based on energy efficiency, annual energy cost, and first cost.

The first alternative involves changing out the centrifugal chillers for single-effect absorption chillers which will be driven by an array of solar absorption panels on the available roof space of the building. Double effect absorption cycle chillers were evaluated for such a system, but were rejected because steam was needed to drive them. Solar panels, absorbing the abundant amount of solar radiation, can generate the necessary temperature to drive the generators of the selected chillers. Therefore, during periods of sunshine, the cooling load can be met via a self-sustained renewable resource with the only cost being to run the circulation pumps and auxiliaries. Such a system would also need an back-up boiler running on natural gas to sustain the hot water temperature during times of little or no solar radiation. The following diagram is a schematic of the hot water components used to drive the generators of the absorption chillers.

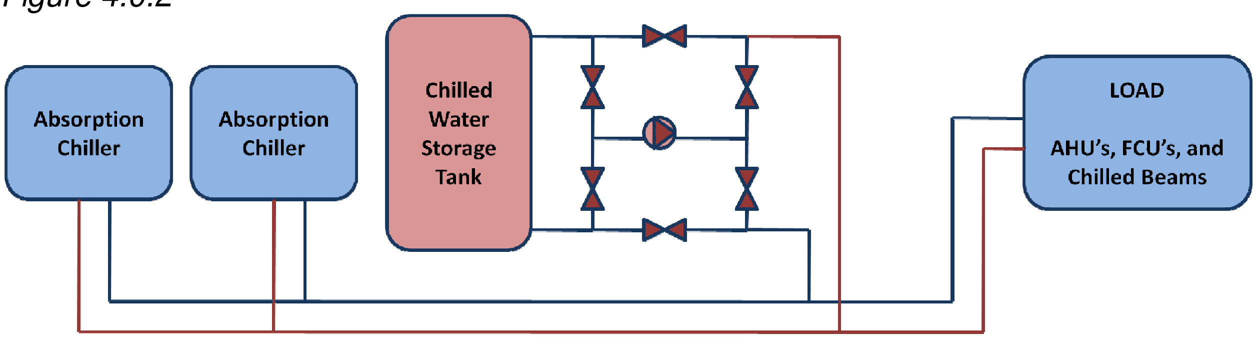
Figure 4.0.1



Such a system, theoretically, should reduce the annual regulated energy usage and drastically reduce the annual energy cost. Even though the absorption chillers are significantly less efficient as the existing chillers, thus expending greater amount of energy, they are primarily being driven by “free”, solar energy during peak loading; which will not only reduce the consumption charge, but the demand charge as well. The initial cost of such a system would be exponentially larger with an increase in annual pumping energy, but the hope is that it will reduce the use of regulated energy enough to have an acceptable payback period. The area of solar absorbers required will also be very large, raising the concern to the available space on roof tops and the roof structure which support them.

The second alternative is the same as the first, except a chilled water storage tank was added to the load loop. The theory being that storing energy during the night hours of the summer months will assist the chillers during peak hours, thus using less chiller energy during that time, and reducing the size of the solar absorber array needed to drive the chillers. The following figure shows the load loop of the cooling system in which chilled water storage is utilized.

Figure 4.0.2



By sizing the storage tank properly, the ability to meet peak loads will stay the same while reducing the amount of solar absorbers needed. This has the possibility of having a lesser first cost than the first alternative, but still a higher first cost than the existing system. This arrangement takes care of the concern to the roof structure and possibly reduces annual pumping energy.

The final alternative was generated to compare the ability of the solar absorbers and absorption chilling cycle to the current centrifugal chillers. The only difference from the existing system is the implementation of a chilled water storage tank on the evaporator side. This alternative will expose the efficiency of such a system in Las Vegas’ harsh climate.

With a correctly sized storage tank, peak loading months from June through September will not consume as much electricity. This is when electricity is most expensive, so the payback should be reasonable.

5.0 Designing the System

Load analysis software, specifically Trane Trace 700, was used to determine annual energy usage, peak load on design day, load profiles, and other parts of load examinations for the existing mechanical system. Unfortunately, the program is incapable of adding specific components such as solar absorbers with their auxiliary boilers and chilled water storage, and lacks the ability to compute the outputs of such components. Therefore a series of spreadsheets show the various calculations necessary to compute such outputs.

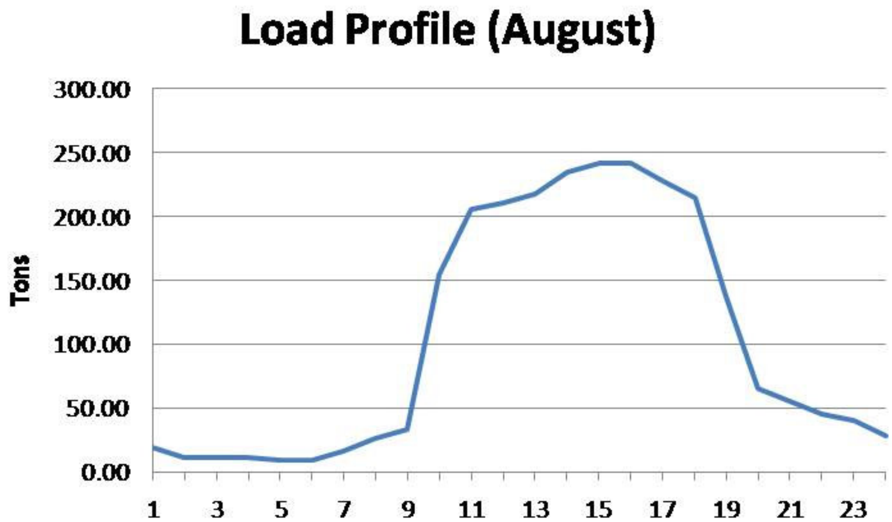
5.1 Procedure

Generally, TMY data was taken and used in comparison with the load profiles from the initial load analysis to generate the results. To simplify the calculation, the TMY data and daily load profiles were taken and converted into monthly averages, which creates a table in which for each month there is an average (typical) day that is broken down hourly. *Table 5.1.1* represents the load profiles for each typical day, which represents an average value for each day of the month. *Figure 5.1.1* shows the load profile for a typical day in August. These values were used to compute annual energy costs for the existing system and all the alternatives.

Table 5.1.1

	Cooling Load (tons) vs. Hour/day											
	J	F	M	A	M	J	J	A	S	O	N	D
0:01 - 1:00	0	0	0	0	0	17.39	17.91	19.33	15.93	0	0	0
1:01 - 2:00	0	0	0	0	0	10.87	11.2	12.08	9.96	0	0	0
2:01 - 3:00	0	0	0	0	0	10.87	11.2	12.08	9.96	0	0	0
3:01 - 4:00	0	0	0	0	0	10.87	11.2	12.08	9.96	0	0	0
4:01 - 5:00	0	0	0	0	0	8.69	8.96	9.66	7.97	0	0	0
5:01 - 6:00	0	0	0	0	0	8.69	8.96	9.66	7.97	0	0	0
6:01 - 7:00	0	0	0	0	0	15.22	15.67	16.91	13.94	0	0	0
7:01 - 8:00	6.62	5.99	6.37	5.62	6.39	23.91	24.63	26.57	21.91	6.7	6.18	6.29
8:01 - 9:00	8.43	7.62	8.11	7.16	8.13	30.43	31.35	33.82	27.88	8.53	7.87	8.01
9:01 - 10:00	38.52	34.85	37.07	32.72	37.19	139.11	143.31	154.6	127.45	38.97	35.98	36.61
10:01 - 11:00	51.16	46.28	49.23	43.46	49.39	184.76	190.33	205.33	169.27	51.76	47.79	48.62
11:01 - 12:00	52.37	47.37	50.39	44.48	50.55	189.11	194.81	210.16	173.26	52.98	48.91	49.77
12:01 - 13:00	54.17	49	52.13	46.02	52.3	195.63	201.53	217.41	179.23	54.8	50.6	51.48
13:01 - 14:00	58.39	52.81	56.18	49.59	56.36	210.84	217.2	234.32	193.17	59.07	54.53	55.49
14:01 - 15:00	60.19	54.45	57.92	51.13	58.11	217.37	223.92	241.57	199.14	60.89	56.22	57.2
15:01 - 16:00	60.19	54.45	57.92	51.13	58.11	217.37	223.92	241.57	199.14	60.89	56.22	57.2
16:01 - 17:00	56.58	51.18	54.44	48.06	54.62	204.32	210.49	227.07	187.2	57.24	52.85	53.77
17:01 - 18:00	53.57	48.46	51.55	45.5	51.71	193.46	199.29	214.99	177.24	54.2	50.04	50.91
18:01 - 19:00	34.31	31.03	33.01	29.14	33.12	123.9	127.64	137.69	113.51	34.71	32.05	32.61
19:01 - 20:00	16.25	14.7	15.64	13.8	15.69	58.69	60.46	65.22	53.77	16.44	15.18	15.44
20:01 - 21:00	13.84	12.52	13.32	11.76	13.36	49.99	51.5	55.56	45.8	14.01	12.93	13.16
21:01 - 22:00	11.44	10.34	11	9.71	11.04	41.3	42.55	45.9	37.84	11.57	10.68	10.87
22:01 - 23:00	10.23	9.26	9.85	8.69	9.88	36.95	38.07	41.07	33.85	10.35	9.56	9.72
23:01 - 24:00	0	0	0	0	0	26.08	26.87	28.99	23.9	0	0	0

Figure 5.1.1



5.2 Control

Even though the existing system was able to be calculated through Trane Trace 700, I chose to calculate annual energy usage through the method described previously to act as a control for the alternatives' calculation results.

Following the extraction of data from Trane Trace, the tonnage per hour values needed to be converted to electrical units to determine the annual cost. This was done by using the chiller efficiency of 0.837 KW/ton given in the design documents. After that conversion, demand and consumption electrical charges were calculated. The following table represents the demand and consumption charges for Nevada Power, Greenspun Hall's electricity provider.

Table 5.2.1

Electric Charge		Summer	All Other Periods
Consumption	On-Peak	$0.10001	$0.06406
	Mid-Peak	$0.0865	
	Off-Peak	$0.06230	
Demand	On-Peak	$9.17	$0.50
	Mid-Peak	$0.68	
	Off-Peak	$0.00	

The results show an annual consumption charge of $27,991.30 and demand charge of $6,960.48, totaling $34,951.78. The system uses roughly 340,000 KWh of energy annually. A detailed series of calculation tables for the existing system is located in *Appendix B Section 1*.

5.3 Alternative 1

From the existing system, both electric driven chillers were swapped out for two single-effect absorption chillers, and an array of solar absorbers with a pair of back-up boilers were added to the system. The same loads were used to calculate annual energy usage as the control calculation, values from *Table 5.1.1*. The solar absorbers allow the chillers to be driven strictly by solar energy for a large part of the year. The following table shows the average solar radiation energy that can heat up the water used to drive the generators of the chillers.

Table 5.3.1

Average Hourly Statistics for Direct Normal Solar Radiation Wh/m²												
Hour	J	F	M	A	M	J	J	A	S	O	N	D
0:01 - 1:00	0	0	0	0	0	0	0	0	0	0	0	0
1:01 - 2:00	0	0	0	0	0	0	0	0	0	0	0	0
2:01 - 3:00	0	0	0	0	0	0	0	0	0	0	0	0
3:01 - 4:00	0	0	0	0	0	0	0	0	0	0	0	0
4:01 - 5:00	0	0	0	1	42	69	42	2	0	0	0	0
5:01 - 6:00	0	0	16	185	340	429	347	253	90	23	0	0
6:01 - 7:00	0	68	244	501	535	640	605	551	452	381	161	27
7:01 - 8:00	302	348	457	674	687	736	726	701	644	646	481	371
8:01 - 9:00	510	523	545	720	777	784	755	780	695	730	607	549
9:01 - 10:00	588	606	593	770	798	752	797	807	798	767	689	613
10:01 - 11:00	655	679	588	769	761	791	810	815	833	748	697	687
11:01 - 12:00	642	630	615	766	679	760	820	812	817	780	735	676
12:01 - 13:00	598	662	641	714	689	770	802	752	817	756	724	675
13:01 - 14:00	577	620	578	673	718	759	775	682	752	696	696	658
14:01 - 15:00	564	543	554	649	690	703	756	658	641	675	629	602
15:01 - 16:00	476	443	429	607	658	698	686	585	604	596	463	406
16:01 - 17:00	144	265	314	470	585	606	614	534	441	323	117	44
17:01 - 18:00	0	15	108	266	352	435	494	369	160	13	0	0
18:01 - 19:00	0	0	0	17	46	152	182	53	0	0	0	0
19:01 - 20:00	0	0	0	0	0	0	0	0	0	0	0	0
20:01 - 21:00	0	0	0	0	0	0	0	0	0	0	0	0
21:01 - 22:00	0	0	0	0	0	0	0	0	0	0	0	0
22:01 - 23:00	0	0	0	0	0	0	0	0	0	0	0	0
23:01 - 24:00	0	0	0	0	0	0	0	0	0	0	0	0

These values were simply converted to Btu/ft^2 and then multiplied by the area of an absorber (40 ft^2) to determine the energy output of each absorber during periods of sunshine. These values are represented in *Table 5.3.2.*

Table 5.3.2

Annual Hourly Energy Created / absorber												
Hour	J	F	M	A	M	J	J	A	S	O	N	D
0:01 - 1:00	0	0	0	0	0	0	0	0	0	0	0	0
1:01 - 2:00	0	0	0	0	0	0	0	0	0	0	0	0
2:01 - 3:00	0	0	0	0	0	0	0	0	0	0	0	0
3:01 - 4:00	0	0	0	0	0	0	0	0	0	0	0	0
4:01 - 5:00	0	0	0	12.69	532.96	875.58	532.96	25.38	0	0	0	0
5:01 - 6:00	0	0	203.03	2347.58	4314.47	5443.85	4403.3	3210.47	1142.07	291.86	0	0
6:01 - 7:00	0	862.89	3096.27	6357.5	6788.95	8121.36	7677.22	6991.98	5735.71	4834.74	2043.03	342.62
7:01 - 8:00	3832.27	4415.99	5799.16	8552.8	8717.77	9339.56	9212.66	8895.42	8172.11	8197.49	6103.71	4707.85
8:01 - 9:00	6471.71	6636.67	6915.84	9136.53	9859.83	9948.66	9580.66	9897.9	8819.29	9263.42	7702.6	6966.6
9:01 - 10:00	7461.5	7689.91	7524.94	9771.01	10126.32	9542.59	10113.63	10240.52	10126.32	9732.94	8743.15	7778.74
10:01 - 11:00	8311.7	8616.25	7461.5	9758.32	9656.8	10037.49	10278.59	10342.04	10570.45	9491.84	8844.66	8717.77
11:01 - 12:00	8146.74	7994.46	7804.12	9720.25	8616.25	9644.11	10405.49	10303.97	10367.42	9897.9	9326.87	8578.18
12:01 - 13:00	7588.39	8400.53	8134.05	9060.39	8743.15	9771.01	10177.07	9542.59	10367.42	9593.35	9187.28	8565.49
13:01 - 14:00	7321.91	7867.56	7334.6	8540.11	9111.15	9631.42	9834.45	8654.32	9542.59	8831.98	8831.98	8349.77
14:01 - 15:00	7156.95	6890.46	7030.05	8235.56	8755.84	8920.8	9593.35	8349.77	8134.05	8565.49	7981.77	7639.15
15:01 - 16:00	6040.26	5621.5	5443.85	7702.6	8349.77	8857.35	8705.08	7423.43	7664.53	7563.01	5875.29	5151.99
16:01 - 17:00	1827.31	3362.75	3984.54	5964.12	7423.43	7689.91	7791.43	6776.26	5596.12	4098.75	1484.69	558.34
17:01 - 18:00	0	190.34	1370.48	3375.44	4466.75	5519.98	6268.67	4682.47	2030.34	164.97	0	0
18:01 - 19:00	0	0	0	215.72	583.72	1928.82	2309.51	672.55	0	0	0	0
19:01 - 20:00	0	0	0	0	0	0	0	0	0	0	0	0
20:01 - 21:00	0	0	0	0	0	0	0	0	0	0	0	0
21:01 - 22:00	0	0	0	0	0	0	0	0	0	0	0	0
22:01 - 23:00	0	0	0	0	0	0	0	0	0	0	0	0
23:01 - 24:00	0	0	0	0	0	0	0	0	0	0	0	0

Through consultations with the manufacturer and knowing that 165^o F water was needed to drive the generators at the given flow rate, the number of absorbers needed was estimated to be 425, equaling 17,000 ft^2. The following tables show the performance data for the absorption chillers and the solar absorbers/boilers that drive them.

Table 5.3.3

	Chiller 1	Chiller 2
Entering CW T	85	85
Leaving CW T	100	100
CW ∆T	15	15
CW gpm	777.33	777.33
Max PD (ft)	14.5	14.5
Entering CHW T	60	60
Leaving CHW T	44	44
CHW ∆T	16	16
CHW gpm	300	300
Max PD (ft)	6.4	6.4
Entering GEN T	165	165
Leaving GEN T	145	145
GEN ∆T	20	20
GEN gpm	346	346
Capacity (tons)	200	200
Capacity (mbh)	2400	2400
Type	Carrier 16LJ - 23	Carrier 16LJ - 23
Qe	2400000	2400000
Qg	3460000	3460000
Qa+Qc	5829975	5829975
Heat Balance	0.99487628	0.99487628
COP	**0.693641618**	**0.693641618**

Solar Absorbers	
The. # of ABS	424.5398773
# of ABS	425
SF of ABS	17000
SF Available	25440

Boiler (2)	
Type	RBI Futera XLF - MB/MW 4000
MBH	3460
GPM	346
∆T	20
η	0.87
Entering T	145
Leaving T	165

In conjunction with the data from *Table 5.3.3*, average temperatures of the hot water were determined and organized into *Table B 2.1* in *Appendix B Section 2*. Through these values, it was determined that the solar array could solely drive the chillers during parts of a typical day, while at other times, the back-up boilers were needed to boost the hot water temperature or drive the chillers entirely on their own (*Table B 2.2*). Thus, this alternative system consumes natural gas and solar energy as its primary energy sources instead of electricity.

