VIRGINIA INSTITUTE OF MARINE SCIENCE

SEAWATER RESEARCH LABORATORY

GLOUCESTER POINT, VA

DANIEL DICRISCIO

AE SENIOR THESIS

MECHANICAL OPTION

2007

www.arche.psu.edu/thesis/eportfolio/2007/portfolios/dsd149

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11.0 Appendices

1.0 EXECUTIVE SUMMARY

This report is an analysis on the feasibility of changing the energy source for the VIMS Seawater Research Laboratory with the results projected toward another analysis of the feasibility of a cogeneration system being applied to the entire VIMS campus. The Seawater Research Laboratory is a very energy dense building with most of the energy being consumed by the aquaculture processes that occur within the building.

The main purpose of this thesis is to identify the effects of switching the building's energy source from a grid fed building to a gas turbine powered building with a heat recovery system that utilizes the waste heat in the exhaust of the combustion process. This feature causes for a change of the building's heating and cooling sources. The existing electric chillers and propane fired boilers get replaced with absorption chillers which use less electricity than the original equipment but also have a lower efficiency. Absorption chillers require higher flow rates, which requires larger pumps and they also require the use of cooling towers. The Seawater Research Laboratory wasn't originally designed with cooling towers and a condenser water loop. This was the biggest change to the system which means more equipment to be placed on site.

The first cost of a cogeneration system is the biggest disadvantage associated with the system. This high first cost requires a life cycle cost analysis, which determines if the energy savings is enough for a reasonable pay back period.

William & Mary
Virginia Institute of Marine Science
Gloucester Point, VA

Structural:

Live loads: 300 psf
Wind lateral loads: 23.8 psf
Foundation: shallow spread concrete footings
Steel structure with W-shape and Hollow Steel Section columns

Mechanical:

Outdoor Design Conditions Summer: 92 FDB 72 FWB
Winter: 14 FDB
One AHU supplying heating and cooling to office and dry lab
One AHU supplying heating and cooling to BSL 3 lab
Both AHU's supply 100% outdoor air
Ducted supply and exhaust
Cooling source is two 105 ton chillers
Heating source is two propane fired boilers supplying 1760 MBTUH each

Architecture:

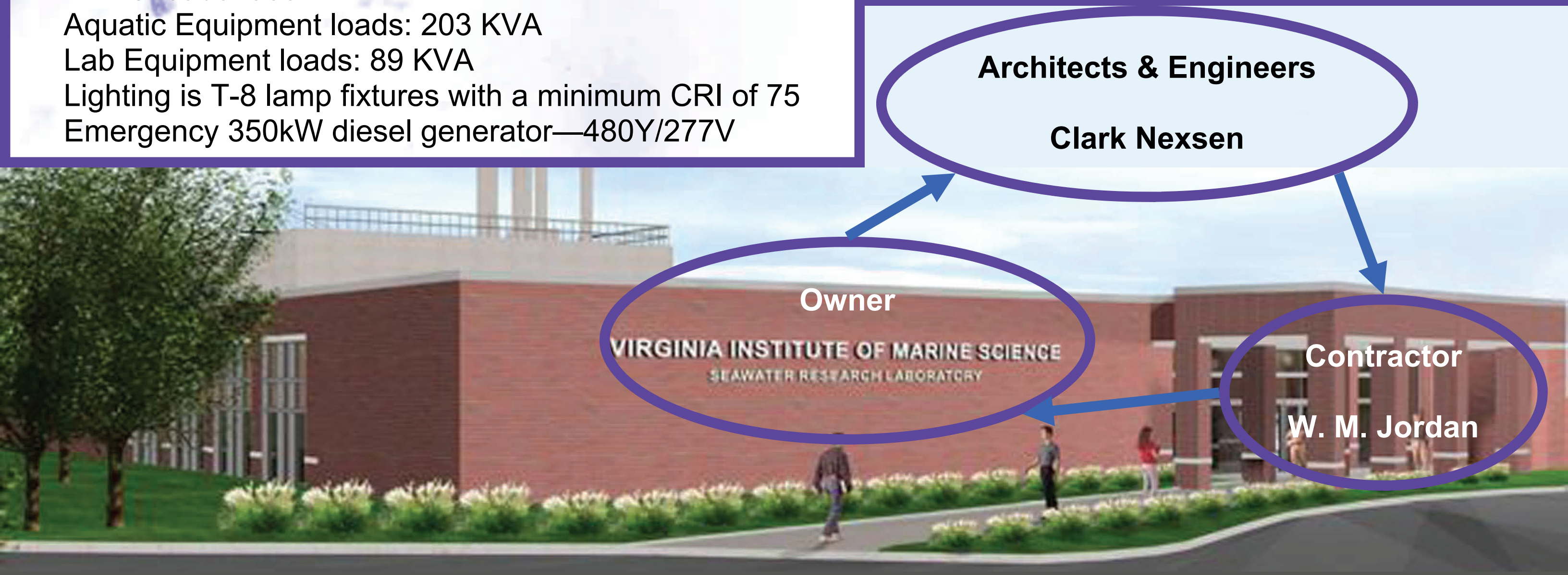
Face brick facade
1 Story (31 ft.) tall
44580 sq. ft.
Flat 4-ply built-up roofing
Precast concrete parapet cap

Electrical:

Main Switchboard 2000 Amps
10 480Y/277 V 3 phase 4 wire panel boards
Nine dry type transformers serving the 208Y/120 V loads
Lighting load: 43 KVA
Receptacle loads: 129 KVA
HVAC loads: 959 KVA
Aquatic Equipment loads: 203 KVA
Lab Equipment loads: 89 KVA
Lighting is T-8 lamp fixtures with a minimum CRI of 75
Emergency 350kW diesel generator—480Y/277V

Construction Management:

Building Cost: $6.5 million
All utilities existing except natural gas
Site demolition of four existing buildings
Delivery: Design-Bid-Build


Architects & Engineers

Clark Nexsen

Owner

Contractor

W. M. Jordan

Daniel DiCriscio
Mechanical
http://www.arche.psu.edu/thesis/eportfolio/2007/portfolios/DSD149

2.2 BUILDING STATISTICS

Building Name: VIMS Seawater Research Laboratory

Location: Virginia Institute of Marine Science, Gloucester Point, VA (coastal area)

Building Occupant: Virginia Institute of Marine Science

Occupancy Type: Laboratory

Building Size: 44580 sq. ft.

Number of Stories: 1 story (15 ft.)

Project Team:

Owner: Virginia Institute or Marine Science – Ron – Herzick – Project Manager
www.vims.edu

Architect: Clark Nexsen – Don Hirtz
www.clarknexsen.com

Mechanical: Clark Nexsen – Mark Elder
www.clarknexsen.com

Plumbing: Clark Nexsen – Ted Morgan
www.clarknexsen.com

Fire Protection: Clark Nexsen – Steve Williams
www.clarknexsen.com

Electrical: Clark Nexsen – Fred Asher
www.clarknexsen.com

Civil: Clark Nexsen – Joe Bushey
www.clarknexsen.com

Structural: Clark Nexsen – Sterling Hoy
www.clarknexsen.com

General Contractor: W. M. Jordan
www.wmjordan.com

Mechanical Contractor: Hampton Roads Mechanical

Dates of Construction: August 2005 - February 2007

Actual Cost: $6,494,202

Project Delivery Method: Design – Bid – Build

Architectural Function:

The Seawater Research Laboratory contains a multi-purpose lab that contains holding tanks for aquatic life. Other labs include two dry labs, biosafety labs levels 1, 2, and 3, and toxicology lab, all connected to a seawater system originating at the end of a 600′ pier, which extends out into the York River. A coral reef lab is also part of this facility. An entrance suite includes offices for the building manager and an engineer, an observation area for visitors, conference room, vending and toilets.

The Water Treatment/Storage Building contains equipment for the plumbing and processing seawater for the Seawater Research Laboratory and also storage for miscellaneous items including aquatic tanks.

The Pier Equipment Building contains the water pumps that extract seawater from the York River and discharge it through pipes from the Seawater Research Laboratory Site.

Building Codes: Virginia Unified Statewide Code (VUSBC)
ASHRAE
December 20, 2006er 20, 2006; IBC

Zoning: The VUSBC use group for all three buildings is B – Business

Building Envelope/Roofing:

The exterior walls are face brick with painted block on the interior and rigid insulation within the cavity. The parapet is capped with precast concrete. Accent panels, overhead, and personnel doors are prefinished galvanized metal.

The roof is four-ply, built-up roofing and is placed over rigid insulation and supported by galvanized metal decking.

Structure:

The structure of the VIMS Seawater Research Laboratory is made of steel using w-shapes and hollow steel sections for columns. The columns are supported by shallow spread concrete footings. The structure was designed to support a live load of 300 psf and a wind load of 23.8 psf.

Mechanical Systems:

The ventilation system utilizes two air handling units and four make-up air units. All of which supply 100% outdoor air to all of the buildings spaces. The cooling source for the building are two 105 ton screw compressor chillers. The heating source for the building are two propane gas fired modular boilers, each supplying 1760 MBtuH. All ductwork is stainless steel or epoxy coated steel to protect against corrosion.

Electrical Systems:

The VIMS Seawater Research Laboratory uses a 2000A main switchboard that distributes power to ten 480Y/277 three phase, four wire panel boards and nine dry type transformers that serve the 208Y120 loads. Some of the building loads are as follows: 43 kVA lighting load, 129 kVA receptacle load, 959 kVA HVAC load, 203 kVA aquatic equipment load, and 89 kVA lab equipment load.

3.0 EXISTING CONDITIONS

3.1 Design Requirements

The primary factor in the design of the building is that the administration spaces within the building must be able to be converted to laboratory spaces. This is to be done without renovations to the building systems, making it necessary to provide 100% outdoor air to all spaces within the building (including all administration spaces).

The environmental sensitive nature of the VIMS mission and existing site characteristics are the reason for the on site propane storage. Given the topography of the site any oil spill or leak on the facility could drain directly into the York River. The fuel storage is located in the equipment yard between the Seawater Research Laboratory and the Water Treatment Building consisting of five 2000 gallon above ground propane tanks that sit on concrete saddles. After talking to the Amerigas propane utility it is possible to get a propane or natural gas utility connection for a demand as large as the proposed CHP system.

3.2 Energy Sources

The source of energy for the Seawater Research Laboratory is a 2000 Amp 3 phase, 4 wire, wye 277/480 V service connection. This is a large electrical load for a building of this size. Also, there is a 300 kW emergency diesel generator that has a fuel storage supply to last 72 hours.

Two focuses of this thesis is reducing emissions generated by this building and to investigate the feasibility of a district CHP system for the campus where the building is located.

4.0 EXISTING MECHANICAL CONDITIONS

4.1 Outdoor Design Conditions

The outdoor weather data was taken from The ASHRAE 2005 Fundamentals Handbook. The location for the data used is Norfolk, VA and the data is as follows.

Summer: 91°FDB
76°FDB

Winter: 20°FDB

4.2 Indoor Design Conditions

The indoor design conditions were divided into six different space conditions based on the space use.

Offices:
Summer: 78FDB
Winter: 70FDB
Ventilation: 20cfm/person
Load Density:4watts/ft^2

Laboratory Spaces:
Summer: 75FDB
Winter: 70FDB
Ventilation: 20cfm/person
Load Density:8watts/ft^2

Open Bay Research Labs:
Summer: 90FDB
Winter: 65FDB
Ventilation: 1.8cfm/ft^2
Load Density: 4watts/ft^2

Mech./Elec. Rooms:
Summer: 90FDB
Winter: 55FDB
Ventilation: To limit temp. rise to 18°
Load Density: 1watt/ft^2

Toilets:
Summer: 78FDB
Winter: 70FDB
Ventilation: 75cfm/water closet
Load Density: 1watt/ft^2

Communication Rooms:
Summer: 78FDB
Winter: 55FDB
Ventilation: .5cfm/ft^2
Load Density: Per equipment in space

4.3 Mechanical System Equipment

The mechanical system's heating plant consists of two propane fired 2000 MBTU modular boilers and the cooling plant consists of two electric centrifugal chillers with a rated minimum capacity of 105 tons. These two plants are also sized to condition seawater that is pumped from the York River to the building to be used in the aquaculture processes that occur within the building.

This thesis will look at the replacement of these two plants with two absorption chillers to handle the heating and cooling loads. They will also be able to reduce the amount of electricity that the mechanical system uses.

The mechanical system doesn't use cooling towers to cool the condenser water from the chillers, the chillers are air cooled. The mechanical system does however utilize a air to air coil closed loop heat exchanger. It takes the waste heat from the exhaust from the BSL-3 space and uses it to preheat the incoming outdoor air for AHU-1.

5.0 PROPOSED SYSTEMS

The main purpose of this thesis is to reduce the amount of energy the building uses to reduce the cost of energy associated with the building operation. Or to reduce the price paid for the energy associated with the building operation.

Reducing the amount of energy the building uses is more difficult to do given the nature of the building being that the majority of the processes that occur within the building are necessary for its function, such as lab experiments that require the chilling of seawater. So to get any significant amount of energy reduction relative to the energy use of the building would prove to be difficult.

That leaves the other option of reducing the price that is paid to operate the building. A good way to do this is to use a cogeneration system which will economically provide thermal and electrical energy to the building through one fuel source and as an added benefit (based on emissions from power generation by the local utilities and fuel source of the cogeneration system) the cogeneration system will also reduce the amount of emissions that are produced by the building or buildings.

A cogeneration system can be easily utilized in projects where that have already been started because of the little change to the building systems. For example the air side of the mechanical and distribution side of the electrical systems do not need to be changed to allow for the cogeneration system to be installed. A few equipment changes are necessary on the water side of the mechanical and supply/service side of the electrical systems to allow for a cogeneration installation.

Potential prime movers that were considered were, fuel cells, reciprocating internal combustion engines, and gas turbines. Fuel cells are very efficient and don’t generate emissions however they are high maintenance and usually have a high first cost. Reciprocating engines are good for load following and have short start up time, but generate higher emissions and are noisy. Gas turbines are good for running at 100% load continuously, produce few emissions and noise compared to a reciprocating engine.

Heat recovery is important in cogeneration systems. This is how these systems achieve such high efficiencies. The recovered heat from the exhaust gas is in the form of saturated steam that can be used to heat and cool the building through absorption chillers. The steam generated can also be moved through a steam turbine which could generate more electricity if desired. Hot water heaters can also use recovered steam to heat the domestic hot water.

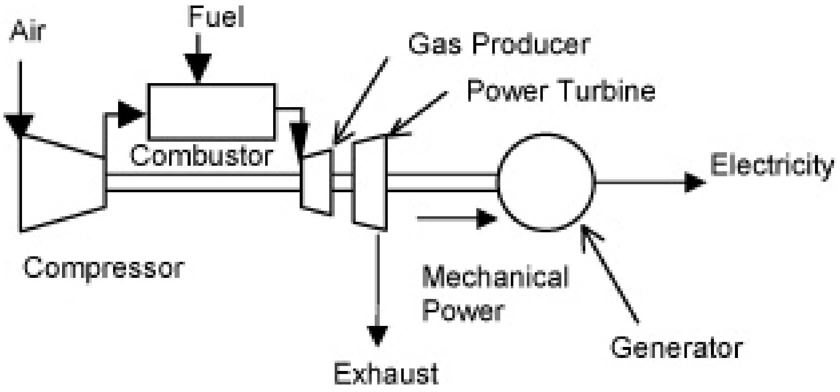
Due to the severe changes to the buildings energy supply and the building systems' energy use characteristics (cooling and heating uses recovered steam as an energy source) a life cycle cost analysis should be preformed to determine the systems feasibility.

6.0 SYSTEM REDESIGN

6.1 Gas Turbine Generators

A gas turbine consists of a compressor, combustion chamber, and expansion power turbine. The compressor increases the combustion air pressure. The combustion chamber mixes the air and fuel and combusts the mixture. As a result of the combustion process the exhaust expands through the power turbine. As the turbine rotates it turns a shaft that is connected to a generator that produces the electricity and to the compressor to bring in and pressurize air for combustion. Approximately one-third of the power produced reaches the generator. The rest is goes to the compressor or consumed by friction losses. FIGURE 1 shows a simple gas turbine schematic.

FIGURE 1



6.2 Turbine Selection

The generator system chosen is a Solar Centaur 40 Generator Set with a HRSG. The Centaur 40 Generator Set is rated at 3.515 MWe for 59°F at sea level (Standard ISO Conditions). Performance data was taken from the performance curves from the Solar catalog. These curves are based on inlet temperature to the turbine. This extrapolated data was matched with bin data from BinMaker Plus for Norfolk, VA, which is the design location for the building.

The Centaur 40 Generator Set was sized to meet the peak load of the daily load profile for the design day. This peak load is just slightly above the rated capacity of the next lowest generator set size. TABLE 1 shows the electrical loads for the Seawater Research Laboratory, these values include the electrical loads required by the new system. The Centaur 40 greatly exceeds the building load. The excess electricity that is produced will be distributed to the surrounding buildings on the VIMS campus at Gloucester Point, VA. The areas, use, and estimated electrical loads of the surrounding buildings are listed in TABLE 2 see APPENDIX A for estimation calculation of the surrounding building loads. Performance date for the Centaur 40 Generator Set can be found in APPENDIX B.

TABLE 1

Total Electrical Demand For VIMS SeaLab		
	kW	% of Total
Outlets	165.00	10.94
Lighting	88.00	5.83
Mech.	761.10	50.44
Aqua.	203.79	13.51
Emergency Equip.	91.00	6.03
Future	200.00	13.25
Total	1508.89	80% Max Use Factor
Peak Load	1207.112	

TABLE 2

Building No.	Building Name	Use	Area (ft2)	Heating Approx. (BTU)	Cooling Approx. (BTU)	Electrical Approx. (W)
B056	Watermen's Hall	Office	40330	1209900	1411550	241980
B073	Nunnally Hall	Lab	17908	716320	859584	268620
B103	Wetlands Facility	Office	1896	56880	66360	11376
B109	Chesapeake Bay Hall	Lab	64100	2564000	3076800	961500
B111	Geddings House	Dorm	2176	43520	54400	8704
B117	Wilson House (CBNERR)	Lab	4018	160720	192864	60270
B122	DCOP Facility	Office	1872	56160	65520	11232
B130	CBNERRVA Annex	Lab	5500	220000	264000	82500
Total			137800	5027500	5991078	1646182

6.3 Inlet Cooling

Inlet cooling was analyzed to determine the improved efficiencies of the system. Although the FERC efficiency actually decreases the percentage of recovered steam used increases bringing the amount of steam consumed over then minimum 5%. This qualifies the system to sell power back to the electrical utilities. An example calculation of inlet cooling is shown below. Adjusted performance data for the Centaur 40 Generator Set with inlet cooling can be found in APPENDIX C.

