April 15, 2020

MCKINSTRY

University of Montana
CHP Feasibility Study

PROJECT NUMBER:
162690

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PREPARED FOR: *MCKINSTRY*

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REVISION HISTORY		
DATE	**REVISED BY**	**REVISION**
4/14/20	G. Drake	A - Draft
4/15/20	G. Drake	B - Draft

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EXECUTIVE SUMMARY

POWER Engineers (PEI) has conducted a study for a proposed Combined Heating and Power (CHP) project at the University of Montana in Missoula. Currently all steam used on campus is generated by package boilers within the historic Central Heating Plant building. The intent of this study is to determine the feasibility of replacing one of the existing boilers with a CHP installation that would maintain/improve the steam production and allow the University to provide electrical power for its on-campus users with no net export of power back to the utility electrical grid. This study includes a review of several gas turbines (GTG) coupled with a Heat Recovery Steam Generator (HRSG) and a Condensing Steam Turbine Generator (STG) with an extraction in the size range capable of supplying the campus electrical needs and delivering steam for campus heating needs. Emphasis was placed on selecting a configuration that would have the overall lowest cost and maximum utility savings.

The gas turbine is the main driver for the CHP plant. It provides the waste heat to the HRSG to produce the steam that is sent to the steam turbine or campus district heating system. Gas turbines in the 2-5MW were evaluated to determine if they would be a good fit for the application. The gas turbines that were initially evaluated to fit the CHP demands were the Solar Centaur 40 and Centaur 50, the OPRA 16-3, and the Siemens A05. Some of the better suited gas turbines for CHP applications are the less efficient models. Poor gas turbine efficiency leads to higher exhaust temperatures and thus, more steam production from the HRSG. The Siemens A05 is more efficient than the Solar or OPRA units and because of this the Siemens unit wasn't evaluated further because of its inability to produce sufficient steam to meet the plants demands.

In summary, key issues identified:

1. The Centaur 40 plant and the Centaur 50 plant have almost the same payback with the 2xOPRA being very close. Final plant configuration may be dependent upon best and final quotes from the respective vendors.
2. For purposes of this study the Centaur 40/50 were utilized for equipment sizing for general arrangement purposes.
3. Natural gas supply and pressure is assumed to be sufficient for any of the gas turbine options. If ~225psig is not available, then cost will need to be added to all estimates to include a fuel gas compressor.
4. There may be an opportunity to increase the size, and subsequent cost, of the HRSG to produce more than 50kpph of 180psig saturated steam. This design was not considered during this study due to cost and size limitations.

Table 1 below summarizes the costs of the CHP plant options reviewed in the study

TABLE 1: COGENERATION PLANT PERFORMANCE & COST SUMMARY

TURBINE OPTIONS			
Turbine Model	Centaur 40	Centaur 50	OPRA 16-3
Number of Units	1	1	2
Average Electric Power Required by Campus (kW)	4,083	4,083	4,083
Average Steam Flow Required by Campus (lb/hr)	19,165	19,165	19,165

TABLE 1: COGENERATION PLANT PERFORMANCE & COST SUMMARY			
TURBINE OPTIONS			
Turbine Model	Centaur 40	Centaur 50	OPRA 16-3
Estimated Capital Cost	**$15,323,632**	**$15,723,329**	**$15,655,896**
Annual Gas Costs (GTG, Boilers & Turbine)	**$1,725,524**	**$1,659,998**	**$1,730,011**
Annual Electricity Cost	**$117,763**	**$9,519**	**$39,509**
Annual Utility Costs	**$1,843,286**	**$1,669,517**	**$1,769,520**
Annual Utility Cost Savings with Cogen	**$2,453,686**	**$2,627,455**	**$2,527,452**
Annual Cogen Maintenance Costs	**$277,596**	**$421,212**	**$407,024**
Simple Payback	7.0	7.1	7.4

Annual utility cost savings are calculated using the monthly average steam and power requirements as a basis for the performance models. Models were created for each scenario to see how the new CHP plant would perform to meet the steam and power loads of the campus. Gas and electrical costs were calculated and then compared again what the campus would have spent to produce the same steam and purchase the required amount of electricity. Costs savings may be skewed to the high side because of the basis for the performance models and doesn't take into account the hourly fluctuations of the campus. Actual values may differ, but these numbers are representative for comparative purposes.

STEAM CONDITIONS AND FLOW REQUIREMENTS

The current configuration of the steam supply to campus is via three (3) natural gas fired firetube boilers producing saturated steam at 180 psig for heating uses on campus. This is described further in the project description.

In order to minimize any impacts to the campus distribution system and allow the continued use of two (2) of the existing boilers and other auxiliary equipment the new Gas Turbine (GTG), Heat Recovery Steam Generator (HRSG), and steam turbine (STG) selection was limited to units matching the existing steam conditions and units that would be able to provide enough waste heat to support the steam needs of the campus.

Steam flow values for the last three years have been provided in order to analyze the steam loads and size the CHP plant. During recent stack testing for the boilers it was shown that the boilers were more efficient than expected and it is generally understood that the meters monitoring flow are reporting too high. During investigation of some recent stack testing and typical methods for boiler efficiency (Cleaver Brooks Boiler Efficiency Guide) based on exhaust gas temperature, CO2%, and typical boiler heat losses it was concluded that the values provided by the current heating system were discovered to by erroneous by a factor of ~20 to 30%. For this reason, all the steam production values will be reduced to 80% of the reported value for the purposes of this study.

Below is one example calculation utilizing the Cleaver Brook's method to determine boiler efficiency. It is assumed that because the gas is metered by the utility it has a high degree of accuracy. An exhaust gas exit temperature of 305°F was assumed after the economizer:

		From Portable Stack Analyzer Printout									From Operator's Panel						
Date	Time	CO2 %	O2%	CO, ppm	Coaf, ppm	Flue Temp, F	Inlet Temp, F	Eff, %	Loss, %	Xair, %	Stack Temp, Before Economizer, F	Windbox Temp, F	Steam Flow, PPH	Natural Gas Flow, CuFt/h	% of Gas to Utilities	Gas to Boilers	Stack O2%
12/27/2019	10:06	8.0	6.8	4.0	6.0	519.9	96.0	77.6	22.4	47.8	490	80	50,319	51,155	1278.875	49,876	4.5

http://cleaverbrooks.com/reference-center/insights/Boiler%20Efficiency%20Guic

deltaT	Stack Loss %	Radiaton and Convection Losses	Total Eff. Loss	Fuel to Steam Efficiency	Assumed BTU/ft^3	Natural Gas Flow, BTU/h	Enthalpy of Sat Steam (165psig), BTU/lb	Steam Flow, lb/h		% of Reported
209.00	15.4%	0.5%	15.9%	84.08%	1035	51,621,789	1199.51	36,182.29		72%

The steam flow that was reportedly going to the existing steam turbine was also analyzed to see if the quantity of steam provided to the steam turbine resulted in the expected power output.

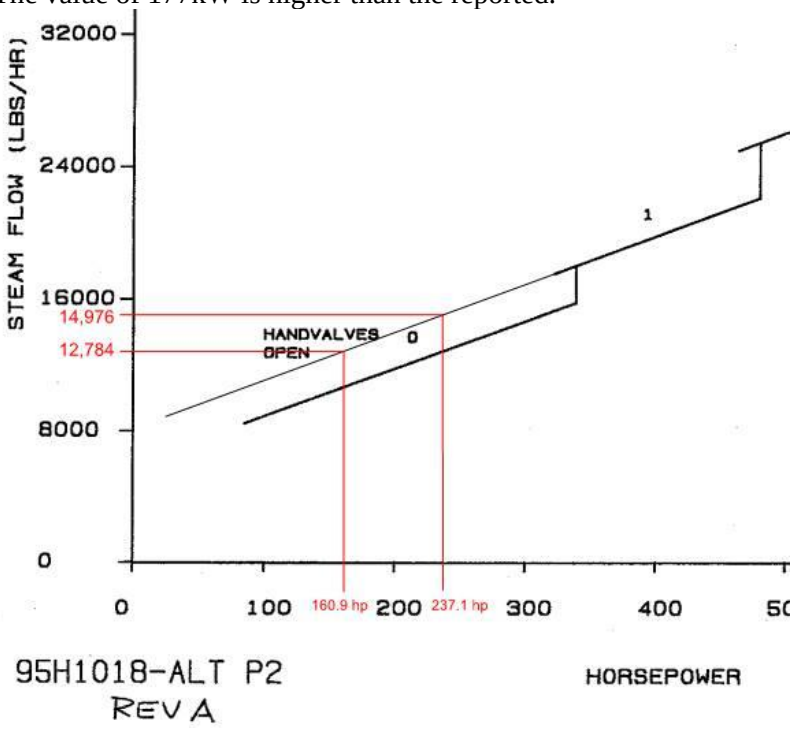
PEI took steam flows from the midnight reading for April 30th (pg1 of the pdf, "APR 2017 – UM Heating Plant Log") under the cogen heading. In this scenario, all the steam is going to the existing steam turbine.

- Reported steam flow is 14, 976 lb/hr at 162.3 psig inlet pressure & 30.1 psig exhaust pressure.
- Reported output is 120kW.

Co-Gen	Midnight
Ch 1 KW	120
Ch 2 Inlet Pressure	162.3
Ch 3 Exhaust Pressure	30.1
Ch 4 Steam Flow PPH	14,976
Main Valve Opening %	20
PRV Opening %	0
Turbine RPM	3604
#1 Valve H/A O/C	O
#2 Valve H/A O/C	X

The "UM Steam Turbine Performance Curves – 95H1018-ALT P2 RevA" provided (pg. 2 of 3 of the pdf) and it shows:

- One valve open, per plant log
- Steam flow of 14,976 lb/hr
- Steam Turbine output for the reported flow = 237.1 hp = 177 kW.
- The value of 177kW is higher than the reported.



- Power output is ~68% lower than what the curves say it should be.
- The reported output of 120kW (160.9hp) would require a flow of ~12,784 lb which is about 85% lower than the reported flow.

GENERAL PLANT PERFORMANCE

Table 2 shows the performance estimates for two (2) variations of the Solar gas turbines, the Centaur 40 and 50, along with the OPRA units at ISO conditions (59°F/60%RH) and site altitude. The cogeneration facility efficiency and output will vary based on ambient temperature. The plant is sized to meet the steam demands and electrical demand of the campus. The performance estimates for the new turbines were calculated using Thermoflow GT Pro software and checked against manufacturer data. The HRSG has been fired to 1600°F for all turbine options. This is typically an upper limit for traditional HRSGs. Typical process flow diagrams for these configurations at ISO conditions are included in Appendix A

TABLE 2: COGENERATION NOMINAL PERFORMANCE SUMMARY

TURBINE OPTIONS			
Turbine Model	Centaur 40	Centaur 50	OPRA 16
Number of Units	1	1	2
Plant Net Output at 59°F (kW)	3,990	4,888	3,884
Plant Net LHV Heat Rate (BTU/kWh)	17,133	14,921	16,481
Plant Fuel Gas Consumption, HHV (MMBTU/hr)	75.85	80,93	70.48
Steam Production (kpph)	46.02	46.98	42.18
Extracted Steam to Campus (kpph)	41.36	42.08	37.77
CHP efficiency (%)	79.19	79.46	79.07

The current campus operates with three (3) watertube type boilers producing steam for the campus and electricity is purchased for the campus load. In order to select a configuration each plan type was modeled for the monthly average conditions and the cost of gas, backup stream required, and electricity purchased was compared against the current operating costs. The plant model was customized to minimize having to produce steam in the existing boilers as well as electricity that would have to be purchased from the grid. In situations where there was the need to potentially purchase electricity because the GTG could not meet the entire load the HRSG was fired to send more steam to steam turbine for power to be produced there. It was determined that firing the HRSG to produce more steam and subsequently more power in the steam turbine was less expensive than purchasing power from the grid.

The steam turbine has been sized to accept the fully fired capacity of the HRSG in order to meet the electrical requirements of the facility. In the summer there are instances of “peak” power 5MW+ being needed at campus and steam needs are near 5,000 – 10,000 lb/hr. On these occasions the gas turbine would be at 100% capacity and the HRSG would be fired to produce the required steam to meet the power demands and extraction demands.

Annual utility cost savings are calculated using the monthly average steam and power requirements as a basis for the performance models. Models were created for each monthly average scenario to see how the new CHP plant would perform to meet the steam and power loads of the campus. Gas and electrical costs were calculated and then compared again what the campus would have spent to produce the same steam and purchase the required amount of electricity. Costs savings may be

skewed to the high side because of the basis for the performance models and doesn't take into account the hourly fluctuations of the campus. Actual values may differ but these numbers are representative for comparative purposes.

A summary of the usage for the current installation and the new cogen is included in the Executive Summary and the detailed worksheet is included in Appendix A

BALANCE OF PLANT EQUIPMENT

Additional plant equipment will be required to operate the balance of plant. Equipment includes an air compressor system, cooling tower and condenser system, various pumps and control valves for operation. A control system will need to be implemented for the new equipment, with interfaces to the existing systems.

The cost estimates include addition of the following major equipment items:

- Gas Turbine Generator
- Heat Recovery Steam Generator w/ associated ducting and stack.
- Steam Turbine Generator
- Condenser
- Cooling Tower
- Boiler Feedwater Pumps
- Circulating Water Pumps
- Vacuum Pump System
- Air Compressor System w/ Dryer
- Black Start Diesel Generator
- Control System and Instrumentation

Items that are to be retained and reused are the following:

- Condensate Return Pumps
- Deaerator
- Water Softening System
- Blowdown System

Refreshed vendor quotes were requested for equipment items that carry a large capital cost. Vendor quotes that were used to populate the cost estimates can be found in Appendix E.

For the purposes of this study a firetube type HRSG was considered in lieu of a watertube type HRSG. It is understood that a watertube type is the preference of the University however in order to minimize project costs the firetube type boiler is used as a basis. While both boilers are suitable for the pressures and temperatures a firetube boiler is ~50 to 60% less expensive. While utilization of a firetube boiler is less up front capital cost it also could be a major source of construction man-hours savings because there will be less field assembly required due to relatively small window opening available in the existing building. A watertube type HRSG will likely be packaged and thus more difficult to install while maintaining the integrity of the historical building.

COST ESTIMATES

Economic evaluation of the three turbine options for this study considers initial capital costs of the generating plant equipment and construction, operation and maintenance costs, fuel costs, and electrical costs. Capital cost estimates were compiled using a cost estimate program internal to GTPro called PEACE along with vendor quotes for the major equipment items. PEACE stands for Plant Engineering And Construction Estimator. PEACE estimates engineering and construction costs for green field sites. Output from this program was subsequently edited to reflect the brown field nature of the University site. Labor and productivity were also adjusted for the area to try to accurately reflect an "all in" rate for craft labor at the site. Major equipment suppliers were contacted to provide cost estimates for major plant equipment and long term maintenance agreements. The BOP items were priced either by database pricing or utilizing the pricing from the GTPro Software. A summary of the total installed cost by configuration is below. The complete cost evaluation reports are included in Appendix B.

TABLE 3 – TOTAL INSTALLED COSTS

	1 X CENTAUR 40	1 X CENTAUR 50	2 X OPRA 16-3
Specialized Equipment	$7,248,094	$7,309,757	$7,300,647
Other Equipment	$471,545	$476,939	$467,287
Civil Construction Costs	$601,100	$779,409	$684,122
Mech. Construction Costs	$868,996	$881,798	$901,418
Elec. Construction Costs	$435,481	$452,254	$455,579
Building Modifications	$334,851	$334,851	$333,307
Engineering and Startup	$1,161,480	$1,161,480	$1,161,480
Estimated Contractor Soft & Misc. Costs	$2,936,832	$2,855,620	$3,057,367
Estimated Owners Soft & Misc. Costs	$1,265,254	$1,471,221	$1,292,689
Total Installed Cost	**$15,323,632**	**$15,723,329**	**$15,655,896**

STRUCTURAL CONSIDERATIONS

The conceptual general arrangement in Appendix C plans for exterior equipment to be supported by isolated concrete foundations. Exterior foundations can be locally sleeved if utility lines interfere with designed concrete placement for future maintenance or replacement.

Main Equipment:

1) GTG – The Gas Turbine Generator is considered rotating equipment and will require a mass concrete foundation. Footprint is to be determined based on final equipment selection. Foundation thickness can be anticipated up to four feet. The proposed GTG, located on the north side of the existing U of M Central Plant, will require exploration and study with regard to existing utility lines and protection during excavation.

2) STG – The Steam Turbine Generator is considered rotating equipment and will require a mass concrete foundation. Footprint is to be determined based on final equipment selection. Foundation thickness can be anticipated up to four feet. The proposed STG location within current maintenance shop, will require the existing floor to be removed to allow a new isolated mass foundation. The shop floor has an existing basement vent that will need to be abandon or relocated. Note, there is an interior column within the shop space that supports the upper office/lab/locker room area. Additional engineering, demolition and construction will be required to modify support for the upper floor above the shop space. It is anticipated to bring the new STG into the shop space thru the existing east side double doors.
3) HRSG – The Heat Recovery Steam Generator will be placed on the existing Boiler 3 steel frame. The existing frame will remain after demo of Boiler #3. This frame can be plated for a walking surface and will provide direct load transfer to the existing concrete piers. Note, the load from the new HRSG must not exceed the load applied from the existing Boiler #3. It is anticipated to bring the new HRSG into the building by temporarily removing one of the large north side window frames.
4) CONDENSER – The new condenser will be placed on the east side of the existing Central Plant building. The condenser will require a mat foundation.
5) COOLING TOWER – The new cooling tower will be placed on the east side of the existing Central Plant building. The cooling tower will require a mat foundation.

PLANT ARRANGEMENT

A conceptual plant arrangement has been created using drawings of the existing steam plant and overlaying the proposed major equipment. The arrangement assumes that penetrations can be made through the building for the exhaust ducting from the gas turbine to the new HRSG and also from the steam turbine exhaust to the new condenser located on the east side of the steam plant. Conceptually the new steam turbine will be placed in an existing shop space adjacent to the new HRSG. This layout was developed using the Solar Centaur 50 gas turbine located on the north side of the existing building. The Solar Centaur 40 and 50 have relatively the same footprint with the 50 having upgraded internals to produce more power. A preliminary general arrangement drawing is in Appendix C.

GAS SUPPLY

Gas is supplied to the campus via a low-pressure gas line on the north side of the boiler building. Presently, the gas supply pressure is not sufficient for any of the gas turbine options. The gas turbines will need ~225psig at the turbine flange. The cost of gas compression or to upgrade the line has not been included as part of this study. It is assumed that there is adequate gas supply to the boiler building as well and that supply piping will not need to be upgraded. The average blended rate of natural gas as detailed in utility bills provided by the University is $3.285 per MMBTU of gas on a higher heating value (HHV) basis.

An initial estimation for annual gas usage for the new CHP is between 525,000 and 550,000 MMBTU/yr. on an HHV basis.

ELECTRICAL SUPPLY

The Monthly Average electrical load ranges from 3,700 to 4,500 kW throughout the year. This includes the power required by the stadium.

The current electrical demands for the University of Montana are met by Northwestern Energy. Currently the electric utility does not have an option for selling the excess power produced by the proposed campus cogen facility however that may change in the future. The simple payback calculation does not include a selling option. As proposed, the production of electrical power to the campus will be just short of the total demand with the remaining small amount of power to be purchased from Northwestern Energy. Based on information provided by the University the average price of electricity purchased is $0.098 per kWh. This is a blended rate that wraps in all surcharges, fees, and demand charges.

STEAM PRODUCTION

Currently the campus facility produces 10,000 to 60,000 lb/hr of steam for campus heat during the year. The summer months see the lowest amount of required steam for campus heating, while the highest is during the winter months due to all the campus heating requirements The proposed HRSG is equipped with a duct firing dual fuel system with a total nominal steam production of 50,000 lb/hr. During times of high campus steam demand the existing boilers will need to supplement steam to meet any demands exceeding 50,000 lb/hr. A letdown valve is currently in service at the facility and will reduce any remaining steam to 30 psig if it cannot be utilized in the steam turbine. See Appendix D for monthly 3 hour data intervals of steam production, power load, Temperature, and Relative Humidity during the 2018 year.

Steam production from the HRSG will supply a Steam Turbine with an associated generator. The steam turbine can accept the fully fired HRSG flowrate of ~50,000 lb/hr and produce 1,500 to 3,000 kW of power. The inlet to the steam turbine will accept steam at 180 psig with an extraction at 30 psig to be sent to the campus for heating demands. The non-extracted steam will pass through the tail end of the steam turbine producing a small amount of electricity prior to being condensed in the condenser.

AIR QUALITY PERMIT

Currently the campus facility has no Air Quality Permit. Once the selection process for major equipment is completed a permitting approach will be determined. It is assumed that the new cogeneration unit will need permitting with the State of Montana. Permitting support has not been included as part of this study. Bison Engineering has been identified to provide air permitting support.

Table 4 below summarizes the emission rates provided by the turbine manufactures to this point.

TABLE 4 – PRELIMINARY EMISSION RATES, 15% O2

NATURAL GAS	1 X CENTAUR 40	1 X CENTAUR 50	2 X OPRA 16-3
NOx	42 ppmvd, 27.7 tons/yr	25 ppmvd, 20.6 tons/yr	< 30 ppmvd
CO	50 ppmvd, 20.1 tons/yr	50 ppmvd, 25.1 tons/yr	< 60 ppmvd
VOC	25 ppmvd, 5.8 tons/yr	25 ppmvd, 7.2	TBD

TABLE 4 – PRELIMINARY EMISSION RATES, 15% O2			
NATURAL GAS	**1 X CENTAUR 40**	**1 X CENTAUR 50**	**2 X OPRA 16-3**
Notes	Emissions are guaranteed 50-100% Load and 0 – 120°F	Emissions are guaranteed 50-100% Load and 0 – 120°F	Emissions are for 70 to 100% Load
LIQUID FUEL	**1 X CENTAUR 40**	**1 X CENTAUR 50**	**2 X OPRA 16-3**
NOx	96 ppmvd	75 ppmvd	TBD
CO	50 ppmvd	50 ppmvd	TBD
VOC	25 ppmvd	25 ppmvd	TBD

SUMMARY

POWER Engineers (PEI) has conducted a study for a proposed Combined Heating and Power (CHP) project at the University of Montana in Missoula. This study includes a review of several gas turbines (GTG) coupled with a Heat Recovery Steam Generator (HRSG) and a Condensing Steam Turbine Generator (STG) with an extraction in the size range capable of supplying the campus electrical needs and delivering steam for campus heating needs. Emphasis was placed on selecting a configuration that would have the overall lowest cost and maximum utility savings.

In summary, key issues identified:

1. The Centaur 40 plant and the Centaur 50 plant have almost the same payback with the 2xOPRA being very close. Final plant configuration may be dependent upon best and final quotes from the respective vendors.
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3. Natural gas supply and pressure is assumed to be sufficient for any of the gas turbine options. If ~225psig is not available, then cost will need to be added to all estimates to include a fuel gas compressor.
4. There may be an opportunity to increase the size, and subsequent cost, of the HRSG to produce more than 50kpph of 180psig saturated steam. This design was not considered during this study due to cost and size limitations.

Table 5 below summarizes the costs of the CHP plant options reviewed in the study

TABLE 5: COGENERATION PLANT COST SUMMARY

TURBINE OPTIONS			
Turbine Model	Centaur 40	Centaur 50	OPRA 16-3
Number of Units	1	1	2
Average Electric Power Produced (kW)	4,083	4,083	4,083
Average Steam Flow Required (lb/hr)	19,165	19,165	19,165
Estimated Capital Cost	**$15,323,632**	**$15,723,329**	**$15,655,896**
Annual Gas Costs (GTG, Boilers & Turbine)	**$1,725,524**	**$1,659,998**	**$1,730,011**
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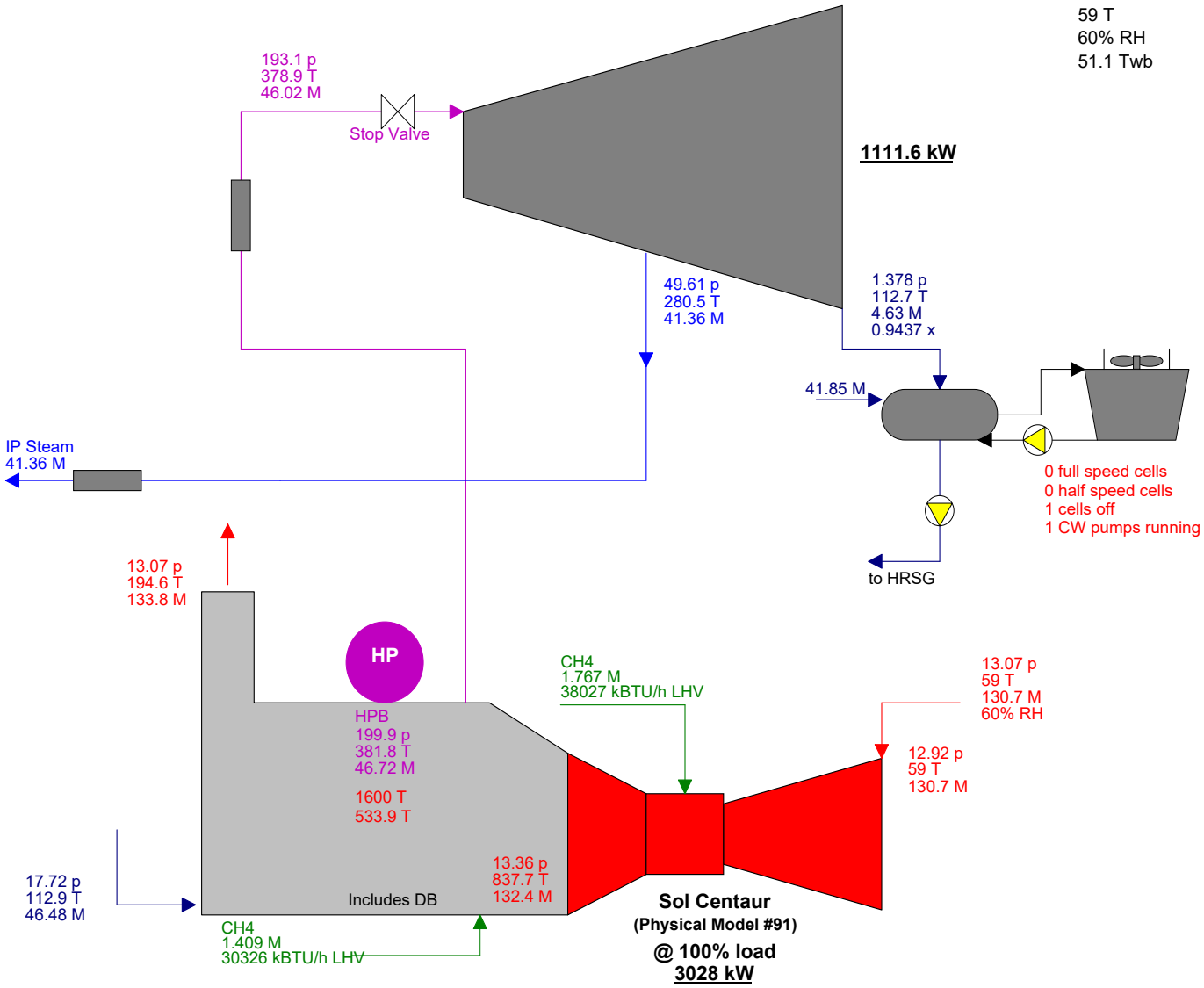
Annual Cogen Maintenance Costs	**$277,596**	**$421,212**	**$407,024**
Simple Payback	7.0	7.1	7.4

APPENDIX A – PROCESS FLOW AND SELECTION CRITERIA

GT MASTER 29.0 POWER Engineers, Inc.

Gross Power	4139 kW
Net Power	3990 kW
Aux. & Losses	149.6 kW
LHV Gross Heat Rate	16514 BTU/kWh
LHV Net Heat Rate	17133 BTU/kWh
LHV Gross Electric Eff.	20.66 %
LHV Net Electric Eff.	19.92 %
Fuel LHV Input	68353 kBTU/h
Fuel HHV Input	75846 kBTU/h
Net Process Heat	40513 kBTU/h

Ambient
13.07 P
59 T
60% RH
51.1 Twb



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GT MASTER 29.0 POWER Engineers, Inc.

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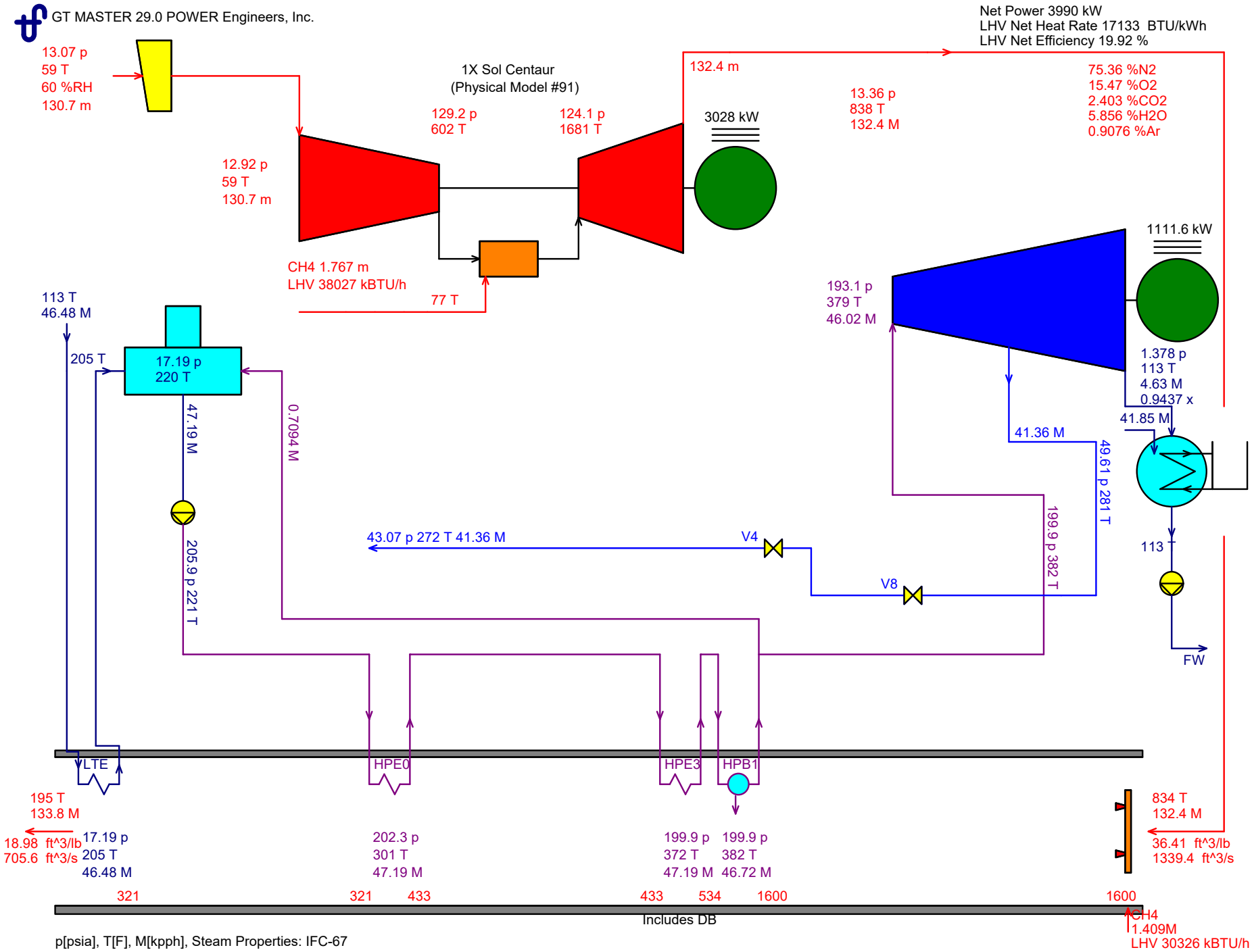

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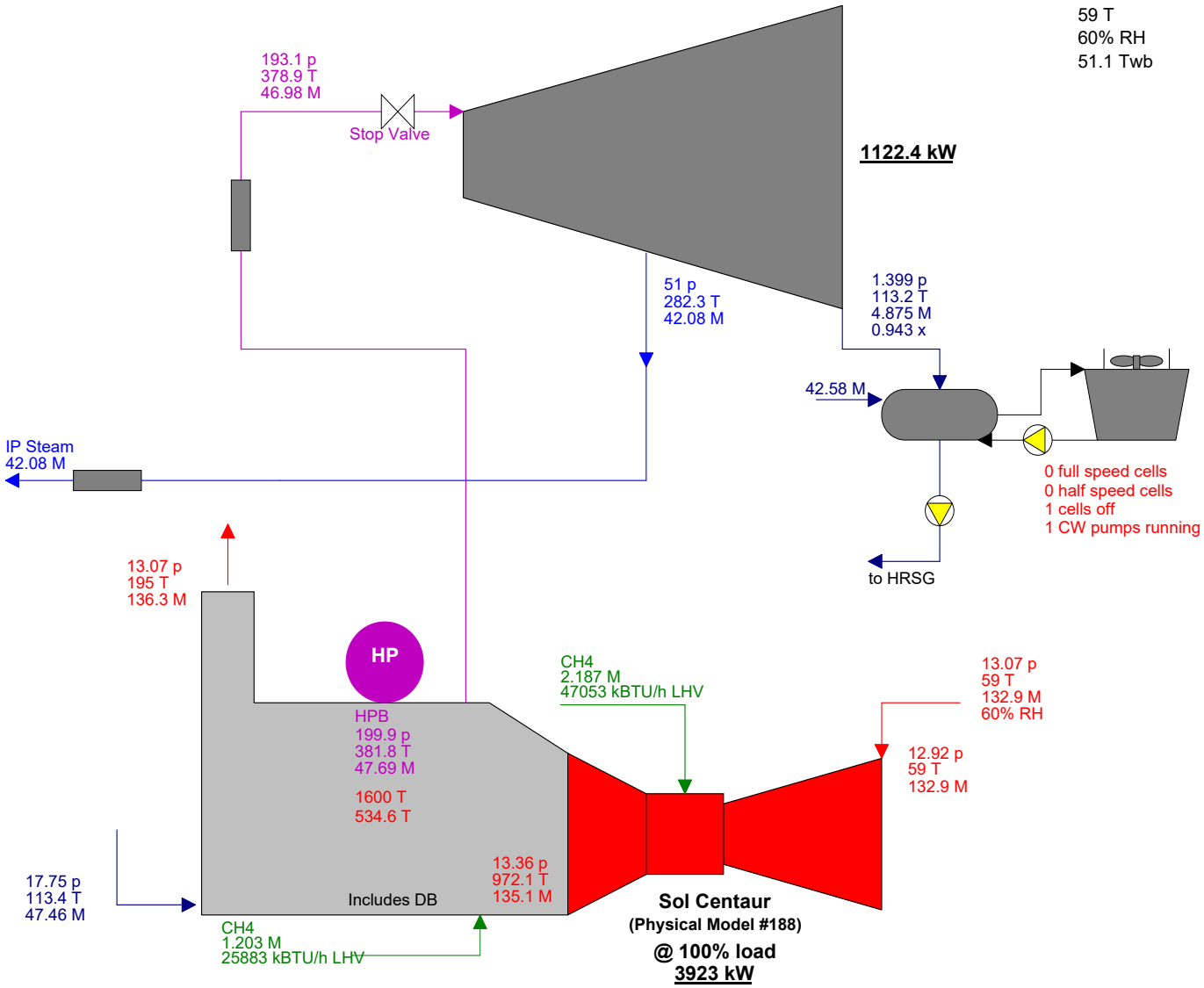
GT MASTER 29.0 POWER Engineers, Inc.

Gross Power	5046 kW
Net Power	4888 kW
Aux. & Losses	157.5 kW
LHV Gross Heat Rate	14455 BTU/kWh
LHV Net Heat Rate	14921 BTU/kWh
LHV Gross Electric Eff.	23.61 %
LHV Net Electric Eff.	22.87 %
Fuel LHV Input	72936 kBTU/h
Fuel HHV Input	80931 kBTU/h
Net Process Heat	41274 kBTU/h

Ambient
13.07 P
59 T
60% RH
51.1 Twb



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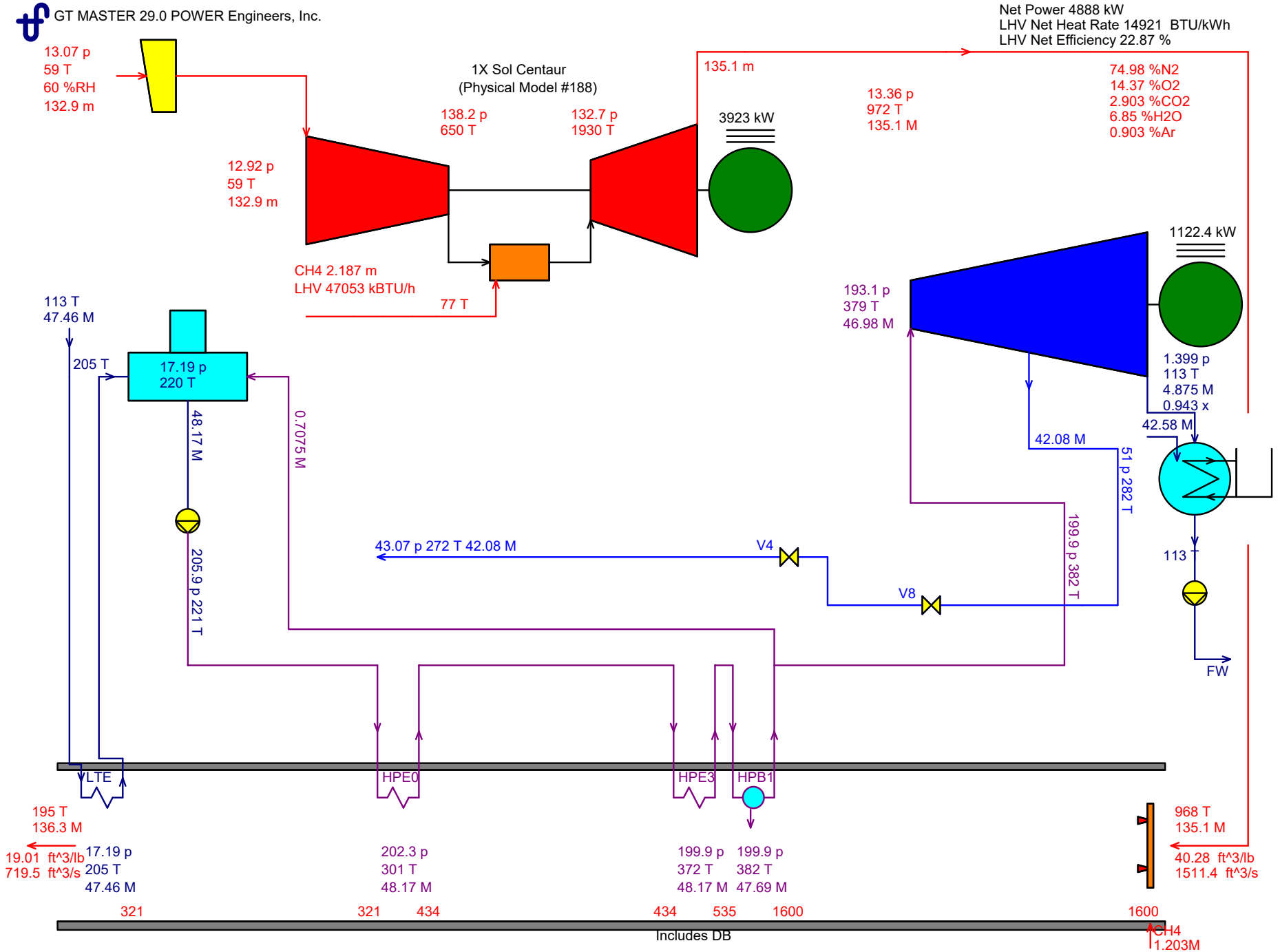

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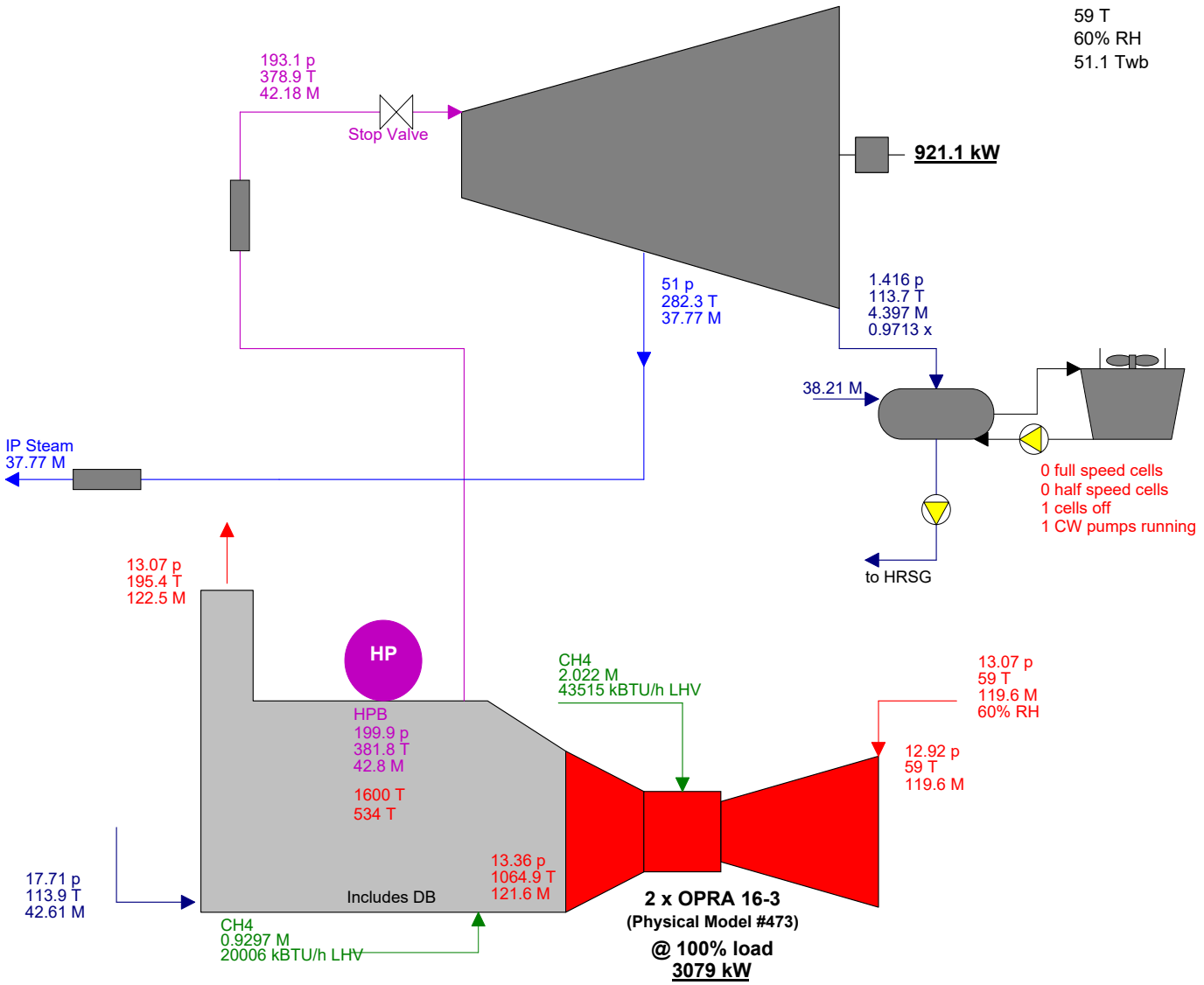
GT MASTER 29.0 POWER Engineers, Inc.

Gross Power	4000 kW
Net Power	3854 kW
Aux. & Losses	146.4 kW
LHV Gross Heat Rate	15878 BTU/kWh
LHV Net Heat Rate	16481 BTU/kWh
LHV Gross Electric Eff.	21.49 %
LHV Net Electric Eff.	20.7 %
Fuel LHV Input	63520 kBTU/h
Fuel HHV Input	70483 kBTU/h
Net Process Heat	37074 kBTU/h



p [psia] T [F] M [kpph], Steam Properties: IFC-67

GT MASTER 29.0 POWER Engineers, Inc.