From the given load and knowing the back-up boilers' change in temperature, the energy needed from the boilers could be determined. The efficiencies of the absorption chillers were needed to determine the energy output of the boilers. These values are summarized in *Table B 2.4* located in *Appendix B Section 2*. These values were then adjusted through the boiler efficiencies to develop the gas firing rate shown in the table below.

$$Cooling\ Load\left(\frac{3460}{2400}\right) = Boiler\ Output$$

Table 5.3.4

Gas Firing Rate (CHF) of Boiler vs. Hour/day												
Hour	J	F	M	A	M	J	J	A	S	O	N	D
0:01 - 1:00	0	0	0	0	0	376.04	387.38	417.91	344.52	0	0	0
1:01 - 2:00	0	0	0	0	0	235.03	242.12	261.19	215.32	0	0	0
2:01 - 3:00	0	0	0	0	0	235.03	242.12	261.19	215.32	0	0	0
3:01 - 4:00	0	0	0	0	0	235.03	242.12	261.19	215.32	0	0	0
4:01 - 5:00	0	0	0	0	0	188.02	193.69	208.96	172.26	0	0	0
5:01 - 6:00	0	0	0	0	0	188.02	193.69	208.96	172.26	0	0	0
6:01 - 7:00	0	0	0	0	0	0	0	0	250.96	0	0	0
7:01 - 8:00	143.18	129.51	105.93	0	0	0	0	0	0	0	62.71	136.07
8:01 - 9:00	21.66	0	0	0	0	0	0	0	0	0	0	0
9:01 - 10:00	0	0	0	0	0	0	0	0	0	0	0	0
10:01 - 11:00	0	0	0	0	0	0	0	0	0	0	0	0
11:01 - 12:00	0	0	0	0	0	0	0	0	0	0	0	0
12:01 - 13:00	0	0	0	0	0	0	0	0	0	0	0	0
13:01 - 14:00	0	0	0	0	0	0	0	0	0	0	0	0
14:01 - 15:00	0	0	0	0	0	0	0	0	0	0	0	0
15:01 - 16:00	690.7	1116.28	0	0	0	0	0	0	0	0	842.53	1237.01
16:01 - 17:00	1223.57	1106.75	1177.35	629.02	0	0	0	0	3942.67	1237.82	1142.84	1162.79
17:01 - 18:00	1158.49	1047.88	1114.73	984.04	1118.33	4183.47	4309.66	4649.26	3832.77	1171.98	1082.05	1100.94
18:01 - 19:00	741.95	671.11	713.93	630.23	716.24	2679.3	2760.12	2977.62	2454.7	750.59	693	705.1
19:01 - 20:00	351.45	317.9	338.18	298.53	339.27	1269.14	1307.42	1410.45	1162.75	355.54	328.26	333.99
20:01 - 21:00	299.38	270.8	288.08	254.3	289.01	1081.12	1113.73	1201.49	990.49	302.87	279.63	284.51
21:01 - 22:00	247.32	223.7	237.98	210.08	238.75	893.1	920.04	992.54	818.23	250.2	231	235.03
22:01 - 23:00	221.28	200.16	212.93	187.96	213.61	799.09	823.19	888.06	732.1	223.86	206.68	210.29
23:01 - 24:00	0	0	0	0	0	564.06	581.08	626.87	516.78	0	0	0

Before the final annual cost could be determined, additional pumping energy had to be calculated. This was done so by using Productive Energy's estimation calculator. Additional pumps that were chosen were all from Bell and Gossett and the estimation calculator gave an output of $3,760 annually. This value, in addition to the annual natural gas expenditure and existing pumping cost given from Trane Trace, the annual running cost of such a system is roughly $15,130. A summary of this annual expenditure is located in *Table B 2.6* which is in section 2 of *Appendix B*.

5.4 Alternative 2

The second alternative builds off of the first one, except another component to the system was added. A chilled water storage tank was sized and added to the evaporator side of the chiller to shift energy consumption to the off-peak hours. The sizing strategy was to assist the solar absorbers in meeting peak loads for the summer while minimizing tank size, thus decreasing the size of the solar absorber array and hopefully reducing the overall first cost. It must also be realized that it is not economical to use the chilled water storage during the non-peak months of the year because there is no variation with fuel prices relative to the time of day during those months. Therefore, the use of such a tank would only create redundancy when it is not needed and ultimately consume more energy than a non-storage system.

By choosing a capacity of 900 tons for the storage tank, the number of solar absorbers could be significantly reduced, a number that needed to be tabulated. After consulting with the manufacturer again, it was realized that a balancing equation could be used to determine the number of absorbers. The peak loads were drastically reduced by 66% due to the chilled water storage thus the flow rate could be reduced accordingly. By using a simple ratio after eliminating constants of the heat transfer equation, it was determined that the flow rate needed was 471.2 gpm and the corresponding number of solar absorbers was 290. This is a reduction of 135 absorbers and 5400 ft^2 of roof space.

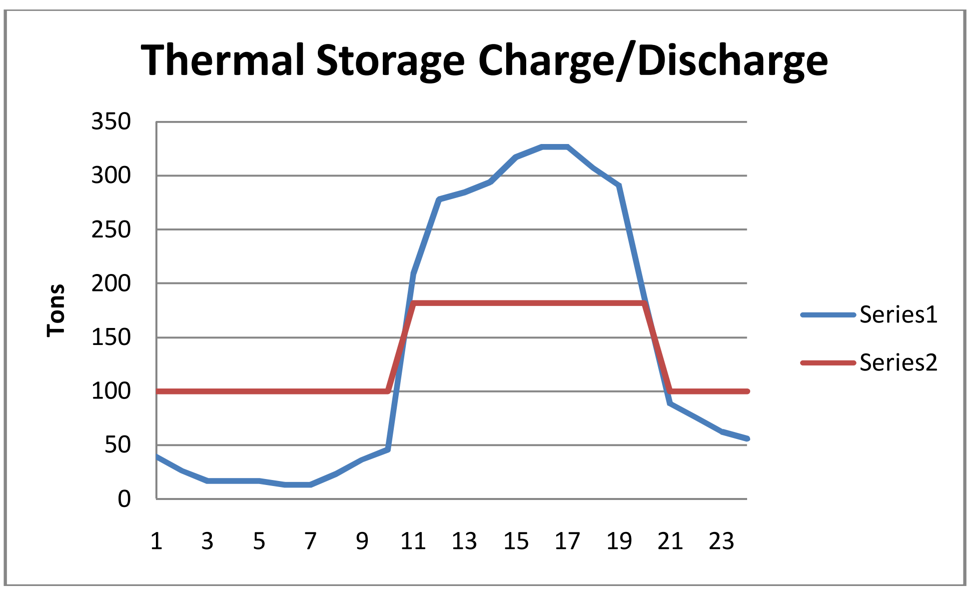
$$\frac{Q_1}{Q_2} = \frac{V_1}{V_2}$$

Charging hours were chosen to be from 10pm until 9am daily during the 4 summer months. Assuming a Figure of Merit to be 0.85 and a ΔT of 20^o F, the tank volume could be determined.

$$V_{gal} = \frac{1440 \times S[ton-h]}{FoM \times \Delta T}$$

The tank size was determined to be roughly 76,000 gallons. *Figure 5.4.1* shows the storage tank charging rates in comparison to the cooling load. A direct interface method of charging and discharging was chosen for the storage tank. Series 1 of figure 5.4.1 shows the load profile on design day and series 2 shows the chiller use on that day.

Figure 5.4.1



After the initial calculations were concluded, the annual energy and cost analysis could be completed. Using the same data from the Alternative 1 calculations and adjusting the load to include the chilled water storage, the following table of cooling loads was developed.

Table 5.4.1

Cooling Load (tons) vs. Hour/day												
Hour	J	F	M	A	M	J	J	A	S	O	N	D
0:01 - 1:00	0	0	0	0	0	100	100	100	100	0	0	0
1:01 - 2:00	0	0	0	0	0	100	100	100	100	0	0	0
2:01 - 3:00	0	0	0	0	0	100	100	100	100	0	0	0
3:01 - 4:00	0	0	0	0	0	100	100	100	100	0	0	0
4:01 - 5:00	0	0	0	0	0	100	100	100	100	0	0	0
5:01 - 6:00	0	0	0	0	0	100	100	100	100	0	0	0
6:01 - 7:00	0	0	0	0	0	100	100	100	100	0	0	0
7:01 - 8:00	6.62	5.99	6.37	5.62	6.39	100	100	100	100	6.7	6.18	6.29
8:01 - 9:00	8.43	7.62	8.11	7.16	8.13	100	100	100	100	8.53	7.87	8.01
9:01 - 10:00	38.52	34.85	37.07	32.72	37.19	39.11	43.31	54.6	27.45	38.97	35.98	36.61
10:01 - 11:00	51.16	46.28	49.23	43.46	49.39	84.76	90.33	105.33	69.27	51.76	47.79	48.62
11:01 - 12:00	52.37	47.37	50.39	44.48	50.55	89.11	94.81	110.16	73.26	52.98	48.91	49.77
12:01 - 13:00	54.17	49	52.13	46.02	52.3	95.63	101.53	117.41	79.23	54.8	50.6	51.48
13:01 - 14:00	58.39	52.81	56.18	49.59	56.36	110.84	117.2	134.32	93.17	59.07	54.53	55.49
14:01 - 15:00	60.19	54.45	57.92	51.13	58.11	117.37	123.92	141.57	99.14	60.89	56.22	57.2
15:01 - 16:00	60.19	54.45	57.92	51.13	58.11	117.37	123.92	141.57	99.14	60.89	56.22	57.2
16:01 - 17:00	56.58	51.18	54.44	48.06	54.62	104.32	110.49	127.07	87.2	57.24	52.85	53.77
17:01 - 18:00	53.57	48.46	51.55	45.5	51.71	93.46	99.29	114.99	77.24	54.2	50.04	50.91
18:01 - 19:00	34.31	31.03	33.01	29.14	33.12	123.9	127.64	137.69	113.51	34.71	32.05	32.61
19:01 - 20:00	16.25	14.7	15.64	13.8	15.69	58.69	60.46	65.22	53.77	16.44	15.18	15.44
20:01 - 21:00	13.84	12.52	13.32	11.76	13.36	49.99	51.5	55.56	45.8	14.01	12.93	13.16
21:01 - 22:00	11.44	10.34	11	9.71	11.04	41.3	42.55	45.9	37.84	11.57	10.68	10.87
22:01 - 23:00	10.23	9.26	9.85	8.69	9.88	100	100	100	100	10.35	9.56	9.72
23:01 - 24:00	0	0	0	0	0	100	100	100	100	0	0	0

Using the same logic as in Alternative 1, the chiller load was evaluated upon when it would consume ‘free’ solar energy and when it would consume natural gas from the boilers usage. The data that relates the chiller operating from the boiler hot water was organized into *Table B 3.1* in *Appendix B.* These values were adjusted for the efficiencies of both the chillers and the boilers to determine annual energy consumption which is summarized in *Table B 3.3*.

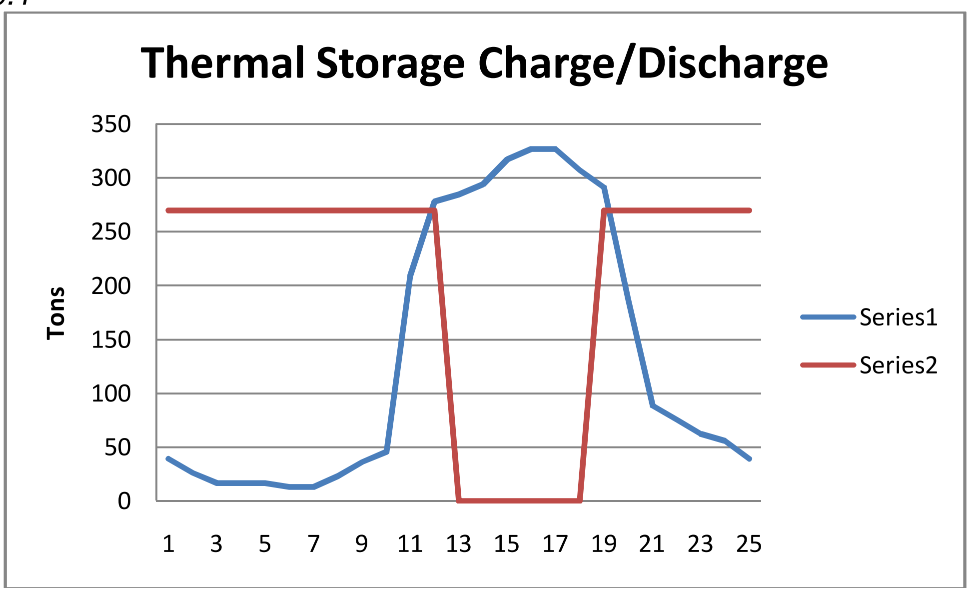
By using the Productive Energy estimation tool once again, the additional pumping cost through to drive the generator of the chillers was $1880, and to charge and discharge the storage tanks during the summer months was $2940. By adding those values to the existing pumping cost and natural gas charges, the annual running cost of *Alternative 2* was determined to be $17,645. A summary of this annual cost is located in *Table B 3.4* which is in section 3 of *Appendix B*.

5.5 Alternative 3

This final analysis involves keeping the original existing system in tact and simply adding chilled water storage to the evaporator side of the chillers. This will evaluate the effectiveness of chilled water storage for this particular application without the interfering influence of solar absorption. The process began by evaluating the most appropriate time to charge and discharge the chilled water storage tank by taking a look at electrical rates. Once again, the summer months are the only times that the storage tank will be utilized because electrical rates only vary during that time. To achieve the most efficient use of the tank, it shall charge when electrical rates are the lowest and discharge during all other times to meet peak loading.

To size the tank, we look at the summer design day and determine the tonnage rating of the tank. In order to discharge for the twelve hours of heightened electric rates, a 2,900 ton tank will be needed. *Figure 5.5.1*, below, shows the charging and discharging during the design day. The tank volume was determined to be 246,000 gallons through the same process described in *Alternative 2*. Series 1, once again displays the load profile and series 2 shows chiller usage during charging and discharging periods.

Figure 5.5.1



By utilizing chilled water storage into this system, the highest electrical rates could be avoided. Chiller outputs for typical days of each month are summarized in the table below.

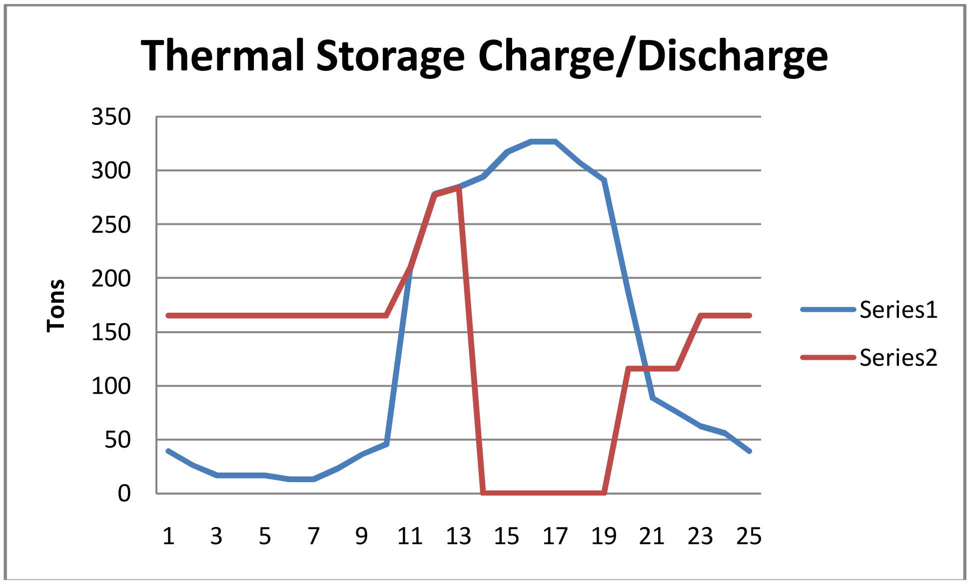
Table 5.5.1

Chiller Output (tons) vs. Hour/day												
Hour	J	F	M	A	M	J	J	A	S	O	N	D
0:01 - 1:00	0	0	0	0	0	270	270	270	270	0	0	0
1:01 - 2:00	0	0	0	0	0	270	270	270	270	0	0	0
2:01 - 3:00	0	0	0	0	0	270	270	270	270	0	0	0
3:01 - 4:00	0	0	0	0	0	270	270	270	270	0	0	0
4:01 - 5:00	0	0	0	0	0	270	270	270	270	0	0	0
5:01 - 6:00	0	0	0	0	0	270	270	270	270	0	0	0
6:01 - 7:00	0	0	0	0	0	270	270	270	270	0	0	0
7:01 - 8:00	6.62	5.99	6.37	5.62	6.39	270	270	270	270	6.7	6.18	6.29
8:01 - 9:00	8.43	7.62	8.11	7.16	8.13	270	270	270	270	8.53	7.87	8.01
9:01 - 10:00	38.52	34.85	37.07	32.72	37.19	0	0	0	0	38.97	35.98	36.61
10:01 - 11:00	51.16	46.28	49.23	43.46	49.39	0	0	0	0	51.76	47.79	48.62
11:01 - 12:00	52.37	47.37	50.39	44.48	50.55	0	0	0	0	52.98	48.91	49.77
12:01 - 13:00	54.17	49	52.13	46.02	52.3	0	0	0	0	54.8	50.6	51.48
13:01 - 14:00	58.39	52.81	56.18	49.59	56.36	0	0	0	0	59.07	54.53	55.49
14:01 - 15:00	60.19	54.45	57.92	51.13	58.11	0	0	0	0	60.89	56.22	57.2
15:01 - 16:00	60.19	54.45	57.92	51.13	58.11	0	0	0	0	60.89	56.22	57.2
16:01 - 17:00	56.58	51.18	54.44	48.06	54.62	0	0	0	0	57.24	52.85	53.77
17:01 - 18:00	53.57	48.46	51.55	45.5	51.71	0	0	0	0	54.2	50.04	50.91
18:01 - 19:00	34.31	31.03	33.01	29.14	33.12	0	0	0	0	34.71	32.05	32.61
19:01 - 20:00	16.25	14.7	15.64	13.8	15.69	0	0	0	0	16.44	15.18	15.44
20:01 - 21:00	13.84	12.52	13.32	11.76	13.36	0	0	0	0	14.01	12.93	13.16
21:01 - 22:00	11.44	10.34	11	9.71	11.04	270	270	270	270	11.57	10.68	10.87
22:01 - 23:00	10.23	9.26	9.85	8.69	9.88	270	270	270	270	10.35	9.56	9.72
23:01 - 24:00	0	0	0	0	0	270	270	270	270	0	0	0

These energy values were converted to kilowatts by using the chillers' efficiencies which is 0.837 KW/ton to develop the electricity consumption. These values are displayed in *Table B 4.1* in *Appendix B*. By applying electrical demand and consumption charges to these values, an annual cost could be determined, totaling $37,000. For a detailed description of these calculations, look in *Appendix B 4 Section 4*.

Due to the fact that the annual cost of operating the proposed system is larger than the existing one and that the first cost is also larger, another storage strategy was applied. Instead of charging and discharging for 12 hours a piece, a new tank will be sized to charge for 12 hours and discharge for the 6 hours of max electrical consumption and demand charges. During this time on design day, it was determined that a 1,800 ton storage tank was needed. The corresponding tank volume became 153,000 gallons and the following figure shows the on/off cycle for the use of the chillers. Series 1 shows the load profile and series 2 shows the chiller operation over the course of 24 hour period.

Figure 5.5.2



By utilizing chilled water storage into this system, the highest electrical rates could be avoided. Chiller outputs for typical days of each month are summarized in the table below.