Design Conditions:

Q [BTU/hr] = $1.08 \times \text{cfm} \times \Delta T$ [^{o}F]

$Q = 1.08 \times 8538.64 \times (99 - 59)$

$Q = 368869.24$ BTU/hr = 30.7 tons

Using excess cooling from absorption chillers

344 tons – 300 tons = 44 tons

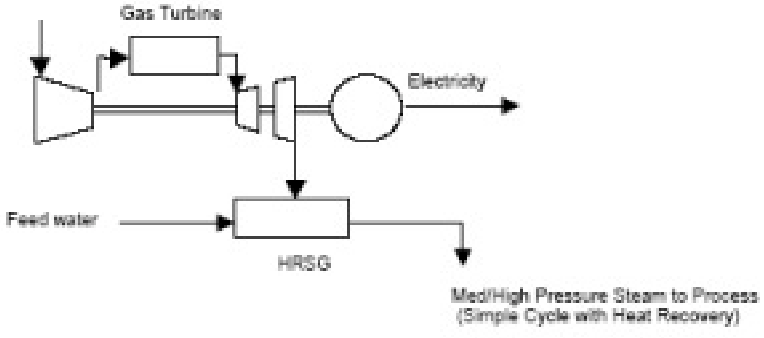
$Q = 44 \text{ tons} = 1.08 \times \{\text{cfm } f(\text{Tinlet})\} \times \Delta T$

Solve for ΔT

6.4 Heat Recovery

Heat recovery is a very important part of the cogeneration system. It is what creates the high system efficiency. The Centaur 40 Generator Set is installed with a Solar designed HRSG which generates process steam. This process steam drives two absorption chillers, a domestic unfired water heater with storage, and could potentially be injected into the turbine inlet with air when burning hydrogen as a fuel. Gas turbines are great for unfired steam generation because of the high exhaust temperatures that are associated with them. Below in FIGURE 2 a heat recovery process is shown.

FIGURE 2



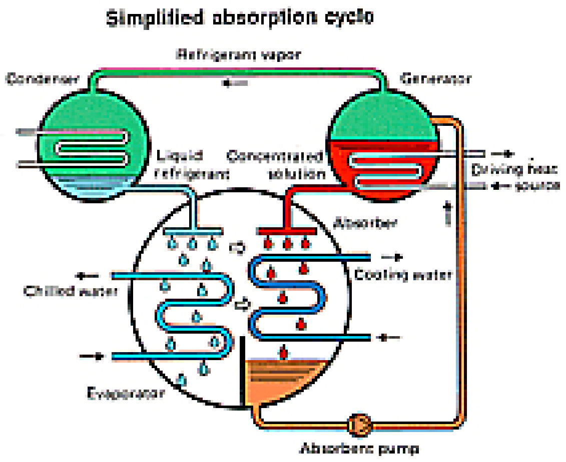
The requirement for the unfired steam generator is 150 psia dry, saturated steam. This requirement is driven by the minimum steam inputs for the absorption chillers and hot water heater.

Solar also offers a HRSG that utilizes supplementary firing which could increase steam production compared to an unfired HRSG. Supplementary firing uses the available excess oxygen in the turbine air flow which is consumed by the burning supplementary fuel. This option is not necessary because the amount of steam that is generated by the unfired HRSG exceeds the amount of steam that is used by the mechanical system. The heat recovery calculations for the Centaur 40 Generator Set can be found in APPENDIX D.

6.5 Absorption Chiller

Absorption chillers reduce the required amount of electrical power that is required by the existing centrifugal chillers. Absorption chillers also allow for the year round use of the waste heat in the exhaust gas leaving the turbine. Reduced emissions, vibrations, allowance for lower pressure systems, and low maintenance are the added benefits of using absorption chillers. See FIGURE 3 for absorption chiller diagram.

FIGURE 3



The new cogeneration system will utilize single-effect absorption chillers, because of the elimination of the recent elimination of the dual-effect absorption chillers of the same size. Single-effect absorption chillers consist of an absorber, condenser, evaporator, and generator.

Single-effect absorption chillers use a refrigerant and an absorbent. In this system water is used as the refrigerant and lithium bromide used as the absorbent. The single-effect cycle works as follows:

- When the lithium bromide absorbs low pressure water vapor it releases heat.
- The lithium bromide solution is pumped to a high pressure generator. This process is similar to the compression process of an electric chiller, but this process uses less electricity.
- Heat is transferred to the generator from the recovered steam.

- The heat causes the water in the solution to separate from the solution and vaporize.
- The water vapor moves through the condenser causing heat to be rejected. The heat rejection is due to the water vapor being condensed into a high pressure liquid.
- The lithium bromide in the generator then passes through a pressure reducing valve.
- Low pressure water vapor from the evaporator mixes with the lithium bromide which repeats the cycle.
- The high pressure liquid is then controlled by an expansion valve.
- The liquid moves to the evaporator, after passing through the expansion valve, where it absorbs heat and vaporizes.

The absorption chillers will be placed in the same position as the centrifugal chillers they are replacing. This will allow the chilled water setup to remain the same except for the replacement of the two chilled water pumps to allow for the increase in head through the absorption chillers.

The chillers that are selected are two York single-effect absorption chillers (YIA ST 2A3). Each chiller is rated for 172 Tons of cooling. These chillers have a higher capacity than the ones they are replacing because they are also replacing the DX fan coil units. The absorption chiller staging will follow the control sequences as the existing system. The absorption chiller data is shown in TABLE 3 and the performance data can be found in APPENDIX E.

TABLE 3

York Absorption Chillers		
Model	YIA ST 2A3	
	Condenser	Evaporator
Flow Rate	620	413
Temperature	101.4 - 85	54 - 44
Pressure Drop	13	12
Input Electrical	5.9	
Input Steam	3140	
Output	172	
Rated COP	0.72	

6.6 Cooling Tower

The new cogeneration system uses absorption chillers which are water cooled. This requires the use of cooling towers. The cooling towers are sized based on condenser flow rate and range. The flow rate for the absorption chillers are 620 gpm per chiller. There will be one cooling tower per chiller set up in parallel to allow the system to better handle part load conditions. The cooling towers will be required to decrease the condenser water temperature from 101.4^{o}F to 85^{o}F this creates a range of 16.4^{o}F. The cooling towers are Marley NC8303FL1. Data for the cooling towers is shown in TABLE 4. Performance data can be found in APPENDIX F.

TABLE 4

Marley Cooling Tower	
Model	NC8303FL1
Quantity	2
Flow Rate (gpm)	620
Temperature (^{o}F)	101.4 - 85
Wet Bulb (^{o}F)	76
Range (^{o}F)	16.4
RPM	356
Fan Motor Output (	15

6.7 Condenser Water Pumps

Since cooling towers are required with the absorption chillers, a condenser water loop must be added to connect the cooling towers to the absorption chillers. The condenser water loop will utilize two pumps in parallel. The pump performance data is given in Appendix G.

7.0 REDESIGN SYSTEM ANALYSIS

7.1 First Cost

The utilities of Gloucester Point, VA require that the customer make all necessary arrangements and pay for the cost to make connections to the utilities grid. Equipment costs are also included in the first cost. Only equipment that was affected by the redesign of the system was taken into consideration. The first cost of the existing and new systems are shown in TABLE 5.

TABLE 5

First Cost				
System & Equipment	Quantity	Unit Price	Cost ($)	Source
CHP				
Centaur 40 Generator Set	3500	1200	4200000	Solar
Steam Fired Water Heater	1	15000	15000	Cemline
Unfired Absorption Chiller	2	150000	300000	York
Cooling Tower	2	16703.75	33408	Marley
Condenser Water Loop Pumps	2	6500	13000	B & G
Hot Water Pumps	2	5300	10600	B & G
Chilled Water Pumps	2	5300	10600	B & G
Condenser Water Piping	200	114	22800	Means
Total			4582608	
Existing System				
Centrifugal Chillers	2	58311.5	116623	Clark Nexsen
Chilled Water Pumps	2	2793.5	5587	Clark Nexsen
Boilers	2	27980	55960	Clark Nexsen
Hot Water Heater	1	14362	14362	Clark Nexsen
FCU	3	15554	46662	Clark Nexsen
ACU	1	4238	4238	Clark Nexsen
Total			243432	

The costs listed above in TABLE 5 are not comparable. They need to be added into the total mechanical cost of the building. TABLE 6 shows the existing mechanical total cost which includes HVAC, plumbing, and fire protection systems, and the reconfigured mechanical total cost of the new system.

TABLE 6

First Cost Comparison	
Existing Mechanical Cost ($)	1681744
Cost of Replaced Equipment ($)	243432
Cost of New Equipment ($)	4582608
New Mechanical Cost ($)	6020920
First Cost Increase ($)	4339176

7.2 Maintenance Cost

The maintenance costs of the existing and new systems are very important in determining the total savings of the new system. The use of the systems with absorption chillers lowers the maintenance cost compared to the use of systems with electric chillers, because there are fewer mechanical parts that would require maintenance. The values used for the annual maintenance cost for the systems are from a range of typical values published by The Northeast CHP Application Center. The maintenance cost for the Centaur 40 Generator Set is listed from Solar. TABLE 7 shows the estimated maintenance costs for the existing and new systems as well as the maintenance costs for the surrounding buildings that will be served by the Centaur 40 Generator Set. TABLE 8 shows the maintenance cost for the Centaur 40 Generator Set.

TABLE 7

Building	Cooling Approx. (Tons)	$/Ton	$/yr	$/22 yr
Existing SeaLab System	300.00	28.00	8400.00	184800.00
Watermen's Hall	117.63	28.00	3293.62	72459.57
Nunnally Hall	71.63	28.00	2005.70	44125.31
Wetlands Facility	5.53	28.00	154.84	3406.48
Chesapeake Bay Hall	256.40	28.00	7179.20	157942.40
Geddings House Energy	4.53	28.00	126.93	2792.53
Wilson House (CBNERR)	16.07	28.00	450.02	9900.35
DCOP Facility	5.46	28.00	152.88	3363.36
CBNERRVA Annex	22.00	28.00	616.00	13552.00
Total Existing Cost			22379.18	492342.00
New SeaLab System	344.00	22.00	7568.00	166496.00
Watermen's Hall	117.63	28.00	3293.62	72459.57
Nunnally Hall	71.63	28.00	2005.70	44125.31
Wetlands Facility	5.53	28.00	154.84	3406.48
Chesapeake Bay Hall	256.40	28.00	7179.20	157942.40
Geddings House Energy	4.53	28.00	126.93	2792.53
Wilson House (CBNERR)	16.07	28.00	450.02	9900.35
DCOP Facility	5.46	28.00	152.88	3363.36
CBNERRVA Annex	22.00	28.00	616.00	13552.00
Total New Cost			21547.18	474038.00
Maintenance Cost Decrease			832.00	18304.00

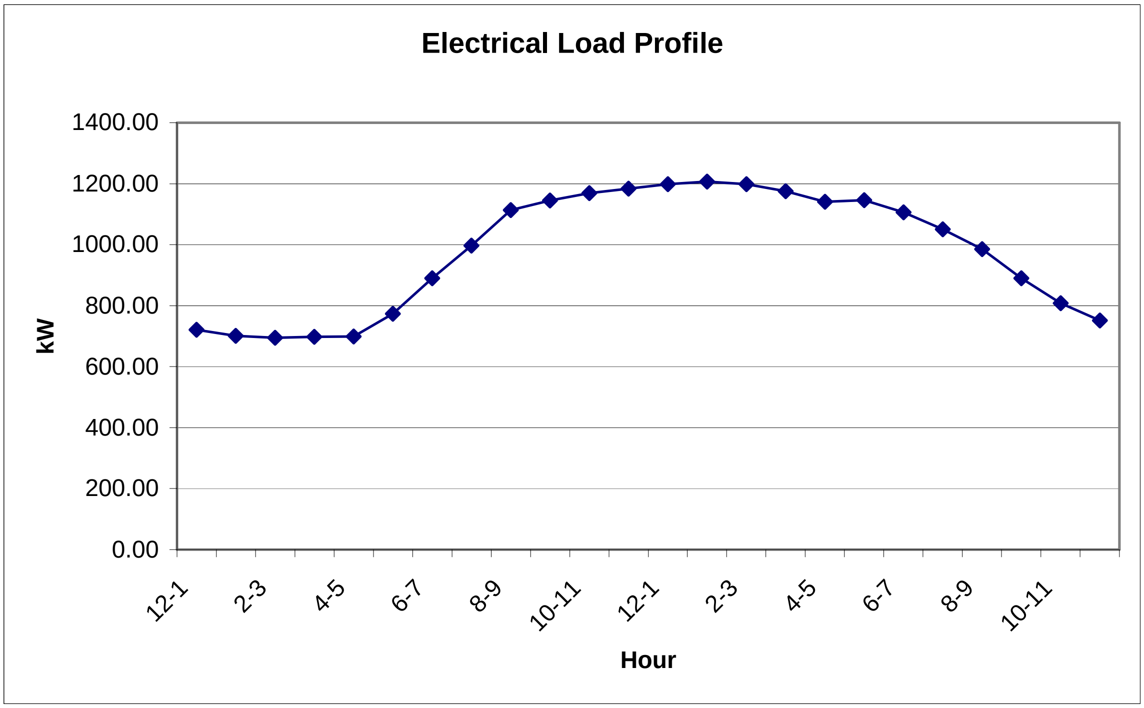
TABLE 8

	Approx kWh/yr	$/kwh	$/yr	$/22 yr
Centaur 40 Generator Set	30817790	0.0088	271196.55	5966324.14

7.3 Energy Cost

A typical electrical load profile for the building was generated from applying the known building loads to an averaged daily load profile that is based off of data from Pacific Gas and Electric Company. The Seawater Research Laboratory's electrical load profile is shown in FIGURE 4.

FIGURE 4



The Energy Information Administration's Annual Energy Outlook predicted average annual prices for electricity and natural gas. System energy costs for both the existing and new systems are calculated and compared in APPENDIX H. The energy cost calculations start with the year 2008 and end with 2030 this provides a 22 year range, which is approximately the range for the turbine life. Both the electricity and natural gas prices follow the same trend which keeps the spark gap around $15.

7.4 Pay Back

The simple payback period is based off of equipment first cost, maintenance costs, and energy savings. The payback period for the cogeneration system is ten years. Most of the annual payback is the annual energy savings that is gained over the existing separate heating and power system. TABLE 9 shows one year of savings and the projected total savings over the 22 years. The annual cost and savings and total payback of the equipments' first cost can be found in APPENDIX I.

TABLE 9

	2018	2030
Energy Savings	899102.199	846441.983
Total Annual Maintenance Cost	292743.734	292743.734
Net Annual Savings	606358.465	553698.249
Life Savings At Year End	6426982.29	13431895.5
New Mechanical Cost ($)	6020919.5	6020919.5
Total Net Life Savings	406062.791	7410976

7.5 Emissions

Propane is one of the cleaner burning fossil fuels. The state of Virginia generates power through a mixture of coal, oil, natural gas, nuclear, hydroelectric, and other renewable sources. Table 10 breaks down the emissions that are associated with generating electricity in Virginia. TABLE 11 shows the emissions associated with the Seawater Research Laboratory and the surrounding buildings that will be supplied with electricity by the new cogeneration system.

TABLE 10

Energy Source	Tons CO2/MWh	Tons SO_2/MWh	Tons NO_x/MWh
Coal	1.032966672	0.006295818	0.001722413
Oil	0.878647234	0.004700742	0.000925158
Natural Gas	0.5146291	1.99761E-06	0.000546596
Other	0	3.80359E-06	1.88333E-05
Total	2.426243007	0.011002361	0.003213

TABLE 11

Building	MWh	Tons CO_2	Tons SO_2	Tons NO_x
Seawater Research Lab Daily	26.37	63.98	0.29	0.08
Seawater Research Lab Yearly	9387.943	22777.43	103.2895	30.16346
Watermen's Hall Daily	4.70	11.40	0.05	0.02
Watermen's Hall Yearly	1673.031	4059.179	18.40729	5.375447
Nunnally Hall Daily	5.22	12.66	0.06	0.02
Nunnally Hall Yearly	1857.217	4506.061	20.43378	5.96724
Wetlands Facility Daily	0.22	0.54	0.00	0.00
Wetlands Facility Yearly	78.65276	190.8307	0.865366	0.252711
Chesapeake Bay Hall Daily	18.67	45.31	0.21	0.06
Chesapeake Bay Hall Yearly	6647.735	16129.02	73.14078	21.35917
Geddings House Daily	0.17	0.41	0.00	0.00
Geddings House Yearly	60.17877	146.0083	0.662109	0.193354
Wilson House (CBNERR) Daily	1.17	2.84	0.01	0.00
Wilson House (CBNERR) Yearly	416.702	1011.02	4.584706	1.338864
DCOP Facility Daily	0.22	0.53	0.00	0.00
DCOP Facility Yearly	77.65716	188.4151	0.854412	0.249512
CBNERRVA Annex Daily	1.60	3.89	0.02	0.01
CBNERRVA Annex Yearly	570.3985	1383.925	6.27573	1.83269

The Centaur 40 Generator Set is burns propane gas and the combustion process is associated with the following combustion chemical equation.

$$C_3H_8 + 6(0_2 + 3.76N_2) \rightarrow 3CO_2 + 4H_2O + O_2 + 22.56N_2$$

All emissions that are associated with this system are directly proportional to the amount of fuel consumed. Since the propane is the only source of power generation for the new system, the system produces fewer emissions because there less fuel will be consumed to power the Seawater Research Laboratory and the surrounding buildings. Less fuel is consumed because the power companies don't have to have the reserve capacity to power these buildings. Also the majority of the power generated by the electric utilities is fueled by coal which is very dirty. Emissions generated by the Centaur 40 Generator Set as a function of inlet temperature can be found in APPENDIX J. The emissions generated by the Seawater Research Laboratory and the surrounding buildings are shown in TABLE 12.

TABLE 12

Building	MWh	Tons CO_2	Tons SO_2	Tons NOx
Seawater Research Lab Daily	23.44347	7.515371	5.47E-08	0.002244
Seawater Research Lab Yearly	8556.868	2743.11	1.99E-05	0.819087
Watermen's Hall Daily	4.699524	1506.546	1.1E-05	0.449852
Watermen's Hall Yearly	1715.326	549889.2	0.003999	164.1958
Nunnally Hall Daily	5.216903	1.672404	1.22E-08	0.000499
Nunnally Hall Yearly	1904.17	610.4275	4.44E-06	0.182272
Wetlands Facility Daily	0.220935	0.070826	5.15E-10	2.11E-05
Wetlands Facility Yearly	80.64117	25.85147	1.88E-07	0.007719
Chesapeake Bay Hall Daily	18.67341	5.986213	4.35E-08	0.001787
Chesapeake Bay Hall Yearly	6815.795	2184.968	1.59E-05	0.652427
Geddings House Daily	0.169041	0.05419	3.94E-10	1.62E-05
Geddings House Yearly	61.70014	19.77947	1.44E-07	0.005906
Wilson House (CBNERR) Daily	1.170511	0.375236	2.73E-09	0.000112
Wilson House (CBNERR) Yearly	427.2366	136.961	9.96E-07	0.040896
DCOP Facility Daily	0.218138	0.069929	5.09E-10	2.09E-05
DCOP Facility Yearly	79.6204	25.52424	1.86E-07	0.007621
CBNERRVA Annex Daily	1.602243	0.513638	3.74E-09	0.000153
CBNERRVA Annex Yearly	584.8186	187.4777	1.36E-06	0.05598

7.6 Efficiencies

Cogeneration system efficiencies are considered in terms of total efficiency, power/steam ratio, net heat rate, and effective electrical efficiency. The cogeneration system average efficiencies are shown in TABLE 13.

TABLE 13

FERC Efficiency	0.47
FERC Efficiency w/ Inlet Cooling	0.46
Total Efficiency	0.70
Total Efficiency w/ Inlet Cooling	0.65
Power/Steam Ratio	0.57
Power/Steam Ratio w/ Inlet Cooling	0.67
Net Heat Rate	3.73
Net Heat Rate w/ Inlet Cooling	3.54
Effective Electrical Efficiency	0.52
Effective Electrical Efficiency w/ Inlet Cooling	0.49

Not all of the steam that is produced by the system gets consumed. The total estimated consumption by all of the equipment and by the surrounding buildings (if equipped with absorption chillers) would only equal 22,575 lb/hr. The remainder of steam produced will be wasted. The adjusted average efficiencies for the system that account for the amount of steam consumed are shown in TABLE 14.