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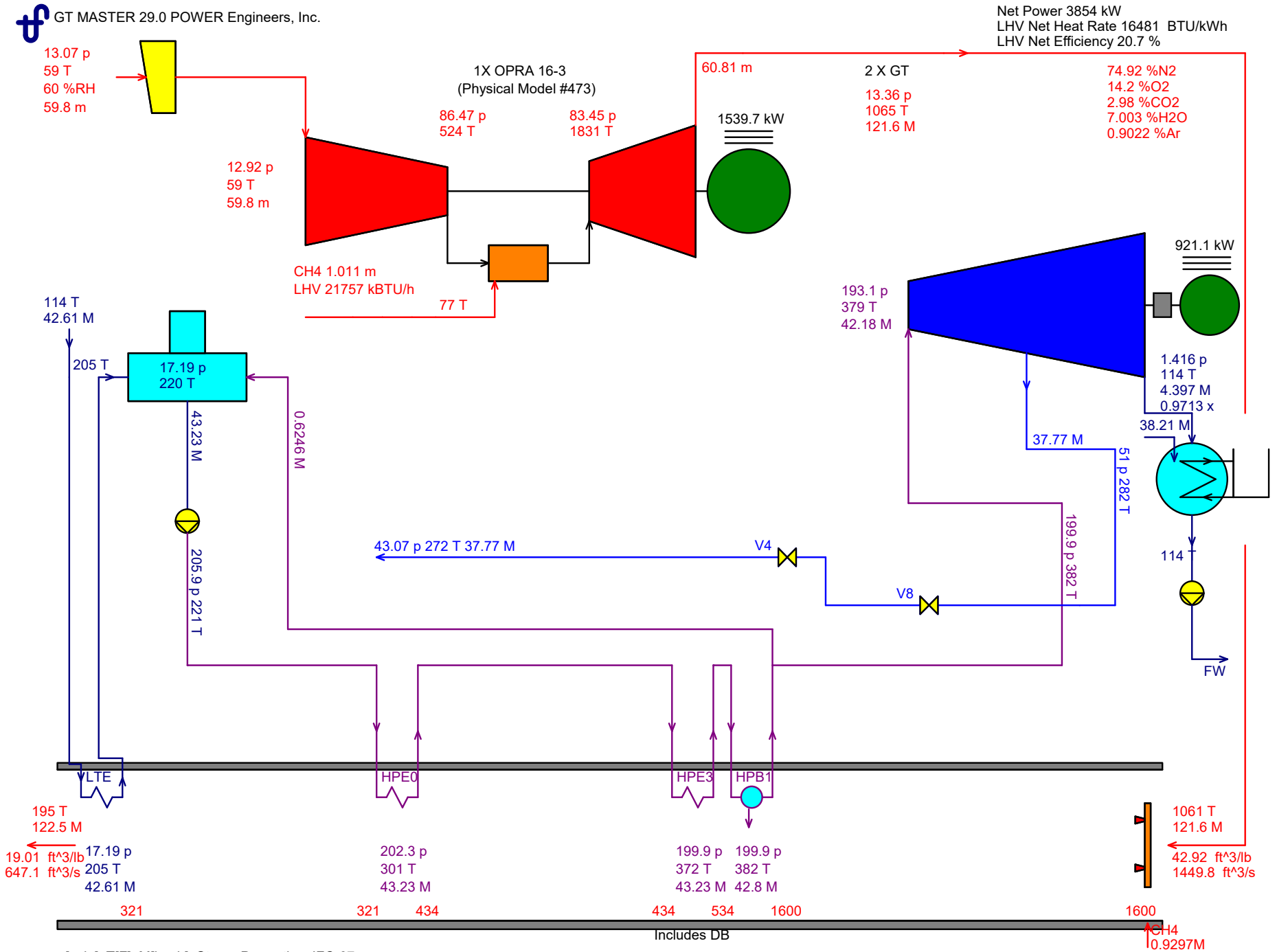

p[psia], T[F], M[kpph], Steam Properties: IFC-67

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Selection Criteria Worksheet - Monthly Average

Centaur 40

	Month	Temp, °F	RH, %	Ave. Steam Export, lb/hr	80% of Steam Export, lb/hr	Ave. Electrical Load, kW	Average Annual Usage, kWh
1	JAN	29.05	83.42	36931	29,545	3668	2728890
2	FEB	24.64	72.64	39875	31,900	3983	2676657
3	MAR	36.50	65.15	31184	24,947	3977	2958933
4	APR	43.23	63.70	26715	21,372	4216	3035535
5	MAY	57.55	64.15	10005	8,004	4076	3032736
6	JUN	58.82	62.91	9315	7,452	3994	2876004
7	JUL	69.10	43.20	7937	6,350	4174	3105822
8	AUG	66.36	45.63	7997	6,397	3894	2897058
9	SEP	56.33	50.34	12997	10,397	4494	3235503
10	OCT	43.51	69.21	27572	22,058	4538	3376116
11	NOV	31.93	82.13	36710	29,368	4321	3110916
12	DEC	26.44	77.42	40241	32,192	3657	2720988
				Average	**19,165**	**4,083**	**35,755,158**

	Month	Steam Export	GTG Output	STG Output	Aux Loads	Electricity Provided	GTG Fuel Input, BTU/hr, LHV	Duct Burner Fuel Input, BTU/hr, LHV	GTG Fuel Input, BTU/hr, HHV	Duct Burner Fuel Input, BTU/hr, LHV	Total, BTU/hr, HHV	Total BTU per month, HHV	Boiler Steam Needed	Electricity Purchased, kWh	Total kW Per Month	Days in Month
1	JAN	29,545	3,049	761	142	3,668	38,008,000	19,931,000	42,150,872	22,103,479	64,254,351	47,805,237,144	0	0	0	31
2	FEB	31,900	3,440	698	155	3,983	41,765,000	18,035,000	46,317,385	20,000,815	66,318,200	44,565,830,400	0	0	0	28
3	MAR	24,947	3,304	459	146	3,617	40,504,000	10,906,000	44,918,936	12,094,754	57,013,690	42,418,185,360	0	360	267885	31
4	APR	21,372	3,222	826	146	3,902	39,763,000	15,000,000	44,097,167	16,635,000	60,732,167	43,727,160,240	0	314	226095	30
5	MAY	8,004	3,052	909	146	3,815	38,213,000	10,000,000	42,378,217	11,090,000	53,468,217	39,780,353,448	0	261	194376	31
6	JUN	7,452	3,038	852	146	3,744	38,078,000	8,800,000	42,228,502	9,759,200	51,987,702	37,431,145,440	0	250	180324	30
7	JUL	6,350	2,909	1446	180	4,174	36,971,000	9,203,000	41,000,839	10,206,127	51,206,966	38,097,982,704	0	0	0	31
8	AUG	6,397	2,909	1164	179	3,894	36,975,000	6,100,000	41,005,275	6,764,900	47,770,175	35,541,010,200	0	0	0	31
9	SEP	10,397	3,064	1148	146	4,066	38,317,000	15,023,000	42,493,553	16,660,507	59,154,060	42,590,923,200	0	428	307983	30
10	OCT	22,058	3,215	1452	149	4,518	39,723,000	25,097,000	44,052,807	27,832,573	71,885,380	53,482,722,720	0	20	14724	31
11	NOV	29,368	3,352	1113	149	4,316	40,981,000	23,227,000	45,447,929	25,758,743	71,206,672	51,268,803,840	0	5	3396	30
12	DEC	32,192	3,077	719	148	3,648	38,255,000	20,604,000	42,424,795	22,849,836	65,274,631	48,564,325,464	0	9	6876	31
											Sum	**525,273,680,160**	**0**		**1201659**	365

Centaur 50

	Month	Temp, °F	RH, %	Ave. Steam Export, lb/hr	80% of Steam Export, lb/hr	Ave. Electrical Load, kW	Average Annual Usage, kWh
1	JAN	29.05	83.42	36930.94355	29545	3668	2728890
2	FEB	24.64	72.64	39875.26786	31900	3983	2676657
3	MAR	36.50	65.15	31183.75806	24947	3977	2958933
4	APR	43.23	63.70	26714.59167	21372	4216	3035535
5	MAY	57.55	64.15	10004.78629	8004	4076	3032736
6	JUN	58.82	62.91	9315.45	7452	3994	2876004
7	JUL	69.10	43.20	7937.459677	6350	4174	3105822
8	AUG	66.36	45.63	7996.671371	6397	3894	2897058
9	SEP	56.33	50.34	12996.7375	10397	4494	3235503
10	OCT	43.51	69.21	27571.92742	22058	4538	3376116
11	NOV	31.93	82.13	36709.695	29368	4321	3110916
12	DEC	26.44	77.42	40240.60887	32192	3657	2720988
				Average	**19,165**	**4,083**	**35,755,158**

	Month	Steam Production	GTG Output	STG Output	Aux Loads	Electricity Provided	GTG Fuel Input, BTU/hr, LHV	Duct Burner Fuel Input, BTU/hr, LHV	GTG Fuel Input, BTU/hr, HHV	Duct Burner Fuel Input, BTU/hr, LHV	Total, BTU/hr, HHV	Total BTU per month, HHV	Boiler Steam Needed	Electricity Needed	Total kWh	
1	JAN	29545	3187	602.7	153	3637	39,992,000	16,608,000	44,351,128	18,418,272	62,769,400	46,700,433,600	0	31	22962	31
2	FEB	31900	3319	816.3	154	3981	41,063,000	20,740,000	45,538,867	23,000,660	68,539,527	46,058,562,144	0	2	1425	28
3	MAR	24947	3367	741	153	3955	41,613,000	14,980,000	46,148,817	16,612,820	62,761,637	46,694,657,928	0	22	16413	31
4	APR	21372	3961	389	151	4199	47,058,000	3,947,000	52,187,322	4,377,223	56,564,545	40,726,472,400	0	17	12255	30
5	MAY	8004	3707	540.6	172	4076	44,956,000	-	49,856,204	-	49,856,204	37,093,015,776	0	0	192	31
6	JUN	7452	3609	530.6	151	3989	44,074,000	-	48,878,066	-	48,878,066	35,192,207,520	0	5	3924	30
7	JUL	6350	3694	631.3	151	4174	44,876,000	-	49,767,484	-	49,767,484	37,027,008,096	0	0	366	31
8	AUG	6397	3490	552.1	151	3891	42,989,000	-	47,674,801	-	47,674,801	35,470,051,944	0	3	2154	31
9	SEP	10397	3971	670.5	152	4490	47,349,000	2,000,000	52,510,041	2,218,000	54,728,041	39,404,189,520	0	4	2703	30
10	OCT	22058	4165	524.6	153	4537	48,935,000	5,350,000	54,268,915	5,933,150	60,202,065	44,790,336,360	0	1	588	31
11	NOV	29368	3807	665.8	154	4319	45,527,000	14,000,000	50,489,443	15,526,000	66,015,443	47,531,118,960	0	2	1236	30
12	DEC	32192	3081	685.9	154	3613	38,949,000	20,000,000	43,194,441	22,180,000	65,374,441	48,638,584,104	0	44	32916	31
											Sum	**505,326,638,352**	**0**		**97134**	365

2xOPRA

	Month	Temp, °F	RH, %	Ave. Steam Export, lb/hr	80% of Steam Export, lb/hr	Ave. Electrical Load, kW	Average Annual Usage, kWh
1	JAN	29.05	83.42	36930.94355	29545	3668	2728890
2	FEB	24.64	72.64	39875.26786	31900	3983	2676657
3	MAR	36.50	65.15	31183.75806	24947	3977	2958933
4	APR	43.23	63.70	26714.59167	21372	4216	3035535
5	MAY	57.55	64.15	10004.78629	8004	4076	3032736
6	JUN	58.82	62.91	9315.45	7452	3994	2876004
7	JUL	69.10	43.20	7937.459677	6350	4174	3105822
8	AUG	66.36	45.63	7996.671371	6397	3894	2897058
9	SEP	56.33	50.34	12996.7375	10397	4494	3235503
10	OCT	43.51	69.21	27571.92742	22058	4538	3376116
11	NOV	31.93	82.13	36709.695	29368	4321	3110916
12	DEC	26.44	77.42	40240.60887	32192	3657	2720988
				Average	**19,165**	**4,083**	**35,755,158**

	Month	Steam Production	GTG Output	STG Output	Aux Loads	Electricity Provided	GTG Fuel Input, BTU/hr, LHV	Duct Burner Fuel Input, BTU/hr, LHV	GTG Fuel Input, BTU/hr, HHV	Duct Burner Fuel Input, BTU/hr, LHV	Total, BTU/hr, HHV	Total BTU per month, HHV	Boiler Steam Needed	Electricity Needed	Total kWh	
1	JAN	29545	3041	765.4	145	3661	42,804,000	15,200,000	47,469,636	16,856,800	64,326,436	47,858,868,384	0	7	5106	31
2	FEB	31900	3425	701.1	145	3981	46,671,000	12,800,000	51,758,139	14,195,200	65,953,339	44,320,643,808	0	2	1425	28
3	MAR	24947	3249	875.5	148	3977	44,962,000	13,518,000	49,862,858	14,991,462	64,854,320	48,251,614,080	0	0	45	31
4	APR	21372	3315	1041.4	145	4211	45,710,000	14,299,000	50,692,390	15,857,591	66,549,981	47,915,986,320	0	5	3615	30
5	MAY	8004	3113	640	143	3610	43,759,000	2,250,000	48,528,731	2,495,250	51,023,981	37,961,841,864	0	466	346896	31
6	JUN	7452	3075	1065	151	3989	43,374,000	-	48,101,766	-	48,101,766	34,633,271,520	0	5	3924	30
7	JUL	6350	2937	1410	176	4171	42,071,000	2,900,000	46,656,739	3,216,100	49,872,839	37,105,392,216	0	3	2598	31
8	AUG	6397	2931.2	1134.3	176	3890	41,960,000	-	46,533,640	-	46,533,640	34,621,028,160	0	4	2898	31
9	SEP	10397	3128	1541	176	4493	43,896,000	7,500,000	48,680,664	8,317,500	56,998,164	41,038,678,080	0	1	543	30
10	OCT	22058	3306	1357.8	147	4517	45,656,000	20,259,000	50,632,504	22,467,231	73,099,735	54,386,202,840	0	21	15468	31
11	NOV	29368	3487	972.6	146	4314	47,390,000	15,730,000	52,555,510	17,444,570	70,000,080	50,400,057,600	0	7	4836	30
12	DEC	32192	3076	705	145	3636	43,143,000	15,209,000	47,845,587	16,866,781	64,712,368	48,146,001,792	0	21	15804	31
											Sum	**526,639,586,664**	**0**		**403158**	365

COGENERATION PLANT PERFORMANCE & COST SUMMARY

New	Centaur 40	Centaur 50	2 x OPRA	Units	Comments
Annual Gas Usage	525,274	505,327	526,640	MMBTU	This is the gas used for GTG and HRSG
Cost for Natural Gas	$ 3.285	$ 3.285	$ 3.285	$/MMBTU	
Annual Gas Cost	$ 1,725,524	$ 1,659,998	$ 1,730,011	$USD	
Average Steam Needed From Boilers	0	0	0	lb/hr	This is the steam that will need supplemented from the existing boilers.
Enthalpy of steam	1,198	1,198	1,198	BTU/lb	
Gas Required to Supply Steam	0	0	0	BTU/hr	
Assume 80% Efficient Boiler	0	0	0	BTU/hr	
Annual Gas Usage	0	0	0	MMBTU	
Cost for Natural Gas	$ 3.285	$ 3.285	$ 3.285	$/MMBTU	
Annual Gas Cost	$ -	$ -	$ -	$USD	O&M costs presently????
Annual Electricity Needed	1,201,659	97,134	403,158	kW	This is power that UofM would othermwise have to purchase
Cost for Electricity	$ 0.098	$ 0.098	$ 0.098	$/kWh	
Annual Electrical Costs	$ 117,762.58	$ 9,519.13	$ 39,509.48	$USD	

Present	Centaur 40	Centaur 50	2 x OPRA	Units	Comments
Average Steam Needed From Boilers	19,165	19,165	19,165	lb/hr	This is the steam that the boilers would otherwise have to produce or the cost we are
Enthalpy of steam	1,198	1,198	1,198	BTU/lb	offsetting.
Gas Required to Supply Steam	22,963,311	22,963,311	22,963,311	BTU/hr	
Assume 80% Efficient Boiler	27,555,974	27,555,974	27,555,974	BTU/hr	
Annual Gas Usage	241,390	241,390	241,390	MMBTU	
Cost for Natural Gas	$ 3.285	$ 3.285	$ 3.285	$/MMBTU	
Annual Gas Cost	$ 792,967	$ 792,967	$ 792,967	$USD	
Annual Electicity Purchased, kWh	35,755,158	35,755,158	35,755,158	kWh	
Cost for Electricity	$ 0.098	$ 0.098	$ 0.098	$/kWh	
Annual Electricity Costs w/o Cogen	$ 3,504,005.48	$ 3,504,005.48	$ 3,504,005.48	$USD	

APPENDIX B – COST ESTIMATES

Project Cost Summary Centaur 40	Reference Cost	Estimated Cost	
I Specialized Equipment	7,241,690	7,248,094	USD
II Other Equipment	457,468	471,545	USD
III Civil	571,788	601,100	USD
IV Mechanical	784,802	868,996	USD
V Electrical Assembly & Wiring	399,617	435,481	USD
VI Buildings & Structures	312,579	334,851	USD
VII Engineering & Plant Startup	1,161,480	1,161,480	USD
Subtotal - Contractor's Internal Cost	10,929,425	11,121,546	USD
VIII Contractor's Soft & Miscellaneous Costs	2,761,688	2,936,832	USD
Contractor's Price	13,691,113	14,058,378	USD
IX Owner's Soft & Miscellaneous Costs	1,232,200	1,265,254	USD
Total - Owner's Cost	14,923,313	15,323,632	USD
Net Plant Output	6.3	6.3	MW
Price per kW - Contractor's	2,182.1	2,240.6	USD per kW
Cost per kW - Owner's	2,378.5	2,442.3	USD per kW

Note: Certain values are hidden if not applicable to cogen facility

	Item Cost	Unit Cost	Quantity	Ref. Cost	Est. Cost
I Specialized Equipment (USD)				7,241,690	7,248,094
1. Gas Turbine Package		3,751,500	1	3,751,500	3,751,500
Combustion Turbine Genset	3,349,600				
Inlet Filter/Silencer System (w/ elements)	included				
Electrical/Control/Instrumentation Package	included				
Gas Fuel Package	included				
Liquid Fuel Package	included				
Starting Package	included				
Lube Oil Package w/ main, auxiliary & emergency pump	included				
Compressor Water Wash System	included				
OEM supplied technical oversight & services required for warranty	included				
Shipping	84,900				
PM & Engineering for ship loose Equipment	59,300				
6% BOP Contingency	59,500				
Commissioning parts startup and testing	198,200				
2. Steam Turbine Package		2,030,750	1	2,030,750	2,030,750
Turbine	included				
Generator	included				
Exhaust System	included				
Electrical/Control/Instrumentation Package	included				
Lube Oil Package w/ main, auxiliary & emergency pump	included				
OEM supplied technical oversight & services required for warranty	included				
User-defined shipping cost [8%]	85,750				
3. Heat Recovery Boiler		1,061,500	1	1,061,500	1,061,500
Duct Burner & Burner Management System	included				
Gas Turbine Exhaust Transition	included				
Bypass Stack	included				
Main Stack	included				
Instrumentation	included				
Deaerator	included				
Steam Vents & Water Drains	included				
Non-Return Valves	included				
OEM supplied technical oversight & services required for warranty	included				
User-defined shipping cost [10%]	96,500				
4. Water-cooled Condenser		269,850	1	269,850	269,850
Vacuum Pump	elsewhere				
User-defined shipping cost [8%]	19,850				
9. Distributed Control System		49,130	1	49,130	51,586
Enclosures	included				
Electronics, Display Units, Printers & Sensors	included				
Approximate shipping to typical US site	included				
10. Transmission Voltage Equipment		29,370	1	29,370	30,838
Circuit Breakers	27,970				
Miscellaneous Equipment	1,400				
Approximate shipping to typical US site	included				
11. Generating Voltage Equipment		49,590	1	49,590	52,069
Generator Buswork	37,540				
Circuit Breakers	9,690				
Miscellaneous Equipment	2,360				
Approximate shipping to typical US site	included				

	Unit Cost	Quantity	Ref. Cost	Est. Cost
II Other Equipment (USD)			457,468	471,545
1. Pumps			71,752	72,812
HP Feedwater Pump	10,230	2	20,460	20,460
Condensate Forwarding Pump	5,410	0		
Condenser C.W. Pump	15,046	2	30,092	30,092
Condenser Vacuum Pump	10,600	2	21,200	22,260
Fuel Oil Unloading Pump	9,520	0		
2. Tanks		2	996	1,046
Fuel Oil	21,090	0		

Demineralized Water	3,240	0		
Raw Water	3,240	0		
Neutralized Water	2,040	0		
Acid Storage	498	1	498	523
Caustic Storage	498	1	498	523
3. Cooling Tower	**117,000**	**1**	**117,000**	**117,000**
4. Auxiliary Heat Exchangers			**3,570**	**3,748**
Auxiliary Cooling Water Heat Exchanger	3,570	1	3,570	3,748
10. Station/Instrument Air Compressors	**23,278**	**1**	**23,278**	**24,442**
11. Recip Engine Genset(s)		**1**	**68,500**	**71,925**
Emergency Generator				
Black Start Generator	68,500	1	68,500	71,925
12. General Plant Instrumentatior	**42,300**	**1**	**42,300**	**44,415**
13. Medium Voltage Equipment	**538**	**1**	**538**	**565**
Circuit Breakers	512			
Miscellaneous	26			
14. Low Voltage Equipment	**107,750**	**1**	**107,750**	**113,137**
Transformers	66,850			
Circuit Breakers	14,720			
Motor Control Centers	21,030			
Miscellaneous	5,130			
15. Miscellaneous Equipment	**21,784**		**21,784**	**22,455**

	Material	Labor Hours	Labor Rate	Unit Cost	Quantity	Ref. Cost	Est. Cost
III Civil (USD)	**308,141**	**6,254**	**41.00**			**571,788**	**601,100**
1. Site Work	**108,750**	**1,390**	**41.00**			**165,740**	**173,861**
Site Clearing	included	included					
Demolition	included	included					
Culverts & Drainage	included	included					
Erosion Control	included	included					
Fencing, Controlled Access Gates	included	included					
Finish Grading	included	included					
Finish Landscaping	included	included					
Material (Dirt, Sand, Stone)	included	included					
Waste Material Removal	included	included					
Obstacles R&R	included	included					
Miscellaneous	included	included					
2. Excavation & Backfill	**24,036**	**466**	**41.00**	**77.02**	**563**	**43,337**	**45,884**
Gas Turbine (1)	50.34	0.99	41.00	90.98	70	6,344	6,748
Steam Turbine (1)	50.20	0.99	41.00		0	91	
Heat Recovery Boiler (1)	48.65	0.95	41.00		0	88	
Water Cooled Condenser (1)	48.41	0.94	41.00	87.10	30	2,613	2,778
Cooling Tower	35.06	0.69	41.00	63.16	178	11,242	11,955
Underground Piping	43.62	0.83	41.00	77.51	150	11,627	12,351
Switchyard	49.12	0.96	41.00	88.50	4	345	367
Other & Miscellaneous	46.55	0.91	41.00	83.88	131	10,988	11,684
3. Concrete	**169,349**	**4,384**	**41.00**	**1,974.55**	**180**	**356,130**	**374,691**
Gas Turbine (1)	998.84	22.92	41.00	1,938.74	40	77,550	82,907
Steam Turbine (1)	1,043.28	25.15	41.00	2,074.23	10	20,742	22,211
Laydown pads:	895.10	22.77	41.00		0	1,829	
Heat Recovery Boiler (1)	753.12	19.38	41.00		0	1,548	
Water Cooled Condenser (1)	1,060.98	29.43	41.00	2,267.61	23	51,316	55,207
Cooling Tower	856.89	24.62	41.00	1,866.26	40	74,651	80,404
Electrical Power Equipment	855.11	22.43	41.00	1,774.56	25	43,601	46,820
Pumps (4)	855.42	20.81	41.00	1,708.52	3	5,126	5,490
Station/Instrument Air Compressors (2)	799.40	19.25	41.00	1,588.46	2	3,199	3,426
Recip Engine Genset(s) (1)	1,160.20	27.38	41.00	2,282.69	3	7,181	7,685
Tanks:	903.68	26.32	41.00		0	1,983	
Switchyard	804.93	21.61	41.00		0	1,691	
Miscellaneous	909.73	23.61	41.00	1,877.55	35	65,714	70,541
4. Roads, Parking, Walkways	**6,006**	**14**	**41.00**	**6.58**	**1,000**	**6,582**	**6,664**
Pavement, Curbing, Striping	6.01	0.01	41.00	6.58	1,000	6,582	6,664
Lighting	0.00	0.00	47.00		0		

	Material	Labor Hours	Labor Rate	Unit Cost	Quantity	Ref. Cost	Est. Cost
IV Mechanical (USD)	**296,116**	**10,615**	**46.00**			**784,802**	**868,996**
1. On-Site Transportation & Rigging	**124,750**					**124,750**	**136,757**
2. Equipment Erection & Assembly	**65,174**	**7,054**	**46.00**			**389,663**	**435,903**
Gas Turbine Package	9,880	1,070	46.00	59,100	1	59,100	66,114
Steam Turbine Package	10,430	1,130	46.00	62,410	1	62,410	69,817
HRSG	11,870	1,280	46.00	70,750	1	70,750	79,140
Condenser	6,910	749	46.00	41,364	1	41,364	46,274
Cooling Tower	elsewhere	elsewhere					
Electrical Power Equipment	9,170	993	46.00			54,848	61,357
Pumps	4,270	463	46.00			25,568	28,603
Tanks + Auxiliary Heat Exchangers	4,940	535	46.00			29,550	33,057
Station/Instrument Air Compressors	879	95	46.00			5,258	5,882
Recip Engine Genset(s)	895	97	46.00			5,353	5,988
Miscellaneous	5,930	642	46.00			35,462	39,670
3. Piping	**102,402**	**3,522**	**46.00**	**199.69**	**1,326**	**264,791**	**290,480**
High Pressure Steam	94.97	5.54	46.00	349.95	100	34,995	38,866
Intermediate Pressure Steam	24.77	2.01	46.00		0	117	131
Circulating Water	111.27	1.50	46.00	180.40	100	18,040	19,304
Auxiliary Cooling Water	41.90	2.03	46.00	135.07	100	13,507	14,940

Feedwater	49.76	2.32	46.00	156.46	100	15,646	17,291
Raw Water	17.77	1.19	46.00		0	73	81
Service Water	19.17	1.33	46.00		0	81	90
Fuel Gas	52.41	2.07	46.00	147.80	200	29,560	32,540
Fuel Oil	34.32	1.94	46.00		0	124	137
Lube Oil	201.01	7.34	46.00	538.56	120	64,627	71,003
Service Air	18.21	1.34	46.00	79.91	200	15,982	17,832
Vacuum Air	47.38	3.38	46.00	202.90	42	8,522	9,503
Boiler & Equipment Drain	92.27	0.62	46.00	120.66	97	11,704	12,320
Boiler Blowdown	25.67	1.27	46.00	84.00	97	8,148	9,017
Steam Blowoff	624.35	7.93	46.00	989.35	20	19,787	21,139
Miscellaneous	56.34	2.24	46.00	159.19	150	23,879	26,288
4. Steel	**3,790**	**39**	**46.00**	**5,553.83**	**1**	**5,598**	**5,856**
Racks, Supports, Ladders, Walkways, Platforms	3,759.92	39.00	46.00	5,553.83	1	5,598	5,856
	Material	**Labor Hours**	**Labor Rate**	**Unit Cost**	**Quantity**	**Ref. Cost**	**Est. Cost**
V Electrical (USD)	**147,944**	**5,355**	**47.00**			**399,617**	**435,481**
1. Controls	**21,230**	**1,675**	**47.00**			**99,971**	**111,191**
Gas Turbine Package	5,410	458	47.00	26,936.00	1	26,936	30,003
Steam Turbine Package	5,710	484	47.00	28,458.00	1	28,458	31,700
HRSG	3,790	321	47.00	18,877.00	1	18,877	21,027
Condenser	1,560	132	47.00	7,764.00	1	7,764	8,648
Cooling Tower	elsewhere	elsewhere					
Pumps	2,340	198	47.00	11,646.00	1	11,646	12,972
Station/Instrument Air Compressor	1,200	41	47.00	3,117.60	1	3,118	3,391
Recip Engine Genset(s)	1,220	42	47.00	3,171.91	1	3,172	3,450
2. Assembly & Wiring	**126,714**	**3,679**	**47.00**			**299,647**	**324,290**
Motor Control Centers	144	78	47.00	3,797.75	4	15,191	17,274
Feeders	754	27	47.00	2,034.47	47	95,620	104,193
Medium/Low Voltage Cable Bus	1,560	45	47.00	3,675.00	6	22,050	23,858
Cable Tray	6,690	80	47.00	10,442.95	1	10,443	10,978
General Plant Instrumentation	306	5	47.00	534.88	80	42,790	45,402
Generator to Step-up Transformer Bus	3,310	47	47.00	5,508.89	2	11,018	11,644
Transformers	1,130	48	47.00	3,386.00	1	3,386	3,707
Circuit Breakers	6,180	175	47.00	14,386.20	5	71,931	77,778
Miscellaneous	11,520	334	47.00	27,218.00	1	27,218	29,455

	Area	**Cost/Unit Area**	**Ref. Cost**	**Est. Cost**
VI Buildings (USD)			**312,579**	**334,851**
1. Turbine Hall	**0.0**	**230.60**		
2. Administration, Control Room, Machine Shop / Wareho	**2,030.0**	**153.98**	**312,579**	**334,851**
3. Water Treatment System				
4. Guard House				
5. User-defined			**0.00**	**0**

	Material	**Labor Hours**	**Labor Rate**	**Unit Cost**	**Quantity**	**Ref. Cost**	**Est. Cost**
VII Engineering & Startup (USD)	**38,520**	**1,060**	**116.00**			**1,161,480**	**1,161,480**
1. Engineering						1,000,000	1,000,000
2. Start-Up	38,520	1,060	116.00	161,480		161,480	161,480
3. User-defined						0	0

	Ref. Cost	**Est. Cost**
VIII Soft & Miscellaneous Costs (USD)	**3,993,888**	**4,202,086**
1. Contractor's Soft Costs	**2,761,688**	**2,936,832**
Contingency:	1,122,501	1,242,886
Profit:	874,128	915,438
Permits, Licenses, Fees, Miscellaneous	0	0
Bonds and Insurance	218,589	222,431
Spare Parts & Materials	0	0
Contractor's Fee	546,471	556,077
2. Owner's Soft Costs	**1,232,200**	**1,265,254**
Permits, Licenses, Fees, Miscellaneous	273,822	281,168
Land Cost	0	0
Utility Connection Cost	0	0
Legal & Financial Costs	273,822	281,168
Escalation and Interest During Construction	547,645	562,335
Spare Parts & Materials	0	0
Project Administration & Developer's Fee	136,911	140,584
3. Total of all user-defined costs displayed on each accoun	**0**	**0**

Project Cost Summary Centaur 50	Reference Cost	Estimated Cost	
I Specialized Equipment	7,302,830	7,309,757	USD
II Other Equipment	462,605	476,939	USD
III Civil	741,828	779,409	USD
IV Mechanical	796,744	881,798	USD
V Electrical Assembly & Wiring	415,148	452,254	USD
VI Buildings & Structures	312,579	334,851	USD
VII Engineering & Plant Startup	1,161,480	1,161,480	USD
Subtotal - Contractor's Internal Cost	11,193,215	11,396,488	USD
VIII Contractor's Soft & Miscellaneous Costs	2,694,969	2,855,620	USD
Contractor's Price	13,888,184	14,252,108	USD
IX Owner's Soft & Miscellaneous Costs	1,249,937	1,471,221	USD
Total - Owner's Cost	15,138,121	15,723,329	USD
Net Plant Output	7.2	7.2	MW
Price per kW - Contractor's	1,918.8	1,969.1	USD per kW
Cost per kW - Owner's	2,091.5	2,172.4	USD per kW
Note: Certain values are hidden if not applicable to cogen facility			

	Item Cost	Unit Cost	Quantity	Ref. Cost	Est. Cost
I Specialized Equipment (USD)				7,302,830	7,309,757
1. Gas Turbine Package		3,801,900	1	3,801,900	3,801,900
Combustion Turbine Genset	3,400,000				
Inlet Filter/Silencer System (w/ elements)	included				
Electrical/Control/Instrumentation Package	included				
Gas Fuel Package	included				
Liquid Fuel Package	included				
Starting Package	included				
Lube Oil Package w/ main, auxiliary & emergency pump	included				
Compressor Water Wash System	included				
OEM supplied technical oversight & services required for warranty	included				
Shipping	84,900				
PM & Engineering for ship loose Equipment	59,300				
6% BOP Contingency	59,500				
Commissioning parts startup and testing	198,200				
2. Steam Turbine Package		2,030,750	1	2,030,750	2,030,750
Turbine	included				
Generator	included				
Exhaust System	included				
Electrical/Control/Instrumentation Package	included				
Lube Oil Package w/ main, auxiliary & emergency pump	included				
OEM supplied technical oversight & services required for warranty	included				
User-defined shipping cost [8%]	85,750				
3. Heat Recovery Boiler		1,061,500	1	1,061,500	1,061,500
Duct Burner & Burner Management System	included				
Gas Turbine Exhaust Transition	included				
Bypass Stack	included				
Main Stack	included				
Instrumentation	included				
Deaerator	included				
Steam Vents & Water Drains	included				
Non-Return Valves	included				
OEM supplied technical oversight & services required for warranty	included				
User-defined shipping cost [10%]	96,500				
4. Water-cooled Condenser		270,140	1	270,140	270,140
Vacuum Pump	elsewhere				
User-defined shipping cost [8%]	20,140				
9. Distributed Control System		51,700	1	51,700	54,285
Enclosures	included				
Electronics, Display Units, Printers & Sensors	included				
Approximate shipping to typical US site	included				
10. Transmission Voltage Equipment		30,890	1	30,890	32,434
Circuit Breakers	29,420				
Miscellaneous Equipment	1,470				
Approximate shipping to typical US site	included				
11. Generating Voltage Equipment		55,950	1	55,950	58,747
Generator Buswork	41,940				
Circuit Breakers	11,330				
Miscellaneous Equipment	2,660				
Approximate shipping to typical US site	included				

	Unit Cost	Quantity	Ref. Cost	Est. Cost
II Other Equipment (USD)			462,605	476,939
1. Pumps			71,752	72,812
HP Feedwater Pump	10,230	2	20,460	20,460
Condensate Forwarding Pump	5,410	0		
Condenser C.W. Pump	15,046	2	30,092	30,092
Condenser Vacuum Pump	10,600	2	21,200	22,260
Fuel Oil Unloading Pump	9,520	0		
2. Tanks		2	1,008	1,058
Fuel Oil	24,180	0		

Demineralized Water	3,280	0		
Raw Water	3,280	0		
Neutralized Water	2,070	0		
Acid Storage	504	1	504	529
Caustic Storage	504	1	504	529
3. Cooling Tower	**117,000**	**1**	**117,000**	**117,000**
4. Auxiliary Heat Exchangers			**4,400**	**4,620**
Auxiliary Cooling Water Heat Exchanger	4,400	1	4,400	4,620
10. Station/Instrument Air Compressors	**23,278**	**1**	**23,278**	**24,442**
11. Recip Engine Genset(s)		**1**	**68,500**	**71,925**
Black Start Generator	68,500	1	68,500	71,925
12. General Plant Instrumentation	**42,300**	**1**	**42,300**	**44,415**
13. Medium Voltage Equipment	**538**	**1**	**538**	**565**
Circuit Breakers	551			
Miscellaneous	28			
14. Low Voltage Equipment	**111,800**	**1**	**111,800**	**117,390**
Transformers	69,150			
Circuit Breakers	15,850			
Motor Control Centers	21,470			
Miscellaneous	5,320			
15. Miscellaneous Equipment	**22,029**		**22,029**	**22,711**

	Material	Labor Hours	Labor Rate	Unit Cost	Quantity	Ref. Cost	Est. Cost
III Civil (USD)	**420,424**	**7,654**	**41.05**			**741,828**	**779,409**
1. Site Work	**202,250**	**2,620**	**41.00**			**309,670**	**324,977**
Site Clearing	included	included					
Demolition	included	included					
Culverts & Drainage	included	included					
Erosion Control	included	included					
Fencing, Controlled Access Gates	included	included					
Finish Grading	included	included					
Finish Landscaping	included	included					
Material (Dirt, Sand, Stone)	included	included					
Waste Material Removal	included	included					
Obstacles R&R	included	included					
Miscellaneous	included	included					
2. Excavation & Backfill	**23,103**	**448**	**41.00**	**77.84**	**535**	**41,637**	**44,075**
Gas Turbine (1)	50.37	0.99	41.00	91.01	70	6,371	6,776
Steam Turbine (1)	50.21	0.99	41.00		0	91	
Heat Recovery Boiler (1)	48.32	0.94	41.00		0	87	
Water Cooled Condenser (1)	48.38	0.94	41.00	87.03	30	2,611	2,776
Cooling Tower	35.08	0.69	41.00	63.40	150	9,510	10,115
Underground Piping	43.50	0.82	41.00	77.22	150	11,583	12,303
Switchyard	49.25	0.96	41.00	88.74	4	346	368
Other & Miscellaneous	46.92	0.91	41.00	84.27	131	11,039	11,736
3. Concrete	**172,704**	**4,505**	**41.00**	**2,012.98**	**181**	**364,442**	**383,749**
Gas Turbine (1)	1,067.55	25.27	41.00	2,103.68	40	84,147	90,053
Steam Turbine (1)	1,038.25	24.95	41.00	2,061.06	10	20,611	22,068
Laydown pads:	894.93	22.76	41.00		0	1,828	
Heat Recovery Boiler (1)	747.51	19.23	41.00		0	1,536	
Water Cooled Condenser (1)	1,060.79	29.44	41.00	2,267.82	23	52,228	56,189
Cooling Tower	853.58	24.61	41.00	1,862.62	40	74,505	80,256
Electrical Power Equipment	854.85	22.42	41.00	1,773.98	25	44,350	47,624
Pumps (4)	856.44	20.84	41.00	1,710.75	3	5,132	5,497
Station/Instrument Air Compressors (2)	853.17	20.51	41.00	1,694.12	2	3,415	3,657
Recip Engine Genset(s) (1)	1,128.32	26.99	41.00	2,234.96	3	6,705	7,178
Tanks:	895.56	26.05	41.00		0	1,964	
Switchyard	802.40	21.61	41.00		0	1,688	
Miscellaneous	914.30	23.93	41.00	1,895.24	35	66,333	71,226
4. Roads, Parking, Walkways	**22,366**	**81**	**45.96**	**26.00**	**1,003**	**26,079**	**26,608**
Pavement, Curbing, Striping	6.01	0.01	41.00	6.58	1,000	6,582	6,664
Lighting	5,453.33	22.25	47.00	6,499.08	3	19,497	19,944

	Material	Labor Hours	Labor Rate	Unit Cost	Quantity	Ref. Cost	Est. Cost
IV Mechanical (USD)	**299,210**	**10,807**	**46.00**			**796,744**	**881,798**
1. On-Site Transportation & Rigging	**118,300**					**118,300**	**129,686**
2. Equipment Erection & Assembly	**65,262**	**7,069**	**46.00**			**390,418**	**436,752**
Gas Turbine Package	8,490	919	46.00	50,764	1	50,764	56,788
Steam Turbine Package	10,740	1,160	46.00	64,100	1	64,100	71,704
HRSG	12,180	1,320	46.00	72,900	1	72,900	81,553
Condenser	6,980	756	46.00	41,756	1	41,756	46,712
Cooling Tower	elsewhere	elsewhere					
Electrical Power Equipment	9,390	1,020	46.00			56,310	62,996
Pumps	4,300	466	46.00			25,736	28,791
Tanks + Auxiliary Heat Exchangers	5,330	577	46.00			31,872	35,654
Station/Instrument Air Compressors	892	97	46.00			5,336	5,969
Recip Engine Genset(s)	1,030	112	46.00			6,182	6,916
Miscellaneous	5,930	642	46.00			35,462	39,670
3. Piping	**111,228**	**3,693**	**46.00**	**212.29**	**1,326**	**281,501**	**308,534**
High Pressure Steam	94.97	5.54	46.00	349.95	100	34,995	38,866
Intermediate Pressure Steam	24.77	2.01	46.00		0	117	131
Circulating Water	110.92	1.49	46.00	179.66	100	17,966	19,222
Auxiliary Cooling Water	40.07	1.95	46.00	129.91	100	12,991	14,371

Feedwater	48.38	2.27	46.00	152.72	100	15,272	16,879
Raw Water	17.75	1.19	46.00		0	72	81
Service Water	19.08	1.32	46.00		0	80	89
Fuel Gas	52.17	2.06	46.00	147.00	200	29,401	32,365
Fuel Oil	35.43	1.93	46.00		0	124	138
Lube Oil	228.00	8.14	46.00	602.57	120	72,309	79,398
Service Air	18.10	1.34	46.00	79.69	200	15,939	17,785
Vacuum Air	47.38	3.38	46.00	202.90	42	8,522	9,503
Boiler & Equipment Drain	90.81	0.61	46.00	118.78	97	11,521	12,128
Boiler Blowdown	62.02	1.76	46.00	142.87	97	13,858	15,126
Steam Blowoff	736.09	9.89	46.00	1,191.09	20	23,822	25,487
Miscellaneous	58.96	2.27	46.00	163.42	150	24,512	26,966
4. Steel	**4,420**	**46**	**46.00**	**5,558.67**	**1**	**6,526**	**6,826**
Racks, Supports, Ladders, Walkways, Platforms	3,764.91	38.99	46.00	5,558.67	1	6,526	6,826
	Material	**Labor Hours**	**Labor Rate**	**Unit Cost**	**Quantity**	**Ref. Cost**	**Est. Cost**
V Electrical (USD)	**154,756**	**5,540**	**13.95**			**415,148**	**452,254**
1. Controls	**20,970**	**1,644**	**47.00**			**98,255**	**109,269**
Gas Turbine Package	4,650	394	47.00	23,168.00	1	23,168	25,807
Steam Turbine Package	5,880	498	47.00	29,286.00	1	29,286	32,621
HRSG	3,890	330	47.00	19,400.00	1	19,400	21,610
Condenser	1,570	133	47.00	7,821.00	1	7,821	8,712
Cooling Tower	elsewhere	elsewhere					
Pumps	2,350	200	47.00	11,750.00	1	11,750	13,089
Station/Instrument Air Compressor	1,220	41	47.00	3,165.80	1	3,166	3,443
Recip Engine Genset(s)	1,410	48	47.00	3,664.59	1	3,665	3,986
2. Assembly & Wiring	**133,786**	**3,896**				**316,893**	**342,986**
Motor Control Centers	147	79	47.00	3,859.50	4	15,438	17,554
Feeders	966	35	47.00	2,605.74	40	104,230	113,578
Medium/Low Voltage Cable Bus	1,768	49	47.00	4,055.67	6	24,334	26,290
Cable Tray	6,760	81	47.00	10,555.25	1	10,555	11,096
General Plant Instrumentation	309	5	47.00	540.73	80	43,258	45,897
Generator to Step-up Transformer Bus	3,445	49	47.00	5,733.90	2	11,468	12,120
Transformers	1,160	49	47.00	3,463.00	1	3,463	3,791
Circuit Breakers	6,326	179	47.00	14,729.60	5	73,648	79,636
Miscellaneous	12,780	377	47.00	30,499.00	1	30,499	33,024
	Area	**Cost/Unit Area**	**Ref. Cost**	**Est. Cost**			
VI Buildings (USD)			**312,579**	**334,851**			
1. Turbine Hall	**0.0**	**230.60**					
2. Administration, Control Room, Machine Shop / Warehous	**2,030.0**	**153.98**	**312,579**	**334,851**			
3. Water Treatment System							
4. Guard House	**0.0**	**144.95**					
5. User-defined			**0.00**	**0**			
	Material	**Labor Hours**	**Labor Rate**	**Unit Cost**	**Quantity**	**Ref. Cost**	**Est. Cost**
VII Engineering & Startup (USD)	**38,520**	**1,060**	**116.00**			**1,161,480**	**1,161,480**
1. Engineering						**1,000,000**	**1,000,000**
2. Start-Up	**38,520**	**1,060**	**116.00**	**161,480**		**161,480**	**161,480**
3. User-defined						**0**	**0**
	Ref. Cost	**Est. Cost**					
VIII Soft & Miscellaneous Costs (USD)	**3,944,906**	**4,326,841**					
1. Contractor's Soft Costs	**2,694,969**	**2,855,620**					
Contingency:	1,051,061	1,159,957					
Profit:	860,383	897,910					
Permits, Licenses, Fees, Miscellaneous	0	0					
Bonds and Insurance	223,864	227,930					
Spare Parts & Materials	0	0					
Contractor's Fee	559,661	569,824					
2. Owner's Soft Costs	**1,249,937**	**1,471,221**					
Permits, Licenses, Fees, Miscellaneous	277,764	326,938					
Land Cost	0	0					
Utility Connection Cost	0	0					
Legal & Financial Costs	277,764	326,938					
Escalation and Interest During Construction	555,527	653,876					
Spare Parts & Materials	0	0					
Project Administration & Developer's Fee	138,882	163,469					
3. Total of all user-defined costs displayed on each accoun	**0**	**0**					

Project Cost Summary OPRA 16	Reference Cost	Estimated Cost	
I Specialized Equipment	7,293,260	7,300,647	USD
II Other Equipment	455,318	469,287	USD
III Civil	649,533	684,122	USD
IV Mechanical	813,023	901,418	USD
V Electrical Assembly & Wiring	418,176	455,579	USD
VI Buildings & Structures	311,138	333,307	USD
VII Engineering & Plant Startup	1,161,480	1,161,480	USD
Subtotal - Contractor's Internal Cost	11,101,928	11,305,840	USD
VIII Contractor's Soft & Miscellaneous Costs	2,869,138	3,057,367	USD
Contractor's Price	13,971,065	14,363,207	USD
IX Owner's Soft & Miscellaneous Costs	1,257,396	1,292,689	USD
Total - Owner's Cost	15,228,461	15,655,896	USD
Net Plant Output	5.9	5.9	MW
Price per kW - Contractor's	2,352.0	2,418.0	USD per kW
Cost per kW - Owner's	2,563.7	2,635.6	USD per kW