Table 5.5.2

Chiller Output (tons) vs. Hour/day												
Hour	J	F	M	A	M	J	J	A	S	O	N	D
0:01 - 1:00	0	0	0	0	0	165	165	165	165	0	0	0
1:01 - 2:00	0	0	0	0	0	165	165	165	165	0	0	0
2:01 - 3:00	0	0	0	0	0	165	165	165	165	0	0	0
3:01 - 4:00	0	0	0	0	0	165	165	165	165	0	0	0
4:01 - 5:00	0	0	0	0	0	165	165	165	165	0	0	0
5:01 - 6:00	0	0	0	0	0	165	165	165	165	0	0	0
6:01 - 7:00	0	0	0	0	0	165	165	165	165	0	0	0
7:01 - 8:00	6.62	5.99	6.37	5.62	6.39	165	165	165	165	6.7	6.18	6.29
8:01 - 9:00	8.43	7.62	8.11	7.16	8.13	165	165	165	165	8.53	7.87	8.01
9:01 - 10:00	38.52	34.85	37.07	32.72	37.19	139.11	143.31	154.6	127.45	38.97	35.98	36.61
10:01 - 11:00	51.16	46.28	49.23	43.46	49.39	184.76	190.33	205.33	169.27	51.76	47.79	48.62
11:01 - 12:00	52.37	47.37	50.39	44.48	50.55	189.11	194.81	210.16	173.26	52.98	48.91	49.77
12:01 - 13:00	54.17	49	52.13	46.02	52.3	0	0	0	0	54.8	50.6	51.48
13:01 - 14:00	58.39	52.81	56.18	49.59	56.36	0	0	0	0	59.07	54.53	55.49
14:01 - 15:00	60.19	54.45	57.92	51.13	58.11	0	0	0	0	60.89	56.22	57.2
15:01 - 16:00	60.19	54.45	57.92	51.13	58.11	0	0	0	0	60.89	56.22	57.2
16:01 - 17:00	56.58	51.18	54.44	48.06	54.62	0	0	0	0	57.24	52.85	53.77
17:01 - 18:00	53.57	48.46	51.55	45.5	51.71	0	0	0	0	54.2	50.04	50.91
18:01 - 19:00	34.31	31.03	33.01	29.14	33.12	123.9	127.64	137.69	113.51	34.71	32.05	32.61
19:01 - 20:00	16.25	14.7	15.64	13.8	15.69	58.69	60.46	65.22	53.77	16.44	15.18	15.44
20:01 - 21:00	13.84	12.52	13.32	11.76	13.36	49.99	51.5	55.56	45.8	14.01	12.93	13.16
21:01 - 22:00	11.44	10.34	11	9.71	11.04	165	165	165	165	11.57	10.68	10.87
22:01 - 23:00	10.23	9.26	9.85	8.69	9.88	165	165	165	165	10.35	9.56	9.72
23:01 - 24:00	0	0	0	0	0	165	165	165	165	0	0	0

These values were converted to kilowatts by using the chiller's efficiency and annual electrical rates were applied. These tables can be found in *Appendix B Section 4*. The annual running cost of such a system was determined to be $33,000.

Since the analysis of thermal storage systems alone with the existing chillers gave forth larger or nearly equal annual operation cost without extra pumping energy included, *Alternative 3* was automatically forfeit from the feasible design considerations which omit it from the cost comparison and payback analysis. Therefore, an additional pumping energy calculation was not performed for *Alternative 3*. Through these series of calculations, it was determined that chilled water storage is not applicable for such a building in such a climate.

6.0 Simple Payback Analysis

This analysis began by determining and comparing the additional first costs of the alternatives in comparison to the existing system. Therefore the first cost of the existing chillers had to be found. By contacting the Carrier Corporation at the Harrisburg office, it was established that the existing chillers have a first cost value of $70,000 a piece. RBI sales representatives were contacted for the boiler information. Storage tank costs were taken from R.S. Means book in the engineering library. The table below summarizes the costs of each alternative system and their components.

Table 6.0.1

Component			First Cost	Total First Cost	Annual Maintanence
Control	Chiller	Carrier 19XR	63,000	126,000	4,000
	Chiller	Carrier 19XR	63,000		4,000
Alternative 1	Absorption Chiller	Carrier 16LJ	103,000	472,625	6,000
	Absorption Chiller	Carrier 16LJ	103,000		6,000
	Boiler	RBI Futera XLF	52,000		500
	Boiler	RBI Futera XLF	52,000		500
	Solar Absorbers (425)		265,625		1,000
	Additional Pumps	B&G	4,000		--
Alternative 2	Absorption Chiller	Carrier 16LJ	103,000	556,050	6,000
	Absorption Chiller	Carrier 16LJ	103,000		6,000
	Boiler	RBI Futera XLF	52,000		500
	Boiler	RBI Futera XLF	52,000		500
	Solar Absorbers (290)		187,050		1,000
	900 ton Storage Tank		52,000		--
	Additional Pumps	B&G	7,000		--
Alternative 3a	Chiller	Carrier 19XR	63,000	427,000	4,000
	Chiller	Carrier 19XR	63,000		4,000
	2,900 ton Storage Tank		295,000		--
	Additional Pumps	B&G	6,000		--
Alternative 3b	Chiller	Carrier 19XR	63,000	372,000	4,000
	Chiller	Carrier 19XR	63,000		4,000
	1,650 ton Storage Tank		240,000		--
	Additional Pumps	B&G	6,000		--

As previously stated, since *Alternative 3* does not save any money, there is no payback period for such a system. A simple payback comparison was made by comparing the additional first cost to the annual energy savings. *Table 5.0.2* shows the breakdown of the payback period calculations.

$$Payback(years) = \frac{Additional\ First\ Cost}{Annual\ Energy\ Savings}$$

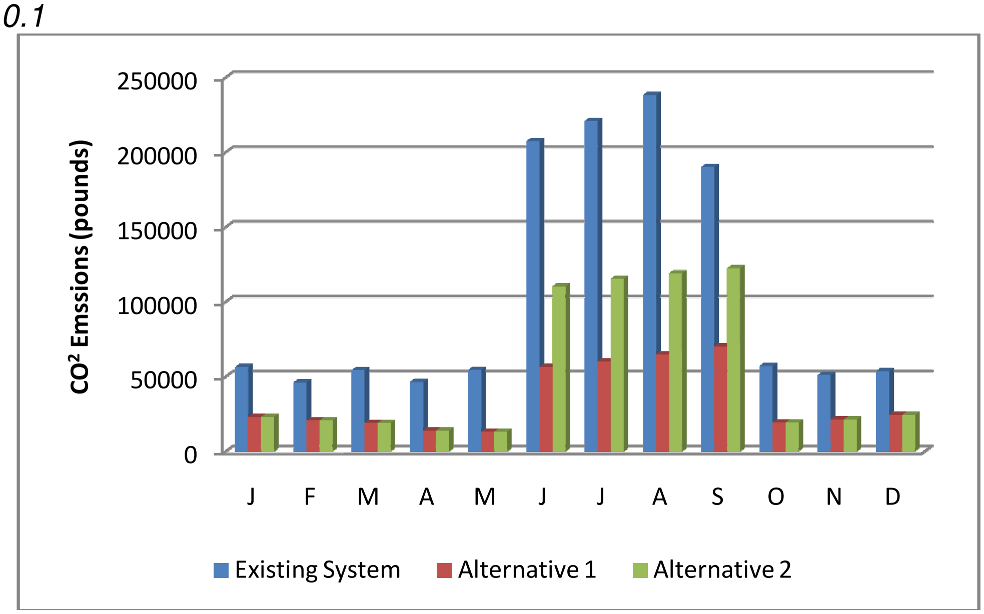
Table 6.0.2

Simple Payback Calculation		
	Alternative 1	Alternative 2
Additional First Cost	346,625	430,050
Additional Maintenance Cost	6,000	6,000
Annual Savings	19,700	17,185
Payback Period	17.60	25.02

Alternative 1 has the most respectable payback period due to the fact that it costs less initially and saves more money annually. This is a positive response because not only are these systems saving money, they're saving energy as well. However, due to the large number of years such a system would take to break even, the initial investment might not ever be made.

This analysis was based off of current energy rates which are sure to fluctuate. Hypothetically speaking if Lake Mead dries up; the Hoover Dam supplies the majority of electric power to Las Vegas and all surrounding cities with the rest coming from the few existing solar farms. Assuming that the Las Vegas will need to obtain and sustain another type of energy to supply its electricity, carbon emissions would increase dramatically. The following figure shows the differences in emissions of CO^2 gas for *Alternative 1*, *Alternative 2*, and the existing system if such a scenario were to take place.

Figure 6.0.1



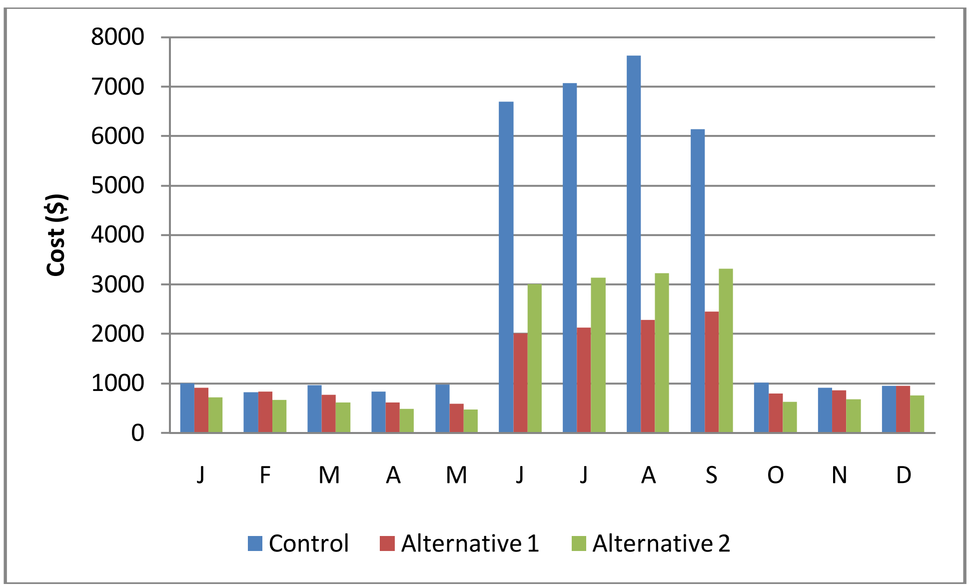
If a sort of CO^2 credit was given to systems operating with fewer emissions, the payback period would become very favorable for *Alternative 1*.

7.0 Depth Summary

The existing system for UNLV Greenspun Hall is innovative and energy efficient, achieving LEED Gold certification. However, such a system could be improved by adding different system components to take advantage of the amount of solar radiation present in the Las Vegas valley. Three alternatives were proposed to attempt to improve on the existing system.

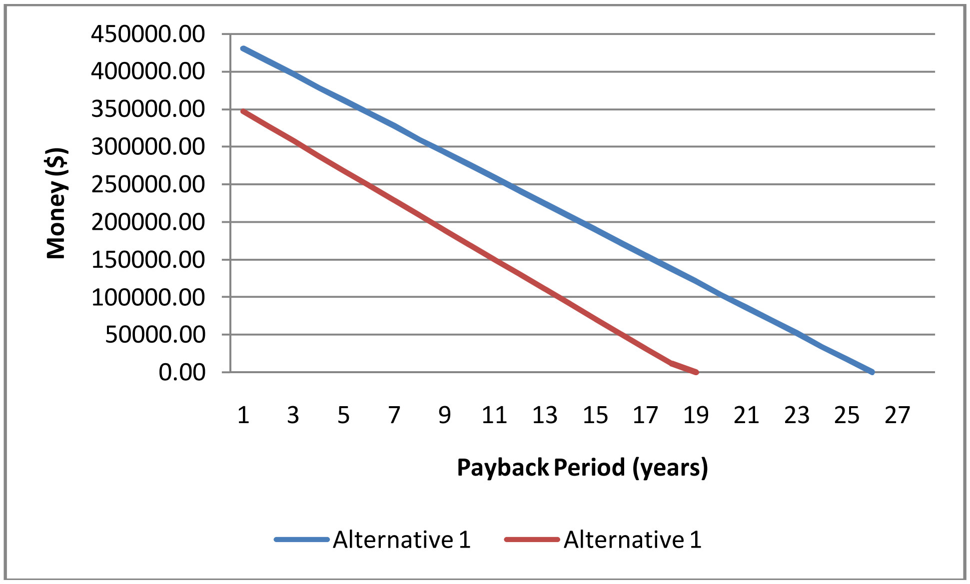
Alternative 1 added 17,000 ft^2 of solar absorbers to the roof to drive the single-effect absorption chillers which would replace the existing ones. *Alternative 2* utilizes a chiller water thermal storage tank to shift the peak load, thus reducing the area of the solar absorbers need to drive the generators. *Alternative 3* differs from the other alternatives in that it keeps the existing chillers, and just adds chilled water storage to the load loop to shift energy consumption to periods of cheaper electricity cost. Annual operating costs of all the alternatives and the existing system were computed and compared. Through this analysis, it was apparent that *Alternative 3* consumed more energy than the existing system. *Alternative 1* saved the most energy and cost annually. *Figure 7.0.1* shows the cost savings of the other two alternatives in comparison to the existing system.

Figure 7.0.1



A simple payback computation was also prepared. Since *Alternative 3* did not save any money, a payback period could not be determined. Through this analysis, Figure 7.0.2 was created to display the first cost and payback period for *Alternative 1* and *Alternative 2*.

Figure 7.0.2



Since *Alternative 1* had a smaller first cost than the second alternative, saved more money annually, and had a reasonable payback period, it would be an appropriate replacement for the existing system. Such a system would also produce less pollutants and emissions than the other choices, therefore becomes a more attractive option. *Alternative 1* saves $19,700 annually and has a 17.6 year payback period.

8.0 Structural Breadth

As a part of the redesign of the mechanical system, some alternatives (1and 2) require the addition of mechanical equipment to the roof structure. This breadth analyzes the current roof system under the new heavier loading of added equipment.

The current roof is a non-composite slab with 7ft. spans with a depth of 5”. A 2C22 deck was used in the original construction. The table below shows that this particular deck meets building standards.

Table 8.0.1

Roof Loads	
Description	Weight (psf)
Mech./Elec./Plumbing	10
Roof Mat	20
Slab/Deck (2C22)	50
Miscellaneous	5
Beams/Joists	10
Total	95

The table from the *Vulcraft Steel Deck Manual* the allowable weight of a 2C22 3-span deck at 7 ft. spans is 98 psf. Since this value is greater than the load of the given structure, this is allowable. The next step is to check the maximum clear span of the deck, which is 7’1”, by the *Vulcraft Manual*.

In *Alternative 1* and *Alternative 2*, solar absorbers were added to the roof. The weight given for these absorbers by the manufacturer’s data was roughly 12.5 psf. This value includes the absorber, piping, and fluid weight during operation. This weight was added to the MEP weight for the typical roof load, which makes the total weight 107.5 psf. Under this new loading, it is apparent that the current roof system would not support this load and therefore must be changed.

This change in roof system can come in several different ways. The first way to explore is to decrease the span of the steel deck, which means extra joists must be installed. According to the *Vulcraft Manual*, a 6’6” span of the same steel deck used in the original design could be used as it supports a load of 113 psf. However, due to the proximity of this value to the given load, the span would probably be reduced to 6’.

Another option, which would not include adding more joists, would be to decrease the gauge of the deck, thus increasing its strength. By choosing the 2C20 deck type, a 7’ span could support 127 psf of load and the maximum clear span becomes 8’7”. Both of these values exceed requirements for the proposed system, thus this change could be implemented.

Summary

With the additional weight of the added absorbers to the roof, one of two things would need to be done. Either add more joists to the roof system or increase the strength of the deck by decreasing the gauge. The first solution is a 5" non-composite 2C22 deck at a 6' span and the second solution is a 5" non-composite 2C20 deck at a 7' span.

The construction and material cost for adding additional joists would far exceed the extra material cost for decreasing the gauge of the deck by 2. Therefore the suggested solution to chose is the second one; increase the strength of the deck. This solution would not only be cheaper than the other, but it would not change construction scheduling. The page of the *Vulcraft Steel Deck Manual* that was used is located in *Appendix C*.

9.0 Construction Management Breadth

With two of the alternative designs, thermal storage tanks were incorporated to meet the cooling loads. These two alternatives came with three possible tank sizes. These tanks would not be able to be installed anywhere on site besides the mechanical yard, which happens to be far too small to hold such equipment. The proposed solution is to extend the mechanical yard away from the parking lot towards a neutral greenery area.

In order to complete this solution, the strip footer, slab, and CMU wall had to be extended by 20 ft for one tank size and 30 ft for the others. Figure 9.0.1 shows an elementary version of the layout of the existing mechanical yard. Figure 9.0.2 shows the extension of the mechanical yard with a thermal storage tank installed.

Figure 9.0.1

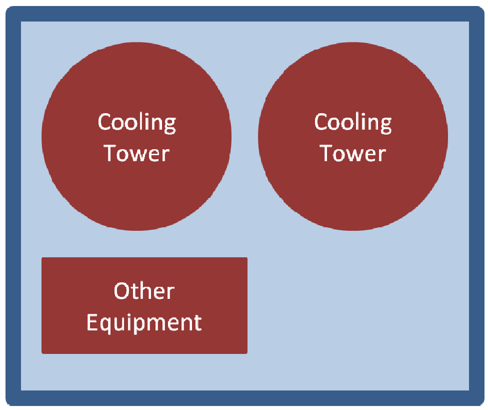
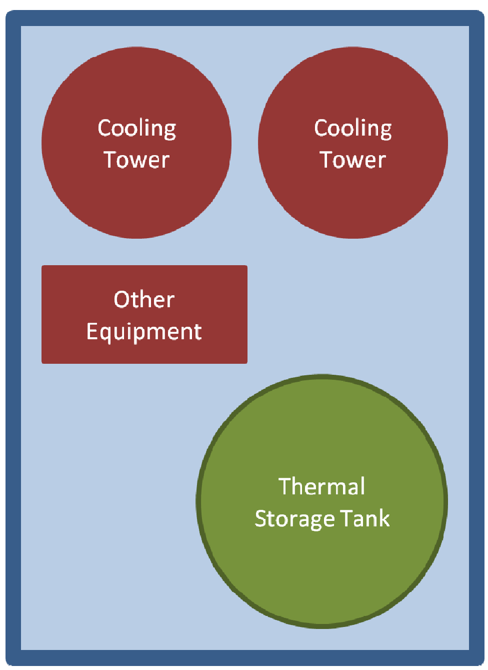


Figure 9.0.2



In order to complete such an expansion, the labor, material, and equipment costs had to be determined for both a 20ft. extension of the south wall and a 30 ft. one. *Table 9.0.1* displays a cost comparison of the two expansions.

