STEAM PLANT CLIMATE ACTION PLAN STUDY

FINAL SUBMISSION

Appalachian STATE UNIVERSITY

JULY 2020

RMF Engineering
Reliability. Efficiency. Integrity.

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Executive Summary

The existing boilers that serve the Appalachian State University campus are approaching the end of their useful life. The University wanted to understand how replacing the boilers with electric boilers or replacing the natural gas with biofuels would affect the operation and carbon emissions of the Steam Plant.

Based upon the hourly meter data, the minimum summer load is less than 40,000 pph and the peak for the campus is close to 80,000 pph. The following is the capacity and the corresponding cost for the electric boilers evaluated:

Option	Description	Project Cost ($)
A	20,000 pph Unit	1,700,000
B	40,000 pph Unit	2,200,000
C	80,000 pph Unit	2,510,000
D	(2) 40,000 pph Unit	3,290,000

Table No. 1: Electric Boiler Capital Cost Summary

While all options are thoroughly evaluated in this report, Option B has clear advantages over the remainder of the options. Summer loads regularly exceed 20,000 PPH and would require a gas fired boiler to operate at all times in parallel with Option A, making this option undesirable from an operational standpoint. Option C and D require costly electrical infrastructure work including switchgear and electrical distribution upgrades that are not necessary for Option B.

Through discussions with New River Light and Power (NRLP), the electric boiler would be located at the Steam Plant and would have to be on a new dedicated electric service and account. The campus currently purchases power that is generated from the burning of fossil fuels, so there are carbon emissions with operating an electric boiler. There is a potential for the University to purchase renewable electricity, which has zero carbon emission associated with it, but has a premium price. The following is a summary of the annual costs and carbon emissions for the different options and electric purchased:

Option	Fuel	Total Fuel Costs ($/yr)	25-year Present value Of Annual Costs ($Million)	CO_2 Emission (TPY)	Carbon Savings (TPY)	Cost of Carbon ($/Ton)
Base	Nat. Gas	1,700,000	29.5	16,500	---	---
1A	Utility Electric	2,300,000	40.0	24,400	---	---
1B		2,600,000	45.7	27,200	---	---
1C		2,800,000	49.1	27,800	---	---
1D		2,800,000	49.1	27,800	---	---
2A	Renewable Electric	2,900,000	50.3	5,400	11,100	106
2B		3,400,000	59.6	1,300	15,200	113
2C		3,600,000	63.7	500	16,000	122
2D		3,600,000	63.7	500	16,000	122

Table No. 2: Annual Operating and Carbon Emission Cost Comparison

There is no operating fuel savings for any of the electric boiler options. There is only carbon savings if the University purchases renewable electricity. For the Option 2C (80,000 pph unit), the carbon emission for the steam plant could be reduced by 96%. The increased annual cost for Option 2C is approximately $1.9 million per year. If there is an annual carbon tax of $122 per ton applied to the University, then the is no operational cost difference between Option 2C and a natural gas boiler.

In 2018, the U.S. House of Representatives introduced a bill (HR 7173 Energy Innovation and Carbon Dividend Act). That would have a starting rate of $15 per ton in 2019 and increased by $10 each year until “progress is made to meeting specified emissions reduction targets”. This means by 2031, the tax could have been as high as $135 per ton. As of 2019, there are more than 40 governments worldwide that have adopted some sort of carbon pricing. For Canada, the current tax starts at $15 per ton and will rise up to $38 per ton by 2022. It is not typical for the carbon tax to be over $100 per ton, but there is a potential in future for this to occur.

As an alternative to installing a new electric boiler, the purchasing of biofuels was considered. When evaluating the carbon emission for the biofuels, the biogenic carbon and the total carbon emissions were identified. Biogenic carbon dioxide emissions are defined as emissions directly resulting from the combustion or decomposition of biologically-based materials other than fossil fuels. The carbon emission from fossil fuels releases carbon that would be in the ground, while burning a biofuel emits carbon that is part of the biogenic cycle. The following is a comparison of the liquid biofuels evaluated:

Biofuel	Capital Costs ($)	Fuel Cost ($/mmbtu)	Biogenic CO_2 Factor (lb/mmbtu)	Total CO_2 Factor (lb/mmbtu)
Nat. Gas	---	5.42	N/A	117.1
Biodiesel	200,000	15-20	162.8	162.9
Biodiesel Residual Oil	200,000	17-22	162.8	162.9
Renewable Fuel Oil	3.0 million	19-23	162.8	162.9
Renewable Natural Gas	---	6-30	114.8	115.3

Table No. 3: Biofuel comparison

If the University were to exclude the biogenic carbon emission factors from the fuels, then the biofuels listed above are close to carbon neutral. However, if the University does not exclude the biogenic carbon, then only the Renewable Natural Gas has a lower carbon footprint than natural gas. The savings in carbon emissions is only 2%, but the cost is between 5% to 500% that of natural gas.

The unitary cost at $25 to $30 per million British Thermal Units (mmbtu) is based the University procuring a long-term contract (15+ years) for renewable natural gas. A third-party provider will construct an anaerobic digester system to collect the renewable natural gas and inject it into the natural gas distribution system. This will guarantee the University the availability of this gas for 20-years. Alternatively, the University can purchase the renewable natural gas from the market. Currently, NRLP is receiving quotes for renewable natural gas around 5% higher than natural gas. The disadvantage to this type of purchase is the cost can swing dramatically based upon the availability of the gas.

Existing Steam System

The University's Steam Plant serves the heating and process load requirements of the campus through approximately three-mile steam loop. The heating requirements for Appalachian State University are handled through the production of steam within the Steam Plant. The major equipment within the Steam Plant consists of four boilers.

Boiler Nos. 1 through 4 were originally installed in the late 1995. Three of the four boilers (Boiler Nos. 1 through 3) have a design capacity of 80,000 pound per hour (pph) each and Boiler No. 4 has a boiler capacity of 40,000 pph. The total steam generation for the plant is 280,000 pph. The firm capacity of the plant is defined as the total output without the availability of the largest single unit. It is recommended for steam plants to maintain a firm capacity greater than the peak boiler load to ensure an appropriate level of reliability. For the Steam Plant, the firm capacity equals 280,000 pph minus the 80,000 pph or 200,000 pph. A plant layout identifying the location of each boiler is presented in Figure No. 1.

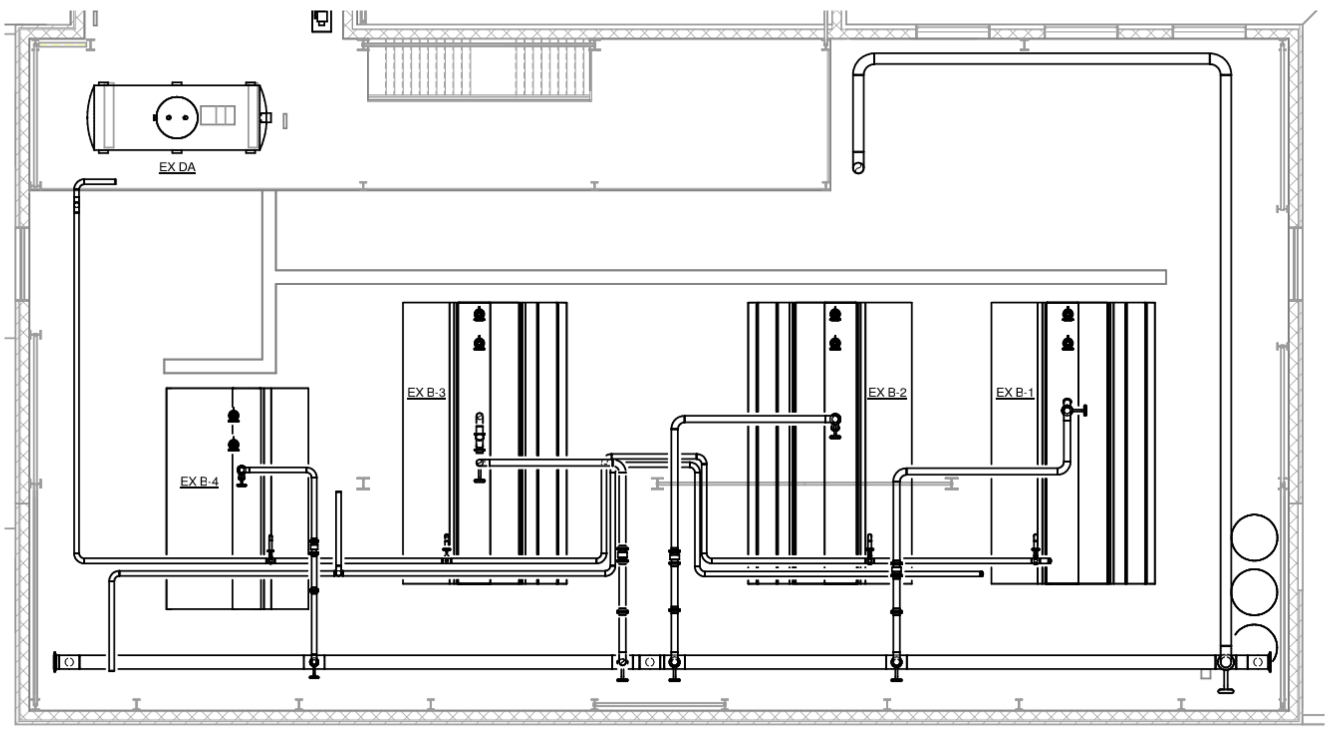

Figure No. 1: Steam Plant Boiler Layout

The American Society for Heating, Refrigeration and Air Conditioning Engineers (ASHRAE) has identified a typical service life for boilers to be approximately 30 years. Based upon the age of the boiler equipment within the Steam Plan, the University should start budgeting the replacement of all the boilers.

Prior to switching to natural gas as the primary fuel, the University used to operate solely on No. 2 fuel oil. There is currently 300,000 gallons of storage on the campus for fuel oil.

Natural Gas and Potential Electric Costs at the Steam Plant

Natural Gas is the primary fuel utilized within the Steam Plant. The monthly natural gas bills were reviewed for 2016 through 2019. A summary of these bills is presented in the Appendix. The average natural gas costs for 2019 was approximately $5.42 per million British Thermal Units (mmbtu).

The University also provided the historical electric usage and demand for the campus from 2016 through 2019. A summary of this data is also presented in the Appendix. The electricity is provided by New River Light and Power (NRLP). Through conversations with NRLP, if the University were to install an electric boiler, then the boiler would be on a new billing schedule. The following are the potential rates for the boiler schedule:

Coincident Peak Demand:	$15.00 per kilowatt (kW)
Non-Coincident Peak Demand:	$4.00 per kW
Energy rate:	$0.03000 per kilowatt hour (kWh)

The coincident peak demand is based upon the electric consumption recorded when the entire NRLP records its peak demand. When evaluating the electric boiler, NRLP believes that they can predict what day a peak demand will occur and will inform the University the day before. If the proposed electric boiler is not operating, then there is no coincident peak demand cost for the boiler operation.

In 2019, NRLP produced 3,065,657 megawatt hours (MWH) of electricity while emitting 1,202,476 tons of CO_2. The carbon emission for the electricity consumed is 864.9 pounds per megawatt hour (lbs/MWH). From NRLP, the University has the option to purchase renewable electricity that would have no carbon emissions, but the energy rate would increase to $0.042 per kWh while the demand costs would remain the same.

Central Heating Plant Operation

Monthly log data, provided by Appalachian personnel, was reviewed to assess the current operation of the Steam Plant. Different categories, such as steam production and fuel consumption were summarized for each of the boilers within the plant. A summary of the annual boiler operation is presented in Table No. 4 It can be seen that the Boiler No. 4 (40.000 pph) operates the majority of the year. During the summer months Boiler No. 4 is

TABLE NO. 4: MONTHLY BOILER LOG SUMMARY (2016-2019)

APPALACHIAN STATE UNIVERSITY

YEAR	MONTH	BOILER NO. 1 (80,000 PPH)				BOILER NO. 2 (80,000 PPH)				BOILER NO. 3 (80,000 PPH)				BOILER NO. 4 (40,000 PPH)				TOTAL STEAM PROD.			
		STEAM PROD. (MLBS)	N.G CONSUM. (MMBTU)	FUEL OIL (MMBTU)	BOILER EFF. (%)	STEAM PROD. (MLBS)	N.G CONSUM. (MMBTU)	FUEL OIL (MMBTU)	BOILER EFF. (%)	STEAM PROD. (MLBS)	N.G CONSUM. (MMBTU)	FUEL OIL (MMBTU)	BOILER EFF. (%)	STEAM PROD. (MLBS)	N.G CONSUM. (MMBTU)	FUEL OIL (MMBTU)	BOILER EFF. (%)	STEAM PROD. (MLBS)	N.G CONSUM. (MMBTU)	FUEL OIL (MMBTU)	BOILER EFF. (%)
2016	JAN	11,232	14,575	---	77.1	---	---	---	---	17,778	18,699	---	95.1	5,551	6,706	---	82.8	34,561	39,980	---	86.4
	FEB	14,741	18,389	---	80.2	11,337	14,800	---	76.6	2,966	3,928	---	75.5	1,819	1,959	---	92.9	30,863	39,076	---	79.0
	MAR	17,981	23,125	---	77.8	---	---	---	---	1,978	2,338	---	84.6	1,443	1,790	---	80.6	21,402	27,253	---	78.5
	APR	18,595	24,352	---	76.4	---	---	---	---	---	---	---	---	---	---	---	---	18,595	24,352	---	76.4
	MAY	7,103	8,418	---	84.4	---	---	---	---	---	---	---	---	5,910	9,177	---	64.4	13,013	17,595	---	74.0
	JUN	---	---	---	---	---	---	---	---	---	---	---	---	12,468	15,026	---	83.0	12,468	15,026	---	83.0
	JUL	---	---	---	---	---	---	---	---	---	---	---	---	12,187	14,751	---	82.6	12,187	14,751	---	82.6
	AUG	---	---	---	---	---	---	---	---	2,786	3,690	---	75.5	10,131	12,206	---	83.0	12,917	15,896	---	81.3
	SEP	---	---	---	---	---	---	---	---	13,396	17,789	---	75.3	---	---	---	---	13,396	17,789	---	75.3
	OCT	2,270	2,928	---	77.5	10,413	13,923	---	74.8	2,540	1,962	---	129.5	---	---	---	---	15,223	18,812	---	80.9
	NOV	11,617	15,064	---	77.1	8,265	10,818	---	76.4	---	---	---	---	725	921	---	78.7	20,607	26,803	---	76.9
	DEC	13,947	17,762	---	78.5	8,666	13,419	---	64.6	---	---	---	---	3,728	4,614	---	80.8	26,341	35,796	---	73.6
	TOTAL	97,486	124,613	---	78.2	38,681	52,959	---	73.0	41,444	48,406	---	85.6	53,962	67,151	---	80.4	231,573	293,129	---	79.0
2017	JAN	408	445	153	68.2	8,305	8,935	---	92.9	14,300	18,207	---	78.5	3,930	4,901	---	80.2	26,943	32,488	153	82.5
	FEB	9,423	12,201	---	77.2	---	---	---	---	10,197	12,641	---	80.7	3,243	3,639	---	89.1	22,863	28,481	---	80.3
	MAR	11,544	14,721	---	78.4	11,101	14,975	---	74.1	---	---	---	---	1,566	1,964	---	79.7	24,211	31,660	---	76.5
	APR	8,648	11,939	---	72.4	5,855	7,631	---	76.7	---	---	---	---	---	---	---	---	14,503	19,570	---	74.1
	MAY	7,394	8,831	---	83.7	---	---	---	---	---	---	---	---	6,369	7,787	---	81.8	13,763	16,618	---	82.8
	JUN	---	---	---	---	---	---	---	---	---	---	---	---	11,750	16,243	---	72.3	11,750	16,243	---	72.3
	JUL	---	---	---	---	---	---	---	---	---	---	---	---	12,365	13,300	---	93.0	12,365	13,300	---	93.0
	AUG	---	---	---	---	---	---	---	---	---	---	---	---	13,314	16,239	---	82.0	13,314	16,239	---	82.0
	SEP	---	---	---	---	7,974	11,405	---	69.9	---	---	---	---	5,732	6,900	---	83.1	13,706	18,306	---	74.9
	OCT	11,381	14,986	---	75.9	5,100	5,882	---	86.7	---	---	---	---	---	---	---	---	16,481	20,868	---	79.0
	NOV	11,019	14,263	---	77.3	10,107	13,360	---	75.7	---	---	---	---	---	---	---	---	21,126	27,622	---	76.5
	DEC	---	---	---	---	13,755	17,988	---	76.5	9,161	12,875	---	71.2	5,315	7,043	---	75.5	28,231	37,906	---	74.5
	TOTAL	59,817	77,386	153	77.1	62,197	80,176	---	77.6	33,658	43,723	---	77.0	63,584	78,015	---	81.5	219,256	279,300	153	78.5
2018	JAN	10,638	13,168	97	80.2	6,143	8,272	---	74.3	12,562	13,585	1,640	82.5	4,681	5,717	---	81.9	34,024	40,742	1,738	80.1
	FEB	---	---	---	---	---	---	---	---	18,392	24,580	---	74.8	3,399	4,153	---	81.9	21,791	28,733	---	75.8
	MAR	14,248	20,316	---	70.1	3,265	4,394	---	74.3	8,651	9,916	---	87.2	---	---	---	---	26,164	34,626	---	75.6
	APR	10,820	12,790	---	84.6	9,143	12,191	---	75.0	---	---	---	---	---	---	---	---	19,963	24,981	---	79.9
	MAY	---	---	---	---	6,858	9,254	---	74.1	---	---	---	---	6,803	8,362	---	81.4	13,661	17,616	---	77.5
	JUN	168	5	250	65.8	---	---	---	---	---	---	---	---	13,623	17,372	---	78.4	13,791	17,377	250	78.2
	JUL	---	---	---	---	---	---	---	---	---	---	---	---	13,708	16,309	---	84.1	13,708	16,309	---	84.1
	AUG	---	---	---	---	---	---	---	---	---	---	---	---	14,418	19,307	---	74.7	14,418	19,307	---	74.7
	SEP	---	---	---	---	2,756	3,665	---	75.2	---	---	---	---	11,235	12,163	---	92.4	13,991	15,828	---	88.4
	OCT	5,912	7,721	---	76.6	1,737	2,141	---	81.1	9,930	12,446	---	79.8	---	---	---	---	17,579	22,308	---	78.8
	NOV	7,994	10,164	---	78.7	11,663	16,207	---	72.0	---	---	---	---	5,506	7,893	---	69.8	25,163	34,264	---	73.4
	DEC	---	---	---	---	8,115	9,531	---	85.1	9,938	13,045	---	76.2	10,269	12,580	---	81.6	28,322	35,156	---	80.6
	TOTAL	49,780	64,163	348	77.2	49,680	65,656	---	75.7	59,473	73,571	1,640	79.1	83,642	103,855	---	80.5	242,575	307,245	1,988	78.4
2019	JAN	8,371	11,044	---	75.8	---	---	---	---	17,525	21,805	---	80.4	6,520	7,625	---	85.5	32,416	40,473	---	80.1
	FEB	2,468	3,149	111	75.7	10,091	13,191	---	76.5	6,383	8,042	---	79.4	4,531	5,858	56	76.6	23,473	30,240	167	77.2
	MAR	17,075	23,233	---	73.5	---	---	---	---	5,775	7,355	---	78.5	2,350	2,648	---	88.8	25,200	33,236	---	75.8
	APR	8,761	10,079	---	86.9	8,224	10,701	---	76.9	---	---	---	---	---	---	---	---	16,985	20,780	---	81.7
	MAY	---	---	---	---	---	---	---	---	---	---	---	---	11,479	15,561	---	73.8	11,479	15,561	---	73.8
	JUN	---	---	---	---	---	---	---	---	---	---	---	---	13,243	15,125	---	87.6	13,243	15,125	---	87.6
	JUL	---	---	---	---	---	---	---	---	---	---	---	---	12,927	15,734	---	82.2	12,927	15,734	---	82.2
	AUG	---	---	---	---	---	---	---	---	---	---	---	---	13,759	17,824	---	77.2	13,759	17,824	---	77.2
	SEP	---	---	---	---	905	3,665	---	24.7	---	---	---	---	12,530	12,163	---	103.0	13,435	15,828	---	84.9
	OCT	13,831	18,127	---	76.3	---	---	---	---	---	---	---	---	2,787	3,337	---	83.5	16,618	21,464	---	77.4
	NOV	6,652	9,003	---	73.9	---	---	---	---	17,163	24,712	---	69.5	---	---	---	---	23,815	33,715	---	70.6
	DEC	---	---	---	---	21,582	28,698	---	75.2	2,626	2,648	---	99.2	---	---	---	---	24,208	31,345	---	77.2
	TOTAL	57,158	74,634	111	76.5	40,802	56,255	---	72.5	49,472	64,561	---	76.6	80,126	95,874	56	83.5	227,558	291,325	167	78.1

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typically the only boiler operating. The following (Table No. 5) is the calculated boiler efficiency for each boiler based upon the monthly log data:

Boiler No.	2016 Boiler Eff (%)	2017 Boiler Eff (%)	2018 Boiler Eff (%)	2019 Boiler Eff (%)
1	78.2	77.1	77.2	76.5
2	73.0	77.6	75.7	72.5
3	85.6	77.0	79.1	76.6
4	80.4	81.5	80.5	83.5
Total	79.0	78.5	78.4	78.1

Table No. 5: Boiler System Efficiency Summary

For the energy model, the average boiler system efficiency of 78.1% will be utilized for the base option.

Existing Heating Loads

Hourly steam data from the Steam Plant was also reviewed for 2017 through 2019 to estimate an annual load profile for the site. The hourly steam generation over the 3-year period is presented in Figure No. 2.

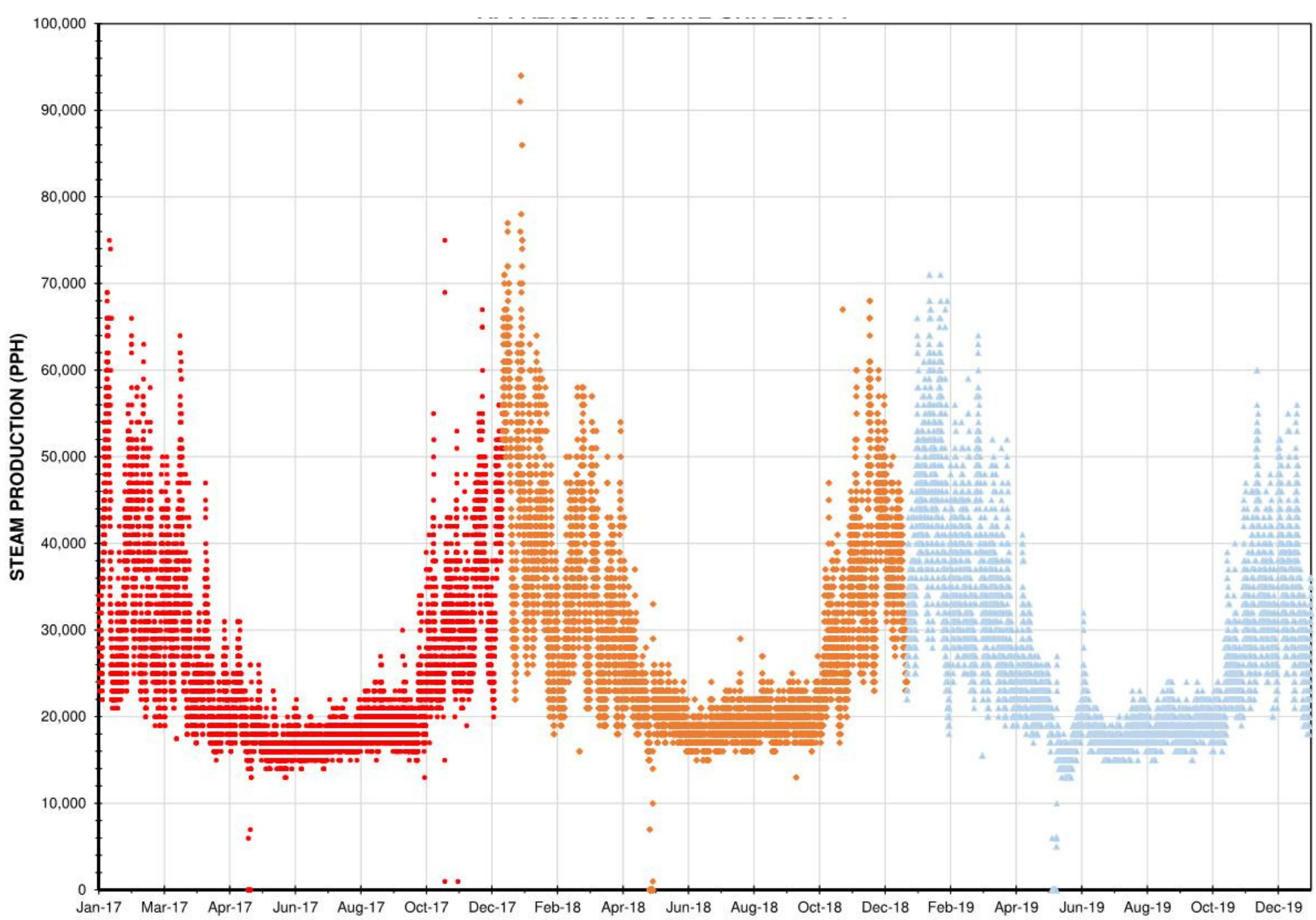

Figure No. 2: Annual Steam Production Summary

A graph of the hourly boiler output versus the ambient dry-bulb temperature is presented in Figure No. 3. The typical winter design dry-bulb temperature published by the ASHRAE for the Boone area is 10.5℉. At this design temperature the corresponding peak boiler load for the campus was approximately 70,000 pph. However, in the last three years there were approximately 150 hours where the dry-bulb temperature was lower than the design point. The peak load is approximately 80,000 pph at the low temperature conditions.