Note: Certain values are hidden if not applicable to cogen facility

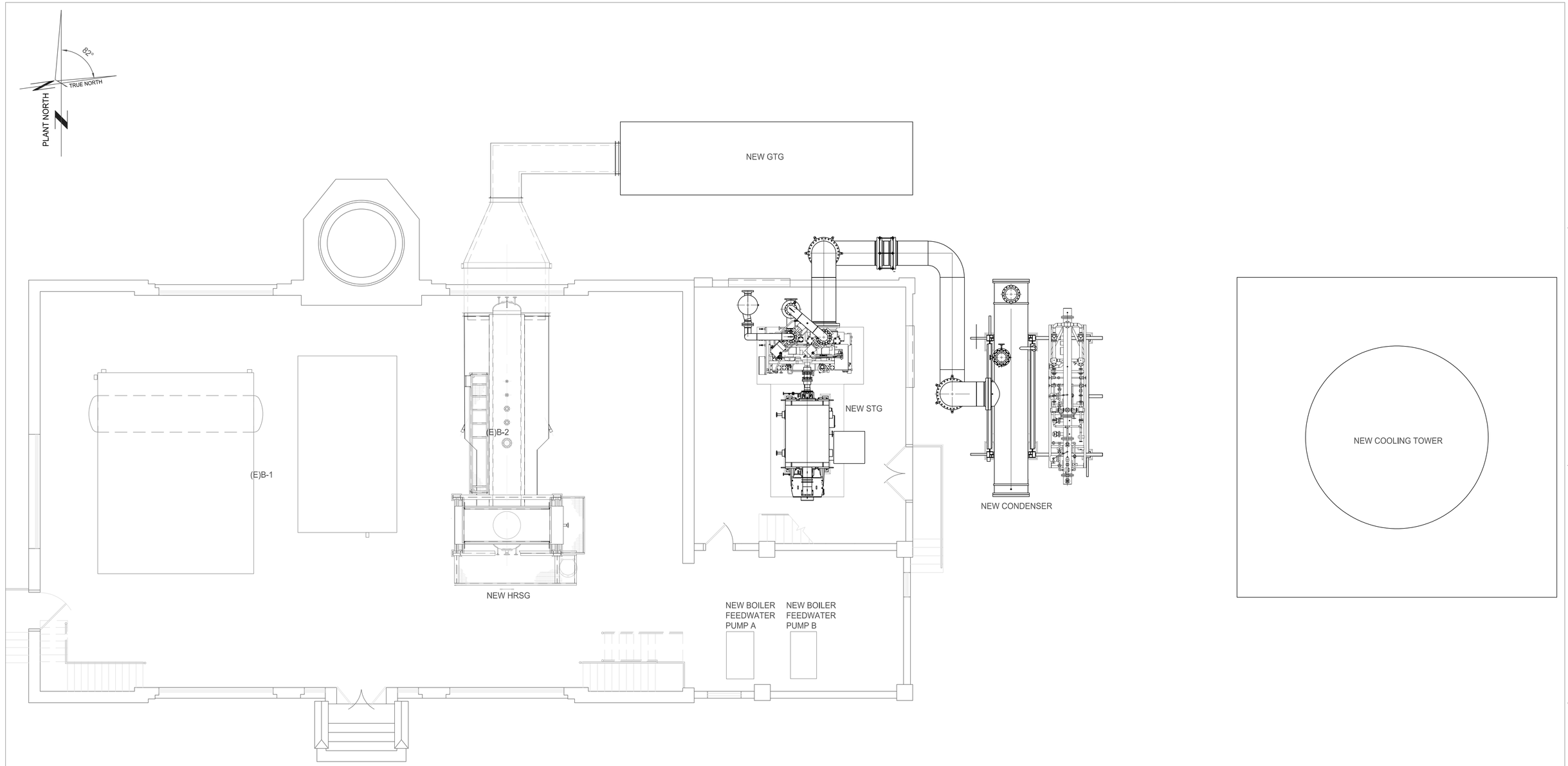
	Item Cost	Unit Cost	Quantity	Ref. Cost	Est. Cost
I Specialized Equipment (USD)				7,293,260	7,300,647
1. Gas Turbine Package		1,892,290	2	3,784,580	3,784,580
Combustion Turbine Genset (including multi-unit discount)	1,778,500				
Inlet Filter/Silencer System (w/ elements)	included				
Electrical/Control/Instrumentation Package	included				
Gas Fuel Package	included				
Liquid Fuel Package	20,690				
Starting Package	included				
Lube Oil Package w/ main, auxiliary & emergency pump	included				
Compressor Water Wash System	included				
OEM supplied technical oversight & services required for warranty	included				
User-defined shipping cost [7%]	93,100				
2. Steam Turbine Package		2,030,750	1	2,030,750	2,030,750
Turbine	included				
Generator	included				
Exhaust System	included				
Electrical/Control/Instrumentation Package	included				
Lube Oil Package w/ main, auxiliary & emergency pump	included				
OEM supplied technical oversight & services required for warranty	included				
User-defined shipping cost [8%]	85,750				
3. Heat Recovery Boiler		1,061,500	1	1,061,500	1,061,500
Duct Burner & Burner Management System	included				
Gas Turbine Exhaust Transition	included				
Bypass Stack	included				
Main Stack	included				
Instrumentation	included				
Deaerator	included				
Steam Vents & Water Drains	included				
Non-Return Valves	included				
OEM supplied technical oversight & services required for warranty	included				
User-defined shipping cost [10%]	96,500				
4. Water-cooled Condenser		268,680	1	268,680	268,680
Vacuum Pump	elsewhere				
User-defined shipping cost [8%]	18,680				
9. Distributed Control System		65,900	1	65,900	69,195
Enclosures	included				
Electronics, Display Units, Printers & Sensors	included				
Approximate shipping to typical US site	included				
10. Transmission Voltage Equipment		29,100	1	29,100	30,555
Circuit Breakers	27,710				
Miscellaneous Equipment	1,390				
Approximate shipping to typical US site	included				
11. Generating Voltage Equipment		52,750	1	52,750	55,387
Generator Buswork	40,880				
Circuit Breakers	9,350				
Miscellaneous Equipment	2,510				
Approximate shipping to typical US site	included				

	Unit Cost	Quantity	Ref. Cost	Est. Cost
II Other Equipment (USD)			455,318	469,287
1. Pumps			71,752	72,812
HP Feedwater Pump	10,230	2	20,460	20,460
Condensate Forwarding Pump	5,410	0		
Condenser C.W. Pump	15,046	2	30,092	30,092
Condenser Vacuum Pump	10,600	2	21,200	22,260
Fuel Oil Unloading Pump	9,520	0		
2. Tanks		2	1,008	1,058
Fuel Oil	24,180	0		
Demineralized Water	3,280	0		
Raw Water	3,280	0		
Neutralized Water	2,070	0		

Acid Storage	504	1	504	529			
Caustic Storage	504	1	504	529			
3. Cooling Tower	**117,000**	**1**	**117,000**	**117,000**			
4. Auxiliary Heat Exchangers			**4,210**	**4,420**			
Auxiliary Cooling Water Heat Exchanger	4,210	1	4,210	4,420			
10. Station/Instrument Air Compressors	**23,278**	**1**	**23,278**	**24,442**			
11. Recip Engine Genset(s)		**1**	**68,500**	**71,925**			
Black Start Generator	68,500	1	68,500	71,925			
12. General Plant Instrumentatior	**42,300**	**1**	**42,300**	**44,415**			
13. Medium Voltage Equipment	**538**	**1**	**538**	**565**			
Circuit Breakers	495						
Miscellaneous	25						
14. Low Voltage Equipment	**105,050**	**1**	**105,050**	**110,302**			
Transformers	65,850						
Circuit Breakers	14,230						
Motor Control Centers	19,980						
Miscellaneous	5,000						
15. Miscellaneous Equipment	**21,682**		**21,682**	**22,347**			
	Material	**Labor Hours**	**Labor Rate**	**Unit Cost**	**Quantity**	**Ref. Cost**	**Est. Cost**
III Civil (USD)	**345,565**	**7,228**	**41.00**			**649,533**	**684,122**
1. Site Work	**108,550**	**1,390**	**41.00**			**165,540**	**173,661**
Site Clearing	included	included					
Demolition	included	included					
Culverts & Drainage	included	included					
Erosion Control	included	included					
Fencing, Controlled Access Gates	included	included					
Finish Grading	included	included					
Finish Landscaping	included	included					
Material (Dirt, Sand, Stone)	included	included					
Waste Material Removal	included	included					
Obstacles R&R	included	included					
Miscellaneous	included	included					
2. Excavation & Backfill	**24,912**	**484**	**41.00**	**77.74**	**578**	**44,923**	**47,570**
Gas Turbine (2)	49.92	0.98	41.00	90.14	85	7,656	8,142
Steam Turbine (1)	50.09	0.99	41.00		0	91	
Heat Recovery Boiler (2)	48.75	0.95	41.00		0	88	
Water Cooled Condenser (1)	48.50	0.95	41.00	87.34	30	2,620	2,786
Cooling Tower	35.60	0.70	41.00	64.25	178	11,437	12,164
Underground Piping	43.79	0.83	41.00	77.91	150	11,687	12,416
Switchyard	49.21	0.96	41.00	88.55	4	346	367
Other & Miscellaneous	46.72	0.91	41.00	83.96	131	10,999	11,694
3. Concrete	**206,096**	**5,340**	**41.00**	**2,132.20**	**203**	**432,488**	**456,227**
Gas Turbine (2)	1,153.33	28.03	41.00	2,302.60	59	136,360	146,059
Steam Turbine (1)	1,211.68	28.96	41.00	2,398.95	10	23,990	25,681
Laydown pads:	897.96	22.77	41.00		0	1,831	
Heat Recovery Boiler (2)	961.29	24.77	41.00		0	1,977	
Water Cooled Condenser (1)	1,062.26	29.47	41.00	2,270.44	23	52,220	56,180
Cooling Tower	868.52	24.89	41.00	1,888.95	40	75,558	81,374
Electrical Power Equipment	852.04	22.30	41.00	1,766.54	27	47,520	51,025
Pumps (3)	897.47	22.08	41.00	1,802.62	3	6,206	6,650
Station/Instrument Air Compressors (2)	799.40	19.25	41.00	1,588.46	2	3,199	3,426
Recip Engine Genset(s) (1)	1,245.38	28.40	41.00	2,409.65	3	7,229	7,727
Tanks:	895.79	26.03	41.00		0	1,963	
Switchyard	802.05	21.61	41.00		0	1,688	
Miscellaneous	996.88	26.01	41.00	2,063.16	35	72,747	78,105
4. Roads, Parking, Walkways	**6,006**	**14**	**41.00**	**6.58**	**1,000**	**6,582**	**6,664**
Pavement, Curbing, Striping	6.01	0.01	41.00	6.58	1,000	6,582	6,664
Lighting	0.00	0.00	47.00		0		
	Material	**Labor Hours**	**Labor Rate**	**Unit Cost**	**Quantity**	**Ref. Cost**	**Est. Cost**
IV Mechanical (USD)	**289,585**	**11,370**	**46.00**			**813,023**	**901,418**
1. On-Site Transportation & Rigging	**117,100**					**117,100**	**128,371**
2. Equipment Erection & Assembly	**65,925**	**7,136**	**46.00**			**394,164**	**440,939**
Gas Turbine Package	6,540	708	46.00	39,108	2	78,216	87,498
Steam Turbine Package	6,610	715	46.00	39,500	1	39,500	44,187
HRSG	11,120	1,204	46.00	66,504	1	66,504	74,396
Condenser	6,630	718	46.00	39,658	1	39,658	44,364
Cooling Tower	elsewhere	elsewhere					
Electrical Power Equipment	11,010	1,190	46.00			65,750	73,550
Pumps	4,820	522	46.00			28,832	32,254
Tanks + Auxiliary Heat Exchangers	5,080	550	46.00			30,380	33,985
Station/Instrument Air Compressors	879	95	46.00			5,258	5,882
Recip Engine Genset(s)	706	76	46.00			4,222	4,723
Miscellaneous	5,990	649	46.00			35,844	40,098
3. Piping	**101,850**	**4,185**	**46.00**	**209.67**	**1,406**	**294,802**	**324,832**
High Pressure Steam	105.50	5.07	46.00	338.52	150	50,777	56,154
Intermediate Pressure Steam	24.80	2.03	46.00		0	118	132
Circulating Water	88.78	1.42	46.00	154.18	100	15,418	16,572
Auxiliary Cooling Water	30.55	1.74	46.00	110.55	100	11,055	12,271
Feedwater	41.08	2.09	46.00	137.28	100	13,728	15,201
Raw Water	17.84	1.20	46.00		0	73	81
Service Water	19.29	1.34	46.00		0	81	90

Fuel Gas	47.10	2.71	46.00	171.57	200	34,314	38,097
Fuel Oil	42.92	2.48	46.00		0	157	175
Lube Oil	186.90	8.26	46.00	566.77	150	85,016	93,837
Service Air	18.29	1.35	46.00	80.53	200	16,106	17,972
Vacuum Air	49.25	3.53	46.00	211.40	42	8,879	9,901
Boiler & Equipment Drain	93.84	0.63	46.00	122.65	97	11,897	12,523
Boiler Blowdown	25.95	1.29	46.00	85.26	97	8,271	9,153
Steam Blowoff	377.92	8.42	46.00	765.08	20	15,302	16,594
Miscellaneous	50.84	2.32	46.00	157.41	150	23,611	26,080
4. Steel	**4,710**	**49**	**46.00**	**5,556.05**	**1**	**6,956**	**7,276**
Racks, Supports, Ladders, Walkways, Platforms	3,761.98	39.00	46.00	5,556.05	1	6,956	7,276
	Material	**Labor Hours**	**Labor Rate**	**Unit Cost**	**Quantity**	**Ref. Cost**	**Est. Cost**
V Electrical (USD)	**155,702**	**5,585**	**47.00**			**418,176**	**455,579**
1. Controls	**20,636**	**1,640**	**47.00**			**97,695**	**108,676**
Gas Turbine Package	3,580	303	47.00	17,821.00	2	35,642	39,701
Steam Turbine Package	3,620	307	47.00	18,049.00	1	18,049	20,105
HRSG	1,780	151	47.00	8,877.00	2	17,754	19,777
Condenser	1,490	127	47.00	7,459.00	1	7,459	8,310
Cooling Tower	elsewhere	elsewhere					
Pumps	2,640	224	47.00	13,168.00	1	13,168	14,668
Station/Instrument Air Compressor	1,200	41	47.00	3,117.60	1	3,118	3,391
Recip Engine Genset(s)	966	33	47.00	2,505.72	1	2,506	2,725
2. Assembly & Wiring	**135,066**	**3,945**	**47.00**			**320,481**	**346,903**
Switchgear							
Motor Control Centers	109	66	47.00	3,230.00	5	16,150	18,374
Feeders	746	27	47.00	2,031.43	49	99,540	108,515
Medium/Low Voltage Cable Bus	976	33	47.00	2,509.63	8	20,077	21,825
Cable Tray	8,730	104	47.00	13,618.00	1	13,618	14,315
General Plant Instrumentation	300	5	47.00	523.93	80	41,914	44,472
Generator to Step-up Transformer Bus	2,933	41	47.00	4,876.00	3	14,628	15,458
Transformers	1,110	47	47.00	3,319.00	1	3,319	3,634
Circuit Breakers	5,878	166	47.00	13,688.17	6	82,129	88,806
Miscellaneous	12,280	358	47.00	29,106.00	1	29,106	31,504
3. User-defined						**0**	**0**
	Area	**Cost/Unit Area**	**Ref. Cost**	**Est. Cost**			
VI Buildings (USD)			**311,138**	**333,307**			
1. Turbine Hall	**0.0**	**230.60**					
2. Administration, Control Room, Machine Shop / Wareho	**2,030.0**	**153.27**	**311,138**	**333,307**			
3. Water Treatment System							
4. Guard House							
5. User-defined			**0.00**	**0**			
	Material	**Labor Hours**	**Labor Rate**	**Unit Cost**	**Quantity**	**Ref. Cost**	**Est. Cost**
VII Engineering & Startup (USD)	**38,520**	**1,060**	**116.00**			**1,161,480**	**1,161,480**
1. Engineering						**1,000,000**	**1,000,000**
2. Start-Up	**38,520**	**1,060**	**116.00**	**161,480**		**161,480**	**161,480**
3. User-defined						**0**	**0**
	Ref. Cost	**Est. Cost**					
VIII Soft & Miscellaneous Costs (USD)	**4,126,534**	**4,350,056**					
1. Contractor's Soft Costs	**2,869,138**	**3,057,367**					
Contingency:	1,190,353	1,319,894					
Profit:	901,650	946,065					
Permits, Licenses, Fees, Miscellaneous	0	0					
Bonds and Insurance	222,039	226,117					
Spare Parts & Materials	0	0					
Contractor's Fee	555,096	565,292					
2. Owner's Soft Costs	**1,257,396**	**1,292,689**					
Permits, Licenses, Fees, Miscellaneous	279,421	287,264					
Land Cost	0	0					
Utility Connection Cost	0	0					
Legal & Financial Costs	279,421	287,264					
Escalation and Interest During Construction	558,843	574,528					
Spare Parts & Materials	0	0					
Project Administration & Developer's Fee	139,711	143,632					
3. Total of all user-defined costs displayed on each accoun	**0**	**0**					

APPENDIX C – PRELIMINARY GENERAL ARRANGEMENT



FIRST FLOOR MECHANICAL ARRANGEMENT

SCALE 1/8" = 1'-0"

MECH GA.DWG

REV	REVISIONS	DATE	DRN	DSGN	CKD	APPD	REFERENCE DRAWINGS
A	ISSUED FOR REVIEW		KAC	GD			M1-1 MECHANICAL ARRANGEMENT BASEMENT
							M1-3 MECHANICAL ARRANGEMENT 2ND FLOOR

DSGN	KAC	
DRN	KAC	04/07/2020
CKD		

SCALE: 1/8" = 1'-0"

FOR 22x34 DWG ONLY

POWER ENGINEERS

UNIVERSITY OF MONTANA

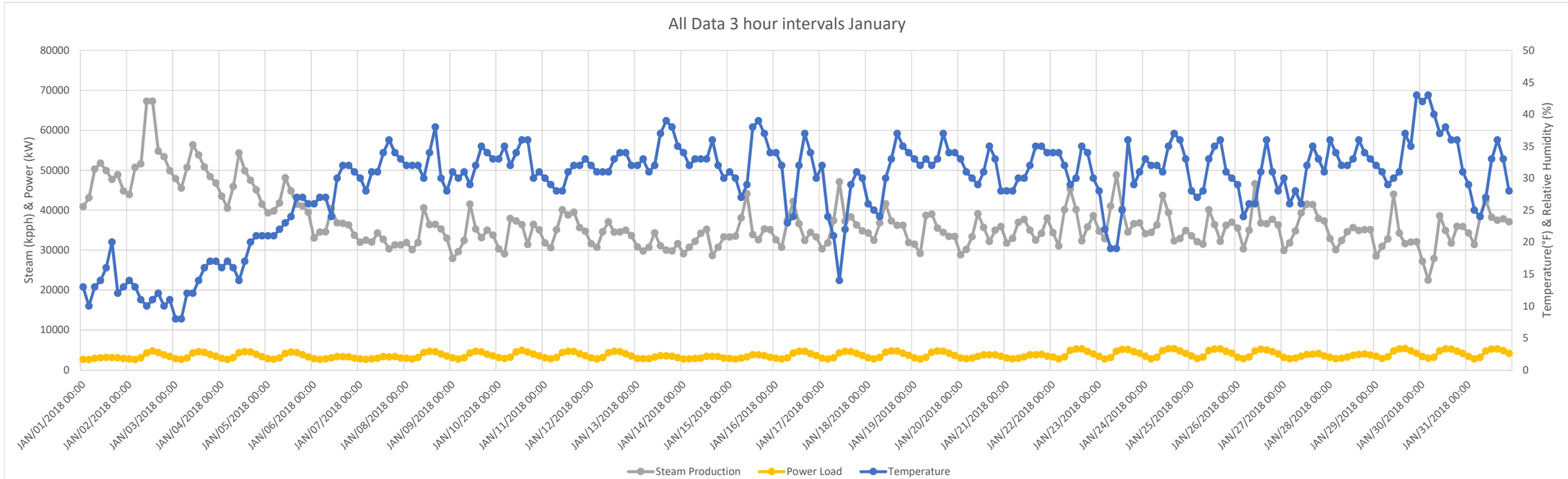
McKinstry

GENERAL ARRANGMENT
FIRST FLOOR

JOB NUMBER	REV
162690	A

DRAWING NUMBER
M1-1

APPENDIX D – STEAM AND POWER LOADS – 3HR INCREMENTS


All Data 3 hour intervals January
Steam (kpph) & Power (kW)
Temperature(°F) & Relative Humidity (%)
80000
70000
60000
50000
40000
30000
20000
10000
0
50
45
40
35
30
25
20
15
10
5
0
JAN/01/2018 00:00
JAN/02/2018 00:00
JAN/03/2018 00:00
JAN/04/2018 00:00
JAN/05/2018 00:00
JAN/06/2018 00:00
JAN/07/2018 00:00
JAN/08/2018 00:00
JAN/09/2018 00:00
JAN/10/2018 00:00
JAN/11/2018 00:00
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JAN/13/2018 00:00
JAN/14/2018 00:00
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JAN/17/2018 00:00
JAN/18/2018 00:00
JAN/19/2018 00:00
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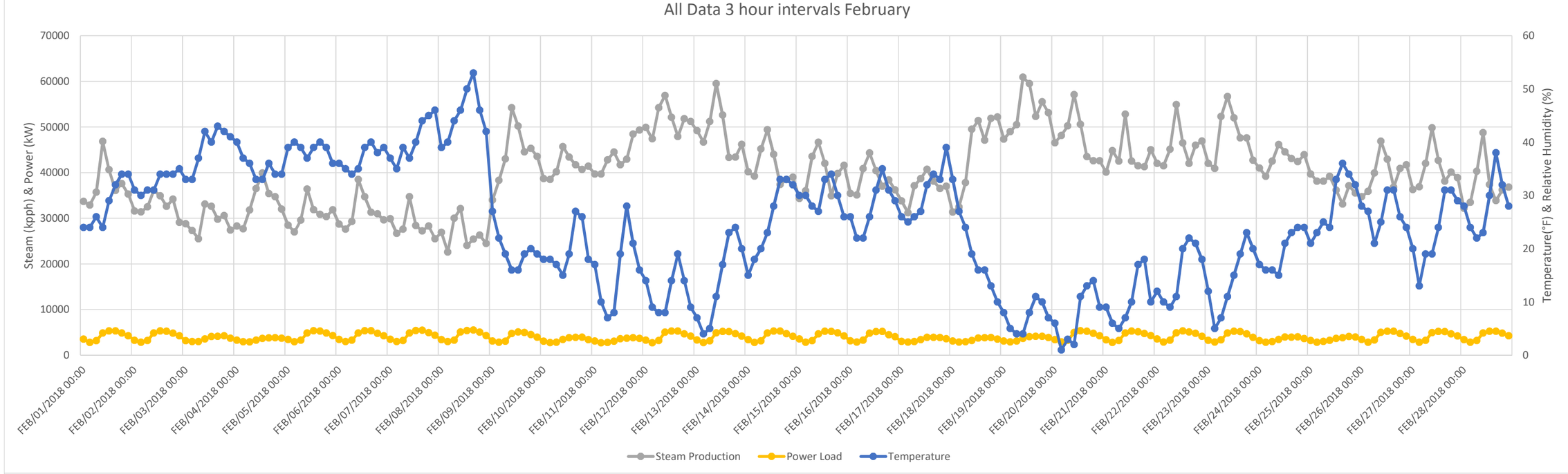
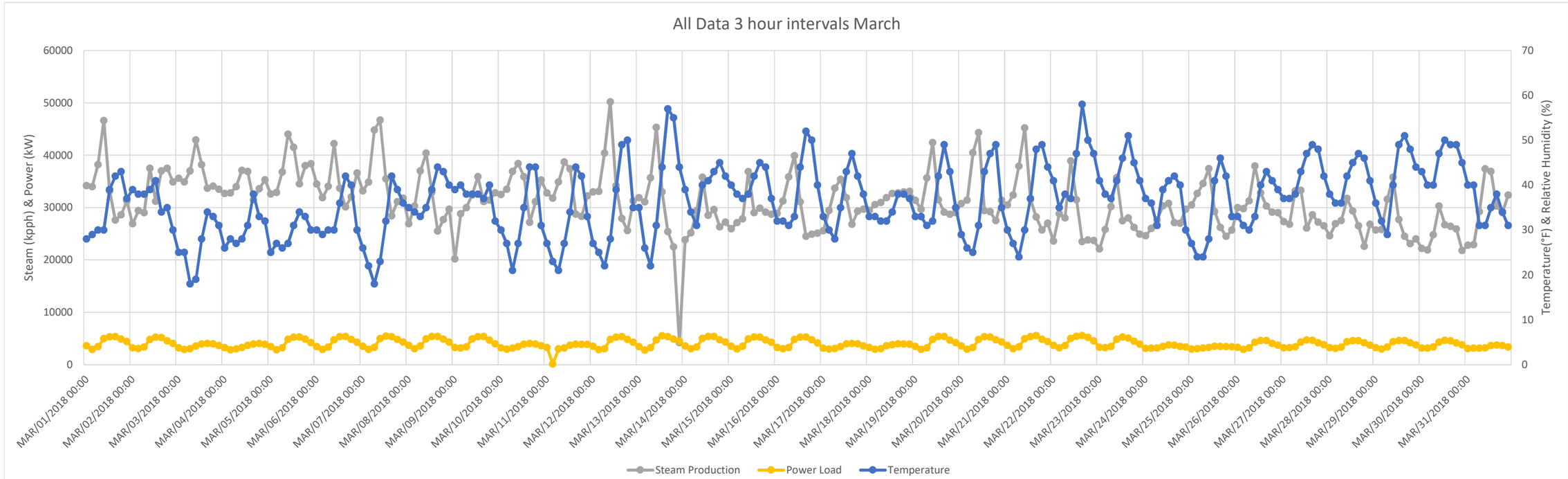
JAN/21/2018 00:00
JAN/22/2018 00:00
JAN/23/2018 00:00
JAN/24/2018 00:00
JAN/25/2018 00:00
JAN/26/2018 00:00
JAN/27/2018 00:00
JAN/28/2018 00:00
JAN/29/2018 00:00
JAN/30/2018 00:00
JAN/31/2018 00:00
Steam Production
Power Load
Temperature


All Data 3 hour intervals February
Steam (kpph) & Power (kW)
Temperature(°F) & Relative Humidity (%)
70000
60000
50000
40000
30000
20000
10000
0
60
50
40
30
20
10
0
FEB/01/2018 00:00
FEB/02/2018 00:00
FEB/03/2018 00:00
FEB/04/2018 00:00
FEB/05/2018 00:00
FEB/06/2018 00:00
FEB/07/2018 00:00
FEB/08/2018 00:00
FEB/09/2018 00:00
FEB/10/2018 00:00
FEB/11/2018 00:00
FEB/12/2018 00:00
FEB/13/2018 00:00
FEB/14/2018 00:00
FEB/15/2018 00:00
FEB/16/2018 00:00
FEB/17/2018 00:00
FEB/18/2018 00:00
FEB/19/2018 00:00
FEB/20/2018 00:00
FEB/21/2018 00:00
FEB/22/2018 00:00
FEB/23/2018 00:00
FEB/24/2018 00:00
FEB/25/2018 00:00
FEB/26/2018 00:00
FEB/27/2018 00:00
FEB/28/2018 00:00
Steam Production
Power Load
Temperature


All Data 3 hour intervals March
Steam (kpph) & Power (kW)
Temperature(°F) & Relative Humidity (%)
60000
50000
40000
30000
20000
10000
0
70
60
50
40
30
20
10
0
MAR/01/2018 00:00
MAR/02/2018 00:00
MAR/03/2018 00:00
MAR/04/2018 00:00
MAR/05/2018 00:00
MAR/06/2018 00:00
MAR/07/2018 00:00
MAR/08/2018 00:00
MAR/09/2018 00:00
MAR/10/2018 00:00
MAR/11/2018 00:00
MAR/12/2018 00:00
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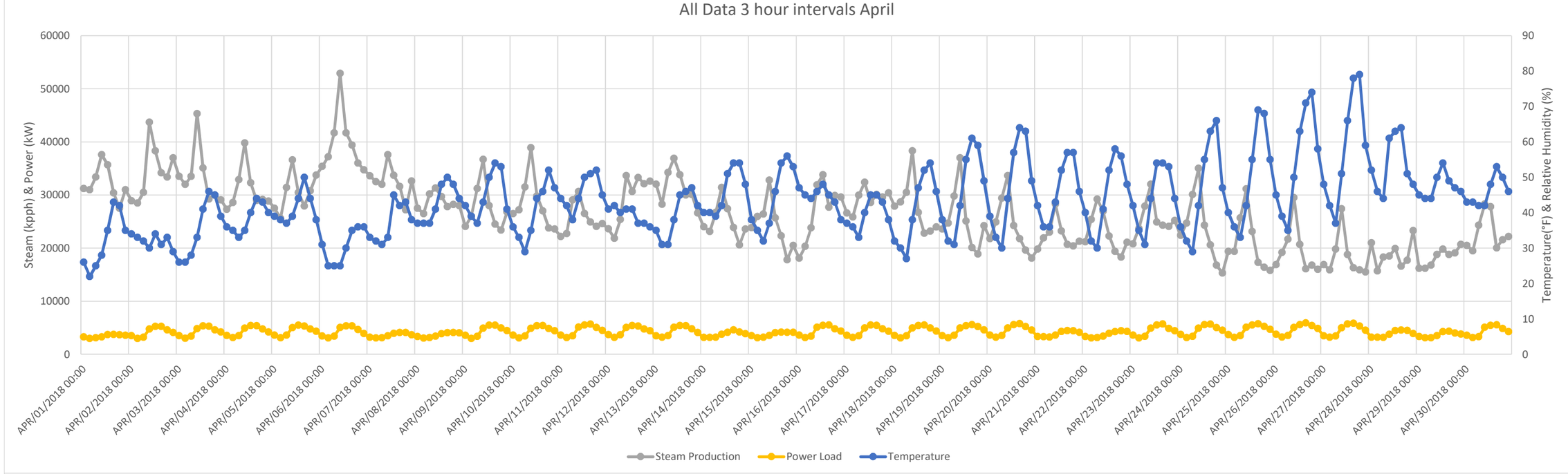
MAR/14/2018 00:00
MAR/15/2018 00:00
MAR/16/2018 00:00
MAR/17/2018 00:00
MAR/18/2018 00:00
MAR/19/2018 00:00
MAR/20/2018 00:00
MAR/21/2018 00:00
MAR/22/2018 00:00
MAR/23/2018 00:00
MAR/24/2018 00:00
MAR/25/2018 00:00
MAR/26/2018 00:00
MAR/27/2018 00:00
MAR/28/2018 00:00
MAR/29/2018 00:00
MAR/30/2018 00:00
MAR/31/2018 00:00
Steam Production
Power Load
Temperature


All Data 3 hour intervals April
Steam (kpph) & Power (kW)
Temperature(°F) & Relative Humidity (%)
60000
50000
40000
30000
20000
10000
0
90
80
70
60
50
40
30
20
10
0
APR/01/2018 00:00
APR/02/2018 00:00
APR/03/2018 00:00
APR/04/2018 00:00
APR/05/2018 00:00
APR/06/2018 00:00
APR/07/2018 00:00
APR/08/2018 00:00
APR/09/2018 00:00
APR/10/2018 00:00
APR/11/2018 00:00
APR/12/2018 00:00
APR/13/2018 00:00
APR/14/2018 00:00
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APR/18/2018 00:00
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APR/20/2018 00:00
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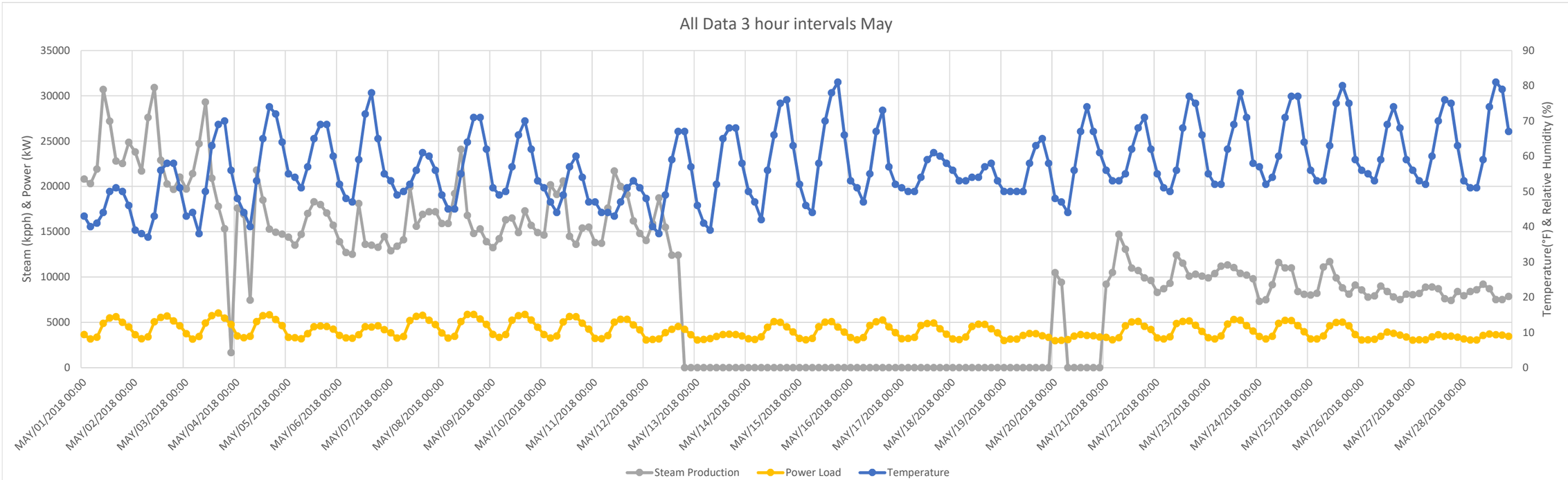
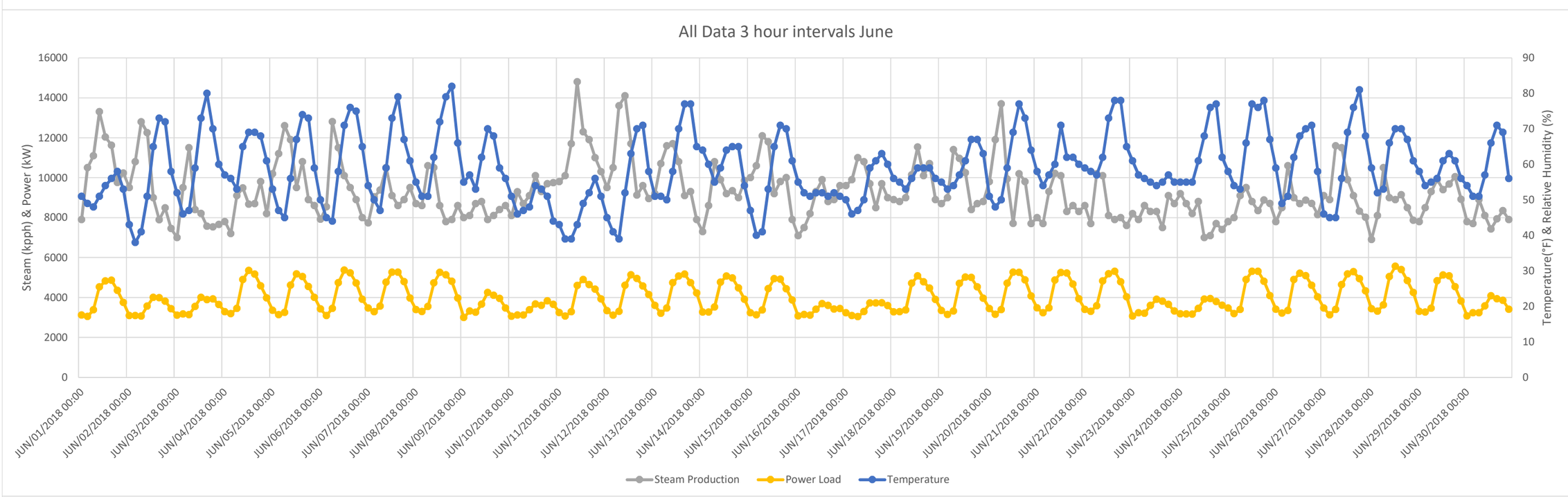
APR/25/2018 00:00
APR/26/2018 00:00
APR/27/2018 00:00
APR/28/2018 00:00
APR/29/2018 00:00
APR/30/2018 00:00
Steam Production
Power Load
Temperature


All Data 3 hour intervals May
Steam (kpph) & Power (kW)
Temperature(°F) & Relative Humidity (%)
35000
30000
25000
20000
15000
10000
5000
0
90
80
70
60
50
40
30
20
10
0
MAY/01/2018 00:00
MAY/02/2018 00:00
MAY/03/2018 00:00
MAY/04/2018 00:00
MAY/05/2018 00:00
MAY/06/2018 00:00
MAY/07/2018 00:00
MAY/08/2018 00:00
MAY/09/2018 00:00
MAY/10/2018 00:00
MAY/11/2018 00:00
MAY/12/2018 00:00
MAY/13/2018 00:00
MAY/14/2018 00:00
MAY/15/2018 00:00
MAY/16/2018 00:00
MAY/17/2018 00:00
MAY/18/2018 00:00
MAY/19/2018 00:00
MAY/20/2018 00:00
MAY/21/2018 00:00
MAY/22/2018 00:00
MAY/23/2018 00:00
MAY/24/2018 00:00
MAY/25/2018 00:00
MAY/26/2018 00:00
MAY/27/2018 00:00
MAY/28/2018 00:00
Steam Production
Power Load
Temperature


All Data 3 hour intervals June
Steam (kpph) & Power (kW)
Temperature(°F) & Relative Humidity (%)
16000
14000
12000
10000
8000
6000
4000
2000
0
90
80
70
60
50
40
30
20
10
0
JUN/01/2018 00:00
JUN/02/2018 00:00
JUN/03/2018 00:00
JUN/04/2018 00:00
JUN/05/2018 00:00
JUN/06/2018 00:00
JUN/07/2018 00:00
JUN/08/2018 00:00
JUN/09/2018 00:00
JUN/10/2018 00:00
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JUN/16/2018 00:00
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JUN/19/2018 00:00
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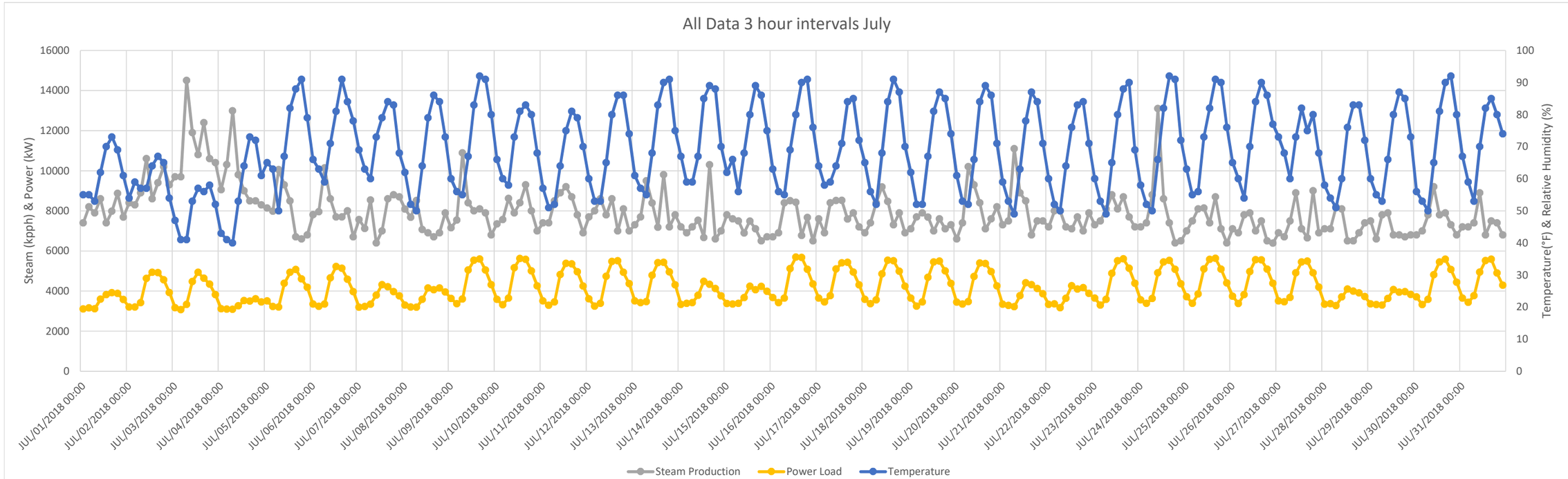
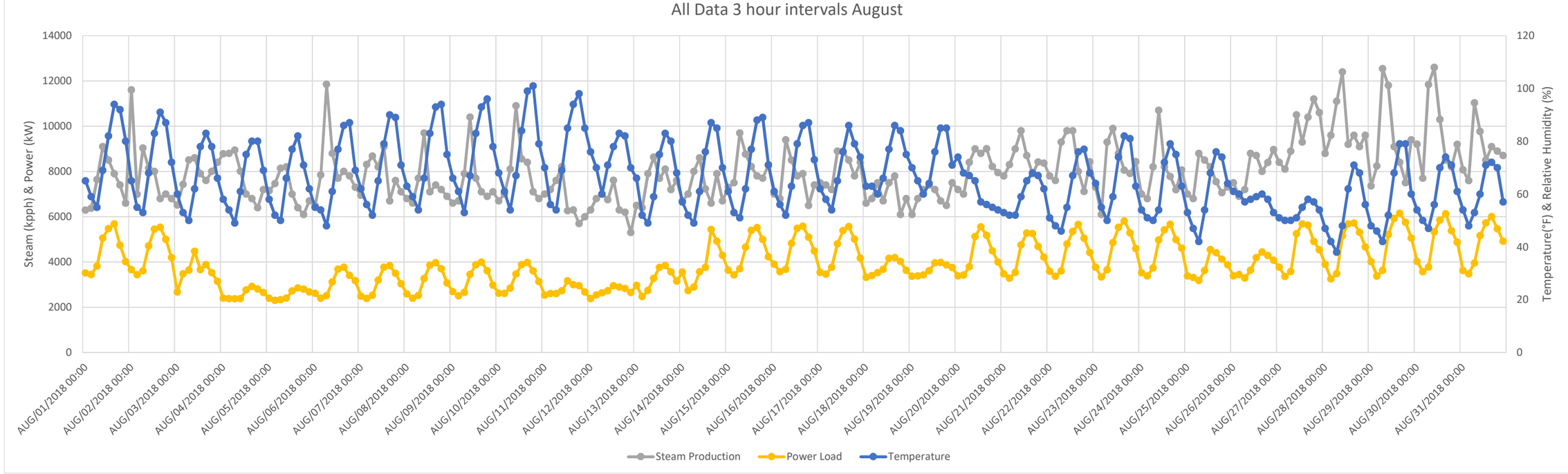
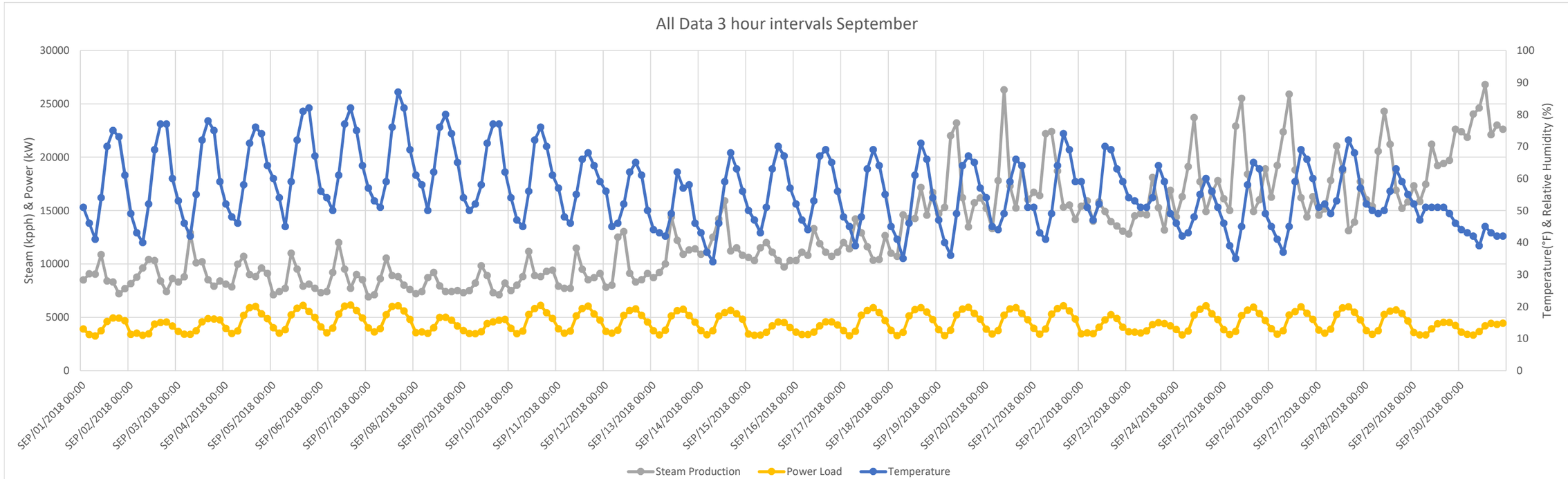
JUN/21/2018 00:00
JUN/22/2018 00:00
JUN/23/2018 00:00
JUN/24/2018 00:00
JUN/25/2018 00:00
JUN/26/2018 00:00
JUN/27/2018 00:00
JUN/28/2018 00:00
JUN/29/2018 00:00
JUN/30/2018 00:00
Steam Production
Power Load
Temperature