Table 9.0.1

Cost Analysis						
	Component		Material	Labor	Equipment	Total
20 ft. Extension	Strip Footer	12" x 12"	259.26	26.31	0.86	286.43
	Slab	6"	1111.11	159.44	5.00	1275.56
	Wire Fabric	6x6	195.00	147.00	0.00	342.00
	CMU Wall	12" x 10ft.	2169.60	3360.00	0.00	5529.60
	Formwork		22.40	135.10	0.00	157.50
	Total Cost					7591.09
30 ft. Extension	Strip Footer	12" x 12"	333.33	33.83	1.10	368.27
	Slab	6"	1666.67	239.17	7.50	1913.33
	Wire Fabric	6x6	292.50	220.50	0.00	513.00
	CMU Wall	12" x 10ft.	3254.40	5040.00	0.00	8294.40
	Formwork		28.80	173.70	0.00	202.50
	Total Cost					11291.50

Along with the extra cost that goes into such an addition, scheduling must be completed as well. The table below summarizes the extra time it would take to build this larger mechanical yard. A 20 ft. extension of the enclosure would take 3.5 days to construct, and a 30 ft. extension would take 5 days.

Table 9.0.2

Days of Work		
	20 ft. Extension	30 ft. Extension
Strip Footer	0.05	0.06
Formwork	0.13	0.15
Wire Fabric	0.21	0.31
Slab	0.19	0.28
Subtotal	1	1
CMU Wall	2.4	3.6
Total	3.5	5

Summary

If *Alternative 2* or *Alternative 3* were selected, as opposed to the current existing system, the mechanical yard would have to be enlarged. The tables shown above show the additional costs and time it would take to complete such construction. These values are ultimately minuscule in comparison to the total system and cost and construction time, thus the extension of the south wall of the mechanical yard is a feasible option.

10.0 Conclusions

After all analyses and comparisons were completed, I conclude that *Alternative 1* would be the best choice to replace the existing system. Due to a reasonable first cost increase and large energy savings, a suitable payback period was revealed. Such a system would also reduce the amount of pollutants and emissions released into the Earth's atmosphere.

Due to the large solar absorber array, however, the structural system for the roof would need to be stronger and therefore more expensive. The expansion of the mechanical yard would not need to take place, thus not interfering with the existing schedule.

To summarize, this system would be more energy efficient but also more expensive, costing an extra $346,000 upfront. By saving $19,700 annually on regulated energy, a payback period of 17.6 years was calculated. By implementing this system, designers would not just obtain their design goals, but exceed them.

11.0 References

ASHRAE Standard 62.1-2007

RS Means

Carrier Corporation
http://www.carrier.com

RBI Boilers
http://www.rbiwaterheaters.com/index.asp

Nevada Power
http://www.nvenergy.com/

US Department of Energy
http://www.energy.gov

Energy Information Administration
http://www.eia.doe.gov

Performance Energy Group
http://www.productiveenergy.com

US DOE Energy Efficiency and Renewable Energy
http://eere.energy.gov

Appendix A

Table A 1.
Annual Hourly Temperature for Las Vegas, Nevada.

Average Temperature (°F) vs. Hour/day												
Hour	J	F	M	A	M	J	J	A	S	O	N	D
0:01 - 1:00	41.4	43.3	49.6	59.5	68.9	77.9	83.3	80.8	74.1	61.2	49.8	41.5
1:01 - 2:00	41.2	42.6	48.6	58.6	67.5	75.9	81.7	79.3	72.9	59.7	49.1	41.2
2:01 - 3:00	40.5	41.5	47.8	57.2	66.0	75.0	80.6	77.9	71.6	59.4	48.0	39.9
3:01 - 4:00	40.1	41.2	47.3	56.7	65.5	73.9	78.8	77.0	70.2	58.3	47.5	39.0
4:01 - 5:00	39.9	40.5	46.8	55.8	64.8	72.3	78.3	76.3	69.1	57.4	46.8	38.5
5:01 - 6:00	39.6	39.7	46.4	55.8	66.6	75.2	80.4	77.2	68.7	57.0	46.4	37.9
6:01 - 7:00	39.6	40.6	48.4	60.3	70.9	80.4	85.3	81.7	73.4	58.6	47.3	37.8
7:01 - 8:00	41.0	43.7	51.6	64.4	74.8	84.7	90.0	86.4	79.2	63.7	52.7	40.5
8:01 - 9:00	44.2	48.4	54.5	67.6	78.3	88.2	93.0	89.6	82.9	67.5	57.6	46.9
9:01 - 10:00	47.5	51.4	57.2	70.2	80.6	90.1	95.9	92.7	86.4	70.2	60.8	50.0
10:01 - 11:00	49.6	54.1	60.1	72.7	83.1	93.2	98.1	95.7	88.9	72.7	62.6	53.2
11:01 - 12:00	51.3	55.8	61.9	74.5	84.4	94.8	100.0	97.7	91.4	74.8	64.0	55.8
12:01 - 13:00	52.5	57.4	63.3	76.1	85.5	96.4	101.5	99.0	93.0	76.6	65.3	57.0
13:01 - 14:00	54.0	58.3	64.0	77.2	86.7	97.5	102.0	99.3	94.1	77.9	65.8	57.9
14:01 - 15:00	54.1	58.8	64.2	77.5	87.1	97.7	102.6	99.9	93.6	78.4	66.2	58.6
15:01 - 16:00	53.6	58.6	63.7	77.4	87.1	97.7	102.4	99.1	93.0	77.7	65.1	57.9
16:01 - 17:00	52.3	56.8	63.0	76.6	86.2	96.3	101.3	99.0	91.8	76.1	61.9	54.5
17:01 - 18:00	50.4	53.2	60.1	74.7	84.4	94.8	99.7	96.8	88.3	73.6	59.2	50.0
18:01 - 19:00	47.8	51.6	58.1	71.4	81.0	91.8	97.0	93.4	84.6	69.4	56.3	47.7
19:01 - 20:00	46.4	49.1	56.5	68.5	77.9	88.2	93.9	90.5	81.5	67.3	54.5	46.4
20:01 - 21:00	45.0	47.7	54.7	66.0	75.4	85.8	90.7	88.0	79.7	65.8	52.7	44.8
21:01 - 22:00	44.1	46.4	53.2	64.4	73.8	83.5	88.5	86.2	77.5	64.2	51.6	43.5
22:01 - 23:00	43.7	45.1	52.2	62.8	72.0	81.7	86.7	84.4	75.9	63.3	50.9	42.6
23:01 - 24:00	43.2	44.4	51.3	61.3	70.5	80.1	84.7	82.6	74.7	61.9	49.8	41.7

Table A 2.

Annual Hourly Solar Radiation for Las Vegas, Nevada.

Average Direct Solar Radiation vs. Hour/day												
Hour	J	F	M	A	M	J	J	A	S	O	N	D
0:01 - 1:00	0	0	0	0	0	0	0	0	0	0	0	0
1:01 - 2:00	0	0	0	0	0	0	0	0	0	0	0	0
2:01 - 3:00	0	0	0	0	0	0	0	0	0	0	0	0
3:01 - 4:00	0	0	0	0	0	0	0	0	0	0	0	0
4:01 - 5:00	0	0	0	1	42	69	42	2	0	0	0	0
5:01 - 6:00	0	0	16	185	340	429	347	253	90	23	0	0
6:01 - 7:00	0	68	244	501	535	640	605	551	452	381	161	27
7:01 - 8:00	302	348	457	674	687	736	726	701	644	646	481	371
8:01 - 9:00	510	523	545	720	777	784	755	780	695	730	607	549
9:01 - 10:00	588	606	593	770	798	752	797	807	798	767	689	613
10:01 - 11:00	655	679	588	769	761	791	810	815	833	748	697	687
11:01 - 12:00	642	630	615	766	679	760	820	812	817	780	735	676
12:01 - 13:00	598	662	641	714	689	770	802	752	817	756	724	675
13:01 - 14:00	577	620	578	673	718	759	775	682	752	696	696	658
14:01 - 15:00	564	543	554	649	690	703	756	658	641	675	629	602
15:01 - 16:00	476	443	429	607	658	698	686	585	604	596	463	406
16:01 - 17:00	144	265	314	470	585	606	614	534	441	323	117	44
17:01 - 18:00	0	15	108	266	352	435	494	369	160	13	0	0
18:01 - 19:00	0	0	0	17	46	152	182	53	0	0	0	0
19:01 - 20:00	0	0	0	0	0	0	0	0	0	0	0	0
20:01 - 21:00	0	0	0	0	0	0	0	0	0	0	0	0
21:01 - 22:00	0	0	0	0	0	0	0	0	0	0	0	0
22:01 - 23:00	0	0	0	0	0	0	0	0	0	0	0	0
23:01 - 24:00	0	0	0	0	0	0	0	0	0	0	0	0

Appendix B

Section 1

Table B 1.1

Annual KWh per day and Nevada Power's demand charge for each month.

	KWh / day											
Time	J	F	M	A	M	J	J	A	S	O	N	D
0:01 - 1:00	0.00	0.00	0.00	0.00	0.00	14.55	14.99	16.18	13.33	0.00	0.00	0.00
1:01 - 2:00	0.00	0.00	0.00	0.00	0.00	9.10	9.37	10.11	8.33	0.00	0.00	0.00
2:01 - 3:00	0.00	0.00	0.00	0.00	0.00	9.10	9.37	10.11	8.33	0.00	0.00	0.00
3:01 - 4:00	0.00	0.00	0.00	0.00	0.00	9.10	9.37	10.11	8.33	0.00	0.00	0.00
4:01 - 5:00	0.00	0.00	0.00	0.00	0.00	7.28	7.50	8.09	6.67	0.00	0.00	0.00
5:01 - 6:00	0.00	0.00	0.00	0.00	0.00	7.28	7.50	8.09	6.67	0.00	0.00	0.00
6:01 - 7:00	0.00	0.00	0.00	0.00	0.00	12.74	13.12	14.15	11.67	0.00	0.00	0.00
7:01 - 8:00	5.54	5.01	5.33	4.71	5.35	20.01	20.62	22.24	18.34	5.61	5.18	5.27
8:01 - 9:00	7.05	6.38	6.79	5.99	6.81	25.47	26.24	28.31	23.34	7.14	6.59	6.70
9:01 - 10:00	32.24	29.17	31.03	27.39	31.13	116.44	119.95	129.40	106.68	32.62	30.12	30.64
10:01 - 11:00	42.82	38.74	41.21	36.38	41.34	154.64	159.31	171.86	141.68	43.32	40.00	40.70
11:01 - 12:00	43.83	39.65	42.18	37.23	42.31	158.28	163.06	175.91	145.01	44.34	40.94	41.65
12:01 - 13:00	45.34	41.01	43.63	38.52	43.77	163.74	168.68	181.97	150.02	45.87	42.35	43.09
13:01 - 14:00	48.87	44.20	47.02	41.51	47.18	176.48	181.80	196.13	161.68	49.44	45.65	46.44
14:01 - 15:00	50.38	45.57	48.48	42.79	48.64	181.93	187.42	202.19	166.68	50.97	47.06	47.88
15:01 - 16:00	50.38	45.57	48.48	42.79	48.64	181.93	187.42	202.19	166.68	50.97	47.06	47.88
16:01 - 17:00	47.36	42.84	45.57	40.23	45.72	171.02	176.18	190.06	156.68	47.91	44.23	45.01
17:01 - 18:00	44.84	40.56	43.15	38.09	43.29	161.92	166.81	179.95	148.35	45.36	41.88	42.61
18:01 - 19:00	28.72	25.98	27.63	24.39	27.72	103.70	106.83	115.25	95.01	29.05	26.82	27.29
19:01 - 20:00	13.60	12.30	13.09	11.55	13.13	49.12	50.60	54.59	45.00	13.76	12.71	12.93
20:01 - 21:00	11.59	10.48	11.15	9.84	11.19	41.85	43.11	46.50	38.34	11.72	10.82	11.01
21:01 - 22:00	9.57	8.66	9.21	8.13	9.24	34.57	35.61	38.42	31.67	9.68	8.94	9.10
22:01 - 23:00	8.56	7.75	8.24	7.28	8.27	30.93	31.86	34.37	28.34	8.66	8.00	8.14
23:01 - 24:00	0.00	0.00	0.00	0.00	0.00	21.83	22.49	24.26	20.00	0.00	0.00	0.00
Max KWh	50.38	45.57	48.48	42.79	48.64	181.93	187.42	202.19	166.68	50.97	47.06	47.88
Demand Charge	0.50	0.50	0.50	0.50	0.50	9.17	9.17	9.17	9.17	0.50	0.50	0.50
Total	25.19	22.79	24.24	21.40	24.32	1668.34	1718.67	1854.10	1528.49	25.48	23.53	23.94
$$$$	6960.48											

Table B 1.2

Consumption Charge rates, consumption charges, and total annual operating costs.

Consumption Charge ($/KW) vs. Hour/day												
Time	J	F	M	A	M	J	J	A	S	O	N	D
0:01 - 1:00	0.06406	0.06406	0.06406	0.06406	0.06406	0.0623	0.0623	0.0623	0.0623	0.06406	0.06406	0.06406
1:01 - 2:00	0.06406	0.06406	0.06406	0.06406	0.06406	0.0623	0.0623	0.0623	0.0623	0.06406	0.06406	0.06406
2:01 - 3:00	0.06406	0.06406	0.06406	0.06406	0.06406	0.0623	0.0623	0.0623	0.0623	0.06406	0.06406	0.06406
3:01 - 4:00	0.06406	0.06406	0.06406	0.06406	0.06406	0.0623	0.0623	0.0623	0.0623	0.06406	0.06406	0.06406
4:01 - 5:00	0.06406	0.06406	0.06406	0.06406	0.06406	0.0623	0.0623	0.0623	0.0623	0.06406	0.06406	0.06406
5:01 - 6:00	0.06406	0.06406	0.06406	0.06406	0.06406	0.0623	0.0623	0.0623	0.0623	0.06406	0.06406	0.06406
6:01 - 7:00	0.06406	0.06406	0.06406	0.06406	0.06406	0.0623	0.0623	0.0623	0.0623	0.06406	0.06406	0.06406
7:01 - 8:00	0.06406	0.06406	0.06406	0.06406	0.06406	0.0623	0.0623	0.0623	0.0623	0.06406	0.06406	0.06406
8:01 - 9:00	0.06406	0.06406	0.06406	0.06406	0.06406	0.0623	0.0623	0.0623	0.0623	0.06406	0.06406	0.06406
9:01 - 10:00	0.06406	0.06406	0.06406	0.06406	0.06406	0.0623	0.0623	0.0623	0.0623	0.06406	0.06406	0.06406
10:01 - 11:00	0.06406	0.06406	0.06406	0.06406	0.06406	0.08653	0.08653	0.08653	0.08653	0.06406	0.06406	0.06406
11:01 - 12:00	0.06406	0.06406	0.06406	0.06406	0.06406	0.08653	0.08653	0.08653	0.08653	0.06406	0.06406	0.06406
12:01 - 13:00	0.06406	0.06406	0.06406	0.06406	0.06406	0.08653	0.08653	0.08653	0.08653	0.06406	0.06406	0.06406
13:01 - 14:00	0.06406	0.06406	0.06406	0.06406	0.06406	0.10001	0.10001	0.10001	0.10001	0.06406	0.06406	0.06406
14:01 - 15:00	0.06406	0.06406	0.06406	0.06406	0.06406	0.10001	0.10001	0.10001	0.10001	0.06406	0.06406	0.06406
15:01 - 16:00	0.06406	0.06406	0.06406	0.06406	0.06406	0.10001	0.10001	0.10001	0.10001	0.06406	0.06406	0.06406
16:01 - 17:00	0.06406	0.06406	0.06406	0.06406	0.06406	0.10001	0.10001	0.10001	0.10001	0.06406	0.06406	0.06406
17:01 - 18:00	0.06406	0.06406	0.06406	0.06406	0.06406	0.10001	0.10001	0.10001	0.10001	0.06406	0.06406	0.06406
18:01 - 19:00	0.06406	0.06406	0.06406	0.06406	0.06406	0.10001	0.10001	0.10001	0.10001	0.06406	0.06406	0.06406
19:01 - 20:00	0.06406	0.06406	0.06406	0.06406	0.06406	0.08653	0.08653	0.08653	0.08653	0.06406	0.06406	0.06406
20:01 - 21:00	0.06406	0.06406	0.06406	0.06406	0.06406	0.08653	0.08653	0.08653	0.08653	0.06406	0.06406	0.06406
21:01 - 22:00	0.06406	0.06406	0.06406	0.06406	0.06406	0.08653	0.08653	0.08653	0.08653	0.06406	0.06406	0.06406
22:01 - 23:00	0.06406	0.06406	0.06406	0.06406	0.06406	0.0623	0.0623	0.0623	0.0623	0.06406	0.06406	0.06406
23:01 - 24:00	0.06406	0.06406	0.06406	0.06406	0.06406	0.0623	0.0623	0.0623	0.0623	0.06406	0.06406	0.06406
Total	31.44	28.43	30.25	26.7	30.35	167.5	172.55	186.15	153.46	31.8	29.36	29.87
Days	31	28	31	30	31	30	31	31	30	31	30	31
Total	974.49	796.15	937.68	801.05	940.71	5024.99	5349.1	5770.62	4603.74	985.84	880.84	926.09
$$$$	**27991.30**											

Appendix B
Section 2

Table B 2.1
Hot Water Temperature generated by a 17,000 ft^2 solar absorber array

Temperature Generated vs. Hour/day												
Hour	J	F	M	A	M	J	J	A	S	O	N	D
0:01 - 1:00	0	0	0	0	0	0	0	0	0	0	0	0
1:01 - 2:00	0	0	0	0	0	0	0	0	0	0	0	0
2:01 - 3:00	0	0	0	0	0	0	0	0	0	0	0	0
3:01 - 4:00	0	0	0	0	0	0	0	0	0	0	0	0
4:01 - 5:00	0	0	0	0.4	16.56	26.9	16.56	0.8	0	0	0	0
5:01 - 6:00	0	0	6.37	68.67	117.72	142.39	119.76	91.14	34.78	9.14	0	0
6:01 - 7:00	0	26.52	88.26	160.48	168.44	190.68	183.66	172.06	148.35	129.4	60.39	10.71
7:01 - 8:00	106.41	120.04	149.62	197.12	199.48	207.9	206.25	201.97	191.46	191.84	155.62	126.6
8:01 - 9:00	162.62	165.67	170.71	205.24	214.35	215.4	210.96	214.81	200.91	206.91	184.07	171.61
9:01 - 10:00	180.11	183.87	181.16	213.29	217.45	210.48	217.31	218.73	217.45	212.83	199.84	185.3
10:01 - 11:00	193.57	198.03	180.11	213.14	211.9	216.43	219.15	219.85	222.29	209.85	201.26	199.48
11:01 - 12:00	191.07	188.71	185.71	212.68	198.03	211.75	220.54	219.43	220.13	214.81	207.74	197.49
12:01 - 13:00	182.21	194.89	190.87	204.22	199.84	213.29	218.02	210.48	220.13	211.12	205.91	197.3
13:01 - 14:00	177.76	186.72	177.98	196.93	204.9	211.59	214.05	198.58	210.48	201.09	201.09	194.13
14:01 - 15:00	174.94	170.26	172.73	192.42	200.02	202.32	211.12	194.13	190.87	197.3	188.52	183.04
15:01 - 16:00	154.39	146.04	142.39	184.07	194.13	201.44	199.3	179.47	183.45	181.79	151.14	136.26
16:01 - 17:00	54.4	94.95	110.03	152.9	179.47	183.87	185.5	168.21	145.52	112.72	44.71	17.33
17:01 - 18:00	0	5.98	41.43	95.27	121.2	143.96	158.79	126.04	60.04	5.19	0	0
18:01 - 19:00	0	0	0	6.77	18.1	57.23	67.65	20.8	0	0	0	0
19:01 - 20:00	0	0	0	0	0	0	0	0	0	0	0	0
20:01 - 21:00	0	0	0	0	0	0	0	0	0	0	0	0
21:01 - 22:00	0	0	0	0	0	0	0	0	0	0	0	0
22:01 - 23:00	0	0	0	0	0	0	0	0	0	0	0	0
23:01 - 24:00	0	0	0	0	0	0	0	0	0	0	0	0