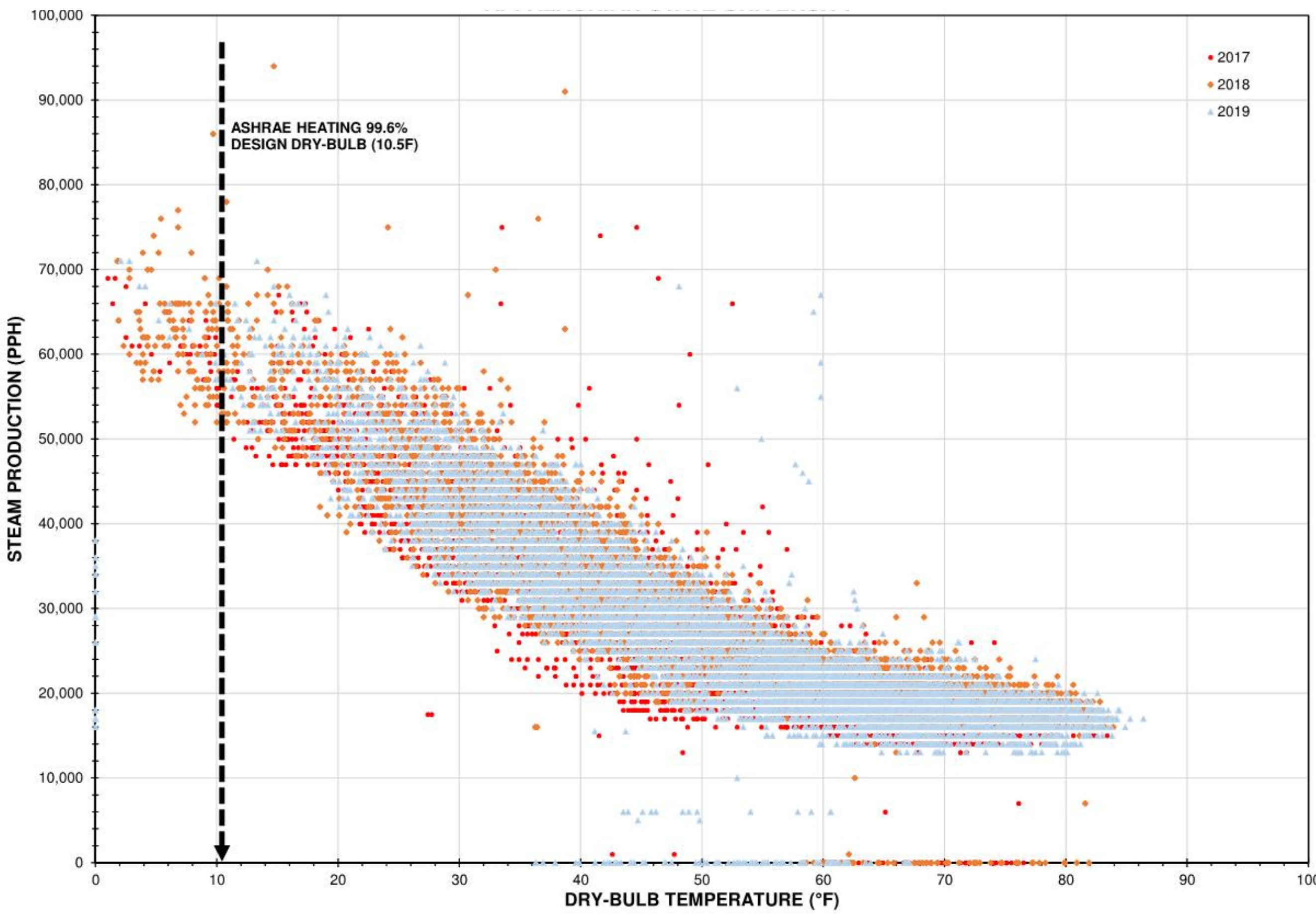

Figure No. 3: Annual Steam Production vs. Outdoor Air Temperature

When the dry-bulb temperature is above 40℉ the peak boiler operation is 40,000 pph with a minimum boiler operation of 15,000 pph.

Electric Boiler Options

The University was interested in understanding the capital costs, operating costs, life cycle costs, and carbon emissions for replacing one of the existing natural gas boilers with an electric boiler. The following evaluation considered the replacement of one of the 80,000 pph units with 20,000 pph, 40,000 pph, and 80,000 pph unit or two 40,000 pph units.

In order to estimate the annual costs for each option a computer model was developed to simulate the hourly plant operation. The model was based upon the load profile from 2019. The results of the energy modeling provide the annual natural gas and electric use and costs for each of the 25-years.

The electric boiler would be base loaded and would only not be operated for one day each month to ensure that the University would not be charged for the coincident peak demand. To match this assumption would require constant communication between NRLP and the University.

A second set of options considered if the University purchased renewable electricity. This would increase the energy costs but would reduce the carbon emissions to zero for the electric boiler operation. However, the University would need to purchase renewable electricity.

The annual operating costs were estimated for each year of anticipated operation for a total of 25 years. The projected annual costs were then converted to a present value utilizing a 2% escalation and 5% discount rate. Summing these values for each year, the total present value of the annual operating costs was developed.

The monthly annual operating cost for each option is presented in Appendix. Table No. 6 is a summary of the annual costs for each of the options:

OPTION NO.	DESCRIPTION	ANNUAL FUEL USAGE		FUEL COSTS			
		NATURAL GAS (MMBTU/YR)	ELECTRIC USAGE (KWH/YR)	NATURAL GAS ($/YR)	ELECTRIC COSTS ($/YR)	TOTAL COST ($/YR)	PV OF ANNUAL COSTS ($)
BASE	NAT. GAS ONLY	310,718	---	1,684,100	---	1,684,100	29,519,000
1A	20,000 PPH ELECTRIC BOILER	101,161	48,455,675	548,400	1,737,800	2,286,200	40,073,000
1B	40,000 PPH ELECTRIC BOILER	24,790	66,100,218	134,400	2,474,200	2,608,600	45,724,000
1C	80,000 PPH ELECTRIC BOILER	9,947	69,532,176	54,000	2,747,800	2,801,800	49,110,000
1D	(2) 40,000 PPH ELEC. BOILERS	9,947	69,532,176	54,000	2,747,800	2,801,800	49,110,000
2A	20,000 PPH ELECTRIC BOILER (RENEWABLE ELECTRIC)	101,161	48,455,675	548,400	2,319,400	2,867,800	50,267,000
2B	40,000 PPH ELECTRIC BOILER (RENEWABLE ELECTRIC)	24,790	66,100,218	134,400	3,267,400	3,401,800	59,627,000
2C	80,000 PPH ELECTRIC BOILER (RENEWABLE ELECTRIC)	9,947	69,532,176	54,000	3,582,100	3,636,100	63,734,000
2D	(2) 40,000 PPH ELEC. BOILERS (RENEWABLE ELECTRIC)	9,947	69,532,176	54,000	3,582,100	3,636,100	63,734,000

Table No. 6: Annual Operating Costs Comparison

There is no operating savings associated with the installation of an electric boiler. The unitary cost of electricity is higher than the unitary cost of natural gas.

Table No. 7 is a summary of the carbon emissions for each option and the potential cost per ton of carbon saved:

OPTION NO.	DESCRIPTION	ANNUAL FUEL USAGE		EMISSION FACTORS		
		NATURAL GAS (MMBTU/YR)	ELECTRIC USAGE (KWH/YR)	CO_2 EMISSIONS (TPY)	CO_2 SAVING (TPY)	ANNUAL COST OF CARBON ($/TON)
BASE	NAT. GAS ONLY	310,718	---	16,487	---	---
1A	20,000 PPH ELECTRIC BOILER	101,161	48,455,675	24,374	(7,887)	---
1B	40,000 PPH ELECTRIC BOILER	24,790	66,100,218	27,243	(10,756)	---
1C	80,000 PPH ELECTRIC BOILER	9,947	69,532,176	27,801	(11,314)	---
1D	(2) 40,000 PPH ELEC. BOILERS	9,947	69,532,176	27,801	(11,314)	---
2A	20,000 PPH ELECTRIC BOILER (RENEWABLE ELECTRIC)	101,161	48,455,675	5,368	11,119	106
2B	40,000 PPH ELECTRIC BOILER (RENEWABLE ELECTRIC)	24,790	66,100,218	1,315	15,172	113
2C	80,000 PPH ELECTRIC BOILER (RENEWABLE ELECTRIC)	9,947	69,532,176	528	15,959	122
2D	(2) 40,000 PPH ELEC. BOILERS (RENEWABLE ELECTRIC)	9,947	69,532,176	528	15,959	122

Table No. 7: Carbon Emission Comparison

Option No. 1 considers operating the electric boiler with the existing electrical supply, which is generated by fossil fuel burning facilities. There are no carbon emission savings when the electric is generated by fossil fuels. However, there are significant savings if the University were to purchase renewable electricity (Option No. 2).

For example, the carbon emission for the steam plant could be reduced by 92% if an 80,000 pph boiler is installed (Option 2C). When compared to natural gas, the increased annual cost for Option 2C is approximately $1.9 million per year. If in the future the state or federal government implements a carbon tax, and if the carbon tax was set to $122 per ton of carbon or greater, then Option 2C would cost the same as the natural gas option.

In 2018, the U.S. House of Representatives introduced a bill (HR 7173 Energy Innovation and Carbon Dividend Act) that would have a starting rate of $15 per ton in 2019 and increased by $10 each year until “progress is made to meeting specified emissions reduction targets”. This means by 2031, the tax could have been as high as $135 per ton. As of 2019, there are more than 40 governments worldwide that have adopted some sort of carbon pricing. For Canada, the current tax starts at $15 per ton and will rise up to $38 per ton by 2022. It is not typical for the carbon tax to be over $100 per ton, but there is a potential in future for this to occur

Capital Costs Development

Capital improvement costs for each option were developed based on the replacement of Boiler #3 based on feedback from Appalachian State staff. Boilers 1, 2, and 3 all have similar footprints and either could be replaced with an electrode boiler. To simplify layout options, only Option C and D are indicated graphically as they each represent the largest footprint. Options A & B would have similar installations with smaller boiler footprints.

Figure Nos. 4 and 5 show plan and section of Option C (80,000 PPH electrode boiler). The boiler will be installed through the removable storefront windows and utilizing the footprint of the demolished natural gas boiler have adequate clearances for operation and maintenance. Option D (installation of two 40,000 pph electrode boiler) is presented in Figure Nos 6 and 7. Again, the footprint of the natural gas boiler allows both units to be installed with adequate clearances. In the case of Option D the boilers could be installed together or over two phases.

Boiler prices were quoted from four manufacturers. There is a large spread of pricing and the lowest of the four was considered for the purposes of this study. First cost as quoted by the various manufacturers are summarized in Table No. 8.

	MANUFACTURER			
SIZE	**CLEAVER-BROOKS**	**VAPOR POWER**	**ACME**	**PRECISION**
20K PPH	$280,000	---	$560,000	$830,000
40K PPH	$410,000	$510,000	$840,000	$945,000
80K PPH	$530,000	$925,000	$1,176,000	$1,650,000

Table No. 8: Boiler Pricing Comparison

Power from the campus substation to the boiler plant is being provided by Appalachian State and NRLP. NRLP has spare conduits that can support up to ~12MW (40,000 PPH) to the plant and would need to install new conduit & update switchgear if a 24 MW (80,000 PPH) unit were installed. Cost for conduit, switchgear modifications and wiring from the NRLP substation to the boiler plant are not included in the capital cost summary. Capital costs do include a new metal-clad switchgear, conduit, wiring and all electrical work within the boiler plant.

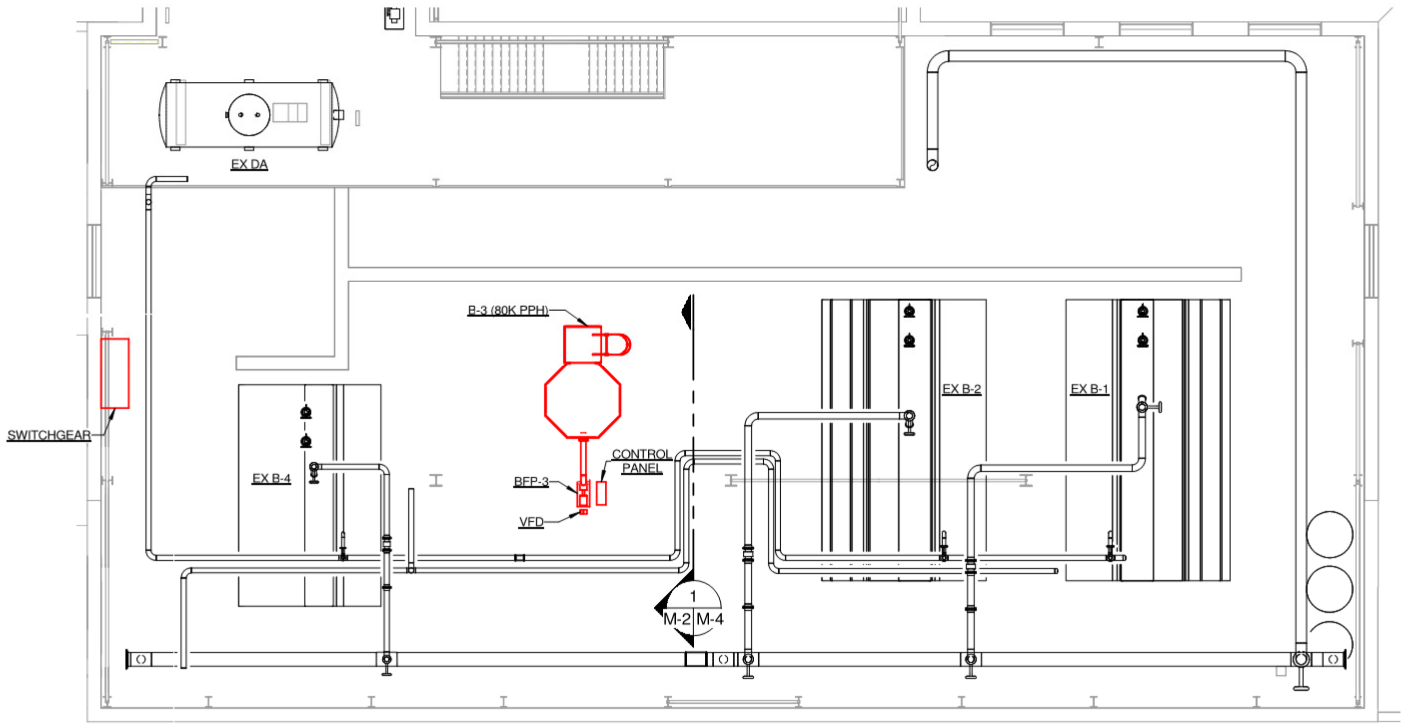

Figure No. 4: 80,000 PPH Electric Boiler Layout

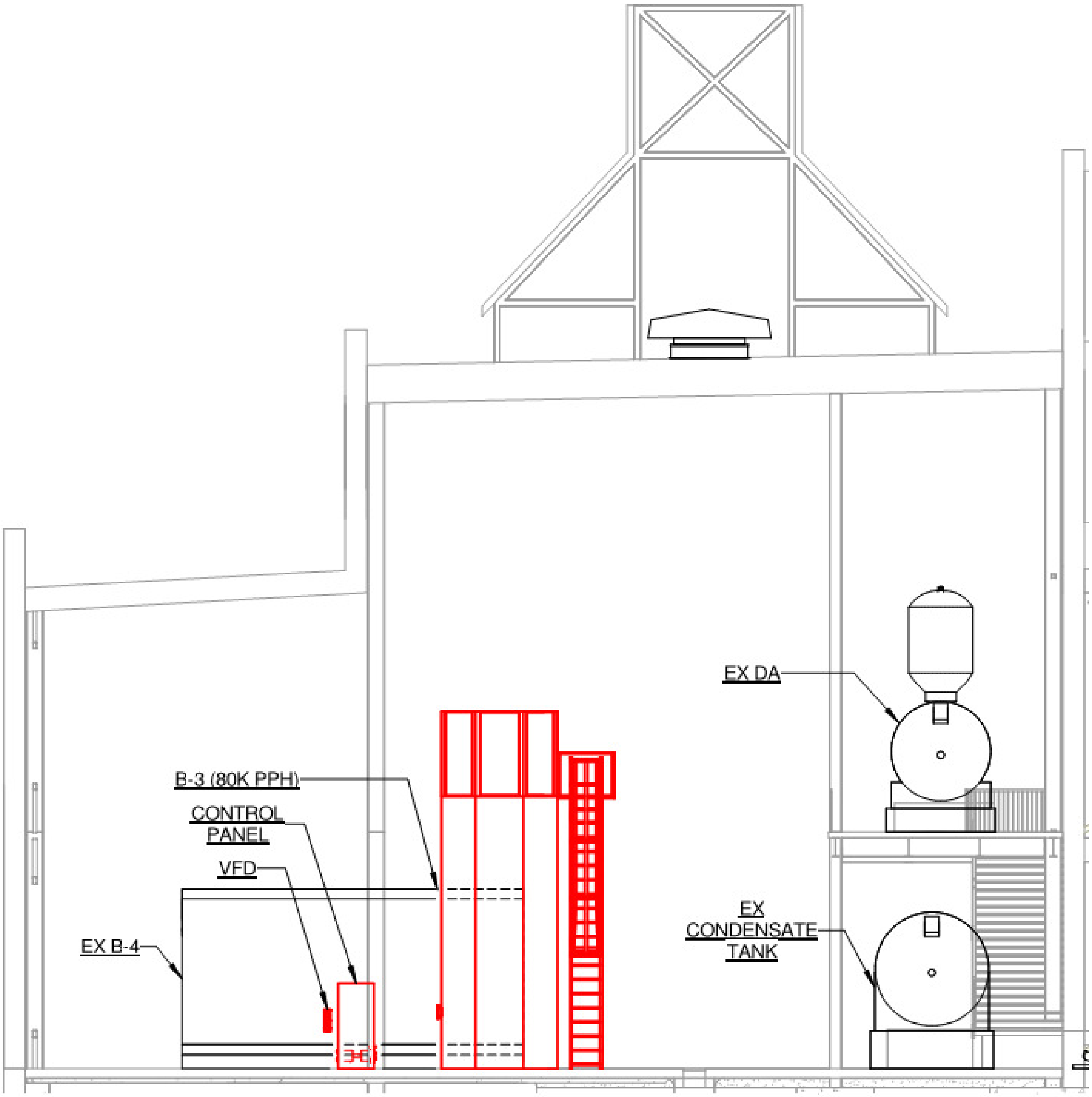

Figure No. 5: 80,000 PPH Electric Boiler Section View

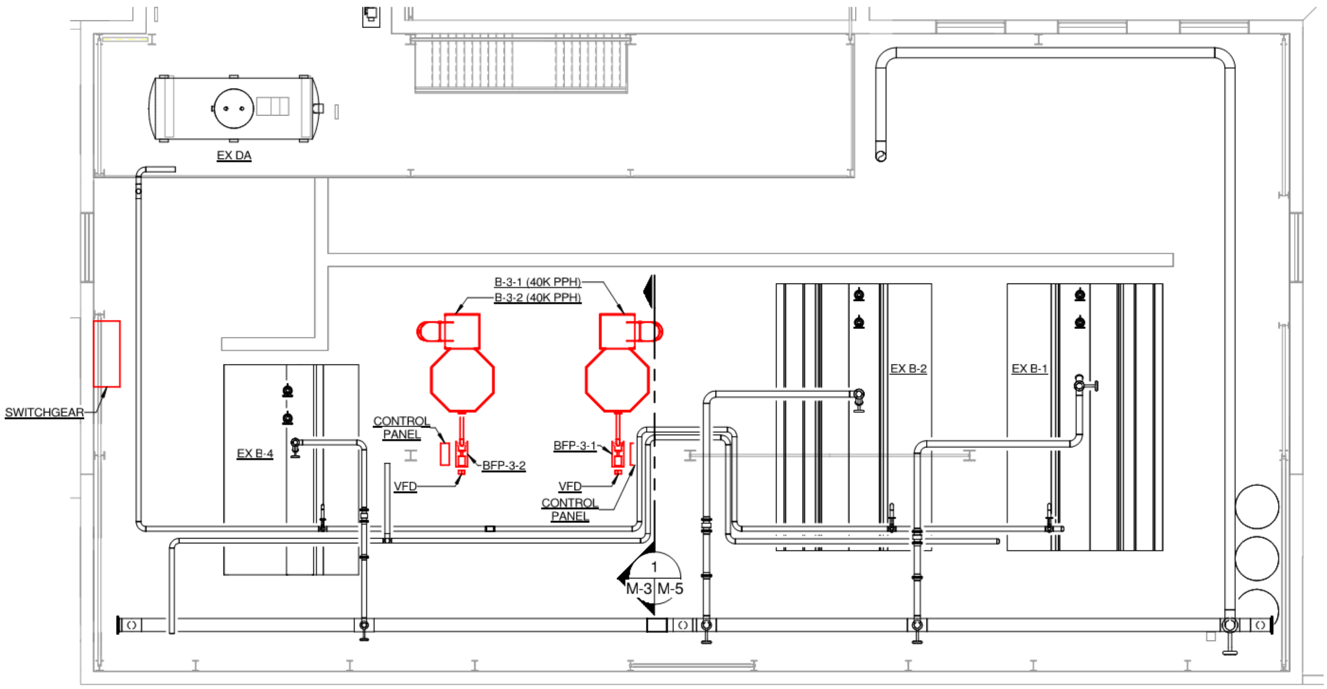

Figure No. 6: (2) 40,000 PPH Electric Boilers Layout

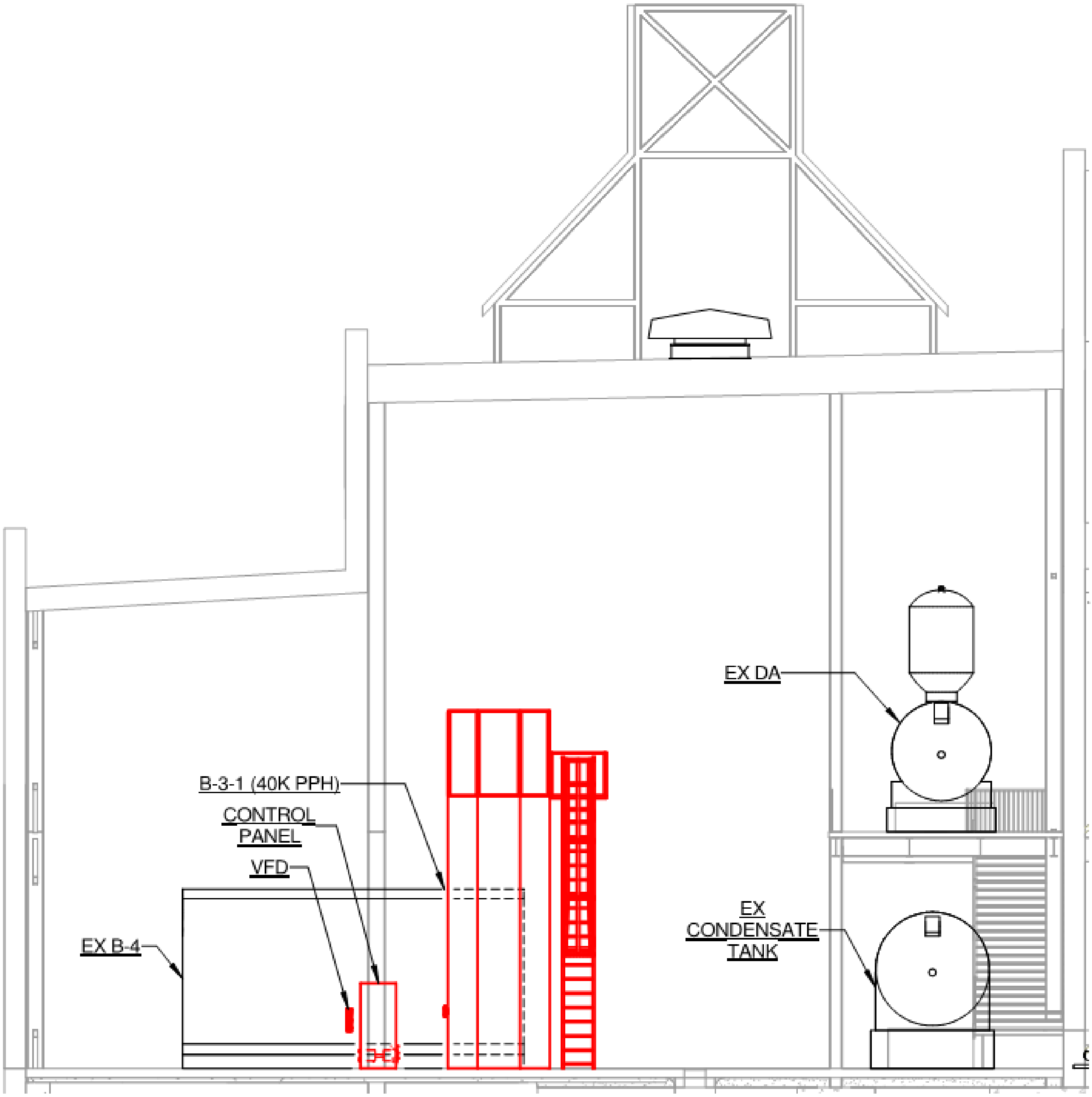

Figure No. 7: (2) 40,000 PPH Electric Boiler Section View

Life Cycle Costs Analysis

The estimated capital cost was added to the present value of annual operating costs to sum a total present value of life cycle costs for each option. A summary of the first year operating costs as well as the present value of the operating costs over the 25-year period is presented in Table No. 9.