All Data 3 hour intervals July
Steam (kpph) & Power (kW)
Temperature(°F) & Relative Humidity (%)
16000
14000
12000
10000
8000
6000
4000
2000
0
100
90
80
70
60
50
40
30
20
10
0
JUL/01/2018 00:00
JUL/02/2018 00:00
JUL/03/2018 00:00
JUL/04/2018 00:00
JUL/05/2018 00:00
JUL/06/2018 00:00
JUL/07/2018 00:00
JUL/08/2018 00:00
JUL/09/2018 00:00
JUL/10/2018 00:00
JUL/11/2018 00:00
JUL/12/2018 00:00
JUL/13/2018 00:00
JUL/14/2018 00:00
JUL/15/2018 00:00
JUL/16/2018 00:00
JUL/17/2018 00:00
JUL/18/2018 00:00
JUL/19/2018 00:00
JUL/20/2018 00:00
JUL/21/2018 00:00
JUL/22/2018 00:00
JUL/23/2018 00:00
JUL/24/2018 00:00
JUL/25/2018 00:00
JUL/26/2018 00:00
JUL/27/2018 00:00
JUL/28/2018 00:00
JUL/29/2018 00:00
JUL/30/2018 00:00
JUL/31/2018 00:00
Steam Production
Power Load
Temperature


All Data 3 hour intervals August
Steam (kpph) & Power (kW)
Temperature(°F) & Relative Humidity (%)
14000
12000
10000
8000
6000
4000
2000
0
120
100
80
60
40
20
0
AUG/01/2018 00:00
AUG/02/2018 00:00
AUG/03/2018 00:00
AUG/04/2018 00:00
AUG/05/2018 00:00
AUG/06/2018 00:00
AUG/07/2018 00:00
AUG/08/2018 00:00
AUG/09/2018 00:00
AUG/10/2018 00:00
AUG/11/2018 00:00
AUG/12/2018 00:00
AUG/13/2018 00:00
AUG/14/2018 00:00
AUG/15/2018 00:00
AUG/16/2018 00:00
AUG/17/2018 00:00
AUG/18/2018 00:00
AUG/19/2018 00:00
AUG/20/2018 00:00
AUG/21/2018 00:00
AUG/22/2018 00:00
AUG/23/2018 00:00
AUG/24/2018 00:00
AUG/25/2018 00:00
AUG/26/2018 00:00
AUG/27/2018 00:00
AUG/28/2018 00:00
AUG/29/2018 00:00
AUG/30/2018 00:00
AUG/31/2018 00:00
Steam Production
Power Load
Temperature


All Data 3 hour intervals September
Steam (kpph) & Power (kW)
Temperature(°F) & Relative Humidity (%)
30000
25000
20000
15000
10000
5000
0
100
90
80
70
60
50
40
30
20
10
0
SEP/01/2018 00:00
SEP/02/2018 00:00
SEP/03/2018 00:00
SEP/04/2018 00:00
SEP/05/2018 00:00
SEP/06/2018 00:00
SEP/07/2018 00:00
SEP/08/2018 00:00
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SEP/12/2018 00:00
SEP/13/2018 00:00
SEP/14/2018 00:00
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SEP/16/2018 00:00
SEP/17/2018 00:00
SEP/18/2018 00:00
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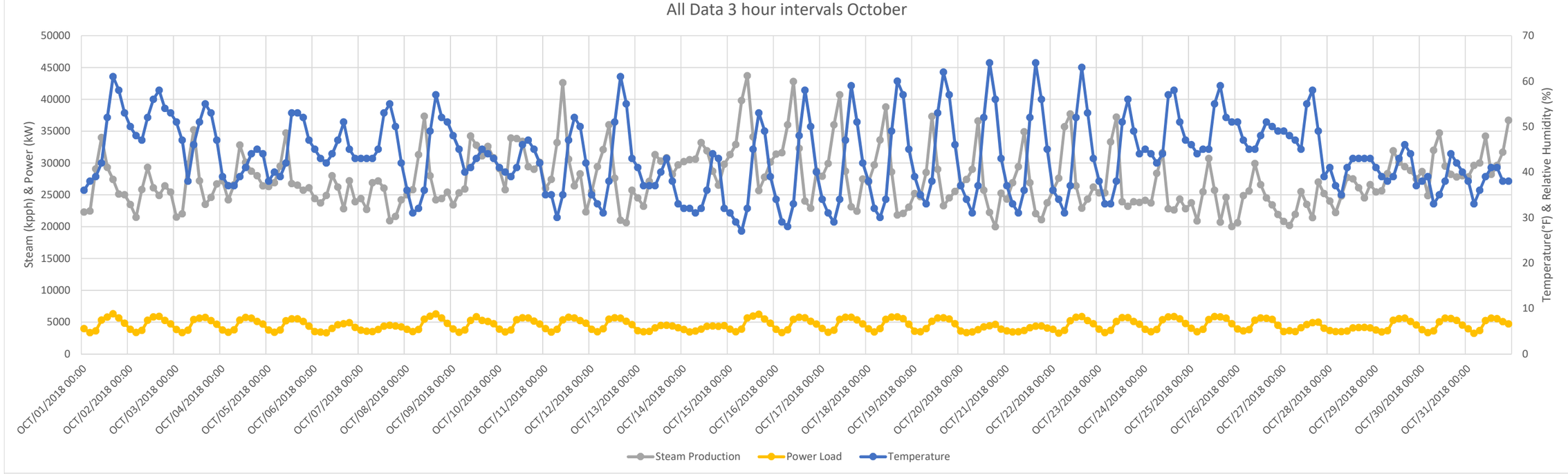
SEP/25/2018 00:00
SEP/26/2018 00:00
SEP/27/2018 00:00
SEP/28/2018 00:00
SEP/29/2018 00:00
SEP/30/2018 00:00
Steam Production
Power Load
Temperature


All Data 3 hour intervals October
Steam (kpph) & Power (kW)
Temperature(°F) & Relative Humidity (%)
50000
45000
40000
35000
30000
25000
20000
15000
10000
5000
0
70
60
50
40
30
20
10
0
OCT/01/2018 00:00
OCT/02/2018 00:00
OCT/03/2018 00:00
OCT/04/2018 00:00
OCT/05/2018 00:00
OCT/06/2018 00:00
OCT/07/2018 00:00
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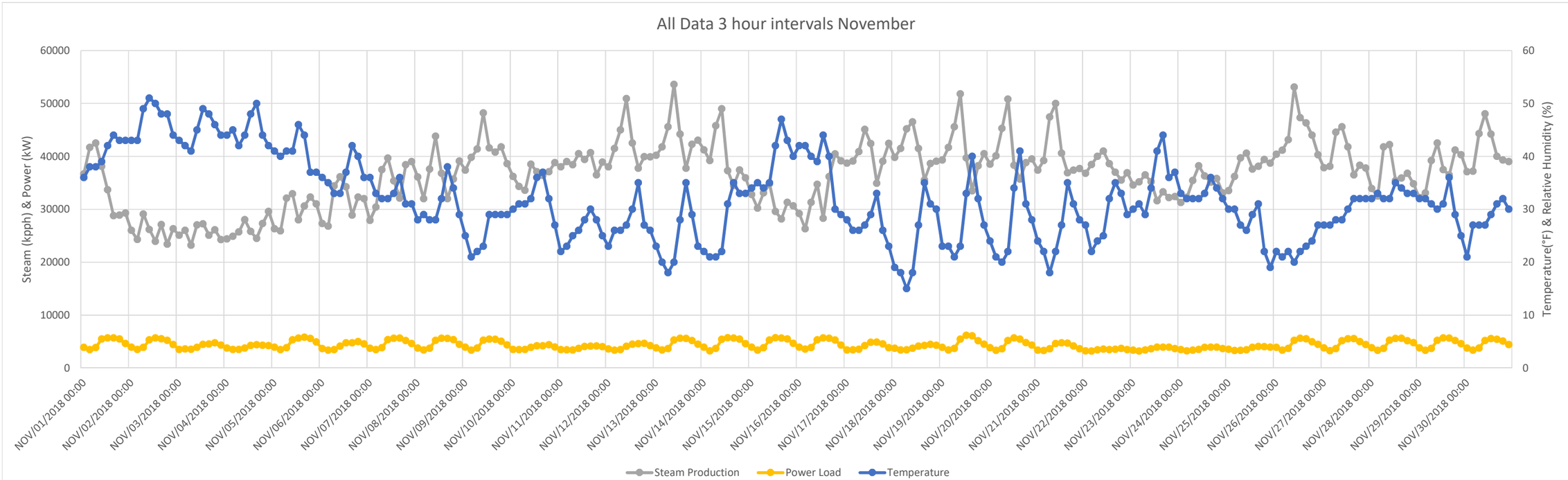
OCT/22/2018 00:00
OCT/23/2018 00:00
OCT/24/2018 00:00
OCT/25/2018 00:00
OCT/26/2018 00:00
OCT/27/2018 00:00
OCT/28/2018 00:00
OCT/29/2018 00:00
OCT/30/2018 00:00
OCT/31/2018 00:00
Steam Production
Power Load
Temperature


All Data 3 hour intervals November
Steam (kpph) & Power (kW)
Temperature(°F) & Relative Humidity (%)
60000
50000
40000
30000
20000
10000
0
60
50
40
30
20
10
0
NOV/01/2018 00:00
NOV/02/2018 00:00
NOV/03/2018 00:00
NOV/04/2018 00:00
NOV/05/2018 00:00
NOV/06/2018 00:00
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NOV/08/2018 00:00
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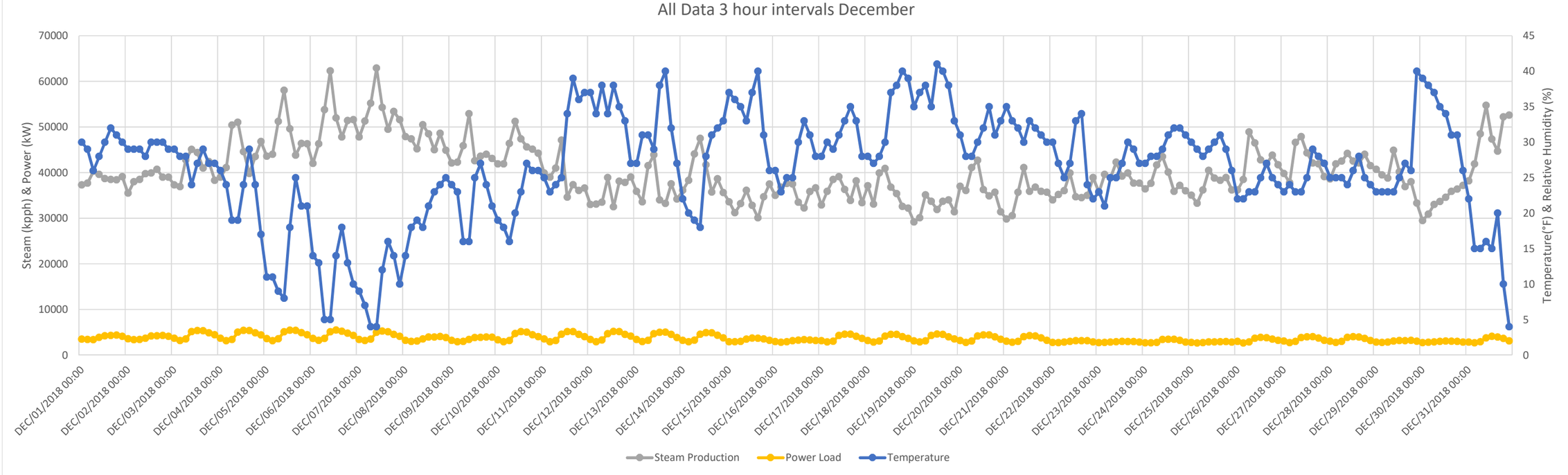
NOV/24/2018 00:00
NOV/25/2018 00:00
NOV/26/2018 00:00
NOV/27/2018 00:00
NOV/28/2018 00:00
NOV/29/2018 00:00
NOV/30/2018 00:00
Steam Production
Power Load
Temperature


All Data 3 hour intervals December
Steam (kpph) & Power (kW)
Temperature(°F) & Relative Humidity (%)
70000
60000
50000
40000
30000
20000
10000
0
45
40
35
30
25
20
15
10
5
0
DEC/01/2018 00:00
DEC/02/2018 00:00
DEC/03/2018 00:00
DEC/04/2018 00:00
DEC/05/2018 00:00
DEC/06/2018 00:00
DEC/07/2018 00:00
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DEC/28/2018 00:00
DEC/29/2018 00:00
DEC/30/2018 00:00
DEC/31/2018 00:00
Steam Production
Power Load
Temperature

APPENDIX E – VENDOR QUOTES

Solar Turbines Incorporated

Budgetary Estimate for Customer Name

Inquiry # Inquiry Number

March 23, 2020

For more information contact Lisa Marlo Conley, 1 858 694-6523, lisamarloconley@solarturbines.com

(Prices shown below quoted in US Dollars $, using a conversion of US dollar price times 1)

Quotation is for information only and does not constitute Solar's agreement to offer a firm proposal in the future.

Gas Turbine Equipment

(1) Centaur 40 SoLoNOx Turbine Generator Set, Dual Fuel $3,349,600

Commissioning Parts, Startup, and Site Testing $198,600

Electrical Equipment

Power and Utility Breaker Control Options $21,000

Total for Electrical Equipment $20,500

Mechanical Equipment

1 Heat Recovery Steam Generator with ductburners $2,143,700

Total for Heat Recovery Steam System $2,143,700

Miscellaneous

Construction Estimate . . . . . by others

Project Management & Engineering (Loose Ship Equipment Only) $151,500

Shipping $114,700

Grand Total for Turbomachinery and Balance of Plant $5,978,600

Estimation of cost per ISO rating kilowatt for selected equipment $1,703

*Duties and taxes not included in estimate.

Centaur 40-4700S Generator Set Package Features

Gas Turbine:

One shaft turbine, designed for industrial use
Axial compressor design
Annular type combustor employing dry, low NOx technology (42 ppm NOx @15%O2)

Basic Options:

Fully enclosed, generator set package requiring 460V, 3-phase, 60 Hz AC power
Rated Class I, Div II, Groups C,D per NEC
120V, 1-phase, 50/60 Hz internal lighting and heater power
Gas turbine engine in upward oriented air inlet and axially oriented exhaust outlet
1800 rpm; 60 Hz
Continuous Duty, Open Drip Proof Medium voltage generator featuring Class F insulation, B rise

Included Package Features:

Direct AC start motor system
Duplex lube oil filter system
Allen-Bradley based Turbotronics control system including:
- Ethernet network interface
- Touch Screen display with Engine Performance map
- Software for heat recovery interface (without diverter valve control)
- Software for CO2 system "lock out" (maintenance access to enclosure)
- Backup Safety Shutdown System
- kW Control
- kVAR/Power Factor Control

Included Factory Testing/Customer Witness/Quality Control Documentation:

Standard package static testing
Factory vibration testing
Factory emissions testing per Solar's ES 9-97
Observation on "Non-Interference" basis
Quality Control documentation (Level 1)

Field-installed Ancillary Equipment (excludes ducting):

Updraft air inlet filter
Engine air inlet silencer
Exhaust bellows (interface to waste heat recovery equipment)
Elbow type enclosure inlet/exhaust ventilation system with silencer

Included "Off-Skid" Components/Systems:

Remote desktop PC/monitor and Printer/Logger
Gas fuel flow meter (for Gas-only and Dual Fuel configurations)
AC motor-driven Liquid Fuel boost pump skid (for Liquid Fuel configurations)
3-micron duplex filter/coalescer with auto drain (for Liquid Fuel configurations)
CO2 system cabinet
Air/Oil lube oil cooler
VRLA Batteries with 120V DC charging system (back-up post lube)
Portable engine cleaning cart

Miscellaneous

Short-term preservation for shipment
Four (4) paper copies of Solar's Instruction, Operation and Maintenance manuals
Four (4) CD-ROM copies of Solar's Instruction, Operation and Maintenance manuals
UV Light and Gas Sensor test kit
Internal equipment handling system

Cogeneration Plant Estimated Performance Summary

Customer Name

Solar Turbines Incorporated

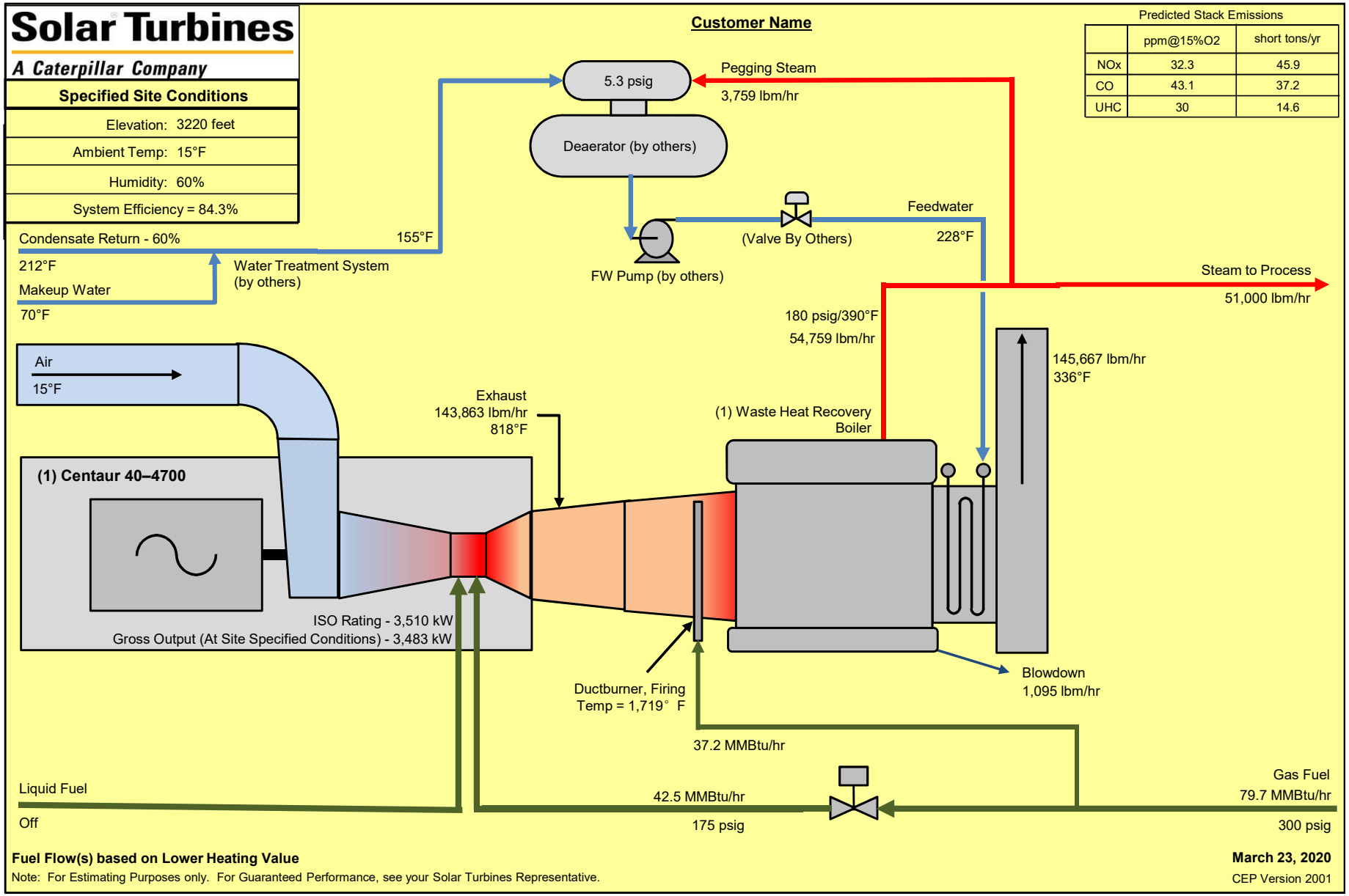
March 23, 2020

Performance listed below is estimated, not guaranteed.

Gas Turbine:		
KW Gross Output @ ISO Conditions:	3,510	kW
Site Ambient Temperature for Performance Analysis:	15	°F
Site Elevation for Performance Analysis:	3,220	feet
Site Ambient Relative Humidity for Performance Analysis:	60	%
Turbine Inlet Pressure Loss:	4.0	"H2O
Turbine Outlet Pressure Loss:	10.0	"H2O
Turbine Fuel Consumption @ specified site conditions (LHV):	42.5	MMBtu/hr
KW Gross Output @ specified site conditions:	3,483	kW
Turbine Auxiliary Power:	21	kW
Condensate Pump Power:	1.9	kW
Boiler Feed Pump Power:	24.1	kW
Total Auxiliary Power Consumption:	47	kW
Net Gas Turbine Power Production:	3,436	kW
Black Start kW Requirement (Turbine Generator Set Only):	350	kW

Boiler:		
Condensate Return:	60	%
Condensate Temperature:	212	°F
Makeup Water Temperature:	70	°F
Process Steam Pressure:	180.0	psig
Process Steam Temperature:	390	°F
Steam Contributed by Gas Turbine:	17,345	lbm/hr
Steam Contributed by Ductburners:	37,416	lbm/hr
Ductburner Fuel Consumption (LHV):	37.2	MMBtu/hr
Deaerator Steam Consumption:	3,759	lbm/hr
Boiler Steam Flow (HRSG design uses 27.0°F pinch, 18.0°F approach):	54,761	lbm/hr
Steam Flow to Process:	51,000	lbm/hr

Cycle Performance (lower heating value basis):		
Net Turbine Electrical Heat Rate:	12,380	Btu/kWHR
Gross Plant Heat Rate (Process steam or Tons converted to equivalent KW):	4,050	Btu/kWHR
Overall Cycle Efficiency (LHV):	84.3	%


Solar Turbines
A Caterpillar Company
Specified Site Conditions
Elevation: 3220 feet
Ambient Temp: 15°F
Humidity: 60%
System Efficiency = 84.3%
Customer Name
Predicted Stack Emissions
ppm@15%O2
short tons/yr
NOx 32.3 45.9
CO 43.1 37.2
UHC 30 14.6
5.3 psig
Pegging Steam
3,759 lbm/hr
Deaerator (by others)
Feedwater
228°F
(Valve By Others)
FW Pump (by others)
Condensate Return - 60%
212°F
155°F
Water Treatment System
(by others)
Makeup Water
70°F
Steam to Process
51,000 lbm/hr
180 psig/390°F
54,759 lbm/hr
145,667 lbm/hr
336°F
Air
15°F
Exhaust
143,863 lbm/hr
818°F
(1) Waste Heat Recovery
Boiler
(1) Centaur 40–4700
ISO Rating - 3,510 kW
Gross Output (At Site Specified Conditions) - 3,483 kW
Ductburner, Firing
Temp = 1,719° F
Blowdown
1,095 lbm/hr
37.2 MMBtu/hr
Liquid Fuel
Off
42.5 MMBtu/hr
175 psig
Gas Fuel
79.7 MMBtu/hr
300 psig
Fuel Flow(s) based on Lower Heating Value
Note: For Estimating Purposes only. For Guaranteed Performance, see your Solar Turbines Representative.
March 23, 2020
CEP Version 2001

Off Design Performance Worksheet

Customer Name

March 23, 2020

Prepared by Lisa Marlo Conley

Centaur 40-4700S

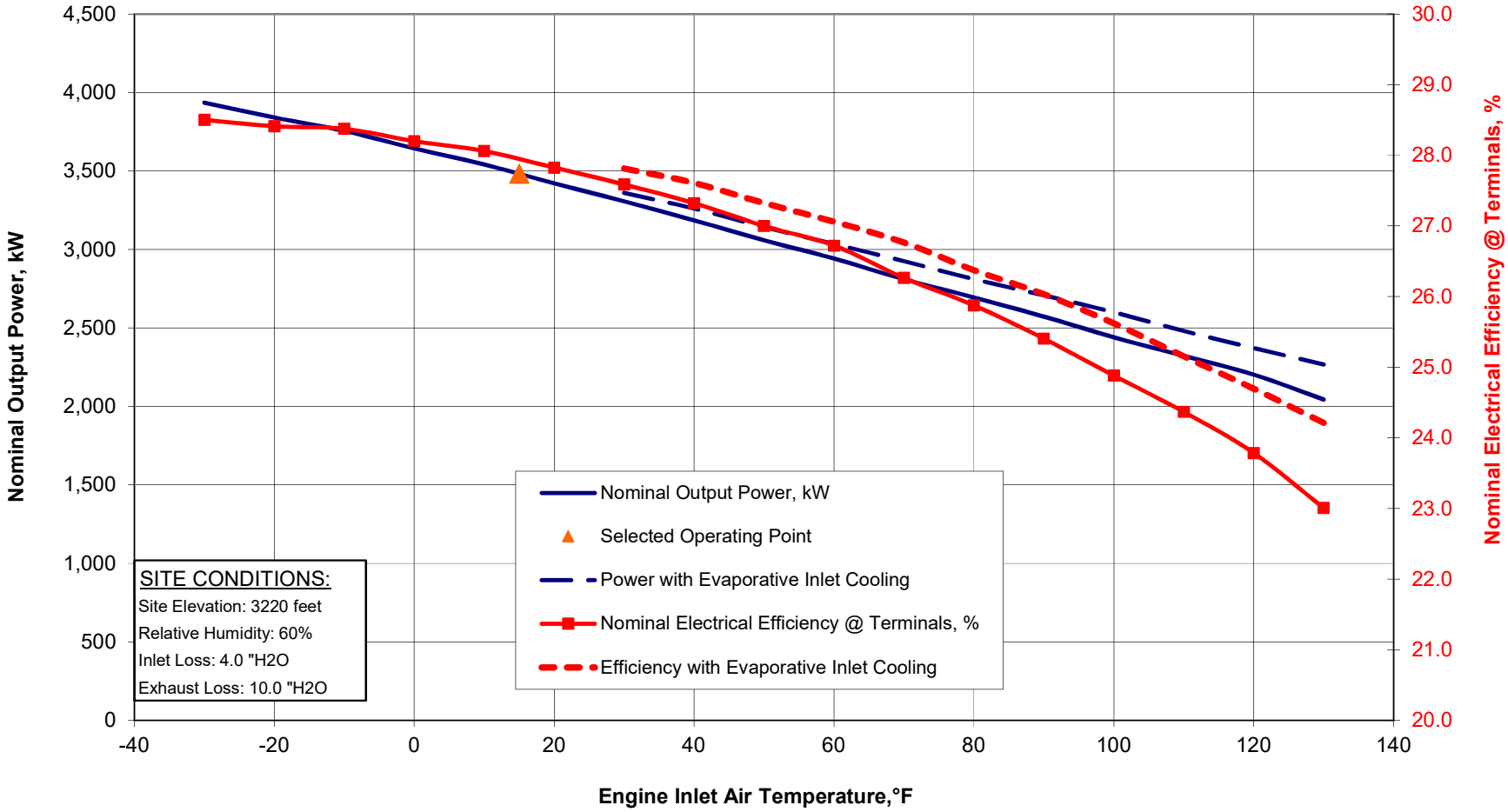
Dual Fuel - Natural Gas

	As-Designed Values						
Site Elevation	3,220	feet					
Barometric Pressure	26.60	"Hg					
Inlet Duct Loss	4.0	"H2O					
Exhaust Duct Loss	10.0	"H2O					
# of Turbines in Service	1	1	1	1	1	1	
Ambient Temperature (T1)	15.0	80.0	65.0	50.0	35.0	15.0	°F
Relative Humidity	60.0	60.0	60.0	60.0	60.0	60.0	%
Part Power (kW), % Load, or 0 for Max	0	0.00	0.00	0.00	0.00	0.00	kW
Engine Inlet Air Temperature (T1)	15.0	80.0	65.0	50.0	35.0	15.0	°F
Nominal Output Power @ Terminals	3,483	2,720	2,894	3,072	3,260	3,483	kW
Fuel Flow (LHV)	42.5	35.5	37.1	38.7	40.4	42.5	MMBtu/hr
Inlet Air Flow	141,799	125,055	128,866	132,913	137,191	141,799	lbm/hr
Exhaust Gas Temperature (T7)	818	850	842	834	826	818	°F
Exhaust Gas Mass Flow	143,863	126,779	130,664	134,789	139,152	143,863	lbm/hr
Exhaust Gas Volumetric Flow	36,298	31,949	32,936	33,985	35,095	36,298	SCFM
Nominal Electrical Efficiency @ Terminals	28.0	26.1	26.7	27.1	27.5	28.0	%
Nominal Electrical Heat Rate @ Terminals	12,211	13,069	12,804	12,588	12,395	12,211	Btu/kWHR
Exhaust Heat Captured	18.1	16.8	17.1	17.4	17.6	18.1	MMBtu
% Argon, wet	0.9	0.9	0.9	0.9	0.9	0.9	
% CO2, wet	2.5	2.4	2.4	2.4	2.5	4.6	
% H2O, wet	4.9	4.7	4.7	4.8	4.9	8.9	
% N2, wet	76.1	76.2	76.2	76.2	76.2	74.6	
% Oxygen, wet	15.5	15.8	15.7	15.7	15.6	11.0	
	51,000	Process Steam Demand				50,000	lbm/hr
	16,154	Unfired Steam Flow				16,154	lbm/hr
	98,831	Max Steam Flow				51,397	lbm/hr
	1,719	Firing Temperature				1,695	°F
	37.2	Duct Burner Fuel Flow				36.1	MMBtu/hr
	84.3	Net CHP System Efficiency				84.1	%

Fuel Flow(s) based on Lower Heating Value

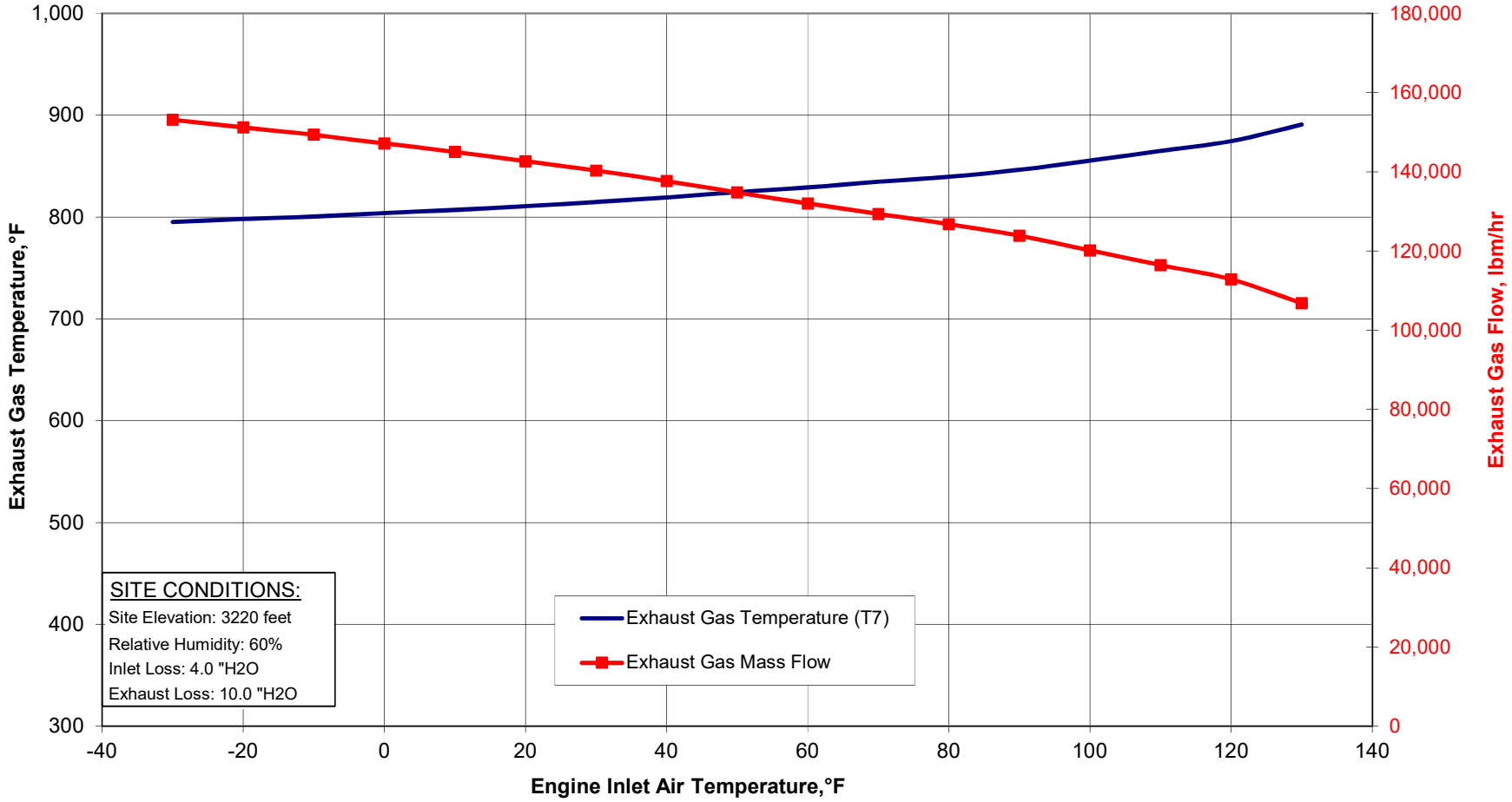
Centaur 40-4700S (Dual Fuel - Natural Gas)

FULL LOAD PERFORMANCE



Centaur 40-4700S (Dual Fuel - Natural Gas)

FULL LOAD PERFORMANCE



Solar Turbines Incorporated

Budgetary Estimate for Power Engineers

Inquiry # Inquiry Number

February 25, 2020

For more information contact Lisa Marlo Conley, 1 858 694-6523, lisamarloconley@solarturbines.com

(Prices shown below quoted in US Dollars $, using a conversion of US dollar price times 1)

Quotation is for information only and does not constitute Solar's agreement to offer a firm proposal in the future.

Gas Turbine Equipment	
(1) Centaur 50 SoLoNOx Turbine Generator Set, Dual Fuel	$3,400,000
Commissioning Parts, Startup, and Site Testing	$198,200
Electrical Equipment	
No Additional Electrical Equipment Included	
Mechanical Equipment	
Fuel Gas Compressor	by others
1 Heat Recovery Steam Generator	$846,700
Total for Heat Recovery Steam System	$846,700
Miscellaneous	
Construction Estimate	by others
Project Management & Engineering (Loose Ship Equipment Only)	$59,300
Shipping	$84,900
6% Balance of Plant Contingency	$59,500
Total for BOP Equipment (installation not included)	$1,050,400
Grand Total for Turbomachinery and Balance of Plant	**$4,648,600**
Estimation of cost per ISO rating kilowatt for selected equipment	$1,010

*Duties and taxes not included in estimate.

CEP Version 2001

Centaur 50-T6200S Generator Set Package Features

Gas Turbine:

One shaft turbine, designed for industrial use
Axial compressor design
Annular type combustor employing dry, low NOx technology (25 ppm NOx @15%O2)

Basic Options:

Fully enclosed, generator set package requiring 460V, 3-phase, 60 Hz AC power
Rated Class I, Div II, Groups C,D per NEC
120V, 1-phase, 50/60 Hz internal lighting and heater power
Gas turbine engine in upward oriented air inlet and axially oriented exhaust outlet
1800 rpm; 60 Hz
Continuous Duty, Open Drip Proof Medium voltage generator featuring Class F insulation, B rise

Included Package Features:

Direct AC start motor system
Duplex lube oil filter system
Allen-Bradley based Turbotronics control system including:
- Ethernet network interface
- Touch Screen display with Engine Performance map
- Software for heat recovery interface (without diverter valve control)
- Software for CO2 system "lock out" (maintenance access to enclosure)
- Backup Safety Shutdown System
- kW Control
- kVAR/Power Factor Control

Included Factory Testing/Customer Witness/Quality Control Documentation:

Standard package static testing
Factory vibration testing
Factory emissions testing per Solar's ES 9-97
Observation on "Non-Interference" basis
Quality Control documentation (Level 1)

Field-installed Ancillary Equipment (excludes ducting):

Updraft air inlet filter
Engine air inlet silencer
Exhaust bellows (interface to waste heat recovery equipment)
Elbow type enclosure inlet/exhaust ventilation system with silencer

Included "Off-Skid" Components/Systems:

Remote desktop PC/monitor and Printer/Logger
Gas fuel flow meter (for Gas-only and Dual Fuel configurations)
AC motor-driven Liquid Fuel boost pump skid (for Liquid Fuel configurations)
3-micron duplex filter/coalescer with auto drain (for Liquid Fuel configurations)
CO2 system cabinet
Air/Oil lube oil cooler
VRLA Batteries with 120V DC charging system (back-up post lube)
Portable engine cleaning cart

Miscellaneous

Short-term preservation for shipment
Four (4) paper copies of Solar's Instruction, Operation and Maintenance manuals
Four (4) CD-ROM copies of Solar's Instruction, Operation and Maintenance manuals
UV Light and Gas Sensor test kit
Internal equipment handling system

Cogeneration Plant Estimated Performance Summary

Power Engineers

Solar Turbines Incorporated

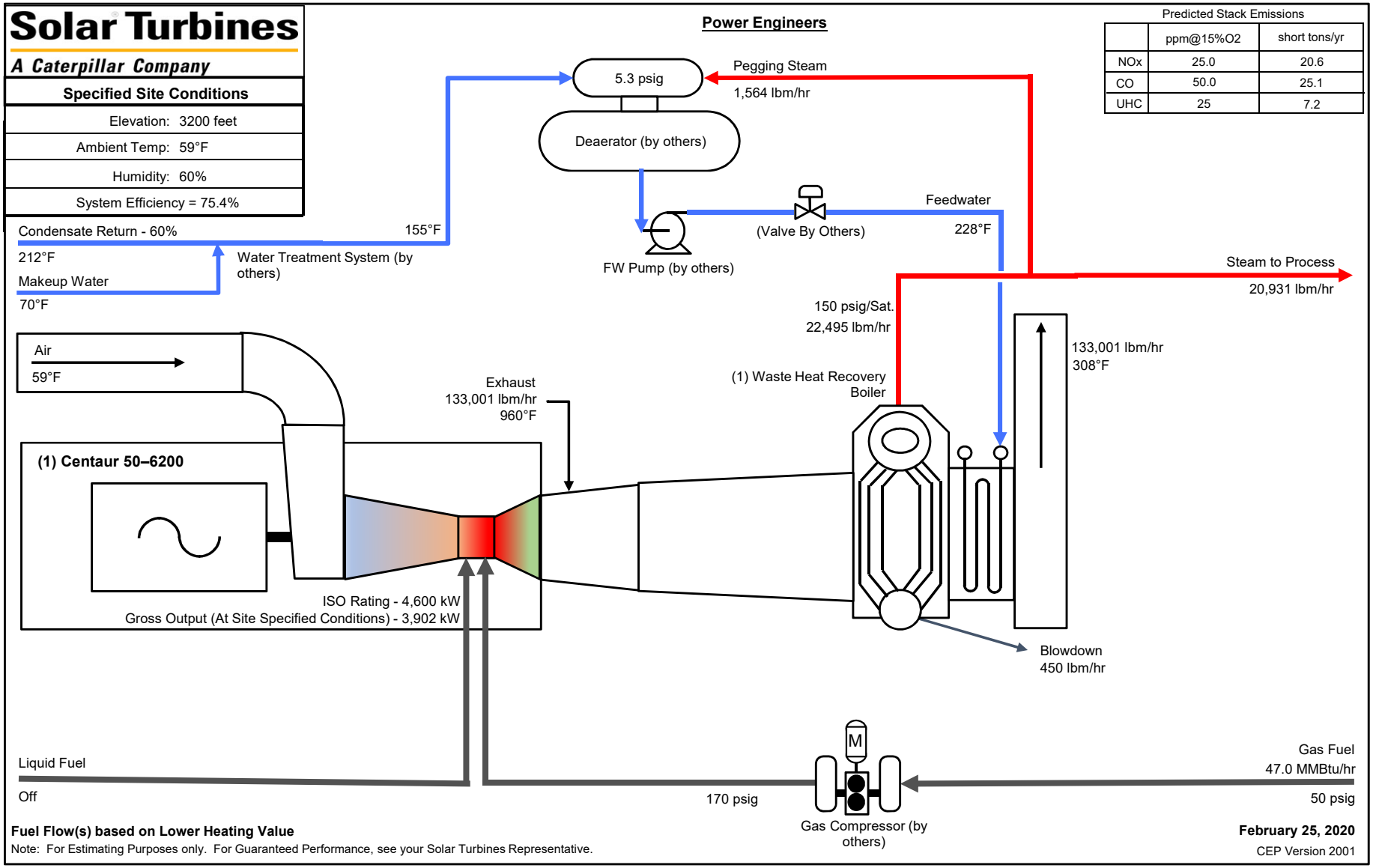
February 25, 2020

Performance listed below is estimated, not guaranteed.