Table B 2.2

Change in Hot Water temperature needed from Auxiliary Boilers

ΔT needed from Auxiliary Boilers vs. Hour/day												
Hour	J	F	M	A	M	J	J	A	S	O	N	D
0:01 - 1:00	20	20	20	20	20	20	20	20	20	20	20	20
1:01 - 2:00	20	20	20	20	20	20	20	20	20	20	20	20
2:01 - 3:00	20	20	20	20	20	20	20	20	20	20	20	20
3:01 - 4:00	20	20	20	20	20	20	20	20	20	20	20	20
4:01 - 5:00	20	20	20	20	20	20	20	20	20	20	20	20
5:01 - 6:00	20	20	20	20	20	20	20	20	20	20	20	20
6:01 - 7:00	20	20	20	4.52	0	0	0	0	16.65	20	20	20
7:01 - 8:00	20	20	15.38	0	0	0	0	0	0	0	9.38	20
8:01 - 9:00	2.38	0	0	0	0	0	0	0	0	0	0	0
9:01 - 10:00	0	0	0	0	0	0	0	0	0	0	0	0
10:01 - 11:00	0	0	0	0	0	0	0	0	0	0	0	0
11:01 - 12:00	0	0	0	0	0	0	0	0	0	0	0	0
12:01 - 13:00	0	0	0	0	0	0	0	0	0	0	0	0
13:01 - 14:00	0	0	0	0	0	0	0	0	0	0	0	0
14:01 - 15:00	0	0	0	0	0	0	0	0	0	0	0	0
15:01 - 16:00	10.61	18.96	0	0	0	0	0	0	0	0	13.86	20
16:01 - 17:00	20	20	20	12.1	0	0	0	0	19.48	20	20	20
17:01 - 18:00	20	20	20	20	20	20	20	20	20	20	20	20
18:01 - 19:00	20	20	20	20	20	20	20	20	20	20	20	20
19:01 - 20:00	20	20	20	20	20	20	20	20	20	20	20	20
20:01 - 21:00	20	20	20	20	20	20	20	20	20	20	20	20
21:01 - 22:00	20	20	20	20	20	20	20	20	20	20	20	20
22:01 - 23:00	20	20	20	20	20	20	20	20	20	20	20	20
23:01 - 24:00	20	20	20	20	20	20	20	20	20	20	20	20

Table B 2.3

Energy output of chillers driven by the auxiliary boilers.

Output of chiller (MBH) vs. hour/day												
Hour	J	F	M	A	M	J	J	A	S	O	N	D
0:01 - 1:00	0	0	0	0	0	208.67	214.96	231.9	191.18	0	0	0
1:01 - 2:00	0	0	0	0	0	130.42	134.35	144.94	119.49	0	0	0
2:01 - 3:00	0	0	0	0	0	130.42	134.35	144.94	119.49	0	0	0
3:01 - 4:00	0	0	0	0	0	130.42	134.35	144.94	119.49	0	0	0
4:01 - 5:00	0	0	0	0	0	104.34	107.48	115.95	95.59	0	0	0
5:01 - 6:00	0	0	0	0	0	104.34	107.48	115.95	95.59	0	0	0
6:01 - 7:00	0	0	0	0	0	0	0	0	139.26	0	0	0
7:01 - 8:00	79.45	71.87	58.78	0	0	0	0	0	0	0	34.8	75.51
8:01 - 9:00	12.02	0	0	0	0	0	0	0	0	0	0	0
9:01 - 10:00	0	0	0	0	0	0	0	0	0	0	0	0
10:01 - 11:00	0	0	0	0	0	0	0	0	0	0	0	0
11:01 - 12:00	0	0	0	0	0	0	0	0	0	0	0	0
12:01 - 13:00	0	0	0	0	0	0	0	0	0	0	0	0
13:01 - 14:00	0	0	0	0	0	0	0	0	0	0	0	0
14:01 - 15:00	0	0	0	0	0	0	0	0	0	0	0	0
15:01 - 16:00	383.28	619.44	0	0	0	0	0	0	0	0	467.53	686.44
16:01 - 17:00	678.98	614.15	653.33	349.05	0	0	0	0	2187.84	686.88	634.18	645.25
17:01 - 18:00	642.86	581.48	618.58	546.06	620.58	2321.46	2391.49	2579.94	2126.86	650.35	600.45	610.93
18:01 - 19:00	411.72	372.41	396.17	349.72	397.45	1486.78	1531.63	1652.32	1362.14	416.51	384.56	391.27
19:01 - 20:00	195.03	176.4	187.66	165.66	188.27	704.26	725.51	782.68	645.23	197.3	182.16	185.34
20:01 - 21:00	166.13	150.27	159.86	141.12	160.37	599.93	618.02	666.73	549.64	168.07	155.17	157.88
21:01 - 22:00	137.24	124.14	132.06	116.57	132.48	495.59	510.54	550.77	454.05	138.84	128.19	130.42
22:01 - 23:00	122.79	111.07	118.15	104.3	118.54	443.43	456.8	492.8	406.25	124.22	114.69	116.69
23:01 - 24:00	0	0	0	0	0	313.01	322.45	347.86	286.77	0	0	0

Table B 2.4

Boiler energy output to drive absorption chillers.

Boiler Output (MBH) vs. hour/day												
Hour	J	F	M	A	M	J	J	A	S	O	N	D
0:01 - 1:00	0	0	0	0	0	300.83	309.91	334.33	275.62	0	0	0
1:01 - 2:00	0	0	0	0	0	188.02	193.69	208.96	172.26	0	0	0
2:01 - 3:00	0	0	0	0	0	188.02	193.69	208.96	172.26	0	0	0
3:01 - 4:00	0	0	0	0	0	188.02	193.69	208.96	172.26	0	0	0
4:01 - 5:00	0	0	0	0	0	150.42	154.95	167.16	137.81	0	0	0
5:01 - 6:00	0	0	0	0	0	150.42	154.95	167.16	137.81	0	0	0
6:01 - 7:00	0	0	0	0	0	0	0	0	200.77	0	0	0
7:01 - 8:00	114.55	103.61	84.74	0	0	0	0	0	0	0	50.17	108.86
8:01 - 9:00	17.33	0	0	0	0	0	0	0	0	0	0	0
9:01 - 10:00	0	0	0	0	0	0	0	0	0	0	0	0
10:01 - 11:00	0	0	0	0	0	0	0	0	0	0	0	0
11:01 - 12:00	0	0	0	0	0	0	0	0	0	0	0	0
12:01 - 13:00	0	0	0	0	0	0	0	0	0	0	0	0
13:01 - 14:00	0	0	0	0	0	0	0	0	0	0	0	0
14:01 - 15:00	0	0	0	0	0	0	0	0	0	0	0	0
15:01 - 16:00	552.56	893.02	0	0	0	0	0	0	0	0	674.02	989.61
16:01 - 17:00	978.86	885.4	941.88	503.22	0	0	0	0	3154.14	990.26	914.27	930.24
17:01 - 18:00	926.79	838.3	891.78	787.23	894.67	3346.78	3447.72	3719.41	3066.22	937.58	865.64	880.75
18:01 - 19:00	593.56	536.89	571.14	504.18	572.99	2143.44	2208.09	2382.09	1963.76	600.47	554.4	564.08
19:01 - 20:00	281.16	254.32	270.54	238.82	271.42	1015.31	1045.94	1128.36	930.2	284.44	262.61	267.2
20:01 - 21:00	239.51	216.64	230.46	203.44	231.21	864.9	890.99	961.2	792.39	242.3	223.71	227.61
21:01 - 22:00	197.85	178.96	190.38	168.06	191	714.48	736.03	794.03	654.59	200.16	184.8	188.03
22:01 - 23:00	177.03	160.13	170.34	150.37	170.89	639.27	658.55	710.45	585.68	179.09	165.35	168.23
23:01 - 24:00	0	0	0	0	0	451.25	464.86	501.49	413.42	0	0	0

Table B 2.5

Energy Input to boiler supplied by natural gas.

Gas Firing Rate (CFH) of Boiler vs. Hour/day												
Hour	J	F	M	A	M	J	J	A	S	O	N	D
0:01 - 1:00	0	0	0	0	0	376.04	387.38	417.91	344.52	0	0	0
1:01 - 2:00	0	0	0	0	0	235.03	242.12	261.19	215.32	0	0	0
2:01 - 3:00	0	0	0	0	0	235.03	242.12	261.19	215.32	0	0	0
3:01 - 4:00	0	0	0	0	0	235.03	242.12	261.19	215.32	0	0	0
4:01 - 5:00	0	0	0	0	0	188.02	193.69	208.96	172.26	0	0	0
5:01 - 6:00	0	0	0	0	0	188.02	193.69	208.96	172.26	0	0	0
6:01 - 7:00	0	0	0	0	0	0	0	0	250.96	0	0	0
7:01 - 8:00	143.18	129.51	105.93	0	0	0	0	0	0	0	62.71	136.07
8:01 - 9:00	21.66	0	0	0	0	0	0	0	0	0	0	0
9:01 - 10:00	0	0	0	0	0	0	0	0	0	0	0	0
10:01 - 11:00	0	0	0	0	0	0	0	0	0	0	0	0
11:01 - 12:00	0	0	0	0	0	0	0	0	0	0	0	0
12:01 - 13:00	0	0	0	0	0	0	0	0	0	0	0	0
13:01 - 14:00	0	0	0	0	0	0	0	0	0	0	0	0
14:01 - 15:00	0	0	0	0	0	0	0	0	0	0	0	0
15:01 - 16:00	690.7	1116.28	0	0	0	0	0	0	0	0	842.53	1237.01
16:01 - 17:00	1223.57	1106.75	1177.35	629.02	0	0	0	0	3942.67	1237.82	1142.84	1162.79
17:01 - 18:00	1158.49	1047.88	1114.73	984.04	1118.33	4183.47	4309.66	4649.26	3832.77	1171.98	1082.05	1100.94
18:01 - 19:00	741.95	671.11	713.93	630.23	716.24	2679.3	2760.12	2977.62	2454.7	750.59	693	705.1
19:01 - 20:00	351.45	317.9	338.18	298.53	339.27	1269.14	1307.42	1410.45	1162.75	355.54	328.26	333.99
20:01 - 21:00	299.38	270.8	288.08	254.3	289.01	1081.12	1113.73	1201.49	990.49	302.87	279.63	284.51
21:01 - 22:00	247.32	223.7	237.98	210.08	238.75	893.1	920.04	992.54	818.23	250.2	231	235.03
22:01 - 23:00	221.28	200.16	212.93	187.96	213.61	799.09	823.19	888.06	732.1	223.86	206.68	210.29
23:01 - 24:00	0	0	0	0	0	564.06	581.08	626.87	516.78	0	0	0

Table B 2.6

Natural Gas and Total Cost Analysis

Natural Gas Cost Analysis												
Month	J	F	M	A	M	J	J	A	S	O	N	D
Days	31	28	31	30	31	30	31	31	30	31	30	31
Therm/day	5.1	5.08	4.19	3.19	2.92	12.9	13.3	14.37	16.04	4.29	4.87	5.41
Therm/month	158.07	142.35	130	95.8	90.4	388	413	445.34	481.09	133.08	146	168
Cost/Therm	0.98	0.98	0.98	0.98	0.98	0.98	0.98	0.98	0.98	0.98	0.98	0.98
Cost/Month	155.41	139.96	128	94.2	88.9	381	406	437.84	472.99	130.84	144	165
Base/Month	30	30	30	30	30	30	30	30	30	30	30	30
Total/Month	185.41	169.96	158	124	119	411	436	467.84	502.99	160.84	174	195
Total	3103.24											
Existing Pump Cost	8265.62											
Additional Pump Cost	3760											
Total System Cost	**$15,128.86**											

Appendix B
Section 3

Table B 3.1
Energy Output of Chiller via Boiler Hot Water.

Chiller Output (tons) via Boiler Hot Water vs. Hour/day												
Hour	J	F	M	A	M	J	J	A	S	O	N	D
0:01 - 1:00	0	0	0	0	0	100	100	100	100	0	0	0
1:01 - 2:00	0	0	0	0	0	100	100	100	100	0	0	0
2:01 - 3:00	0	0	0	0	0	100	100	100	100	0	0	0
3:01 - 4:00	0	0	0	0	0	100	100	100	100	0	0	0
4:01 - 5:00	0	0	0	0	0	100	100	100	100	0	0	0
5:01 - 6:00	0	0	0	0	0	100	100	100	100	0	0	0
6:01 - 7:00	0	0	0	0	0	0	0	0	83.25	0	0	0
7:01 - 8:00	6.62	5.99	4.9	0	0	0	0	0	0	0	2.9	6.29
8:01 - 9:00	1	0	0	0	0	0	0	0	0	0	0	0
9:01 - 10:00	0	0	0	0	0	0	0	0	0	0	0	0
10:01 - 11:00	0	0	0	0	0	0	0	0	0	0	0	0
11:01 - 12:00	0	0	0	0	0	0	0	0	0	0	0	0
12:01 - 13:00	0	0	0	0	0	0	0	0	0	0	0	0
13:01 - 14:00	0	0	0	0	0	0	0	0	0	0	0	0
14:01 - 15:00	0	0	0	0	0	0	0	0	0	0	0	0
15:01 - 16:00	31.94	51.62	0	0	0	0	0	0	0	0	38.96	57.2
16:01 - 17:00	56.58	51.18	54.44	29.09	0	0	0	0	84.92	57.24	52.85	53.77
17:01 - 18:00	53.57	48.46	51.55	45.5	51.71	93.46	99.29	114.99	77.24	54.2	50.04	50.91
18:01 - 19:00	34.31	31.03	33.01	29.14	33.12	123.9	127.64	137.69	113.51	34.71	32.05	32.61
19:01 - 20:00	16.25	14.7	15.64	13.8	15.69	58.69	60.46	65.22	53.77	16.44	15.18	15.44
20:01 - 21:00	13.84	12.52	13.32	11.76	13.36	49.99	51.5	55.56	45.8	14.01	12.93	13.16
21:01 - 22:00	11.44	10.34	11	9.71	11.04	41.3	42.55	45.9	37.84	11.57	10.68	10.87
22:01 - 23:00	10.23	9.26	9.85	8.69	9.88	100	100	100	100	10.35	9.56	9.72
23:01 - 24:00	0	0	0	0	0	100	100	100	100	0	0	0

Table B 3.2

Boiler Output to drive chiller generators.

Boiler Output (MBH) vs. Hour/day												
Hour	J	F	M	A	M	J	J	A	S	O	N	D
0:01 - 1:00	0	0	0	0	0	1730	1730	1730	1730	0	0	0
1:01 - 2:00	0	0	0	0	0	1730	1730	1730	1730	0	0	0
2:01 - 3:00	0	0	0	0	0	1730	1730	1730	1730	0	0	0
3:01 - 4:00	0	0	0	0	0	1730	1730	1730	1730	0	0	0
4:01 - 5:00	0	0	0	0	0	1730	1730	1730	1730	0	0	0
5:01 - 6:00	0	0	0	0	0	1730	1730	1730	1730	0	0	0
6:01 - 7:00	0	0	0	0	0	0	0	0	1440.22	0	0	0
7:01 - 8:00	114.55	103.61	84.74	0	0	0	0	0	0	0	50.17	108.86
8:01 - 9:00	17.33	0	0	0	0	0	0	0	0	0	0	0
9:01 - 10:00	0	0	0	0	0	0	0	0	0	0	0	0
10:01 - 11:00	0	0	0	0	0	0	0	0	0	0	0	0
11:01 - 12:00	0	0	0	0	0	0	0	0	0	0	0	0
12:01 - 13:00	0	0	0	0	0	0	0	0	0	0	0	0
13:01 - 14:00	0	0	0	0	0	0	0	0	0	0	0	0
14:01 - 15:00	0	0	0	0	0	0	0	0	0	0	0	0
15:01 - 16:00	552.56	893.02	0	0	0	0	0	0	0	0	674.02	989.61
16:01 - 17:00	978.86	885.4	941.88	503.22	0	0	0	0	1469.19	990.26	914.27	930.24
17:01 - 18:00	926.79	838.3	891.78	787.23	894.67	1616.78	1717.72	1989.41	1336.22	937.58	865.64	880.75
18:01 - 19:00	593.56	536.89	571.14	504.18	572.99	2143.44	2208.09	2382.09	1963.76	600.47	554.4	564.08
19:01 - 20:00	281.16	254.32	270.54	238.82	271.42	1015.31	1045.94	1128.36	930.2	284.44	262.61	267.2
20:01 - 21:00	239.51	216.64	230.46	203.44	231.21	864.9	890.99	961.2	792.39	242.3	223.71	227.61
21:01 - 22:00	197.85	178.96	190.38	168.06	191	714.48	736.03	794.03	654.59	200.16	184.8	188.03
22:01 - 23:00	177.03	160.13	170.34	150.37	170.89	1730	1730	1730	1730	179.09	165.35	168.23
23:01 - 24:00	0	0	0	0	0	1730	1730	1730	1730	0	0	0

Table B 3.3
Natural Gas Analysis.