Option	Fuel	Capital Costs ($Million)	Total Fuel Costs ($M/yr)	25-year Present Value Of Annual Costs ($Million)	Total Present Value ($Million)	Diff (%)
Base	Nat. Gas	5.2	1.7	29.5	34.7	---
1A	Utility Electric	1.7	2.3	40.1	41.6	-20
1B		2.2	2.6	45.7	47.8	-37
1C		2.5	2.8	49.1	51.5	-48
1D		3.3	2.8	49.1	52.3	-51
2A	Renewable Electric	1.7	2.9	50.3	51.8	-49
2B		2.2	3.4	59.6	61.7	-77
2C		2.5	3.6	63.7	66.1	-91
2D		3.3	3.6	63.7	66.9	-93

Table No. 9: Total Present Value Comparison

Electric Sensitivity

A comparison of the present value for each of the options are varying electric rates is presented in Figure No. 8

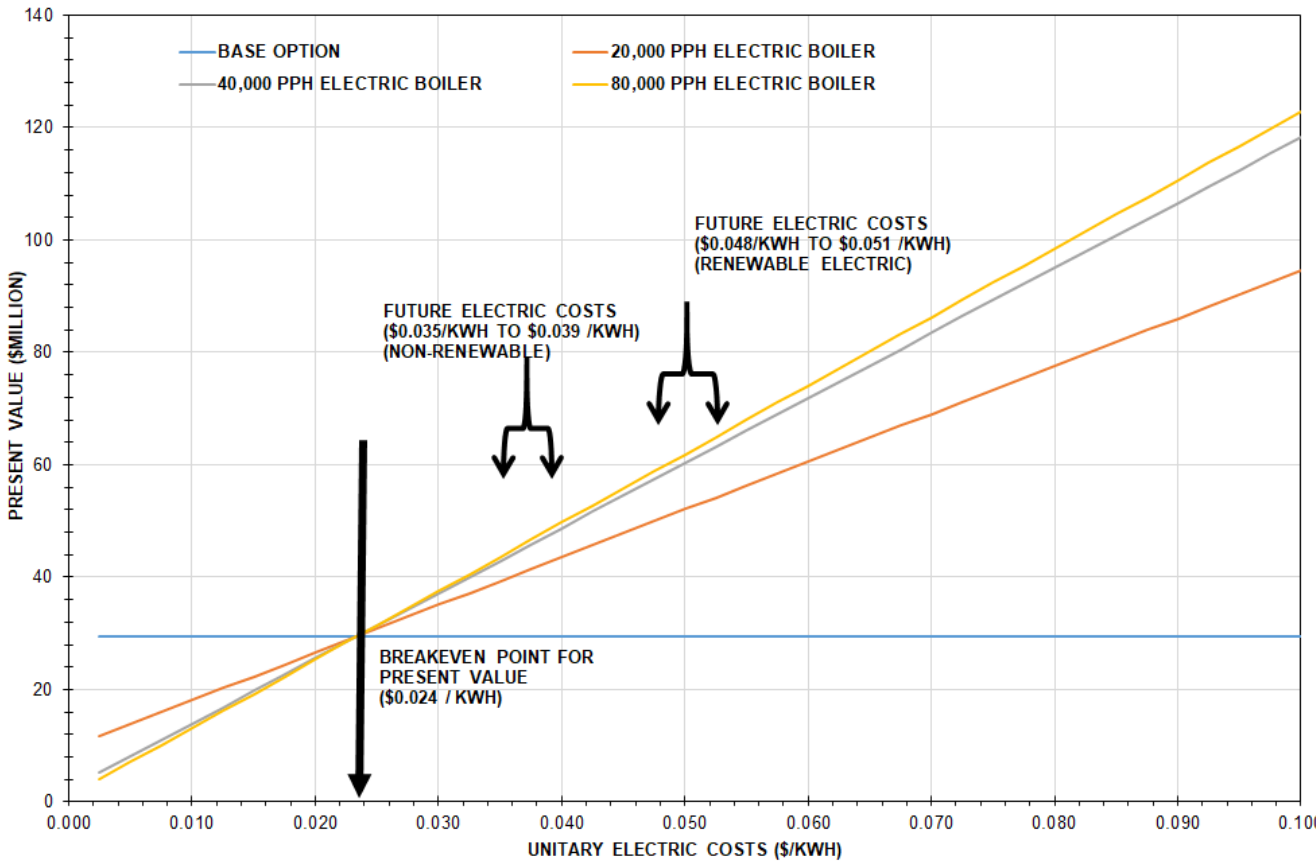

Figure No. 8: Electric Sensitivity

If electricity unitary rates are reduced to $0.024 /kWh then the options would be considered economically equivalent.

Biofuel Analysis

To reduce the carbon emissions, the University also wanted to evaluate utilizing biofuels instead of natural gas. The current boiler plant utilizes natural gas and No. 2 fuel oil as the source for heating. In order to utilize a solid fuel (biomass), it would require new boilers and fuel handling equipment. This could be two to three times the cost of a packaged natural gas boiler. The University would also have to allocate space for additional outdoor fuel storage and handling. For these reason solid fuels were not considered in this analysis and this study concentrated on liquid biofuels.

When evaluating the carbon emission for the biofuels, the biogenic carbon and the total carbon emissions were identified. Biogenic carbon dioxide emissions are defined as emissions directly resulting from the combustion or decomposition of biologically-based materials other than fossil fuels. The carbon emission from fossil fuels releases carbon that would be in the ground, while burning a biofuel emits carbon that is part of the biogenic cycle.

Biodiesel is made primarily from oily plants (such as the soybean or oil palm) and to a lesser extent from other oily sources (such as waste cooking fat from restaurant deep-frying). The majority of the biodiesel utilized within boiler plants are mixed with No.2 fuel oil. To reduce issues with the existing operation and the need to replace burners, the biodiesel would only make up 20% of the fuel (B20). Because of this, there is not a significant emissions savings with the use of B20 fuel and was not considered in this analysis.

Pure biodiesel (B100) is corrosive to brass, bronze, and copper and it mildly corrosive to carbon steel. The University could utilize 100% biodiesel (B99 or B100), but this would require investment in the plant. Due to the viscosity of the fuel, the heating and steam atomization is required to ensure that it can be pumped, filtered, and atomized. Steam heaters, electric heaters, heat tracing, insulated pipe, as well as proper burner fuel train construction will be required to ensure biodiesel of adequate viscosity is delivered to the oil burner.

Biodiesel absorbs water and this can lead to sludge 30 times faster than diesel fuel. If the tanks are vented to atmosphere there is a potential for water to condense on the tanks and be absorbed by the fuel, which will lead to sludge formation. Frequent filtration and de-watering is required to prevent biologic degradation. The fuel has a shelf life of approximately 6 months.

Biodiesel Residual Oil (BRO) (Heavy Esters) operates similar to No. 6 fuel oil. It is produced as a byproduct of the biodiesel process. With regards to upgrades, has the same requirements as biodiesel and potentially require upgrades to seals and gaskets and will require the installation of heater for the fuel.

Renewable Fuel Oil (RFO) is usually made from commercial tree farm trimmings. A pyrolysis process is used to convert the wood waste into a liquid fuel that has about 70% of the heating value by volume as diesel fuel and a pH of about 2.5. This requires the replacement of the all carbon steel fuel oil system to a stainless steel system. The fuel competes with No. 6 fuel oil and only currently commercially available from ENSYN Technologies.

Renewable Natural Gas (RNG) would operate the same as the existing boiler system on natural gas. There are no changes to the existing plant or operation needed. Sources of the RNG is animal waste, crop residuals, food waste, wastewater treatment plants, and landfills. A third party would operate a digester that would inject the biogas into the natural gas pipeline. This is similar to how solar farms operate today. A solar farm is plugged into the electrical distribution system, but may not be located a University campus. The University has paid for the electricity from the farm, but is not directly tied into their system.

The cost of renewable natural gas can swing dramatically depending on the source of the gas. The unitary cost can be as high as $25 to $30 per million British Thermal Units (mmbtu). This renewable natural gas cost is based the University procuring a long-term contract (15+ years) to have a third party provide gas from a newly constructed anaerobic digester system. This will guarantee the University the availability of this gas for 20-years. An alternative to a long term contract, the University can purchase the renewable natural gas at market value. These costs can swing dramatically based upon the availability of gas in the region. Currently, NRLP is evaluating purchasing renewable natural gas (landfill gas) from the market and have been able to receive quotes for around 5% higher than natural gas.

The following is a comparison of the liquid biofuels evaluated:

Biofuel	Higher Heating Value (btu/gal)	Capital Costs ($)	Fuel Cost ($/mmbtu)	Biogenic CO_2 Factor (lb/mmbtu)	Total CO_2 Factor (lb/mmbtu)
Nat. Gas	---	---	5.42	N/A	117.1
B100	127,960	200,000	15-20	162.8	162.9
BRO	137,900	200,000	17-22	162.8	162.9
RFO	78,000	3.0 million	19-23	162.8	162.9
RNG	---	---	6-30	114.8	115.3

Table No. 10: Biofuels Comparison

If the University were to exclude the biogenic carbon emission factors from the fuels, then the biofuels listed above are close to carbon neutral. However, if the University does not exclude the biogenic carbon factors, then only the Renewable Natural Gas has a lower carbon footprint than natural gas. The savings in carbon emissions is only 2%, but the cost is anywhere from 5% to 500% that of natural gas.

Appendix Items

Appendix No. 1 – Natural Gas Bills (2016-2019)

MONTHLY NATURAL GAS BILL SUMMARY (2016-2019)

APPALACHIAN STATE UNIVERSITY

YEAR	MONTH	USAGE SUMMARY			COSTS				
		FRONTIER CONSUM. (DTHERMS)	TRANSPORT CONSUM. (DTHERMS)	AVERAGE USAGE (MMTBU)	FRONTIER COSTS ($/YR)	TRANSPORT CONSUM. ($/YR)	TOTAL COSTS ($/YR)	UNITARY COSTS ($/MMBTU)	12-MONTH UNITARY COSTS ($/MMBTU)
2016	JAN	42,297	37,628	41,281	67,941	149,870	217,811	5.28	
	FEB	37,892	37,880	39,136	60,893	127,050	187,942	4.80	
	MAR	26,519	26,624	27,448	42,697	82,763	125,460	4.57	
	APR	23,231	23,209	23,986	37,436	71,205	108,641	4.53	
	MAY	16,809	16,805	17,362	27,161	53,506	80,667	4.65	
	JUN	15,608	15,601	16,119	25,239	48,800	74,039	4.59	
	JUL	15,229	15,226	15,730	24,632	63,446	88,078	5.60	
	AUG	16,052	16,059	16,585	25,950	62,270	88,219	5.32	
	SEP	16,054	16,066	16,590	25,953	66,727	92,680	5.59	
	OCT	19,035	19,026	19,658	30,722	82,897	113,619	5.78	
	NOV	25,567	25,572	26,413	41,173	105,338	146,511	5.55	
	DEC	32,409	32,401	33,474	52,121	142,212	194,333	5.81	
	TOTAL	286,701	282,097	293,784	461,916	1,056,084	1,518,000	5.17	
2017	JAN	32,346	32,035	33,253	51,525	163,218	214,743	6.46	5.30
	FEB	27,577	27,548	28,472	44,389	131,055	175,445	6.16	5.46
	MAR	28,654	28,658	29,601	46,112	108,671	154,783	5.23	5.52
	APR	19,630	19,800	20,366	31,674	85,421	117,095	5.75	5.63
	MAY	17,293	17,294	17,864	27,935	74,485	102,420	5.73	5.70
	JUN	14,476	14,471	14,951	23,427	63,687	87,114	5.83	5.77
	JUL	15,596	15,598	16,112	25,219	66,809	92,028	5.71	5.78
	AUG	16,467	16,463	17,008	25,895	68,297	94,192	5.54	5.79
	SEP	16,613	16,606	17,158	26,847	70,240	97,087	5.66	5.79
	OCT	20,843	20,848	21,534	33,615	89,745	123,360	5.73	5.79
	NOV	26,217	26,185	27,066	42,214	102,567	144,780	5.35	5.77
	DEC	34,878	34,864	36,022	56,071	142,869	198,939	5.52	5.73
	TOTAL	270,590	270,370	279,406	434,924	1,167,064	1,601,988	5.73	---
2018	JAN	40,520	40,499	41,846	65,098	163,708	228,805	5.47	5.61
	FEB	25,773	25,743	26,608	41,502	126,471	167,973	6.31	5.62
	MAR	32,128	32,140	33,194	51,670	122,261	173,931	5.24	5.62
	APR	24,739	24,739	25,556	39,849	95,394	135,243	5.29	5.58
	MAY	17,723	17,733	18,313	28,623	70,684	99,306	5.42	5.56
	JUN	16,471	16,479	17,019	26,620	66,575	93,195	5.48	5.54
	JUL	17,473	17,480	18,053	28,224	72,734	100,958	5.59	5.54
	AUG	18,265	18,272	18,871	29,490	72,850	102,341	5.42	5.53
	SEP	17,815	17,816	18,403	28,770	72,540	101,310	5.51	5.52
	OCT	21,457	21,463	22,168	34,597	91,805	126,401	5.70	5.52
	NOV	31,372	31,356	32,399	50,462	136,399	186,860	5.77	5.56
	DEC	34,913	34,880	36,048	56,127	205,094	261,221	7.25	5.76
	TOTAL	298,648	298,600	308,479	481,031	1,296,514	1,777,545	5.76	---
2019	JAN	39,588	39,554	40,877	63,607	190,136	253,743	6.21	5.86
	FEB	28,763	28,744	29,702	46,287	119,582	165,868	5.58	5.80
	MAR	30,393	30,378	31,388	48,896	122,620	171,515	5.46	5.82
	APR	21,678	21,667	22,387	34,950	84,930	119,880	5.35	5.83
	MAY	15,128	15,117	15,621	24,471	58,757	83,228	5.33	5.83
	JUN	16,715	16,711	17,265	27,010	65,159	92,169	5.34	5.82
	JUL	16,218	16,223	16,756	26,215	61,175	87,390	5.22	5.80
	AUG	17,333	17,335	17,906	27,995	63,922	91,916	5.13	5.79
	SEP	16,905	16,912	17,467	27,315	63,282	90,597	5.19	5.77
	OCT	20,740	20,729	21,419	33,450	78,231	111,682	5.21	5.73
	NOV	27,882	27,881	28,802	44,877	104,972	149,849	5.20	5.68
	DEC	31,377	31,359	32,403	50,470	113,452	163,921	5.06	5.42
	TOTAL	282,720	282,610	291,993	455,543	1,126,216	1,581,759	5.42	---

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Appendix No. 2 – Electric Demand and Usage Summary (2016-2019)

ELECTRIC DEMAND AND USAGE SUMMARY (2016-2019)
APPALACHIAN STATE UNIVERSITY

YEAR	MONTH	ACTUAL CAMPUS METER USAGE				OTHER DEMANDS		
		METER PEAK DEMAND (KW)	ELECTRICAL USAGE (KWH)	EQUIVALENT FULL LOAD HOURS (EFLH)	AVERAGE (KW)	CAMPUS DEMAND AT NRLP PEAK DEMAND (KW)	CAMPUS DEMAND AT TRANSMISSION PEAK DEMAND (KW)	CAMPUS DEMAND AT GENERATION PEAK DEMAND (KW)
2016	JAN	7,322	3,776,456		5,076	6,947	6,072	6,072
	FEB	7,187	3,830,931		5,504	6,409	5,903	5,903
	MAR	7,524	3,736,669		5,022	6,344	5,716	5,716
	APR	8,535	4,112,277		5,711	5,223	4,355	8,333
	MAY	8,385	3,892,268		5,232	7,685	5,295	7,368
	JUN	8,198	4,334,647		6,020	8,159	7,738	7,750
	JUL	8,722	4,820,668		6,479	8,126	8,022	7,990
	AUG	10,154	5,286,493		7,106	9,798	9,293	9,526
	SEP	9,733	5,125,174		7,118	9,584	9,332	9,714
	OCT	8,930	4,325,348		5,814	---	4,906	8,671
	NOV	8,755	3,808,288		5,289	6,299	5,547	5,450
	DEC	6,519	3,114,699		4,186	5,696	4,679	4,679
	TOTAL	---	50,163,918	4,940	5,711	---	---	---
2017	JAN	6,726	3,449,215		4,636	4,251	4,323	4,919
	FEB	6,772	3,488,332		5,191	5,975	4,523	5,521
	MAR	7,582	3,749,060		5,039	4,938	4,828	4,932
	APR	8,340	4,007,555		5,566	6,079	5,372	7,413
	MAY	8,528	3,957,473		5,319	7,822	6,402	6,338
	JUN	7,945	4,063,900		5,644	7,679	7,057	7,685
	JUL	8,444	4,647,679		6,247	8,068	7,685	7,854
	AUG	10,135	4,862,387		6,535	10,109	9,312	8,917
	SEP	9,513	4,665,592		6,480	9,429	9,053	9,325
	OCT	10,096	4,407,176		5,924	6,493	6,079	8,547
	NOV	8,327	3,772,753		5,240	5,437	5,534	5,534
	DEC	7,057	3,394,289		4,562	5,806	4,102	5,806
	TOTAL	---	48,465,411	4,782	5,533	---	---	---
2018	JAN	6,927	3,726,166		5,008	6,169	5,100	5,100
	FEB	8,139	3,708,263		5,518	5,884	4,711	4,711
	MAR	7,420	3,746,866		5,036	6,616	4,841	5,839
	APR	7,750	3,830,563		5,320	6,059	5,696	5,696
	MAY	8,120	4,359,389		5,859	7,835	6,590	6,590
	JUN	8,859	4,509,990		6,264	8,709	8,055	8,619
	JUL	8,768	4,804,749		6,458	8,509	8,133	8,262
	AUG	10,336	5,130,511		6,896	10,187	8,774	9,798
	SEP	10,258	5,219,852		7,250	9,811	9,759	9,811
	OCT	9,545	4,490,942		6,036	9,481	5,891	9,105
	NOV	7,329	3,704,572		5,145	6,364	5,728	5,728
	DEC	6,772	3,303,861		4,441	6,137	5,716	5,716
	TOTAL	---	50,535,724	4,890	5,769	---	---	---
2019	JAN	6,915	3,650,533		4,907	5,171	5,074	5,884
	FEB	6,876	3,473,292		5,169	6,111	5,722	5,722
	MAR	7,057	3,640,287		4,893	5,230	5,061	5,061
	APR	8,509	3,968,756		5,512	6,046	5,418	8,366
	MAY	8,638	4,163,864		5,597	7,770	7,225	7,595
	JUN	8,159	4,091,772		5,683	8,126	7,206	7,970
	JUL	8,392	4,628,946		6,222	8,185	7,647	8,146
	AUG	10,109	4,902,482		6,589	10,109	8,211	8,807
	SEP	10,232	4,161,685		5,780	9,811	---	9,565
	OCT	9,668	4,365,076		5,867	9,299	9,079	9,079
	NOV	7,018	3,532,438		4,906	6,027	5,716	5,716
	DEC	6,552	3,105,095		4,174	6,046	4,873	4,180
	TOTAL	---	47,684,226	4,661	5,443	---	---	---

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Appendix No. 3 – Annual Operating Costs

ANNUAL OPERATING COSTS SUMMARY - BASE OPTION (NO ELECTRIC BOILERS)

APPALACHIAN STATE UNIVERSITY

MONTH	CAMPUS LOAD				BOILER PROD. SUMMARY			NATURAL GAS BILL		PLANT ELECTRIC BILL				TOTAL ANNUAL COSTS ($/YR)
	PEAK STEAM (PPH)	STEAM PROD (MLBS)	PEAK CAMPUS DEMAND (KW)	CAMPUS USAGE (KWH)	ELECTRIC BOILER (MLBS)	NAT. GAS BOILER (MLBS)	TOTAL STEAM PRODUCED (MLBS)	NAT. GAS USAGE (MMBTU)	NAT GAS COSTS ($/YR)	COINC. PEAK DEMAND (KW)	NON-COINC PEAK DEMAND (KW)	TOTAL ELECTRIC USAGE (KWH)	COST ($/YR)	
JAN	77,000	34,049	6,927	3,726,541	---	34,049	34,049	43,607	236,300	---	---	---	---	236,300
FEB	60,000	21,893	8,139	3,709,493	---	21,893	21,893	28,019	151,900	---	---	---	---	151,900
MAR	58,000	26,177	7,420	3,747,797	---	26,177	26,177	33,512	181,600	---	---	---	---	181,600
APR	54,000	19,944	7,750	3,831,548	---	19,944	19,944	25,533	138,400	---	---	---	---	138,400
MAY	33,000	14,152	8,120	4,359,628	---	14,152	14,152	18,116	98,200	---	---	---	---	98,200
JUN	24,000	13,398	9,172	4,509,981	---	13,398	13,398	17,159	93,000	---	---	---	---	93,000
JUL	24,000	13,711	9,210	4,804,762	---	13,711	13,711	17,541	95,100	---	---	---	---	95,100
AUG	29,000	14,412	10,336	5,130,992	---	14,412	14,412	18,440	99,900	---	---	---	---	99,900
SEP	25,000	14,000	10,424	5,219,860	---	14,000	14,000	17,926	97,200	---	---	---	---	97,200
OCT	47,000	17,559	9,545	4,492,991	---	17,559	17,559	22,479	121,800	---	---	---	---	121,800
NOV	68,000	25,026	7,329	3,705,325	---	25,026	25,026	32,044	173,700	---	---	---	---	173,700
DEC	60,000	28,390	6,772	3,304,706	---	28,390	28,390	36,342	197,000	---	---	---	---	197,000
TOTAL	---	242,711	---	50,543,624	---	242,711	242,711	310,718	1,684,100	---	---	---	---	1,684,100

<u>NOTES</u>: 1. BOILER EFFICIENCY BASED UPON THE FOLLOWING FACTORS

NAT. GAS BOILER: 78% BASED UPON EXISTING BOILER EFFICIENCY

ELECTRIC BOILER: 99%

2. NATURAL GAS BASED UPON THE FOLLOWING UTILITY RATE (2019 NATURAL GAS BILLS)

NAT. GAS RATE $5.42 /MMBTU

3. ELECTRIC COSTS BASED UPON THE FOLLOWING NEW RIVER LIGHT AND POWER (NRLP) FACTORS (SCHEDULE A - APPALACHIAN STATE UNIVERSITY)