Gas Turbine:		
KW Gross Output @ ISO Conditions:	4,600	kW
Site Ambient Temperature for Performance Analysis:	59	°F
Site Elevation for Performance Analysis:	3,200	feet
Site Ambient Relative Humidity for Performance Analysis:	60	%
Turbine Inlet Pressure Loss:	4.0	"H2O
Turbine Outlet Pressure Loss:	10.0	"H2O
Turbine Fuel Consumption @ specified site conditions (LHV):	47.0	MMBtu/hr
KW Gross Output @ specified site conditions:	3,902	kW
Gas Compressor Power:	69	kW
Turbine Auxiliary Power:	21	kW
Condensate Pump Power:	0.8	kW
Boiler Feed Pump Power:	6.7	kW
Total Auxiliary Power Consumption:	98	kW
Net Gas Turbine Power Production:	3,804	kW
Black Start kW Requirement (Turbine Generator Set Only):	350	kW

Boiler:		
Condensate Return:	60	%
Condensate Temperature:	212	°F
Makeup Water Temperature:	70	°F
Process Steam Pressure:	150.0	psig
Process Steam Temperature:	366	°F
Deaerator Steam Consumption:	1,564	lbm/hr
Boiler Steam Flow (HRSG design uses 27.0°F pinch, 18.0°F approach):	22,495	lbm/hr
Steam Flow to Process:	20,931	lbm/hr

Cycle Performance (lower heating value basis):		
Net Turbine Electrical Heat Rate:	12,350	Btu/kWHR
Gross Plant Heat Rate (Process steam or Tons converted to equivalent KW):	4,520	Btu/kWHR
Overall Cycle Efficiency (LHV):	75.4	%


Solar Turbines
A Caterpillar Company
Power Engineers
Specified Site Conditions
Elevation: 3200 feet
Ambient Temp: 59°F
Humidity: 60%
System Efficiency = 75.4%
Predicted Stack Emissions
ppm@15%O2
short tons/yr
NOx 25.0 20.6
CO 50.0 25.1
UHC 25 7.2
5.3 psig
Pegging Steam
1,564 lbm/hr
Deaerator (by others)
Feedwater
228°F
(Valve By Others)
FW Pump (by others)
Condensate Return - 60%
212°F
155°F
Water Treatment System (by others)
Makeup Water
70°F
Steam to Process
20,931 lbm/hr
150 psig/Sat.
22,495 lbm/hr
133,001 lbm/hr
308°F
Air
59°F
Exhaust
133,001 lbm/hr
960°F
(1) Waste Heat Recovery Boiler
(1) Centaur 50–6200
ISO Rating - 4,600 kW
Gross Output (At Site Specified Conditions) - 3,902 kW
Blowdown
450 lbm/hr
Liquid Fuel
Off
170 psig
M
Gas Compressor (by others)
Gas Fuel
47.0 MMBtu/hr
50 psig
Fuel Flow(s) based on Lower Heating Value
Note: For Estimating Purposes only. For Guaranteed Performance, see your Solar Turbines Representative.
February 25, 2020
CEP Version 2001

Off Design Performance Worksheet

Power Engineers

February 25, 2020

Prepared by Lisa Marlo Conley

Centaur 50-T6200S

Dual Fuel - Natural Gas

	As-Designed Values						
Site Elevation	3,200	feet					
Barometric Pressure	26.62	"Hg					
Inlet Duct Loss	4.0	"H2O					
Exhaust Duct Loss	10.0	"H2O					
# of Turbines in Service	1	1	1	1	1	1	
Ambient Temperature (T1)	59.0	-20.0	10.0	40.0	80.0	59.0	°F
Relative Humidity	60.0	60.0	60.0	60.0	60.0	60.0	%
Part Power (kW), % Load, or 0 for Max	0	0.00	0.00	0.00	0.00	0.00	kW
Engine Inlet Air Temperature (T1)	59.0	-20.0	10.0	40.0	80.0	59.0	°F
Nominal Output Power @ Terminals	3,902	4,831	4,499	4,152	3,566	3,902	kW
Fuel Flow (LHV)	47.0	55.9	52.7	49.4	44.1	47.0	MMBtu/hr
Inlet Air Flow	130,721	148,527	142,511	136,117	123,960	130,721	lbm/hr
Exhaust Gas Temperature (T7)	960	951	945	945	971	960	°F
Exhaust Gas Mass Flow	133,001	151,238	145,069	138,513	126,099	133,001	lbm/hr
Exhaust Gas Volumetric Flow	33,799	38,484	36,897	35,209	32,035	33,799	SCFM
Nominal Electrical Efficiency @ Terminals	28.3	29.5	29.1	28.7	27.6	28.3	%
Nominal Electrical Heat Rate @ Terminals	12,042	11,566	11,718	11,892	12,356	12,042	Btu/kWHR
Exhaust Heat Captured	22.5	25.3	24.0	22.9	21.7	22.5	MMBtu
% Argon, wet	0.9	0.9	0.9	0.9	0.9	0.9	
% CO2, wet	3.0	3.1	3.1	3.0	3.0	3.0	
% H2O, wet	6.4	6.7	6.6	6.5	6.4	6.4	
% N2, wet	75.3	75.2	75.2	75.3	75.3	75.3	
% Oxygen, wet	14.4	14.1	14.2	14.3	14.4	14.4	
	20,931	Unfired Steam Flow				20,931	lbm/hr
	960	Firing Temperature				960	°F
	75.4	Net CHP System Efficiency				75.4	%

Fuel Flow(s) based on Lower Heating Value

Estimated Power Island Emissions

Power Engineers

Estimated using data available as of February 25, 2020

(1) Centaur 50-T6200S with HRSG		**Plant Total**
Ambient Temperature	°F	59.0
Gross Power Output	kW	3,902
Fuel Type	Dual Fuel - Natural Gas	
Assumed Fuel Sulfur Content	lbm/MMBtu*	0.00339
Gas Turbine Exhaust Flow	lbm/hr	133,000
Stack Exhaust Flow	lbm/hr	133,000
Flue Gas Temperature Leaving Gas Turbine	°F	960
Flue Gas Temperature At Stack	°F	308
Heat Input to Gas Turbine	MMBtu/hr*	52.1
PM10/PM2.5 Particulates from Gas Turbine	lbm/MMBtu*	0.01
Turbine Exhaust Gas Analysis		
H2O, assumes 60% relative humidity	% vol	6.4%
N_2	% vol	75.3%
CO_2	% vol	3.0%
O_2	% vol	14.4%
SO_2	% vol	0.0%
Argon	% vol	0.9%

Exhaust Emissions At Stack		
NOx	ppm@15%O2	25.0
	lbm/MMBtu*	0.0903
	lbm/hr	4.71
	short tons/yr	20.6
CO	ppm@15%O2	50.0
	lbm/MMBtu*	0.11
	lbm/hr	5.73
	short tons/yr	25.1
UHC	ppm@15%O2	25.0
	lbm/MMBtu*	0.0314
	lbm/hr	1.64
	short tons/yr	7.17
VOC	ppm@15%O2	5.0
	lbm/MMBtu*	0.00628
	lbm/hr	0.328
	short tons/yr	1.43
$PM_{10}/PM_{2.5}$	lbm/hr	0.521
	lbm/MMBtu*	0.01
	short tons/yr	2.28
SO_2	lbm/hr	0.177
	lbm/MMBtu*	0.0034
	short tons/yr	0.78
CO_2	lbm/MMBtu*	118
	lbm/hr	6,160
	short tons/yr	27,000
	tonne/year	24,500

*HHV

Emissions Notes:

1. This document is for initial emissions estimates only. For air permit applications, Solar can provide appropriate site-specific turbine emissions documentation.

2. Fuels must comply with Solar specification ES 9-98. Actual emissions may vary due to site fuel characteristics. Zero fuel bound nitrogen is assumed for gaseous fuels, and less than 0.02% for liquid fuels.

3. Turbine "ppm" values are applicable for operation at ambient temperatures between 0 and 120°F.

4. The table below gives the load ranges to which the turbine ppm emissions listed above apply. Mass based estimates are valid at ambient temperature and operating load noted.

Pollutant	Load Range
NOx	50 to 100%
CO	50 to 100%
UHC	50 to 100%

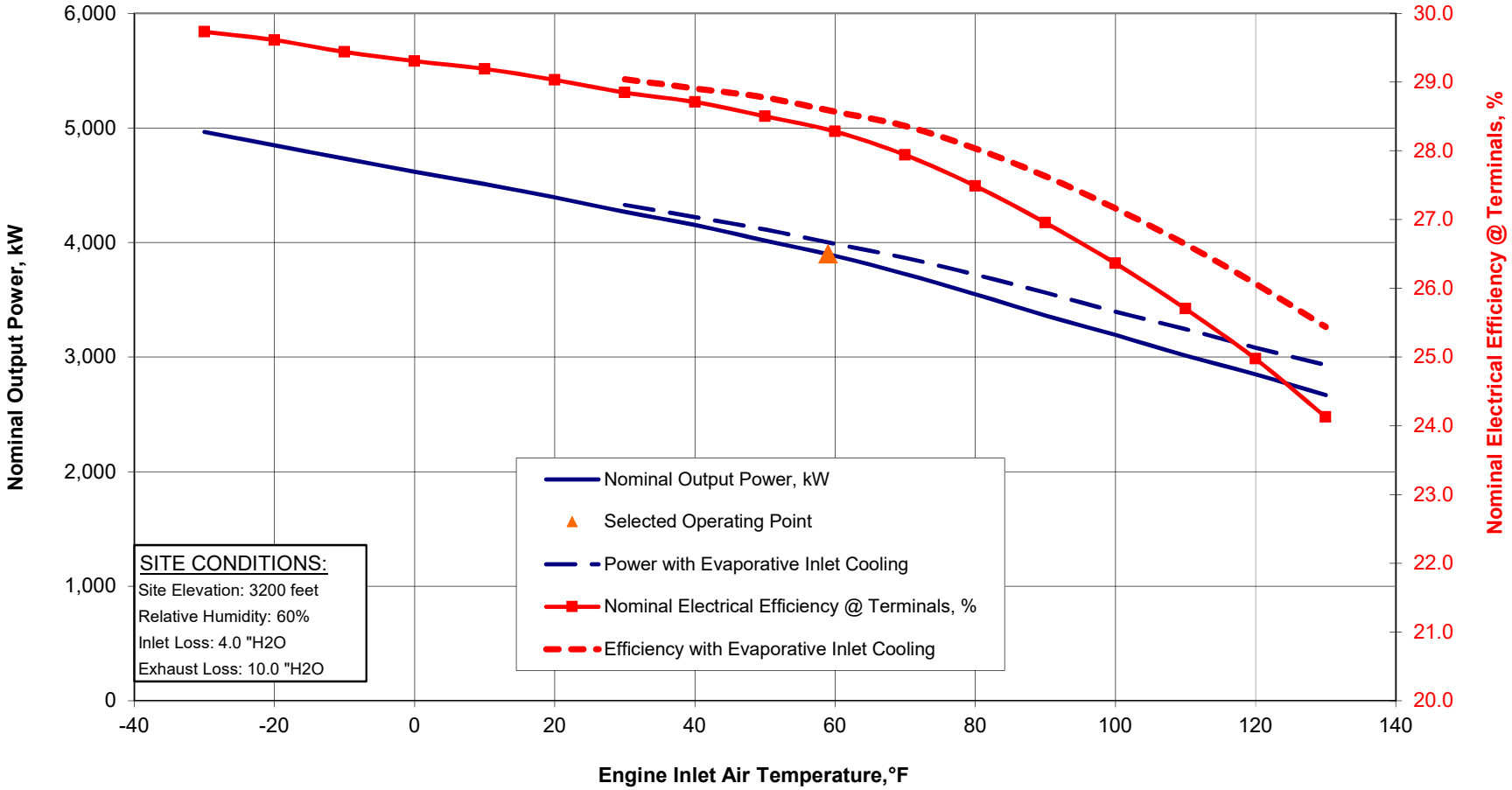
5. SO2 emissions depend upon the fuel's sulfur content. The SO2 estimate is based upon EPA's AP-42 document (Tables 3.1-2a. and 3.1-2b. April 2000).

6. Annual estimates shown above assume 8760 hours/year operation.

Contact: Lisa Marlo Conley, 1 858 694-6523, lisamarloconley@solarturbines.com

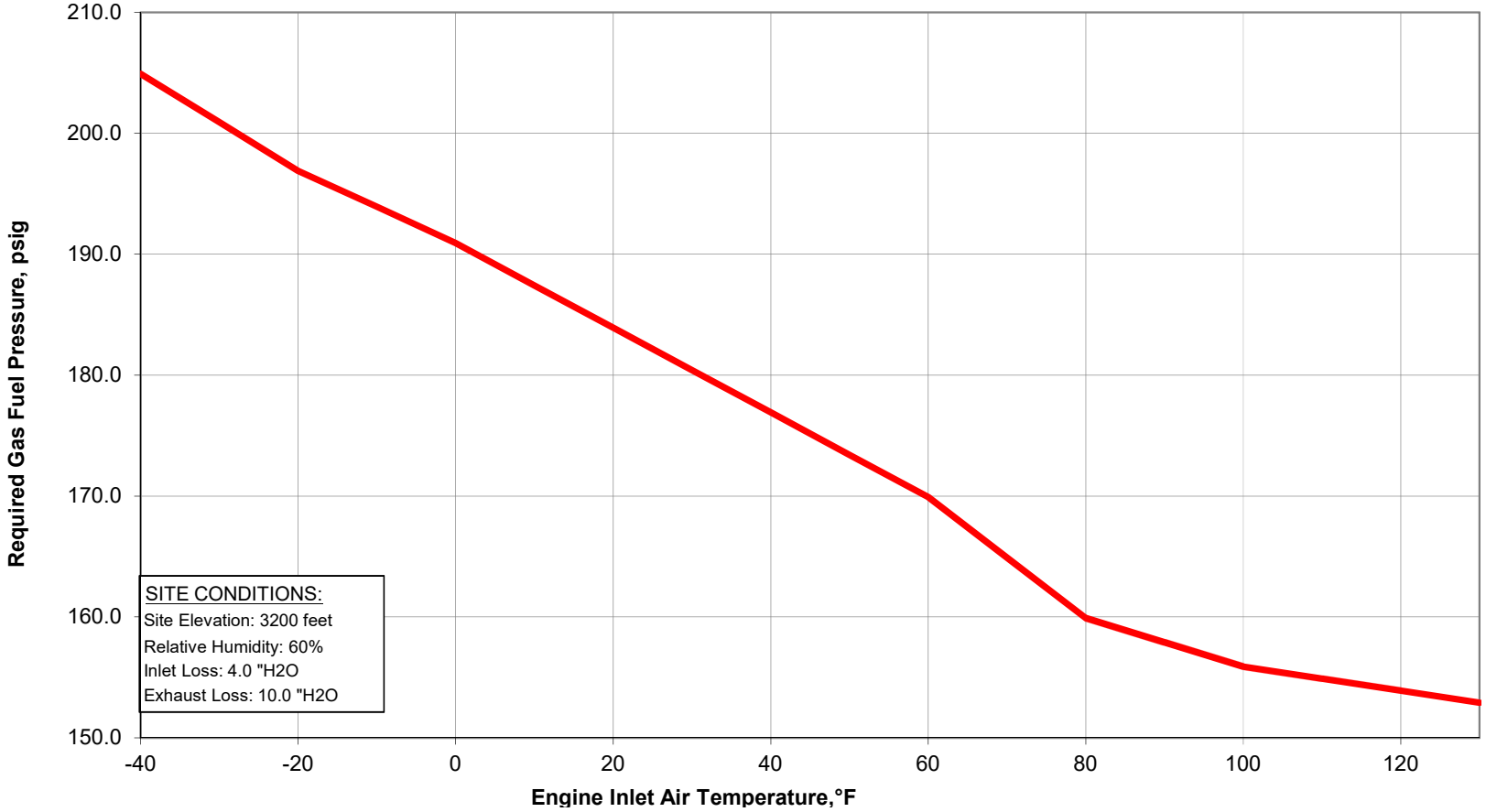
Centaur 50-T6200S (Dual Fuel - Natural Gas)

FULL LOAD PERFORMANCE



Centaur 50-T6200S (Dual Fuel - Natural Gas)

FULL LOAD PERFORMANCE



At skid edge, allowance should be made for external piping loss

 CEP Version 2001

Budgetary Proposal

Customer: University of Montana

Customer Address:
32 Campus Drive
Missoula, MT 59812

Project name: University CHP

Project reference: **Q2020-074**

Proposal issue date: **13 April 2020**

Airem Energy Contact: **Ryan Zwicker**

Tel. : 713-834-7865

E-mail : rzwicker@airemenergy.com

Introduction

Airem Energy's generator set is powered by the environmentally friendly, reliable, economical OP16 all-radial industrial gas turbine unique in its power range. As an industrial turbine, it is designed from the outset to provide long life and high reliability for continuous duty electrical power generator applications. The single-shaft configuration is particularly suited to constant-speed generator loads. The compressor and turbine are integral in design, with all bearings and bearing supports in the cold section of the engine for extended bearing and lubricating oil life. Oil consumption is negligible with the overhung rotor configuration.

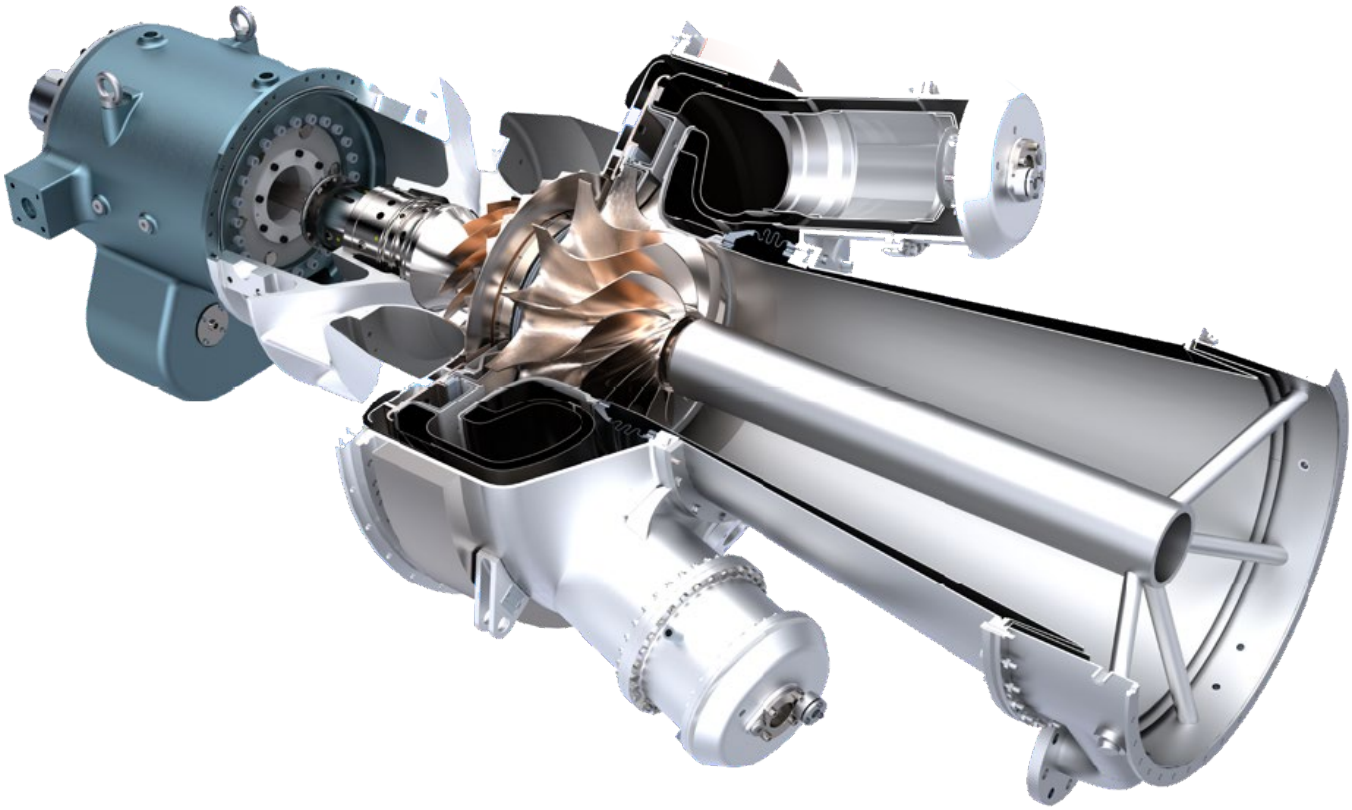


Table of Contents

Scope of Supply

OP16 Gas Turbine engine:

- OP16 all-radial industrial gas turbine designed for simplicity, ruggedness and durability, rated 1.788MW(e) at ISO conditions. Single-shaft configuration with bearings and supports located in the engine's cold section. Single-stage centrifugal compressor with a 6.7/1 compression ratio offering a high flow path efficiency. Insulated AISI 316 exhaust diffuser.

- Integrated reduction gearbox: A proprietary design, 2-stage epicyclical configuration speed reduction gearbox to reduce speed to 1800 rpm (60Hz) on the output shaft to the generator. Shear pins located on the output shaft for overload protection.

- Flexible drive coupling between gearbox and coupling safeguarded by a fully-enclosed coupling guard.

- Flame monitoring system: 2 thermocouples per combustor can confirming ignition and presence of a combustion flame.

Combustion system:

OP16-3B Dry Low Emissions (gas fuel only):

- 3B low-emission premixed combustion system.
- Gaseous fuel system with stainless steel gas system piping equipped with pressure and temperature transmitters. Cellular filter with a pressure differential switch. Failsafe pneumatic/electrical double block and bleed valves system, 3B fuel metering system, bleed air system, 4 gas fuel nozzles and a control system upgrade for DLE equipment.

Enclosure and support systems:
Gas turbine enclosure:

- Multi-point steel base frame/3-point vibration-isolating sub-skid mounted inside structural base frame.
- Enclosure walls receive an outside protection consisting of a 2-layer coating (Intercure 200HS and Interthane 870). Suitable for atmospheres with temperatures up to 250°F (120°C). Enclosure and control room walls are insulated with 2 layers of mineral wool covered with perforated sheet. Enclosure rated IP54. Average turbine enclosure noise pressure emissions are attenuated up to 85 dBa @ 3ft (1m), (free field conditions), additional lower noise emissions levels available.

Exhaust gas interface for installations with heat recovery systems:

- Exhaust diffuser, expansion joint and axial exhaust duct (maximum 6ft length).

Firefighting system:

- Consists of manual release button outside the enclosure, alarm signals, two flame detectors, two heat detection sensors, piping, valves, mechanical actuator(s), electrical actuator(s), pressure switches and spray nozzles to effectively fill the enclosure with fire extinguishing agent. One bottle containing the extinguishing agent are located in a bottle rack. Fire extinguishing agent is Novec 1230, compliant to NFPA 2001.

Oil system:

- Lubrication oil system has a stainless steel, oil tank containing 55 gallons (200 liters) of ISO32 grade lubrication oil, provided with level transmitter. Lube oil circulation heater with thermostatic temperature control to ensure the right viscosity and oil temperature in case of system standstill. The lube oil system further consists of an engine driven oil pump, suction filters, distribution block, AC motor driven auxiliary pump, oil piping and hoses. The duplex-type lube oil filter with external by-pass valve and manual changeover and the air-oil lube oil cooler including cooler matrix, AC motor, fan, fan guard and fan housing are mounted outside the enclosure to prevent spilling of oil to the environment as the OP16 base frame is designed to contain all lube oil in case of a leakage.
-
- The starting system consists of a hydraulic starter pump driven by an electric motor, pressurizing lubrication oil driving the hydraulic starter motor mounted on the gearbox. The starting system starts the turbine until reaching the self-sustained and purges the exhaust system prior to the starting sequence at purge speed.

Gas detection:

- To sense unwanted gas accumulation in case of gas leakage, the turbine enclosure is provided with three infrared gas detectors located at the ventilation outlet, combustion air inlet and inside the enclosure. The sensors are connected to the safety system.

Electrical generator:

480V Standard generator:

- Synchronous generator 480 V, 60Hz, 59°F (15°C) (0.8 power factor), open drip proof, protection class IP23, roller bearings. Temperature rise class B. Insulation class F.

Air inlet, filtration and ventilation:

Air inlet system:

- Filter house made of carbon steel with integrated carbon steel inlet ducting leading to enclosure ventilation and combustion air inlets. The filter house contains sound dampers to attenuate average sound levels to 85 dB(a) @ 3ft (1m) (free field conditions).
- Two inlet ventilation fans with G4 filter elements filters air going through the enclosure ventilation system and creates a slight over pressure in the turbine enclosure. The ventilation system is used to ventilate the enclosure, blow out the radiation heat from the turbine/generator and to avoid any gas pockets. The oil cooler also uses this ventilation air stream.
- Also integrated in the air inlet system is a separate turbine combustion air filtration system, of a two-stage G4 and F9 air filter configuration.
- The OP16 anti-icing is accomplished via infra-red heaters upstream of the filters, heating the surface of the filters to prevent ice build-up.
- Operating temperatures of the OP16 enclosure with standard air inlet system are between-20°F (-29°C) and 110°F (43°C).

Control system:

Allen Bradley based control system:

- The OP16 control system hardware is based on Allen Bradley L72S and L72SP with I/O cards belonging to the Flex I/O family.

- The OP16 controller (PLC) integrates turbine and other equipment controls with sub-controls and safety logic. Main controller takes care of startup and shutdown sequences, speed governing, synchronization, electrical load control, engine protection, alarm and status indication. Control system interfaces the Customer's control system with an Ethernet/Modbus protocol.
- Vibration monitoring system: Bently Nevada 1900/65A vibration analyzer and vibration sensor. All vibration data is processed by the control system and trends/history is displayed on the HMI.
- DEIF generator protection system. Generator protection & control and differential current protection. Modules: DEIF AGC-4 and DEIF MDR-2.
- Visualization of the OP16 system is on a full-color HMI MOXA MPC-2150 series edition panel.
- Remote monitoring and data logging system, which allows Airem Energy to directly monitor the performance for the genset in Airem Energy's headquarters. Requires internet connection and cellular account. The high-speed internet connection and cellular account are not in Airem Energy's scope of supply.

Integrated control panels:

- Control panels are installed inside a 480V OP16 configuration. Panels can be accessed from outside of the OP16 enclosure.

Transport, installation & commissioning:

Due to the modular and standardized design of the OP16 genset, the time required for the installation and commissioning can be reduced to a minimum.
The installation and commissioning is divided into three distinct phases (see Phase 1, 2 and 3 as detailed below). Customer shall declare that all preparations for the next phase have been completed in accordance with respective specification(s) as provided by Airem Energy.

Installation & commissioning:

- I&C Phase 1: Supervision of Genset placement on foundation and setting interface between genset enclosure and Air Treatment Module

- I&C Phase 2: Installation and connection of system interfaces, ducting, gas pipes, cables, exhaust and batteries.

- I&C Phase 3: Commissioning and handover of the Equipment

Certifications, tests and approvals:

- OP16 core engine Factory Acceptance Test: A standard core OP16 engine performance, signal, vibrations and duration test. Test performed in the engine test facilities.

- OP16 gas turbine Systems Integration Test. Test aimed to check equipment is correctly installed and working, assessing system safety, start and shutdown procedures.

Documentation:
Documents provided in English language

User and operation manual:

- Includes equipment and interface drawings.

P&IDs and Drawings:

- P&ID drawings.
- EWD – Electrical Wiring Diagrams
- GA's – General Arrangement Drawings

Manufacturer Record Book:

- Includes test reports, quality certificates and special components lists.

Maintenance manual:

- Includes how to maintain the OP16 system.

Tagging system:

- All components numbers are shown on the equipment and in the documentation. Simple tagging on equipment and documentation. Numbering according to Airem Energy specification. Units on transmitters etc. and in Imperial units/SI-units.

Optional services and equipment:

Special tools:

- Special tools set includes:
  - Gearbox turning tool
  - OP16 engine lifting frame
  - Engine support frame
  - Engine transportation frame
  - Gearbox shear pin tool
  - Gearbox seal fitting tool
  - Coupling tool
  - Gearbox seal replacement tools
  - Gearbox guide pins tooling
  - Shaft rotation tool
  - Alignment tool

Additional User Interface:

- Additional computer with identical HMI software to the HMI in the control cabinet.

Training:

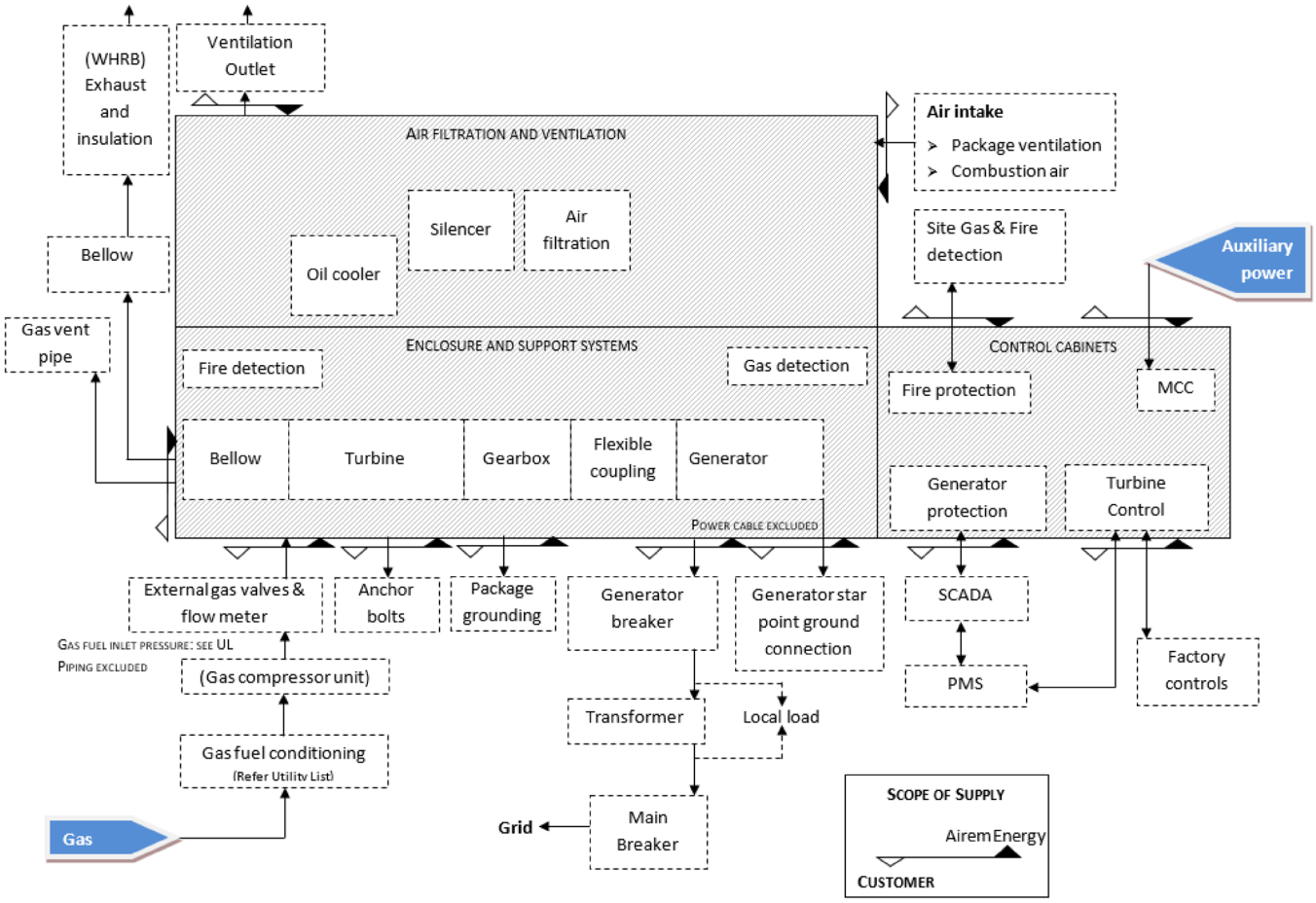
- Operator and maintenance training of the Customer's employees for safe operation of the OP16 gas turbine generating set (2 full days for a total of 1 shift).

Exclusions

The following items are not included in Airem Energy's Scope of Supply and should be included in other contractor's scope(s) of supply. Airem Energy may quote for specific items if requested to do so:

- Civil engineering design of any kind, including foundations
- Civil construction, incl. foundation calculations, anchor bolts or concrete
- Haz-op study
- Air inlet/outlet ducting (including WHRU equipment) outside the OP16 enclosure
- Off-skid drains, vents, fuel or electrical pipes and wires unless otherwise stated
- Fuel gas supply and storage, fuel gas boosting or fuel treatment facilities
- Off-skid interconnect power cabling, transformers, switchgear, interconnect piping and supports
- Control house for unit control system (non-hazardous area)
- Loading and unloading of equipment from the transport
- Installation, commissioning and site testing (To be performed in accordance with standard field rates in Exhibit A)
- Start-up, commissioning spares beyond incl. in scope of supply summary
- Two-year operating spares beyond incl. in scope of supply summary
- First fill of fluids
- Lifting tools (Spreader bars, skates, slings, shackles etc.)
- Calibration tools and ordinary hand tools
- Positive Material Identification (PMI) requirements and Third-Party inspection
- Lightning Protection
- Long Term Preservation & Storage
- Seaworthy Freight & Packing unless specifically quoted
- Applicable local, state or federal taxes, duties or fees
- Field Installation Labor (To be performed in accordance with standard field rates in Exhibit A)
- Factory facility full load string test unless otherwise quoted
- Transformers, breakers, switches and other electrical gear unless otherwise quoted

Limits of Scope of Supply



Customer Connections

Controls Interfaces:

- Control system connection: The OP16 control system interfaces with a port connection to integrate selected parameters into the Customer's site control system. Cabling between OP16 system and the Customer's control system excluded.
- Load limitation (Island Mode): OP16 will automatically control voltage, frequency, and power factor through DEIF and will automatically respond to varying load within safety limits.
- Load limitation (Fixed Power or Base Mode): Generator output power and power factor will be fixed value selected in the DEIF. Voltage and Frequency is controlled by the grid or others.
- Ethernet internet connection and cellular account are required for remote monitoring of the OP16 gas turbine generating set and email/text notifications. Interfacing the OP16, the internet connection, cellular account and cabling are excluded from Airem Energy scope.
- Switchgear and transformer controls: OP16 control system has open ports to connect to the switchgear and transformer to control starts/stops. Equipment is to be designed according to Airem Energy requirements. All cables, switchgear and transformer are excluded from Airem Energy scope.
- Gas fuel flow meter: Certified gas fuel meter to determine OP16 efficiency. The OP16 receives a pulse signal (open collector, suitable for 24 Vdc). Alternatively, a 4-20mA current feedback signal can be used. Gas fuel flow meter is not included in Airem Energy scope.

Fuel Interfaces:

- Gas connection: Connection of the Customer's gas system to the OP16 gas system found at the OP16 enclosure edge. Interface is a flanged 2" Class 150 RF connection.
- Gas ventilation pipe interface: ½" Sch. 80 seamless pipe interfacing at OP16 enclosure edge.
- Liquid fuel connection: Liquid fuel shall be supplied to the OP16 through the DN25/PN16 interface. Flange connection located at the exhaust side of the OP16 skid. Return flange size is DN25/PN16.

Mechanical Interfaces:

- Pressurized air interface: Continuous pressurized air connection for fuel valve operation. Interface connection female ¼ BSPP located at skid edge.
- Air intake: a combined air intake is found at the generator side of the air filtration and ventilation module. When applicable, inlet air ducting can directly connect to the air filtration module.
- Exhaust system interface: Metal expansion joint/spool piece with a flange connection located at skid edge.
- OP16 foundation: The skid requires multiple support points. Proper foundation shall be provided by the Customer for which Airem Energy provides the engineering parameters
-

Electrical Interfaces:

- Generator cable connection: OP16 genset is delivered quick connect (cam type) outside on a bulkhead allowing easy connection for power cables.
- Auxiliary power: Following the power requirement detailed in the Utility List, the End-User or the Contractor shall provide cabling up to the 250-amp quick-connect bulkhead supplying 480V 3-phase 60 Hz power.
- Grounding of the OP16 Package – Protective Grounding: Grounding pads are provided on the skid structure at each corner (2, 1/2"-13 UNC threads) Customer to wire any two diagonally opposite corners to protective earth connection. Ground connection to be less than 5 ohms.
- Grounding of the OP16 Package – Clean/Instrument Grounding: Customer to connect to the clean ground connection (1, 1/2"-13 UNC bolt) provided on the package to the clean/instrument ground connection on site. Ground connection preferably lower than the protective connection but less than 5 ohms.
- Generator Star Point Connection: Generator comes with for a floating start point. Provisions for grounded start point are available and can be quoted as an option.

Performance

PARAMETRIC STUDY

RESULTS TABLE

Nominal Performance at Max Load

Tamb	Elec Power	Elec EFF	EGT	FF	Exhaust Flow	Shaft Power	Heat Rate
[degF]	[kW]	[%]	[degF]	[MBtu/h]	[lb/h]	[kW]	[Btu/kWhr]
-20	2055	26,4%	982	26,537	73404,367	2138	12913
0	1912	25,5%	1000	25,547	71424,477	1990	13361
20	1745	24,6%	1015	24,257	68776,743	1816	13898
40	1582	23,6%	1028	22,872	65629,996	1648	14458
60	1449	22,7%	1043	21,749	62748,705	1509	15010
80	1276	21,2%	1063	20,492	59391,479	1329	16057

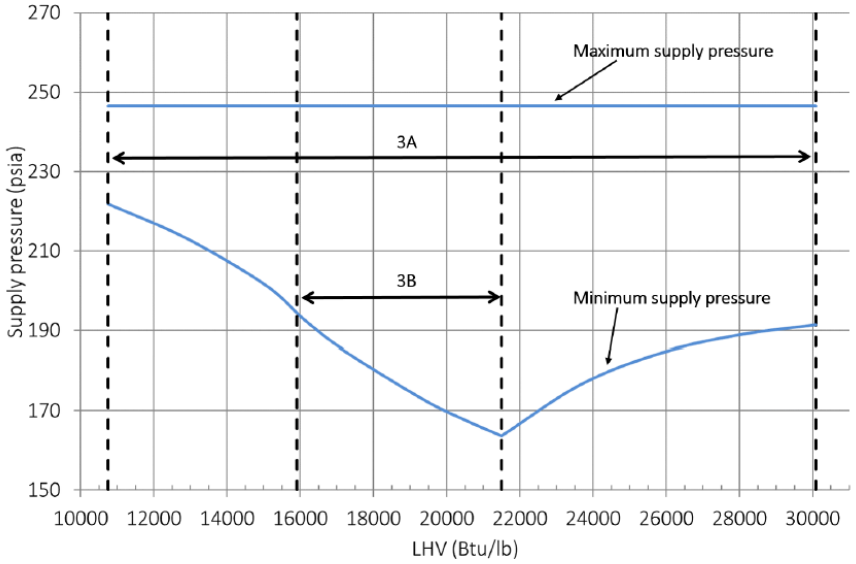
These performance figures are estimates, with an assumed natural gas composition. Actual performance will be refined and confirmed with actual site conditions and fuel composition.

Utility List

Gas Fuel

3B Combustor	
Lower heating value	12,900 – 22,350 BTU/lbm (30-52 MJ/kg) and 725-1,350 BTU/scf (27-50 MJ/ Nm^3)
Temperature Minimum Maximum	 45°F (6°C) above dew point 185°F (85°C)
Supply pressure Minimum Maximum	 Dependent of LHV (see chart below) 250 psi(a) (17 barg(a))

Complete fuel analysis, detailing properties of the fuel, as supplied to the turbine skid must be submitted to Airem Energy for review and approval.



Auxiliary Power Consumption

Equipment	Power consumption (kWe)	Stand still	Startup	Operation
Generator anti condensation heater	0.5	x	-	-
Motor anti condensation heaters	0.25	x	-	-
Lube oil heater	3.0	x	-	-
Hydraulic starter motor	45.0	-	x	-
Aux lube oil pump	0.55	-	x	-
Lube oil cooler fan	2.2	-	x	x
Control room aircooling	1.5	x	x	x
Enclosure ventilation fan	16.1	-	x	x
Unit control panel	1.0	x	x	x
Enclosure light	0.35	x	x	x
Total 400/480 VAC 3 Phase		**6.6**	**66.7**	**21.15**

Pricing and Delivery

This budget offer includes the engineering, fabrication, and testing of all equipment as detailed in the Scope of Supply.

The total budget price for one (1) OP16-3B Turbine Generator set:

Total contract price:	$ 1,795,000
Delivery:	6 Months Ex-works per Incoterms 2010

All prices are in USD and are exclusive of any taxes and/or other duties on the supply of the Goods.

The budget pricing above is subject to the gas turbine generator set being covered by a long-term maintenance contract detailed in option 1.

Optional services and equipment

No.	Item	Price
1	Long Term Service Offer	Ref Document

Validity

Unless otherwise specifically stated in the offer, all prices are in USD and are valid for a period of thirty (30) days from the date of the offer

The equipment detailed in the offer will be subject to prior sale until written notification has been issued by Airem Energy of an accepted purchase order.

Terms of payment

The terms of payment are based on the contract price including any optional services and equipment and will be invoiced in stage payments as follow:

- 15% of the total contract price to be invoiced on acceptance of contract.
- 15% of the total contract price to be invoiced on first issuance of general arrangement, P&ID and on-line diagram drawings.
- 25% of the total contract price to be invoiced on placing purchase order for gas turbine, gearbox and generator
- 35% of the total contract price to be invoiced on receipt of gas turbine, gearbox and generator
- 10% of the total contract price to be invoiced on notification of readiness to ship of the equipment but before shipment.

First payment to be paid in full within (14) days of signature of contract and all remaining payments to be paid within (30) days.

Delivery

Delivery is EXW New Iberia, Louisiana in accordance with INCOTERMS 2010 and subject to approval by Airem Energy of a detailed project program prior to order.

Terms & Conditions

The terms and conditions of this offer are based on AFGlobal's standard terms & conditions.

Warranty

Airem Energy warrants to the Purchaser that the Goods of its manufacture will be free from defects in material or workmanship caused by Airem Energy for twelve (12) months from date of installation or eighteen (18) months from date of delivery ex works (Incoterms 2010), whichever occurs first. If Airem Energy replaces or renews any Goods then the provisions of this paragraph will apply to the Goods repaired or replaced, provided however that the foregoing will not serve to extend any warranty period beyond eighteen (18) months from delivery ex works (Incoterms 2010) of the original Goods.

Applicable Law:

This offer as well as the Contract shall be governed by and construed in accordance with the laws of Texas.

Airem Energy Long Term Service Agreements (LTSA)

The OP16 is designed for minimal maintenance requirements with long service intervals. A standard maintenance cycle includes annual inspections and a major overhaul every 40,000 hours

.

Annual Inspection	Major Overhaul
Every 8,000-8,500 fired hours	At approx. 40,000 fired hours
Basic inspection of equipment	Core engine swap with zero-hour engine
Replacement of consumable items	Replacement of generator bearings
Calibration of safety critical items	

In order to ensure that the equipment is running at best possible performance with the highest availability, a comprehensive maintenance plan has been developed with spare parts stored in territory. Airem Energy offers three LTSA service levels as summarized in the below table.

	Airem Energy LTSA Service Offering
Contract duration	5 Years
24/7 hotline	Yes
Remote monitoring	Yes
Scheduled annual maintenance *including mob/demob, board & lodging, labor and spare parts*	Yes
Major overhaul @ 40,000h	Yes
Unscheduled maintenance *including mob/demob, board & lodging, labor and spare parts*	Yes
Availability guarantee *including % availability guarantee, penalty/bonus, insurance spares and spare engine pool*	Option

24/7 hotline

At times of emergency a quick response and availability of local service is critical. Airem Energy has a system in place that ensures availability of service around the clock, 365 days per year.

Remote monitoring

Airem Energy can remotely monitor the genset from our headquarters in the US. In case of an issue, Airem Energy will be notified instantly. Problems will be diagnosed and rectified remotely if possible. If this is not possible to solve problems remotely, Airem Energy certified technicians will be deployed to the site to solve any issue.

Scheduled maintenance
Annual inspections, performed every 8,000-8,500 fired hours, are the only scheduled maintenance events other than the major overhaul. This involves cleaning, inspection and/or replacement of parts. A full borescope inspection with and service report is also included in the annual inspection.

Major overhaul
Under normal operating conditions, a Major Overhaul (MO) is required after 40,000 fired hours. The existing core engine is retrofitted by a zero-hour engine. The original core engine is shipped back to Airem Energy facilities where the major overhaul is carried out. In addition to swapping the engine, the generator is inspected and main bearings are replaced during the major overhaul.

Unscheduled maintenance
Unscheduled maintenance includes all risk of unscheduled and unforeseen maintenance expenditure. This option effectively provides an extended warranty on the gas turbine genset.

Availability guarantee
Airem Energy offers an optional availability guarantee of the genset with a bonus / penalty arrangement. Airem Energy will pay a penalty in case the guaranteed availability in a year is not met and the client pays a bonus to Airem Energy in case the guaranteed availability is exceeded.
Availability is defined as the total hours in the period less the total outage hours divided by the total hours in the period. For clarity, scheduled maintenance activities are not included in the outage hours and do not count against availability.
Hours of availability includes all hours of actual operation of the power plant, plus:

- Scheduled maintenance activities
- Downtime due to customer's requirements.
- Hours when the power plant installation is available for use but is offline because the customer's load requirements are insufficient at that time.
- Downtime due to force majeure.
- Curtailment directed by the local utilities or caused by utility outage or process requirements.
- Downtime due to insufficient quantity or quality of fuel to operate the power plant and covered equipment resulting from activities or occurrences not under direct control of the manufacturer.

Availability Rate = *1 - Offline hours in period / Total hours in period*

A dedicated spare engine pool is allocated to customers who select the optional availability guarantee.

Scope and Pricing

This quotation is based on one (1) gas fuel OP16-3B gas turbine genset located in Missoula, MT.
This proposal is based on the provided information that the unit will run at least 8,000 hours per year. In case of a different operating regime, the quoted prices will change.

Item	***Price***
○ *Long-Term Service Agreement*	$22 *per fired hour*
Options	***Price***
○ *Field training of 3 weeks*	*To be charged per Airem Energy field service rates in Exhibit A*

Price Escalation

The indicated prices are firm and fixed for the calendar year of signing of this Contract and will be adjusted annually on 1st of January for each calendar year of the remaining period that this Contract is in force. This annual price adjustment will be in accordance with the indices for wages as published by the Producer Price Index (PPI) for Turbine and turbine generator set units. The index will be as published for December of each calendar year or, if not published in December, the most recent Index published in the same year. If no Index is published in the last six months of a calendar year, the price adjustment for the immediately following calendar year will be delayed until an Index is published and all prices will be retroactively adjusted to January 1. The price escalation will apply to all prices and fees, including repair prices, labor fees and spare parts pricing in accordance with the following formula:

$P_1 = P_0 * (PPI_1/PPI_0)$
In which:
P_1 = Price valid for the calendar year beginning January 1;
P_0 = Price valid in the preceding calendar year;
PPI_1= the Index for December or the latest index published in the calendar year
PPI_0= the PPI_1 Index used in the preceding calendar year

EXHIBIT A

Rates for Field Service Representatives 2020

Period	Domestic	International	Offshore
Straight Time (8 hours)	145	220	290
Overtime weekdays	220	330	435
Straight Time Saturday (8 hours)	220	330	435
Overtime Saturday and Sunday	290	440	580

The minimum charge for any service request is one day.

Overtime
The standard rate is applicable for any 8-hour day between Monday and Friday; all additional hours will be per rates listed in table above.

Travel and waiting hours

Travel hours will be invoiced at a standard rate of $115/hour. Waiting hours will be invoiced according to the above service rates.

Travel and living expenses

Travel, accommodation expenses, and subsistence allowances (including permits etc.) will be invoiced at cost + 15% administration and handling fee.

Terms of payment

Net 30 days from date of invoice issuance.

General

AFGlobal Standard Terms and Conditions apply.

Validity

Rates are valid for services provided between January 1, 2020 and December 31, 2020.
Issue date: January 1, 2020
Revision: 0

Service Center contact information

Phone: 1-888-354-5392
Email: Service.Turbines@AIREMenergy.com

Office/Shop
P.O. Box 702274
2300 S. Adams Road
Sand Springs, OK 74063
U.S.A.