Gas Firing Rate (CFH) of Boiler vs. Hour/day												
Hour	J	F	M	A	M	J	J	A	S	O	N	D
0:01 - 1:00	0	0	0	0	0	2162.5	2162.5	2162.5	2162.5	0	0	0
1:01 - 2:00	0	0	0	0	0	2162.5	2162.5	2162.5	2162.5	0	0	0
2:01 - 3:00	0	0	0	0	0	2162.5	2162.5	2162.5	2162.5	0	0	0
3:01 - 4:00	0	0	0	0	0	2162.5	2162.5	2162.5	2162.5	0	0	0
4:01 - 5:00	0	0	0	0	0	2162.5	2162.5	2162.5	2162.5	0	0	0
5:01 - 6:00	0	0	0	0	0	2162.5	2162.5	2162.5	2162.5	0	0	0
6:01 - 7:00	0	0	0	0	0	0	0	0	1800.28	0	0	0
7:01 - 8:00	143.18	129.51	105.93	0	0	0	0	0	0	0	62.71	136.07
8:01 - 9:00	21.66	0	0	0	0	0	0	0	0	0	0	0
9:01 - 10:00	0	0	0	0	0	0	0	0	0	0	0	0
10:01 - 11:00	0	0	0	0	0	0	0	0	0	0	0	0
11:01 - 12:00	0	0	0	0	0	0	0	0	0	0	0	0
12:01 - 13:00	0	0	0	0	0	0	0	0	0	0	0	0
13:01 - 14:00	0	0	0	0	0	0	0	0	0	0	0	0
14:01 - 15:00	0	0	0	0	0	0	0	0	0	0	0	0
15:01 - 16:00	690.7	1116.28	0	0	0	0	0	0	0	0	842.53	1237.01
16:01 - 17:00	1223.57	1106.75	1177.35	629.02	0	0	0	0	1836.49	1237.82	1142.84	1162.79
17:01 - 18:00	1158.49	1047.88	1114.73	984.04	1118.33	2020.97	2147.16	2486.76	1670.27	1171.98	1082.05	1100.94
18:01 - 19:00	741.95	671.11	713.93	630.23	716.24	2679.3	2760.12	2977.62	2454.7	750.59	693	705.1
19:01 - 20:00	351.45	317.9	338.18	298.53	339.27	1269.14	1307.42	1410.45	1162.75	355.54	328.26	333.99
20:01 - 21:00	299.38	270.8	288.08	254.3	289.01	1081.12	1113.73	1201.49	990.49	302.87	279.63	284.51
21:01 - 22:00	247.32	223.7	237.98	210.08	238.75	893.1	920.04	992.54	818.23	250.2	231	235.03
22:01 - 23:00	221.28	200.16	212.93	187.96	213.61	2162.5	2162.5	2162.5	2162.5	223.86	206.68	210.29
23:01 - 24:00	0	0	0	0	0	2162.5	2162.5	2162.5	2162.5	0	0	0

Table B 3.4
Annual Natural Gas and Total Cost Analysis for Alternative 2

Natural Gas Cost Analysis												
Month	J	F	M	A	M	J	J	A	S	O	N	D
Days	31	28	31	30	31	30	31	31	30	31	30	31
Therm/day	5.1	5.08	4.19	3.19	2.92	25.24	25.55	26.37	28.03	4.29	4.87	5.41
Therm/month	158.06	142.36	129.86	95.81	90.37	757.31	792.01	817.43	841	133.08	146.06	167.57
Cost/Therm	0.98	0.98	0.98	0.98	0.98	0.98	0.98	0.98	0.98	0.98	0.98	0.98
Cost/Month	155.4	139.96	127.67	94.2	88.84	744.56	778.67	803.66	826.84	130.84	143.6	164.75
Base/Month	30	30	30	30	30	30	30	30	30	30	30	30
Total/Month	185.4	169.96	157.67	124.2	118.84	774.56	808.67	833.66	856.84	160.84	173.6	194.75
Total	4559											
Existing Pump Cost	8265.62											
Additional Pump Cost	4820											
Total System Cost	17,644.62											

Appendix B
Section 4

Table B 4.1
Chiller KW consumption with 246,000 gal storage tank

KW with Storage vs. Hour/day												
Hour	J	F	M	A	M	J	J	A	S	O	N	D
0:01 - 1:00	0	0	0	0	0	225.99	225.99	225.99	225.99	0	0	0
1:01 - 2:00	0	0	0	0	0	225.99	225.99	225.99	225.99	0	0	0
2:01 - 3:00	0	0	0	0	0	225.99	225.99	225.99	225.99	0	0	0
3:01 - 4:00	0	0	0	0	0	225.99	225.99	225.99	225.99	0	0	0
4:01 - 5:00	0	0	0	0	0	225.99	225.99	225.99	225.99	0	0	0
5:01 - 6:00	0	0	0	0	0	225.99	225.99	225.99	225.99	0	0	0
6:01 - 7:00	0	0	0	0	0	225.99	225.99	225.99	225.99	0	0	0
7:01 - 8:00	5.54	5.01	5.33	4.71	5.35	225.99	225.99	225.99	225.99	5.61	5.18	5.27
8:01 - 9:00	7.05	6.38	6.79	5.99	6.81	225.99	225.99	225.99	225.99	7.14	6.59	6.7
9:01 - 10:00	32.24	29.17	31.03	27.39	31.13	0	0	0	0	32.62	30.12	30.64
10:01 - 11:00	42.82	38.74	41.21	36.38	41.34	0	0	0	0	43.32	40	40.7
11:01 - 12:00	43.83	39.65	42.18	37.23	42.31	0	0	0	0	44.34	40.94	41.65
12:01 - 13:00	45.34	41.01	43.63	38.52	43.77	0	0	0	0	45.87	42.35	43.09
13:01 - 14:00	48.87	44.2	47.02	41.51	47.18	0	0	0	0	49.44	45.65	46.44
14:01 - 15:00	50.38	45.57	48.48	42.79	48.64	0	0	0	0	50.97	47.06	47.88
15:01 - 16:00	50.38	45.57	48.48	42.79	48.64	0	0	0	0	50.97	47.06	47.88
16:01 - 17:00	47.36	42.84	45.57	40.23	45.72	0	0	0	0	47.91	44.23	45.01
17:01 - 18:00	44.84	40.56	43.15	38.09	43.29	0	0	0	0	45.36	41.88	42.61
18:01 - 19:00	28.72	25.98	27.63	24.39	27.72	0	0	0	0	29.05	26.82	27.29
19:01 - 20:00	13.6	12.3	13.09	11.55	13.13	0	0	0	0	13.76	12.71	12.93
20:01 - 21:00	11.59	10.48	11.15	9.84	11.19	0	0	0	0	11.72	10.82	11.01
21:01 - 22:00	9.57	8.66	9.21	8.13	9.24	225.99	225.99	225.99	225.99	9.68	8.94	9.1
22:01 - 23:00	8.56	7.75	8.24	7.28	8.27	225.99	225.99	225.99	225.99	8.66	8	8.14
23:01 - 24:00	0	0	0	0	0	225.99	225.99	225.99	225.99	0	0	0

Table B 4.2
Annual Cost analysis with 246,000 gal storage tank

246,000 gal Cost Analysis												
Month	J	F	M	A	M	J	J	A	S	O	N	D
Max Demand	50.38	45.57	48.48	42.79	48.64	225.99	225.99	225.99	225.99	50.97	47.06	47.88
Demand Charge	0.5	0.5	0.5	0.5	0.5	9.17	9.17	9.17	9.17	0.5	0.5	0.5
$/month	25.19	22.79	24.24	21.4	24.32	2072.33	2072.33	2072.33	2072.33	25.48	23.53	23.94
$/day	31.44	28.43	30.25	26.7	30.35	174.43	174.43	174.43	174.43	31.8	29.36	29.87
days	31	28	31	30	31	30	31	31	30	31	30	31
Consumption Cost	974.49	796.2	937.7	801.1	940.7	5232.78	5407.2	5407.2	5232.78	985.8	880.8	926.1
Total Cost	**37003.2**											

Table B 4.3

Chiller KW consumption with 153,000 gal storage tank

KW with storage vs. hour/day												
Hour	J	F	M	A	M	J	J	A	S	O	N	D
0:01 - 1:00	0	0	0	0	0	138.11	138.11	138.11	138.11	0	0	0
1:01 - 2:00	0	0	0	0	0	138.11	138.11	138.11	138.11	0	0	0
2:01 - 3:00	0	0	0	0	0	138.11	138.11	138.11	138.11	0	0	0
3:01 - 4:00	0	0	0	0	0	138.11	138.11	138.11	138.11	0	0	0
4:01 - 5:00	0	0	0	0	0	138.11	138.11	138.11	138.11	0	0	0
5:01 - 6:00	0	0	0	0	0	138.11	138.11	138.11	138.11	0	0	0
6:01 - 7:00	0	0	0	0	0	138.11	138.11	138.11	138.11	0	0	0
7:01 - 8:00	5.54	5.01	5.33	4.71	5.35	138.11	138.11	138.11	138.11	5.61	5.18	5.27
8:01 - 9:00	7.05	6.38	6.79	5.99	6.81	138.11	138.11	138.11	138.11	7.14	6.59	6.7
9:01 - 10:00	32.24	29.17	31.03	27.39	31.13	116.44	119.95	129.4	106.68	32.62	30.12	30.64
10:01 - 11:00	42.82	38.74	41.21	36.38	41.34	154.64	159.31	171.86	141.68	43.32	40	40.7
11:01 - 12:00	43.83	39.65	42.18	37.23	42.31	158.28	163.06	175.91	145.01	44.34	40.94	41.65
12:01 - 13:00	45.34	41.01	43.63	38.52	43.77	0	0	0	0	45.87	42.35	43.09
13:01 - 14:00	48.87	44.2	47.02	41.51	47.18	0	0	0	0	49.44	45.65	46.44
14:01 - 15:00	50.38	45.57	48.48	42.79	48.64	0	0	0	0	50.97	47.06	47.88
15:01 - 16:00	50.38	45.57	48.48	42.79	48.64	0	0	0	0	50.97	47.06	47.88
16:01 - 17:00	47.36	42.84	45.57	40.23	45.72	0	0	0	0	47.91	44.23	45.01
17:01 - 18:00	44.84	40.56	43.15	38.09	43.29	0	0	0	0	45.36	41.88	42.61
18:01 - 19:00	28.72	25.98	27.63	24.39	27.72	103.7	106.83	115.25	95.01	29.05	26.82	27.29
19:01 - 20:00	13.6	12.3	13.09	11.55	13.13	49.12	50.6	54.59	45	13.76	12.71	12.93
20:01 - 21:00	11.59	10.48	11.15	9.84	11.19	41.85	43.11	46.5	38.34	11.72	10.82	11.01
21:01 - 22:00	9.57	8.66	9.21	8.13	9.24	138.11	138.11	138.11	138.11	9.68	8.94	9.1
22:01 - 23:00	8.56	7.75	8.24	7.28	8.27	138.11	138.11	138.11	138.11	8.66	8	8.14
23:01 - 24:00	0	0	0	0	0	138.11	138.11	138.11	138.11	0	0	0

Table B 4.4

Annual Cost analysis with 153,000 gal storage tank

153,000 gal Cost Analysis												
Month	J	F	M	A	M	J	J	A	S	O	N	D
Max Demand	50.38	45.57	48.48	42.79	48.64	158.28	163.06	175.91	145.01	50.97	47.06	47.88
Demand Charge	0.5	0.5	0.5	0.5	0.5	9.17	9.17	9.17	9.17	0.5	0.5	0.5
$/month	25.19	22.79	24.24	21.4	24.32	1451.46	1495.24	1613.06	1329.78	25.48	23.53	23.94
$/day	31.44	28.43	30.25	26.7	30.35	159.17	160.75	165.02	154.76	31.8	29.36	29.87
days	31	28	31	30	31	30	31	31	30	31	30	31
Consumption Cost	974.49	796.2	937.7	801.1	940.7	4775.04	4983.37	5115.68	4642.82	985.8	880.8	926.1
Total Cost	**32,840.19**											

Appendix C

The following pages contain cut sheets and performance data of the mechanical equipment analyzed in this thesis, including chillers, boilers, pumps, and solar absorbers.

Also included are other information sheets that were used to evaluate the mechanical systems of this thesis.

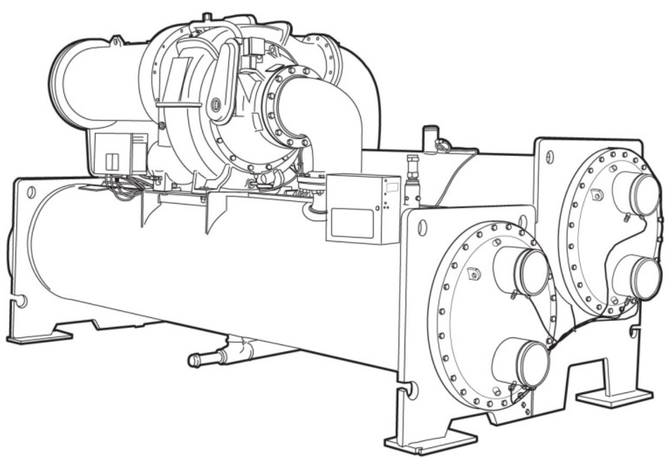
Existing Chiller: Carrier 19

Product Data

EVERGREEN®
19XR,XRV
High-Efficiency
Hermetic Centrifugal Liquid Chiller
50/60 Hz
HFC-134a

19XR — 200 to 1500 Nominal Tons (703 to 5275 kW)
19XRV — 200 to 1450 Nominal Tons (703 to 5100 kW)

Evergreen® CHILLERS



19XR,XRV

Carrier's Evergreen® centrifugal chillers offer:

- The use of non-ozone depleting refrigerant HFC-134a, which is not affected by scheduled refrigerant phaseouts
- An annual leak rate of 0.1%, the lowest published in the industry
- The ability to store the entire charge of refrigerant inside the chiller, minimizing the chance of leaks during refrigerant transfer for maintenance
- Hermetic compression
- Refrigerant-cooled VFD (19XRV)
- Modular construction
- Positive pressure design

Features/Benefits

The Carrier-designed Evergreen family of chillers achieve superior efficiencies without compromising the environment.

The Evergreen chillers superior efficiencies are obtained at true operating conditions. Therefore, the effects of potential direct or indirect global warming are greatly diminished.

High efficiency

Today's owners of chilled water plants demand high efficiency from their chillers. Per ARI 550/590, chillers operate at design conditions less than one percent of the time. As a result, superior part-load efficiency is required for today's chilled water applications.

Copyright 2009 Carrier Corporation

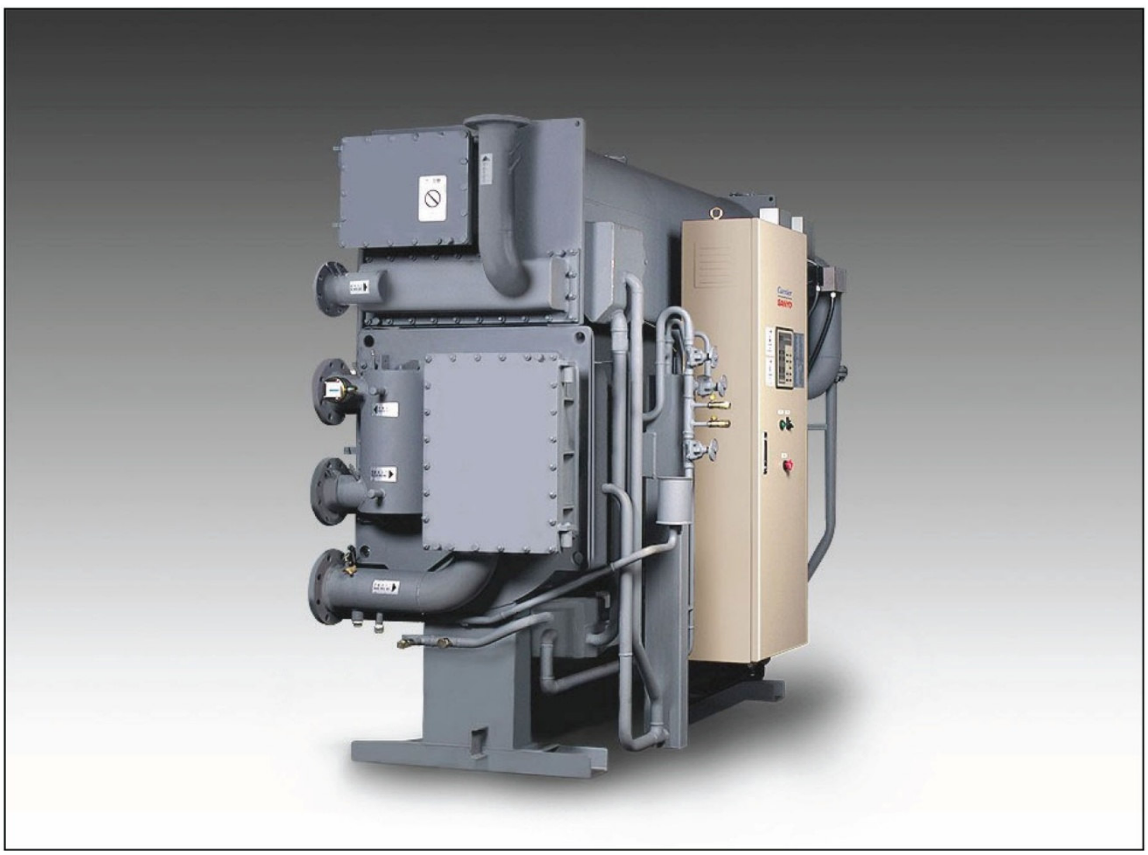
Form 19XR-8PD

Absorption Chiller

Absorption Chiller

SERVICE TRAINING BOOK

LJ | TJ Model



Physical data

UNIT 16LJ	11	12	13	14	21
NOMINAL COOLING CAPACITY (ton)	75	90	110	135	155
RIGGING WEIGHT (lb)	7,800	8,000	10,000	10,400	12,600
OPERATING WEIGHT (lb)	8,900	9,300	11,500	12,200	14,800
LITHIUM BROMIDE SOLUTION CHARGE (lb)	950	950	1,240	1,370	1,660
REFRIGERANT (WATER) CHARGE (lb)	130	130	220	200	240
CHILLED WATER Pipe Connection Size (in.)	3	3	4	4	5
No. of Passes	5	5	3	3	3
COOLING WATER Pipe Connection Size (in.)	5	5	5	5	6
No. of Passes Absorber	4	4	4	4	4
Condenser	2	2	2	2	2
HOT WATER Pipe Connection Size (in.)	4	4	4	4	5
No. of Passes	6	4	4	4	4

UNIT 16LJ	22	23	24	31	32
NOMINAL COOLING CAPACITY (ton)	180	210	240	270	300
RIGGING WEIGHT (lb)	13,300	15,500	16,100	19,900	20,800
OPERATING WEIGHT (lb)	15,700	18,100	19,200	23,400	24,500
LITHIUM BROMIDE SOLUTION CHARGE (lb)	1,790	2,170	2,360	2,720	2,960
REFRIGERANT (WATER) CHARGE (lb)	260	330	310	420	370
CHILLED WATER Pipe Connection Size (in.)	5	5	5	6	6
No. of Passes	3	3	3	3	3
COOLING WATER Pipe Connection Size (in.)	6	8	8	8	8
No. of Passes Absorber	4	2	2	2	2
Condenser	2	2	2	2	2
HOT WATER Pipe Connection Size (in.)	5	6	6	6	6
No. of Passes	4	3	3	3	3

UNIT 16LJ	41	42	51	52	53
NOMINAL COOLING CAPACITY (ton)	335	375	420	470	525
RIGGING WEIGHT (lb)	23,900	24,700	33,300	36,200	38,900
OPERATING WEIGHT (lb)	28,500	29,600	40,200	43,500	46,600
LITHIUM BROMIDE SOLUTION CHARGE (lb)	3,440	3,710	4,300	4,790	5,340
REFRIGERANT (WATER) CHARGE (lb)	550	510	570	640	680
CHILLED WATER Pipe Connection Size (in.)	8	8	8	8	8
No. of Passes	3	3	3	2	2
COOLING WATER Pipe Connection Size (in.)	10	10	12	12	12
No. of Passes Absorber	2	2	4	2	2
Condenser	2	2	2	2	2
HOT WATER Pipe Connection Size (in.)	8	8	8	8	8
No. of Passes	3	3	3	3	3