COINCIDENT PEAK DEMAND: $15.00 /KW

NON-COINCIDENT PEAK DEMAND: $4.00 /KW

ENERGY RATE $0.030000 /KWH

ENERGY RATE RENEWABLE $0.042000 /KWH (RENEWABLE - PROVIDED BY NRLP)

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RMF 23 JUN 2020

ANNUAL OPERATING COSTS SUMMARY - OPTION NO. 1A (20,000 PPH ELECTRIC BOILERS)

APPALACHIAN STATE UNIVERSITY

	CAMPUS LOAD				BOILER PROD. SUMMARY			NATURAL GAS BILL		PLANT ELECTRIC BILL				
MONTH	PEAK STEAM (PPH)	STEAM PROD (MLBS)	PEAK CAMPUS DEMAND (KW)	CAMPUS USAGE (KWH)	ELECTRIC BOILER (MLBS)	NAT. GAS BOILER (MLBS)	TOTAL STEAM PRODUCED (MLBS)	NAT. GAS USAGE (MMBTU)	NAT GAS COSTS ($/YR)	COINC. PEAK DEMAND (KW)	NON-COINC PEAK DEMAND (KW)	TOTAL ELECTRIC USAGE (KWH)	COST ($/YR)	TOTAL ANNUAL COSTS ($/YR)
JAN	77,000	34,049	6,927	3,726,541	14,400	19,649	34,049	25,158	136,400	---	5,919	4,261,680	151,500	287,900
FEB	60,000	21,893	8,139	3,709,493	12,950	8,943	21,893	11,464	62,100	---	5,919	3,832,552	138,700	200,800
MAR	58,000	26,177	7,420	3,747,797	14,391	11,786	26,177	15,088	81,800	---	5,919	4,259,016	151,400	233,200
APR	54,000	19,944	7,750	3,831,548	13,877	6,067	19,944	7,786	42,200	---	5,919	4,106,896	146,900	189,100
MAY	33,000	14,152	8,120	4,359,628	12,808	1,344	14,152	1,729	9,400	---	5,919	3,790,515	137,400	146,800
JUN	24,000	13,398	9,172	4,509,981	12,785	613	13,398	784	4,200	---	5,919	3,783,664	137,200	141,400
JUL	24,000	13,711	9,210	4,804,762	13,198	513	13,711	652	3,500	---	5,919	3,905,888	140,900	144,400
AUG	29,000	14,412	10,336	5,130,992	13,691	721	14,412	915	5,000	---	5,919	4,051,816	145,200	150,200
SEP	25,000	14,000	10,424	5,219,860	13,236	764	14,000	976	5,300	---	5,919	3,917,160	141,200	146,500
OCT	47,000	17,559	9,545	4,492,991	14,083	3,476	17,559	4,477	24,300	---	5,919	4,167,848	148,700	173,000
NOV	68,000	25,026	7,329	3,705,325	13,911	11,115	25,026	14,222	77,100	---	5,919	4,116,960	147,200	224,300
DEC	60,000	28,390	6,772	3,304,706	14,400	13,990	28,390	17,910	97,100	---	5,919	4,261,680	151,500	248,600
TOTAL	---	242,711	---	50,543,624	163,730	78,981	242,711	101,161	548,400	---	---	48,455,675	1,737,800	2,286,200

NOTES: 1. BOILER EFFICIENCY BASED UPON THE FOLLOWING FACTORS

NAT. GAS BOILER: 78% BASED UPON EXISTING BOILER EFFICIENCY

ELECTRIC BOILER: 99%

2. NATURAL GAS BASED UPON THE FOLLOWING UTILITY RATE (2019 NATURAL GAS BILLS)

NAT. GAS RATE $5.42 /MMBTU

3. ELECTRIC COSTS BASED UPON THE FOLLOWING NEW RIVER LIGHT AND POWER (NRLP) FACTORS (SCHEDULE A - APPALACHIAN STATE UNIVERSITY)

COINCIDENT PEAK DEMAND: $15.00 /KW

NON-COINCIDENT PEAK DEMAND: $4.00 /KW

ENERGY RATE $0.030000 /KWH

ENERGY RATE RENEWABLE $0.042000 /KWH (RENEWABLE - PROVIDED BY NRLP)

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RMF 23 JUN 2020

ANNUAL OPERATING COSTS SUMMARY - OPTION NO. 1B (40,000 PPH ELECTRIC BOILERS)

APPALACHIAN STATE UNIVERSITY

MONTH	CAMPUS LOAD				BOILER PROD. SUMMARY			NATURAL GAS BILL		PLANT ELECTRIC BILL				TOTAL ANNUAL COSTS ($/YR)
	PEAK STEAM (PPH)	STEAM PROD (MLBS)	PEAK CAMPUS DEMAND (KW)	CAMPUS USAGE (KWH)	ELECTRIC BOILER (MLBS)	NAT. GAS BOILER (MLBS)	TOTAL STEAM PRODUCED (MLBS)	NAT. GAS USAGE (MMBTU)	NAT GAS COSTS ($/YR)	COINC. PEAK DEMAND (KW)	NON-COINC PEAK DEMAND (KW)	TOTAL ELECTRIC USAGE (KWH)	COST ($/YR)	
JAN	77,000	34,049	6,927	3,726,541	27,019	7,030	34,049	8,989	48,700	---	11,838	7,996,347	287,200	335,900
FEB	60,000	21,893	8,139	3,709,493	20,171	1,722	21,893	2,199	11,900	---	11,838	5,969,715	226,400	238,300
MAR	58,000	26,177	7,420	3,747,797	23,885	2,292	26,177	2,939	15,900	---	11,838	7,068,891	259,400	275,300
APR	54,000	19,944	7,750	3,831,548	19,162	782	19,944	1,007	5,500	---	11,838	5,671,164	217,500	223,000
MAY	33,000	14,152	8,120	4,359,628	13,722	430	14,152	546	3,000	---	9,767	4,061,059	160,900	163,900
JUN	24,000	13,398	9,172	4,509,981	12,905	493	13,398	634	3,400	---	7,103	3,819,184	143,000	146,400
JUL	24,000	13,711	9,210	4,804,762	13,276	435	13,711	555	3,000	---	7,103	3,928,976	146,300	149,300
AUG	29,000	14,412	10,336	5,130,992	13,977	435	14,412	556	3,000	---	8,583	4,136,472	158,400	161,400
SEP	25,000	14,000	10,424	5,219,860	13,530	470	14,000	602	3,300	---	7,399	4,004,184	149,700	153,000
OCT	47,000	17,559	9,545	4,492,991	17,035	524	17,559	675	3,700	---	11,838	5,041,610	198,600	202,300
NOV	68,000	25,026	7,329	3,705,325	22,779	2,247	25,026	2,876	15,600	---	11,838	6,741,574	249,600	265,200
DEC	60,000	28,390	6,772	3,304,706	25,886	2,504	28,390	3,212	17,400	---	11,838	7,661,042	277,200	294,600
TOTAL	---	242,711	---	50,543,624	223,347	19,364	242,711	24,790	134,400	---	---	66,100,218	2,474,200	2,608,600

<u>NOTES</u>: 1. BOILER EFFICIENCY BASED UPON THE FOLLOWING FACTORS

NAT. GAS BOILER: 78% BASED UPON EXISTING BOILER EFFICIENCY

ELECTRIC BOILER: 99%

2. NATURAL GAS BASED UPON THE FOLLOWING UTILITY RATE (2019 NATURAL GAS BILLS)

NAT. GAS RATE $5.42 /MMBTU

3. ELECTRIC COSTS BASED UPON THE FOLLOWING NEW RIVER LIGHT AND POWER (NRLP) FACTORS (SCHEDULE A - APPALACHIAN STATE UNIVERSITY)

COINCIDENT PEAK DEMAND: $15.00 /KW

NON-COINCIDENT PEAK DEMAND: $4.00 /KW

ENERGY RATE $0.030000 /KWH

ENERGY RATE RENEWABLE $0.042000 /KWH (RENEWABLE - PROVIDED BY NRLP)

ANNUAL OPERATING COSTS SUMMARY - OPTION NO. 1C (80,000 PPH ELECTRIC BOILERS)

APPALACHIAN STATE UNIVERSITY

MONTH	CAMPUS LOAD				BOILER PROD. SUMMARY			NATURAL GAS BILL		PLANT ELECTRIC BILL				TOTAL ANNUAL COSTS ($/YR)
	PEAK STEAM (PPH)	STEAM PROD (MLBS)	PEAK CAMPUS DEMAND (KW)	CAMPUS USAGE (KWH)	ELECTRIC BOILER (MLBS)	NAT. GAS BOILER (MLBS)	TOTAL STEAM PRODUCED (MLBS)	NAT. GAS USAGE (MMBTU)	NAT GAS COSTS ($/YR)	COINC. PEAK DEMAND (KW)	NON-COINC PEAK DEMAND (KW)	TOTAL ELECTRIC USAGE (KWH)	COST ($/YR)	
JAN	77,000	34,049	6,927	3,726,541	33,430	619	34,049	790	4,300	---	22,789	9,893,869	388,000	392,300
FEB	60,000	21,893	8,139	3,709,493	21,200	693	21,893	888	4,800	---	17,757	6,274,292	259,300	264,100
MAR	58,000	26,177	7,420	3,747,797	25,138	1,039	26,177	1,330	7,200	---	17,166	7,439,779	291,900	299,100
APR	54,000	19,944	7,750	3,831,548	19,302	642	19,944	823	4,500	---	15,982	5,712,604	235,300	239,800
MAY	33,000	14,152	8,120	4,359,628	13,722	430	14,152	546	3,000	---	9,767	4,061,059	160,900	163,900
JUN	24,000	13,398	9,172	4,509,981	12,905	493	13,398	634	3,400	---	7,103	3,819,184	143,000	146,400
JUL	24,000	13,711	9,210	4,804,762	13,276	435	13,711	555	3,000	---	7,103	3,928,976	146,300	149,300
AUG	29,000	14,412	10,336	5,130,992	13,977	435	14,412	556	3,000	---	8,583	4,136,472	158,400	161,400
SEP	25,000	14,000	10,424	5,219,860	13,530	470	14,000	602	3,300	---	7,399	4,004,184	149,700	153,000
OCT	47,000	17,559	9,545	4,492,991	17,051	508	17,559	655	3,600	---	13,910	5,046,346	207,000	210,600
NOV	68,000	25,026	7,329	3,705,325	24,101	925	25,026	1,183	6,400	---	20,125	7,132,867	294,500	300,900
DEC	60,000	28,390	6,772	3,304,706	27,310	1,080	28,390	1,385	7,500	---	17,757	8,082,544	313,500	321,000
TOTAL	---	242,711	---	50,543,624	234,942	7,769	242,711	9,947	54,000	---	---	69,532,176	2,747,800	2,801,800

<u>NOTES</u>: 1. BOILER EFFICIENCY BASED UPON THE FOLLOWING FACTORS

NAT. GAS BOILER: 78% BASED UPON EXISTING BOILER EFFICIENCY

ELECTRIC BOILER: 99%

2. NATURAL GAS BASED UPON THE FOLLOWING UTILITY RATE (2019 NATURAL GAS BILLS)

NAT. GAS RATE $5.42 /MMBTU

3. ELECTRIC COSTS BASED UPON THE FOLLOWING NEW RIVER LIGHT AND POWER (NRLP) FACTORS (SCHEDULE A - APPALACHIAN STATE UNIVERSITY)

COINCIDENT PEAK DEMAND: $15.00 /KW

NON-COINCIDENT PEAK DEMAND: $4.00 /KW

ENERGY RATE $0.030000 /KWH

ENERGY RATE RENEWABLE $0.042000 /KWH (RENEWABLE - PROVIDED BY NRLP)

ANNUAL OPERATING COSTS SUMMARY - OPTION NO. 2A (20,000 PPH ELECTRIC BOILERS) - RENEWABLE

APPALACHIAN STATE UNIVERSITY

MONTH	CAMPUS LOAD				BOILER PROD. SUMMARY			NATURAL GAS BILL		PLANT ELECTRIC BILL				TOTAL ANNUAL COSTS ($/YR)
	PEAK STEAM (PPH)	STEAM PROD (MLBS)	PEAK CAMPUS DEMAND (KW)	CAMPUS USAGE (KWH)	ELECTRIC BOILER (MLBS)	NAT. GAS BOILER (MLBS)	TOTAL STEAM PRODUCED (MLBS)	NAT. GAS USAGE (MMBTU)	NAT GAS COSTS ($/YR)	COINC. PEAK DEMAND (KW)	NON-COINC PEAK DEMAND (KW)	TOTAL ELECTRIC USAGE (KWH)	COST ($/YR)	
JAN	77,000	34,049	6,927	3,726,541	14,400	19,649	34,049	25,158	136,400	---	5,919	4,261,680	202,700	339,100
FEB	60,000	21,893	8,139	3,709,493	12,950	8,943	21,893	11,464	62,100	---	5,919	3,832,552	184,600	246,700
MAR	58,000	26,177	7,420	3,747,797	14,391	11,786	26,177	15,088	81,800	---	5,919	4,259,016	202,600	284,400
APR	54,000	19,944	7,750	3,831,548	13,877	6,067	19,944	7,786	42,200	---	5,919	4,106,896	196,200	238,400
MAY	33,000	14,152	8,120	4,359,628	12,808	1,344	14,152	1,729	9,400	---	5,919	3,790,515	182,900	192,300
JUN	24,000	13,398	9,172	4,509,981	12,785	613	13,398	784	4,200	---	5,919	3,783,664	182,600	186,800
JUL	24,000	13,711	9,210	4,804,762	13,198	513	13,711	652	3,500	---	5,919	3,905,888	187,700	191,200
AUG	29,000	14,412	10,336	5,130,992	13,691	721	14,412	915	5,000	---	5,919	4,051,816	193,900	198,900
SEP	25,000	14,000	10,424	5,219,860	13,236	764	14,000	976	5,300	---	5,919	3,917,160	188,200	193,500
OCT	47,000	17,559	9,545	4,492,991	14,083	3,476	17,559	4,477	24,300	---	5,919	4,167,848	198,700	223,000
NOV	68,000	25,026	7,329	3,705,325	13,911	11,115	25,026	14,222	77,100	---	5,919	4,116,960	196,600	273,700
DEC	60,000	28,390	6,772	3,304,706	14,400	13,990	28,390	17,910	97,100	---	5,919	4,261,680	202,700	299,800
TOTAL	---	242,711	---	50,543,624	163,730	78,981	242,711	101,161	548,400	---	---	48,455,675	2,319,400	2,867,800

NOTES: 1. BOILER EFFICIENCY BASED UPON THE FOLLOWING FACTORS

NAT. GAS BOILER: 78% BASED UPON EXISTING BOILER EFFICIENCY

ELECTRIC BOILER: 99%

2. NATURAL GAS BASED UPON THE FOLLOWING UTILITY RATE (2019 NATURAL GAS BILLS)

NAT. GAS RATE $5.42 /MMBTU

3. ELECTRIC COSTS BASED UPON THE FOLLOWING NEW RIVER LIGHT AND POWER (NRLP) FACTORS (SCHEDULE A - APPALACHIAN STATE UNIVERSITY)

COINCIDENT PEAK DEMAND: $15.00 /KW

NON-COINCIDENT PEAK DEMAND: $4.00 /KW

ENERGY RATE $0.030000 /KWH

ENERGY RATE RENEWABLE $0.042000 /KWH (RENEWABLE - PROVIDED BY NRLP)

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ANNUAL OPERATING COSTS SUMMARY - OPTION NO. 2B (40,000 PPH ELECTRIC BOILERS) - RENEWABLE

APPALACHIAN STATE UNIVERSITY

MONTH	CAMPUS LOAD				BOILER PROD. SUMMARY			NATURAL GAS BILL		PLANT ELECTRIC BILL				TOTAL ANNUAL COSTS ($/YR)
	PEAK STEAM (PPH)	STEAM PROD (MLBS)	PEAK CAMPUS DEMAND (KW)	CAMPUS USAGE (KWH)	ELECTRIC BOILER (MLBS)	NAT. GAS BOILER (MLBS)	TOTAL STEAM PRODUCED (MLBS)	NAT. GAS USAGE (MMBTU)	NAT GAS COSTS ($/YR)	COINC. PEAK DEMAND (KW)	NON-COINC PEAK DEMAND (KW)	TOTAL ELECTRIC USAGE (KWH)	COST ($/YR)	
JAN	77,000	34,049	6,927	3,726,541	27,019	7,030	34,049	8,989	48,700	---	11,838	7,996,347	383,200	431,900
FEB	60,000	21,893	8,139	3,709,493	20,171	1,722	21,893	2,199	11,900	---	11,838	5,969,715	298,100	310,000
MAR	58,000	26,177	7,420	3,747,797	23,885	2,292	26,177	2,939	15,900	---	11,838	7,068,891	344,200	360,100
APR	54,000	19,944	7,750	3,831,548	19,162	782	19,944	1,007	5,500	---	11,838	5,671,164	285,500	291,000
MAY	33,000	14,152	8,120	4,359,628	13,722	430	14,152	546	3,000	---	9,767	4,061,059	209,600	212,600
JUN	24,000	13,398	9,172	4,509,981	12,905	493	13,398	634	3,400	---	7,103	3,819,184	188,800	192,200
JUL	24,000	13,711	9,210	4,804,762	13,276	435	13,711	555	3,000	---	7,103	3,928,976	193,400	196,400
AUG	29,000	14,412	10,336	5,130,992	13,977	435	14,412	556	3,000	---	8,583	4,136,472	208,100	211,100
SEP	25,000	14,000	10,424	5,219,860	13,530	470	14,000	602	3,300	---	7,399	4,004,184	197,800	201,100
OCT	47,000	17,559	9,545	4,492,991	17,035	524	17,559	675	3,700	---	11,838	5,041,610	259,100	262,800
NOV	68,000	25,026	7,329	3,705,325	22,779	2,247	25,026	2,876	15,600	---	11,838	6,741,574	330,500	346,100
DEC	60,000	28,390	6,772	3,304,706	25,886	2,504	28,390	3,212	17,400	---	11,838	7,661,042	369,100	386,500
TOTAL	---	242,711	---	50,543,624	223,347	19,364	242,711	24,790	134,400	---	---	66,100,218	3,267,400	3,401,800

NOTES: 1. BOILER EFFICIENCY BASED UPON THE FOLLOWING FACTORS

NAT. GAS BOILER: 78% BASED UPON EXISTING BOILER EFFICIENCY

ELECTRIC BOILER: 99%

2. NATURAL GAS BASED UPON THE FOLLOWING UTILITY RATE (2019 NATURAL GAS BILLS)

NAT. GAS RATE $5.42 /MMBTU

3. ELECTRIC COSTS BASED UPON THE FOLLOWING NEW RIVER LIGHT AND POWER (NRLP) FACTORS (SCHEDULE A - APPALACHIAN STATE UNIVERSITY)

COINCIDENT PEAK DEMAND: $15.00 /KW

NON-COINCIDENT PEAK DEMAND: $4.00 /KW

ENERGY RATE $0.030000 /KWH

ENERGY RATE RENEWABLE $0.042000 /KWH (RENEWABLE - PROVIDED BY NRLP)

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ANNUAL OPERATING COSTS SUMMARY - OPTION NO. 2C (80,000 PPH ELECTRIC BOILERS) - RENEWABLE

APPALACHIAN STATE UNIVERSITY

MONTH	CAMPUS LOAD				BOILER PROD. SUMMARY			NATURAL GAS BILL		PLANT ELECTRIC BILL				TOTAL ANNUAL COSTS ($/YR)
	PEAK STEAM (PPH)	STEAM PROD (MLBS)	PEAK CAMPUS DEMAND (KW)	CAMPUS USAGE (KWH)	ELECTRIC BOILER (MLBS)	NAT. GAS BOILER (MLBS)	TOTAL STEAM PRODUCED (MLBS)	NAT. GAS USAGE (MMBTU)	NAT GAS COSTS ($/YR)	COINC. PEAK DEMAND (KW)	NON-COINC PEAK DEMAND (KW)	TOTAL ELECTRIC USAGE (KWH)	COST ($/YR)	
JAN	77,000	34,049	6,927	3,726,541	33,430	619	34,049	790	4,300	---	22,789	9,893,869	506,700	511,000
FEB	60,000	21,893	8,139	3,709,493	21,200	693	21,893	888	4,800	---	17,757	6,274,292	334,500	339,300
MAR	58,000	26,177	7,420	3,747,797	25,138	1,039	26,177	1,330	7,200	---	17,166	7,439,779	381,100	388,300
APR	54,000	19,944	7,750	3,831,548	19,302	642	19,944	823	4,500	---	15,982	5,712,604	303,900	308,400
MAY	33,000	14,152	8,120	4,359,628	13,722	430	14,152	546	3,000	---	9,767	4,061,059	209,600	212,600
JUN	24,000	13,398	9,172	4,509,981	12,905	493	13,398	634	3,400	---	7,103	3,819,184	188,800	192,200
JUL	24,000	13,711	9,210	4,804,762	13,276	435	13,711	555	3,000	---	7,103	3,928,976	193,400	196,400
AUG	29,000	14,412	10,336	5,130,992	13,977	435	14,412	556	3,000	---	8,583	4,136,472	208,100	211,100
SEP	25,000	14,000	10,424	5,219,860	13,530	470	14,000	602	3,300	---	7,399	4,004,184	197,800	201,100
OCT	47,000	17,559	9,545	4,492,991	17,051	508	17,559	655	3,600	---	13,910	5,046,346	267,600	271,200
NOV	68,000	25,026	7,329	3,705,325	24,101	925	25,026	1,183	6,400	---	20,125	7,132,867	380,100	386,500
DEC	60,000	28,390	6,772	3,304,706	27,310	1,080	28,390	1,385	7,500	---	17,757	8,082,544	410,500	418,000
TOTAL	---	242,711	---	50,543,624	234,942	7,769	242,711	9,947	54,000	---	---	69,532,176	3,582,100	3,636,100

<u>NOTES</u>: 1. BOILER EFFICIENCY BASED UPON THE FOLLOWING FACTORS

NAT. GAS BOILER: 78% BASED UPON EXISTING BOILER EFFICIENCY

ELECTRIC BOILER: 99%

2. NATURAL GAS BASED UPON THE FOLLOWING UTILITY RATE (2019 NATURAL GAS BILLS)

NAT. GAS RATE $5.42 /MMBTU

3. ELECTRIC COSTS BASED UPON THE FOLLOWING NEW RIVER LIGHT AND POWER (NRLP) FACTORS (SCHEDULE A - APPALACHIAN STATE UNIVERSITY)

COINCIDENT PEAK DEMAND: $15.00 /KW

NON-COINCIDENT PEAK DEMAND: $4.00 /KW

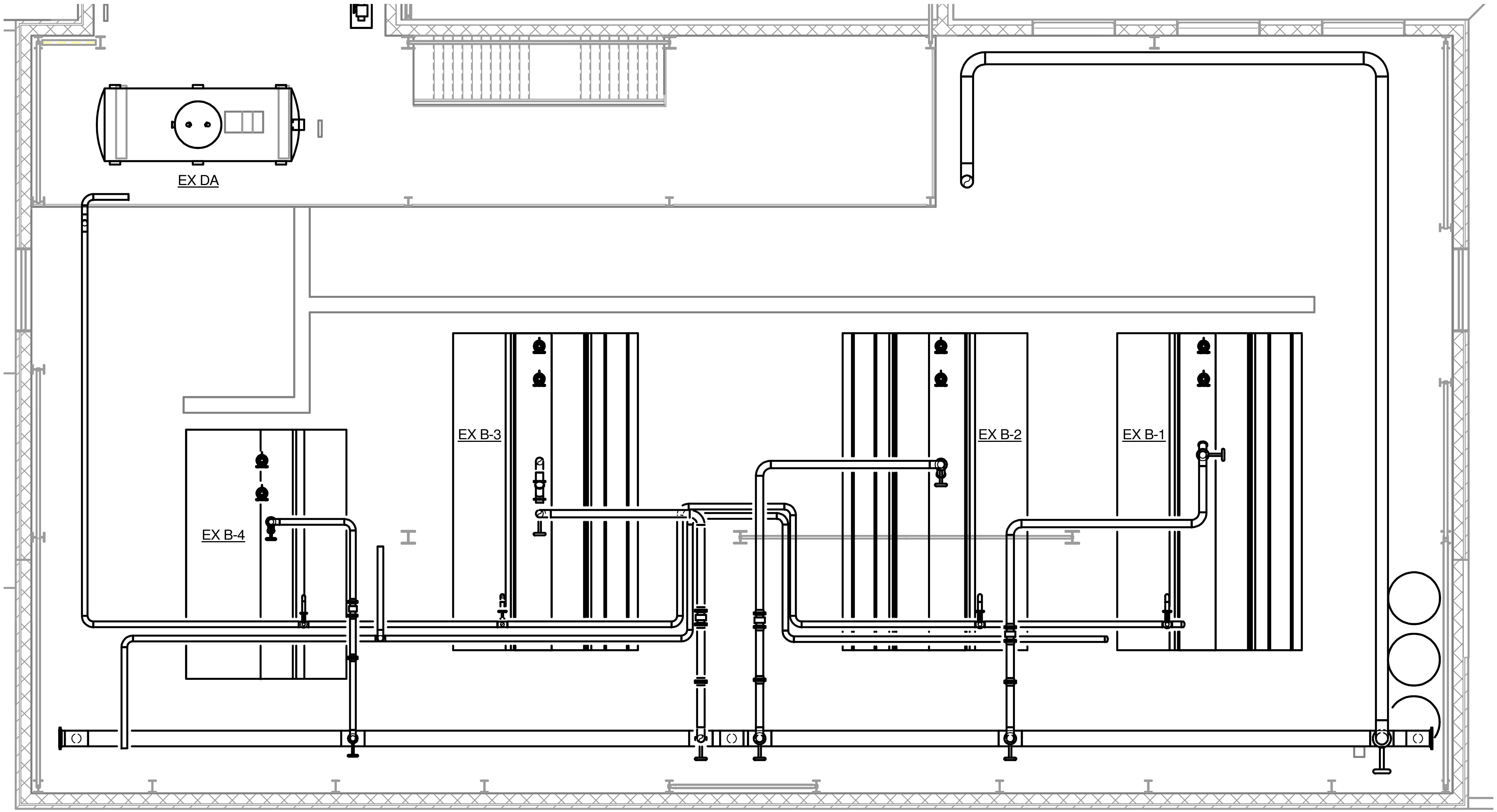
ENERGY RATE $0.030000 /KWH

ENERGY RATE RENEWABLE $0.042000 /KWH (RENEWABLE - PROVIDED BY NRLP)

FILE: P:\NC\20\220143A0\MP\CALC\220143A-LOAD PROFILE.XLSX

RMF 23 JUN 2020

Appendix No. 4 – Steam Plant Equipment Layouts



C:\Users\demockoj\Documents\ASU Boiler Plant MEP R20_jacob.democko.rvt

RMF Engineering
Reliability. Efficiency. Integrity.