Contacts:
Ph: 918-215-1900
Fax: 918-215-1908
E-mail: sales@tulsacombustion.com
Web site: www.tulsacombustion.com

Gus Drake, ME
Power Engineers
Boise ID

4/15/20

Ref: University of Montana Boiler
TC-16-09-1992-Q03

Gentlemen:

Tulsa Combustion is pleased to update our offer a 50,000 pound per hour boiler for your consideration. We are designing the boiler to fit in the space made available by the planned removal of one of your older boilers. Tulsa Combustion is proposing the supply of the complete heat recovery system from the turbine outlets through the boiler, including the turbine exhaust bypass with muffler and a single stack for either the boiler or bypass mode of each turbine.

Our boiler will make 29,000 lbs/hr of 200 psig saturated steam using only the waste energy available from the turbine exhaust. The boiler can make 50,000 lb/hr with supplemental firing of the turbine exhaust gas or by firing with ambient air. The Tulsa Combustion Advection type boiler provides a much higher efficiency than is possible with a duct burner fired boiler. An important efficiency difference is that the boiler burners fire into a water-cooled radiant section providing higher efficiency in the co-firing mode. This allows the exit O2 to be reduced to 3% at the maximum firing conditions. The Tulsa Combustion Advection boiler design is detailed in the data sheets that follow.

The attached drawing illustrates the turbine exhaust ducting and boiler design. The boiler is 12 feet in diameter and approximately 24 feet long. The boiler down comers and burner add to this length but are removable for shipment. The 3 foot diameter by 20 foot-long drum installs above the boiler. The Tulsa Combustion Advection boiler uses 3 passes. The first pass is comprised of four fire tubes, two pairs which are connected to each one of your turbine exhausts. The second pass is through nominal 2 inch pipe boiler tubes. The third pass is a flue gas passage in a gap between the boiler shell and an outer advection shell. The advection shell is internally lined with ceramic fiber. This pass also acts as a silencer. A breeching is provided on the advection shell to direct the flue gases up and through a convective economizer. Adjoining the flue gas breeching for the flue gases is a passage for the turbine exhausts to bypass the boiler and economizer. The bypass flow section is muffled to attenuate the turbine exhaust noise. The breeching, economizer, bypass common stack are lined with ceramic fiber insulation.

Tulsa Combustion has elected to provide a separate ducting for the exhaust of each of the turbines. This arrangement simplifies the ducting and provides for more efficient operation. With this arrangement, greater efficiency can be achieved by only firing one set of fire tubes.

This arrangement will facilitate higher thermal efficiencies when firing less than full co-firing rates as well as continued operation if one of the turbines needs to be out of service.

The Advection boiler and ducting are designed to operate within the allowable back pressure available from the turbines. A combustion air blower is provided to supply air for up to a 100% ambient boiler operation. The Combustion air blower will have a 40 HP, 460v/3Ph/60 Hz motor. Combustion air flow will be controlled by VFD motor speed control. Dampers are provided on the combustion air ducts to direct flow to only fire tubes requiring supplemental or ambient air operation.

A ladder and platform is provided to access the elevated steam drum and instruments and controls.

The Tulsa Combustion Advection Boiler offers a superior solution to fit into your available space and to meet your defined operations. The fire tube arrangement for turbine exhaust heat recovery with or without supplemental firing is far more compact than a duct burner-fired heat recovery boiler system. The Advection boiler exceeds the thermal efficiency offered by the large duct burner fired heat recovery boilers. We believe the Advection boiler represents the best option to meet your turbine exhaust and space limitation while producing up to 50,000 lb/hr of 200 psig saturated steam. The Tulsa Combustion pricing for our complete boiler system including turbine exhaust ducting and stack follow in the commercial section of this proposal.

Best Regards,

Mitt Chinsethagid
Sales manager

CC: Dave Salem – Brad Thompson Co.

Attachments: TC-16-09-1992-201-Q01 GA Drawing

INDEX

1. **Boiler Data Sheet**

1	Service	HRSG		Tag No.				
2	Boiler Type	ADVECTION		No. Boilers	ONE			
3				Model No.	TCLLC-AB-HRSG-XXX			
4	Package / Field Erected	PACKAGED		Indoor / Outdoor	INDOOR			
5	**DESIGN DATA**							
6	Maximum Continuous Rating (MCR)			50,000	LBS/HR			
7	Maximum Steam Flow			50,000	LBS/HR			
8	Turndown			0-100%	0% To 100% Of Maximum Steam Flow			
9	Minimum Load On Automatic Control			5000	LBS/HR			
10	Operating Steam Pressure			200	PSIG			
11	Operating Steam Temperature From Superheater			NA	°F			
12	Design Pressure			200	PSIG			
13	Design Temperature			400	°F			
14	Steam Purity Required			1	ppm (Dissolved solids)			
15	Maximum Allowable Pressure Drop Through Superheater			NA	PSIG			
16	Feedwater Temperature			240	°F			
17	Site Elevation				FT.(ASL)			
18	Special Characteristics Of The Application:							
19								
20								
21								
22								
23	**SCOPE OF SUPPLY**							
24	Boiler Pressure Parts	[X] Yes [ ] No		Feed Stop-Check Valve	[X] Yes [ ] No			
25	Burner(s)	[X] Yes [ ] No		Blowdown Valves	[X] Yes [ ] No			
26	Pilots	[X] Yes [ ] No		Piping To Blowdown Valves	[X] Yes [ ] No			
27	Forced Draft Fan	[X] Yes [ ] No		Auto. Blowdown Control	[X] Yes [ ] No			
28	Forced Draft Fan Motor Drive	[X] Yes [ ] No		Feedwater Regulator	[X] Yes [ ] No			
29	Forced Draft Fan Turbine Drive	[ ] Yes [X] No		Feedwater Reg. Bypass	[X] Yes [ ] No			
30	Forced Draft Fan Gear	[ ] Yes [X] No		Non Return Valve	[X] Yes [ ] No			
31	Forced Draft Fan Damper	[X] Yes [ ] No		Combustion Controls	[X] Yes [ ] No			
32	Air Ducts	[X] Yes [ ] No		Flame Safety Control	[X] Yes [ ] No			
33	Gas Ducts (Flue Gas)	[X] Yes [ ] No		Panelboard	[X] Yes [ ] No			
34	Carbon Monoxide Gas Ducts	[ ] Yes [X] No		Boiler Outlet Damper	[X] Yes [ ] No			
35	Superheater	[ ] Yes [X] No		Furnace Draft Regulator	[X] Yes [ ] No			
36	Economizer	[X] Yes [ ] No		Lifting Lugs	[X] Yes [ ] No			
37	Air Preheater	[ ] Yes [X] No		Prime Paint	[X] Yes [ ] No			
38	Steam Coil Air Heater	[ ] Yes [X] No		Final Paint	[X] Yes [ ] No			
39	Sootblowers With PV & F	[ ] Yes [X] No		Field Erection Labor	[ ] Yes [X] No			
40	Sootblower Wall Boxes Only	[ ] Yes [X] No		Erection Superintendent	[ ] Yes [X] No			
41	Stack	[X] Yes [ ] No		Startup Engineer	[X] Yes [ ] No	**PER DIEM**		
42	Stack Lining	[X] Yes [ ] No		Hydrostatic Test	[X] Yes [ ] No	**Shop**		
43	Platforms, Stairs & Ladders	[X] Yes [ ] No		Casing Pressure Test	[ ] Yes [ ] No	**NA**		
44	Safety Valves	[X] Yes [ ] No		Factrory AcceptanveTest (Shop)	[X] Yes [ ] No			
45	Water Column	[X] Yes [ ] No		Boilout And Dryout	[ ] Yes [X] No			
46	Gauge Glass	[X] Yes [ ] No		Domestic Freight	[ ] Yes [X] No			
47	Steam Gauge & Piping	[X] Yes [ ] No		Export Packing	[ ] Yes [X] No			
48	Others (Specify)			Ocean Freight	[ ] Yes [X] No			
49								
50								
51								
52								
53								

54		**FUELS**											
55		GAS				OIL N/A				TURBINE EXHAUST			
56		LHV	1000	BTU/SCF		LHV		BTU/LB		TEMP	950	F	
57		HHV		BTU/SCF		HHV		BTU/LB		LBS/HR	67933	each	
58		Press. @ Burner	30	PSIG		Press. @ Burner		PSIG			135,866	total	
59		Temp. @ Burner	40-80	°F		Temp. @ Burner		°F					
60		Mol. Weight	18			Viscosity		cP					
61						Atomizing		PSIG					
62													
63		Analysis		VOL. %		Analysis		WT %		Analysis			wt%
64										CO_2	4.02		
65										H_2O	7.09		
66										O_2	15.95		
67										N_2	71.45		
68										Ar	1.21		
69													
70													
71													
72		**MECHANICAL DESIGN**											
73													
74		Model No.		TCLLC-CF-200-50		Boiler Type		ADVECTION					
75		Boiler Surface		9649	FT^2								
76		Furnace Surface		628	FT^2								
77		Furnace Volume		393	FT^2								
78		Drums											
79		Steam:	ID	36	IN	Length		120	IN	Volume	70.686	ft^3	
80		Pressure	Max	200	PSIG	Operating		200	PSIG				
81		Thickness	Tubesheet	1	IN	Wrapper			IN				
82		Internals:											
83		Steam Purity			ppm								
84		Mud:	ID		IN	Length		IN		Volume		ft^3	
85		Furnace Tubes											
86		OD		2.375	IN	Wall Thickness	0.154	IN		C-C Spacing	3.75	IN	
87		Material		SA53B									
88		No.		706									
89		Econonmizer Tubes											
90		OD		2.375	IN	Wall Thickness	0.154	IN		C-C Spacing	6	IN	
91		Material		SA53B									
92		No.		128									
93		Type & Size Of Fins		Serrated 0.75" high, 0.040" thick, 6 fins/inch									
94		Screen Tubes											
95		OD		N/A	IN	Spacing		IN		No. Rows			
96		Superheater											
97		Type		N/A						Surface		m^2	
98		Tube Material				Diameter		IN		Spacing		IN	
99		Tube Spacer Material								Tubewall Thick.		IN	
100		Temperature Characteristic											
101		Temperature Control											
102		Others (Specify)											
103													
104													
105													
106													
107													

108		**MECHANICAL DESIGN (continued)**							
109		Burner							
110		Manufacturer	TCLLC	Model	TCLLC-CF-200-50	Size	50000		
111									
112		Heat Release: Normal	1.39E+07 BTU/HR	Maximum		4	Number of burners		
113		Size & Type Of Pilots	ONE PER BURNER TCLLC HS-1						
114									
115									
116									
117									
118									
119		Stack							
120		Number	1	Self-Supported					
121		Location	OVER ECONOMIZER						
122		Material	CS				Thickness	IN	
123		Top Inside Diameter	28" IN	Height	30 ft				
124		Lining Material	CERMIC FIBER						
125		Ductwork							
126		TEG Ducts:							
127		Material	CS						
128		Lining Material	CERMIC FIBER						
129									
130									
131									
132		Painting per:							
133		Specification:	TCLLC STANDARS			Total dry thickness:		3 MILS	
134		System no.:	High Heat	Color:	Black				
135		Total Unit Weight:	160,000 lb	Boiler complete with economizer and turbine exhaust ducts					
136		Platforms, Stairs, Ladders:							
137			Steam Drum Access						
138									
139									
140		Combustion Controls:							
141			FULL BMS TO NFPA with SELF-CHECKING UV SCANNERS						
142			Firng Rate Controls						
143									
144									
145		Boiler Controls:							
146			Boiler 3 Element Drum Control						
147			ASME Section 1 required valves						
148			Continuous and Manual Blowdown						
149			Chemical Injection						
150		Air Pollution Control Measures:							
151			Low Nox burners						
152									
153									
154									
155									
156		**REMARKS**							
157									
158									
159									
160									
161									

2. Proposed Equipment:

Item 1: Tulsa Combustion Advection Boiler
One (1) Advection Boiler, ASME Section 1 Design, complete with:

- Four fire tubes for turbine exhaust flow and for supplemental or ambient air firing

- Fire Tube boiler designed for 29,000 lb/hr of 200 psig saturated steam with only turbine exhaust flow or for supplemental and/or ambient air firing for up to 50,000 lb/hr of 200 psig saturated steam.
- 36” diameter by 20 ft-long steam drum with internal demister steam separator
- Economizer
- Boiler controls and safety instruments
- Four Tulsa Combustion fire tube burners for supplemental/ambient air firing.
- BMS and firing rate controls for the burners.

Item 2: Turbine Exhaust Ducting

The following items are included:

- Ducting from each turbine exhaust discharge to two of the first pass fire tubes. The ducting includes damper for isolation of each turbine. The ducting is designed with expansion joint to handle the duct thermal expansion without loading the turbine discharge. Ducting and boiler pressure drop are engineered to be below the maximum back pressure recommended by the turbine manufacturer.
- Turbine exhaust ducting to bypass the boiler and economizer. This ducting connects to a muffled flow section adjoining the economizer box. Dampers are provided to direct the exhaust flow to the bypass or to the burners. The bypass ducting with its muffler are designed to allow for the maximum turbine exhaust flow without exceeding the turbine manufacturer’s maximum.
- One stack for boiler operation or for turbine exhaust gas flow.
- Controls and instruments for ducting flow control and operation.

3. Drawings, Documents and Standards

The following customer deliverables are included in pricing:

	DRAWING/DATA	For Approval A	For Record B
1	Process Flow Diagram	A	B
2	Piping & Instrumentation Diagram	A	B
3	Engineering Drawings	A	B
4	System Plans & Elevations	A	B
5	Instrument List	A	B
6	General Assembly-Major Components	A	B
7	Foundation Plan & Anchor Bolt Layout	A	B
8	Inspection and Test Plan	A	B
9	Paint Procedures	A	B
10	General Description of System	A	B

11	Start-up/Checkout Procedures	A	B
12	Control Philosophy	A	B
13	Operating Manual	A	B
14	All Available Vendor Data		B
15	Specification Sheets	A	B

Pricing includes one submission, one review and return of documents incorporating all customer comments for submission A. Submission B will be for record only and not subject to review or modification within the original scope. Additional comments, format changes, additional documents are not included in the quoted price and will be supplied at the current professional rates and will be charged to the customer.

DEFINITIONS

1. Process Flow Diagram: A schematic representation of the process indicating state of the fluid at the input and output of each major component.
2. Piping and Instrumentation Diagram: A schematic representation of the process, based on the process flow diagram, indicating control, scope, functions, major interconnecting line sizes, and instrument locations (panel, field, etc.).
3. Engineering Drawings: Plan and Elevation with Member sizes and connection details
4. System Plans and Elevations: An orthographic depiction of the equipment indicating overall size of major components, plot area requirements, height and location of major components with respect to each other.
5. Instrument List: A list indicating type of instrument, tag number, location, and vendor.
6. General Assembly of Major Components: An orthographic depiction of each major component. This drawing will indicate overall dimensions, weight, connection locations, Nozzle legends, materials of construction and equipment features.
7. Foundation Plan and Anchor Bolt Layout: Orthographic depiction of foundation requirements including anchor bolt location and loading.
8. Inspection and Test Plan (ITP): Quality control document.
9. Paint Procedures: Document outlining surface preparation, paint materials and application methods.
10. General Description of the System: A short narrative describing the system.
11. Start-up/Checkout Procedures: A checklist utilized for initial system start-up and checkout.
12. Control Philosophy: A short narrative describing the control system.
13. Operating Manual: Checklists for normal start-up, shutdown, operation and emergency procedures.
14. All Available Vendor Data: All technical and maintenance data furnished to TCM by its component vendors.
15. Specification Sheets: The technical specifications that were used to purchase major components and instrumentation.

The following items are not included:

1. Calculations: TCM will perform calculations. They will not be subject to formal review.
2. Shop details/fabrication drawings
3. Foundation design
4. Wire and conduit schedules

The following items are to be provided by the customer unless otherwise specified in this proposal:

1. Shipment of all material from Point of Manufacture
2. Interconnecting piping, conduit and wire
3. Fuel and labor for cure of refractory (supervised by TCM)

CLARIFICATIONS: STANDARDS FOR PROPOSED EQUIPMENT
Unless otherwise specified in this Proposal, the following standards will apply to the proposed equipment:

1. WELDING: Per AWS Standards.
2. PIPING MATERIAL: A-106 or A-53B. Unless specifically called out in this proposal, piping 1.5" or smaller will be field-fabricated by others from materials supplied by TCM.
3. CARBON STEEL: A-36 or equal. A-500 for structural pipe 4. INSPECTION AND TESTING:
   a. The following items are not provided for:
      - Hydrostatic test
      - PMI
      - Hardness
      - Charpy tests
   b. The following tests will be performed:
      - X ray as required by ASME code calculations only Hydro Tests as required by ASME code or B31.3

4. Project Schedule

Drawings for Approval: 3 to 6 weeks after the receipt of an order
Normal Shipment Time: 24 to 30 weeks after the receipt of approved prints
Improved Delivery: Please advise your requirements.

5. Pricing and Commercial Terms

Budget Pricing
Tulsa Combustion Advection Boiler System as noted above has a budget price of

US$ 965,000.00

Field Services
Tulsa Combustion can support the commissioning of the system and operator training. Rates for these services are per the Tulsa Combustion Professional Rate Schedule in this Proposal.

Payment Schedule
Payments required by Tulsa Combustion to keep the project in a neutral cash flow will be due according the completion of milestones as follows:

- 20% of purchase order value at time of order and due immediately
- 25% of purchase order value upon submittal of drawings by Tulsa Combustion and due net 15 days
- 40% of purchase order value upon submittal of unpriced purchase order for major material and due net 15 days

- 10% of purchase order value upon completion of fabrication and due net 15 days
- 5% of purchase order value upon notification equipment is ready to ship or shipment whichever occurs first and due net 15 days

Terms of Sale

Commercial terms will be as mutually agreed. Progress payments are required to keep Tulsa Combustion cash neutral. Tulsa Combustion's standard Terms of Sale appear on the following pages.

Tulsa Combustion LLC
Terms of Sale

1. LIMITATION OF LIABILITY: UNDER NO CIRCUMSTANCES SHALL TULSA COMBUSTION BE RESPONSIBLE FOR LOSS OF USE/LOST PROFIT, INCIDENTAL, CONSEQUENTIAL, INDIRECT, OR SPECIAL DAMAGES, NOR SHALL TULSA COMBUSTION' TOTAL AGGREGATE LIABILITY UNDER THIS PURCHASE ORDER EXCEED THE VALUE OF THE PURCHASE ORDER.

2. WARRANTY: Tulsa Combustion warrants the equipment of its manufacture to be free from defects in material or workmanship for 18 months after shipment or 12 months after first operation, whichever occurs first. Vendor-supplied items will carry the standard vendors' warranties, which will be transferred to the end user. This warranty shall be for the repair or replacement, at Tulsa Combustion' option, of any defective parts, Ex-Works (EXW) point of manufacture. All costs for labor, equipment, and/or material costs for removal and/or reinstallation of parts, are expressly excluded from this warranty. ALL WARRANTIES SHALL BE VOIDED, AND BUYER AGREES TO INDEMNIFY AND HOLD TULSA COMBUSTION HARMLESS FROM, ANY CLAIM OF LIABILITY BY ANYONE, IF: (1) ANY REPAIRS, ALTERATIONS, MODIFICATIONS, OR DISASSEMBLIES ARE MADE WITHOUT TULSA COMBUSTION' APPROVAL OR IN VIOLATION OF THE OPERATING MANUAL INSTRUCTIONS; (2) ANY REPLACEMENT PARTS ARE USED ON THE EQUIPMENT OTHER THAN THOSE SUPPLIED OR APPROVED BY TULSA COMBUSTION; (3) THE EQUIPMENT IS UTILIZED FOR ANY PURPOSE OR IN ANY MANNER OTHER THAN AS STATED HEREIN; OR (4) THE EQUIPMENT IS OPERATED OTHER THAN IN STRICT CONFORMANCE WITH THE OPERATING MANUAL, BY QUALIFIED PERSONNEL. The above warranty is the sole and exclusive guarantee and warranty provided by Tulsa Combustion, and all other warranties or guarantees (express, implied, in law, or in equity, including warranties of merchantability and fitness for a particular purpose) are hereby disclaimed and excluded. Tulsa Combustion' total aggregate liability with regard to warranties shall not exceed the order amount. Consumables, such as, but not limited to, bulbs, gaskets, thermocouples, refractory, etc. are specifically excluded from the above warranty. Warranties of purchased equipment will be pass through and will carry the term and conditions under which Tulsa Combustion purchased them.

3. CHANGES: Tulsa Combustion is dedicated to meeting the requirements of the Buyer's specifications. Many small changes may significantly affect both Price and Schedule. A high level of communication regarding the impact of changes is required to update the Buyer regarding the project status. A design freeze will be placed on the project prior to release for fabrication and the Buyer will be notified of this date. If Buyer desires to make changes in quantities or Goods or Work, in specifications or drawings governing the Goods or the Work, or otherwise amend or modify the Purchase Order, it shall deliver a Change Order to Tulsa Combustion. If, within 21 days, Buyer and Tulsa Combustion are unable to reach an agreement regarding changes in Price or time of delivery, this Purchase Order shall remain in effect as originally issued. Unless otherwise agreed in writing by the Seller, the time spent by the parties to evaluate the need for a Change Order as set forth above shall be automatically added to the time for Seller's delivery of the Goods or performance of the Work, without the need for a signed Change Order to such effect. Any change made after the design freeze may incur disproportionate cost and schedule impacts.

4. PATENTS: Under no circumstances, shall a patent infringement indemnity granted by Tulsa Combustion, if any, apply to any equipment, or any part thereof, manufactured to Buyer's design or to changes in Tulsa Combustion' design requested by Buyer. As to such equipment or part, Tulsa Combustion assumes no liability whatsoever for patent infringement. Further, such an indemnity, if any, will be expressly conditioned upon Buyer's agreement to promptly

notify Tulsa Combustion of any claim or suit or proceeding in which such infringement by Buyer is alleged, and Buyer shall permit Tulsa Combustion to control completely the defense or compromise of any such claim, suit, or proceeding, and Buyer shall render such reasonable assistance in the defense thereof as Tulsa Combustion may require.

5. CANCELLATION: Any Purchase Order resulting from this proposal may be canceled by Buyer for its convenience by giving Tulsa Combustion written notice of such cancellation. Upon receipt of such notice, Tulsa Combustion shall cease all of its own activity (except that related to the cancellation) and terminate under the most reasonably favorable terms all related subcontracts as soon after such cancellation as reasonably practicable. Buyer shall pay the greater of (a) 25% of total Purchase Order value, or (b) Tulsa Combustion' costs incurred for this Order to the point of cancellation, plus costs incurred in the termination of related subcontracts (including reasonable cancellation charges actually paid by Tulsa Combustion to its sub suppliers and reasonable costs incurred in preserving and protecting materials, work in progress, and completed goods), plus a reasonable allowance for overhead and profit on such costs, whichever is greater. However, in no event shall the amounts payable to Tulsa Combustion for cancellation under this paragraph exceed the total price of this Order, less payments previously made by Buyer to Tulsa Combustion under this Order. Upon receipt of Buyer's payment by Tulsa Combustion, title to all materials, work in process, and completed goods shall vest in Buyer, as-is, where-is.

6. INFORMATION AND IMPROVEMENTS: Tulsa Combustion agrees to supply drawings, specifications, and other data (collectively, "Information") to Buyer as provided herein. Buyer shall have the limited right to use such Information internally for the purposes of evaluating the equipment design, and operating, maintaining, and repairing the equipment, and shall have the right to reproduce such Information for these limited purposes. Buyer shall not be obligated to return to Tulsa Combustion any such Information. However, neither Buyer nor any other party is granted any other rights by this Agreement, including but not limited to rights to the designs of, or license to manufacture or have manufactured, the equipment or anything else contained or shown in such Information. Technical information and all other work products emanating from or developed by Tulsa Combustion or its agents or employees in connection with the Purchase Order, including but not limited to inventions, discoveries, and improvements, patentable or unpatentable, shall be Tulsa Combustion' sole and exclusive property and may be used or transferred by Tulsa Combustion in any manner it finds appropriate without restriction.

7. INDEMNITY: Under no circumstances will Tulsa Combustion indemnify buyer or any other party for claims or losses, which are not caused by the negligence or willful misconduct of Tulsa Combustion.

8. ALTERNATE DISPUTE RESOLUTION: If a dispute arises concerning or related to this Agreement, it is the express intent of the parties hereto that they commit to enter into good faith efforts to resolve the dispute at a meeting or meetings in which officials from both parties who have authority to settle the dispute shall participate. The purpose of such negotiations will be an honest effort to allow each party an opportunity to determine if the dispute is resolvable prior to expensive and lengthy litigation. The parties shall have complete discretion as to what procedures shall be used and what agenda shall be discussed. All parties shall hold any such negotiation or series of negotiations as confidential, and the parties hereto do commit themselves that they shall not disclose either the existence of such proceedings or the content thereof. Any participation in or initiation of such discussions shall not be deemed to be an admission of liability, and no statement made or provided in or related to such negotiations shall be construed as a statement against interest or otherwise disclosed or used in any proceeding involving the parties.

   If the dispute cannot be resolved at such meeting or meetings of senior officials, the parties agree to submit the dispute to non-binding mediation by a mediator mutually selected by the

parties. If the parties are unable to agree upon a mediator, then the American Arbitration Association shall appoint the mediator. In any event, the mediation shall take place within thirty (30) days of the date a party gives the other party written notice of its desire to mediate the dispute.

The parties commit to commence these negotiations prior to litigation being filed (except for injunctive relief), but in no event shall they commence later than four (4) months after litigation is filed. If the party failing to participate in such meetings and mediation prior to litigation being filed is the party who filed the litigation, the party failing to participate in such meetings and mediation prior to litigation being filed shall be liable to the other party for the reasonable attorney fees and expenses of the other party for the reasonable attorney fees and expenses of the other party incurred in seeking a stay of the litigation pending the conclusion of such meetings and mediation.

6. Professional Rate Schedule

All rates are based on an 8 hr/day, Monday through Friday and exclude Holidays.

Principal Engineer: A principal engineer has a minimum of 30 years' experience and extensive testing, design, start-up and industry knowledge. The engineer will have been responsible for significant innovations and developments in their field. This rate applies to Roger Noble, Roger Witte, and Mike Keller.

Nominal Rate $200/hr

Senior Engineer or Senior Technician: A senior design engineer or technician has a minimum of 10 years experience including testing, design, start-up and trouble-shooting of process equipment and systems.

Nominal Rate $150/hr

Engineer or Technician: An engineer or technician has a minimum of 5 years of experience including testing, design and start-up of combustion systems.

Nominal Rate $125/hr

Associate Engineer or Junior Technician: An associate engineer or junior technician has a minimum of 2 years of experience including testing, design and start-up.

Nominal Rate $75/hr

Drafting Supervisor or Senior Design Draftsman: A Senior Design draftsman or Supervisor who has 10 years design experience in the design of combustion systems.

Nominal Rate $200/hr

Associate Design Draftsman: An associate design draftsman has a minimum of 5 years experience in design of combustion systems.

Nominal Rate $80/ hr

Design Draftsman: An associate design draftsman has a minimum of 2 years experience in design of combustion systems.

Nominal Rate $70 / hr

Shop rates: Combination rate for Shop Supervision and Scheduling, QC, Lead Men, Welders, Fitters, Helpers, Electrical, Controls/ Instrumentation, Purchasing, Shipping and Receiving efforts including all welding consumables, tools , overheads and burdens

Nominal Rate $78

Third party Charges

Crane and other special equipment rentals, third party inspection, x-ray and testing etc., will be billed at cost plus 10%.

Above rates include normal and customary secretarial and administrative services, use of computers and normal copying and plotting services. Extraordinary administrative charges will be billed at direct cost plus 10%.

Weekend and overtime rates are billed at 1.5 times the above rates. Holidays are billed at 2 times the above rates.

Material Charges
All material necessary to complete the job will be billed at cost plus 10%.

Start-up and Commissioning Assistance
Consultants for assistance and advice during start-up and commissioning of equipment are provided on the following basis:

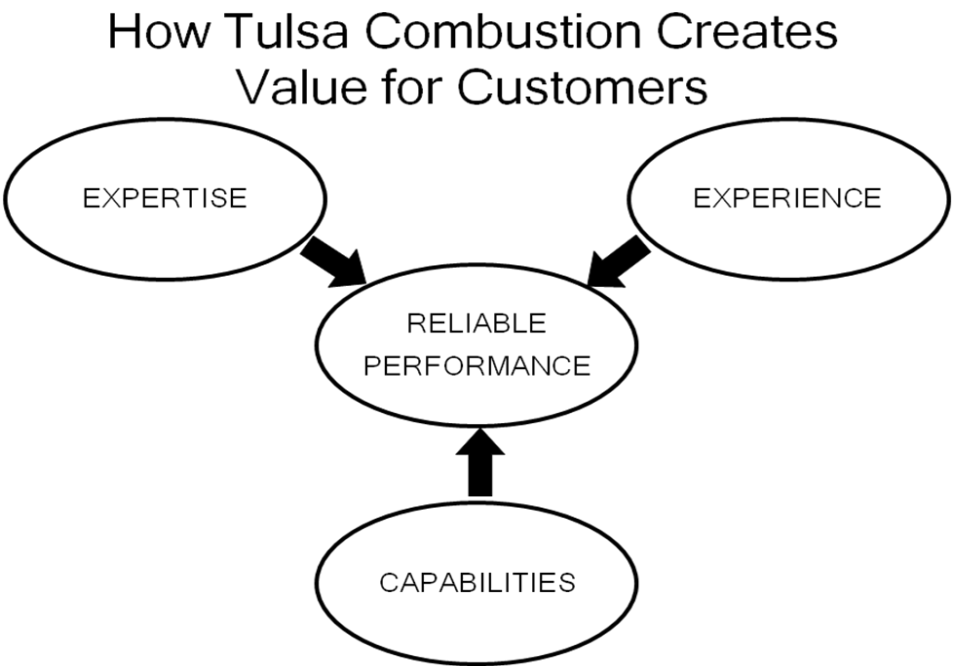
A. Within the United States and Canada: (Prices in U.S. Dollars)
   1. $1,600 per day for up to 10 hours per day or portion of a day. Saturdays and Sundays not included.
   2. $215 per hour each additional hour.
   3. Saturdays and Sundays: $1,900 per day up to 10 hours per day. $265 per each additional hour.

B. Outside the United States and Canada:
   4. $2,150 per day for up to 10 hours except Saturday and Sunday.
   5. $300 per hour for each additional hour.
   6. Saturdays and Sundays: $2,300 per day for up to 10 hours. $375 per hour for each additional hour.

C. Personnel act in an advisory role only. The above rates apply to work at site and travel time. Travel days will not be billed for overtime. All living and travel cost will be billed at actual cost. International travel will be on business class basis. Start-up and Commissioning rates for war-risk countries will be negotiated based on the level of exposure to possible injury or loss.

Invoicing
Invoices will reflect two weeks of charges, including time, materials and third party charges, and will be submitted BI-weekly for payment on receipt. The first week of the invoice will be actual charges and the second week will be estimated charges for the next week. The subsequent invoice will true up the estimated charges from the second week. All invoices will include copies of the invoices from our vendors as well as copies of time sheets of employees.

7. Tulsa Combustion's Qualifications



EXPERTISE

Technologies and Skills

- Process Efficiency Optimization
- Plant Economic Analysis
- Process Control Integrity
- Access to Industry Experts

Specialized Knowledge and Tools

- Knowledge of Industry Practices
- Manufacturing Engineering
- Project Management
- Field Installation

Reliable Systems

- Predictable Systems Performance
- Safe Project Execution
- Environmental Compliance
- Capital Cost Containment
- Operating Cost Minimization
- On-time Completion
- Superior Return on Investment

EXPERIENCE

History of Success

- Long-tenured Staff
- Staff Backgrounds in Industry
- Staff Roles in Industry
- Customer Collaboration

Successful Projects

- Reference Projects
- Global Reach
- Repeat Customer Engagements
- Organizational Learning

Predictable Investment

- Best-practice Design Strategies
- Optimal Technology Selection
- Competent Decision Support
- Proven Solutions
- Pragmatic Approach
- Flexible Scoping
- Regionalization
- Consistent High-level Support

CAPABILITIES

Resources

- Process & Controls Engineering
- Procurement & Logistics
- Project Management
- Strong Financial Position

Execution Capacity & Certification

- Internal Fabrication Facility
- Regional Partnerships
- Sea Port Access in Oklahoma
- Industry Standards Compliance

Smooth & Consistent Execution

- Reliable Project Completion
- Flexibility in Accommodating Customer Standards
- Single-source Simplicity
- Effective Functional Integration
- Superior Schedule Performance
- Appropriate Local Content
- Flat Organization for Ease of Decision-making and Access to Owners

HRSG

WATER WALL

RENTECH

Budget HRSG QUOTATION

FOR:

University of Montana

Proposal GTB-SPO-4974-DE-20

Boilers for people who know and care

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I. Budget Pricing Summary

Item	Description	Budget Price
Base Bid	One (1) HRSG system utilizing (2) OPRA GT's with the scope of supply as defined herein, ex-works Abilene, TX.	$1,772,000 USD
Option 1	One (1) HRSG system utilizing (1) Centaur 50 GT with the scope of supply as defined herein, ex-works Abilene, TX.	$1,484,000 USD
Option 2	Fresh Air Firing	$115,000 USD

A. Terms of Payment

For this order, progress payments in accordance with the following schedule will be required.

10% Upon receipt of purchase order
10% Upon submittal of approval drawings.
15% Upon receipt of tubes
15% Upon receipt of drum cylinders
20% Upon stabbing first tube
30% Upon shipment

Payment Terms: Net 30 days
Warranty – 12 months from acceptance, not to exceed 18 months from shipment.

B. Drawing Schedule

The following preliminary schedule is provided for your consideration.

Schedule for Drawing Submittals will be as follows:
Overall General Arrangement – 8 Weeks ARO
Trim and Piping Drawing – 8 Weeks ARO
Foundation Plan with Loads – 8 Weeks ARO
Process and Instrument Drawings – 8 Weeks ARO
Electrical / Instrumentation Drawings – 8 Weeks ARO
Return of approved drawings: 2 weeks ARO.

C. Shipment

Preliminary shipping schedule would be 38 weeks after receipt of a purchase order. In order to meet this schedule a pre-release on the boiler pressure parts would be required.

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II. Summary Information

A. General Design Conditions

The HRSG system described in this proposal has been designed for the following main parameter:

Combustion Turbine - Future

CT:	OPRA GT
CT (Option 1):	Centaur 50
CT Fuels:	Natural Gas

Steam Conditions:

Steam Pressure:	175 psig
Steam Temperature:	Saturated
Steam Flow:	50,000 lbs/hr
F.W. Temperature	228 °F

HRSG Design Pressures

Evaporator:	300 psig
Economizer:	400 psig

HRSG Design Codes

Evaporator:	ASME Section I
Economizer:	ASME Section I

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III. Equipment List

Item	Weight (Lbs.)	Description
Inlet Ductwork	10,000	Insulated ductwork from the gas turbine to the duct burner fabricated from 1/4" carbon steel outer casing with 14 gauge 409 SS inner liner.
Duct Burner	5,000	Low NOx windbox burner including FD fan, valve rack and controls.
Evaporator Module With Integral Steam Drum	120,000	The evaporator will be an O-type arranged for a single pass by the exhaust gasses with integral steam and mud drums. The evaporator will utilize membrane wall construction throughout the unit. The combustion chamber (furnace) is integral with the boiler structure and in formed from watercooled surfaces utilizing membrane wall construction. The membrane wall will be 2" tubes on 4" centers connected via ¼" membranes. The duct burner is mounted on the boiler front wall. There will be two (2) downcomers connecting the steam drum and the mud drums to provide an optimal circulation ratio. Fin material will be carbon steel with alloy steel utilized only as required by the design conditions. The membrane wall construction will be insulated with 4" of mineral fiber insulation and protected with a .022" thick pebble grain corrugated aluminum lagging.
Economizer	20,000	The finned tube economizer arranged for a single pass by the exhaust gases. Economizer headers will be constructed of carbon steel materials. Economizer assemblies will include high point vents and low point drains as required by final design.
Economizer Outlet Duct	3,000	Insulated ductwork from the economizer outlet to the main stack inlet fabricated from 1/4" carbon steel casing
Main Stack w/ Silencer	6,000	The 48" diameter x 50' total elevation exhaust stack, fabricated from 1/4" carbon steel with silencer
Controls	500	Free standing control panel with Allen-Bradley Compact Logix processor.
Force Draft Fan	5,000	The FD Fan will allow the HRSG to continue producing steam while the turbine is offline
Ladders / Platforms	10,200	Galvanized steel platforms along length of the steam drum, steam drum ends and main stack EPA ports.

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IV. Thermal Insulation and Casing Details

The following describes materials utilized in various portions of the heat recovery system (listed from hot face to cold face).

DUCTS AND CASING SUMMARY	Operating Temp (Hot Face)	Inner Liner		Insulation			Outer Casing		Operating Temp (Cold Face)
	Degree F	Thk	Material	Thk	Material	Density	Thk	Material	Degree F
		Gauge	Type	Inches	Type	lbs/cu ft	Inch	Type	
Inlet Ducting & Diverter Valve	1100	14 Gauge	409SS	6	Ceramic Fiber	8	1/4"	CS	140
Evaporator	29010	Membrane Wall		4	Mineral Fiber	8	0.040"	Pebble Grain Corrugated Aluminum	140
Economizer	460	10 gauge	CS	3	Mineral Fiber	8	30 Gauge	Corrugated Galvanized	140
Economizer Outlet Duct and Stack	310	1/4"	CS	Note 1	Note 1	Note 1	NA	NA	Note 1

NOTES:

1. Insulation and lagging for the round inlet ducting is to be provided and installed by others in the field.
2. All materials will be first quality products suitable for the surface and temperature where installed. All joints will be staggered with tight fitting butt joints. All ducts and casings are designed to withstand an internal pressure of 20" W.C. Outer surface temperature calculations are based on 100°F ambient in 1 mph wind.

The following small localized areas can be expected to exceed the average design surface temperature requirement**:**

- Large and small bore piping penetrations
- Test connections and wall sleeve penetrations
- Turbine exhaust expansion joint interface with the inlet duct.

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V. Domestic Field Service Rate Sheet

RENTECH Boiler Systems can provide services of an authorized service representative to inspect, startup, test and provide general instruction of plant personnel. The following rates will apply:

Category	Service Type	Standard Hourly Rate	Description
I	Mechanical Assistance	$200.00 + Expenses	Boiler Assembly & Erection Assistance
II	Boiler Start Up	$270.00 + Expenses	Boiler Start up, Boiler Maintenance, Boiler Operational Training
IV	Engineering Consultation	Varies	Call Field Service Manager
Other	Auxiliary Equipment Vendors	Varies	See note 6, below. Rates and terms for each vendor can be provided on request.

1. Rates are quoted on a time and material basis, and do not include travel or living expenses. The rates above are good thru December 31st, 2020 only.
2. Standard Hourly Rate is defined as time worked from Monday to Friday up to a maximum of 8 hours per day. Time beyond this is considered overtime and will be billed at 1-1/2 times the standard rate. Work performed during the hours of 6:00P.M through 6:00A.M will be billed at 1-1/2 times the standard rate. Any work performed on Saturdays will be billed at 1-1/2 times the standard rate. Any work performed on Sundays or Holidays will be billed at 2 times the standard hourly rate.
3. Travel time will be billed at standard hourly rates. Premium rates still apply to weekend and holiday travel time. International travel time is billed portal-to-portal. Days that include both Travel time and Work will be billed up to 8 hours at the applicable rate, and premium rates will apply to anything beyond 8 hours..
4. All travel and lodging expenses will be billed at cost plus 20% administration fee.
5. Meals will be billed at a per diem rate. No receipts will be submitted.
6. Service from auxiliary equipment vendors (burner, fan, turbine etc.) can be hired thru Rentech upon request. Such service will be billed at the vendor's current rate plus 20%, and will be according to the terms stipulated by that vendor.
7. Rentech may elect to use subcontractors for Boiler mechanical (Category I) or Boiler Startup (Category II). The rates listed above will still apply.
8. Minimum charge per day will be 8 hours. This applies to travel, onside, and standby hours.
9. Standby time is defined as readily available to report to the jobsite, such as standing by in the hotel, and is billed at the standard hourly rate. Standby will be charged for any non-working days if the technician has not been released to travel home, including weekends.
10. Timesheets will be provided by all Rentech Field Service Representatives, Subcontractors, and Sub-Vendors. Customer will monitor hours and days worked while onsite and will sign timesheets approving those hours before the technician is dismissed from the site.
11. All field service provided by or through Rentech Boiler Systems (including sub-vendors) is strictly Technical Field Assistance (Inspection, Advisory, Supervisory, or Consulting Service). Any tools, safety equipment other than basic PPE, equipment access, permits,

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work by qualified tradesmen, or any other physical labor are the responsibility of the General Contractor and/or Owner.

12. The General Contractor and/or Owner shall supply qualified operators at all times for any equipment, especially during startup and commissioning. Personnel dispatched by Rentech and its sub-vendors are not qualified or permitted to operate boilers or other equipment unassisted. Any direction by Rentech or its sub-vendors in the operation of the equipment is made in good faith, but any final operational decisions shall remain the responsibility of the qualified operators provided by others.
13. Rentech reserves the right to request payment in advance for International Field Service.
14. Time and expenses incurred obtaining visas and other required travel documentation is also billable at the applicable rate.
15. All international flights will be Business Class Fare or equivalent.
16. All Purchase Orders subject to review and acceptance by Rentech Boiler Systems, Inc.
17. Rentech Field Service is available on a worldwide basis, except for areas covered by a US State Department Travel Warning and subject to technician availability.
18. "Rentech Technical Assistance Terms and Conditions" apply to all Field Service work contracted through Rentech Boiler Systems, Inc

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A. RENTECH BOILER SYSTEMS, INC. STANDARD TECHNICAL ASSISTANCE TERMS AND CONDITIONS

All Technical Assistance provided by RENTECH Boiler Systems, Inc. (the "Seller") are based upon and conditioned upon the following terms and conditions. No provision, printed or otherwise, contained in any order, acceptance, confirmation or acknowledgment which is inconsistent with, different from or in addition to these Standard Terms and Conditions of Sale is accepted by Seller, unless specifically agreed to in writing by Seller. No order for or changes to any terms or scope of an order for the Seller's Technical Assistance ("Service") shall be binding until accepted in writing by the Seller at its home office at Abilene, Texas.

1. **QUOTATIONS.** Seller's quotations are valid for thirty (30) days from the date of the quotation unless otherwise stated. The latest quotation supersedes all previous quotations or correspondence concerning the transaction. If Service is performed on an hourly basis then the most current Rate Sheet will apply.

2. PRICE. Rates are valid for thirty days from date of initial dispatch of the Service technician. Thereafter rates may be changed by Seller with one week advance written notice.

3. PAYMENT. Unless otherwise stated in writing by Seller, payment of all invoices shall be net 30 days. To the extent permitted by applicable laws, Buyer shall pay on demand, as a late charge, an amount equal to 1.5% per month of each payment which remains overdue or the maximum rate allowed by applicable law. Buyer's failure to make payment when due shall be a material breach of the order and these terms and conditions. The Seller, at its sole option, and without incurring any liability, may suspend its performance until such time as the overdue payment is made or Seller is provided assurances, adequate in Seller's opinion, that the payment shall be promptly made. Payments due hereunder shall in no event be subject to set-off with any other order or business arrangement. Waivers of lien by Seller shall be contingent upon Seller receiving in full all payments due hereunder.

4. **WARRANTY** All Service shall be performed by seller in a workman like manner, consistent typical industry practices. If within 90 days of the performance of service, any service that is found to be deficient, the Seller will correct the deficiency. There are no other warranties, express or implied, except as expressly stated herein. Seller extends no implied warranty of merchantability or fitness for a particular purpose. The seller shall not be responsible for Goods and Services furnished by the Buyer or other third parties, or the costs thereof. Buyer's remedies under this warranty are specifically limited to the correction of any deficient Services performed by Seller and are exclusive of all other remedies.

5. **OBLIGATIONS OF BUYER**. Services rendered by Seller, whether with or without charge, are only technical or advisory in nature and are merely incidental to the sale of any Equipment. When any such services are rendered, Buyer will retain full responsibility for and full control, custody and supervision of the Equipment and the installation, selection of material therefore, use or operation there of, and a representative of Buyer shall be present with full authority to direct operations. If Seller furnishes technical or other advice to Buyer, whether or not at Buyer's request, with respect to Buyer's process or equipment, such advice shall be made in good faith, and Buyer assumes all risk of such advice and the results thereof. Buyer shall provide for free and safe access to the worksite and equipment.