TABLE 14

FERC Efficiency	0.48
Total Efficiency	0.71
Power/Steam Ratio	0.55
Net Heat Rate	3.73
Effective Electrical Efficiency	0.52

To improve these efficiencies the thermal loads of the entire campus should be considered to allow for more steam consumption. However, if it is desired to power the entire campus with electricity as well as provide it with steam for heating and cooling purposes and large turbine generator will be required to handle the increased electrical load.

The current cogeneration system provides 667.1 kW of excess electricity which could be sold back to the electrical utility grid. However, the during the design day without inlet cooling the amount of steam consumed by the Seawater Research Laboratory and surrounding buildings (if equipped with absorption chillers) would be less than the required 5%, but with inlet cooling the percentage of steam consumed would be greater than 5% on the design day. The minimum FERC efficiency of the cogeneration system must be 45%. The absorption chillers are sized to accommodate inlet cooling which on the design day would require 30 tons of cooling. The system efficiencies can be found in APPENDIX K. The reason for the lower FERC efficiencies with the use of inlet cooling is due to the lack of hours that require inlet cooling. Calculations for the system efficiencies adjusted for amount of steam consumed can be found in APPENDIX L.

7.7 Power Sell Back

Since there is an excess of 661.7 kW of electricity produced there are some considerations involved with power sell back. One factor of involved with both options is the electrical distribution equipment. Solar specifies Eaton protective switches and relays to distribute the electricity from the generator. Another is that protective equipment is necessary to protect personnel that are working on a deenergized utility and the generator is energized. To prevent this from happening the utility installs an external disconnect switch which allows the generator to be isolated when the utility is deenergized for maintenance.

Power sell back is a requirement by PURPA for cogeneration systems less than 80 MW. Since this system qualifies, power sell back is negotiated through a contract with the electrical utilities. Usually this contract is negotiated that the utilities will buy power from the cogeneration system for the cost of generation. Calculations for the power sell back are shown in APPENDIX M. Power sell back revenue was not factored into the life cycle cost analysis, because the amount of excess power available isn’t stable enough to predict over the 22 year analysis.

8.0 CONCLUSIONS

Cogeneration systems have both advantages and disadvantages. The two biggest advantages are reduction of emissions associated with power generation and lower energy costs. The biggest disadvantage is the first cost of the system. Depending on where the system is located the system might have increased savings trough incentives that are provided by the state of which it is located.

Cogeneration systems are great for campus applications because of the lower emissions and the high demand for the recovered heat. Another not so evident benefit of a campus cogeneration system is that the owner has full control over the system.

As the power generation technology develops cogeneration systems will become more beneficial both economically and environmentally.

The results from my calculations point towards a more extensive analysis involving the actual existing building loads for the entire VIMS campus.

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10.0 ACKNOWLEDGEMENTS

I would like to thank the engineers at Clark Nexsen for providing me with all of the necessary information on the building, especially Alicia Carbin.

The AE Faculty and Staff, Dr. Freihaut has been especially helpful providing me with excellent advice.

I would also like to thank my peers who have provided me with support and untimely distractions.

Finally, I would like to thank my family and my loving girlfriend who has had to put up with and supported me through the experience that is AE 5th year THESIS.

APPENDIX A:

Building No.	Building Name	Use	Area (ft^2)	Heating Approx. (BTU/ft^2)	Cooling Approx. (BTU/ft^2)	Electrical Approx. (W/ft^2)	Heating Approx. (BTU)	Cooling Approx. (BTU)	Cooling Approx. (Tons)	Electrical Approx. (W)
B056	Watermen's Hall	Office	40330	30	35	6	1209900	1411550	117.6291667	241980
B073	Nunnally Hall	Lab	17908	40	48	15	716320	859584	71.632	268620
B103	Wetlands Facility	Office	1896	30	35	6	56880	66360	5.53	11376
B109	Chesapeake Bay Hall	Lab	64100	40	48	15	2564000	3076800	256.4	961500
B111	Geddings House	Dorm	2176	20	25	4	43520	54400	4.533333333	8704
B117	Wilson House (CBNERR)	Lab	4018	40	48	15	160720	192864	16.072	60270
B122	DCOP Facility	Office	1872	30	35	6	56160	65520	5.46	11232
B130	CBNERRVA Annex	Lab	5500	40	48	15	220000	264000	22	82500
Total			137800				5027500	5991078		1646182

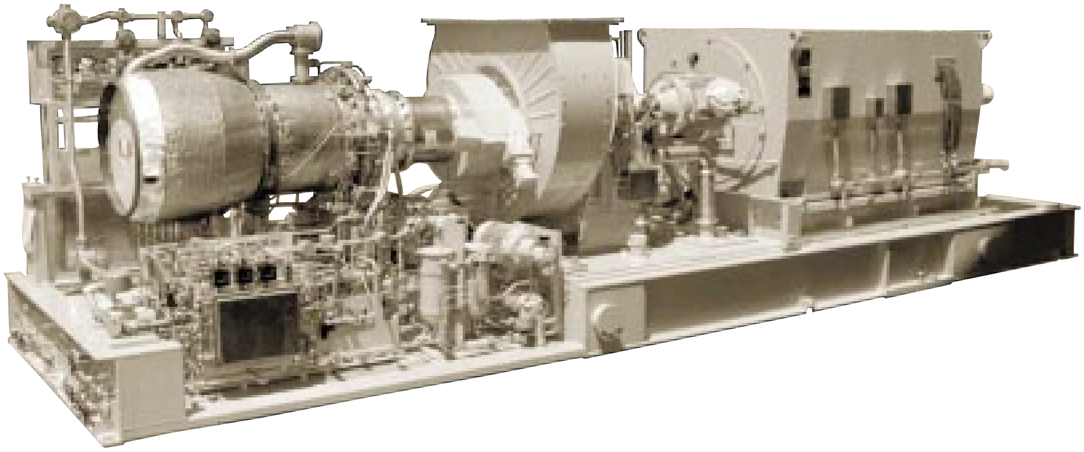
Hour	Example %	Watermen's Hall	Nunnally Hall	Wetlands Facility	Chesapeake Bay Hall	Geddings House	Wilson House (CBNERR)	DCOP Facility		CBNERRVA Annex
12-1	60	144535	160447	6795	574304	5199	35999	6709		49277
1-2	58	140501	155969	6605	558276	5054	34995	6522		47902
2-3	58	139222	154549	6545	553194	5008	34676	6462		47466
3-4	58	139931	155336	6578	556012	5033	34853	6495		47708
4-5	58	140217	155654	6592	557148	5044	34924	6508		47805
5-6	64	155142	172222	7294	616451	5580	38641	7201		52894
6-7	74	178436	198080	8389	709010	6418	44443	8282		60836
7-8	83	199800	221796	9393	793899	7187	49764	9274		68119
8-9	92	223170	247739	10492	886759	8027	55585	10359		76087
9-10	95	229448	254708	10787	911703	8253	57149	10650		78227
10-11	97	234430	260239	11021	931499	8432	58389	10882		79926
11-12	98	237352	263483	11158	943113	8538	59117	11017		80922
12-1	99	240151	266590	11290	954232	8638	59814	11147		81876
1-2	100	241980	268620	11376	961500	8704	60270	11232		82500
2-3	99	240305	266761	11297	954844	8644	59853	11154		81929
3-4	97	235561	261494	11074	935993	8473	58671	10934		80311
4-5	95	228739	253922	10754	908889	8228	56972	10617		77986
5-6	95	229778	255075	10802	913017	8265	57231	10666		78340
6-7	92	221712	246120	10423	880965	7975	55222	10291		75590
7-8	87	210540	233719	9898	836574	7573	52439	9773		71781
8-9	82	197508	219252	9285	784792	7104	49193	9168		67338
9-10	74	178446	198092	8389	709051	6419	44446	8283		60839
10-11	67	161984	179817	7615	643638	5827	40345	7519		55226
11-12	62	150636	167220	7082	598549	5418	37519	6992		51358
Daily Total		4699524	5216903	220935	18673412	169041	1170511	218138		1602243
Yearly Total		1715326255	1904169512	80641175	6815795496	61700139	427236604	79620400		584818646

APPENDIX B:

Ambient Temp (^{o}F)	Hours	Mwe^{-}	Mwe^{-}h	Fuel Flow (lbm/hr)	lbm - mole C_3H_8/hr	Fuel Flow (MMBTU/hr)	Air Flow (lbm/hr)	Exhaust Flow (lbm/hr)	Exhaust H_2O (lbm/hr)	Exhaust CO_2 (lbm/hr)	Exhaust O_2 (lbm/hr)	Exhaust N_2 (lbm/hr)	Exhuast Temp (^{o}F)	Output (MMBTU/hr)	Qevap (BTU/hr)	Mstm (lbm/hr)	Qstm (BTU/hr)
99.00	2.00	2.59	5.17	1948.65	44.29	42.01	36478.64	206113.46	17103.27	1948.65	7601.46	150052.72	840.21	8.82	23347393.87	25524.82	25428588.47
97.00	4.00	2.64	10.54	1963.34	44.62	42.33	36753.70	205546.56	17056.23	1963.34	7580.55	149640.02	838.50	8.99	23193522.18	25356.59	25261000.61
95.00	4.00	2.68	10.74	1978.08	44.96	42.65	37029.75	204979.35	17009.17	1978.08	7559.63	149227.08	836.79	9.16	23040189.36	25188.96	25093999.66
93.00	15.00	2.73	40.99	1992.89	45.29	42.97	37306.84	204411.78	16962.07	1992.89	7538.70	148813.88	835.09	9.32	22887381.95	25021.90	24927570.94
91.00	58.00	2.78	161.33	2007.75	45.63	43.29	37585.04	203843.82	16914.94	2007.75	7517.75	148400.40	833.38	9.49	22735086.62	24855.40	24761699.96
89.00	66.00	2.83	186.77	2022.67	45.97	43.61	37864.41	203275.44	16867.78	2022.67	7496.79	147986.61	831.67	9.66	22583290.25	24689.45	24596372.40
87.00	115.00	2.88	330.97	2037.66	46.31	43.93	38144.99	202706.59	16820.57	2037.66	7475.81	147572.49	829.97	9.82	22431979.85	24524.03	24431574.15
85.00	150.00	2.93	438.88	2052.72	46.65	44.26	38426.85	202137.25	16773.33	2052.72	7454.81	147158.00	828.27	9.98	22281142.61	24359.13	24267291.22
83.00	184.00	2.97	547.14	2067.84	47.00	44.58	38710.05	201567.38	16726.04	2067.84	7433.80	146743.13	826.56	10.15	22130765.88	24194.72	24103509.86
81.00	223.00	3.02	673.69	2083.05	47.34	44.91	38994.64	200996.94	16678.71	2083.05	7412.76	146327.84	824.86	10.31	21980837.17	24030.81	23940216.45
79.00	320.00	3.07	981.86	2098.33	47.69	45.24	39280.68	200425.90	16631.32	2098.33	7391.70	145912.12	823.16	10.47	21831344.17	23867.38	23777397.59
77.00	190.00	3.12	591.91	2113.69	48.04	45.57	39568.24	199854.23	16583.88	2113.69	7370.62	145495.94	821.45	10.63	21682274.70	23704.41	23615040.02
75.00	402.00	3.16	1271.19	2129.13	48.39	45.90	39857.36	199281.88	16536.39	2129.13	7349.51	145079.26	819.75	10.79	21533616.79	23541.88	23453130.69
73.00	701.00	3.21	2249.35	2144.66	48.74	46.24	40148.11	198708.83	16488.84	2144.66	7328.37	144662.07	818.05	10.95	21385358.60	23379.80	23291656.71
71.00	504.00	3.26	1640.62	2160.29	49.10	46.58	40440.55	198135.03	16441.23	2160.29	7307.21	144244.34	816.34	11.11	21237488.47	23218.14	23130605.40
69.00	403.00	3.30	1330.49	2176.00	49.45	46.91	40734.72	197560.46	16393.55	2176.00	7286.02	143826.05	814.64	11.26	21089994.91	23056.89	22969964.21
67.00	329.00	3.35	1101.34	2191.81	49.81	47.26	41030.70	196985.08	16345.80	2191.81	7264.80	143407.16	812.93	11.42	20942866.59	22896.04	22809720.82
65.00	382.00	3.39	1296.31	2207.72	50.18	47.60	41328.54	196408.84	16297.99	2207.72	7243.55	142987.66	811.22	11.58	20796092.35	22735.58	22649863.08
63.00	370.00	3.44	1272.54	2223.73	50.54	47.94	41628.29	195831.73	16250.10	2223.73	7222.27	142567.52	809.51	11.73	20649661.19	22575.49	22490378.99
61.00	359.00	3.49	1251.12	2239.85	50.91	48.29	41930.02	195253.70	16202.13	2239.85	7200.95	142146.70	807.80	11.89	20503562.29	22415.76	22331256.78
59.00	156.00	3.53	550.78	2256.08	51.27	48.64	42233.78	194674.71	16154.09	2256.08	7179.60	141725.20	806.09	12.05	20357784.98	22256.39	22172484.84
57.00	259.00	3.58	926.24	2272.42	51.65	48.99	42539.63	194094.74	16105.96	2272.42	7158.21	141302.97	804.38	12.20	20212318.78	22097.36	22014051.73
55.00	372.00	3.62	1347.30	2288.87	52.02	49.35	42847.63	193513.75	16057.75	2288.87	7136.78	140880.00	802.66	12.36	20067153.36	21938.65	21855946.22
53.00	210.00	3.67	770.14	2305.44	52.40	49.71	43157.83	192931.69	16009.45	2305.44	7115.31	140456.26	800.94	12.51	19922278.58	21780.27	21698157.25
51.00	239.00	3.71	887.39	2322.13	52.78	50.07	43470.30	192348.55	15961.06	2322.13	7093.81	140031.72	799.22	12.67	19777684.46	21622.19	21540673.96
49.00	237.00	3.76	890.79	2338.95	53.16	50.43	43785.09	191764.27	15912.58	2338.95	7072.26	139606.37	797.50	12.82	19633361.19	21464.41	21383485.67
47.00	307.00	3.80	1167.96	2355.89	53.54	50.79	44102.26	191178.83	15864.00	2355.89	7050.67	139180.16	795.78	12.98	19489299.14	21306.91	21226581.87
45.00	296.00	3.85	1139.71	2372.96	53.93	51.16	44421.87	190592.20	15815.32	2372.96	7029.03	138753.08	794.05	13.14	19345488.83	21149.69	21069952.27
43.00	318.00	3.90	1239.10	2390.17	54.32	51.53	44743.98	190004.32	15766.54	2390.17	7007.35	138325.10	792.32	13.29	19201920.99	20992.73	20913586.74
41.00	184.00	3.94	725.50	2407.51	54.72	51.91	45068.64	189415.18	15717.65	2407.51	6985.62	137896.20	790.58	13.45	19058586.49	20836.03	20757475.35
39.00	284.00	3.99	1133.06	2425.00	55.11	52.28	45395.92	188824.74	15668.66	2425.00	6963.85	137466.35	788.84	13.61	18915476.40	20679.57	20601608.39
37.00	297.00	4.04	1198.90	2442.62	55.51	52.66	45725.86	188232.95	15619.55	2442.62	6942.02	137035.53	787.10	13.77	18772581.97	20523.35	20445976.29
35.00	210.00	4.08	857.67	2460.39	55.92	53.05	46058.54	187639.79	15570.33	2460.39	6920.15	136603.70	785.35	13.94	18629894.59	20367.35	20290569.71
33.00	161.00	4.13	665.26	2478.31	56.33	53.43	46393.99	187045.22	15520.99	2478.31	6898.22	136170.85	783.60	14.10	18487405.86	20211.58	20135379.49
31.00	114.00	4.18	476.57	2496.38	56.74	53.82	46732.30	186449.21	15471.54	2496.38	6876.24	135736.95	781.85	14.26	18345107.56	20056.01	19980396.67
29.00	72.00	4.23	304.52	2514.61	57.15	54.21	47073.50	185851.72	15421.96	2514.61	6854.20	135301.96	780.09	14.43	18202991.65	19900.64	19825612.49
27.00	107.00	4.28	457.86	2533.00	57.57	54.61	47417.67	185252.71	15372.25	2533.00	6832.11	134865.88	778.33	14.60	18061050.24	19745.46	19671018.38
25.00	73.00	4.33	316.05	2551.54	57.99	55.01	47764.86	184652.15	15322.42	2551.54	6809.96	134428.67	776.56	14.77	17919275.66	19590.46	19516605.97
23.00	20.00	4.38	87.61	2570.25	58.41	55.41	48115.12	184050.00	15272.45	2570.25	6787.76	133990.30	774.79	14.95	17777660.41	19435.64	19362367.08
21.00	21.00	4.43	93.08	2589.13	58.84	55.82	48468.51	183446.24	15222.35	2589.13	6765.49	133550.75	773.01	15.12	17636197.17	19280.98	19208293.76
19.00	25.00	4.49	112.13	2608.18	59.28	56.23	48825.10	182840.81	15172.11	2608.18	6743.16	133110.00	771.23	15.30	17494878.80	19126.49	19054378.23
17.00	16.00	4.54	72.62	2627.40	59.71	56.65	49184.94	182233.70	15121.73	2627.40	6720.77	132668.01	769.44	15.49	17353698.38	18972.14	18900612.94
15.00	1.00	4.59	4.59	2646.80	60.15	57.07	49548.09	181624.86	15071.21	2646.80	6698.32	132224.77	767.65	15.67	17212649.14	18817.93	18746990.52
13.00		4.65	0.00	2666.38	60.60	57.49	49914.60	181014.26	15020.55	2666.38	6675.80	131780.25	765.85	15.87	17071724.51	18663.87	18593503.82

Solar® Turbines
A Caterpillar Company

CENTAUR 40
Gas Turbine Generator Set



General Specifications

Centaur® 40 Gas Turbine
- Industrial, Single-Shaft
- Axial Compressor
  - – 11-Stage
  - – Variable Inlet Guide Vanes
  - – Compression Ratio: 9.7:1
  - – Inlet Airflow: 18.4 kg/sec (40.5 lb/sec)
  - – Max. Speed: 14,944 rpm (50 Hz) 14,951 rpm (60 Hz)
- Combustion Chamber
  - – Annular-Type
  - – Optional: Lean-Premix, Dry, Low Emission (*SoLoNO$_x$*™) or Water Injection
  - – 10 Fuel Injectors
  - – Torch Ignitor System
- Turbine
  - – 3-Stage, Reaction
- Bearings
  - – Journal: Tilting-Pad
  - – Thrust: Fixed Tapered Land
- Coatings
  - – Compressor: Inorganic Aluminum
  - – Turbine and Nozzle Blades: Precious Metal Diffusion Aluminide
- Vibration Transducer Type
  - – Velocity

Main Reduction Drive
- Epicyclic Type
- 1500 or 1800 rpm

Generator
- Type: Salient Pole, 3 Phase, 6 Wire, Wye Connected, Synchronous, with Brushless Exciter
- Construction Options
  - – Open Drip Proof
  - – Weather Protected II (WPII)
  - – Totally Enclosed Water/Air Cooled
- Sleeve Bearings
- Voltage Regulation
  - – Solid-State Regulation with Permanent Magnet Generator
- Insulation/Rise Options
  - – NEMA Class F with F Rise
  - – NEMA Class F with B Rise
- Voltages: 3300 to 13,800 Volt
- Frequency: 50 or 60 Hz