TITLE:
BOILER PLANT - EXISTING CONDITIONS

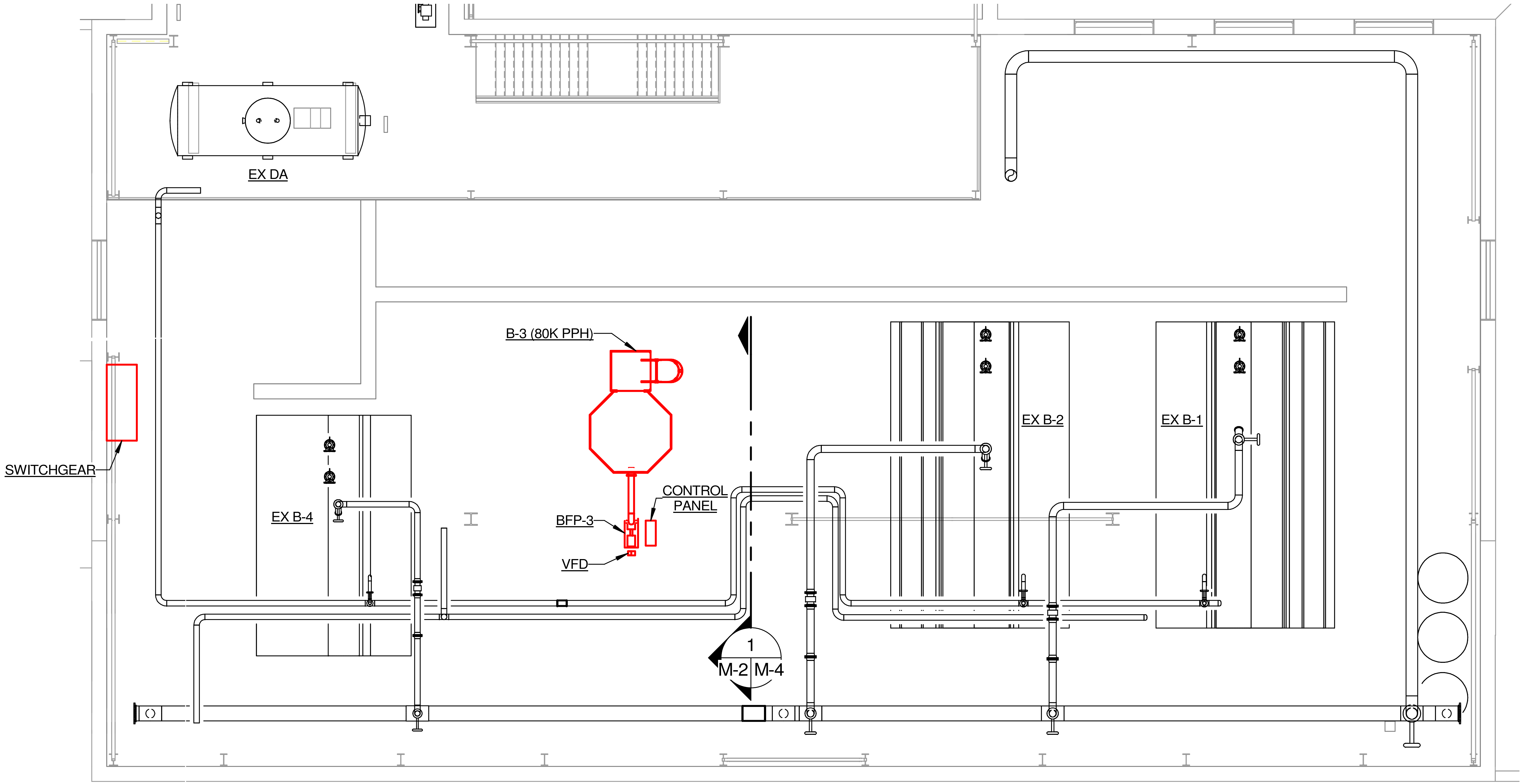
PROJECT:
STEAM PLANT CLIMATE ACTION PLAN STUDY

DATE: 06/26/2020

SCALE: 1" = 10'-0"

RMF PROJECT No: 220143.A0

M-1



C:\Users\demockoj\Documents\ASU Boiler Plant MEP R20_jacob.democko.rvt

RMF Engineering
Reliability. Efficiency. Integrity.

TITLE: BOILER OPTION C PLAN - 80K PPH

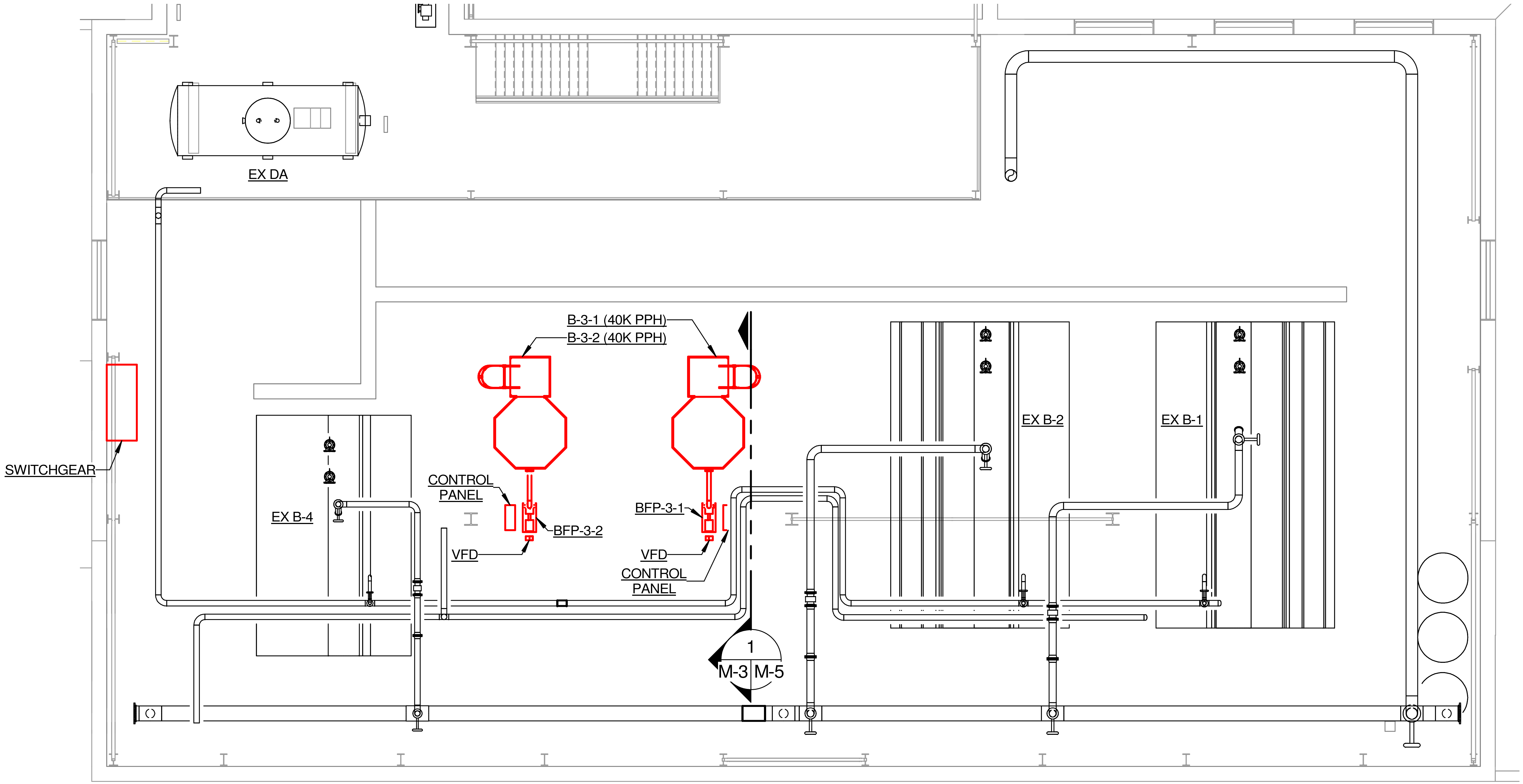
PROJECT: STEAM PLANT CLIMATE ACTION PLAN STUDY

DATE: 06/26/2020

SCALE: 1" = 10'-0"

RMF PROJECT No: 220143.A0

M-2



C:\Users\demockoj\Documents\ASU Boiler Plant MEP R20_jacob.democko.rvt

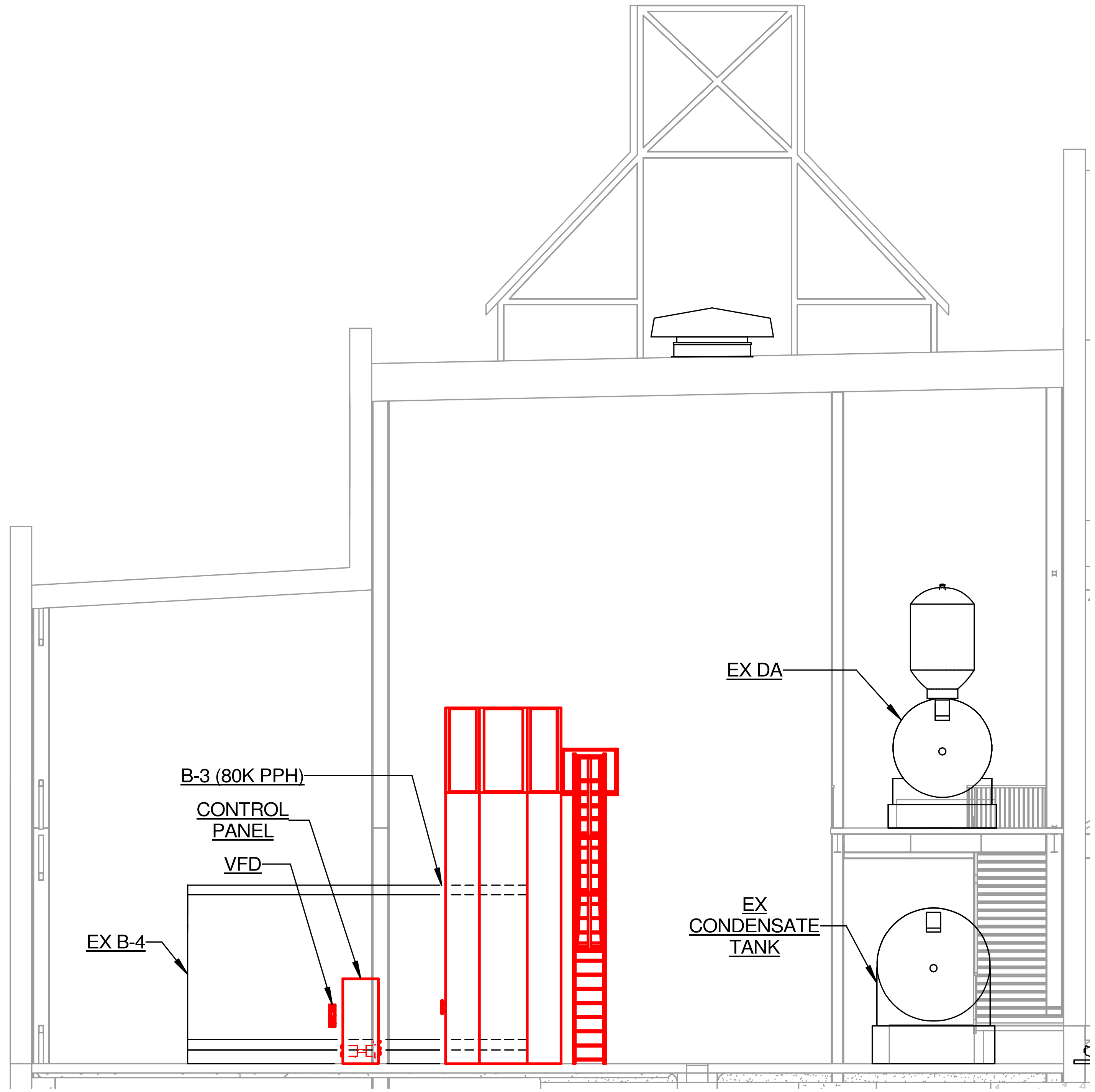
RMF Engineering
Reliability. Efficiency. Integrity.

TITLE:
BOILER OPTION D PLAN - 2 X 40K PPH

PROJECT:
STEAM PLANT CLIMATE ACTION PLAN STUDY

DATE: 06/26/2020
SCALE: 1" = 10'-0"
RMF PROJECT No: 220143.A0

M-3



RMF Engineering
Reliability. Efficiency. Integrity.

TITLE:
BOILER OPTION 1 SECTION - 80K PPH

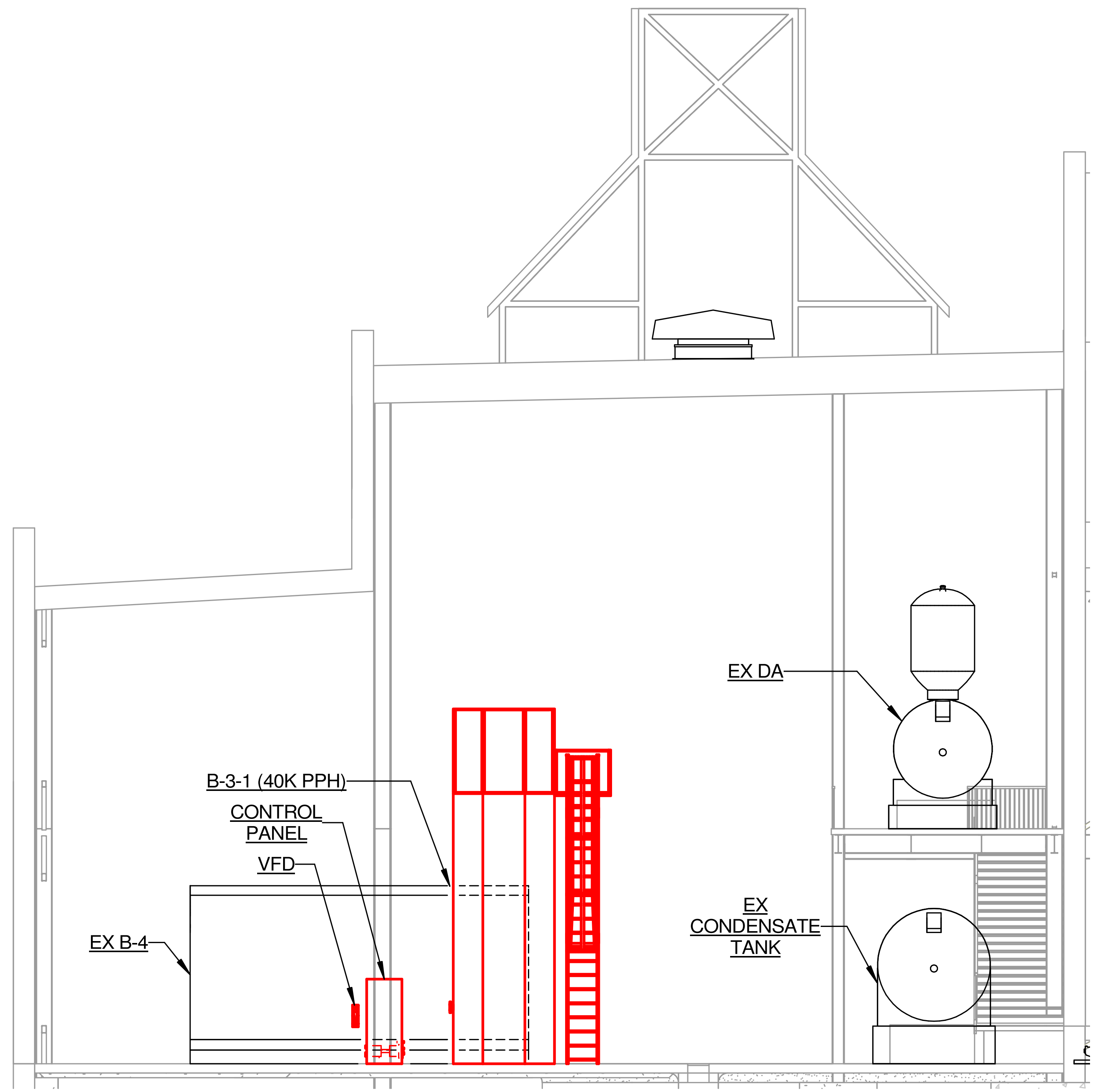
PROJECT:
STEAM PLANT CLIMATE ACTION PLAN STUDY

DATE: 06/26/2020

SCALE: 1" = 10'-0"

RMF PROJECT No: 220143.A0

M-4



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RMF Engineering
Reliability. Efficiency. Integrity.

TITLE:
BOILER OPTION 2 SECTION - 2 X 40K PPH

PROJECT:
STEAM PLANT CLIMATE ACTION PLAN STUDY

DATE: 06/26/2020
SCALE: 1" = 10'-0"
RMF PROJECT No: 220143.A0

M-5

Appendix No. 5 – Construction Cost Estimates

CONSTRUCTION COST ESTIMATE

RMF Engineering
Reliability. Efficiency. Integrity.

PROJECT **STEAM PLANT STUDY**		
LOCATION **APPALACHIAN STATE UNIVERSITY**	DATE PREPARED **07/30/20**	
ARCHITECT/ENGINEER **RMF ENGINEERING, INC.**	PROJECT NO. **220143.A0**	
DRAWING NO.	ESTIMATOR **RMF**	CHECKED BY **JDE**

BASIS FOR ESTIMATE

- ☐ PROPOSAL
- ☐ 100% REVIEW
- ☐ SCHEMATIC DESIGN
- ☐ CONSTRUCTION DOCUMENTS
- ☐ DESIGN DEVELOPMENT
- ☑ OTHER STUDY

LINE #	SUMMARY	QUANTITY		MATERIAL		LABOR		TOTAL COST
		NO. UNITS	UNIT MEAS.	PER UNIT	TOTAL	PER UNIT	TOTAL	
1	**OPTION A - 20K PPH**				**$ 927,199**		**$ 383,423**	**$ 1,310,623**
2								
3								
4								
5	**OPTION B - 40K PPH**				**$ 1,224,473**		**$ 469,981**	**$ 1,694,455**
6								
7								
8								
9	**OPTION C - 80K PPH**				**$ 1,443,765**		**$ 488,758**	**$ 1,932,523**
10								
11								
12								
13	**OPTION D - 40K PPH X 2**				**$ 1,916,157**		**$ 610,763**	**$ 2,526,921**
14								
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CONSTRUCTION COST ESTIMATE

PROJECT
STEAM PLANT STUDY

LOCATION
APPALACHIAN STATE UNIVERSITY

DATE PREPARED
07/30/20

ARCHITECT/ENGINEER
RMF ENGINEERING, INC.

PROJECT NO.
220143.A0

DRAWING NO.