6. **LIMITATION OF LIABILITY**. SELLER'S LIABILITY IS LIMITED TO THE PRICE ALLOCABLE TO THE SERVICE DETERMINED DEFECTIVE, AND IN NO EVENT WILL SELLER'S CUMULATIVE LIABILITY BE IN EXCESS OF THE TOTAL PRICE OF SERVICE, WHETHER ARISING UNDER WARRANTY, CONTRACT, NEGLIGENCE, STRICT LIABILITY, INDEMNIFICATION, OR ANY OTHER CAUSE OR COMBINATION OF CAUSES WHATSOEVER. SELLER AND BUYER WILL NOT BE LIABLE FOR ANY SPECIAL, INDIRECT, INCIDENTAL OR CONSEQUENTIAL DAMAGES OR LOST PROFIT WHETHER ARISING UNDER WARRANTY, CONTRACT, NEGLIGENCE, STRICT LIABILITY, INDEMNIFICATION, OR ANY OTHER CAUSE OR COMBINATION OF CAUSES WHATSOEVER. THIS LIMITATION SHALL APPLY NOTWITHSTANDING ANY FAILURE OF ESSENTIAL PURPOSE OF ANY LIMITED REMEDY. BUYER'S REMEDIES ARE SPECIFICALLY LIMITED TO THE REPAIR OR REPLACEMENT OF THE DEFECTIVE SERVICE AND ARE EXCLUSIVE OF ALL OTHER REMEDIES. SHOULD THESE REMEDIES BE FOUND INADEQUATE OR TO HAVE FAILED THEIR ESSENTIAL PURPOSE FOR ANY REASON WHATSOEVER, BUYER AGREES THAT RETURN OF THE FULL SALES ORDER PRICE TO IT BY SELLER SHALL PREVENT THE REMEDIES FROM FAILING THEIR ESSENTIAL PURPOSE AND SHALL BE CONSIDERED BY BUYER AS A FAIR AND ADEQUATE REMEDY.

7. **EQUIPMENT SALE**. It is expressly understood that any Equipment furnished by Seller will be addressed in a separate written agreement between the parties. In no event will any such Equipment provided by Seller constitute a waiver by Seller of any of these terms and conditions or affect or expand Seller's obligations under these terms and conditions, this order or any other contractual arrangement.

8. **DURATION**. If, at the request of the Buyer, the service personnel are required to remain on site in excess of five days beyond the original schedule, Seller, at its option, may replace the service personnel with a service personnel of like

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qualifications and all cost associated with such a replacement will be to the Buyer's account.

9. **INDEMNITY** Seller shall, at its own cost and expense and to the fullest extent allowed by applicable laws, subject to the limit on Seller's liability, defend, indemnify and hold harmless Purchaser, its parent, affiliates, subsidiaries, officers, directors, employees and agents, and their successors and assigns against all damages, losses, costs, claims, strict liability claims, liens, encumbrances, liabilities, and expenses (including attorneys' fees), as and to the extent arising out of or resulting from the negligent acts or omissions of Seller. Purchaser shall, at its own cost and expense and to the fullest extent allowed by applicable laws, subject to the limits on Purchaser's liability, defend, indemnify and hold harmless Seller, its parent, affiliates, subsidiaries, officers, directors, employees and agents, and their successors and assigns, against all damages, losses, costs, claims, strict liability claims, liens, encumbrances, liabilities, and expenses (including attorneys' fees), as and to the extent arising out of or resulting from the negligent acts or omissions of Purchaser. All liability, losses, damages, costs or expenses resulting from personal injury, including death, loss of or physical damage to property, caused by the joint or concurring acts of Purchaser and Seller, and their respective officers, directors, employees or agents, shall be borne by Purchaser and Seller to the extent each is determined negligent either by agreement of the parties or by a court of competent jurisdiction. The obligations of the parties under this paragraph shall survive the expiration or other termination of this agreement.

10. **SEVERABILITY**. Invalidity of any of these terms and conditions will not affect the validity of any other provision and the remaining provisions will remain in full force and effect.

11. **WAIVER**. Failure to enforce any of these terms and conditions in a particular instance will not constitute a waiver of, or preclude subsequent enforcement of, any of these provisions.

12. **APPLICABLE LAW**. These terms and conditions, this order and the legal relations of the parties shall be determined in accordance with the laws of the State of Texas. The parties consent and will submit to the jurisdiction of the courts of, and of the federal courts seated in, the State of Texas with respect to disputes relating to the order.

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VI. ASME WATER QUALITY

Suggested Water Chemistry Limits
Industrial Watertube, High Duty,
Primary Fuel Fired, Drum Type

Makeup water percentage: Up to 100% of feedwater
Conditions: Includes superheater, turbine drives, or process restriction on steam purity
Saturated steam purity target: See tabulated values below.

Drum Operating Pressure (1) (11)	Psig 0-300 (MPa) (0-2.07)	301-450 (2.08-3.10)	451-600 (3.11-4.14)	601-750 (4.15-5.17)	751-900 (5.18-6.21)	901-1000 (6.22-6.89)	1001-1500 (6.90-10.34)	1501-2000 (10.35-13.79)
Feedwater (7)								
Dissolved oxygen ppm (mg/l)O2 - measured before chemical oxygen scavenger addition (8)	< 0.007	< 0.007	< 0.007	< 0.007	< 0.007	< 0.007	< 0.007	< 0.007
Total iron ppm (mg/l) Fe	< 0.1	< 0.05	< 0.03	< 0.025	< 0.02	< 0.02	< 0.01	< 0.01
Total copper ppm (mg/l) Cu	< 0.05	< 0.025	< 0.02	< 0.02	< 0.015	< 0.01	< 0.01	< 0.01
Total hardness ppm (mg/l)*	< 0.3	< 0.3	< 0.2	< 0.2	< 0.1	< 0.05	ND	ND
pH @ 250C	8.3-10.0	8.3-10.0	8.3-10.0	8.3-10.0	8.3-10.0	8.8-9.6	8.8-9.6	8.8-9.6
Chemicals for preboiler system protection	NS	NS	NS	NS	NS	VAM	VAM	VAM
Nonvolatile TOC ppm (mg/l) C (6)	< 1	< 1	< 0.5	< 0.5	< 0.5	< 0.2	< 0.2	< 0.2
Oily matter ppm (mg/l)	< 1	< 1	< 0.5	< 0.5	< 0.5	< 0.2	< 0.2	< 0.2
Boiler Water								
Silica ppm (mg/l)	< 150	< 90	< 40	< 30	< 20	< 8	< 2	< 1
Total alkalinity ppm (mg/l)*	< 700(3)	< 600(3)	< 500(3)	< 200(3)	< 150(3)	< 100(3)	< NS(4)	< NS(4)
Free OH alkalinity ppm (mg/l)* (2)	NS	NS	NS	NS	NS	NS	ND(4)	ND(4)
Specific conductance (12) µmhos/cm (µS/cm) 250C without neutralization	5400-1100(5)	4600-900(5)	3800-800(5)	1500-300(5)	1200-200(5)	100-200(5)	< 150	< 80
Total Dissolved Solids in Steam (9)								
TDS (maximum) ppm (mg/l)	1.0-0.2	1.0-0.2	1.0	0.2	0.5-0.1	0.5-0.1	0.1	0.1

* as CaCO3
NS = not specified
ND = not detectable
VAM = Use only volatile alkaline materials upstream of attemperation water source. (10)
Notes to Table:
(1) With local heat fluxes >1.5 x 105 Btu/hr/ft2 (>473.2 kW/m2), use values for at least the next higher pressure range.
(2) Minimum hydroxide alkalinity concentrations in boilers below 900 psig (6.21 MPa) must be individually specified by a qualified water treatment consultant with regard to silica solubility and other components of internal treatment. See section 6.6 of ASME code.
(3) Maximum total alkalinity consistent with acceptable steam purity. If necessary, should override conductance as blowdown control parameter. If makeup is demineralized quality water and boiler operates at less that 1000 psig (6.89 MPa) drum pressure, the boiler water conductance should be that in table for 100-1500 psig (6.9-10.34 MPa) range. In this case, the necessary continuous blowdown will usually keep these parameters below the tabulated maximum values. Alkalinity values in excess of 10% of specific conductance values may cause foaming.
(4) Not detectable in these cases refers to free sodium or potassium hydroxide alkalinity. Some small variable amount of total alkalinity will be present and measurable with the assumed congruent or coordinated phosphate-pH control or volatile treatment employed at these high pressure ranges.

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(5) Maximum values are often not achievable without exceeding maximum total alkalinity values, especially in boilers below 900 psig (6.21 MPa) with >20% makeup of water whose total alkalinity is >20% of TDS naturally or after pretreatment by lime-soda, or sodium cycle ion exchange softening. Actual permissible conductance values to achieve any desired steam purity must be established for each case by careful steam purity measurements. Relationship between conductance and steam purity is affected by too many variables to allow its reduction to a simple list of tabulated values.
(6) Nonvolatile TOC is that organic carbon not intentionally added as part of the water treatment regime. See Section 6.4 of ASME code.
(7) Boilers below 900 psig (6.21 MPa) with large furnaces, large steam release space, and internal chelant, polymer, and/or antifoam treatment can sometimes tolerate higher levels of feed water impurities than those in the table and still achieve adequate deposition control and steam purity. Removal of these impurities by external pretreatment is always a more positive solution. Alternatives must be evaluated as to practicality and economics in each individual case.
(8) Values in the table assume existence of a deaerator.
(9) Achievable steam purity depends on many variables, including boiler water total alkalinity and specific and specific conductance as well as design of boiler steam drums internals and operating conditions [(Note 5)]. Since boilers in this category require a relatively high degree of steam purity for protection of the superheaters and turbines, more stringent steam purity requirements such as process steam restrictions on individual chemical species or restrictions more stringent than 0.1 ppm (mg/l) TDS turbine steam purity must be addressed specifically.
(10) As a general rule, the requirements for attemperation spray water quality are the same as those for steam purity. In some cases boiler feed water is suitable; however, frequently additional purification is required. In all cases the spray water should be obtained from a source that is free of deposit forming and corrosive chemicals such as sodium hydroxide, sodium sulfite, sodium phosphate, iron, and copper. The suggested limits for spray water quality are < 30 ppb (µg/l) TDS maximum, < 10 ppb (µg/l) Na maximum, < 20 ppb (µg/l) SiO_2 maximum, and it should be essentially oxygen free.
(11) Low pressure boilers frequently use feed water that is suitable for use in higher pressure boilers. In these cases the boiler water chemistry limits should be based on the pressure range that is most consistent with the feed water quality. See Sections 1 and 6.2 of ASME code regarding blowdown.
(12) Conversion from ppm (mg/l) TDS values in the ABMA standards [12] used a factor of 0.65. See Section 6.7 of ASME code

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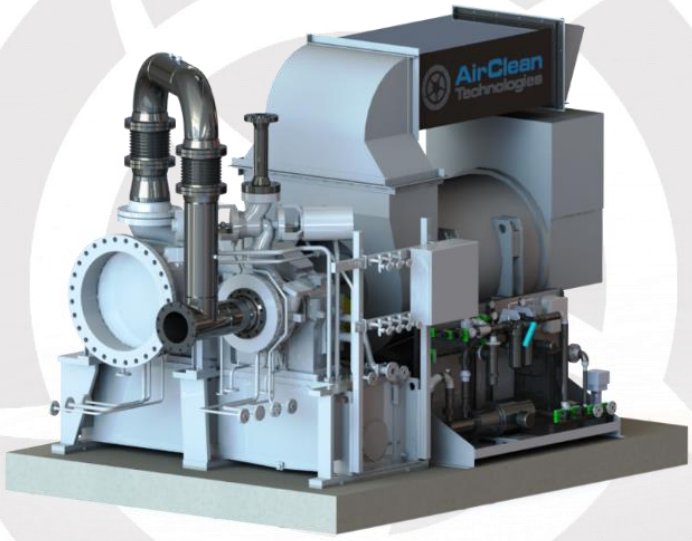
ACQ-16096-UMO
April 14, 2020

Extraction/Condensing Steam Turbine Generator and Condenser



Presented to: **McKinstry Mechanical**
Seattle WA 98134

Attn: Jeff Davis
c/o Gus Drake at Power Engineers

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1.0 INTRODUCTION

AirClean is a Seattle-based process engineering firm that specializes in modular industrial energy systems. We have extensive experience designing, fabricating, and installing steam turbine systems like the one proposed here. Your project is supported by engineers who are experts in industrial energy applications from concept to completion.

AirClean's Service Engineers perform full installation, commissioning and training.

Based on your projected steam conditions and the estimated utility and fuel costs we received, your project looks very promising. The simple payback for this turbine generator system is very attractive. It should be noted that many Universities are installing backpressure steam turbine generators to improve the overall steam cycle efficiency, and promote this to the students, administration and outside stakeholders. AirClean is currently working with Penn State University, University and the University of Iowa on similar projects. Note: These turbines are not critical to the University infrastructure. They are efficiency devices that improve the steam cycle, but can be bypassed should there be a turbine trip or any reason to take them off-line. The control systems are designed to allow seamless transition from turbine to PRV control.

AirClean fabrication team in our Seattle shop with one of our custom process skids

Thank you for the opportunity to present this proposal. If you have any questions, please reach out to us. This proposal has been customized for your application and can be modified in any way. If you would like to visit our facility to see our work and our process, we would be happy to have you visit.

Best regards,

Bill Hunter, PE
Principal Engineer
206-860-4930
bhunter@aircleanenergy.com

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2.0 TURBINE SELECTION

For your application, we have selected a Twin model dual pressure steam turbine. This unit has two separate turbine wheels which turn a centralized shaft which operates the generator. This unit has the advantage of being both highly efficient for its size and designed to accommodate the variable extraction steam required of a campus load.

Howden Twin Turbine		
Extraction Condensing Steam Turbines		
Stage #1		
Mass flow	50,000	lb/h
Inlet pressure	325	psig
Inlet temperature	429	°F
Extraction pressure	30	psig
Extraction temperature	275	°F
Stage #2		
Mass flow	20,000	lb/h
Inlet pressure	30	psig
Inlet temperature	275	°F
Exhaust pressure	2	psia
Exhaust temperature	120	°F
Generator Performance		
Outlet speed	1,800	RPM
Estimated power at terminals	**2,125**	**kWe**

This system includes:

- Howden twin turbine drive
- 2.5 MWe Generator
- Control panel with a complete PLC based turbine steam control scheme
- Quick acting inlet trip valve
- Bearing temperature monitoring
- Vibration monitoring for gearbox housing and generator bearings
- Skid mounted water-cooled forced lubrication system
- Turbines mounted on a structural steel base plate
- All skid piping and wiring brought to edge of the skid for a single point of connection

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thermodynamics

	HP				LP								
	p0	t0	h0	wetness before ST_1	p0	t0	h0	wetness before ST_2	p2	t2	h2	wetness after ST_1	wetness after ST_2
main data	340 psi	429.0 °F	2,804 kJ/kg	0.00 %	43.55 psi	274.3 °F	2,727.8 kJ/kg	0.00 %	1.2 psi	108.0 °F	2,362.3 kJ/kg	7.57 %	8.76 %
spring	340 psi	429.0 °F	2,804 kJ/kg	0.00 %	43.55 psi	274.3 °F	2,727.8 kJ/kg	0.00 %	1 psi	125.4 °F	2,593.4 kJ/kg	6.00 %	0.00 %
feb	340 psi	429.0 °F	2,804 kJ/kg	0.00 %	43.55 psi	274.3 °F	2,727.8 kJ/kg	0.00 %	1 psi	116.3 °F	2,583.7 kJ/kg	6.50 %	0.00 %
summer	340 psi	429.0 °F	2,804 kJ/kg	0.00 %	43.55 psi	274.3 °F	2,727.8 kJ/kg	0.00 %	1.5 psi	115.7 °F	2,381.6 kJ/kg	6.12 %	8.32 %
fall	340 psi	429.0 °F	2,804 kJ/kg	0.00 %	43.55 psi	274.3 °F	2,727.8 kJ/kg	0.00 %	1 psi	126.4 °F	2,594.4 kJ/kg	7.03 %	0.00 %
dec	340 psi	429.0 °F	2,804 kJ/kg	0.00 %	43.55 psi	274.3 °F	2,727.8 kJ/kg	0.00 %	1.2 psi	125.1 °F	2,592.9 kJ/kg	6.66 %	0.00 %
worst steam conditions	306 psi	419.2 °F	2,801.5 kJ/kg	0.00 %	43.55 psi	251.3 °F	2,725.4 kJ/kg	0.00 %	1.5 psi	115.7 °F	2,381.3 kJ/kg	7.17 %	8.33 %
best steam data	374 psi	479.4 °F	2,872.8 kJ/kg	0.00 %	43.55 psi	324.7 °F	2,786.5 kJ/kg	0.00 %	1 psi	101.8 °F	2,396.7 kJ/kg	5.47 %	7.04 %
max. steam data	374 psi	479.4 °F	2,872.8 kJ/kg	0.00 %	43.55 psi	324.7 °F	2,786.5 kJ/kg	0.00 %	1.5 psi	115.7 °F	2,428.1 kJ/kg	5.47 %	6.37 %
max. wetness	374 psi	438.1 °F	2,805.8 kJ/kg	0.00 %	43.55 psi	292.2 °F	2,748.6 kJ/kg	0.00 %	1 psi	101.8 °F	2,367.7 kJ/kg	8.00 %	8.24 %

The above table uses a bin type analysis to illustrate expected power output as the University steam demand changes, which is largely a function of ambient temperature. In the summer there is less campus load, so a larger portion of the 'unfired steam' from the gas turbine output goes to the turbine and fully loads the condensing turbine, increasing output.

A very similar 3 MW steam turbine generator installed in a small steel structure.

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3.0 DETAILED SYSTEM DESCRIPTION

MECHANICAL SYSTEM

The Twin turbine is manufactured by Howden in Frankenthal, Germany. The unit will be shipped to the AirClean fabrication facility for system and auxiliary integration. The turbine design includes two separate steam cases connected to one integral, two pinion parallel shaft gearbox with central bull wheel at the gear exit. This is a high-efficiency turbine design, optimized around the steam conditions for this project.

Twin Turbine – Designed for Saturated Steam

- Turbine A: Axial flown 400mm Curtis wheel
- Turbine B: Axial flown 600mm Curtis wheel
- Quick acting hydraulic trip and inlet control valve
- Carbon ring type end gland shaft seals
- Gear wheel speed pickup
- (4) drain valves
- Thermally insulated by mineral wool blankets
- Cyclone type inlet moisture removal, supplied loose

Turbine Piping Connections

- Inlet: 8” ANSI 600#
- Extraction: 10” ANSI 300#
- Exhaust: 32” ANSI 150#

Integral Gear Reducer

- Designed and manufactured in Howden workshop
- Qty (6) forced-oil lubricated hydrodynamic sleeve bearings
- Turbine wheels are mounted onto the pinion shafts by a self-centering Hirth-toothed coupling
- Resistance thermometer PT 100 on each gearbox bearing insert
- Low vibration, low noise design

Circulating Oil System

- Carbon steel reservoir
- 5 minutes of retention time
- Hydraulic rack with pressure/temperature gauges, overflow valves etc.
- Sight glass for oil level indication
- Water-cooled oil heat exchanger
- Duplex oil filter (filter mesh 10 µm) with changeover valve and fouling indicator
- Mechanically driven main oil pump (integrated into gearbox /shaft driven /100%)
- Electrically-driven auxiliary oil pump (electric driven/100%)

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ELECTRICAL SYSTEM

- 2,500 kW generator rating
- 12,470 Volts
- 3 Phase/ 60 Hz
- 0.9 PF
- 4 Poles (1,800 RPM)
- Frame Size TBD
- Protection/Cooling – IP54/TEWAC
- Insulation Class: Class F
- Enclosure: Totally enclosed water cooled
- Brushless, Permanent Magnet Excitation
- Forced Oil Bearing lubrication (sleeve type)
- 2 Bearing RTD's
- Winding RTD's (2/phase)
- 3 Current Transformers
- Expected Noise ~ 85 dB(A)
- Space Heaters

CONTROL SYSTEM

The Turbine Generator Control System incorporates turbine control, auto synchronizing, steam pressure control, optional temperature and pressure monitoring and generator/intertie protection into a single fully-integrated cogeneration control system designed to operate in parallel with utility power. The controls incorporate all the features needed to operate a cogeneration system that maximizes efficiency and is easy to use.

Control system features

- Automatic controlled start with manual override
- Automatic synchronizing
- Exhaust pressure control, with power output limiting option available
- Electronic overspeed protection to backup mechanical protection on the turbine
- Turbine generator monitoring including alarming, tripping and data display on the HMI
- Turbine speed
- Inlet or exhaust pressure
- Revenue grade electrical metering (V, A, kW, kWh, kVAR, Hz, PF)
- Turbine trip relay, de-energize to trip, sequential trip
- Overspeed trip
- Low lube oil pressure
- High lube oil temperature
- High exhaust pressure
- Customer trips
- Emergency stop pushbuttons

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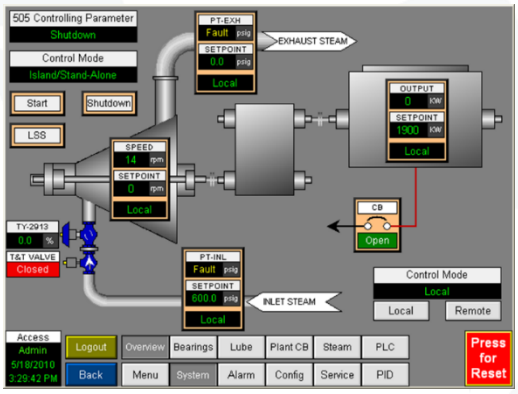
Control System Enclosure
Heavy duty free-standing welded NEMA 12 enclosure with gasketed door and 3-point latch, and interior light and service receptacle. Dimensions 72H x 36W x 24D

Human Machine Interface (HMI)
9-inch color touchscreen HMI in main panel. The following screens are typical.
Directory screen and other screens required for HMI navigation
System overview screen showing system status, control mode and a summary of operating parameters

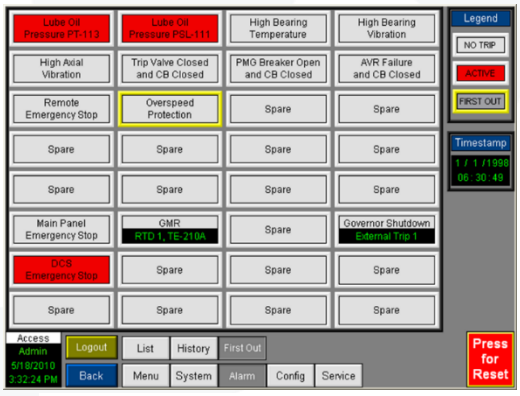
- Startup screen
- Shutdown screen
- Overspeed test
- Screens for set points for control and monitoring parameters
- Service screens for PID tuning with real time trending
- Alarms and shutdowns

Auto Synchronizer
Fully automatic synchronizing with Backup manual synchronizing including display of generator and bus frequency and voltage and synchroscope display. Both automatic and manual synchronizing are supervised by the synch check relay in the generator protection relay.

Generator Protection Relay
Schweitzer Engineering Laboratories SEL 700G utility-grade generator protection relay for complete electrical system protection including sync check (25), voltage (27/59), reverse power (32), loss of field (40), current imbalance (46), voltage controlled time overcurrent (51V), loss of PT fuse (60FL) frequency (81O/U) and many other functions. *NOTE: GPR settings not included.*



Overview Screen



First Out Screen

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4.0 CONDENSER

A standard shell and tube surface condenser will be provided to support steam flow supplied by the CHP plant greater than the campus demand. The steam conditions are estimated, and incorporated into the AirClean design, as shown below:

Shell and Tube Condenser		
Mass flow of steam	35,600	lb/h
Condensing pressure	1.4	psia
Makeup flow rate	32	gpm
Cooling tower fan horsepower	60	BHP
Recirculation pump horsepower	40	BHP

The surface condenser includes the following design features and auxiliaries:

- NCG removal system.
- Skid mounted recirculation pump.
- Qty (2) 12' diameter 30 HP Fans. (To be reviewed and verified)
- Condenser atmospheric relief valve.
- Shell pressure transmitter and pressure gauge.
- Hotwell condensate temperature gauge and RTD.

Note: The condenser is not designed to be a dump condenser. Further review of the system design and operation is needed to determine where steam is routed during a steam turbine generator trip.

The steam exhaust pipe from the steam turbine generator exit to the condenser is included in this scope, including the pressure-balanced expansion joints. The condenser, pressure reducing valves and the enclosure can all be supplied prior to the steam turbine generator delivery, according to the needs of the project. AirClean will work with the project team to optimize site installation.

Note: The STG is the long-lead item and would be placed in the enclosure/building once available. The condenser/cooling tower could be installed before delivery of the STG.

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5.0 PRICE SUMMARY

Design and Supply Only **$1,900,000**
Steam Turbine Generator and Condenser

Adder: Commissioning and Startup **$45,000**

6.0 PAYMENT TERMS AND SHIPPING

Payment Terms	Equipment Only	Weeks ARO/Release
Purchase Order*	10%	0
Mechanical drawing submittal	15%	8-10
Control system drawing submittal	15%	12-14
50% Manufacturing	30%	24-26
Upon STG shipment	20%	46-50
Upon successful start-up or 120 days from shipment	10%	77-79

** The steam turbine is a long lead time item and will be released for fabrication upon receipt of order. If client requires approval drawings prior to release to manufacturing the lead time for fabrication and delivery will be extended.*

All invoices submitted are payable net 30 days. Factory inspections are permitted, with prior schedule.

Shipping: STG Skid - FOB Seattle, WA
Control Panels – FOB Greenfield, MA
Condenser / Cooling tower – FOB manufacturer's facility
Condensate and circulating water pump skids: - FOB Seattle, WA

Freight Estimate: $85,750 (billed at cost)

Validity: 30 days

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7.0 EXCLUSIONS (EQUIPMENT ONLY)

If the deduct is selected, and chooses to supply the PRV station and enclosure, then the following items are specifically excluded, although this is not a comprehensive list:

General

- Receiving and offloading turbine generator skid and associated equipment
- Spare parts (will be offered as options later)
- Taxes, fees, and permits other than duties associated with shipping the turbine from Germany

Piping

- All steam piping outside of the equipment
- All condensate and leak-off piping outside of the equipment
- All cooling water piping outside of the equipment
- All plant and instrument air piping / tubing outside of the equipment
- Supply of safety relief valves needed for over-pressure protection
- Interconnecting water, steam, and condensate piping between major AirClean supplied equipment
- Miscellaneous drains, vents, and steam traps
- Cooling water condenser bypass line and associated valves
- Isolation valves at major equipment connections (e.g., cooling water connection to condenser, steam connection to turbine inlet, etc.)

Electrical

- All the connecting cables between the supplied equipment
- Lighting and communication system
- Motor control center for all electric motors and heaters
- Uninterruptible power supply (UPS) for the Turbine Control System
- Power transformer
- Settings for AirClean supplied generator protection relay
- Testing of generator protection relay

Instrumentation

- Cables for instruments between the skid mounted junction box and the local control room
- Installation of loose supplied field instruments

Engineering

- Machinery foundation design
- Piping design
- Power distribution system design

Installation & Startup

- Machinery and auxiliary equipment installation, piping installation
- Initial lube oil fill, and flushing (as necessary)
- Materials and installation of cooling tower concrete water basin (design by AirClean)

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8.0 STG COMMISSIONING

AirClean's primary responsibility and scope during commissioning is the mechanical, instrumentation, and control checkout of the supplied STG skid and associated equipment. AirClean will assist where possible with electrical phasing verification and checkout. Tasks listed below provide a general framework for commissioning duties and may not necessarily be completed in the order listed.

Tasks Completed by Customer (Equipment Only Contract)

- Complete installation of turbine skid and customer steam piping to allow pipe steam blows.
- Perform initial steam blows per pipe blow down procedure in NEMA SM-24, including discharge piping for back pressure turbines. Completed prior to AirClean final commissioning trip.
- Verify generator/breaker electrical phasing with AirClean assistance during pre-startup or commissioning trip.
- Supply generator protection relay settings and perform static testing prior to AirClean final commissioning trip. AirClean can upload supplied settings during pre-startup trip.

AirClean Pre-Startup Site Trip

- Verify skid installation, piping installation, and exhaust relief valve settings.
- Perform coupling cold alignment and pipe strain check.
- Inspect and clean turbine bearings/shaft, flush bearing housings and fill with oil**.**
- Manually verify trip mechanism and safety devices in good condition.
- Verify STG control wiring, inspect pneumatic and cooling water piping and connections.
- Stroke turbine throttle actuator with hand held signal generator and verify stroke length.
- Upload customer supplied Generator Protection Relay settings.

AirClean Final Commissioning Trip

- Electrical/wiring checkout of turbine control panel, breaker, and related electrical equipment.
- Momentarily close breaker to "bump" generator and confirm rotation.
- Verify all piping and safety devices, warm up turbine, conduct over speed and trip testing.
- Run turbine to rated speed and check all instrument values and inspect piping, valves, coupling, bearings, etc. for noise, leaks. Run for min 2 hours and check hot alignment.
- Close generator breaker and record/confirm electrical output and readings.
- Tune turbine throttle valve PID loop and hand valve open and closure.

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9.0 O&M DISCUSSION

Operation of a steam turbine generator is not complicated. AirClean has included a steam strainer and moisture separator at the inlet of the turbine, assuring high quality steam to the turbine. This reduces concern of erosion over time. Without steam erosion, the turbine wheels have an almost infinite life. Indeed, many operate for many decades without replacement. However, as with all rotating equipment, bearings and seals need to be inspected and replaced, and the lube oil needs to be maintained. Below is a list of expected maintenance:

A. Daily: 5 minutes (By Client)
   1. Walk by inspection once per shift to visually inspect for external damage and leaks.
   2. Check vibration/noise levels, temperatures and pressures against previously established normal operating conditions
   3. Check for oil leaks and proper oil levels
   4. Check control air pressure and coalescent filter (drain if necessary)
   5. Observe the amount of steam existing leak off drains. Excessive steam may be a sign of damaged or worn seals.

B. Monthly: 60 minutes (By client)
   1. Check oil/grease bearings and reservoirs and add oil/grease as necessary.
   2. Change air and oil filters as necessary.
   3. Check all air breathers (oil reservoir, bearing covers, etc.)
   4. If the system can be stopped, check the trip system and trip valve functionality
   5. Check foundation bolts for tightness
   6. Record, and review, vibration levels against historical data.
   7. Perform test of all overspeed devices.

C. Yearly: 30-40 hours (By AirClean or approved/trained client technician)
   1. Remove and clean steam strainers and separator.
      Note these are located both in the high pressure inlet piping and turbine inlet.
   2. Inspect, clean and flush turbine and gear bearing housings as needed. Bearings should be checked for wear and clearance. Check shaft end play. Replace parts as necessary.
   3. Check gear shafts end play.
   4. Clean generator thoroughly and check air gap clearance
   5. Perform megger test on generator
   6. Check generator shaft endplay
   7. Check coupling alignment and lubrication. Correct alignment as necessary
   8. Check foundation and bolting
   9. Calibrate pressure and temperature transmitters and test pressure switches
   10. Check tuning parameters and control loops for response and stability
   11. Measure vibration levels with system back in operation
   12. Inspect switch gear components

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D. Three year inspection and overhaul: 60- 80 Man hours (By AirClean or approved/trained client technician)
    1. Includes all yearly work plus the items listed below:
    2. Check operation and calibration of governor valve
    1. If valve performance requires review, dissemble and check components for wear. Replace worn parts as necessary including valve steam seals and packing.
    3. Check trip valve for operation and closing time.
    1. If valve performance requires review, dissemble and check components for wear. Replace worn parts as necessary including valve steam seals and packing.
    4. Carbon ring gland seals should be inspected, and replaced as necessary based on review of steam blow by.

E. 12 year Safety Inspection: 100-120 hours (By AirClean or Howden Approved Technician)
    1. Perform required 3 year service and provide additional safety inspections outlined below.
    2. Inspections for structural integrity of:
        a. Inlet trip and throttle and nozzle group control valves
        b. Turbine casing
        c. Turbine rotors
        d. Rotor shafts and shaft connections

A standard Extended Service Agreement (ESA) is available where AirClean will provide the above services, except A and B which are expected to be performed by the end-user (which requires little product specific expertise). AirClean will follow up with the ESA later should be interested.

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10.0 TERMS AND CONDITIONS

AGREEMENT: This Agreement is between customer ("**Buyer**") and AirClean Technologies, Inc. ("**Seller**").

TERMS: Buyer will make full payment thirty (30) days from date of invoice, unless otherwise specified in the quotation document. The terms listed are general terms for the sale of goods only. (See *FREIGHT* for payment of freight invoices).

LATE PAYMENT CHARGES: A 1-1/2 % monthly service charge will be added to Buyer's account on invoices not paid within net thirty (30) day terms.

PRICES: All prices are F.O.B. Seller's plant and do not include any applicable Federal, State, Local Sales or Excise Taxes or other surcharges unless specifically indicated.

PAYMENTS: remittances must be made to:
AIRCLEAN TECHNOLOGIES, Incorporated / PO Box 46017 / Seattle WA 98126 USA
If the financial condition or credit of the Buyer at any time shall, in the judgment of the Seller, not warrant shipment of products ordered, the Seller may at its option require full payment prior to shipment or refuse to ship.

DESIGN: The Seller reserves the right to make design improvements without notice.

CANCELLATION: The Buyer may cancel upon the written consent of the Seller, but the Seller is entitled to reasonable cancellation charges including but not limited to labor expended, materials obtained or expended, reasonable overhead and profit.

SPECIAL AND CONSEQUENTIAL DAMAGES: In no event shall the Seller be liable for any consequential or special damages arising from any breach of these terms.

SHIPMENT AND DELIVERY: Shipment dates are based upon the Seller's best estimate only. The Seller will exercise its best efforts to ship on schedule, but shall not be liable for any damages or loss caused by any delay in delivery, including but not limited to delay caused by strikes, floods, fires, accidents, inability to obtain sufficient materials or products from suppliers, inability to obtain sufficient labor, or any legislative, administrative or exclusive law, order, or requisition of the Federal Government or any State or Municipal Government or any subdivision, department or office thereof. All shipments are F.O.B. Seller's plant. The responsibility of goods lost or damaged in transit rests with the Buyer and any recourse you may have rests with the carrier. Seller will make reasonable efforts to use reputable carriers with adequate insurance, but is not responsible for any loss incurred in transit. The Buyer must file any claims with the carrier. Damage to the equipment in transit is not just cause for delayed or partial payment of Seller's invoice. Buyer may contract with **AIRCLEAN TECHNOLOGIES, INC. Service Department** which can provide qualified supervisory personnel to assist installation of the products supplied.

MODIFICATION OR ADDITION OF TERMS AND CONDITIONS: No modification, addition to, or waiver, of any of the terms and conditions stated herein shall be binding upon the Seller except by written consent of an authorized officer of the Seller.

ACCEPTANCE: Any order by the Buyer placed pursuant to a quotation is subject to written acceptance and acknowledgement by Seller in Seattle, WA. By placing an order, Buyer will be deemed to have assented to the terms & conditions stated herein.

CLAIMS: All claims for corrections or deductions must be made in writing within ten (10) days after delivery of goods. If no claim is made within ten (10) days, Buyer will be deemed to have accepted all goods.

FREIGHT: Charges will be collect or prepaid third party billing.

WARRANTY: Seller warrants the equipment of its manufacture against defects in workmanship (excluding corrosion and/or erosion related problems) and against defects in structural design for a period of one (1) year from the date of installation or eighteen (18) months from date of shipment whichever comes first. This warranty covers the product except for the turbines, generators, gearboxes, actuators, etc., which are not manufactured by Seller**.** Seller will pass on to Buyer the manufacturer's guarantee on such component equipment, if any. Seller will repair or replace (at Seller's option) F.O.B. point of original shipment, or refund the purchase price of any parts proven to be faulty material or workmanship. The maximum liability under this warranty is the purchase price of the defective part. This warranty does not cover trucking, handling, storage, or installation damage at the jobsite or problems created through improper or incorrect installation/operation.

WARRANTY CONDITIONS: This warranty is effective only if the following conditions are satisfied: (1) System conditions do not exceed the maximum System operating conditions; (2) The unit has never been subject to conditions or used other than those for which it has been designed; (3) The unit has not been in contact with abrasive or corrosive media or subjected to electrolytic action; (4) The unit has not been modified or remodeled by others after shipment.

WARRANTY DISCLAIMER: EXCEPT FOR THE LIMITED WARRANTY PROVIDED HEREIN, SELLER MAKES NO WARRANTIES (EXPRESS OR IMPLIED) WITH RESPECT TO THE PRODUCTS AND DISCLAIMS ALL IMPLIED WARRANTIES, INCLUDING FOR MERCHANTABILITY, FITNESS FOR A PARTICULAR PURPOSE, TITLE AND NON-INFRINGEMENT. This warranty is expressly in lieu of all other warranties, either expressed or implied unless agreed to in writing by an authorized officer of the Seller.

GOVERNING LAW; VENUE AND JURISDICTION: This Agreement will be governed by the laws of the State of Washington, without reference to its rules governing choice of law. The parties hereby irrevocably consent to the exclusive jurisdiction and venue of the federal and state courts located at King County, Washington with respect to any claims, suits or proceedings arising out of or in connection with this Agreement.

Kelvion B.V.
Product Director J. A Gende
Sales department

Tel. (717) 487-8194
Fax fax
Joe.Gende@Kelvion.com
20/10/2016

QUOTATION

Kelvion INC., 100 GEA Drive, US, PA 17406, YORK
University of Montana

Montana
UNITED STATES

Att.
Tel.:
Fax:
E-mail:
Mobile:

Quotation cooling tower

Your reference :
Our project number : **112247**

Dear Mr./Mrs. ,

As an answer to your enquiry referenced above we are pleased to submit our offer for the required cooling tower.

Based on the basic cooling tower design data as specified in your enquiry we selected a cooling tower from our counter flow model range.

Scope of supply

1 Cell **Polacel Type CMDR19 300-DM-120-PS/3, make Kelvion B.V.**

The cooling tower consists of the following main parts:

- Durable cooling tower casing consisting of hot moulded FRP side panels fitted in a stainless steel frame.
- All bolts, nuts for assembly out of stainless steel.
- Inspection panel for access in the cooling tower.
- Aerodynamic shaped FRP impeller casing – transition piece to the rectangular cooling tower casing.
- Galvanised mild steel mechanical support frame with an axial flow fan assembly mounted directly on the shaft of a geared motor.
- High efficient film type fill PP.
- PP water distribution system and PP drift eliminators.
- Stainless steel supports for the cooling tower fill, water distribution system and drift eliminator.
- FRP louvers at the air intake.
- Packed for TKD delivery (Total Knock Down) and delivered to site in Montana

- Optional Assembly or supervisor
- Optional mechanical engineer running test (dry) with balancing check.
- The operation manual in the Dutch, English, French or German language will be supplied on a CD. The additional price for each hard copy is € 150,-.

General Technical Description

In general
The cooling tower and all optional part as offered in this quotation are all made in accordance with the manufacturer's standard. The colour of the cooling tower is standard light grey RAL7035.
For further details we refer to the attached technical specification and dimension drawing.

Construction /2
In case the last two digits of the cooling tower type equal "/2", the cooling tower is delivered without a cold water basin. In this construction the cooling tower is suitable for mounting on a customer's concrete water basin. The water basin is not included in our scope of supply.

Construction /3
In case the last two digits of the cooling tower type equal "/3", the cooling tower is delivered including a GRP cold water basin with a hot dip galvanised foundation frame.
The colour of the water basin is grey.

Thermal performance
The performance details of the cooling tower are strictly based on the basic design conditions as given in the technical data sheets as attached. Differences between design and normal operating data and deviations in process and/ or environmental conditions will lead to a different cooling tower performance than that is calculated. If required we will present a comprehensive performance analysis of design circumstances.

The thermal performance of the cooling tower is measured according to DIN EN 13741 with a tolerance on temperature of 0,5°C. The test hast to be executed between 3 and 12 months after start-up of the cooling tower providing the use of correct treated cooling tower water. The cost of this performance test has to be ordered separately (see price list options).

Cooling tower control
The cooling tower should preferably be controlled by varying the air flow through the cooling tower. Reduction of the water flow increases the risk of clogging of the fill or freezing of the cooling tower at low temperatures.
Besides the possibility to switch the impeller on and off, we can offer 3 alternatives of varying the air flow through the cooling tower. The most appropriate option depends on the accuracy of the cold water temperature that the process requires.

✓ Two (1:2) speed Dahlander motor	On request
✓ Two (3/3 – 2/3) speed motor with separate windings	On request
✓ E motor prepared for frequency control	Standard option

Switching between high/ low speed or reverse and control of the frequency converter is generally done on the basis of continuous temperature measurement of the cold water.
The temperature element is not included in our scope of supply. In their standard construction our cooling towers are suitable for max. 6 switch shifts per hour.
If required we will present a comparison in kW for the 3 different types of control of the cooling tower.

Cooling tower connections
In the case of a cooling tower construction /3, the GRP cold water basin can be arranged with a horizontal or vertical discharge connection for a natural or forced discharge of the cold water. Cooling tower has to be connected free of tensions.

In the case of natural discharge, the cold water connection is fitted with an anti-vortex cross to ensure a maximal water flow.
In the case of forced extraction, the cold water discharge connection is fitted with a suction basket that prevents the intake of air by the pump within a limited variation of the water level. A connection for supplied water controlled by a floating valve and an overflow connection is also included with this alternative. The preferred type of cold water connection should be specified in the purchase order.

Optional a heating element mounted close to the discharge connection prevents that the water basin completely freezes when the cooling tower is switched off during winter and enables start up of the system. The temperature at which the heating element will automatically switch on is adjustable. Warm water coming from the process should defrost the cooling tower before switching on the axial fan.

Environmental noise
Sound power levels as listed in the technical specification are preliminary and need to be confirmed. Falling water and the drive equipment are recognised as the major sound producing sources from a counter flow cooling tower. Special provisions such as floating noise attenuation and low noise impellers can be included to suit the customer's environmental noise requirements. If required we will present a comprehensive noise calculation including a sound pressure level calculation at a certain noise measurement point.

Safe cooling tower operation
The cooling tower is manufactured in accordance with the CE regulations. This means that the cooling tower can be operated safely. All operational-and maintenance-activities may only be carried out by qualified and authorized personnel. Realize that switching off has implications for the cooling processes.
Legionella risks management. The conditions in the cooling tower can lead to a strong organic growth of micro-organisms, including the Legionella bacterium, the last can cause serious lung diseases. The growth of micro-organisms can effectively be governed by a good water treatment and regular monitoring. Emissions of droplets are minimized by the presence of a drift eliminator. Inspection and maintenance ensure your cooling tower to stay in an optimal condition.
The cooling tower is fully equipped to work in accordance with the different European directives, such as the Dutch guidesline AI-32 and the English Health and Safety Executive OC 255/11 (revised HS(G)70).

The cooling tower meets the recommendations made in the publication 9/7 of Eurovent.
In several European countries it is mandatory to register the cooling tower.

Applied codes and certificates

• 2006/42/CE	European Machine Directive
• NEN-EN 547-1	Safety of machinery
• NEN-EN-ISO 1461	Hot Dipped Galvanized coatings on iron and Steel
• NEN-EN-ISO 14122	Staircases, cage ladders, platforms and handrails
• NEN-EN-ISO 3834-2	Quality requirements for fusion welding of metallic parts
• NEN-EN 1092-1	Flanges and their Joints
• ANSI B16,5 150# *	Flanges American standard
• ISO 10816-1 en 3	Mechanical Vibrations
• ISO 14694	Industrial fans Specifications for balance quality and vibration levels
• DIN 45635	Calculation of noise emitting sources
• ATEX directive 2014/34/EU *	Explosive Conditions
• NEN-EN-ISO 9001:2008	Quality certificate TÜV register 2266/7.18
• SCC** (2008/5.1)	Safety certificate TÜV register 2266/7.13
• CTI STD-201(11)	Cooling Technology Institute register 13-25-02
	GOST-R and/or RTN Certificate Export certificate

* on request and with additional costs

Transportation and Assembly

All cooling towers are delivered as loose or pre-assembled parts.
The cooling tower need to be further assembled at ground level. The assembly requires a flat paved area that extends the cooling tower outline dimension with at least 2 meter, and a temporary lay down area close to the assembly area. The optional price for the assembly as offered in this quotation includes the scaffolding during the assembly on ground level. A crane for hoisting the separate parts is offered separately. The assembly and lay down areas and access roads to these areas should be well accessible and suitable for the crane and trucks. Temporary pavement provisions (if applicable) for the assembly floor, lay down area and access roads to these areas are not included in this offer.

In the event that further installation of the cooling towers to a certain final elevation height, for example a concrete water basin or building roof is required, we prefer to hoist the complete assembled cooling tower as soon as its foundation is ready for this. This approach can lead to a substantial shorter duration time. The capacity of the crane that is needed for this, not only depends on the weight of the cooling tower and the installation height, but in a much larger extent on the required outreach of the crane. The crane for single cell hoisting can be included in our offer as soon as these details are known.

As an option Kelvion can quote for an uninterrupted assembly of the cooling towers until these are mechanical complete and, if applicable, hoisted on their final position. Then we will leave the site for a mutually agreed intermediate period that allows the Purchaser to connect the cooling towers to the power supply and foundation, process and process control system. After that we will return for a mechanical running test that including a balancing check of the mechanical equipment.

In any case the quotation does not include:
- Civil work, foundation bolts.
- Connection of the cooling tower to the foundation, power supply, process and process control system.
- Temporary pavement provisions if necessary for the assembly and lay down area or access roads to the areas.
- Water, power supply, personnel rooms and lighting of the assembly area during assembly.
- Lighting on the cooling tower.
- Lightning protection system on the cooling tower.
- Earth connection of the cooling towers during assembly and after final installation.