Key Package Features
- Base Frame with Drip Pans
- 316L Stainless Steel Piping
- Compression-Type Tube Fittings
- Fluid Gauge Panel
- Electrical System Options
  - – NEC, Class I, Group D, Div 2
  - – IEC, Zone 2
- *Turbotronic™* Microprocessor Control System
  - – Free-Standing Control Console
  - – Color Video Display
  - – Vibration Monitoring
- Control Options
  - – 24-Vdc Control Battery/Charger
  - – Gas Turbine and Package Temperature Monitoring
  - – Serial Link Supervisory Interface
  - – Turbine Performance Map
  - – Historical Displays
  - – Printer/Logger
  - – Predictive Emissions Monitoring
  - – Field Programming
- Start Systems
  - – Pneumatic
  - – Direct Drive AC
- Fuel Systems
  - – Natural Gas
  - – Liquid
  - – Dual (Gas/Liquid)
  - – Alternate Fuels
- Integrated Lube Oil System
  - – Turbine-Driven Accessories
- Oil System Options
  - – Oil Cooler
  - – Oil Heater
  - – Tank Vent Separator
  - – Flame Trap
- Axial Compressor Cleaning Systems
  - – On-Crank
  - – On-Crank/On-Line
  - – Stationary Cleaning Tank
  - – Portable Cleaning Tank
- Air Inlet and Exhaust System Options
- Enclosure and Associated Options
- Factory Testing of Turbine and Package
- Documentation
  - – Drawings
  - – Quality Control Data Book
  - – Inspection and Test Plan
  - – Test Reports

Solar Turbines
A Caterpillar Company

CENTAUR 40
Gas Turbine Generator Set

Performance

No Inlet/Exhaust Losses,
Relative Humidity 60%,
Natural Gas Fuel with
LHV = 31.5 to 43.3 MJ/nm^3
(800 to 1100 Btu/scf)

Nominal Rating – ISO
At 15°C (59°F), Sea Level

Output Power
Continuous Duty
3515 kW$_e$

Heat Rate
12 912 kJ/kW$_e$-hr
(12,240 Btu/kW$_e$-hr)

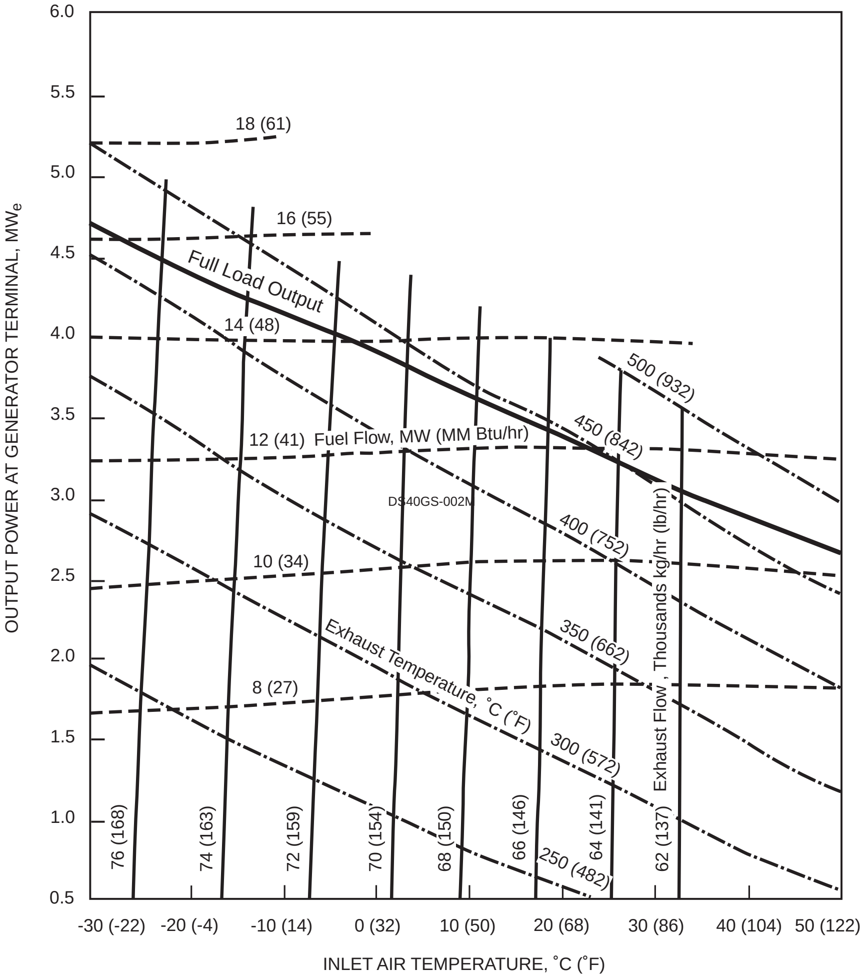
Exhaust Flow
67 004 kg/hr
(147,718 lb/hr)

Exhaust Temp
437°C (819°F)

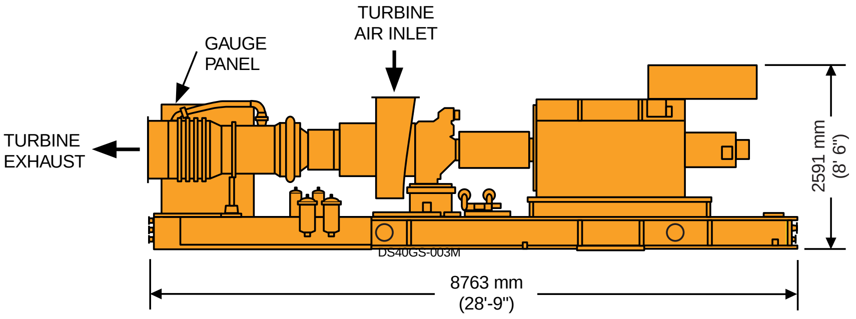
Nominal/Expected Power
Not Guaranteed

°C = (°F - 32) 5/9; 0.7457 kW = 1 hp;
1.055 kJ/kW$_e$-hr = 1 Btu/kW$_e$-hr;
0.4536 kg = 1 lb
STANDBY RATINGS AVAILABLE

Available Power



Package Dimensions



Typical Package Weight = 26 015 kg (57,350 lb)
Width = 2.44 m (8' 0")

Solar Turbines Incorporated
P.O. Box 85376
San Diego, CA 92186-5376

FOR MORE INFORMATION
Telephone: (+1) 619-544-5352
Telefax: (+1) 619-544-2633
Telex: 695045

ISO-9001
DNV
CERTIFICATED FIRM

DS40GS/997/2M

APPENDIX C:

Ambient Temp (^oF)	Hours	Mwe$^-$	Inlet Temp (^oF)	Output w/ Inlet Cooling (MMBTU/hr)	Fuel Flow w/ Inlet Cooling (MMBTU/hr)	Exhaust Temp w/ Inlet Cooling (^oF)	Exhaust Flow w/ Inlet Cooling (lbm/hr)	Output (MMBTU/hr)	Qevap w/ Inlet Cooling	Mstm w/ Inlet Cooling(lbm/hr)	Qstm w/ Inlet Cooling (BTU/hr)
99.00	2.00	3.87	44.00	13.22	51.35	793.18	190298.42	13.22	19273675.17	20907.91	20829082.52
97.00	4.00	3.87	44.00	13.22	51.35	793.18	190298.42	13.22	19273675.17	20907.91	20829082.52
95.00	4.00	3.87	44.00	13.22	51.35	793.18	190298.42	13.22	19273675.17	20907.91	20829082.52
93.00	15.00	3.87	44.00	13.22	51.35	793.18	190298.42	13.22	19273675.17	20907.91	20829082.52
91.00	58.00	3.87	44.00	13.22	51.35	793.18	190298.42	13.22	19273675.17	20907.91	20829082.52
89.00	66.00	3.87	44.00	13.22	51.35	793.18	190298.42	13.22	19273675.17	20907.91	20829082.52
87.00	115.00	3.87	44.00	13.22	51.35	793.18	190298.42	13.22	19273675.17	20907.91	20829082.52
85.00	150.00	3.87	44.00	13.22	51.35	793.18	190298.42	13.22	19273675.17	20907.91	20829082.52
83.00	184.00	3.87	44.00	13.22	51.35	793.18	190298.42	13.22	19273675.17	20907.91	20829082.52
81.00	223.00	3.87	44.00	13.22	51.35	793.18	190298.42	13.22	19273675.17	20907.91	20829082.52
79.00	320.00	3.87	44.00	13.22	51.35	793.18	190298.42	13.22	19273675.17	20907.91	20829082.52
77.00	190.00	3.87	44.00	13.22	51.35	793.18	190298.42	13.22	19273675.17	20907.91	20829082.52
75.00	402.00	3.87	44.00	13.22	51.35	793.18	190298.42	13.22	19273675.17	20907.91	20829082.52
73.00	701.00	3.87	44.00	13.22	51.35	793.18	190298.42	13.22	19273675.17	20907.91	20829082.52
71.00	504.00	3.87	44.00	13.22	51.35	793.18	190298.42	13.22	19273675.17	20907.91	20829082.52
69.00	403.00	3.87	44.00	13.22	51.35	793.18	190298.42	13.22	19273675.17	20907.91	20829082.52
67.00	329.00	3.87	44.00	13.22	51.35	793.18	190298.42	13.22	19273675.17	20907.91	20829082.52
65.00	382.00	3.87	44.00	13.22	51.35	793.18	190298.42	13.22	19273675.17	20907.91	20829082.52
63.00	370.00	3.87	44.00	13.22	51.35	793.18	190298.42	13.22	19273675.17	20907.91	20829082.52
61.00	359.00	3.87	44.00	13.22	51.35	793.18	190298.42	13.22	19273675.17	20907.91	20829082.52
59.00	156.00	3.87	44.00	13.22	51.35	793.18	190298.42	13.22	19273675.17	20907.91	20829082.52
57.00	259.00	3.87	44.00	13.22	51.35	793.18	190298.42	13.22	19273675.17	20907.91	20829082.52
55.00	372.00	3.87	44.00	13.22	51.35	793.18	190298.42	13.22	19273675.17	20907.91	20829082.52
53.00	210.00	3.87	44.00	13.22	51.35	793.18	190298.42	13.22	19273675.17	20907.91	20829082.52
51.00	239.00	3.87	44.00	13.22	51.35	793.18	190298.42	13.22	19273675.17	20907.91	20829082.52
49.00	237.00	3.87	44.00	13.22	51.35	793.18	190298.42	13.22	19273675.17	20907.91	20829082.52
47.00	307.00	3.87	44.00	13.22	51.35	793.18	190298.42	13.22	19273675.17	20907.91	20829082.52
45.00	296.00	3.87	44.00	13.22	51.35	793.18	190298.42	13.22	19273675.17	20907.91	20829082.52
43.00	318.00	3.90	43.00	13.29	51.53	792.32	190004.32	13.29	19201920.99	20830.07	20751537.69
41.00	184.00	3.94	41.00	13.45	51.91	790.58	189415.18	13.45	19058586.49	20674.58	20596635.94
39.00	284.00	3.99	39.00	13.61	52.28	788.84	188824.74	13.61	18915476.40	20519.33	20441976.71
37.00	297.00	4.04	37.00	13.77	52.66	787.10	188232.95	13.77	18772581.97	20364.32	20287550.53
35.00	210.00	4.08	35.00	13.94	53.05	785.35	187639.79	13.94	18629894.59	20209.54	20133348.11
33.00	161.00	4.13	33.00	14.10	53.43	783.60	187045.22	14.10	18487405.86	20054.97	19979360.39
31.00	114.00	4.18	31.00	14.26	53.82	781.85	186449.21	14.26	18345107.56	19900.60	19825578.46
29.00	72.00	4.23	29.00	14.43	54.21	780.09	185851.72	14.43	18202991.65	19746.44	19671993.62
27.00	107.00	4.28	27.00	14.60	54.61	778.33	185252.71	14.60	18061050.24	19592.46	19518597.38
25.00	73.00	4.33	25.00	14.77	55.01	776.56	184652.15	14.77	17919275.66	19438.67	19365381.44
23.00	20.00	4.38	23.00	14.95	55.41	774.79	184050.00	14.95	17777660.41	19285.04	19212337.67
21.00	21.00	4.43	21.00	15.12	55.82	773.01	183446.24	15.12	17636197.17	19131.58	19059458.19
19.00	25.00	4.49	19.00	15.30	56.23	771.23	182840.81	15.30	17494878.80	18978.28	18906735.28
17.00	16.00	4.54	17.00	15.49	56.65	769.44	182233.70	15.49	17353698.38	18825.13	18754161.43
15.00	1.00	4.59	15.00	15.67	57.07	767.65	181624.86	15.67	17212649.14	18672.12	18601729.36
13.00		4.65	13.00	15.87	57.49	765.85	181014.26	15.87	17071724.51	18519.25	18449431.95

APPENDIX D:

Ambient Temp (^{o}F)	Hours	Mwe^{-}	Mwe^{-}h	Fuel Flow (lbm/hr)	Fuel Flow (MMBTU/hr)	Air Flow (lbm/hr)	Exhaust Flow (lbm/hr)	Exhuast Temp (^{o}F)	Inlet Temp (^{o}F)	Output w/ Inlet Cooling (MMBTU/hr)	Fuel Flow w/ Inlet Cooling (MMBTU/hr)	Exhaust Temp w/ Inlet Cooling (^{o}F)	Exhaust Flow w/ Inlet Cooling (lbm/hr)	Output (MMBTU/hr)	Qevap w/ Inlet Cooling	Qevap (BTU/hr)	Mstm (lbm/hr)	Mstm w/ Inlet Cooling (lbm/hr)	Qstm (BTU/hr)	Qstm w/ Inlet Cooling
99.00	2.00	2.59	5.17	1948.65	42.01	36478.64	206113.46	840.21	44.00	13.22	51.35	793.18	190298.42	8.82	19273675.17	23347394	25524.82	20907.91	25428588	20829082.52
97.00	4.00	2.64	10.54	1963.34	42.33	36753.70	205546.56	838.50	44.00	13.22	51.35	793.18	190298.42	8.99	19273675.17	23193522	25356.59	20907.91	25261001	20829082.52
95.00	4.00	2.68	10.74	1978.08	42.65	37029.75	204979.35	836.79	44.00	13.22	51.35	793.18	190298.42	9.16	19273675.17	23040189	25188.96	20907.91	25094000	20829082.52
93.00	15.00	2.73	40.99	1992.89	42.97	37306.84	204411.78	835.09	44.00	13.22	51.35	793.18	190298.42	9.32	19273675.17	22887382	25021.90	20907.91	24927571	20829082.52
91.00	58.00	2.78	161.33	2007.75	43.29	37585.04	203843.82	833.38	44.00	13.22	51.35	793.18	190298.42	9.49	19273675.17	22735087	24855.40	20907.91	24761700	20829082.52
89.00	66.00	2.83	186.77	2022.67	43.61	37864.41	203275.44	831.67	44.00	13.22	51.35	793.18	190298.42	9.66	19273675.17	22583290	24689.45	20907.91	24596372	20829082.52
87.00	115.00	2.88	330.97	2037.66	43.93	38144.99	202706.59	829.97	44.00	13.22	51.35	793.18	190298.42	9.82	19273675.17	22431980	24524.03	20907.91	24431574	20829082.52
85.00	150.00	2.93	438.88	2052.72	44.26	38426.85	202137.25	828.27	44.00	13.22	51.35	793.18	190298.42	9.98	19273675.17	22281143	24359.13	20907.91	24267291	20829082.52
83.00	184.00	2.97	547.14	2067.84	44.58	38710.05	201567.38	826.56	44.00	13.22	51.35	793.18	190298.42	10.15	19273675.17	22130766	24194.72	20907.91	24103510	20829082.52
81.00	223.00	3.02	673.69	2083.05	44.91	38994.64	200996.94	824.86	44.00	13.22	51.35	793.18	190298.42	10.31	19273675.17	21980837	24030.81	20907.91	23940216	20829082.52
79.00	320.00	3.07	981.86	2098.33	45.24	39280.68	200425.90	823.16	44.00	13.22	51.35	793.18	190298.42	10.47	19273675.17	21831344	23867.38	20907.91	23777398	20829082.52
77.00	190.00	3.12	591.91	2113.69	45.57	39568.24	199854.23	821.45	44.00	13.22	51.35	793.18	190298.42	10.63	19273675.17	21682275	23704.41	20907.91	23615040	20829082.52
75.00	402.00	3.16	1271.19	2129.13	45.90	39857.36	199281.88	819.75	44.00	13.22	51.35	793.18	190298.42	10.79	19273675.17	21533617	23541.88	20907.91	23453131	20829082.52
73.00	701.00	3.21	2249.35	2144.66	46.24	40148.11	198708.83	818.05	44.00	13.22	51.35	793.18	190298.42	10.95	19273675.17	21385359	23379.80	20907.91	23291657	20829082.52
71.00	504.00	3.26	1640.62	2160.29	46.58	40440.55	198135.03	816.34	44.00	13.22	51.35	793.18	190298.42	11.11	19273675.17	21237488	23218.14	20907.91	23130605	20829082.52
69.00	403.00	3.30	1330.49	2176.00	46.91	40734.72	197560.46	814.64	44.00	13.22	51.35	793.18	190298.42	11.26	19273675.17	21089995	23056.89	20907.91	22969964	20829082.52
67.00	329.00	3.35	1101.34	2191.81	47.26	41030.70	196985.08	812.93	44.00	13.22	51.35	793.18	190298.42	11.42	19273675.17	20942867	22896.04	20907.91	22809721	20829082.52
65.00	382.00	3.39	1296.31	2207.72	47.60	41328.54	196408.84	811.22	44.00	13.22	51.35	793.18	190298.42	11.58	19273675.17	20796092	22735.58	20907.91	22649863	20829082.52
63.00	370.00	3.44	1272.54	2223.73	47.94	41628.29	195831.73	809.51	44.00	13.22	51.35	793.18	190298.42	11.73	19273675.17	20649661	22575.49	20907.91	22490379	20829082.52
61.00	359.00	3.49	1251.12	2239.85	48.29	41930.02	195253.70	807.80	44.00	13.22	51.35	793.18	190298.42	11.89	19273675.17	20503562	22415.76	20907.91	22331257	20829082.52
59.00	156.00	3.53	550.78	2256.08	48.64	42233.78	194674.71	806.09	44.00	13.22	51.35	793.18	190298.42	12.05	19273675.17	20357785	22256.39	20907.91	22172485	20829082.52
57.00	259.00	3.58	926.24	2272.42	48.99	42539.63	194094.74	804.38	44.00	13.22	51.35	793.18	190298.42	12.20	19273675.17	20212319	22097.36	20907.91	22014052	20829082.52
55.00	372.00	3.62	1347.30	2288.87	49.35	42847.63	193513.75	802.66	44.00	13.22	51.35	793.18	190298.42	12.36	19273675.17	20067153	21938.65	20907.91	21855946	20829082.52
53.00	210.00	3.67	770.14	2305.44	49.71	43157.83	192931.69	800.94	44.00	13.22	51.35	793.18	190298.42	12.51	19273675.17	19922279	21780.27	20907.91	21698157	20829082.52
51.00	239.00	3.71	887.39	2322.13	50.07	43470.30	192348.55	799.22	44.00	13.22	51.35	793.18	190298.42	12.67	19273675.17	19777684	21622.19	20907.91	21540674	20829082.52
49.00	237.00	3.76	890.79	2338.95	50.43	43785.09	191764.27	797.50	44.00	13.22	51.35	793.18	190298.42	12.82	19273675.17	19633361	21464.41	20907.91	21383486	20829082.52
47.00	307.00	3.80	1167.96	2355.89	50.79	44102.26	191178.83	795.78	44.00	13.22	51.35	793.18	190298.42	12.98	19273675.17	19489299	21306.91	20907.91	21226582	20829082.52
45.00	296.00	3.85	1139.71	2372.96	51.16	44421.87	190592.20	794.05	44.00	13.22	51.35	793.18	190298.42	13.14	19273675.17	19345489	21149.69	20907.91	21069952	20829082.52
43.00	318.00	3.90	1239.10	2390.17	51.53	44743.98	190004.32	792.32	43.00	13.29	51.53	792.32	190004.32	13.29	19201920.99	19201921	20992.73	20830.07	20913587	20751537.69
41.00	184.00	3.94	725.50	2407.51	51.91	45068.64	189415.18	790.58	41.00	13.45	51.91	790.58	189415.18	13.45	19058586.49	19058586	20836.03	20674.58	20757475	20596635.94
39.00	284.00	3.99	1133.06	2425.00	52.28	45395.92	188824.74	788.84	39.00	13.61	52.28	788.84	188824.74	13.61	18915476.40	18915476	20679.57	20519.33	20601608	20441976.71
37.00	297.00	4.04	1198.90	2442.62	52.66	45725.86	188232.95	787.10	37.00	13.77	52.66	787.10	188232.95	13.77	18772581.97	18772582	20523.35	20364.32	20445976	20287550.53
35.00	210.00	4.08	857.67	2460.39	53.05	46058.54	187639.79	785.35	35.00	13.94	53.05	785.35	187639.79	13.94	18629894.59	18629895	20367.35	20209.54	20290570	20133348.11
33.00	161.00	4.13	665.26	2478.31	53.43	46393.99	187045.22	783.60	33.00	14.10	53.43	783.60	187045.22	14.10	18487405.86	18487406	20211.58	20054.97	20135379	19979360.39
31.00	114.00	4.18	476.57	2496.38	53.82	46732.30	186449.21	781.85	31.00	14.26	53.82	781.85	186449.21	14.26	18345107.56	18345108	20056.01	19900.60	19980397	19825578.46
29.00	72.00	4.23	304.52	2514.61	54.21	47073.50	185851.72	780.09	29.00	14.43	54.21	780.09	185851.72	14.43	18202991.65	18202992	19900.64	19746.44	19825612	19671993.62
27.00	107.00	4.28	457.86	2533.00	54.61	47417.67	185252.71	778.33	27.00	14.60	54.61	778.33	185252.71	14.60	18061050.24	18061050	19745.46	19592.46	19671018	19518597.38
25.00	73.00	4.33	316.05	2551.54	55.01	47764.86	184652.15	776.56	25.00	14.77	55.01	776.56	184652.15	14.77	17919275.66	17919276	19590.46	19438.67	19516606	19365381.44
23.00	20.00	4.38	87.61	2570.25	55.41	48115.12	184050.00	774.79	23.00	14.95	55.41	774.79	184050.00	14.95	17777660.41	17777660	19435.64	19285.04	19362367	19212337.67
21.00	21.00	4.43	93.08	2589.13	55.82	48468.51	183446.24	773.01	21.00	15.12	55.82	773.01	183446.24	15.12	17636197.17	17636197	19280.98	19131.58	19208294	19059458.19
19.00	25.00	4.49	112.13	2608.18	56.23	48825.10	182840.81	771.23	19.00	15.30	56.23	771.23	182840.81	15.30	17494878.80	17494879	19126.49	18978.28	19054378	18906735.28
17.00	16.00	4.54	72.62	2627.40	56.65	49184.94	182233.70	769.44	17.00	15.49	56.65	769.44	182233.70	15.49	17353698.38	17353698	18972.14	18825.13	18900613	18754161.43
15.00	1.00	4.59	4.59	2646.80	57.07	49548.09	181624.86	767.65	15.00	15.67	57.07	767.65	181624.86	15.67	17212649.14	17212649	18817.93	18672.12	18746991	18601729.36
13.00		4.65	0.00	2666.38	57.49	49914.60	181014.26	765.85	13.00	15.87	57.49	765.85	181014.26	15.87	17071724.51	17071725	18663.87	18519.25	18593504	18449431.95