ESTIMATOR
JDE

CHECKED BY
RMF

BASIS FOR ESTIMATE
☐ PROPOSAL ☐ SCHEMATIC DESIGN ☐ DESIGN DEVELOPMENT
☐ 100% REVIEW ☐ CONSTRUCTION DOCUMENTS ☑ OTHER STUDY

LINE #	OPTION A - 20K PPH	QUANTITY		MATERIAL		LABOR		TOTAL COST
		NO. UNITS	UNIT MEAS.	PER UNIT	TOTAL	PER UNIT	TOTAL	
1	**DEMOLITION**							
2	BOILER 3 DEMO	1	EA	20,000.00	20,000.00	20,000.00	20,000.00	**40,000**
3	PVF DEMO	1	EA	7,500.00	7,500.00	7,500.00	7,500.00	**15,000**
4	PAD DEMO	1	EA	10,000.00	10,000.00	10,000.00	10,000.00	**20,000**
5	STACK DEMO	1	EA	5,000.00	5,000.00	5,000.00	5,000.00	**10,000**
6	MOB/SUBMITTALS/ASBUILTS/DEMOB	1	EA	25,000.00	25,000.00	25,000.00	25,000.00	**50,000**
7	**STUCTURAL**							
8	BOILER FOOTING/PAD	1	EA	10,000.00	10,000.00	10,000.00	10,000.00	**20,000**
9	ELECTRICAL/CONTROLLER GEAR PAD	2	EA	2,500.00	5,000.00	2,500.00	5,000.00	**10,000**
10	NEW STOREFRONT	1	EA	10,000.00	10,000.00	10,000.00	10,000.00	**20,000**
11	BOILER ACCESS PLATFORM	1	EA	30,000.00	30,000.00	30,000.00	30,000.00	**60,000**
12	**MECHANICAL EQUIPMENT**							
13	20K PPH ELECTRODE BOILER	1	EA	280,000.00	280,000.00	25,000.00	25,000.00	**305,000**
14	INSULATION	1	LS	20,000.00	20,000.00	20,000.00	20,000.00	**40,000**
15	CONTROLS UPDATE	1	LS	55,000.00	55,000.00	45,000.00	45,000.00	**100,000**
16	**MECHANICAL PIPING AND VALVES**							
17	MISC PVC/DRAIN/SUPPORTS	1	LS	25,000.00	25,000.00	25,000.00	25,000.00	**50,000**
18	6 '' SCH 40 CARBON STEEL PIPE	60	LF	56.25	3,375.00	30.75	1,845.00	**5,220**
19	6 '' GATE VALVE	2	EA	2,281.25	4,562.50	367.50	735.00	**5,298**
20	6 '' SCHED STD 90° ELBOW (LONG RADIUS)	4	EA	157.50	630.00	220.50	882.00	**1,512**
21	2 '' SCH 40 CARBON STEEL PIPE	50	LF	8.25	412.50	11.63	581.25	**994**
22	2 '' GATE VALVE	2	EA	806.25	1,612.50	78.75	157.50	**1,770**
23	2 '' SCHED STD 90° ELBOW (LONG RADIUS)	4	EA	28.13	112.50	71.25	285.00	**398**
24	6 '' SCH 40 CARBON STEEL PIPE	100	LF	56.25	5,625.00	30.75	3,075.00	**8,700**
25	6 '' SCHED STD 90° ELBOW (LONG RADIUS)	4	EA	157.50	630.00	220.50	882.00	**1,512**
26	**ELECTRICAL SUMMARY**							
27	3#250 15KV, MV-105, 133% EPR CABLE + 600V GND	375	LF	40.00	15,000.00	20.00	7,500.00	**22,500**
28	4" RIGID METAL CONDUIT	125	LF	30.00	3,750.00	20.00	2,500.00	**6,250**
29	MV CABLE TERMINATIONS	6	EA	300.00	1,800.00	100.00	600.00	**2,400**
30	15KV, 2000A METAL CLAD SGR (SINGLE VACUUM BKR)	1	EA	100,000.00	100,000.00	5,000.00	5,000.00	**105,000**
31	3# 4 THHN + #8 GND	600	LF	0.75	450.00	0.60	360.00	**810**
32	1" RIGIG METAL CONDUIT	150	LF	8.00	1,200.00	13.00	1,950.00	**3,150**
33	CABLE/SWGR TESTING	1	LS			15,000.00	15,000.00	**15,000**
	OPTION 1 SUBTOTAL				**$ 641,660**		**$ 278,853**	**$ 920,514**
35	OVERHEAD 10%				$ 64,166		$ 27,885	$ 92,051.40
36	PROFIT 15%				$ 96,249		$ 41,828	$ 138,077.10
37	SALES TAX 7%				$ 44,916			$ 44,916.20
38	CONSTRUCTION CONTINGENCY 5%				$ 40,104		$ 17,428	$ 57,532.13
39	DESIGN CONTINGENCY 5%				$ 40,104		$ 17,428	$ 57,532.13
	TOTAL				**$ 927,199**		**$ 383,423**	**$ 1,310,623**

CONSTRUCTION COST ESTIMATE

PROJECT **STEAM PLANT STUDY**	
LOCATION **APPALACHIAN STATE UNIVERSITY**	DATE PREPARED **07/30/20**
ARCHITECT/ENGINEER **RMF ENGINEERING, INC.**	PROJECT NO. **220143.A0**
DRAWING NO.	ESTIMATOR **JDE** / CHECKED BY **RMF**

BASIS FOR ESTIMATE: ☐ PROPOSAL ☐ 100% REVIEW ☐ SCHEMATIC DESIGN ☐ CONSTRUCTION DOCUMENTS ☐ DESIGN DEVELOPMENT ☑ OTHER STUDY

LINE #	OPTION B - 40K PPH	QUANTITY		MATERIAL		LABOR		TOTAL COST
		NO. UNITS	UNIT MEAS.	PER UNIT	TOTAL	PER UNIT	TOTAL	
1	**DEMOLITION**							
2	BOILER 3 DEMO	1	EA	20,000.00	20,000.00	20,000.00	20,000.00	**40,000**
3	PVF DEMO	1	EA	7,500.00	7,500.00	7,500.00	7,500.00	**15,000**
4	PAD DEMO	1	EA	10,000.00	10,000.00	10,000.00	10,000.00	**20,000**
5	STACK DEMO	1	EA	5,000.00	5,000.00	5,000.00	5,000.00	**10,000**
6	MOB/SUBMITTALS/ASBUILTS/DEMOB	1	EA	25,000.00	25,000.00	25,000.00	25,000.00	**50,000**
7	**STUCTURAL**							
8	BOILER FOOTING/PAD	1	EA	10,000.00	10,000.00	10,000.00	10,000.00	**20,000**
9	ELECTRICAL/CONTROLLER GEAR PAD	2	EA	2,500.00	5,000.00	2,500.00	5,000.00	**10,000**
10	NEW STOREFRONT	1	EA	10,000.00	10,000.00	10,000.00	10,000.00	**20,000**
11	BOILER ACCESS PLATFORM	1	EA	30,000.00	30,000.00	30,000.00	30,000.00	**60,000**
12	**MECHANICAL EQUIPMENT**							
13	40K PPH ELECTRODE BOILER	1	EA	410,000.00	410,000.00	30,000.00	30,000.00	**440,000**
14	RIGGING	1	LS	30,000.00	30,000.00	30,000.00	30,000.00	**60,000**
15	INSULATION	1	LS	30,000.00	30,000.00	30,000.00	30,000.00	**60,000**
16	CONTROLS UPDATE	1	LS	55,000.00	55,000.00	45,000.00	45,000.00	**100,000**
17	**MECHANICAL PIPING AND VALVES**							
18	MISC PVC/DRAIN/SUPPORTS	1	LS	30,000.00	30,000.00	30,000.00	30,000.00	**60,000**
19	8 " SCH 40 CARBON STEEL PIPE	60	LF	89.38	5,362.50	37.50	2,250.00	**7,613**
20	8 " GATE VALVE	2	EA	3,500.00	7,000.00	442.50	885.00	**7,885**
21	8 " SCHED STD 90° ELBOW (LONG RADIUS)	4	EA	296.25	1,185.00	295.50	1,182.00	**2,367**
22	3 " SCH 40 CARBON STEEL PIPE	50	LF	20.81	1,040.63	16.50	825.00	**1,866**
23	3 " GATE VALVE	2	EA	1,137.50	2,275.00	157.50	315.00	**2,590**
24	3 " SCHED STD 90° ELBOW (LONG RADIUS)	4	EA	37.50	150.00	101.25	405.00	**555**
25	8 " SCH 40 CARBON STEEL PIPE	100	LF	89.38	8,937.50	37.50	3,750.00	**12,688**
26	8 " SCHED STD 90° ELBOW (LONG RADIUS)	4	EA	296.25	1,185.00	295.50	1,182.00	**2,367**
27	**ELECTRICAL SUMMARY**							
28	3#250 15KV, MV-105, 133% EPR CABLE + 600V GND	750	LF	40.00	30,000.00	20.00	15,000.00	**45,000**
29	4" RIGID METAL CONDUIT	250	LF	30.00	7,500.00	20.00	5,000.00	**12,500**
30	MV CABLE TERMINATIONS	12	EA	300.00	3,600.00	100.00	1,200.00	**4,800**
31	15KV, 2000A METAL CLAD SGR (SINGLE VACUUM BKR)	1	EA	100,000.00	100,000.00	5,000.00	5,000.00	**105,000**
32	3# 4 THHN + #8 GND	600	LF	0.75	450.00	0.60	360.00	**810**
33	1" RIGIG METAL CONDUIT	150	LF	8.00	1,200.00	13.00	1,950.00	**3,150**
34	CABLE/SWGR TESTING	1	LS			15,000.00	15,000.00	**15,000**
	OPTION 1 SUBTOTAL				**$ 847,386**		**$ 341,804**	**$ 1,189,191**
36	OVERHEAD 10%				$ 84,739		$ 34,180	$ 118,919.10
37	PROFIT 15%				$ 127,108		$ 51,271	$ 178,378.65
38	SALES TAX 7%				$ 59,317			$ 59,317.02
39	CONSTRUCTION CONTINGENCY 5%				$ 52,962		$ 21,363	$ 74,324.44
40	DESIGN CONTINGENCY 5%				$ 52,962		$ 21,363	$ 74,324.44
	TOTAL				**$ 1,224,473**		**$ 469,981**	**$ 1,694,455**

CONSTRUCTION COST ESTIMATE

PROJECT **STEAM PLANT STUDY**		
LOCATION **APPALACHIAN STATE UNIVERSITY**		DATE PREPARED **07/30/20**
ARCHITECT/ENGINEER **RMF ENGINEERING, INC.**		PROJECT NO. **220143.A0**
DRAWING NO.	ESTIMATOR **JDE**	CHECKED BY **RMF**

BASIS FOR ESTIMATE

- ☐ PROPOSAL
- ☐ SCHEMATIC DESIGN
- ☐ DESIGN DEVELOPMENT
- ☐ 100% REVIEW
- ☐ CONSTRUCTION DOCUMENTS
- ☑ OTHER STUDY

LINE #	OPTION C - 80K PPH	QUANTITY		MATERIAL		LABOR		TOTAL COST
		NO. UNITS	UNIT MEAS.	PER UNIT	TOTAL	PER UNIT	TOTAL	
1	**DEMOLITION**							
2	BOILER 3 DEMO	1	EA	20,000.00	20,000.00	20,000.00	20,000.00	**40,000**
3	PVF DEMO	1	EA	7,500.00	7,500.00	7,500.00	7,500.00	**15,000**
4	PAD DEMO	1	EA	10,000.00	10,000.00	10,000.00	10,000.00	**20,000**
5	STACK DEMO	1	EA	5,000.00	5,000.00	5,000.00	5,000.00	**10,000**
6	MOB/SUBMITTALS/ASBUILTS/DEMOB	1	EA	25,000.00	25,000.00	25,000.00	25,000.00	**50,000**
7	**STUCTURAL**							
8	BOILER FOOTING/PAD	1	EA	10,000.00	10,000.00	10,000.00	10,000.00	**20,000**
9	ELECTRICAL/CONTROLLER GEAR PAD	2	EA	2,500.00	5,000.00	2,500.00	5,000.00	**10,000**
10	NEW STOREFRONT	1	EA	10,000.00	10,000.00	10,000.00	10,000.00	**20,000**
11	BOILER ACCESS PLATFORM	1	EA	30,000.00	30,000.00	30,000.00	30,000.00	**60,000**
12	**MECHANICAL EQUIPMENT**							
13	80K PPH ELECTRODE BOILER	1	EA	530,000.00	530,000.00	40,000.00	40,000.00	**570,000**
14	INSULATION	1	LS	35,000.00	35,000.00	35,000.00	35,000.00	**70,000**
15	CONTROLS UPDATE	1	LS	55,000.00	55,000.00	45,000.00	45,000.00	**100,000**
16	**MECHANICAL PIPING AND VALVES**							
17	MISC PVC/DRAIN/SUPPORTS	1	LS	35,000.00	35,000.00	35,000.00	35,000.00	**70,000**
18	10 '' SCH 40 CARBON STEEL PIPE	60	LF	112.50	6,750.00	45.75	2,745.00	**9,495**
19	10 '' GATE VALVE	2	EA	5,218.75	10,437.50	502.50	1,005.00	**11,443**
20	10 '' SCHED STD 90° ELBOW (LONG RADIUS)	4	EA	587.50	2,350.00	366.00	1,464.00	**3,814**
21	4 '' SCH 40 CARBON STEEL PIPE	50	LF	30.00	1,500.00	19.13	956.25	**2,456**
22	4 '' GATE VALVE	2	EA	1,437.50	2,875.00	237.00	474.00	**3,349**
23	4 '' SCHED STD 90° ELBOW (LONG RADIUS)	4	EA	70.63	282.50	141.75	567.00	**850**
24	10 '' SCH 40 CARBON STEEL PIPE	100	LF	112.50	11,250.00	45.75	4,575.00	**15,825**
25	10 '' SCHED STD 90° ELBOW (LONG RADIUS)	4	EA	587.50	2,350.00	366.00	1,464.00	**3,814**
26	**ELECTRICAL SUMMARY**							
27	3#250 15KV, MV-105, 133% EPR CABLE + 600V GND	1,500	LF	40.00	60,000.00	20.00	30,000.00	**90,000**
28	4" RIGID METAL CONDUIT	500	LF	30.00	15,000.00	20.00	10,000.00	**25,000**
29	MV CABLE TERMINATIONS	24	EA	300.00	7,200.00	100.00	2,400.00	**9,600**
30	15KV, 2000A METAL CLAD SGR (SINGLE VACUUM BKR)	1	EA	100,000.00	100,000.00	5,000.00	5,000.00	**105,000**
31	3# 4 THHN + #8 GND	600	LF	0.75	450.00	0.60	360.00	**810**
32	1" RIGIG METAL CONDUIT	150	LF	8.00	1,200.00	13.00	1,950.00	**3,150**
33	CABLE/SWGR TESTING	1	LS			15,000.00	15,000.00	**15,000**
	OPTION 1 SUBTOTAL				**$ 999,145**		**$ 355,460**	**$ 1,354,606**
35	OVERHEAD 10%				$ 99,915		$ 35,546	$ 135,460.60
36	PROFIT 15%				$ 149,872		$ 53,319	$ 203,190.90
37	SALES TAX 7%				$ 69,940			$ 69,940.15
38	CONSTRUCTION CONTINGENCY 5%				$ 62,447		$ 22,216	$ 84,662.88
39	DESIGN CONTINGENCY 5%				$ 62,447		$ 22,216	$ 84,662.88
	TOTAL				**$ 1,443,765**		**$ 488,758**	**$ 1,932,523**

CONSTRUCTION COST ESTIMATE

PROJECT **STEAM PLANT STUDY**		
LOCATION **APPALACHIAN STATE UNIVERSITY**		DATE PREPARED **07/30/20**
ARCHITECT/ENGINEER **RMF ENGINEERING, INC.**		PROJECT NO. **220143.A0**
DRAWING NO.	ESTIMATOR **JDE**	CHECKED BY **RMF**

BASIS FOR ESTIMATE: ☐ PROPOSAL ☐ 100% REVIEW ☐ SCHEMATIC DESIGN ☐ CONSTRUCTION DOCUMENTS ☐ DESIGN DEVELOPMENT ☑ OTHER STUDY

LINE #	OPTION D - 40K PPH X 2	QUANTITY		MATERIAL		LABOR		TOTAL COST
		NO. UNITS	UNIT MEAS.	PER UNIT	TOTAL	PER UNIT	TOTAL	
1	**DEMOLITION**							
2	BOILER 3 DEMO	1	EA	20,000.00	20,000.00	20,000.00	20,000.00	**40,000**
3	PVF DEMO	1	EA	7,500.00	7,500.00	7,500.00	7,500.00	**15,000**
4	PAD DEMO	1	EA	10,000.00	10,000.00	10,000.00	10,000.00	**20,000**
5	STACK DEMO	1	EA	5,000.00	5,000.00	5,000.00	5,000.00	**10,000**
6	MOB/SUBMITTALS/ASBUILTS/DEMOB	1	EA	25,000.00	25,000.00	25,000.00	25,000.00	**50,000**
7	**STUCTURAL**							
8	BOILER FOOTING/PAD	2	EA	10,000.00	20,000.00	10,000.00	20,000.00	**40,000**
9	ELECTRICAL/CONTROLLER GEAR PAD	2	EA	2,500.00	5,000.00	2,500.00	5,000.00	**10,000**
10	NEW STOREFRONT	1	EA	10,000.00	10,000.00	10,000.00	10,000.00	**20,000**
11	BOILER ACCESS PLATFORM	2	EA	30,000.00	60,000.00	30,000.00	60,000.00	**120,000**
12	**MECHANICAL EQUIPMENT**							
13	40K PPH ELECTRODE BOILER	2	EA	410,000.00	820,000.00	30,000.00	60,000.00	**880,000**
14	INSULATION	1	LS	45,000.00	45,000.00	45,000.00	45,000.00	**90,000**
15	CONTROLS UPDATE	1	LS	75,000.00	75,000.00	75,000.00	75,000.00	**150,000**
16	**MECHANICAL PIPING AND VALVES**							
17	MISC PVC/DRAIN/SUPPORTS	1	LS	45,000.00	45,000.00	45,000.00	45,000.00	**90,000**
18	10 " SCHED STD REDUCING TEE	2	EA	1,050.00	2,100.00	555.00	1,110.00	**3,210**
19	10 " SCH 40 CARBON STEEL PIPE	20	LF	112.50	2,250.00	45.75	915.00	**3,165**
20	8 " SCH 40 CARBON STEEL PIPE	60	LF	89.38	5,362.50	37.50	2,250.00	**7,613**
21	8 " GATE VALVE	4	EA	3,500.00	14,000.00	442.50	1,770.00	**15,770**
22	8 " SCHED STD 90° ELBOW (LONG RADIUS)	4	EA	296.25	1,185.00	295.50	1,182.00	**2,367**
23	4 " SCH 40 CARBON STEEL PIPE	50	LF	30.00	1,500.00	19.13	956.25	**2,456**
24	4 " GATE VALVE	2	EA	1,437.50	2,875.00	237.00	474.00	**3,349**
25	4 " SCHED STD 90° ELBOW (LONG RADIUS)	4	EA	70.63	282.50	141.75	567.00	**850**
26	6 " SCH 40 CARBON STEEL PIPE	100	LF	56.25	5,625.00	30.75	3,075.00	**8,700**
27	6 " SCHED STD 90° ELBOW (LONG RADIUS)	4	EA	157.50	630.00	220.50	882.00	**1,512**
28	**ELECTRICAL SUMMARY**							
29	3#250 15KV, MV-105, 133% EPR CABLE + 600V GND	750	LF	40.00	30,000.00	20.00	15,000.00	**45,000**
30	4" RIGID METAL CONDUIT	250	LF	30.00	7,500.00	20.00	5,000.00	**12,500**
31	MV CABLE TERMINATIONS	12	EA	300.00	3,600.00	100.00	1,200.00	**4,800**
32	15KV, 2000A METAL CLAD SGR (SINGLE VACUUM BKR)	1	EA	100,000.00	100,000.00	5,000.00	5,000.00	**105,000**
33	3# 4 THHN + #8 GND	600	LF	0.75	450.00	0.60	360.00	**810**
34	1" RIGIG METAL CONDUIT	150	LF	8.00	1,200.00	13.00	1,950.00	**3,150**
35	CABLE/SWGR TESTING	1	LS			15,000.00	15,000.00	**15,000**
	OPTION 1 SUBTOTAL				**$ 1,326,060**		**$ 444,191**	**$ 1,770,252**
37	OVERHEAD 10%				$ 132,606		$ 44,419	$ 177,025.20
38	PROFIT 15%				$ 198,909		$ 66,629	$ 265,537.80
39	SALES TAX 7%				$ 92,824			$ 92,824.20
40	CONSTRUCTION CONTINGENCY 5%				$ 82,879		$ 27,762	$ 110,640.75
41	DESIGN CONTINGENCY 5%				$ 82,879		$ 27,762	$ 110,640.75
	TOTAL				**$ 1,916,157**		**$ 610,763**	**$ 2,526,921**

Appendix No. 6 – Boiler Selections & Quotes

Jonathan Eveleth

From: Jonathan Eveleth
Sent: Tuesday, June 23, 2020 11:33 AM
To: Jonathan Eveleth
Subject: ASU - ACME BOILER PRICING

From: gspresser@acmeprod.com <gspresser@acmeprod.com>
Sent: Tuesday, May 5, 2020 1:31 PM
To: Jonathan Eveleth <jonathan.eveleth@rmf.com>
Cc: rpresser@acmeprod.com; cristian@acmeprod.com; Gizele Tessier <gizele.tessier@acmeprod.com>
Subject: Re: [EXTERNAL] ACME CEJS 75000 lb/hr Steam Boiler

This message originated from an EXTERNAL ADDRESS. Please use extra caution opening attachments or clicking links. Please call the sender if there are any questions of validity.

Jonathan: :

Below are the basic answers for your consideration including budget estimates:

Vessels ASME Section 1, 150 PSI design, operating min 105 PSIG max. 135 PSIG Steam
Voltage 12.47 V 3 ph 4 wire 60 Hz

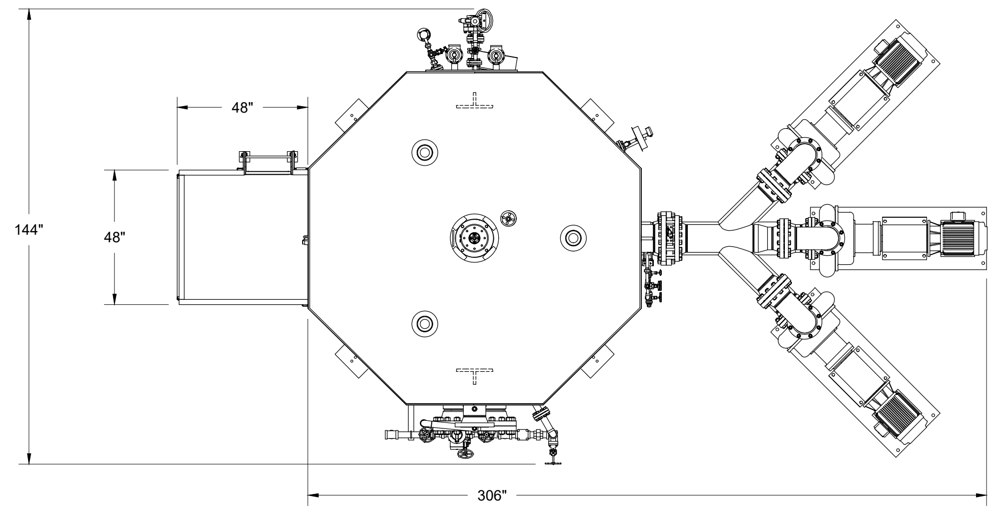
CEJS-600, 20,000 PPH, 6MW, 278 A, $450,000.-
CEJS-1200, 40,000 PPH, 12MW, 556 A, $700,000.-
CEJS-2400, 80,000 PPH, 24MW, 1113 A, $1,000,000.-

Transportation plant to site could vary between 25K and 50K
Add 12% for site reassembly of internals which could be damaged during transportation if mounted at the factory.

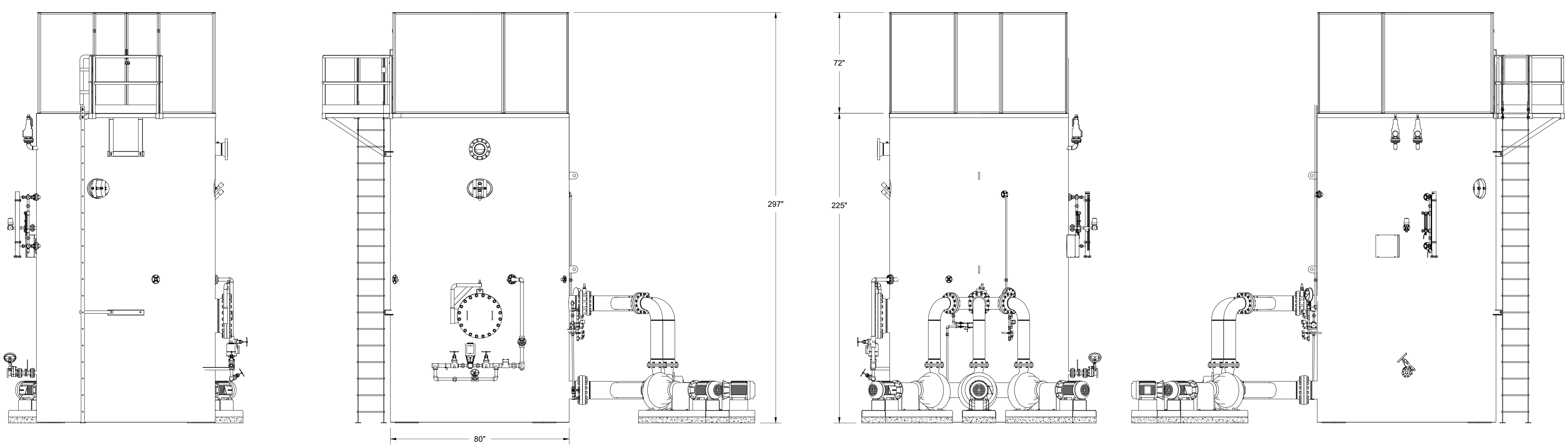
Please let me know your choice and we will send you a filled-in spec sheet. Willl need exact name and location of the project.