Prices

1 Cell Polacel CMDR19 300-DM-120-PS/3 budget price..... $ 117,000.00

Includes:

Assembly at site on ground level .....
Crane for assembly and installation .....
Freight to Site .....
Lubrication lines outside the fan stack for oil fill and level indicator (dip stick) .....
Mechanical vibration switch (Metrix 055-11) .....
Fan ring railing.....
Cage ladder HDGS.....
Fan guard .....

Optional prices are for the total number of cooling towers.

Prices given above are Nett, in US Dollar (€ 1 = $ 1,1275), excl. VAT and strictly based on the terms and conditions below.

Commercial conditions

Delivery
Freight Allowed to University of Montana

Delivery time
To be agreed.
Lead time FCA: 14-16 weeks (single cell) and 16-18 weeks (multiple cell) (week=working week).
Assembly time on site (approx. 1 wk/25 m2CT).
We are normally capable to comply with your project planning.
Our single cell hoisting approach may offer a substantial reduction of the lead time.

Payment
We propose the following payment terms reflecting the progress of the project:

- 20% after date of order payment within 30 days.
- 40% half way the delivery time of the materials payment within 30 days.
- 40% at readiness and before shipment

Warranty period
The warranty period amounts to 12 months after commissioning the cooling tower(s) but is limited to a maximum of 18 months after notice of readiness for shipment of the cooling tower(s).

Limitation of liability
The cumulative maximum liability of Kelvion B.V. and its Subcontractors with respect to claims and costs arising out of or in connection with this Agreement or arising out of the performance or non-performance of the Work, whether based on contract, warranty, tort (including negligence of any nature, whether sole or concurrent), strict liability or otherwise, shall not exceed in the aggregate an amount equal to 100 % of the total contract value. Notwithstanding any other provision of this Agreement, Kelvion B.V. and its Subcontractors shall have no liability whatsoever for any special, incidental, indirect or consequential loss, injury or damage of any nature such as, but not limited to, loss of income, profit, business opportunity or production or loss by reason of plant shutdown, or increased use of raw material, energy or labour, claims of customers, increased financing costs or insurance premiums, whether based on contract, warranty, tort (including negligence of any nature, whether sole or concurrent), strict liability or otherwise.
The foregoing limitations shall not apply in the case of liability for death or personal injury or liability arising from fraud, wilful misconduct or gross negligence, and these limitations shall neither apply to the extent the actual damage is covered and compensated by insurances of Kelvion B.V.

In case of conflict the limitation of liability as stated above shall prevail over any and all other terms and conditions.

Terms of delivery
Delivery will be according the Orgalime S 2012 general conditions for the supply of mechanical, electrical and electronic products (Brussels, March 2012).
Delivery will be according the Orgalime SI 14 general conditions for the supply and installation of mechanical, electrical and electronic products (Brussels, January 2014).

Validity
This offer is valid for 3 months from quotation date.
or
The offered prices are without engagement. On request we can make a binding quotation.

We are confident that this offer meets your requirements and in the event you have any further questions please do not hesitate to contact us.

With kind regards,
Kelvion INC.

Product Director J. A Gende

Kelvion

Phone : (717) 487-8194
Fax : fax
E-mail : Joe.Gende@Kelvion.com

reviewed by:

Attachments:

- Technical specifications
- Dimensional drawing
- General conditions

TECHNICAL SPECIFICATION PER COOLING TOWER

Type	:	Polacel CMDR19 300-DM-120-PS/3
Manufacturer	:	Kelvion B.V.
Cooling principle	:	Counter flow
Number of cells	:	1
Casing Colour	:	Grey (RAL 7035)

Design conditions

Cooling capacity	:	19,625,889 BTU/h
Water flow	:	2,613.0 US Gal/min
Hot water temperature	:	95 °F
Cold water temperature	:	80 °F
Wet bulb temperature	:	63 °F
Max. water temperature	:	131 °F

Higher temperatures are possible, please contact supplier.

Technical Specification

Height of fill	:	4’-0” ft
Required sprayer pressure	:	25 kPa, max. 49 kPa
Air volume per fan	:	3,213.63 ft³/s
External static pressure	:	0 kPa
Number of fans	:	1
Number of motors	:	1
Motor power installed	:	40 HP
Motor power consumption	:	37,5 HP
Motor speed	:	1,800 RPM
Fan speed	:	215 RPM (preliminary)
Type of drive	:	Geared motor
Electrical supply	:	460V-3Ph-60Hz
Class of motor	:	IP 65 F
Power heating element (option)	:	none
Supply heater	:	110V-1Ph-60Hz

Dimensions and weights

Length	:	20’-7” ft
Width	:	16’-6” ft
Height	:	20’-0”ft
Shipping weight	:	13,845 lb
Operating weight	:	31,945 lb
Emergency weight (tower/ fill)	:	On Request

Water consumption

Average evaporated loss : 30,.1 US Gal/min

The maximum evaporation, which determines the design for the make up and drain, can be 25% higher.

Drain loss : Depends on the local water quality

Sound power cooling tower

The total sound power (PWL) of the cooling tower is determined by the logarithmic summation of the partial sources: fan outlet and air inlet. The noise at the air inlet is caused by the falling of the water in the water pan. This noise can be attenuated using floating noise attenuators, a special Polacel development. The values are calculated according to DIN 45635 Sub 46, class 3. The sound pressure at a certain distance can be calculated using the table “conversion from sound power to sound pressure for counter flow cooling towers”.

PWL – fan outlet : 94,8 dB(A) Check

PWL – air inlet without attenuators : 100,1 dB(A)

PWL – cooling tower total (excl. att) : 101,3 dB(A)

The use of floating attenuators reduces the sound power at the air inlet.

PWL – air inlet with attenuators : 89,6 dB(A)

PWL – cooling tower total (including. att) : 96,2 dB(A)

Material specification

Fan blades/ type	:	13-05-36N/B6TR
Fan support	:	Hot dipped galvanized steel
Fill/ type	:	PP / 19 / CF19
Fill support	:	Stainless steel
Eliminator	:	PVC
Eliminator support	:	Stainless steel AISI 304 – EN 1.4301
Framework	:	Stainless steel AISI 304 – EN 1.4301
Casing	:	Fiberglass reinforced polyester
Water pan basin	:	Fiberglass reinforced polyester
Water pan support	:	Hot dipped galvanized steel
Air inlet louvers	:	Glassfiber reinforced polyester
Water distribution/ Number of sprayers	:	PP
Fan guard (option)	:	None

Cooling Tower Complete with:

- Hot Water Inlet Connection: 14” ANSI Clall 125# Flange Pattern
- Cold Water Outlet Connection: 18” with vortex preventer
- Drain/overflow connections: 2” NPT
- Water Make-up float type valve and level controller 2” NPT

CATE Industrial

High Performance Air

Prepared by:

Brian Hunt
Cate Industrial Solutions
1795 So Fremont Dr.
Salt Lake City, UT 84104
208.890.5787
bhunt@cateequipment.com

Presented to:

Gus Drake
Power Engineers
2041 S Cobalt Way
Meridian, ID 83642
208.288.6513
Gus.drake@powereng.com

Ingersoll Rand. Master Distributor

Quoted on 4/13/20 **Quote valid until 5/12/20** **Quote # 20200413-1-Rev0**

RS18ie-A125 Fixed Speed, Contact Cooled, Rotary Screw Compressor

image for reference only

Technical Information:

Capacity: capacity will be reduced by approximately 15% due to the elevation in Rigby, ID.

- 123 cfm @ 110 psig
- 116 cfm @ 125 psig
- 106 cfm @ 145 psig
- 83 cfm @ 200 psig

Weight:

1413 lbs. Basemount

1784 lbs. 120 Gallon Tank

2079 lbs. 240 Gallon Tank

Connection Size: 1" NPT

Fan Flow Required: 2295 CFM

Dimensions (L x W x H):

- 51.2" x 33.5" x 51.2" Baseplate
- 75.4" x 34.7" x 78.6" 120 Gallon Tank
- 91.2" x 34.7" x 85.2" 240 Gallon Tank

Additional Engineering Data available upon request

RS Series: 25HP

Product Description

The RS-Series is an Oli Cooled, Belt Driven, Rotary Screw Compressor designed for easy serviceability. It's more than an integrated air system, it's a complete air solution designed to maximize the key drivers of profitability in today's business.

Standard Features

- **TEFC Motor with Star Delta Starter**
- **208 / 230 / 460/3/60 Tri-Voltage Motor**
- **Xe 70M Microprocessor Controller**
- **Belt Driven with Automatic Tensioner**
- **Dual Control operation, Load/No-load Control**
- **Auto Start/Stop**
- **Spin-on Oil Filter and Separator**
- **Quiet Operation**

Available Options:

- **Base or Tank Mounted**
- **PORO (Power Out Restart Option)**
- **Modulation Control**
- **Optional Total Air System - Integrated Dryer and Filtration**
- **Low ambient**
- **High Ambient (15-25HP)**
- **High Dust Filter**

RS18ie-A125 Fixed Speed, Contact Cooled, Rotary Screw Compressor (Voltage: Specify Voltage)				
RS18ie-A125	***25 HP***	***125psi***	***116 cfm***	*$15,920.00*
Mounting Options (Optional)		*240 Gallon Horizontal Receiver*		*Included*
Enclosure		*NEMA 4*		*Standard*
Enclosure		*High Dust intake filter and package pre filter*		*Standard*
Controls		*Xe-70 microprocessor controller*		*Standard*
Starter		*Star Delta starter (208V, 230V or 460V), (specify voltage when ordering)*		
Motor Voltage and Frequency		*TEFC Voltage Motor: 208/230/460/3/60 (specify voltage when ordering)*		*Standard*
Cooling		*Air-Cooled with Aftercooler filled with UltraCoolant*		*Standard*
Subtotal for RS18ie-A125				***$15,920.00***
Optional Features				
Xe-70 Controller with ECO		*Allows network communication and email notification of faults*		*$335.00*
120 gallon receiver tank		*Deduct from 240 gallon tank included*		*($580.00)*
Power Outage Restart Option (PORO)		*Automatic restart and scheduled start/stop*		*$577.00*
Phase Monitor		*Protection against low voltage and phase loss*		*$660.00*

HLA 120 Twin Tower Desiccant Dryer

image for reference only

Technical Information:

Capacity Range: 120cfm
Pressure Dew Point: -40°F to -100°F (-40°C to -70°C)
ISO Class 1 to 2
Voltage: 115V/1PH/60HZ
Maximum Inlet Pressure: 150 psig (10.3 barg)
Maximum Inlet Temperature: 120°F (50°C)
Desiccant Type: Activated alumina
Dimensions WxDxH: 44.5x32x66.1 (inches)

Product Description:

The HLA Heatless Desiccant Dryers provide constant -40˚F /-40˚C pressure dew point (optional -100˚F / - 70˚C) to ensure that clean, dry air is delivered to the customer's point of usage. These dryers include pre-filters and after-filters to keep the air stream clean and maintain the integrity of the desiccant medium. A digital controller and NEMA 4 electrics complete the premium characteristics of these dryers.

By using system air to purge the desiccant beds, HLA Heatless Dryers and their filters remove contaminants that could spoil the customer's product or manufacturing processes while conserving electrical energy associated with heat regenerative dryers. The switching valves and electrical control design provide increased reliability and reduced maintenance while affording safe and simple operation.

HLA120 Heatless Desiccant Dryer (Voltage: 115V-1~-60hz)				
HLA120	***120 cfm***	***-40F dewpoint***		*$7,358.00*
Energy Management System (Optional) - Adder		*Optional energy saving feature - dew point demand control*		*$3,557.00*
3 Valve Bypass (Optional) - Adder		*Optional maintenance feature – allows the dryer to be bypassed.*		*$720.00*
Subtotal for HLA120				***$11,635.00***

Price quoted valid for 30 days

Pricing and availability subject to change without notice

Vertical Air Receiver Tank

image for reference only

Technical Information:

Capacity: 500 - 1060 Gallons

Design Configurators:

- Vertical Tanks
- Top-plate & Mounting Options
- Internal and External Coatings

Design Specifications:

- ASME Code Section VIII, Division 1
- CSA B.51 latest edition
- Overload, Coast Guard
- Specifications, California PE and
- American Board of Shipping (ABS)

Product Description:

Air Receiver Tanks are an important part of compressed air systems. When adequately sized, they prevent rapid cycling of fixed speed compressors and assist in realizing full unloaded power during periods of low demand. With variable speed compressors, the receiver tank softens the ramp rate and allows the compressor to precisely match the customer's pressure requirement.

Air Receiver Tanks benefits provide increased compressor reliability and lower energy costs. They also reduce system pressure drift which can affect the customer's process and consume excessive horsepower/energy.

To ensure user safety and to meet the ASME Code requirements, Ingersoll Rand Remote Receiver Tanks are tested after completion to ensure that they can sustain pressures 1.3 times their MAWP.

- *Please be aware that for every tank order, an accessory kit should be ordered which will include a drain valve, a pressure gauge, a relief valve and decals*
- *Please add 8" to tank dimensions to allow for standard skirt.*
- *Tank prices include exterior primer finish only unless otherwise stated.*

Vertical Air Receiver Tanks (Voltage: 115V-1~-60hz)				
500 gal – standard primer exterior	***165 psi***	***38016135***	***Vertical tank pressed feet, standard skirt***	*$2,457.00*
660 gal – standard primer exterior	***150 psi***	***38002812***	***Vertical tank pressed feet, standard skirt***	*$3,559.00*
1060 gal – standard primer exterior	***150 psi***	***38002838***	***Vertical tank pressed feet, standard skirt***	*$5,903.00*
ASME Tank Kit (set to tank pressure rating) – one needed per tank	*38003414*	*1/2" NPT valve size*	*Includes gauge and electronic tank drain*	*$401.00*

Price quoted valid for 30 days

Pricing and availability subject to change without notice

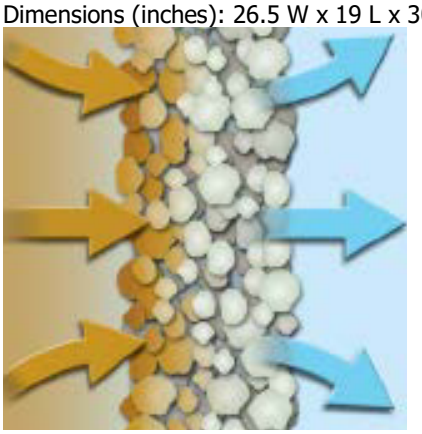
PSG-15 PolySep, Oil Water Separator

image for reference only

Technical Information:

The PolySep is an oil water separator which helps protect and maintain the environment by efficiently separating oil from the condensate, which allows you to return up to 99.9% of the condensate to the sanitary sewers.

Inlet NPT: 0.5”
Outlet NPT: 0.8”
Dimensions (inches): 26.5 W x 19 L x 30 H



Product Description

Compressor systems produce large amounts of condensate. This condensate contains lubricant contaminants that should be disposed of properly. Ingersoll Rand PolySep Oil Water Separators can help your company be strong stewards of the environment while reducing your annual waste removal costs. When properly installed and sized correctly, the PolySep separators are capable of providing condensate discharge levels as low as 15 mg/l. Our separators feature non-corrosive materials and do not require electrical power for operation, further reducing environmental burdens. You can count on PolySep Oil Water Separators to get you… and keep you…green

PSG-15 PolySep, Oil Water Separator (Voltage: N/A)				
PSG-15	***38459040***	***175 cfm***	***Oil Water Separator Unit***	***$1,606.00***
Installation Kit	*38338273*			*$75.00*
Subtotal for PSG-15				*$1,681.00*

Terms & Conditions

Shipment Date	:	Approx. 3-5 Weeks ARO
Payment Terms	:	Net 30, OAC
FOB	:	Origin / Salt Lake City, UT
Freight Terms	:	Not Included, Prepaid and Added to Invoice

Notes and Exclusions

1. *Prices quoted exclude taxes, freight, installation, or start-up unless specifically stated within the proposal body.*
2. *Compressor voltage to be specified on purchase order*
3. *Our Standard Terms and Conditions are an integral part of this quotation and any resulting orders.*
4. *Electrical disconnects and fuses are not included.*
5. *The Company warrants that the equipment manufactured by it and delivered hereunder will be free of defects in material and workmanship for a period of twelve months from the date of placing the Equipment in operation or eighteen months from the date of shipment from the factory, whichever shall first occur.*
6. *Equipment must be installed per manufacturer's specifications.*

Customer Price Sheet

Customer	Power Engineers Meridian	Size / Stages	CPP 10x8x13 (OH1) / 1
Item number	002	Pump speed	1770 rpm
Customer reference		Quote number	1137618

Totals

Grand Total	US$ 30,092		
Scope of Supply Total	US$ 30,092		2,188.0 lb

Scope of Supply

Qty	Description	Average Unit Price	Extended Price
2	*CPP 10x8x13 (OH1) ANSI B73.1 specification compliant-horizontal end suction pump*	*US$ 15,046*	*US$ 30,092*
	Pump		
	Materials		
2	Ductile iron casing		
	Impeller: CD4MCU Duplex		
2	Shaft / shaftsleeve: Solid 316SS Sleeveless Shaft		
	Pump rotation: Clockwise rotation from coupling end		
	Bearing bracket: Cast iron		
	Case Modifications		
2	Casing drain: Drain connection threaded and plugged		
	Case Wear Ring: No case wear rings		
	Impeller wear ring: No impeller wear rings		
2	Flange rating: 150# FF flanges		
	Bearing housing		
2	Inpro/Seal VB45S		
2	Lubrication type: Oil lubrication		
	Miscellaneous modifications		
2	Trim and balance impeller		
2	Casing gasket: Non-asbestos Casing Gasket		
	Shaft sealing		
	Shaft seal type		
	Seal model: EagleBurgmann seal or equal, RP choice of manufacturer		
2	Seal size: Single cartridge Type Unitex. Big bore. 316SS/Silcar/Viton/ Carbon		
	Primary Seal Flush Material: SS tubing		
2	Seal flush plan - primary: Plan 7311 piping - recirculation from pump case through orifice (built into gland) to seal.		
	Bearing housing cooling		
2	Air cooled bearing housing		
	Driver		
	Driver type: Motor drive		
	Motor selection: TEFC NEMA Premium Efficiency IP54		
2	Motor specification: 75HP, 1800RPM, Frame:365T, 3PH, 60Hz, 230/460V, Approx. Wgt:1045lb, factory choice.		
	Baseplate		
	Baseplate construction: Standard groutable baseplate		
2	Baseplate size: Baseplate 380 - 26" x 80"		
2	Driver mounting: Driver Mounting by RP		
	Coupling		
2	Coupling Size: T.B. Woods SC11 or equal (with spacer)		
2	Coupling guard: Steel coupling guard		
	Paint		
2	Paint: Ruhrpumpen Standard Blue Epoxy Paint		
	Munsell paint color match: No Munsell paint color match		

Item number	002	Service	Condenser Circ Water Pumps

Scope of Supply

Qty	Description	Average Unit Price	Extended Price
	Testing		
1	Hydrotest: Standard Hydro Test, 10 minute per ANSI, inc. letter of certification. Non witnessed		
	Documentation		
	Standard Documentation		
1	Standard Documentation Package will include 1 CD with all these documents: Bill of material (B.O.M), Pump performance curve/Pump performance datasheet/Pump performance additional data, Outline drawing, Cross Sectional Drawing, IOM Manual, Spare Parts List, Pre-shipment picture. And if applicable: Motor catalog drawing, Motor diagram connections, Seal drawing with B.O.M., Certified Hydro test , Certified performance test, Seal flush plan drawing, CW piping drawing, Motor routine test report, Balancing certification.		

Optional Adders

Qty	Description	Unit Price	Extended Price
	Performance test		
1	Non-witnessed Performance test to Hydraulic Institute Level "2B"	US$ 312	US$ 312
	NPSH test		
1	NPSH test - non-witnessed	US$ 263	US$ 263

Pump Performance Datasheet

Customer	: Power Engineers Meridian	Quote number	: 1137618
Customer reference	:	Size	: CPP 10x8x13 (OH1)
Item number	: 002	Stages	: 1
Service	: Condenser Circ Water Pumps	Based on curve number	: CPP21-048
Quantity	: 2	Date last saved	: 03/26/2020 1:54 AM

Operating Conditions

Flow, rated	: 3,000.0 USgpm
Differential head / pressure, rated (requested)	: 70.00 ft
Differential head / pressure, rated (actual)	: 70.76 ft
Suction pressure, rated / max	: 0.00 / 0.00 psi.g
NPSH available, rated	: Ample
Frequency	: 60 Hz

Performance

Speed, rated	: 1770 rpm
Impeller diameter, rated	: 10.69 in
Impeller diameter, maximum	: 12.60 in
Impeller diameter, minimum	: 9.80 in
Efficiency	: 78.1 %
NPSH required / margin required	: 16.03 / 0.00 ft
Ns (imp. eye flow) / Nss (imp. eye flow)	: 2,877 / 10,416 US Units
MCSF	: 1,000.0 USgpm
Head, maximum, rated diameter	: 91.76 ft
Head rise to shutoff	: 30.94 %
Flow, best eff. point	: 3,294.6 USgpm
Flow ratio, rated / BEP	: 91.06 %
Diameter ratio (rated / max)	: 84.82 %
Head ratio (rated dia / max dia)	: 48.17 %
Cq/Ch/Ce/Cn [ANSI/HI 9.6.7-2010]	: 1.00 / 1.00 / 1.00 / 1.00
Selection status	: Acceptable

Liquid

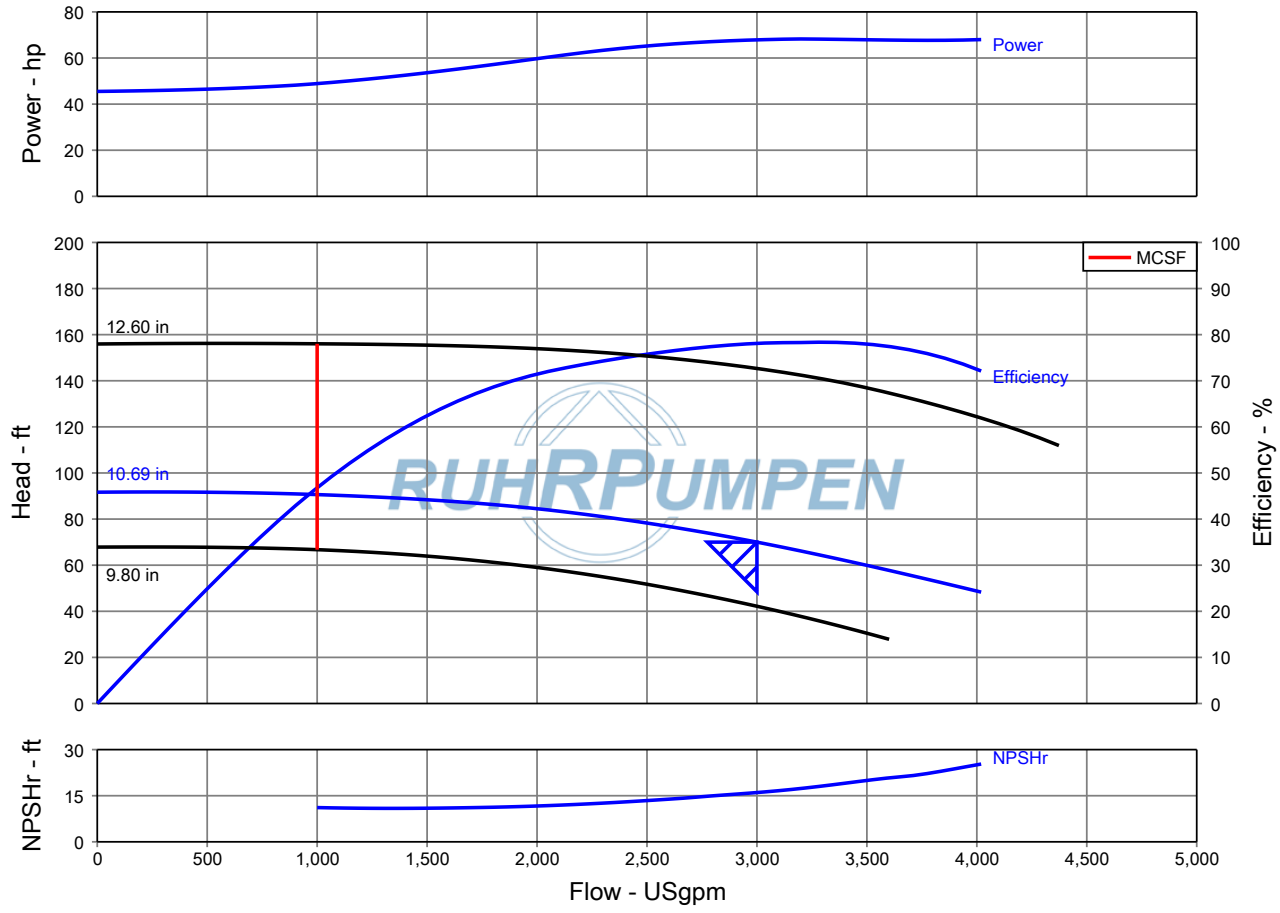
Liquid type	: Water
Additional liquid description	: Steam Plant Water
Solids diameter, max	: 0.00 in
Solids concentration, by volume	: 0.00 %
Temperature, max	: 125.0 deg F
Fluid density, rated / max	: 1.000 / 1.000 SG
Viscosity, rated	: 1.00 cP
Vapor pressure, rated	: 0.34 psi.a

Pressure Data

Maximum discharge pressure	: 39.71 psi.g
Maximum allowable working pressure	: 268.7 psi.g
Maximum allowable suction pressure	: 156.1 psi.g
Hydrostatic test pressure	: 375.6 psi.g

Driver & Power Data (@Max density)

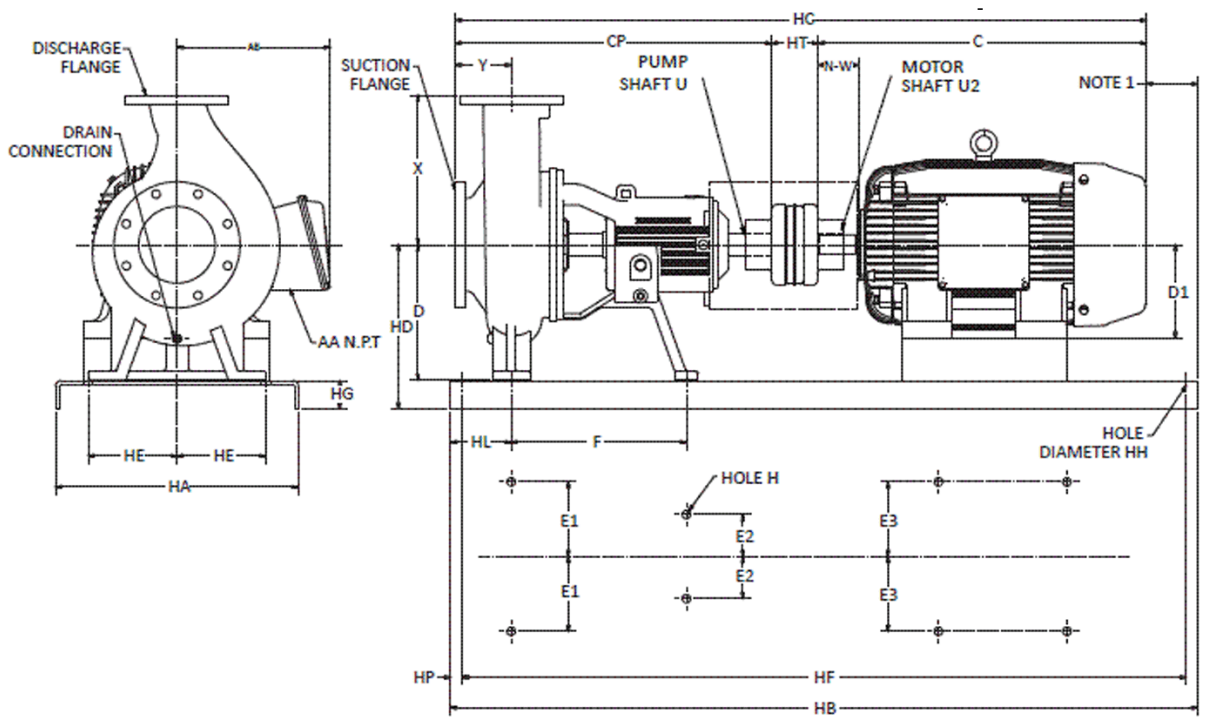
Driver sizing specification	: Rated power
Margin over specification	: 0.00 %
Service factor	: 1.00
Power, hydraulic	: 53.02 hp
Power, rated	: 67.88 hp
Power, maximum, rated diameter	: 68.27 hp
Minimum recommended motor rating	: 75.00 hp / 55.93 kW



RUHRPUMPEN

General Arrangement - CPP 10x8x13 (OH1)

For information only - not for construction
Not to scale
All dimensions in inches unless otherwise stated



CP	D	2E1	2E2	H	F	U	X	Y	AB	C	U2	AA	D1	2F	N-W	S	HC	HAMax	HB	HT MIN
33.88	14.50	16.00	9.00	0.88	18.75	2.38	18.00	6.00	NA	NA	NA	NA	NA	NA	NA	NA	NA	26.00	80.00	NA

HD	HE	HF	HG	HL
NA	NA	NA	NA	NA

Nozzles	Suction	Discharge
Size	10 inch	8 inch
Rating	ANSI 150	ANSI 150
Face	FF	FF
Position	-	Side

Driver	
Manufacturer	Special motor
Rating / Frame	75.00 hp / 365T
Speed / Poles	1770 / 4
Volts / Phase / Hz	- / - / -

Piping	
Seal plan - primary/auxiliary	Plan 11 / -
Cooling water plan	-

Mechanical Seal	
Type	Special mechanical seal

Coupling	
Type & size	TBWoods SC11
Guard	Steel

Weights (Approx.)	
Pump	882.0 lb
Baseplate	261.0 lb
Driver	1,045.0 lb
Total	2,188.0 lb
-	-
-	-
-	-
-	-
-	-

Item	Size	Qty	Description	Connection
-	-	-	-	-
-	-	-	-	-
-	.50 NPT	1	Drain, pump case	-
-	.50 NPT	1	Drain, bearing lube oil	-
-	-	-	Drain, baseplate	-
-	-	-	-	-
-	.50 NPT	1	Fill / vent, bearing lube oil	-
-	-	-	-	-
-	-	-	Oil mist inlet	-
-	-	-	Oil mist outlet	-
-	.25 NPT	1	Seal recirculation connection (Discharge)	-
-	-	-	-	-
Z1	-	-	-	
Z2	-	-	-	
Z3	-	-	-	
Z4	-	-	-	
CLB	-	-	Centerline of baseplate	
CLP	-	-	Centerline of pump	
CLS	-	-	Centerline of suction	

Customer	Power Engineers Meridian
Customer reference	
Project name	1137618 / GTCC Replacement Pumps at University of Montana
Service	Condenser Circ Water Pumps
Item number	002
Pump size	CPP 10x8x13 (OH1)

Customer Price Sheet

Customer	Power Engineers Meridian	Size / Stages	CPPL 3x1.5x13 (OH1) / 1
Item number	003	Pump speed	3500 rpm
Customer reference		Quote number	1137618

Totals

Grand Total	US$ 10,230		
Scope of Supply Total	US$ 10,230		1,415.0 lb

Scope of Supply

Qty	Description	Average Unit Price	Extended Price
1	*CPPL 3x1.5x13 (OH1) ANSI B73.1 specification compliant-horizontal end suction pump*	*US$ 10,230*	*US$ 10,230*
	Pump		
	Materials		
1	Ductile iron casing		
	Impeller: CD4MCU Duplex		
1	Shaft / shaftsleeve: Solid 316SS Sleeveless Shaft		
	Pump rotation: Clockwise rotation from coupling end		
	Bearing bracket: Cast iron		
	Case Modifications		
1	Casing drain: Drain connection threaded and plugged		
1	Flange rating: 150# FF flanges		
	Bearing housing		
1	Inpro/Seal VB45S		
1	Lubrication type: Oil lubrication		
	Miscellaneous modifications		
1	Trim and balance impeller		
1	Casing gasket: Non-asbestos Casing Gasket		
	Shaft sealing		
	Shaft seal type		
	Seal model: EagleBurgmann seal or equal, RP choice of manufacturer		
1	Seal size: Single cartridge Type Unitex. Big bore. 316SS/Silcar/Viton/ Carbon Primary Seal Flush Material: SS tubing		
1	Seal flush plan - primary: Plan 7311 piping - recirculation from pump case through orifice (built into gland) to seal.		
	Bearing housing cooling		
1	Air cooled bearing housing		
	Driver		
	Driver type: Motor drive		
	Motor selection: TEFC NEMA Premium Efficiency IP54		
1	Motor specification: 75HP, 3600RPM, Frame:365TS, 3PH, 60Hz, 230/460V, Approx. Wgt:995lb, factory choice.		
	Baseplate		
	Baseplate construction: Standard groutable baseplate		
1	Baseplate size: Baseplate 264 - 21" x 64"		
1	Driver mounting: Driver Mounting by RP		
	Coupling		
1	Coupling Size: T.B. Woods SC8H or equal (with spacer)		
1	Coupling guard: Steel coupling guard		
	Paint		
1	Paint: Ruhrpumpen Standard Blue Epoxy Paint		
	Munsell paint color match: No Munsell paint color match		

Item number	003	Service	HP Feedwater Pumps

Scope of Supply

Qty	Description	Average Unit Price	Extended Price
	Testing		
	Performance test		
	No performance test		
	NPSH test		
	No NPSH test		
1	Hydrotest: Standard Hydro Test, 10 minute per ANSI, inc. letter of certification. Non witnessed		
	Documentation		
	Standard Documentation		
1	Standard Documentation Package will include 1 CD with all these documents: Bill of material (B.O.M), Pump performance curve/Pump performance datasheet/Pump performance additional data, Outline drawing, Cross Sectional Drawing, IOM Manual, Spare Parts List, Pre-shipment picture. And if applicable: Motor catalog drawing, Motor diagram connections, Seal drawing with B.O.M., Certified Hydro test , Certified performance test, Seal flush plan drawing, CW piping drawing, Motor routine test report, Balancing certification.		

Optional Adders

Qty	Description	Unit Price	Extended Price
	Performance test		
1	Non-witnessed Performance test to Hydraulic Institute Level "2B"	US$ 227	US$ 227
	NPSH test		
1	NPSH test - non-witnessed	US$ 239	US$ 239

Pump Performance Datasheet

Customer	: Power Engineers Meridian	Quote number	: 1137618
Customer reference	:	Size	: CPPL 3x1.5x13 (OH1)
Item number	: 003	Stages	: 1
Service	: HP Feedwater Pumps	Based on curve number	: SC_100_1111.01.
Quantity	: 1	Date last saved	: 03/26/2020 1:54 AM

Operating Conditions

Flow, rated	: 110.0 USgpm
Differential head / pressure, rated (requested)	: 550.0 ft
Differential head / pressure, rated (actual)	: 549.2 ft
Suction pressure, rated / max	: 17.00 / 17.00 psi.g
NPSH available, rated	: Ample
Frequency	: 60 Hz

Performance

Speed, rated	: 3500 rpm
Impeller diameter, rated	: 10.28 in
Impeller diameter, maximum	: 12.75 in
Impeller diameter, minimum	: 9.00 in
Efficiency	: 23.0 %
NPSH required / margin required	: 8.39 / 0.00 ft
Ns (imp. eye flow) / Nss (imp. eye flow)	: 360 / 3,476 US Units
MCSF	: 70.89 USgpm
Head, maximum, rated diameter	: 559.6 ft
Head rise to shutoff	: 1.97 %
Flow, best eff. point	: 177.2 USgpm
Flow ratio, rated / BEP	: 62.08 %
Diameter ratio (rated / max)	: 80.62 %
Head ratio (rated dia / max dia)	: 64.42 %
Cq/Ch/Ce/Cn [ANSI/HI 9.6.7-2010]	: 1.00 / 1.00 / 1.00 / 1.00
Selection status	: Acceptable

Liquid

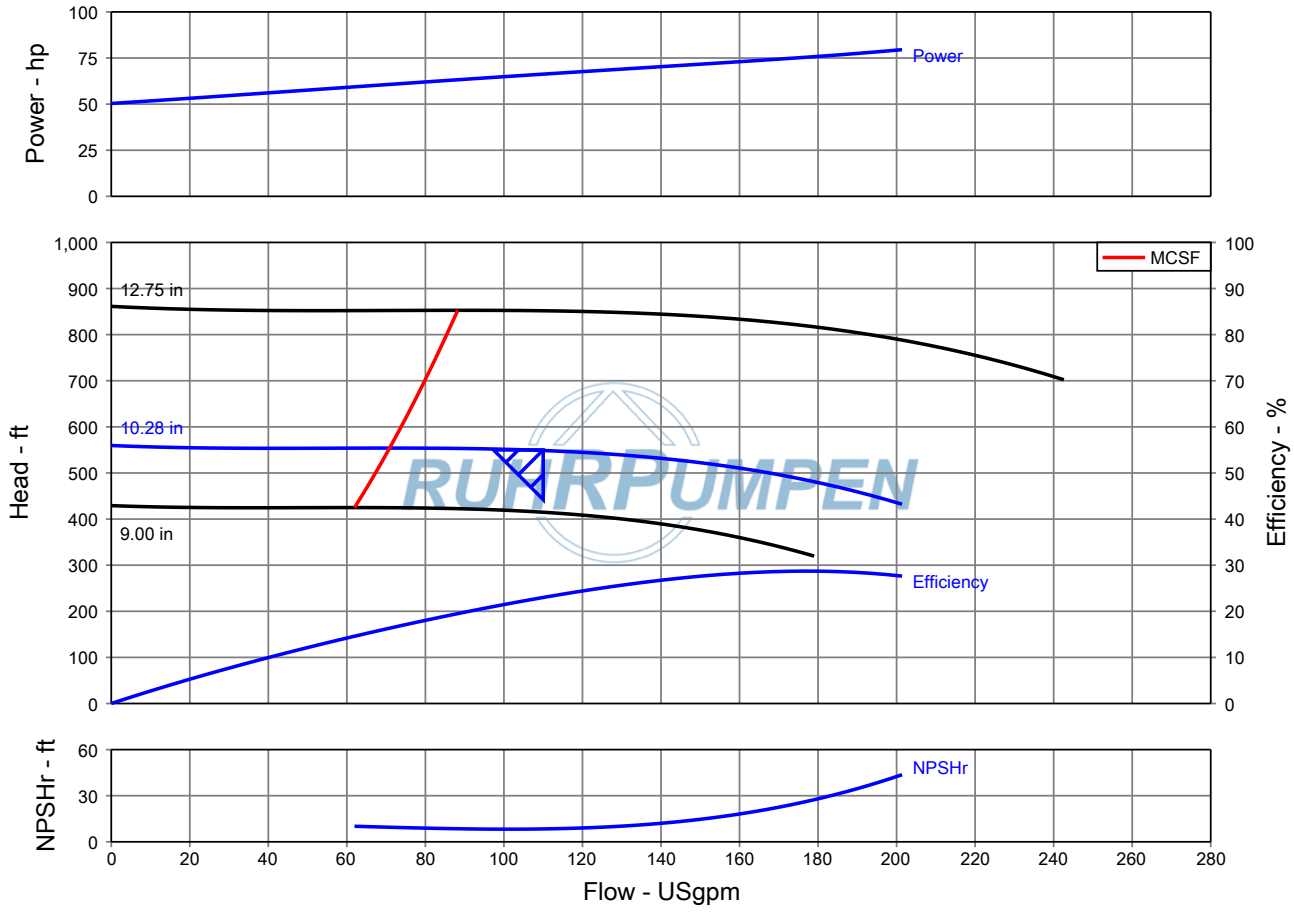
Liquid type	: Water
Additional liquid description	: Steam Plant Water
Solids diameter, max	: 0.00 in
Solids concentration, by volume	: 0.00 %
Temperature, max	: 68.00 deg F
Fluid density, rated / max	: 1.000 / 1.000 SG
Viscosity, rated	: 1.00 cP
Vapor pressure, rated	: 0.34 psi.a

Pressure Data

Maximum discharge pressure	: 259.2 psi.g
Maximum allowable working pressure	: 275.0 psi.g
Maximum allowable suction pressure	: 122.1 psi.g
Hydrostatic test pressure	: 388.8 psi.g

Driver & Power Data (@Max density)

Driver sizing specification	: Rated power
Margin over specification	: 0.00 %
Service factor	: 1.00
Power, hydraulic	: 15.24 hp
Power, rated	: 66.26 hp
Power, maximum, rated diameter	: 79.54 hp
Minimum recommended motor rating	: 75.00 hp / 55.93 kW



General Arrangement - CPPL 3x1.5x13 (OH1)

For information only - not for construction
Not to scale
All dimensions in inches unless otherwise stated
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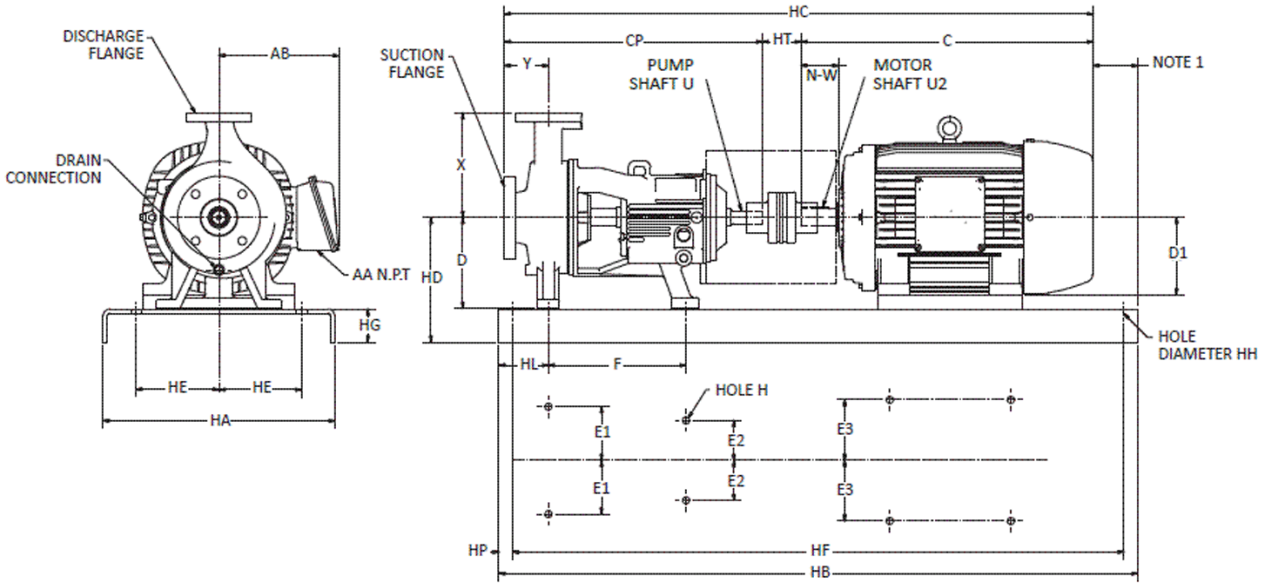

CP	D	2E1	2E2	H	F	U	X	Y	AB	C	U2	AA	D1	2F	N-W	S	HC	HAMax	HB	HT MIN
23.50	10.00	9.75	7.25	0.63	12.50	1.63	10.50	4.00	16.00	31.75	2.38	3.00	9.00	12.25	5.88	0.63	58.75	21.00	64.00	3.50

HD	HE	HF	HG	HL
13.00	7.50	61.50	3.00	4.50

Nozzles	Suction	Discharge
Size	3 inch	1.5 inch
Rating	ANSI 150	ANSI 150
Face	FF	FF
Position	-	Side
Driver		
Manufacturer	Special motor	
Rating / Frame	75.00 hp / 365TS	
Speed / Poles	3500 / 2	
Volts / Phase / Hz	- / - / -	
Piping		
Seal plan - primary/auxiliary	Plan 11 / -	
Cooling water plan	-	
Mechanical Seal		
Type	Special mechanical seal	
Coupling		
Type & size	TBWoods SC8H	
Guard	Steel	
Weights (Approx.)		
Pump	246.0 lb	
Baseplate	174.0 lb	
Driver	995.0 lb	
Total	1,415.0 lb	
-	-	
-	-	
-	-	
-	-	
-	-	

Item	Size	Qty	Description	Connection
-	-	-	-	-
-	-	-	-	-
-	.50 NPT	1	Drain, pump case	-
-	.50 NPT	1	Drain, bearing lube oil	-
-	-	-	Drain, baseplate	-
-	-	-	-	-
-	.50 NPT	1	Fill / vent, bearing lube oil	-
-	-	-	-	-
-	-	-	Oil mist inlet	-
-	-	-	Oil mist outlet	-
-	.25 NPT	1	Seal recirculation connection (Discharge)	-
-	-	-	-	-
Z1	-	-	-	
Z2	-	-	-	
Z3	-	-	-	
Z4	-	-	-	
CLB	-	-	Centerline of baseplate	
CLP	-	-	Centerline of pump	
CLS	-	-	Centerline of suction	

Customer	Power Engineers Meridian
Customer reference	
Project name	1137618 / GTCC Replacement Pumps at University of Montana
Service	HP Feedwater Pumps
Item number	003
Pump size	CPPL 3x1.5x13 (OH1)