APPENDIX L:

Mstm (lbm/hr)	Qstm	FERC Efficiency	Total Efficiency	Power/Steam Ratio	Net Heat Rate (BTU_{stm}/BTU_e)	Effective Electrical Efficiency
22575.00	22489892.25	0.48	0.75	0.39	4.31	0.51
22575.00	22489892.25	0.48	0.74	0.40	4.26	0.52
22575.00	22489892.25	0.48	0.74	0.41	4.22	0.52
22575.00	22489892.25	0.48	0.74	0.41	4.18	0.52
22575.00	22489892.25	0.48	0.74	0.42	4.14	0.52
22575.00	22489892.25	0.48	0.74	0.43	4.10	0.52
22575.00	22489892.25	0.48	0.74	0.44	4.07	0.52
22575.00	22489892.25	0.48	0.73	0.44	4.03	0.52
22575.00	22489892.25	0.48	0.73	0.45	4.00	0.52
22575.00	22489892.25	0.48	0.73	0.46	3.97	0.52
22575.00	22489892.25	0.48	0.73	0.47	3.94	0.52
22575.00	22489892.25	0.48	0.73	0.47	3.91	0.52
22575.00	22489892.25	0.48	0.72	0.48	3.88	0.52
22575.00	22489892.25	0.48	0.72	0.49	3.86	0.52
22575.00	22489892.25	0.48	0.72	0.49	3.83	0.52
22575.00	22489892.25	0.48	0.72	0.50	3.81	0.52
22575.00	22489892.25	0.48	0.72	0.51	3.79	0.52
22575.00	22489892.25	0.48	0.72	0.51	3.77	0.52
22575.00	22489892.25	0.48	0.71	0.52	3.74	0.52
22575.00	22489892.25	0.48	0.71	0.53	3.72	0.52
22575.00	22489892.25	0.48	0.71	0.54	3.71	0.52
22575.00	22489892.25	0.48	0.71	0.54	3.69	0.52
22575.00	22489892.25	0.48	0.71	0.55	3.67	0.52
22575.00	22489892.25	0.48	0.70	0.56	3.65	0.52
22575.00	22489892.25	0.48	0.70	0.56	3.64	0.52
22575.00	22489892.25	0.48	0.70	0.57	3.62	0.52
22575.00	22489892.25	0.48	0.70	0.58	3.60	0.52
22575.00	22489892.25	0.48	0.70	0.58	3.59	0.52
22575.00	22489892.25	0.48	0.69	0.59	3.58	0.52
22575.00	22489892.25	0.48	0.69	0.60	3.56	0.52
22575.00	22489892.25	0.48	0.69	0.61	3.55	0.52
22575.00	22489892.25	0.48	0.69	0.61	3.53	0.52
22575.00	22489892.25	0.47	0.69	0.62	3.52	0.52
22575.00	22489892.25	0.47	0.68	0.63	3.51	0.52
22575.00	22489892.25	0.47	0.68	0.63	3.49	0.52
22575.00	22489892.25	0.47	0.68	0.64	3.48	0.52
22575.00	22489892.25	0.47	0.68	0.65	3.47	0.52
22575.00	22489892.25	0.47	0.68	0.66	3.45	0.52
22575.00	22489892.25	0.47	0.68	0.66	3.44	0.52
22575.00	22489892.25	0.47	0.67	0.67	3.43	0.52
22575.00	22489892.25	0.47	0.67	0.68	3.41	0.52
22575.00	22489892.25	0.47	0.67	0.69	3.40	0.52
22575.00	22489892.25	0.47	0.67	0.70	3.39	0.52
22575.00	22489892.25	0.47	0.67	0.71	3.37	0.52
		0.48	0.71	0.55	3.73	0.52

Ratings

TABLE 7 – NOMINAL RATINGS, STEAM MACHINES – ENGLISH

MODEL YIA-ST	CAPACITY (TONS)	CONSUMPTION (LBS/HR)	EVAPORATOR					ABSORBER/CONDENSER				
			INLET (°F)	OUTLET (°F)	FLOW (GPM)	# OF PASS	PRESS. DROP (FT)	INLET (°F)	OUTLET (°F)	FLOW (GPM)	# OF PASS	PRESS. DROP (FT)
1A1	120	2200	54	44	288	3	13	85	101.4	432	3	16
1A2	155	2840	54	44	372	3	24	85	101.4	558	3	28
2A3	172	3140	54	44	413	2	12	85	101.4	620	2	13
2A4	205	3760	54	44	492	2	17	85	101.4	740	2	20
2B1	235	4300	54	44	564	2	12	85	101.4	846	2	19
3B2	273	4960	54	44	656	2	17	85	101.4	980	2	19
3B3	311	5650	54	44	747	2	23	85	101.4	1120	2	27
4B4	334	6120	54	44	802	2	29	85	101.4	1200	1	14
4C1	363	6650	54	44	872	2	14	85	101.4	1308	2	21
5C2	410	7500	54	44	984	2	18	85	101.4	1475	2	20
5C3	446	8200	54	44	1071	2	25	85	101.4	1600	1	12
6C4	518	9500	54	44	1244	2	35	85	101.4	1870	1	17
7D1	565	10,300	54	44	1356	2	21	85	101.4	2030	2	22
7D2	617	11,300	54	44	1481	2	24	85	101.4	2220	1	11
8D3	704	12,800	54	44	1690	2	36	85	101.4	2530	1	15
8E1	794	14,600	54	44	1906	2	26	85	101.4	2860	1	9
9E2	908	16,600	54	44	2180	2	36	85	101.4	3270	1	12
10E3	960	17,600	54	44	2304	1	8	85	101.4	3450	1	16
12F1	1148	21,000	54	44	2756	2	35	85	101.4	4140	1	12
13F2	1235	22,600	54	44	2964	1	7	85	101.4	4450	1	16
14F3	1377	25,200	54	44	3305	1	10	85	101.4	4960	1	22

NOTES:

1. All IsoFlow Chillers are rated according to ARI 560-2000. Ratings in Tables above represent unit performance at nominal conditions. For full and part load conditions at specific conditions, contact your local YORK office.

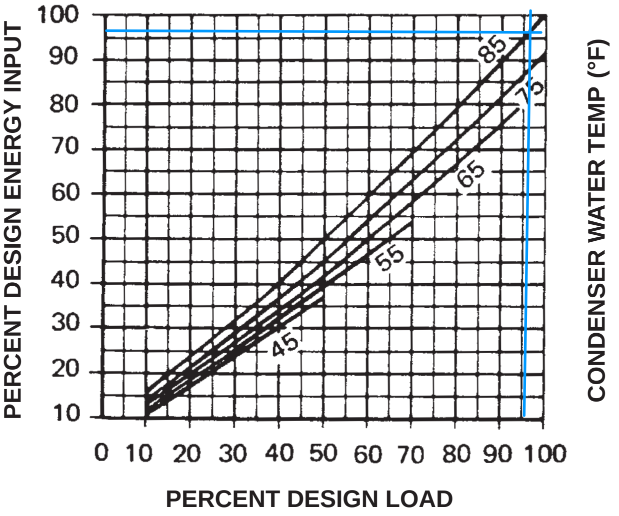


FIG. 9 – TYPICAL PART LOAD ENERGY CONSUMPTION – STANDARD UNIT

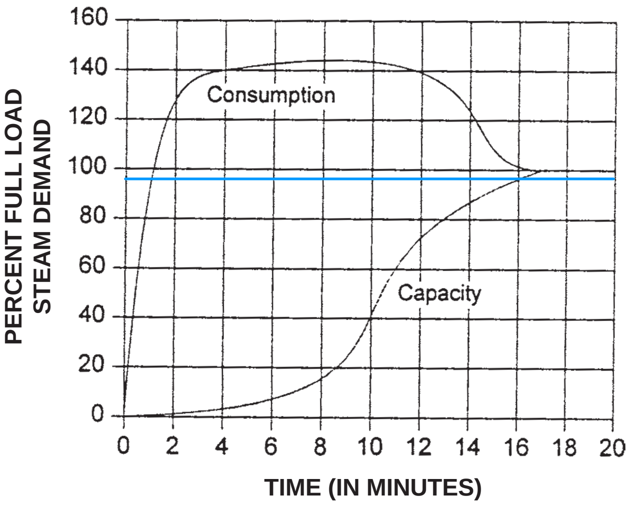


FIG. 10 — TYPICAL CHILLER START-UP PERFORMANCE (Based on NO LOAD LIMITING at startup)