Performance data

UNIT 16LJ	11	12	13	14	21	22	23	24
COOLING CAPACITY (Ton)	75	90	110	135	155	180	210	240
CHILLED WATER								
Flow Rate (gpm)	180	216	264	324	372	432	504	576
Pressure Drop (ft)	18.3	20.1	11.9	13.1	11.7	12.3	24.8	26.5
COOLING WATER								
Flow Rate (gpm)	270	324	396	486	558	648	756	864
Pressure Drop (ft)	12.2	12.9	21.8	26.1	36.0	23.4	34.5	35.3
HOT WATER								
Flow Rate (gpm)	164	197	241	296	339	394	460	526
Pressure Drop (ft)	10.3	4.0	9.9	10.8	10.1	10.1	9.9	10.1

UNIT 16LJ	31	32	41	42	51	52	53
COOLING CAPACITY (Ton)	270	300	335	375	420	470	525
CHILLED WATER							
Flow Rate (gpm)	648	720	804	900	1008	1128	1260
Pressure Drop (ft)	25.4	26.9	25.1	25.0	20.6	10.8	14.1
COOLING WATER							
Flow Rate (gpm)	972	1080	1206	1350	1512	1692	1890
Pressure Drop (ft)	32.4	32.9	33.0	34.3	31.3	29.4	39.1
HOT WATER							
Flow Rate (gpm)	591	657	734	821	920	1029	1150
Pressure Drop (ft)	9.7	9.6	9.4	9.5	9.3	12.4	16.3

NOTE: Ratings are based on ARI 560-2000:
44 F chilled water, 2.4 gpm/ton, .0001 ft^2-hr-F/Btu fouling factor
85 F cooling water, 3.6 gpm/ton, .00025 ft^2-hr-F/Btu fouling factor
203 F hot water, 2.19 gpm/ton, .0001 ft^2-hr-F/Btu fouling factor

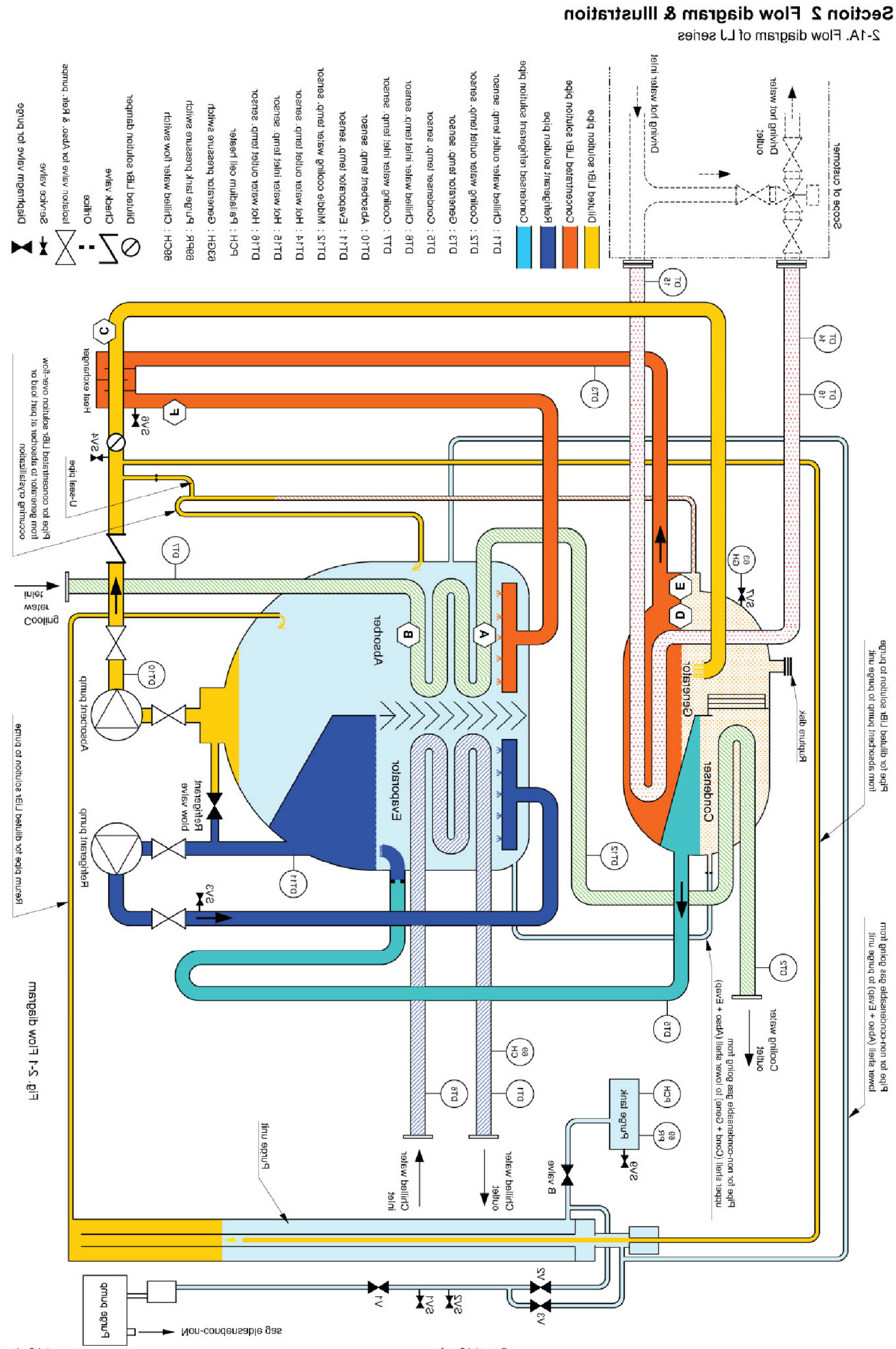
Part-load performance

Part-load performance energy requirements for the 16LJ chiller, ranging from 10% to 100% of full load, can be obtained by contacting a local sales office.

All performance data is rated in accordance with ARI 560, latest edition, which defines Integrated Part Load Value (IPLV) as a measure of part-load efficiency representing the weighted average of overall chiller performance calculated by the following equation:

IPLV = .01A + .42B + .45C + .12D where

A = COP (Coefficient of Performance) at 100%
B = COP at 75%
C = COP at 50%
D = COP at 25% or minimum load


Section 2 Flow diagram & Illustration
Absorber
Evaporator
Generator
Condenser
Absorbent pump
Refrigerant pump
Purge tank
Purge pump
Page 1 / Sec.2
LJ Series

Boiler: Futera XLF

Big-Time Components, Small Diameter Vent

Like all RBI products, the Futera XLF is built with the highest-grade components and materials. The heat exchanger's solid bronze headers prevent rust and corrosion for the life of the unit. XLF's symmetric air/fuel coupling provides a high degree of safety while ensuring consistent combustion quality regardless of changes to fuel or air flow. In addition to its compact dimensions enabling 3 or 4 million Btuhs to be installed in a small space, its small vent diameter is easy to work with and reduces vent material costs. Removal of top and front panels is simple, streamlining installation and service.

Whether to add efficient low-demand output to a larger existing system, or to build a highly space- and energy-efficient heat and hot water system from the ground up, the RBI Futera XLF gives you the power to develop a solution that fits any design.

FUTERA XLF

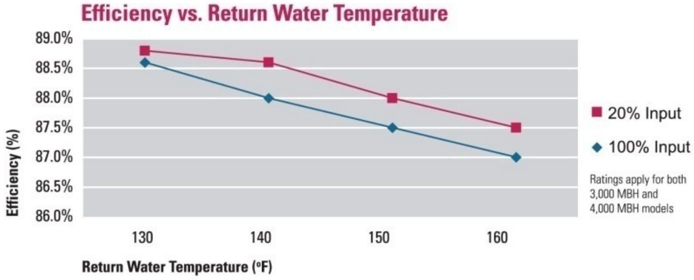
STANDARD FEATURES

- 3,000 – 4,000 MBH
- Finned copper tube heat exchanger, ASME 160 psi max WP, 4-pass design
- Stainless steel jacket panels
- Solid bronze headers
- Variable speed blower
- Digital text annunciator
- Mounted & wired flow switch
- Mounted & wired low water cutoff
- Quick-release service latches
- Multiple venting options
  - Category II or IV
  - Allows differential pressure zones for intake air and exhaust
  - Sealed combustion
  - Direct vent
  - Common venting of multiple boilers
- Seismic restraint base assembly
- HeatNet integrated boiler management system
- Modbus protocol for BMS communications
- Turbo Pilot (patent-pending design)
- Honeywell RM7800 Series flame safeguard

OPTIONAL FEATURES

- Cupro-Nickel Finned Tubes
- Freeze protection package
- BACnet or LonWorks interface module
- Honeywell keyboard display module S7800
- Outdoor sensor with housing

Efficiency vs. Return Water Temperature



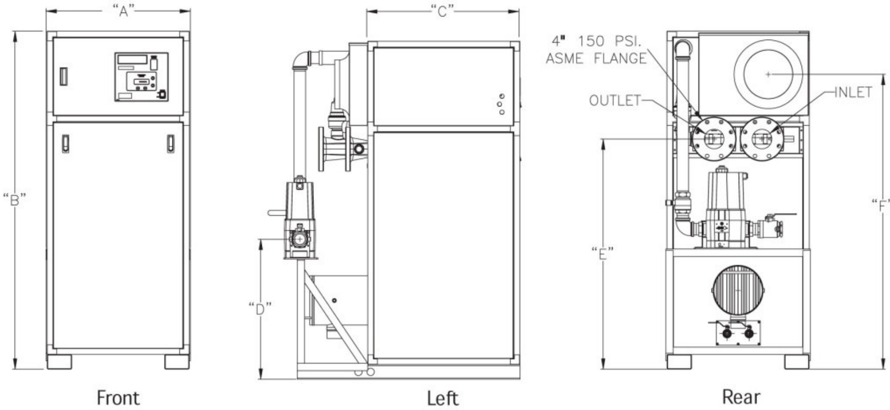
DEPENDABLE, EFFICIENT PERFORMANCE

- High efficiency, up to 88%
- Full modulation with smooth, 5:1 turndown
- Sealed combustion/direct vent
- Symmetrically air/fuel coupled
- Commercial-quality combustion controls
- Linked operating control system for multiple unit applications
- Gasketless heat exchanger assembly
- Low NOx

FUTERA XLF

Dimensions & Ratings

NOTE: Dimensions are approximate and should not be used to "rough-in" equipment.



Model	A In.	A cm	B In.	B cm	C In.	C cm	D In.	D cm	E In.	E cm	F In.	F cm
3000	29 1/2	*74.9*	60	*152.4*	31 1/8	*79.1*	19 5/8	*49.9*	37 15/16	*96.4*	51 1/8	*129.9*
4000	29 1/2	*74.9*	69	*175.3*	31 1/8	*79.1*	28 5/8	*72.7*	46 15/16	*119.2*	60 1/8	*152.7*

MB/MW 3000

Dimensions & Ratings

Input (MBH / *kW*)	3000 / *879*
Output (MBH / *kW*)	2610 / *765*
Flue Vent	8"
Air Intake	8"
Gas Connection	2"
Water Connection	4"
Weight (Lbs / *Kg*)	1023 / *464*

Hourly Recovery Capacity ΔT (GPH & *LPG*)

40° F	7833	*22° C*	*29652*
60° F	5222	*33° C*	*19768*
80° F	3917	*44° C*	*14826*
100° F	3133	*56° C*	*11861*
120° F	2611	*67° C*	*9884*
140° F	2238	*78° C*	*8472*

Temperature Rise / Pressure Drop

20° F / *11.1° C*	
Flow Rate (GPM / *L/s*)	261.0 / *16.5*
Pressure Drop (Ft / *kPa*)	15.20 / *44.7*
25° F / *13.9 C*	
Flow Rate (GPM / *L/s*)	208.8 / *13.2*
Pressure Drop (Ft / *kPa*)	9.73 / *28.7*
30° F / *16.7° C*	
Flow Rate (GPM / *L/s*)	174.0 / *11.0*
Pressure Drop (Ft / *kPa*)	6.75 / *19.9*
35° F / *19.4 C*	
Flow Rate (GPM / *L/s*)	149.1 / *9.4*
Pressure Drop (Ft / *kPa*)	2.80 / *14.6*

MB/MW 4000

Dimensions & Ratings

Input (MBH / *kW*)	4000 / *1172*
Output (MBH / *kW*)	3480 / *1020*
Flue Vent	10"
Air Intake	10"
Gas Connection	2"
Water Connection	4"
Weight (Lbs / *Kg*)	1223 / *555*

Hourly Recovery Capacity ΔT (GPH & *LPG*)

40° F	10444	*22° C*	*39536*
60° F	6963	*33° C*	*26357*
80° F	5222	*44° C*	*19768*
100° F	4178	*56° C*	*15814*
120° F	3481	*67° C*	*13179*
140° F	2984	*78° C*	*11296*

*Flow exceeds recommended maximum; use a greater temperature rise or consult manufacturer. Cupronickel heat exchanger should be considered.

Temperature Rise / Pressure Drop

20° F / *11.1° C*	
Flow Rate (GPM / *L/s*)	348.0* / *22.0*
Pressure Drop (Ft / *kPa*)	27.00 / *79.5*
25° F / *13.9 C*	
Flow Rate (GPM / *L/s*)	278.4 / *17.6*
Pressure Drop (Ft / *kPa*)	17.30 / *51.0*
30° F / *16.7° C*	
Flow Rate (GPM / *L/s*)	232.0 / *14.6*
Pressure Drop (Ft / *kPa*)	12.00 / *35.4*
35° F / *19.4 C*	
Flow Rate (GPM / *L/s*)	198.9 / *12.5*
Pressure Drop (Ft / *kPa*)	8.80 / *25.9*

RBI® 7555 Tranmere Dr., Mississauga, Ontario L5S 1L4 | Tel. 905-670-5888 | Fax 905-670-5782
260 North Elm Street, Westfield, MA 01085 | Tel. 413-568-9571 | Fax 413-568-9613 www.rbiwaterheaters.com
RBI is a division of Mestek, a leader in commercial and residential HVAC technologies
MESTEK, INC.

Electrical Rates: Nevada Power

Electric Consumption (Total), per kWh:
Summer on–peak.......... $ 0.10296
Summer mid–peak......... $ 0.08911
Summer off–peak.......... $ 0.06230
All other periods .... $ 0.06543
Deferred Energy Accounting Adjustment:
All kWh, per kWh .... $ 0.00000
Temp. Green Power Financing (TRED):
All kWh, per kWh........... $ 0.00054
Renewable Energy Program (REPR):
All kWh, per kWh........... $ 0.00071

Primary Service Rates:
Basic Service Charge:
per meter.................. $254.60
Facilities Charge, per kW ..... $ 2.84
Demand Charge, per kW
Summer on–peak.......... $ 9.17
Summer mid–peak......... $ 0.68
Summer off–peak.......... $ 0.00
All other periods .... $ 0.50
Electric Consumption (Total), per kWh:
Summer on–peak.......... $ 0.10001
Summer mid–peak......... $ 0.08653
Summer off–peak.......... $ 0.06230
All other periods .... $ 0.06406
Deferred Energy Accounting Adjustment:
All kWh, per kWh .... $ 0.00000
Temp. Green Power Financing (TRED):
All kWh, per kWh........... $ 0.00054
Renewable Energy Program (REPR):
All kWh, per kWh........... $ 0.00071

Transmission Service Rates:
Basic Service Charge:
per meter.................. $265.90
Facilities Charge, per kW ..... $ 0.44
Demand Charge, per kW
Summer on–peak.......... $ 7.50

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Summer mid–peak......... $ 0.55
Summer off–peak.......... $ 0.00
All other periods .... $ 0.40
Electric Consumption (Total), per kWh:
Summer on–peak.......... $ 0.09116
Summer mid–peak......... $ 0.07926
Summer off–peak.......... $ 0.06231
All other periods .... $ 0.06347
Deferred Energy Accounting Adjustment:
All kWh, per kWh .... $ 0.00000
Temp. Green Power Financing (TRED):
All kWh, per kWh........... $ 0.00054
Renewable Energy Program (REPR):
All kWh, per kWh........... $ 0.00071

Time–of–Use Periods for LGS–2 and LGS–3:
- Summer on–peak is June 1– September 30, from 1:00 p.m. to 7:00 p.m. daily.
- Summer mid–peak is June 1– September 30, from 10:00 a.m. to 1:00 p.m. and 7:00 p.m. to 10:00 p.m. daily.
- Summer off–peak is June 1– September 30, from 10:00 p.m. to 10:00 a.m. daily.
- Winter is all other hours, from October through May.

GENERAL SERVICE – PRIVATE AREA LIGHTING (GS–PAL)
General Service – Private Area Lighting is available to non–residential customers requesting private area lighting in conjunction with non–residential service.
Existing Poles:
Mercury Vapor
(Not available to new customers)
175 watt, per month .... $ 9.75
400 watt, per month .... $ 15.58
High Pressure Sodium
100 watt, per month .... $ 7.86

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200 watt, per month .... $ 10.38
400 watt, per month .... $ 15.53
Thirty–foot Pole
(New pole installations are not available):
Mercury Vapor
(Not available to new customers)
175 watt, per month .... $ 14.56
400 watt, per month .... $ 21.04
High Pressure Sodium
100 watt, per month .... $ 12.69
200 watt, per month .... $ 15.22

POWER FACTOR ADJUSTMENT (LGS-1, OLGS-1-TOU, LGS-2, LGS-3)
Charged at the rate of $.0010 per kVARh for all actual kVARh greater than equivalent kVARh at 90% power level for the Winter months (October - May) and at a rate of $.0020 per KVARh for all actual KVARh greater than equivalent KVARh at 90% power for the Summer months (June - September).

MISCELLANEOUS CHARGES (MC)
Reconnection charge .... $ 20.00
Other customer–
requested visits .... $ 15.00
Same day service .... $ 3.00
Late charge for
past due amounts........... 1.5%/month
Returned check charge .... $ 12.00
Remote meter charge......... $ 50.00
Additional meter test charge. . $ 10.00
Broken seal charge........... $ 5.00
Padlock-only charge .... $ 7.00

Bill Payment Options
Credit/Debit ATM Card Fee.... $ 4.95

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NVEnergy
nvenergy.com

10

nve-s_100M_10/08

Commercial electric RATES
October 1, 2008

Nevada Power dba
NV Energy
Electric Rate Schedules for Commercial Customers

The Public Utilities Commission of Nevada (PUCN) recently authorized changes to certain components of electric rates. These changes became effective on October 1, 2008.

NV Energy's rates shown here are in addition to any business license, franchise taxes or taxes based upon revenue or quantity of energy sold. These taxes are imposed upon the utility by the local governments within our service territory.