Keep healthy,

Steve
Acme Engineering Prod. Inc



Plan View



Rear View

Left Hand Side

Front View

Right Hand Side

REVISIONS
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NOTES:
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SAMPLE DD

SAMPLE DIMENSIONAL DIAGRAM

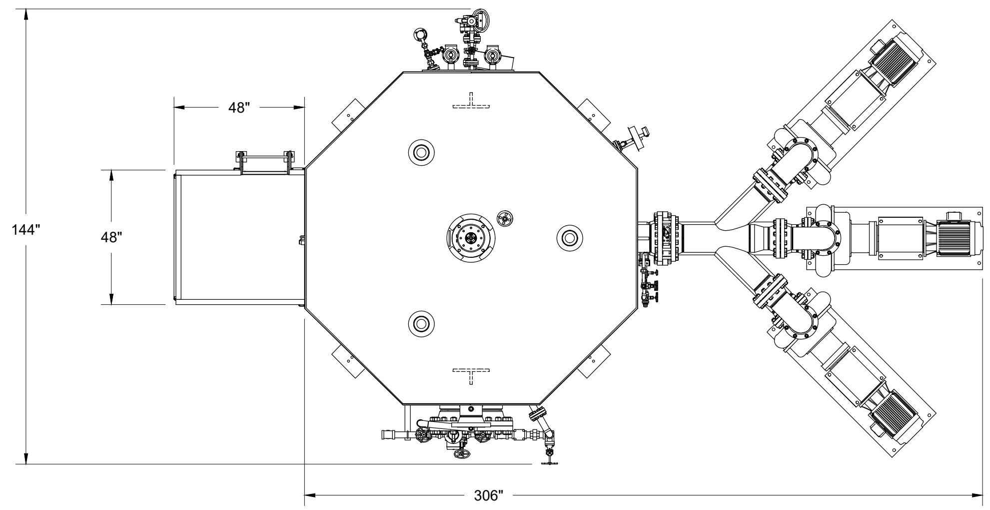
SIZE D

SHT 01 OF 01

SCALE N.T.S.
DATE 6-10-20
DRAWN
CHECKED BY

CleaverBrooks

DRWG. NO. SAMPLE DD 00



Plan View

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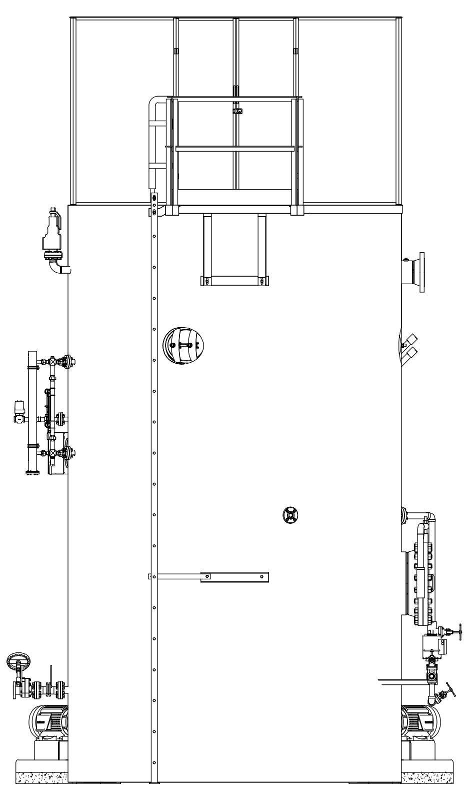
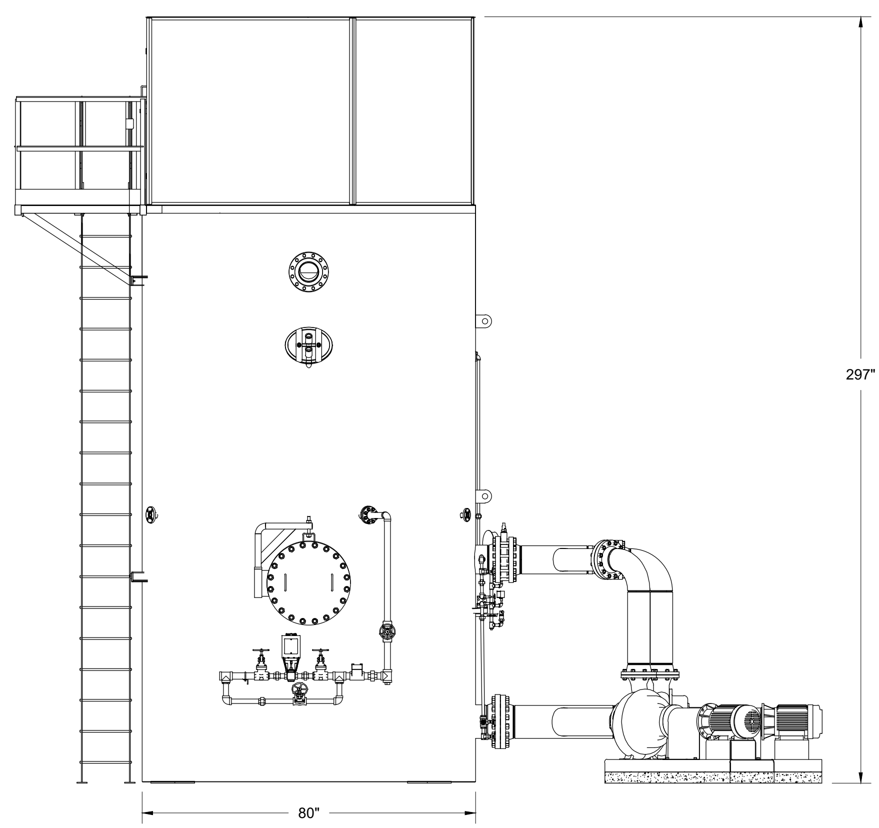
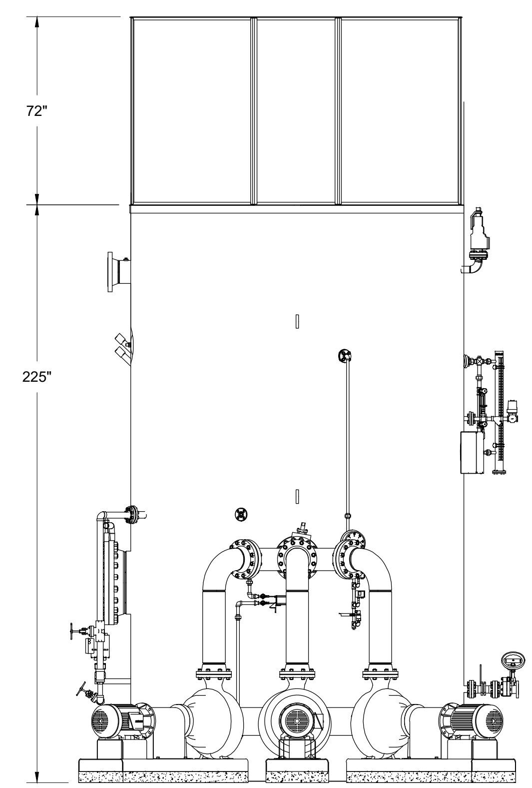


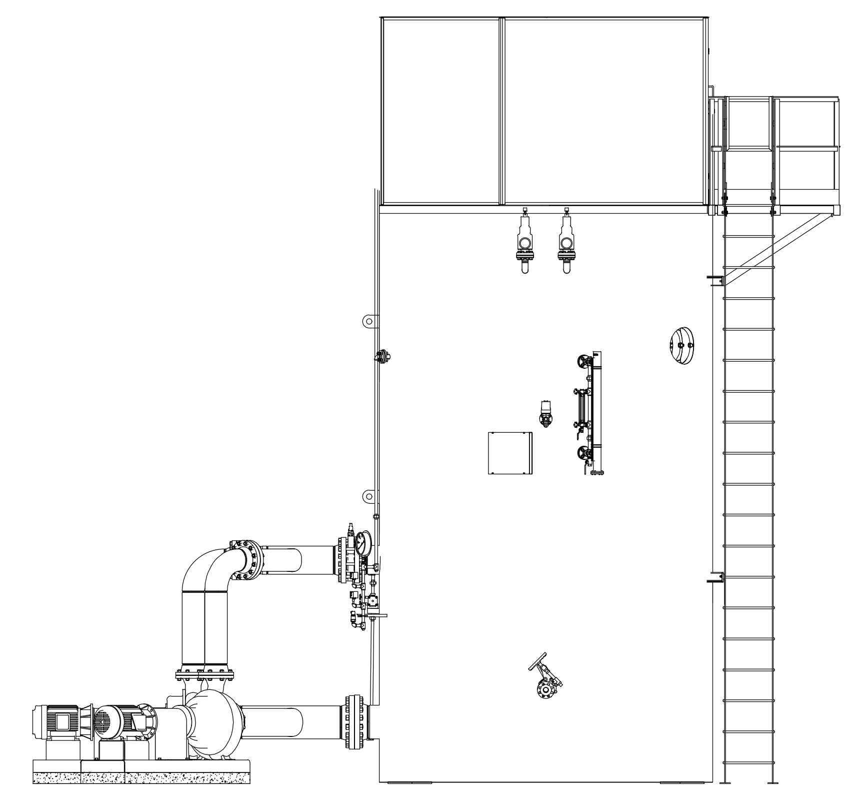
Rear View



Left Hand Side



Front View



Right Hand Side

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SAMPLE DD

SAMPLE DIMENSIONAL DIAGRAM

SIZE D

SHT 01 OF 01

SCALE N.T.S.

DATE 6-10-20

DRAWN

CHECKED BY

CleaverBrooks

DRWG. NO. SAMPLE DD 00

Electrode Boiler Quote

TO :	**RMF Engineering - Raleigh**	**Date :**	**4/29/2020**
ATTN :	**Jonathan Eveleth**	**FROM :**	**Cleaver-Brooks**
JOB NAME :	**ASU Boone 40K**	**QUOTE EXPIRATION DATE:**	**7/28/2020**

QUOTE DESCRIPTION :	**Model**		**Size**		**Rating**		**Pressure**		**Voltage**
	CEJS	**-**	**2400**	**-**	**12 MW**	**-**	**200 ST**	**-**	**12.47 KV**

Quantity : 1
Lead Time : 18-20 weeks

BUDGET PRICE TO CUSTOMER : **$ 410,000 USD**

PART 1: PRODUCT

1.1. PRESSURE VESSEL
   a. 200 psig design with Manufacturer's Data Report and National Board Registration
   b. ASME safety relief valves set @ 200 psig
   c. Total boiler capacity at 212° F feedwater is 39,987 lb/hr each
   d. Pressure vessel factory insulated with 2" nominal thickness fiberglass blanket
   e. Skid mounted vessel and enamel coated sheet metal enclosure over insulation
   f. Hydraulic lift tower assembly
   g. Maintenance ladder and platform

1.2. ELECTRICAL
   a. Electrodes & power train assemblies
   b. Counter electrodes
   c. Boiler circulating pump(s) with mechanical seal(s), 5-20hp each
   d. Hydraulic pump (simplex), 1hp
   e. Junction box on boiler for single point wiring of controls and instruments

1.3. CONTROL
   a. Allen Bradley Compact Logix PLC, proportional pressure, power, and level control
   b. LevelMaster Boiler Water Level Control
      i. Internal probe high and high-high water cutoffs and alarm
      ii. Water level sight glass
   c. Steam pressure and water level transmitters, Endress + Hauser
   d. Steam pressure gauge
   e. Quick open and slow open bottom blowdown valves
   f. Feedwater stop and check valves with 3-valve by-pass
   g. Conductivity control with low and high setpoint and alarm, Rosemount
   h. Automatic surface blowdown with solenoid valve and strainer
   i. Steam stop valve, 10"
   j. Back pressure control valve, Fisher
   k. Manual vent valve
   l. Nexus 1250 advanced performance power meter with power quality management capability:
      i. Waveform and fault recorder
      ii. Phasor analysis to detect phase imbalance
      iii. Data logging for trending analysis
      iv. Expandable inputs/outputs
      v. (c)UL listed, ANSI and IEC compliant
   m. Prewired, attached control cabinet including the following components:
      vi. Control circuitry, PLC
      vii. Electronic metering

viii. Lights, relays, wiring, contacts, terminals, etc.
ix. 10” touch-screen HMI, remote web access
x. Protocol translator for facility monitoring capability
xi. Ethernet port, flash card socket, serial port, USB port

PART 2: ASSEMBLY

2.1 ITEMS SHIPPED LOOSE FOR REASSEMBLY BY OTHERS
- a. Electrode and insulator assemblies
- b. Counter electrodes
- c. Hydraulic tower assembly, cylinder and control rods
- d. High voltage terminal cage
- e. Feedwater & blowdown valve assemblies
- f. Steam outlet valve
- g. Safety relief valves
- h. Circulating pump(s), piping and valves
- i. Maintenance platform and ladder

PART 3: ITEMS NOT INCLUDED

3.1. WATER TREATMENT
- a. Cleaver-Brooks deaerator or boiler feed system
- b. Cleaver-Brooks chemical feed system
- c. Cleaver-Brooks water softener and dealkalizer
- d. Cleaver-Brooks blowdown heat recovery and seperators

3.2. ELECTRICAL
- a. High voltage breaker

3.3. INSTALLATION
- a. Erection and piping
- b. Wiring
- c. Rigging and unloading
- d. Estimated assembly timeline:
  - i. 15 days for assembly of shipped loose items.
  - ii. 12 days for wiring and piping connection to plant.

PART 4: STARTUP

4.1. CLEAVER BROOKS SUPPORT
- a. Five (5) days of startup assistance from one (1) CB Service technician is included; the included Cleaver Brooks Service startup and commissioning support is based on a single travel period.
- b. Additional Cleaver Brooks Service rate will be charged per day, if needed; per Cleaver Brooks Standard Travel Policy, Cleaver Brooks travel expenses will be billed to customer at cost, subject to availability.

4.2. FREIGHT
- a. Price is Ex-Works Thomasville, GA, no freight allowed.
- b. Dry weight each is approximately 40,000 lbs
  - i. Supporting equipment is not included
- c. Vessel approximate shipping dimensions
  - i. 128" Height
  - ii. 116" Width
  - iii. 224" Length
  - iv. 96” Vessel Diameter

4.3. INSTALLED APPROXIMATE DIMENSIONS
- a. 296" Height
- b. 140" Width
- c. 288" Length

4.4. TERMS AND CONDITIONS
- a. 20% with order
- b. 30% upon release for production
- c. 50% upon readiness to ship
- d. All terms are net 30 days

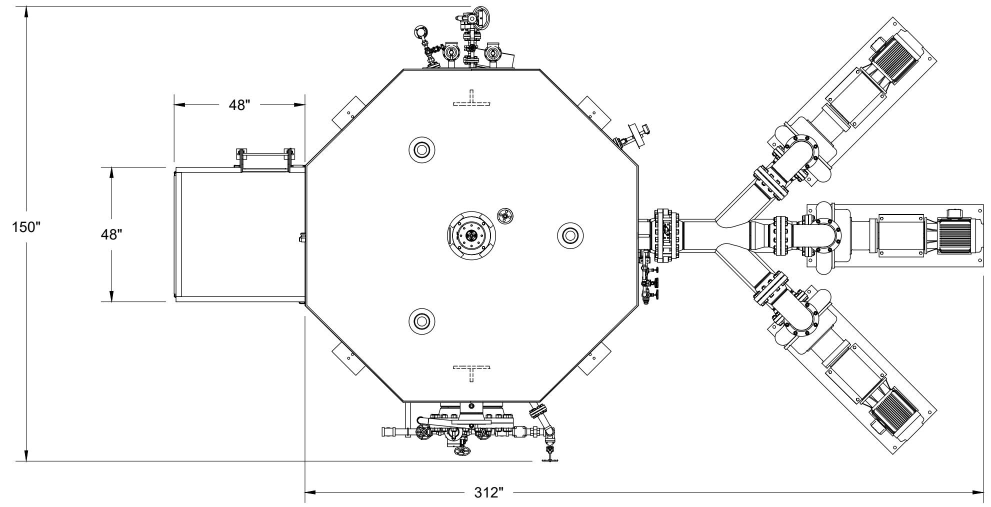
Electrode Boiler Quote

PART 5: CLARIFICATIONS AND EXCEPTIONS

Section:		
Reference	**C/E**	**Description**

Section:		
Reference	**C/E**	**Description**

Section:		
Reference	**C/E**	**Description**



Plan View

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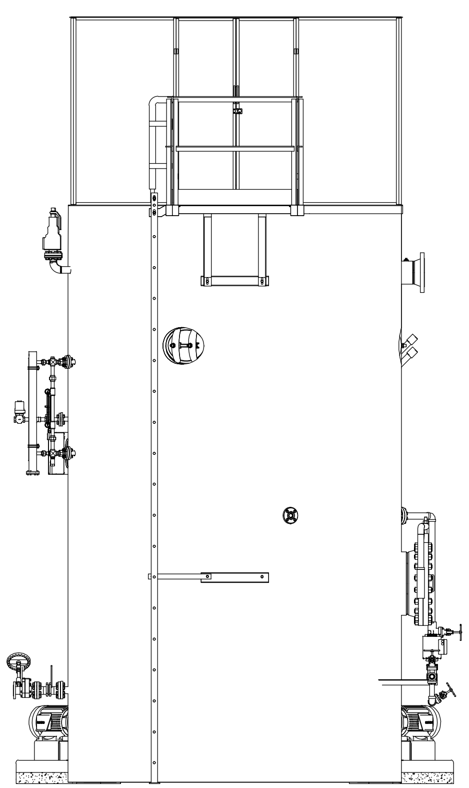
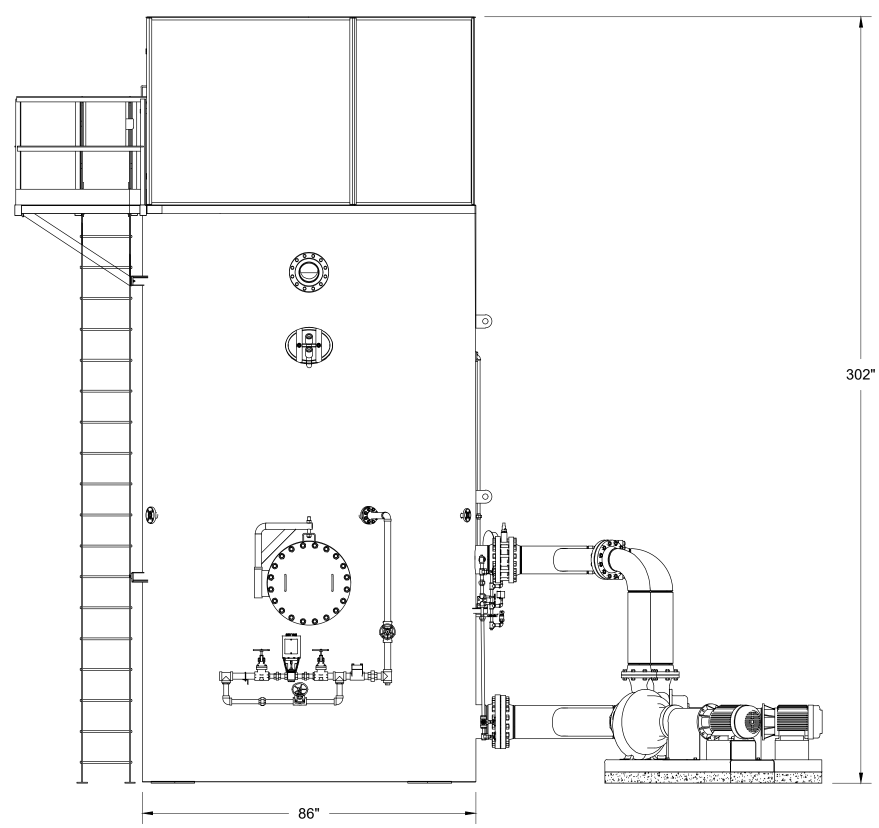


Rear View



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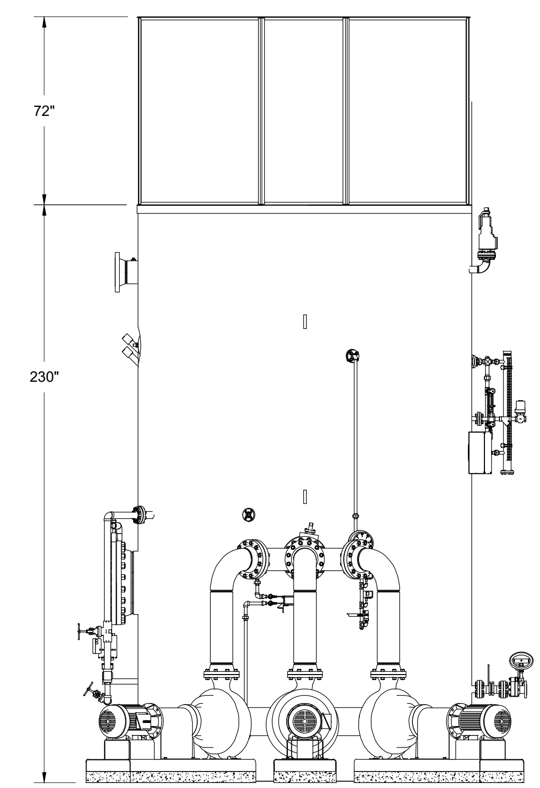
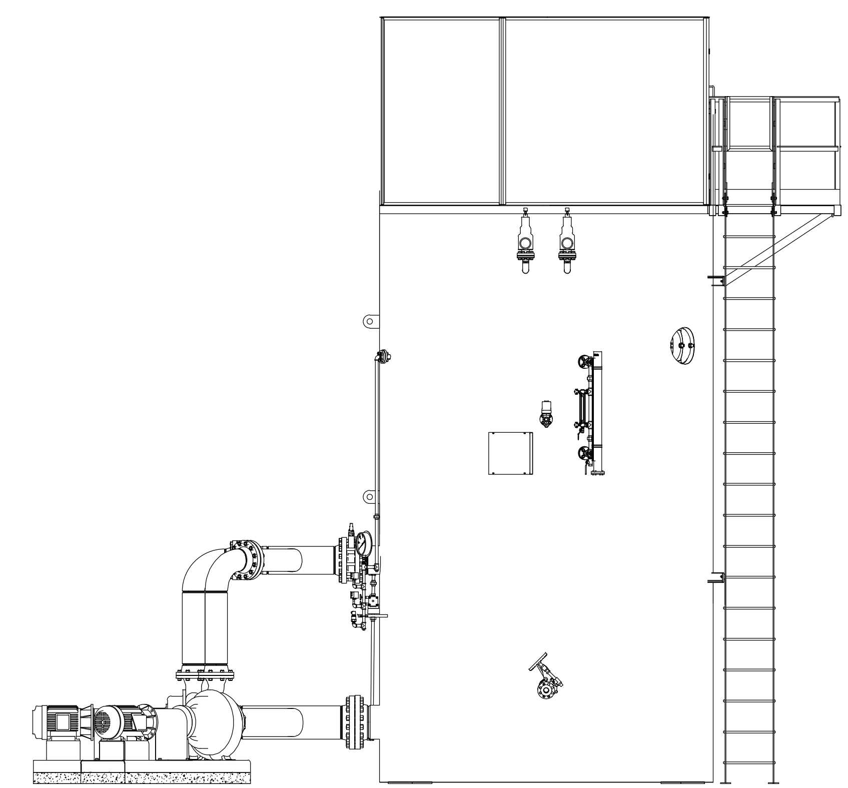


Front View



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REVISIONS
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SAMPLE DD	SAMPLE DIMENSIONAL DIAGRAM
SIZE D	SHT 01 OF 01
SCALE	N.T.S.
DATE	6-10-20
DRAWN	
CHECKED BY	
DRWG. NO.	SAMPLE DD
REV.	00

Electrode Boiler Quote

TO : RMF Engineering – Raleigh **Date :** 5/01/2020

ATTN : Jonathan Eveleth **FROM :** Cleaver-Brooks

JOB NAME : ASU Boone 80K **QUOTE EXPIRATION DATE:** 7/28/2020

QUOTE DESCRIPTION :	Model		Size		Rating		Pressure		Voltage
	CEJS	-	3000	-	24 MW	-	200 ST	-	12.47 KV

Quantity : 1
Lead Time : 18-20 weeks

BUDGET PRICE TO CUSTOMER : **$ 530,000 USD**

PART 1: PRODUCT

1.1. PRESSURE VESSEL
  a. 200 psig design with Manufacturer's Data Report and National Board Registration
  b. ASME safety relief valves set @ 200 psig
  c. Total boiler capacity at 212° F feedwater is 79,974 lb/hr each
  d. Pressure vessel factory insulated with 2" nominal thickness fiberglass blanket
  e. Skid mounted vessel and enamel coated sheet metal enclosure over insulation
  f. Hydraulic lift tower assembly
  g. Maintenance ladder and platform

1.2. ELECTRICAL
  a. Electrodes & power train assemblies
  b. Counter electrodes
  c. Boiler circulating pump(s) with mechanical seal(s), 5-20hp each
  d. Hydraulic pump (simplex), 1hp
  e. Junction box on boiler for single point wiring of controls and instruments

1.3. CONTROL
  a. Allen Bradley Compact Logix PLC, proportional pressure, power, and level control
  b. LevelMaster Boiler Water Level Control
    i. Internal probe high and high-high water cutoffs and alarm
    ii. Water level sight glass
  c. Steam pressure and water level transmitters, Endress + Hauser
  d. Steam pressure gauge
  e. Quick open and slow open bottom blowdown valves
  f. Feedwater stop and check valves with 3-valve by-pass
  g. Conductivity control with low and high setpoint and alarm, Rosemount
  h. Automatic surface blowdown with solenoid valve and strainer
  i. Steam stop valve, 12"
  j. Back pressure control valve, Fisher
  k. Manual vent valve
  l. Nexus 1250 advanced performance power meter with power quality management capability:
    i. Waveform and fault recorder
    ii. Phasor analysis to detect phase imbalance
    iii. Data logging for trending analysis
    iv. Expandable inputs/outputs
    v. (c)UL listed, ANSI and IEC compliant
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g. Safety relief valves
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a. Cleaver-Brooks deaerator or boiler feed system
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d. Cleaver-Brooks blowdown heat recovery and seperators

3.2. ELECTRICAL
a. High voltage breaker

3.3. INSTALLATION
a. Erection and piping
b. Wiring
c. Rigging and unloading
d. Estimated assembly timeline:
i. 15 days for assembly of shipped loose items.
ii. 12 days for wiring and piping connection to plant.