Ratings

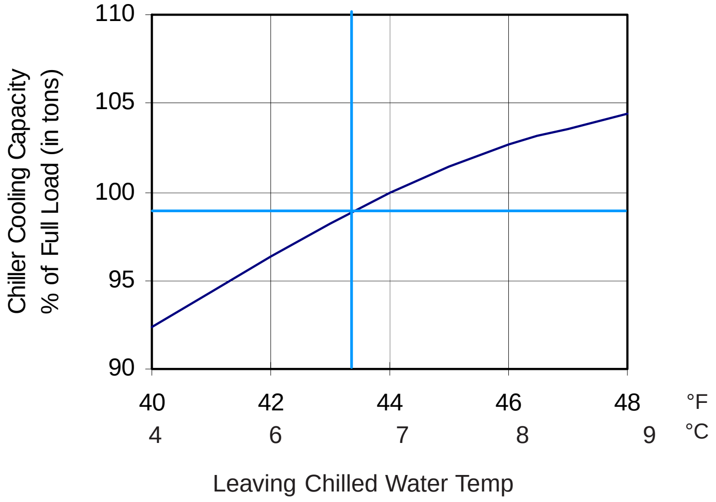


FIG. 11 – TYPICAL CHILLER COOLING CAPACITY FOR REQUIRED LCHWT

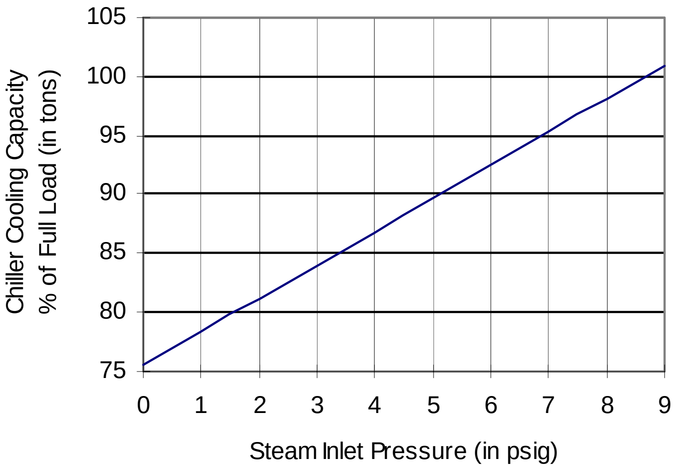


FIG. 12 – TYPICAL CHILLER COOLING CAPACITY FOR AVAILABLE STEAM INLET PRESSURE

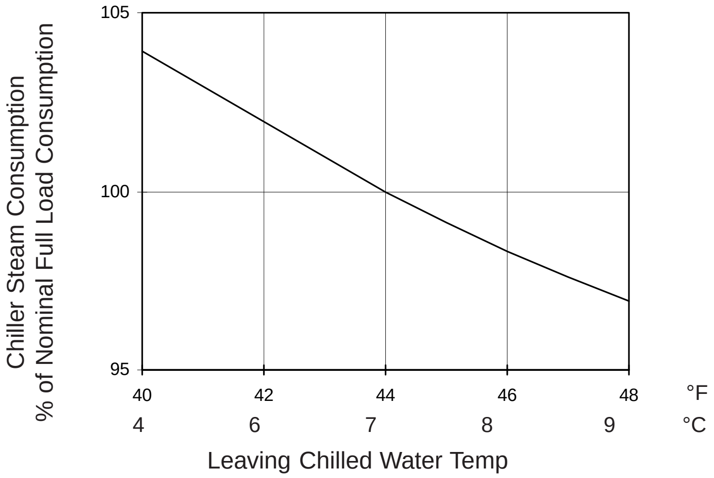


FIG. 13 – TYPICAL CHILLER STEAM CONSUMPTION FOR LCHWT

Electrical Data

TABLE 14 – ELECTRICAL RATINGS

Chiller Model	Voltage (Volts-Ph-Hz)	Solution Pump		Refrigerant Pump		Purge Pump		Minimum Circuit Ampacity	Disconnect Switch (Customer supplied)	Max-Dual Elem. Fuse (Customer supplied)	Total KW
		FLA	LRA	FLA	LRA	FLA	LRA				
1A1	200/208-3-60	12.5	51.0	12.5	51.0	2.10	14.2	35.2	60	45	5.9
	230-3-60	12.0	55.0	12.0	55.0	2.20	12.8	33.5	60	45	5.9
	380-3-50	6.5	23.0	6.5	23.0	1.10	5.4	18.3	30	20	5.9
	400-3-50	6.3	24.5	6.3	24.5	1.05	5.1	17.7	30	20	5.9
	460-3-60	6.0	27.5	6.0	27.5	1.10	6.2	16.8	30	20	5.9
	575-3-60	4.9	24.0	4.9	24.0	1.00	4.9	13.7	30	15	5.9
1A2	200/208-3-60	12.5	51.0	12.5	51.0	2.10	14.2	35.2	60	45	5.9
	230-3-60	12.0	55.0	12.0	55.0	2.20	12.8	33.5	60	45	5.9
	380-3-50	6.5	23.0	6.5	23.0	1.10	5.4	18.3	30	20	5.9
	400-3-50	6.3	24.5	6.3	24.5	1.05	5.1	17.7	30	20	5.9
	460-3-60	6.0	27.5	6.0	27.5	1.10	6.2	16.8	30	20	5.9
	575-3-60	4.9	24.0	4.9	24.0	1.00	4.9	13.7	30	15	5.9
2A3	200/208-3-60	12.5	51.0	12.5	51.0	2.10	14.2	35.2	60	45	5.9
	230-3-60	12.0	55.0	12.0	55.0	2.20	12.8	33.5	60	45	5.9
	380-3-50	6.5	23.0	6.5	23.0	1.10	5.4	18.3	30	20	5.9
	400-3-50	6.3	24.5	6.3	24.5	1.05	5.1	17.7	30	20	5.9
	460-3-60	6.0	27.5	6.0	27.5	1.10	6.2	16.8	30	20	5.9
	575-3-60	4.9	24.0	4.9	24.0	1.00	4.9	13.7	30	15	5.9
2A4	200/208-3-60	12.5	51.0	12.5	51.0	2.10	14.2	35.2	60	45	5.9
	230-3-60	12.0	55.0	12.0	55.0	2.20	11.2	33.5	60	45	5.9
	380-3-50	6.5	23.0	6.5	23.0	1.10	5.4	18.3	30	20	5.9
	400-3-50	6.3	24.5	6.3	24.5	1.05	5.1	17.7	30	20	5.9
	460-3-60	6.0	27.5	6.0	27.5	1.10	6.2	16.8	30	20	5.9
	575-3-60	4.9	24.0	4.9	24.0	1.00	4.9	13.7	30	15	5.9
2B1	200/208-3-60	12.5	51.0	12.5	51.0	2.10	14.2	35.2	60	45	5.9
	230-3-60	12.0	55.0	12.0	55.0	2.20	12.8	33.5	60	45	5.9
	380-3-50	6.5	23.0	6.5	23.0	1.10	5.4	18.3	30	20	5.9
	400-3-50	6.3	24.5	6.3	24.5	1.05	5.1	17.7	30	20	5.9
	460-3-60	6.0	27.5	6.0	27.5	1.10	6.2	16.8	30	20	5.9
	575-3-60	4.9	24.0	4.9	24.0	1.00	4.9	13.7	30	15	5.9
3B2	200/208-3-60	20.0	78.00	12.5	51.0	2.10	14.2	44.6	60	60	7.3
	230-3-60	19.0	80.00	12.0	55.0	2.20	12.8	42.3	60	60	7.3
	380-3-50	6.5	23.0	6.5	23.0	1.10	5.4	18.3	30	20	7.3
	400-3-50	6.3	24.5	6.3	24.5	1.05	5.1	17.7	30	20	7.3
	460-3-60	9.5	40.0	6.0	27.5	1.10	6.2	21.2	30	30	7.3
	575-3-60	7.8	33.0	4.9	24.0	1.00	4.9	17.4	30	25	7.3
3B3	200/208-3-60	20.0	78.00	12.5	51.0	2.10	14.2	44.6	60	60	7.3
	230-3-60	19.0	80.00	12.0	55.0	2.20	12.8	42.3	60	60	7.3
	380-3-50	9.5	38.0	6.5	23.0	1.10	5.4	22.1	30	30	7.3
	400-3-50	10.4	39.0	6.3	24.5	1.05	5.1	22.9	30	30	7.3
	460-3-60	9.5	40.0	6.0	27.5	1.10	6.2	21.2	30	30	7.3
	575-3-60	7.8	33.0	4.9	24.0	1.00	4.9	17.4	30	25	7.3
4B4	200/208-3-60	20.0	78.00	12.5	51.0	2.10	14.2	44.6	60	60	7.3
	230-3-60	19.0	80.00	12.0	55.0	2.20	12.8	42.3	60	60	7.3
	380-3-50	9.5	38.0	6.5	23.0	1.10	5.4	22.1	30	30	7.3
	400-3-50	10.4	39.0	6.3	24.5	1.05	5.1	22.9	30	30	7.3
	460-3-60	9.5	40.0	6.0	27.5	1.10	6.2	21.2	30	30	7.3
	575-3-60	7.8	33.0	4.9	24.0	1.00	4.9	17.4	30	25	7.3
4C1	200/208-3-60	20.0	78.00	12.5	51.0	2.10	14.2	44.6	60	60	7.3
	230-3-60	19.0	80.00	12.0	55.0	2.20	12.8	42.3	60	60	7.3
	380-3-50	9.5	38.0	6.5	23.0	1.10	5.4	22.1	30	30	7.3
	400-3-50	10.4	39.0	6.3	24.5	1.05	5.1	22.9	30	30	7.3
	460-3-60	9.5	40.0	6.0	27.5	1.10	6.2	21.2	30	30	7.3
	575-3-60	7.8	33.0	4.9	24.0	1.00	4.9	17.4	30	25	7.3
5C2	200/208-3-60	20.0	78.00	12.5	51.0	2.10	14.2	44.6	60	60	7.3
	230-3-60	19.0	80.00	12.0	55.0	2.20	12.8	42.3	60	60	7.3
	380-3-50	11.0	40.0	6.5	23.0	1.10	5.4	24.0	30	30	7.3
	400-3-50	10.7	42.0	6.3	24.5	1.05	5.1	23.2	30	30	7.3
	460-3-60	9.5	40.0	6.0	27.5	1.10	6.2	21.2	30	30	7.3
	575-3-60	7.8	33.0	4.9	24.0	1.00	4.9	17.4	30	25	7.3
5C3	200/208-3-60	20.0	78.00	12.5	51.0	2.10	14.2	44.6	60	60	7.3
	230-3-60	19.0	80.00	12.0	55.0	2.20	12.8	42.3	60	60	7.3
	380-3-50	11.0	40.0	6.5	23.0	1.10	5.4	24.0	30	30	7.3
	400-3-50	10.7	42.0	6.3	24.5	1.05	5.1	23.2	30	30	7.3
	460-3-60	9.5	40.0	6.0	27.5	1.10	6.2	21.2	30	30	7.3
	575-3-60	7.8	33.0	4.9	24.0	1.00	4.9	17.4	30	25	7.3

Example COP Calculation

COP for an absorption chiller is calculated with the following equation:

$$\text{COP} = \frac{Q_{\text{output}}}{Q_{\text{input}}} = \frac{\text{Capacity (tons)} \bullet 12{,}000 \text{ (Btuh / ton)}}{\text{Mass Flow} \bullet \text{Enthalpy}}$$

The example chiller has the following operating conditions:

Capacity	1025 tons
ECHWT/LCHWT	50°F / 40°F
ECWT/LCWT	85°F / 97.4°F
Steam Pressure	2.5 psig (dry saturated)
Steam Flow Rate	18806.8 lbs./hr.
Standard fouling in all circuits	

From the steam tables, 2.5 psig (17.2 PSIA) is:

Steam Temperature	219.5°F
Enthalpy of Condensate	180.5 Btu/lb.
Enthalpy of Steam	1150.6 Btu/lb.
Difference	970.1 Btu/lb.

$$\text{COP} = \frac{\text{1025 tons} \bullet 12{,}000 \text{ (Btuh / ton)}}{\text{18806.8 lbs./hr.} \bullet \text{970.1 Btu/lb.}} = 0.67$$

INTEGRATED PART LOAD VALUE (IPLV)

In the English I-P system, IPLV is calculated by the following formula:

$$\begin{array}{l}\text{IPLV}\\ \text{or}\\ \text{APLV}\end{array} = \frac{1}{\frac{0.01}{A} + \frac{0.42}{B} + \frac{0.45}{C} + \frac{0.12}{D}}$$

Where: A = Kw / ton at 100% Load
B = Kw / ton at 75% Load
C = Kw / ton at 50% Load
D = Kw / ton at 25% Load

In SI Metric, the formula is:

$$\begin{array}{l}\text{IPLV}\\ \text{or}\\ \text{APLV}\end{array} = 0.01A + 0.42B + 0.45C + 0.12D$$

Where: A = COP at 100% Load
B = COP at 75% Load
C = COP at 50% Load
D = COP at 25% Load

TABLE 9 – IPLV ANALYSIS

LOAD %	ENTERING CONDENSER WATER TEMP (°F)	COP	WEIGHTING FACTOR (FROM ARI 560-92)	WEIGHTED AVERAGE COP
100	85.00	0.69	0.01	0.007
75	78.75	0.74	0.42	0.311
50	72.50	0.86	0.45	0.387
25	68.00	0.77	0.12	0.093

IPLV (expressed as a COP) = 0.798

TABLE 10 – FOULING FACTOR

ENGLISH I-P	EQUIVALENT SI METRIC
(ft^2 °F hr/Btu)	(m^2 °C/W)
0.00025	0.000044
0.0005	0.000088
0.00075	0.000132

Marley UPDATE™ Version 4.8.1
Product Data: 3/16/2007 (Current)

4/9/2007 3:34:19 PM

Job Information

VIMS SeaLab

Virginia

Selected By

Penn State
104 Engineering Unit A
University Park, PA
wpb5@psu.edu

PSUAE
Tel 814-863-2076

SPX Cooling Technologies Contact

H & H Associates, Inc.
4510 Westport Drive
Mechanicsburg, PA 17055
frank@hhassociates.com

Tel 717-796-2401
Fax 717-796-9717

Cooling Tower Definition

Manufacturer	Marley	Fan Motor Speed	1200 rpm	Design Range	16.40 °F
Product	NC Class	Fan Motor Output per cell	15.00 BHp	Design Wet-Bulb	76.00 °F
Model	NC8303FL1	Fan Motor Efficiency	90.0 %	Cold Water Set Point	85.00 °F
Cells	1	Tower Water Flow	620.0 gpm	Average Wet-Bulb	76.00 °F
Fan	7.000 ft, 8 Blades	Static Lift	11.151 ft	Range at Avg. Wet-Bulb	16.40 °F
Fans per cell	1	Pump Efficiency	70.0 %	Maximum Wet-Bulb	76.00 °F
Wet-Bulb Profile	Linear				

Interval Information					Single-Speed Fan			Two-Speed Fan				Variable-Speed Fan		Pump
Wet-Bulb Interval °F		Cold Water °F	Range °F	Hours	Hours Full	Hours Off	Energy kWh	Hours Full	Hours Half	Hours Off	Energy kWh	Total Fan Motor Output BHp	Energy kWh	Energy kWh
76.00	76.00	85.00	16.40	8760.0	8663.4	96.6	107673.4	7857.5	902.5	0.0	99259.7	11.54	83728.1	16310.0
		Totals		8760.0	8663.4	96.6	107673.4	7857.5	902.5	0.0	99259.7		83728.1	16310.0

Marley UPDATE™ Version 4.8.1
Product Data: 3/16/2007 (Current)

4/9/2007 3:33:56 PM

Job Information

VIMS SeaLab

Virginia

Selected By

Penn State
104 Engineering Unit A
University Park, PA
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PSUAE
Tel 814-863-2076

SPX Cooling Technologies Contact

H & H Associates, Inc.
4510 Westport Drive
Mechanicsburg, PA 17055
frank@hhassociates.com

Tel 717-796-2401
Fax 717-796-9717

Cooling Tower Definition

Manufacturer	Marley	Fan Motor Speed	1200 rpm
Product	NC Class	Fan Motor Capacity per cell	15.00 BHp
Model	NC8303FL1	Fan Motor Output per cell	15.00 BHp
Cells	1	Fan Motor Output total	15.00 BHp
CTI Certified	Yes	Air Flow per cell	85860 cfm
Fan	7.000 ft, 8 Blades	Air Flow total	85860 cfm
Fan Speed	359 rpm, 7894.8 fpm	ASHRAE 90.1 Performance	63.4 gpm/Hp
Fans per cell	1		

Model Group	Low Noise Fan (L)
Sound Pressure Level	76 dBA (Single Cell), 5.000 ft from Air Inlet Face. See sound report for details.

Conditions

Tower Water Flow	620.0 gpm	Air Density In	0.07130 lb/ft³
Hot Water Temperature	101.40 °F	Air Density Out	0.07104 lb/ft³
Range	16.40 °F	Humidity Ratio In	0.01585
Cold Water Temperature	85.00 °F	Humidity Ratio Out	0.03008
Approach	9.00 °F	Wet-Bulb Temp. Out	88.91 °F
Wet-Bulb Temperature	76.00 °F	Estimated Evaporation	10.1 gpm
Relative Humidity	50 %	Total Heat Rejection	5063200 Btu/h

- This selection satisfies your design conditions.

Weights & Dimensions

	Per Cell	Total
Shipping Weight	5840 lb	5840 lb
Max Operating Weight	12100 lb	12100 lb
Width	15.500 ft	15.500 ft
Length	7.896 ft	7.896 ft
Height	11.937 ft	
Static Lift	11.151 ft	

Minimum Enclosure Clearance

Clearance required on air inlet sides of tower without altering performance. Assumes no air from below tower.

Solid Wall	5.184 ft
50 % Open Wall	3.823 ft

Weights and dimensions do not include options; refer to sales drawings. For CAD layouts refer to file NC8303.dxf

Cold Weather Operation

Heater Sizing (to prevent freezing in the collection basin during periods of shutdown)

Heater kW/Cell	12.0	9.0	7.5	6.0	4.5	3.0
Ambient Temperature °F	-21.75	-5.25	3.00	11.25	19.50	27.75

Marley UPDATE™ Version 4.8.1
Product Data: 3/16/2007 (Current)

4/9/2007 8:53:57 PM

Job Information
VIMS SeaLab

Virginia

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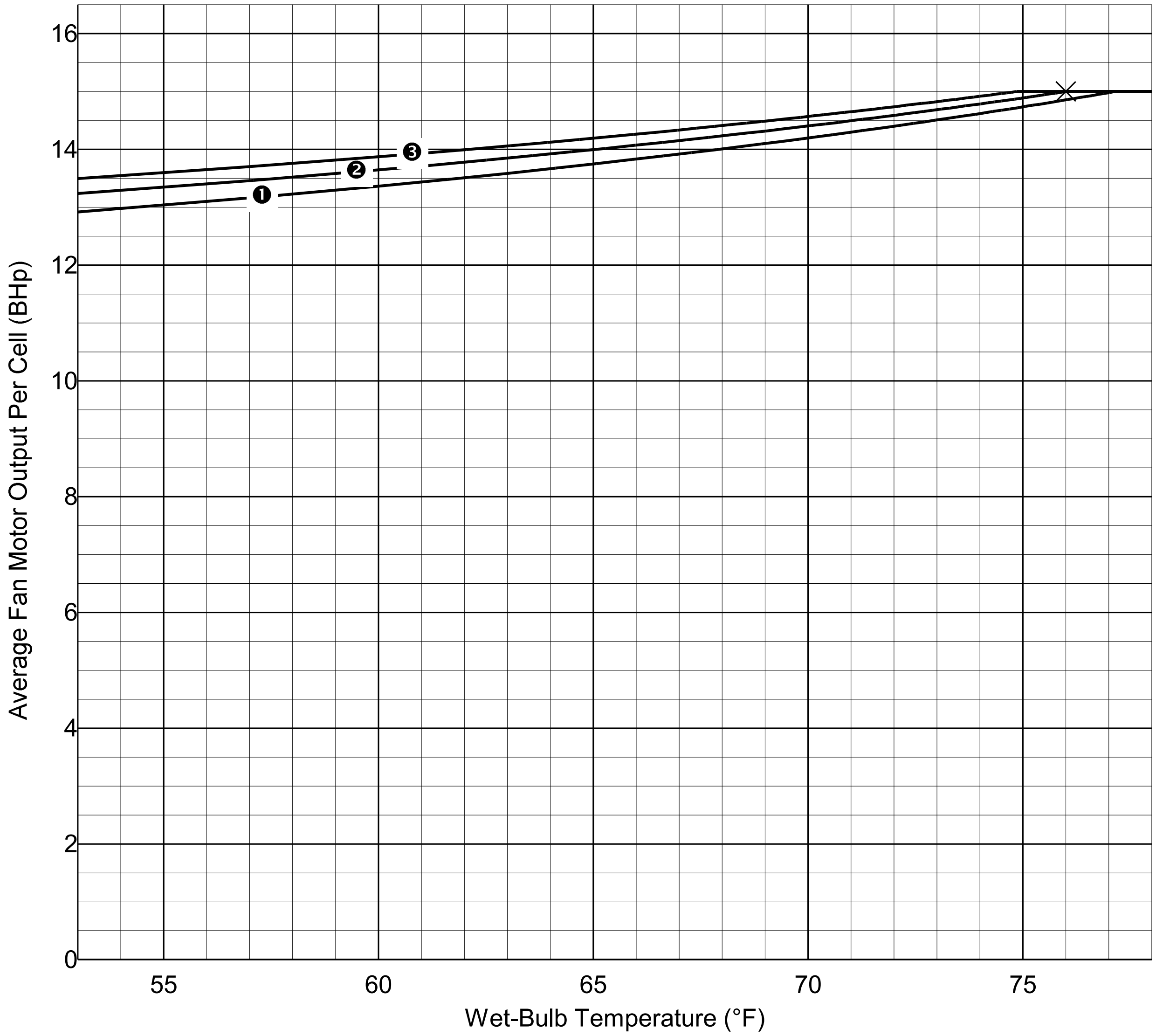
Fax

Cooling Tower Definition

Manufacturer	Marley
Product	NC Class
Model	NC8303FL1
Cells	1
Fan	7.000 ft, 8 Blades
Fans per cell	1
Fan Motor Capacity per cell	15.00 BHp



Design Conditions

Tower Water Flow	620.0 gpm
Hot Water Temperature	101.40 °F
Cold Water Temperature	85.00 °F
Wet-Bulb Temperature	76.00 °F

Curve Conditions

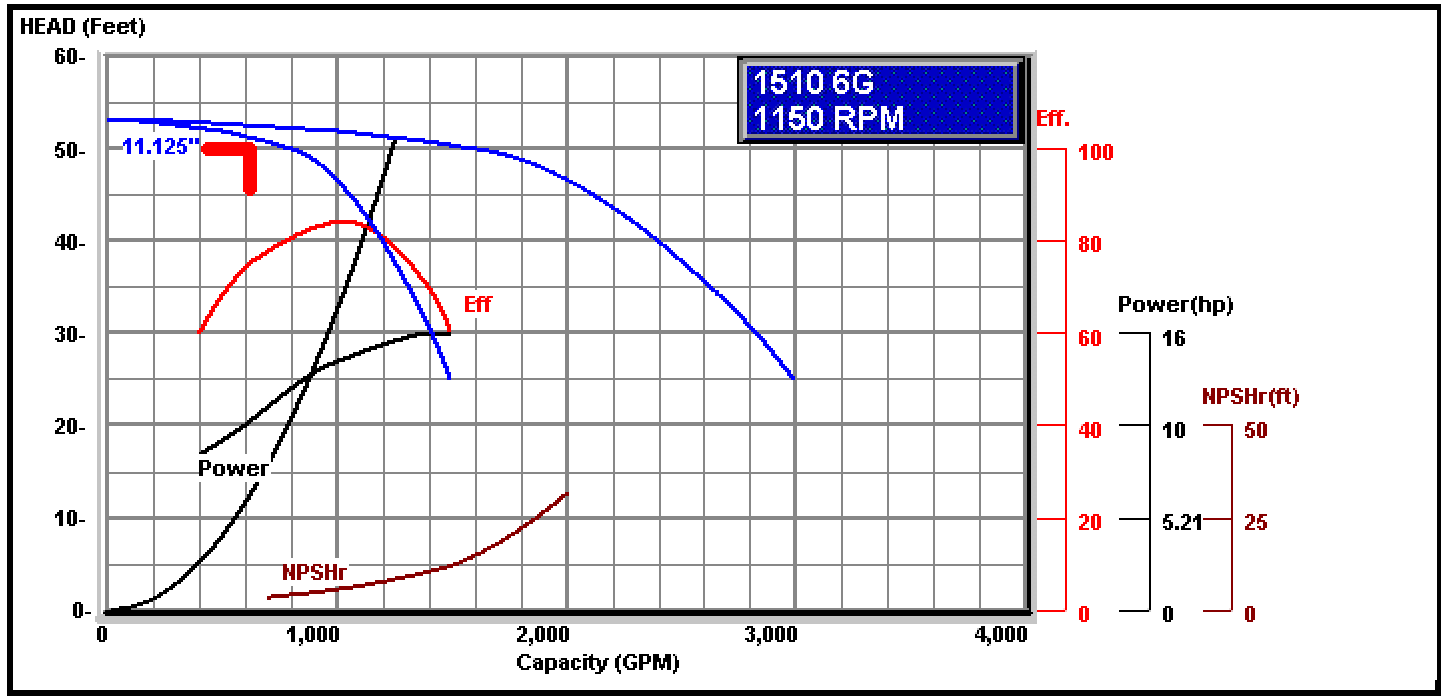
Tower Water Flow (100.0 %)	620.0 gpm
Cold Water Set Point	85.00 °F
Fan Operation	Single-Speed