The Renewable Energy Program (REPR) is $0.00071 per kWh and is a charge combining costs for the new Wind Demonstration Program of $0.00017 per kWh, the Waterpower Demonstration Program of $0.00001 per kWh and the Solar Program of $0.00053 per kWh, which was formerly recovered through the company's Deferred Energy Accounting Adjustment (DEAA) rate. Although the Renewable rates were approved as of October 1, they will not begin billing until November 1, 2008.

In addition, the Customer will also be billed for the Universal Energy Charge of $0.00039 per kWh of usage with monies going to the State of Nevada fund for energy assistance and conservation as set forth in NRS 702.010 to 702.282.

The rates contained in this schedule are for bundled rates. Bundled rates are the combination of all the services necessary (generation, transmission and distribution) to deliver reliable electric power to retail end–use customers. Distribution Only Service is available to certain eligible customers who meet the provisions set forth in chapter 704B of the Nevada Administrative Code.

To view Electric Tariffs online, visit the NV Energy website at: nvenergy.com

GENERAL SERVICE (GS)
General Service is available to non–residential customers where consumption of energy does not exceed 3,500 kWh in any billing period.

Basic Service Charge:
per meter .... $ 22.70
Electric Consumption (Total):
All kWh, per kWh........... $ 0.08328
Deferred Energy Accounting Adjustment:
All kWh, per kWh........... $ 0.00000
Temp. Green Power Financing (TRED):
All kWh, per kWh........... $ 0.00054
Renewable Energy Program (REPR):
All kWh, per kWh........... $ 0.00071

2

LARGE GENERAL SERVICE–1 (LGS–1)
Large General Service–1 is available to non–residential customers whose consumption of energy exceeds 3,500 kWh and where billing demand does not exceed 299 kW in any billing period.

Basic Service Charge:
per meter.................. $ 18.00
Facilities Charge, per kW ..... $ 3.54
Demand Charge, per kW ..... $ 2.00
Electric Consumption (Total):
All kWh, per kWh .... $ 0.07879
Deferred Energy Accounting Adjustment:
All kWh, per kWh .... $ 0.00000
Temp. Green Power Financing (TRED):
All kWh, per kWh........... $ 0.00054
Renewable Energy Program (REPR):
All kWh, per kWh........... $ 0.00071

OPTIONAL GENERAL SERVICE, TIME–OF–USE (OGS–TOU)
Optional General Service, Time–of–Use is available to customers billed under Schedule GS who have requested Time–of–Use rates. Certain restrictions apply.

Basic Service Charge:
per meter.................. $ 24.00
Electric Consumption (Total), per kWh:
Summer on–peak.......... $ 0.20110
Summer off–peak.......... $ 0.06862
All other periods .... $ 0.06836
Deferred Energy Accounting Adjustment:
All kWh, per kWh........... $ 0.00000
Temp. Green Power Financing (TRED):
All kWh, per kWh........... $ 0.00054
Renewable Energy Program (REPR):
All kWh, per kWh........... $ 0.00071

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OPTIONAL LARGE GENERAL SERVICE–1, TIME OF USE (OLGS–1–TOU)
Optional Large General Service–1, Time–of Use is available to customers billed under Schedule LGS–1 who have requested Time–of–Use rates. Certain restrictions apply.

Basic Service Charge:
per meter.................. $ 20.46
Facilities Charge, per kW ..... $ 3.54
Demand Charge, per kW
Summer on–peak.......... $ 5.00
Summer off–peak.......... $ 0.00
All other periods .... $ 0.10
Electric Consumption (Total), per kWh:
Summer on–peak.......... $ 0.15339
Summer off–peak.......... $ 0.07391
All other periods .... $ 0.06732
Deferred Energy Accounting Adjustment:
All kWh, per kWh .... $ 0.00000
Temp. Green Power Financing (TRED):
All kWh, per kWh........... $ 0.00054
Renewable Energy Program (REPR):
All kWh, per kWh........... $ 0.00071

Time–of–Use Periods:

- Summer on–peak is June 1 – September 30, from 1:00 p.m. to 7:00 p.m. daily.
- Summer off–peak is June 1 – September 30, from 7:00 p.m. to 1:00 p.m. daily.
- Winter is all other hours, from October through May.

LARGE GENERAL SERVICE–2 (LGS–2)
Large General Service–2 is available to non–residential customers where consumption of energy exceeds 3,500 kWh and demand is 300 kW up to 999 kW in any billing period.

Secondary Service Rates:

4

Basic Service Charge:
per meter.................. $162.80
Facilities Charge, per kW ..... $ 2.85
Demand Charge, per kW
Summer on–peak.......... $ 7.23
Summer mid–peak......... $ 0.53
Summer off–peak.......... $ 0.00
All other periods .... $ 0.25
Electric Consumption (Total), per kWh:
Summer on–peak.......... $ 0.10731
Summer mid–peak......... $ 0.09292
Summer off–peak.......... $ 0.06267
All other periods .... $ 0.06755
Deferred Energy Accounting Adjustment:
All kWh, per kWh .... $ 0.00000
Temp. Green Power Financing (TRED):
All kWh, per kWh........... $ 0.00054
Renewable Energy Program (REPR):
All kWh, per kWh........... $ 0.00071

Primary Service Rates:
Basic Service Charge:
per meter.................. $255.80
Facilities Charge, per kW ..... $ 2.30
Demand Charge, per kW
Summer on–peak.......... $ 7.75
Summer mid–peak......... $ 0.53
Summer off–peak.......... $ 0.00
All other periods .... $ 0.24
Electric Consumption (Total), per kWh:
Summer on–peak.......... $ 0.09946
Summer mid–peak......... $ 0.08587
Summer off–peak.......... $ 0.06222
All other periods .... $ 0.06395
Deferred Energy Accounting Adjustment:
All kWh, per kWh .... $ 0.00000
Temp. Green Power Financing (TRED):
All kWh, per kWh........... $ 0.00054

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Renewable Energy Program (REPR):
All kWh, per kWh........... $ 0.00071

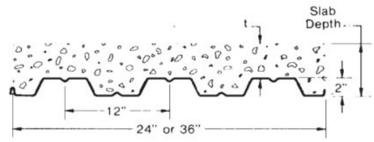
Transmission Service Rates:
Basic Service Charge:
per meter.................. $267.10
Facilities Charge, per kW ..... $ 0.44
Demand Charge, per kW
Summer on–peak.......... $ 7.75
Summer mid–peak......... $ 0.53
Summer off–peak.......... $ 0.00
All other periods .... $ 0.24
Electric Consumption (Total), per kWh:
Summer on–peak.......... $ 0.09576
Summer mid–peak......... $ 0.08304
Summer off–peak.......... $ 0.06222
All other periods .... $ 0.06273
Deferred Energy Accounting Adjustment:
All kWh, per kWh .... $ 0.00000
Temp. Green Power Financing (TRED):
All kWh, per kWh........... $ 0.00054
Renewable Energy Program (REPR):
All kWh, per kWh........... $ 0.00071

LARGE GENERAL SERVICE–3 (LGS–3)
Large General Service–3 is available to non–residential customers where consumption of energy exceeds 3,500 kWh and demand is 1,000 kW or greater in any billing period.

Secondary Service Rates:
Basic Service Charge:
per meter.................. $167.70
Facilities Charge, per kW ..... $ 2.91
Demand Charge, per kW
Summer on–peak.......... $ 8.40
Summer mid–peak......... $ 0.63
Summer off–peak.......... $ 0.00
All other periods .... $ 0.50

6

VULCRAFT



2 C CONFORM

MAXIMUM CONSTRUCTION CLEAR SPANS (S.D.I. CRITERIA)

NON-COMPOSITE

Total Slab Depth	Deck Type	Weight PSF	NW Concrete N=9 145 PCF 1 Span	2 Span	3 Span	Weight PSF	LW Concrete N=14 110 PCF 1 Span	2 Span	3 Span
4 1/2" (t=2 1/2")	2C22	44	5- 7	7- 4	7- 8	34	6- 2	8- 3	8- 4
	2C20	45	6- 7	8- 9	9- 0	34	7- 3	9- 7	9- 11
	2C18	45	8- 2	10- 4	10- 8	35	9- 0	11- 3	11- 7
	2C16	46	9- 3	11- 6	11- 11	36	10- 3	12- 6	12- 11
5" (t=3")	2C22	50	5- 4	6- 9	7- 1	39	5- 11	7- 11	8- 0
	2C20	51	6- 3	8- 5	8- 7	39	6- 11	9- 2	9- 6
	2C18	51	7- 9	9- 10	10- 2	40	8- 7	10- 9	11- 2
	2C16	52	8- 10	11- 0	11- 4	40	9- 9	12- 0	12- 5
5 1/2" (t=3 1/2")	2C22	56	5- 2	6- 2	6- 6	43	5- 8	7- 6	7- 8
	2C20	57	6- 0	8- 1	8- 3	43	6- 8	8- 10	9- 1
	2C18	57	7- 5	9- 6	9- 9	44	8- 3	10- 5	10- 9
	2C16	58	8- 5	10- 7	10- 11	45	9- 4	11- 7	12- 0
6" (t=4")	2C22	62	4- 10	5- 9	6- 1	48	5- 6	7- 0	7- 4
	2C20	63	5- 9	7- 9	7- 11	48	6- 5	8- 7	8- 9
	2C18	63	7- 1	9- 1	9- 5	49	7- 11	10- 1	10- 5
	2C16	64	8- 1	10- 2	10- 6	49	9- 0	11- 2	11- 7
6 1/2" (t=4 1/2")	2C22	68	4- 6	5- 4	5- 8	52	5- 3	6- 7	6- 11
	2C20	69	5- 7	7- 6	7- 8	53	6- 2	8- 3	8- 6
	2C18	69	6- 10	8- 10	9- 1	53	7- 7	9- 9	10- 1
	2C16	70	7- 9	9- 10	10- 2	54	8- 8	10- 10	11- 3
7" (t=5")	2C22	74	4- 3	5- 0	5- 3	57	5- 1	6- 2	6- 6
	2C20	75	5- 5	7- 2	7- 2	57	6- 0	8- 0	8- 3
	2C18	75	6- 7	8- 6	8- 10	58	7- 4	9- 5	9- 9
	2C16	76	7- 6	9- 6	9- 10	59	8- 5	10- 6	10- 11

REINFORCED CONCRETE SLAB ALLOWABLE LOADS

Total Slab Depth	Reinforcement W.W.F.	As	Superimposed Uniform Load (psf) — 3 Span Condition; Clear Span (ft.-in.) 5- 0	5- 6	6- 0	6- 6	7- 0	7- 6	8- 0	8- 6	9- 0	9- 6	10- 0
4 1/2" (t=2 1/2")	6X6-W2.1XW2.1	0.042*	84	69									
	6X6-W2.9XW2.9	0.058	114	94									
	4X4-W2.9XW2.9	0.087	167	138									
5" (t=3")	6X6-W2.1XW2.1	0.042*	**153**	**127**	**107**	**91**	**78**						
	6X6-W2.9XW2.9	0.058*	**206**	**170**	**143**	**122**	**105**						
	4X4-W2.9XW2.9	0.087	**305**	**252**	**212**	**180**	**155**						
5 1/2" (t=3 1/2")	6X6-W2.9XW2.9	0.058*	**255**	**211**	**177**	**151**	**130**	**113**	**100**				
	4X4-W2.9XW2.9	0.087	**378**	**313**	**263**	**224**	**193**	**168**	**148**				
	4X4-W4.0XW4.0	0.120	**400**	**400**	**351**	**299**	**258**	**224**	**197**				
6" (t=4")	6X6-W2.9XW2.9	0.058*	**304**	**251**	**211**	**180**	**155**	**135**	**119**	**105**	**94**		
	4X4-W2.9XW2.9	0.087	**400**	**374**	**314**	**267**	**231**	**201**	**177**	**156**	**140**		
	4X4-W4.0XW4.0	0.120	**400**	**400**	**400**	**359**	**309**	**270**	**237**	**210**	**187**		
6 1/2" (t=4 1/2")	6X6-W2.9XW2.9	0.058*	**353**	**292**	**245**	**209**	**180**	**157**	**138**	**122**	**109**	**98**	**88**
	4X4-W2.9XW2.9	0.087*	**400**	**400**	**365**	**311**	**268**	**234**	**205**	**182**	**162**	**146**	**131**
	4X4-W4.0XW4.0	0.120	**400**	**400**	**400**	**400**	**361**	**315**	**277**	**245**	**219**	**196**	**177**
7" (t=5")	4X4-W2.9XW2.9	0.087*	**400**	**400**	**400**	**355**	**306**	**266**	**234**	**207**	**185**	**166**	**150**
	4X4-W4.0XW4.0	0.120	**400**	**400**	**400**	**400**	**400**	**360**	**316**	**280**	**250**	**224**	**202**
	4X4-W5.0XW5.0	0.150	**400**	**400**	**400**	**400**	**400**	**400**	**389**	**344**	**307**	**276**	**249**
2C22				2C20				2C18			2C16		

NOTES:
1. * As does not meet A.C.I. criterion for temperature and shrinkage.
2. Recommended conform types are based upon S.D.I. criteria and normal weight concrete.
3. Superimposed loads are based upon three span conditions and A.C.I. moment coefficients.
4. Load values for single span and double spans are to be reduced.
5. Superimposed load values in bold type require that mesh be draped. See page 19.
6. Vulcraft's painted or galvanized form deck can be considered as permanent support in most building applications. See page 19.
If uncoated form deck is used, deduct the weight of the slab from the allowable superimposed uniform loads.

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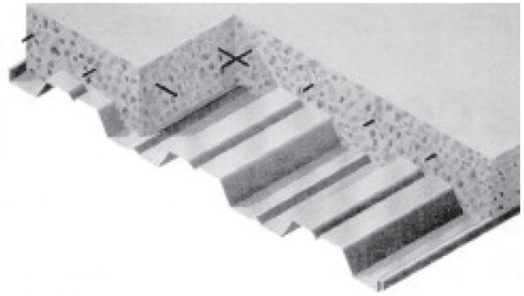

SECTION PROPERTIES

Deck Type	Design Thick.	Weight PSF	Ip in^4/ft	In in^4/ft	Sp in^3/ft	Sn in^3/ft	Fy ksi
2C22	0.0295	1.62	0.338	0.336	0.283	0.287	33
2C20	0.0358	1.97	0.423	0.420	0.367	0.373	33
2C18	0.0474	2.61	0.557	0.557	0.520	0.520	33
2C16	0.0598	3.29	0.704	0.704	0.653	0.653	33

ALLOWABLE UNIFORM LOAD (PSF)

NON-COMPOSITE

Deck Type	No. of Spans	Design Criteria	Clear Span (ft.-in.) 5- 0	5- 6	6- 0	6- 6	7- 0	7- 6	8- 0	8- 6	9- 0	9- 6	10- 0	10- 6	11- 0
2C22	1	Fb = 20,000	151	125	105	89	77	67	59	52	47	42	38	34	31
		DEFL. = l/240	151	125	103	81	65	53	43	36	30	26	22	19	17
		DEFL. = l/180	151	125	105	89	77	67	58	48	41	34	30	26	22
		W1[1]	60	47	37	29	23	18	14	11	9	7	5	4	3
	2	Fb = 20,000	153	127	106	91	78	68	60	53	47	42	38	35	32
		DEFL. = l/240	153	127	106	91	78	68	60	53	47	42	38	35	32
		DEFL. = l/180	153	127	106	91	78	68	60	53	47	42	38	35	32
		W1[1]	75	66	59	53	48	43	37	31	25	21	17	14	12
	3	Fb = 20,000	191	158	133	113	98	85	75	66	59	53	48	43	40
		DEFL. = l/240	191	158	133	113	98	85	75	66	57	49	42	36	31
		DEFL. = l/180	191	158	133	113	98	85	75	66	59	53	48	43	40
		W1[1]	80	71	63	57	51	46	39	32	26	22	18	15	12
2C20	1	Fb = 20,000	196	162	136	116	100	87	76	68	60	54	49	44	40
		DEFL. = l/240	196	162	128	101	81	66	54	45	38	32	28	24	21
		DEFL. = l/180	196	162	136	116	100	87	72	60	51	43	37	32	28
		W1[1]	89	71	57	46	38	31	26	22	18	15	13	11	9
	2	Fb = 20,000	199	164	138	118	101	88	78	69	61	55	50	45	41
		DEFL. = l/240	199	164	138	118	101	88	78	69	61	55	50	45	41
		DEFL. = l/180	199	164	138	118	101	88	78	69	61	55	50	45	41
		W1[1]	118	105	95	86	78	68	58	49	41	35	30	25	21
	3	Fb = 20,000	249	206	173	147	127	111	97	86	77	69	62	56	51
		DEFL. = l/240	249	206	173	147	127	111	97	85	72	61	52	45	39
		DEFL. = l/180	249	206	173	147	127	111	97	86	77	69	62	56	51
		W1[1]	116	104	93	85	77	71	62	53	45	39	33	28	24
2C18	1	Fb = 20,000	277	229	193	164	141	123	108	96	86	77	69	63	57
		DEFL. = l/240	277	219	169	133	106	87	71	59	50	43	37	32	27
		DEFL. = l/180	277	229	193	164	141	115	95	79	67	57	49	42	37
		W1[1]	145	116	95	79	66	56	47	40	35	30	26	23	20
	2	Fb = 20,000	277	229	193	164	141	123	108	96	86	77	69	63	57
		DEFL. = l/240	277	229	193	164	141	123	108	96	86	77	69	63	57
		DEFL. = l/180	277	229	193	164	141	123	108	96	86	77	69	63	57
		W1[1]	211	190	173	144	121	103	88	76	66	57	49	43	37
	3	Fb = 20,000	347	287	241	205	177	154	135	120	107	96	87	79	72
		DEFL. = l/240	347	287	241	205	177	154	135	112	95	80	69	60	52
		DEFL. = l/180	347	287	241	205	177	154	135	120	107	96	87	79	69
		W1[1]	229	206	186	155	131	112	96	83	71	62	54	47	41
2C16	1	Fb = 20,000	348	288	242	206	178	155	136	121	107	96	87	79	72
		DEFL. = l/240	348	277	214	168	135	109	90	75	63	54	46	40	35
		DEFL. = l/180	348	288	242	206	178	146	120	100	84	72	62	53	46
		W1[1]	192	156	128	107	90	77	66	57	49	43	38	34	30
	2	Fb = 20,000	348	288	242	206	178	155	136	121	107	96	87	79	72
		DEFL. = l/240	348	288	242	206	178	155	136	121	107	96	87	79	72
		DEFL. = l/180	348	288	242	206	178	155	136	121	107	96	87	79	72
		W1[1]	328	268	222	186	158	135	116	101	87	76	67	59	52
	3	Fb = 20,000	435	360	302	258	222	193	170	151	134	121	109	99	90
		DEFL. = l/240	435	360	302	258	222	193	170	142	119	102	87	75	65
		DEFL. = l/180	435	360	302	258	222	193	170	151	134	121	109	99	87
		W1[1]	352	288	238	200	170	145	125	109	95	83	73	64	57

[1] W1 is the maximum weight of concrete and deck (W1 in Figure 1 of the SDI Loading Diagrams).
Minimum exterior bearing length required is 2.0 inches. Minimum interior bearing length required is 4.0 inches.