Legend

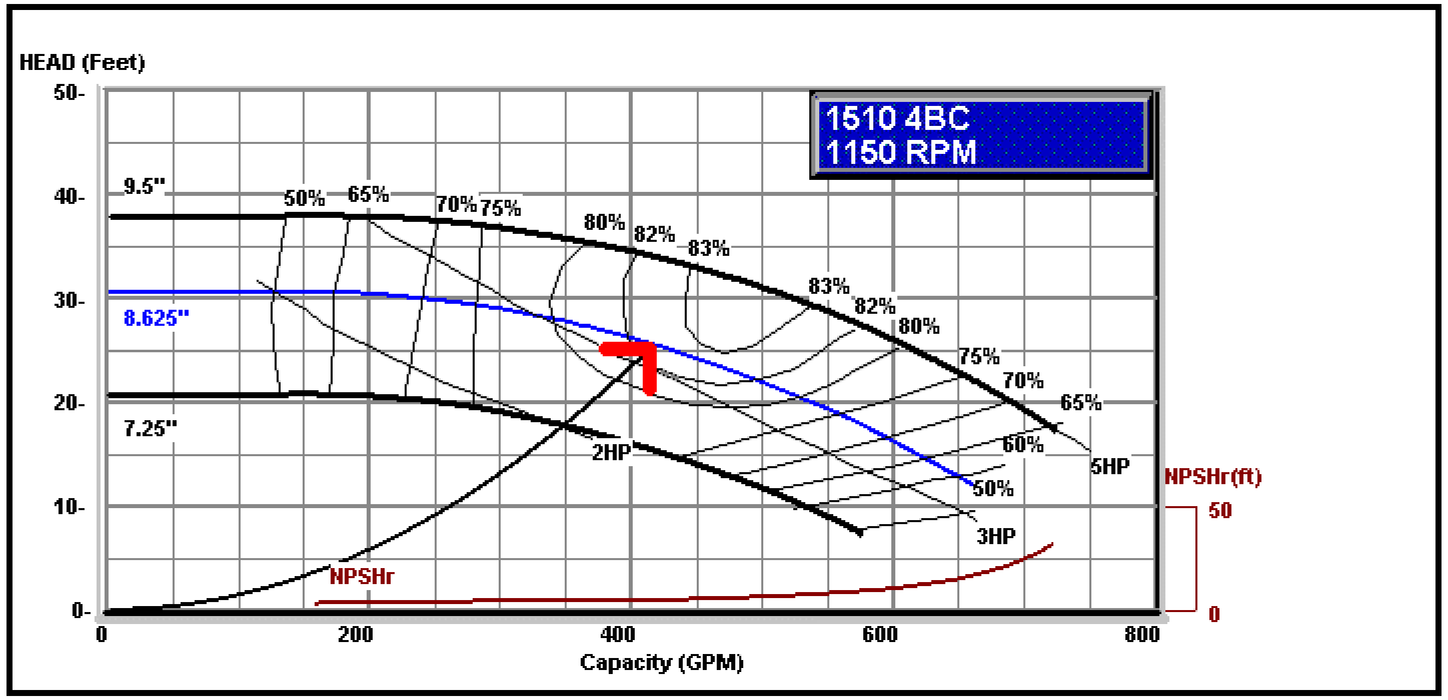
❶ 14.4 °F Range
❷ 16.4 °F Range
❸ 18.4 °F Range
× Design Point

APPENDIX G:

DETAIL SUMMARY FOR CONDENSER WATER PUMP			
Pump Series:	1510	Pump Size:	6G
Flow Rate: (USGPM)	620	Total Head: (ft.)	50
Pump Speed (RPM)	1150	NPSH req (ft)	3.5
Weight: (lbs)	970	Cost Index:	185
Suction Size: (in)	8	Suction Velocity (fps)	4
Discharge Size: (in)	6	Discharge Velocity: (fps)	6.9
Impeller Diameter: (in)	11.125	Efficiency: (%)	75.32
Max Impeller Dia (in)	13.5		
Max Flow (USGPM)	1491	Duty Flow/Max Flow (%)	0.42
Flow @ BEP (USGPM)	1010	Min. Rec. Flow: (USGPM)	400
Motor Power, HP:	15	Frame Size:	284T
Pump Power (BHP)	10.58		
Max Power (BHP)	15.49	Aprox Wt (lbs)	



DETAIL SUMMARY FOR CHILLED AND HOT WATER PUMP			
Pump Series:	1510	Pump Size:	4BC
Flow Rate: (USGPM)	413.5	Total Head: (ft.)	25
Pump Speed (RPM)	1150	NPSH req (ft)	4.7
Weight: (lbs)	410	Cost Index:	130
Suction Size: (in)	5	Suction Velocity (fps)	6.6
Discharge Size: (in)	4	Discharge Velocity: (fps)	10.4
Impeller Diameter: (in)	8.625	Efficiency: (%)	81.95
Max Impeller Dia (in)	9.5		
Max Flow (USGPM)	661	Duty Flow/Max Flow (%)	0.63
Flow @ BEP (USGPM)	433	Min. Rec. Flow: (USGPM)	100
Motor Power, HP:	5	Frame Size:	215T
Pump Power (BHP)	3.23		
Max Power (BHP)	3.46	Aprox Wt (lbs)	



APPENDIX H:

Source	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Electricity (cents/kWh)	8.33	8.24	8.11	7.92	7.82	7.77	7.73	7.73	7.78	7.87	7.93	7.91	7.94	7.96	7.96	7.99	8.03	8.05	8.03	8.03	8.05	8.09	8.09
Natural Gas ($/MMBTU)	8.92	8.37	8.07	7.67	7.51	7.31	7.33	7.28	7.37	7.57	7.51	7.46	7.54	7.53	7.66	7.80	7.92	7.91	7.96	8.06	8.18	8.27	8.33
Electricity ($/MMBTU)	24.41	24.14	23.78	23.20	22.92	22.78	22.65	22.65	22.80	23.06	23.24	23.19	23.26	23.32	23.34	23.41	23.53	23.58	23.54	23.54	23.59	23.70	23.70
Spark Gap	15.49	15.77	15.71	15.53	15.41	15.47	15.33	15.38	15.43	15.49	15.73	15.73	15.72	15.79	15.67	15.61	15.61	15.67	15.57	15.48	15.41	15.43	15.37
CHP Energy Cost	938205	880202	848420	806311	789405	768174	770590	765083	774598	795715	789504	784652	792878	791393	805489	819869	833134	831725	837245	847086	859764	869402	875656
Existing System Energy Cost	801689	792903	780848	762010	752564	748020	744008	743993	748666	757313	763260	761694	763866	765849	766358	768825	772706	774381	773000	772948	774566	778222	778398
Watermen's Hall Energy Cost	142869	141304	139155	135798	134115	133305	132590	132587	133420	134961	136021	135742	136129	136482	136573	137013	137704	138003	137757	137748	138036	138687	138719
Nunnally Hall Energy Cost	158598	156860	154475	150748	148880	147981	147187	147184	148109	149819	150996	150686	151116	151508	151609	152097	152864	153196	152923	152912	153232	153956	153991
Wetlands Facility Energy Cost	6717	6643	6542	6384	6305	6267	6233	6233	6272	6345	6395	6382	6400	6416	6421	6441	6474	6488	6476	6476	6489	6520	6521
Chesapeake Bay Hall Energy Cost	567687	561466	552930	539590	532901	529684	526843	526832	530141	536264	540475	539366	540904	542308	542669	544416	547164	548350	547372	547335	548481	551070	551195
Geddings House Energy Cost	5139	5083	5005	4885	4824	4795	4769	4769	4799	4855	4893	4883	4897	4909	4913	4928	4953	4964	4955	4955	4965	4989	4990
Wilson House (CBNERR)	35585	35195	34659	33823	33404	33202	33024	33024	33231	33615	33879	33809	33906	33994	34016	34126	34298	34372	34311	34309	34381	34543	34551
DCOP Facility Energy Cost	6632	6559	6459	6303	6225	6188	6154	6154	6193	6264	6314	6301	6319	6335	6339	6360	6392	6406	6394	6394	6407	6437	6439
CBNERRVA AnnexEnergy	48710	48176	47443	46299	45725	45449	45205	45204	45488	46013	46375	46279	46411	46532	46563	46713	46949	47050	46966	46963	47062	47284	47294
Total Existing Cost	1773625	1754187	1727518	1685840	1664943	1654890	1646015	1645980	1656320	1675448	1688606	1685141	1689947	1694333	1695460	1700919	1709503	1713209	1710155	1710040	1713619	1721708	1722098
Savings	835420	873985	879097	879529	875538	886716	875425	880897	881721	879733	899102	900489	897070	902940	889970	881049	876369	881484	872909	862954	853854	852306	846442
22 Year Energy Savings	20165001																						

APPENDIX I:

	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Energy Savings	835420	873985	879097	879529	875538	886716	875425	880897	881721	879733	899102	900489	897070	902940	889970	881049	876369	881484	872909	862954	853854	852306	846442
Total Annual Maintenance	292744	292744	292744	292744	292744	292744	292744	292744	292744	292744	292744	292744	292744	292744	292744	292744	292744	292744	292744	292744	292744	292744	292744
Net Annual Savings	542676	581241	586354	586785	582794	593972	582681	588153	588978	586990	606358	607745	604326	610197	597227	588306	583625	588741	580166	570210	561111	559562	553698
Life Savings At Year End	542676	1123917	1710271	1710271	2879850	3473822	4056503	4644657	5233634	5820624	6426982	7034728	7639054	8249250	8846477	9434783	10018408	10607148	11187314	11757524	12318635	12878197	13431896
New Mechanical	6020920	6020920	6020920	6020920	6020920	6020920	6020920	6020920	6020920	6020920	6020920	6020920	6020920	6020920	6020920	6020920	6020920	6020920	6020920	6020920	6020920	6020920	6020920
Total Net Life Savings	-5478244	-4897002	-4310649	-4310649	-3141070	-2547097	-1964416	-1376263	-787285	-200296	406063	1013808	1618134	2228331	2825557	3413863	3997488	4586229	5166395	5736605	6297716	6857278	7410976

APPENDIX J:

Ambient Temp (^oF)	Hours	Mwe$^-$	Mwe$^-$h	Fuel Flow (lbm/hr)	lbm - mole C_3H_8/hr	Fuel Flow (MMBTU/hr)	Air Flow (lbm/hr)	Exhaust Flow (lbm/hr)	Exhaust H_2O (lbm/hr)	Exhaust CO_2 (lbm/hr)	Exhaust O_2 (lbm/hr)	Exhaust N_2 (lbm/hr)	Exhuast Temp (^oF)	SO_2 Generation (lbm/hr)	NO_x Generation (lbm/hr)
99.00	2.00	2.59	5.17	1948.65	44.29	42.01	36478.64	206113.46	17103.27	1948.65	7601.46	150052.72	840.21	0.00001417	0.55
97.00	4.00	2.64	10.54	1963.34	44.62	42.33	36753.70	205546.56	17056.23	1963.34	7580.55	149640.02	838.50	0.00001428	0.54
95.00	4.00	2.68	10.74	1978.08	44.96	42.65	37029.75	204979.35	17009.17	1978.08	7559.63	149227.08	836.79	0.00001439	0.54
93.00	15.00	2.73	40.99	1992.89	45.29	42.97	37306.84	204411.78	16962.07	1992.89	7538.70	148813.88	835.09	0.00001449	0.54
91.00	58.00	2.78	161.33	2007.75	45.63	43.29	37585.04	203843.82	16914.94	2007.75	7517.75	148400.40	833.38	0.00001460	0.54
89.00	66.00	2.83	186.77	2022.67	45.97	43.61	37864.41	203275.44	16867.78	2022.67	7496.79	147986.61	831.67	0.00001471	0.54
87.00	115.00	2.88	330.97	2037.66	46.31	43.93	38144.99	202706.59	16820.57	2037.66	7475.81	147572.49	829.97	0.00001482	0.54
85.00	150.00	2.93	438.88	2052.72	46.65	44.26	38426.85	202137.25	16773.33	2052.72	7454.81	147158.00	828.27	0.00001493	0.54
83.00	184.00	2.97	547.14	2067.84	47.00	44.58	38710.05	201567.38	16726.04	2067.84	7433.80	146743.13	826.56	0.00001504	0.53
81.00	223.00	3.02	673.69	2083.05	47.34	44.91	38994.64	200996.94	16678.71	2083.05	7412.76	146327.84	824.86	0.00001515	0.53
79.00	320.00	3.07	981.86	2098.33	47.69	45.24	39280.68	200425.90	16631.32	2098.33	7391.70	145912.12	823.16	0.00001526	0.53
77.00	190.00	3.12	591.91	2113.69	48.04	45.57	39568.24	199854.23	16583.88	2113.69	7370.62	145495.94	821.45	0.00001537	0.53
75.00	402.00	3.16	1271.19	2129.13	48.39	45.90	39857.36	199281.88	16536.39	2129.13	7349.51	145079.26	819.75	0.00001548	0.53
73.00	701.00	3.21	2249.35	2144.66	48.74	46.24	40148.11	198708.83	16488.84	2144.66	7328.37	144662.07	818.05	0.00001560	0.53
71.00	504.00	3.26	1640.62	2160.29	49.10	46.58	40440.55	198135.03	16441.23	2160.29	7307.21	144244.34	816.34	0.00001571	0.53
69.00	403.00	3.30	1330.49	2176.00	49.45	46.91	40734.72	197560.46	16393.55	2176.00	7286.02	143826.05	814.64	0.00001583	0.52
67.00	329.00	3.35	1101.34	2191.81	49.81	47.26	41030.70	196985.08	16345.80	2191.81	7264.80	143407.16	812.93	0.00001594	0.52
65.00	382.00	3.39	1296.31	2207.72	50.18	47.60	41328.54	196408.84	16297.99	2207.72	7243.55	142987.66	811.22	0.00001606	0.52
63.00	370.00	3.44	1272.54	2223.73	50.54	47.94	41628.29	195831.73	16250.10	2223.73	7222.27	142567.52	809.51	0.00001617	0.52
61.00	359.00	3.49	1251.12	2239.85	50.91	48.29	41930.02	195253.70	16202.13	2239.85	7200.95	142146.70	807.80	0.00001629	0.52
59.00	156.00	3.53	550.78	2256.08	51.27	48.64	42233.78	194674.71	16154.09	2256.08	7179.60	141725.20	806.09	0.00001641	0.52
57.00	259.00	3.58	926.24	2272.42	51.65	48.99	42539.63	194094.74	16105.96	2272.42	7158.21	141302.97	804.38	0.00001653	0.52
55.00	372.00	3.62	1347.30	2288.87	52.02	49.35	42847.63	193513.75	16057.75	2288.87	7136.78	140880.00	802.66	0.00001665	0.51
53.00	210.00	3.67	770.14	2305.44	52.40	49.71	43157.83	192931.69	16009.45	2305.44	7115.31	140456.26	800.94	0.00001677	0.51
51.00	239.00	3.71	887.39	2322.13	52.78	50.07	43470.30	192348.55	15961.06	2322.13	7093.81	140031.72	799.22	0.00001689	0.51
49.00	237.00	3.76	890.79	2338.95	53.16	50.43	43785.09	191764.27	15912.58	2338.95	7072.26	139606.37	797.50	0.00001701	0.51
47.00	307.00	3.80	1167.96	2355.89	53.54	50.79	44102.26	191178.83	15864.00	2355.89	7050.67	139180.16	795.78	0.00001713	0.51
45.00	296.00	3.85	1139.71	2372.96	53.93	51.16	44421.87	190592.20	15815.32	2372.96	7029.03	138753.08	794.05	0.00001726	0.51
43.00	318.00	3.90	1239.10	2390.17	54.32	51.53	44743.98	190004.32	15766.54	2390.17	7007.35	138325.10	792.32	0.00001738	0.51
41.00	184.00	3.94	725.50	2407.51	54.72	51.91	45068.64	189415.18	15717.65	2407.51	6985.62	137896.20	790.58	0.00001751	0.50
39.00	284.00	3.99	1133.06	2425.00	55.11	52.28	45395.92	188824.74	15668.66	2425.00	6963.85	137466.35	788.84	0.00001764	0.50
37.00	297.00	4.04	1198.90	2442.62	55.51	52.66	45725.86	188232.95	15619.55	2442.62	6942.02	137035.53	787.10	0.00001776	0.50
35.00	210.00	4.08	857.67	2460.39	55.92	53.05	46058.54	187639.79	15570.33	2460.39	6920.15	136603.70	785.35	0.00001789	0.50
33.00	161.00	4.13	665.26	2478.31	56.33	53.43	46393.99	187045.22	15520.99	2478.31	6898.22	136170.85	783.60	0.00001802	0.50
31.00	114.00	4.18	476.57	2496.38	56.74	53.82	46732.30	186449.21	15471.54	2496.38	6876.24	135736.95	781.85	0.00001816	0.50
29.00	72.00	4.23	304.52	2514.61	57.15	54.21	47073.50	185851.72	15421.96	2514.61	6854.20	135301.96	780.09	0.00001829	0.50
27.00	107.00	4.28	457.86	2533.00	57.57	54.61	47417.67	185252.71	15372.25	2533.00	6832.11	134865.88	778.33	0.00001842	0.49
25.00	73.00	4.33	316.05	2551.54	57.99	55.01	47764.86	184652.15	15322.42	2551.54	6809.96	134428.67	776.56	0.00001856	0.49
23.00	20.00	4.38	87.61	2570.25	58.41	55.41	48115.12	184050.00	15272.45	2570.25	6787.76	133990.30	774.79	0.00001869	0.49
21.00	21.00	4.43	93.08	2589.13	58.84	55.82	48468.51	183446.24	15222.35	2589.13	6765.49	133550.75	773.01	0.00001883	0.49
19.00	25.00	4.49	112.13	2608.18	59.28	56.23	48825.10	182840.81	15172.11	2608.18	6743.16	133110.00	771.23	0.00001897	0.49
17.00	16.00	4.54	72.62	2627.40	59.71	56.65	49184.94	182233.70	15121.73	2627.40	6720.77	132668.01	769.44	0.00001911	0.49
15.00	1.00	4.59	4.59	2646.80	60.15	57.07	49548.09	181624.86	15071.21	2646.80	6698.32	132224.77	767.65	0.00001925	0.49
13.00		4.65	0.00	2666.38	60.60	57.49	49914.60	181014.26	15020.55	2666.38	6675.80	131780.25	765.85	0.00001939	0.48

APPENDIX K:

Ambient Temp (°F)	Hours	Mwe¯	Mwe¯h	Fuel Flow (lbm/hr)	Fuel Flow (MMBTU/hr)	Exhaust Flow (lbm/hr)	Exhuast Temp (°F)	Inlet Temp (°F)	Output w/ Inlet Cooling (MMBTU/hr)	Fuel Flow w/ Inlet Cooling (MMBTU/hr)	Exhaust Temp w/ Inlet Cooling (°F)	Exhaust Flow w/ Inlet Cooling (lbm/hr)	Output (MMBTU/hr)	Qevap w/ Inlet Cooling	Qevap	Mstm (lbm/hr)	Mstm w/ Inlet Cooling(lbm/hr)	Qstm	Qstm w/ Inlet Cooling	FERC Efficiency	FERC Efficiency w/ Inlet Cooling	Total Efficiency	Total Efficiency w/ Inlet Cooling	Power/Steam Ratio	Power/Steam Ratio w/ Inlet Cooling	Net Heat Rate	Net Heat Rate w/ Inlet Cooling (BTU_{stm}/BTU_e)	Effective Electrical Efficiency	Effective Electrical Efficiency w/ Inlet Cooling
99.00	2.00	2.59	5.17	1948.65	42.01	206113.46	840.21	44.00	13.22	51.35	793.18	190298.42	8.82	19273675.17	23347393.87	25524.82	20907.91	25428588.47	20829082.52	0.51	0.46	0.82	0.66	0.35	0.63	4.31	3.58	0.60	0.49
97.00	4.00	2.64	10.54	1963.34	42.33	205546.56	838.50	44.00	13.22	51.35	793.18	190298.42	8.99	19273675.17	23193522.18	25356.59	20907.91	25261000.61	20829082.52	0.51	0.46	0.81	0.66	0.36	0.63	4.26	3.58	0.60	0.49
95.00	4.00	2.68	10.74	1978.08	42.65	204979.35	836.79	44.00	13.22	51.35	793.18	190298.42	9.16	19273675.17	23040189.36	25188.96	20907.91	25093999.66	20829082.52	0.51	0.46	0.80	0.66	0.36	0.63	4.22	3.58	0.59	0.49
93.00	15.00	2.73	40.99	1992.89	42.97	204411.78	835.09	44.00	13.22	51.35	793.18	190298.42	9.32	19273675.17	22887381.95	25021.90	20907.91	24927570.94	20829082.52	0.51	0.46	0.80	0.66	0.37	0.63	4.18	3.58	0.59	0.49
91.00	58.00	2.78	161.33	2007.75	43.29	203843.82	833.38	44.00	13.22	51.35	793.18	190298.42	9.49	19273675.17	22735086.62	24855.40	20907.91	24761699.96	20829082.52	0.51	0.46	0.79	0.66	0.38	0.63	4.14	3.58	0.58	0.49
89.00	66.00	2.83	186.77	2022.67	43.61	203275.44	831.67	44.00	13.22	51.35	793.18	190298.42	9.66	19273675.17	22583290.25	24689.45	20907.91	24596372.40	20829082.52	0.50	0.46	0.79	0.66	0.39	0.63	4.10	3.58	0.58	0.49
87.00	115.00	2.88	330.97	2037.66	43.93	202706.59	829.97	44.00	13.22	51.35	793.18	190298.42	9.82	19273675.17	22431979.85	24524.03	20907.91	24431574.15	20829082.52	0.50	0.46	0.78	0.66	0.40	0.63	4.07	3.58	0.57	0.49
85.00	150.00	2.93	438.88	2052.72	44.26	202137.25	828.27	44.00	13.22	51.35	793.18	190298.42	9.98	19273675.17	22281142.61	24359.13	20907.91	24267291.22	20829082.52	0.50	0.46	0.77	0.66	0.41	0.63	4.03	3.58	0.57	0.49
83.00	184.00	2.97	547.14	2067.84	44.58	201567.38	826.56	44.00	13.22	51.35	793.18	190298.42	10.15	19273675.17	22130765.88	24194.72	20907.91	24103509.86	20829082.52	0.50	0.46	0.77	0.66	0.42	0.63	4.00	3.58	0.56	0.49
81.00	223.00	3.02	673.69	2083.05	44.91	200996.94	824.86	44.00	13.22	51.35	793.18	190298.42	10.31	19273675.17	21980837.17	24030.81	20907.91	23940216.45	20829082.52	0.50	0.46	0.76	0.66	0.43	0.63	3.97	3.58	0.56	0.49
79.00	320.00	3.07	981.86	2098.33	45.24	200425.90	823.16	44.00	13.22	51.35	793.18	190298.42	10.47	19273675.17	21831344.17	23867.38	20907.91	23777397.59	20829082.52	0.49	0.46	0.76	0.66	0.44	0.63	3.94	3.58	0.55	0.49
77.00	190.00	3.12	591.91	2113.69	45.57	199854.23	821.45	44.00	13.22	51.35	793.18	190298.42	10.63	19273675.17	21682274.70	23704.41	20907.91	23615040.02	20829082.52	0.49	0.46	0.75	0.66	0.45	0.63	3.91	3.58	0.55	0.49
75.00	402.00	3.16	1271.19	2129.13	45.90	199281.88	819.75	44.00	13.22	51.35	793.18	190298.42	10.79	19273675.17	21533616.79	23541.88	20907.91	23453130.69	20829082.52	0.49	0.46	0.75	0.66	0.46	0.63	3.88	3.58	0.55	0.49
73.00	701.00	3.21	2249.35	2144.66	46.24	198708.83	818.05	44.00	13.22	51.35	793.18	190298.42	10.95	19273675.17	21385358.60	23379.80	20907.91	23291656.71	20829082.52	0.49	0.46	0.74	0.66	0.47	0.63	3.86	3.58	0.54	0.49
71.00	504.00	3.26	1640.62	2160.29	46.58	198135.03	816.34	44.00	13.22	51.35	793.18	190298.42	11.11	19273675.17	21237488.47	23218.14	20907.91	23130605.40	20829082.52	0.49	0.46	0.74	0.66	0.48	0.63	3.83	3.58	0.54	0.49
69.00	403.00	3.30	1330.49	2176.00	46.91	197560.46	814.64	44.00	13.22	51.35	793.18	190298.42	11.26	19273675.17	21089994.91	23056.89	20907.91	22969964.21	20829082.52	0.48	0.46	0.73	0.66	0.49	0.63	3.81	3.58	0.53	0.49
67.00	329.00	3.35	1101.34	2191.81	47.26	196985.08	812.93	44.00	13.22	51.35	793.18	190298.42	11.42	19273675.17	20942866.59	22896.04	20907.91	22809720.82	20829082.52	0.48	0.46	0.72	0.66	0.50	0.63	3.79	3.58	0.53	0.49
65.00	382.00	3.39	1296.31	2207.72	47.60	196408.84	811.22	44.00	13.22	51.35	793.18	190298.42	11.58	19273675.17	20796092.35	22735.58	20907.91	22649863.08	20829082.52	0.48	0.46	0.72	0.66	0.51	0.63	3.77	3.58	0.53	0.49
63.00	370.00	3.44	1272.54	2223.73	47.94	195831.73	809.51	44.00	13.22	51.35	793.18	190298.42	11.73	19273675.17	20649661.19	22575.49	20907.91	22490378.99	20829082.52	0.48	0.46	0.71	0.66	0.52	0.63	3.74	3.58	0.52	0.49
61.00	359.00	3.49	1251.12	2239.85	48.29	195253.70	807.80	44.00	13.22	51.35	793.18	190298.42	11.89	19273675.17	20503562.29	22415.76	20907.91	22331256.78	20829082.52	0.48	0.46	0.71	0.66	0.53	0.63	3.72	3.58	0.52	0.49
59.00	156.00	3.53	550.78	2256.08	48.64	194674.71	806.09	44.00	13.22	51.35	793.18	190298.42	12.05	19273675.17	20357784.98	22256.39	20907.91	22172484.84	20829082.52	0.48	0.46	0.70	0.66	0.54	0.63	3.71	3.58	0.52	0.49
57.00	259.00	3.58	926.24	2272.42	48.99	194094.74	804.38	44.00	13.22	51.35	793.18	190298.42	12.20	19273675.17	20212318.78	22097.36	20907.91	22014051.73	20829082.52	0.47	0.46	0.70	0.66	0.55	0.63	3.69	3.58	0.51	0.49
55.00	372.00	3.62	1347.30	2288.87	49.35	193513.75	802.66	44.00	13.22	51.35	793.18	190298.42	12.36	19273675.17	20067153.36	21938.65	20907.91	21855946.22	20829082.52	0.47	0.46	0.69	0.66	0.57	0.63	3.67	3.58	0.51	0.49
53.00	210.00	3.67	770.14	2305.44	49.71	192931.69	800.94	44.00	13.22	51.35	793.18	190298.42	12.51	19273675.17	19922278.58	21780.27	20907.91	21698157.25	20829082.52	0.47	0.46	0.69	0.66	0.58	0.63	3.65	3.58	0.51	0.49
51.00	239.00	3.71	887.39	2322.13	50.07	192348.55	799.22	44.00	13.22	51.35	793.18	190298.42	12.67	19273675.17	19777684.46	21622.19	20907.91	21540673.96	20829082.52	0.47	0.46	0.68	0.66	0.59	0.63	3.64	3.58	0.50	0.49
49.00	237.00	3.76	890.79	2338.95	50.43	191764.27	797.50	44.00	13.22	51.35	793.18	190298.42	12.82	19273675.17	19633361.19	21464.41	20907.91	21383485.67	20829082.52	0.47	0.46	0.68	0.66	0.60	0.63	3.62	3.58	0.50	0.49
47.00	307.00	3.80	1167.96	2355.89	50.79	191178.83	795.78	44.00	13.22	51.35	793.18	190298.42	12.98	19273675.17	19489299.14	21306.91	20907.91	21226581.87	20829082.52	0.46	0.46	0.67	0.66	0.61	0.63	3.60	3.58	0.50	0.49
45.00	296.00	3.85	1139.71	2372.96	51.16	190592.20	794.05	44.00	13.22	51.35	793.18	190298.42	13.14	19273675.17	19345488.83	21149.69	20907.91	21069952.27	20829082.52	0.46	0.46	0.67	0.66	0.62	0.63	3.59	3.58	0.50	0.49
43.00	318.00	3.90	1239.10	2390.17	51.53	190004.32	792.32	43.00	13.29	51.53	792.32	190004.32	13.29	19201920.99	19201920.99	20992.73	20830.07	20913586.74	20751537.69	0.46	0.46	0.66	0.66	0.64	0.64	3.58	3.58	0.49	0.49
41.00	184.00	3.94	725.50	2407.51	51.91	189415.18	790.58	41.00	13.45	51.91	790.58	189415.18	13.45	19058586.49	19058586.49	20836.03	20674.58	20757475.35	20596635.94	0.46	0.46	0.66	0.66	0.65	0.65	3.56	3.56	0.49	0.49
39.00	284.00	3.99	1133.06	2425.00	52.28	188824.74	788.84	39.00	13.61	52.28	788.84	188824.74	13.61	18915476.40	18915476.40	20679.57	20519.33	20601608.39	20441976.71	0.46	0.46	0.65	0.65	0.66	0.67	3.55	3.55	0.49	0.49
37.00	297.00	4.04	1198.90	2442.62	52.66	188232.95	787.10	37.00	13.77	52.66	787.10	188232.95	13.77	18772581.97	18772581.97	20523.35	20364.32	20445976.29	20287550.53	0.46	0.45	0.65	0.65	0.67	0.68	3.53	3.53	0.49	0.48
35.00	210.00	4.08	857.67	2460.39	53.05	187639.79	785.35	35.00	13.94	53.05	785.35	187639.79	13.94	18629894.59	18629894.59	20367.35	20209.54	20290569.71	20133348.11	0.45	0.45	0.65	0.64	0.69	0.69	3.52	3.52	0.48	0.48
33.00	161.00	4.13	665.26	2478.31	53.43	187045.22	783.60	33.00	14.10	53.43	783.60	187045.22	14.10	18487405.86	18487405.86	20211.58	20054.97	20135379.49	19979360.39	0.45	0.45	0.64	0.64	0.70	0.71	3.51	3.51	0.48	0.48
31.00	114.00	4.18	476.57	2496.38	53.82	186449.21	781.85	31.00	14.26	53.82	781.85	186449.21	14.26	18345107.56	18345107.56	20056.01	19900.60	19980396.67	19825578.46	0.45	0.45	0.64	0.63	0.71	0.72	3.49	3.49	0.48	0.48
29.00	72.00	4.23	304.52	2514.61	54.21	185851.72	780.09	29.00	14.43	54.21	780.09	185851.72	14.43	18202991.65	18202991.65	19900.64	19746.44	19825612.49	19671993.62	0.45	0.45	0.63	0.63	0.73	0.73	3.48	3.48	0.48	0.47
27.00	107.00	4.28	457.86	2533.00	54.61	185252.71	778.33	27.00	14.60	54.61	778.33	185252.71	14.60	18061050.24	18061050.24	19745.46	19592.46	19671018.38	19518597.38	0.45	0.45	0.63	0.62	0.74	0.75	3.47	3.47	0.47	0.47
25.00	73.00	4.33	316.05	2551.54	55.01	184652.15	776.56	25.00	14.77	55.01	776.56	184652.15	14.77	17919275.66	17919275.66	19590.46	19438.67	19516605.97	19365381.44	0.45	0.44	0.62	0.62	0.76	0.76	3.45	3.45	0.47	0.47
23.00	20.00	4.38	87.61	2570.25	55.41	184050.00	774.79	23.00	14.95	55.41	774.79	184050.00	14.95	17777660.41	17777660.41	19435.64	19285.04	19362367.08	19212337.67	0.44	0.44	0.62	0.62	0.77	0.78	3.44	3.44	0.47	0.47
21.00	21.00	4.43	93.08	2589.13	55.82	183446.24	773.01	21.00	15.12	55.82	773.01	183446.24	15.12	17636197.17	17636197.17	19280.98	19131.58	19208293.76	19059458.19	0.44	0.44	0.62	0.61	0.79	0.79	3.43	3.43	0.47	0.47
19.00	25.00	4.49	112.13	2608.18	56.23	182840.81	771.23	19.00	15.30	56.23	771.23	182840.81	15.30	17494878.80	17494878.80	19126.49	18978.28	19054378.23	18906735.28	0.44	0.44	0.61	0.61	0.80	0.81	3.41	3.41	0.47	0.47
17.00	16.00	4.54	72.62	2627.40	56.65	182233.70	769.44	17.00	15.49	56.65	769.44	182233.70	15.49	17353698.38	17353698.38	18972.14	18825.13	18900612.94	18754161.43	0.44	0.44	0.61	0.60	0.82	0.83	3.40	3.40	0.47	0.46
15.00	1.00	4.59	4.59	2646.80	57.07	181624.86	767.65	15.00	15.67	57.07	767.65	181624.86	15.67	17212649.14	17212649.14	18817.93	18672.12	18746990.52	18601729.36	0.44	0.44	0.60	0.60	0.84	0.84	3.39	3.39	0.46	0.46
13.00		4.65	0.00	2666.38	57.49	181014.26	765.85	13.00	15.87	57.49	765.85	181014.26	15.87	17071724.51	17071724.51	18663.87	18519.25	18593503.82	18449431.95	0.44	0.44	0.60	0.60	0.85	0.86	3.37	3.37	0.46	0.46
																				0.47	0.46	0.70	0.65	0.57	0.67	3.73	3.54	0.52	0.49

APPENDIX M:

Ambient Temp (^{o}F)	Hours	Mwe$^-$	Inlet Temp (^{o}F)	Output w/ Inlet Cooling (MMBTU/hr)	Fuel Flow w/ Inlet Cooling (MMBTU/hr)	Excess Electricity Generated kW	$/hr Propane	Sell Back kWh	Sell Back $
99.00	2.00	3.87	44.00	13.22	51.35	1020.43	504.7333	2040.863	1009.467
97.00	4.00	3.87	44.00	13.22	51.35	1020.43	504.7333	4081.725	2018.933
95.00	4.00	3.87	44.00	13.22	51.35	1020.43	504.7333	4081.725	2018.933
93.00	15.00	3.87	44.00	13.22	51.35	1020.43	504.7333	15306.47	7570.999
91.00	58.00	3.87	44.00	13.22	51.35	1020.43	504.7333	59185.01	29274.53
89.00	66.00	3.87	44.00	13.22	51.35	1020.43	504.7333	67348.46	33312.4
87.00	115.00	3.87	44.00	13.22	51.35	1020.43	504.7333	117349.6	58044.33
85.00	150.00	3.87	44.00	13.22	51.35	1020.43	504.7333	153064.7	75709.99
83.00	184.00	3.87	44.00	13.22	51.35	1020.43	504.7333	187759.4	92870.92
81.00	223.00	3.87	44.00	13.22	51.35	1020.43	504.7333	227556.2	112555.5
79.00	320.00	3.87	44.00	13.22	51.35	1020.43	504.7333	326538	161514.7
77.00	190.00	3.87	44.00	13.22	51.35	1020.43	504.7333	193881.9	95899.32
75.00	402.00	3.87	44.00	13.22	51.35	1020.43	504.7333	410213.4	202902.8
73.00	701.00	3.87	44.00	13.22	51.35	1020.43	504.7333	715322.3	353818
71.00	504.00	3.87	44.00	13.22	51.35	1020.43	504.7333	514297.4	254385.6
69.00	403.00	3.87	44.00	13.22	51.35	1020.43	504.7333	411233.8	203407.5
67.00	329.00	3.87	44.00	13.22	51.35	1020.43	504.7333	335721.9	166057.3
65.00	382.00	3.87	44.00	13.22	51.35	1020.43	504.7333	389804.7	192808.1
63.00	370.00	3.87	44.00	13.22	51.35	1020.43	504.7333	377559.6	186751.3
61.00	359.00	3.87	44.00	13.22	51.35	1020.43	504.7333	366334.8	181199.2
59.00	156.00	3.87	44.00	13.22	51.35	1020.43	504.7333	159187.3	78738.39
57.00	259.00	3.87	44.00	13.22	51.35	1020.43	504.7333	264291.7	130725.9
55.00	372.00	3.87	44.00	13.22	51.35	1020.43	504.7333	379600.4	187760.8
53.00	210.00	3.87	44.00	13.22	51.35	1020.43	504.7333	214290.6	105994
51.00	239.00	3.87	44.00	13.22	51.35	1020.43	504.7333	243883.1	120631.3
49.00	237.00	3.87	44.00	13.22	51.35	1020.43	504.7333	241842.2	119621.8
47.00	307.00	3.87	44.00	13.22	51.35	1020.43	504.7333	313272.4	154953.1
45.00	296.00	3.87	44.00	13.22	51.35	1020.43	504.7333	302047.7	149401.1
43.00	318.00	3.90	43.00	13.29	51.53	1043.54	506.5602	331845.8	161086.1
41.00	184.00	3.94	41.00	13.45	51.91	1089.95	510.2358	200550.8	93883.38
39.00	284.00	3.99	39.00	13.61	52.28	1136.66	513.941	322810.1	145959.2
37.00	297.00	4.04	37.00	13.77	52.66	1183.71	517.6764	351560.8	153749.9
35.00	210.00	4.08	35.00	13.94	53.05	1231.16	521.4427	258542.8	109503
33.00	161.00	4.13	33.00	14.10	53.43	1279.06	525.2405	205928.7	84563.72
31.00	114.00	4.18	31.00	14.26	53.82	1327.48	529.0705	151332.2	60314.04
29.00	72.00	4.23	29.00	14.43	54.21	1376.46	532.9334	99105.2	38371.21
27.00	107.00	4.28	27.00	14.60	54.61	1426.08	536.8298	152590.6	57440.79
25.00	73.00	4.33	25.00	14.77	55.01	1476.40	540.7604	107777	39475.51
23.00	20.00	4.38	23.00	14.95	55.41	1527.48	544.7259	30549.56	10894.52
21.00	21.00	4.43	21.00	15.12	55.82	1579.39	548.7268	33167.24	11523.26
19.00	25.00	4.49	19.00	15.30	56.23	1632.21	552.7638	40805.29	13819.1
17.00	16.00	4.54	17.00	15.49	56.65	1686.01	556.8377	26976.16	8909.402
15.00	1.00	4.59	15.00	15.67	57.07	1740.86	560.949	1740.863	560.949
13.00		4.65	13.00	15.87	57.49	1796.85	565.0984	0	0
						Total			4451010