PART 4: STARTUP

4.1. CLEAVER BROOKS SUPPORT
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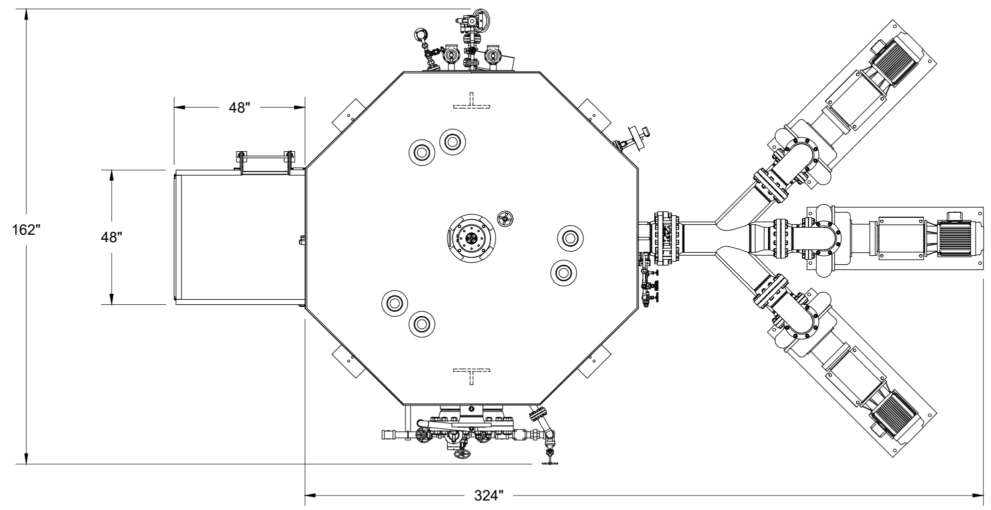
b. Additional Cleaver Brooks Service rate will be charged per day, if needed; per Cleaver Brooks Standard Travel Policy, Cleaver Brooks travel expenses will be billed to customer at cost, subject to availability.

4.2. FREIGHT
a. Price is Ex-Works Thomasville, GA, no freight allowed.
b. Dry weight each is approximately 55,000 lbs
i. Supporting equipment is not included
c. Vessel approximate shipping dimensions
i. 140" Height
ii. 128" Width
iii. 246" Length
iv. 108” Vessel Diameter

4.3. INSTALLED APPROXIMATE DIMENSIONS
a. 318" Height
b. 152" Width
c. 300" Length

4.4. TERMS AND CONDITIONS
a. 20% with order
b. 30% upon release for production
c. 50% upon readiness to ship
d. All terms are net 30 days

7	6	5	4	3	2	1



Plan View

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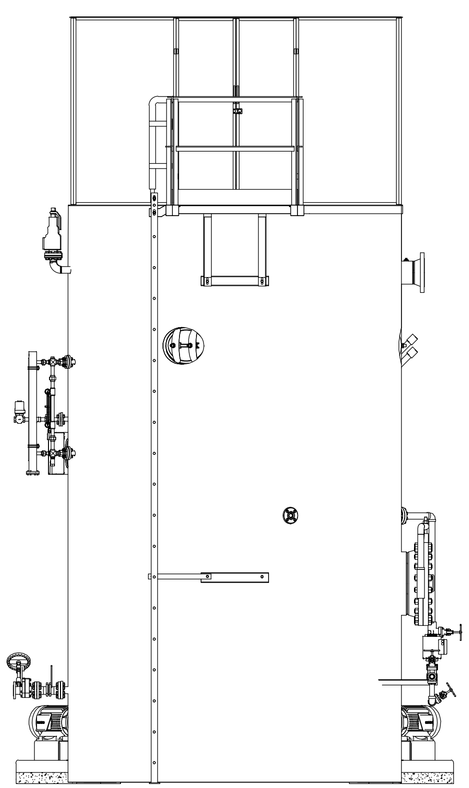
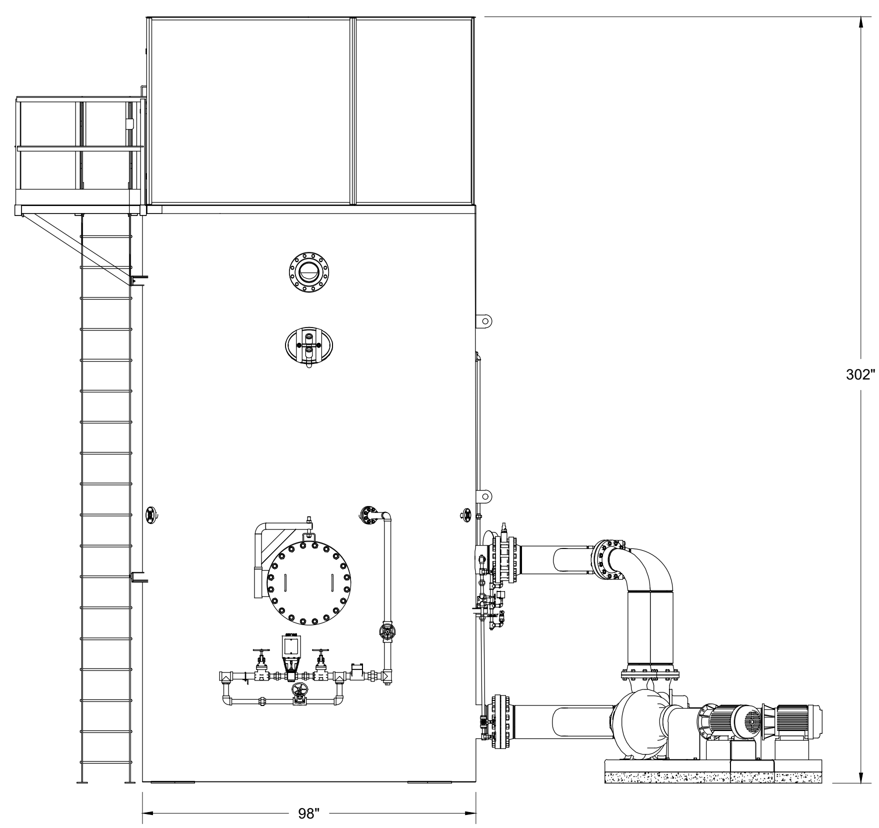


Rear View



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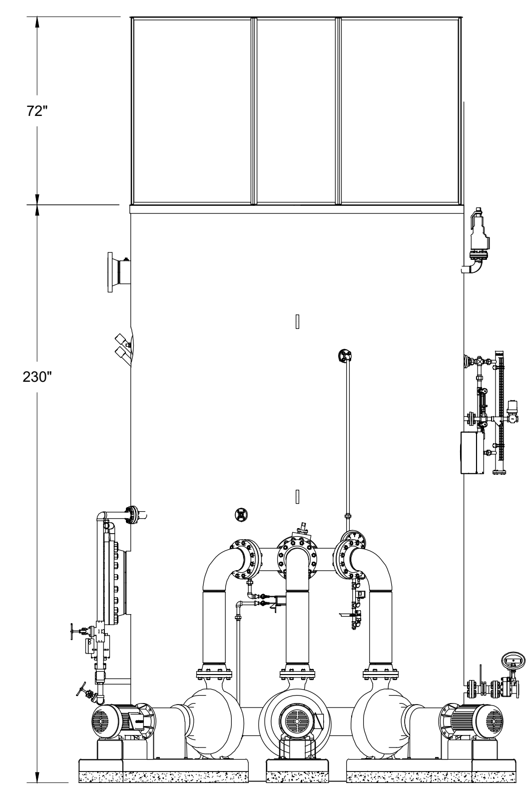
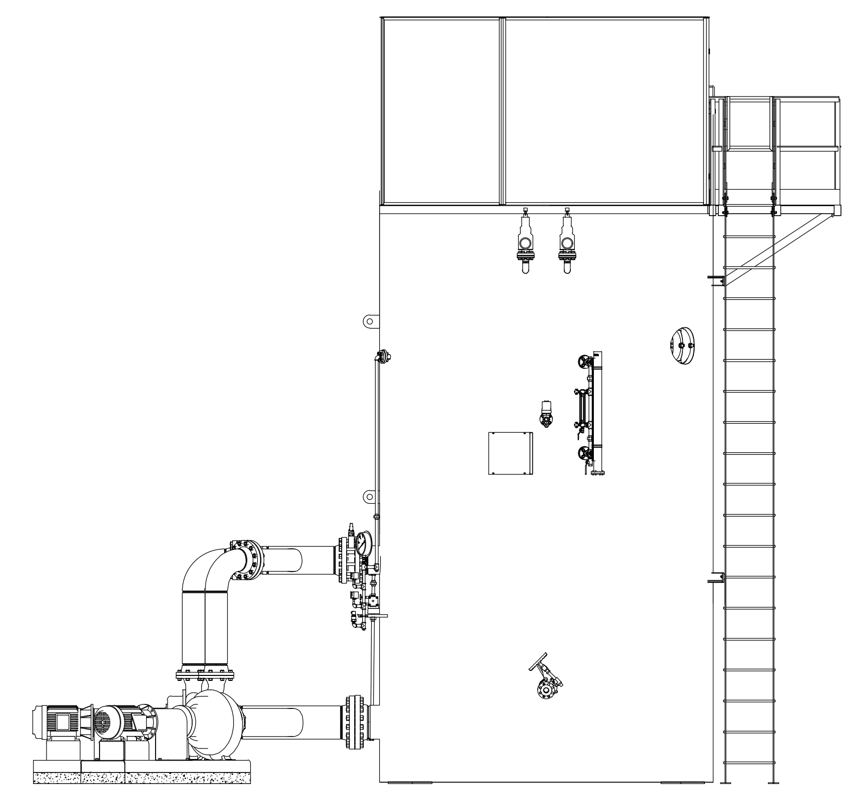


Front View



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WARNING

LIFTING LUGS PROVIDED ON THE VESSEL SHALL ONLY BE USED TO LIFT THE VESSEL WHEN IT IS DRY.

WARNING

CHANGES, MODIFICATIONS OR ALTERATIONS ARE STRICTLY PROHIBITED.

CHANGES TO THIS DRAWING AND SUBSEQUENT MODIFICATION OF EQUIPMENT COULD RESULT IN DAMAGE TO THE EQUIPMENT AND/OR SERIOUS PERSONAL INJURY.

SAMPLE DD

SAMPLE DIMENSIONAL DIAGRAM

SIZE D

SHT 01 OF 01

SCALE N.T.S.
DATE 6-10-20
DRAWN
CHECKED BY

CleaverBrooks

DRWG. NO. SAMPLE DD 00

E	D	C	B	A

Jonathan Eveleth

From: Jonathan Eveleth
Sent: Tuesday, June 23, 2020 11:37 AM
To: Jonathan Eveleth
Subject: ASU - PRECISION BOILER PRICING

From: Suchy, Dan <Dan.Suchy@trane.com>
Sent: Thursday, June 18, 2020 11:12 AM
To: Jonathan Eveleth <jonathan.eveleth@rmf.com>
Subject: [EXTERNAL] RE: App State-Precision HVJ Information

This message originated from an EXTERNAL ADDRESS. Please use extra caution opening attachments or clicking links. Please call the sender if there are any questions of validity.

Jonathan,

Here are budget prices for each of the boiler sizes:

Model HVJ-138-200 - $830,000

Model HVJ-228-200 - $945,000

Model HVJ-438-200 - $1,650,000

Budgets include a dedicated automatic chemical feed system, spare parts, factory startup, and owner training. The typical lead time is 22-24weeks.

Dan Suchy
Sales Engineer, Brady Trane

401 Kitty Hawk Drive, Morrisville, NC 27560
919-232-5743 : Direct
919-801-8306 : Mobile
919-781-9195 : Fax
dan.suchy@trane.com

PRECISION BOILERS

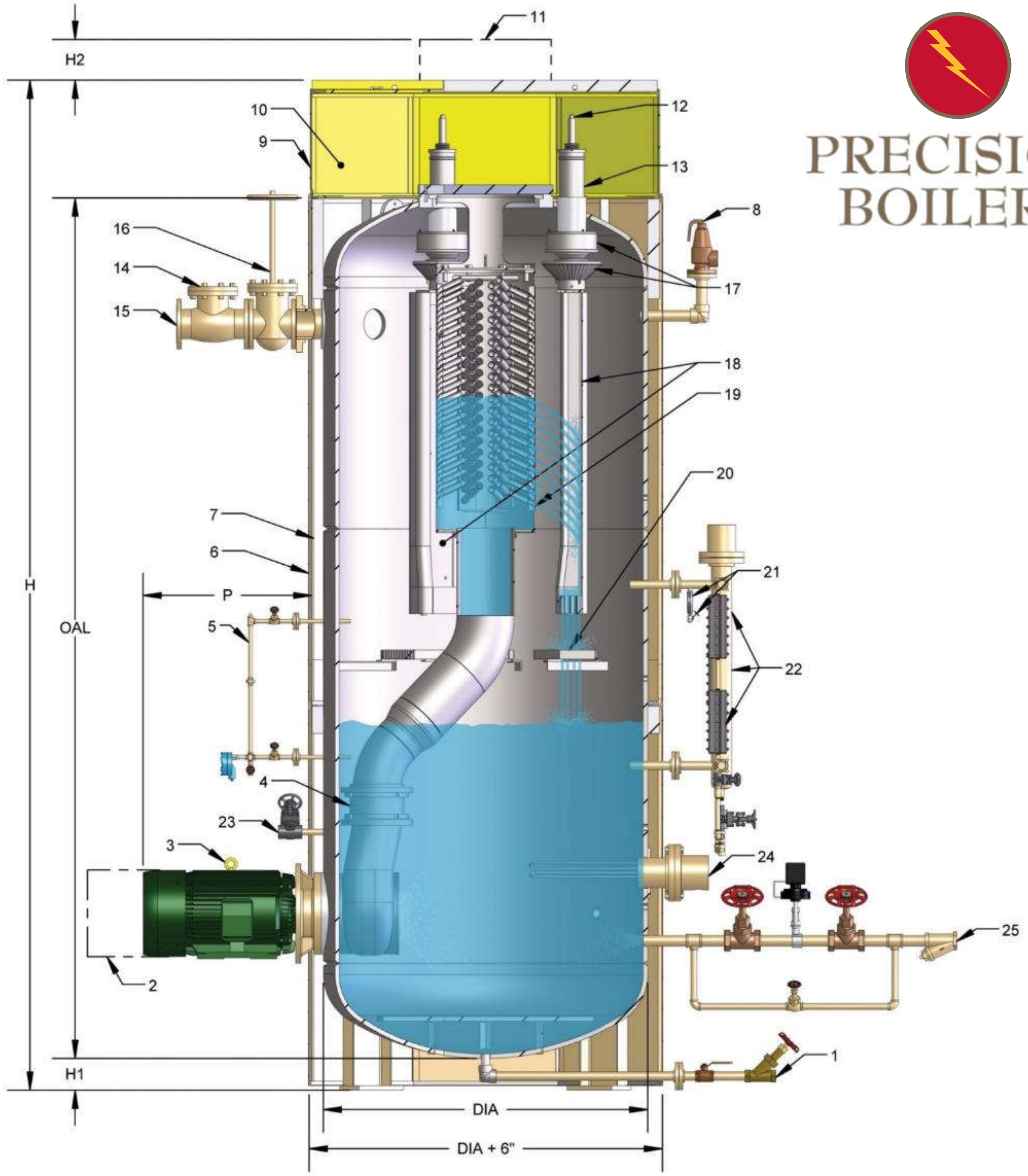
Model HVJ-138-200
ELECTRODE STEAM BOILER

DESIGN ADVANTAGES

- Highest Efficiency - 99.5%
- Zero Emissions
- No Emission Permitting Required
- Full Modulation (0% to 100%) Output
- Lower Total Installed Capital Cost
- Best Steam Quality > 99.9% Pure
- Lower Maintenance Cost
- Lower Insurance Cost
- Less Chemical Usage
- Higher Reliability
- More Forgiving to Operator Error
- “Fail Safe” in Low Water Condition
- No Cold Water Shock
- Few Proprietary Spare Parts

STANDARD FEATURES AND ACCESSORIES

• ASME Section I, Part PEB, pressure vessel with Manufacturer's Data Report & National Board Registration	• Feedwater Control, Stop and Check Valves with three-valve bypass
• Pressure vessel Factory-insulated with 4" nominal thickness fiberglass and skid-mounted in an enameled sheet metal enclosure.	• Automatic Surface Blow-off, with air-operated valve, strainer & bleed valve (activated by Conductivity Control)
• Water Column with Low & High Water Cutoffs and Progressive Alarms	• Quick-opening and slow-opening bottom Blowdown Valves
• External Boiler Circulation Pump with Mechanical Seal	• Water Level Sight and Steam Pressure Gauges
• VFD to Drive Circulation Pump Motor	• Integral, lockable 15KV terminal enclosure.
• ASME Safety Valves	• Conductivity Control with Low & High Set points with alarm
• Proportional Pressure, KW and Level Controls	• Steam Pressure & Water Level Transmitters
• Manual & Auto reset High Pressure Cutouts w/Alarms	• Standby Immersion Heater
• Auto and Manual Vent Valves	• Steam Stop & Check Valves
• Junction Box for single point wiring controls/instruments	• Back Pressure Control Valve
• Bypass Feeder for Electrolyte (w/funnel and valves)	• Sample Cooler w/ Valves (316 SS)



PRECISION BOILERS

1 – Bottom Blowdown Valves
2 - Pump Removal Clearance
3 - Circulation Pump w/VFD
4 - Check Valve (for multiple pumps only)
5 - Conductivity Cell
6 - Sheet Metal Enclosure
7 - Insulation
8 - Safety Valves (2)
9 - Electrode Terminal Enclosure
10 - Conduit Entrance Panel
11 - Header Removal Clearance
12 - Conductor Rod
13 - High Voltage Insulators
14 - Back Pressure Regulator
15 - Steam Outlet
16 - Non-Return Valve
17 - Insulator Shields
18 - Electrode/Strike Plate
19 - Nozzle Header Assembly
20 - Counter Electrode
21 - Pressure Manifold & Gage
22 - Water Column & Gage
23 - Surface Blowoff Valve
24 - Standby Heater
25 - Feedwater Valve w/Bypass
26 - Manhole

PRECISION BOILERS

MODEL HVJ-138-200 ELECTRODE STEAM BOILER

	Maximum Rating in MW**			Maximum Rating in PPH**			Dimensions (inches)							Weight (lbs)***	
	4160V	6.9kV	12.4 kV	4160V	6.9kV	13.2 kV	Dia.	OAL	H	H1	H2	P	Ship	Operate
HVJ-138			7.7			25,645	60	176	206	6	36	36	13,000	17,800

**Boiler Maximum Ratings are for peak operation at 150 psi (10 bar) with 220ºF (104ºC) feedwater. ***Weights are for boiler built to 175 psi (12 bar) design pressure.

		Model 138
Guaranteed Performance Operating at 140 psi Working Pressure with 220°F Feedwater Supply and 12.4 kV Power Supply	Maximum Output Rating @ 12.4kV	7.7 MW 25,645 PPH
	90% Continuous Duty Rating @ 12.4kV	6.93 MW 23,080 PPH
Configuration	No. of Electrodes	3
Recirculation Pump	Quantity @ HP	1 @ 20 HP
	VFD HP	25
Feedwater	Flow (gpm)	54
Tank Capacity	Operating (gal)	650
	Flooded (gal)	2,000
Standby Heater	Rating (kW)	30
	Time Req'd (hrs)	10
Connection Sizes	Steam Output	6-inch Flange
	Feedwater	1-1/2-inch FLG
	Bottom Blowdown	1-1/2-inch NPT
	Surface Blowoff	3/4-inch NPT
	Air Release	1-inch NPT
	Riser Pipe	8-inch
Weight (Lbs)	Tank***	12,000 lbs
	Circulation Pump	N/A

PRECISION BOILERS

Model HVJ-228-200
ELECTRODE STEAM BOILER

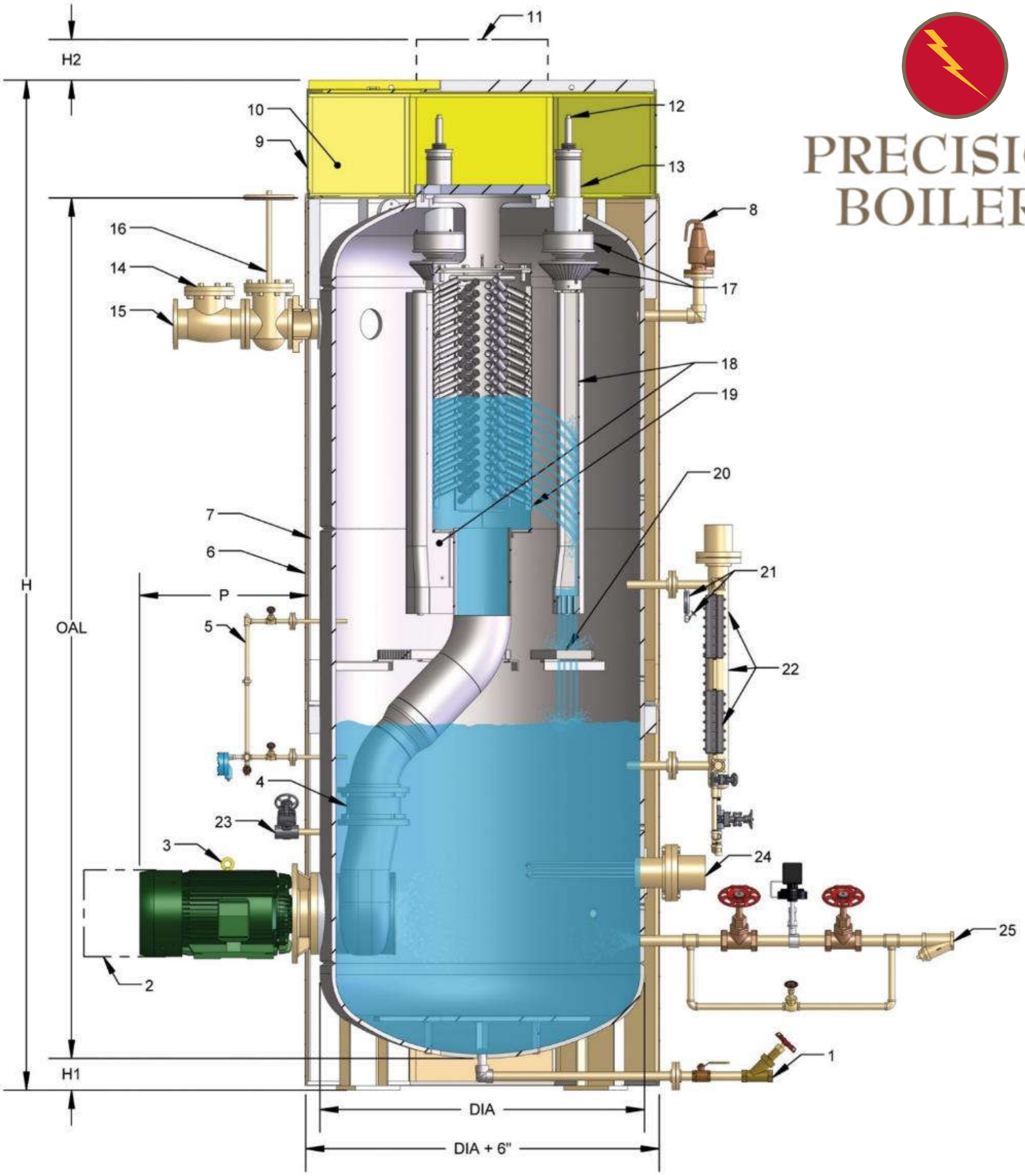
DESIGN ADVANTAGES

- Highest Efficiency - 99.5%
- Zero Emissions
- No Emission Permitting Required
- Full Modulation (0% to 100%) Output
- Lower Total Installed Capital Cost
- Best Steam Quality > 99.9% Pure
- Lower Maintenance Cost
- Lower Insurance Cost
- Less Chemical Usage
- Higher Reliability
- More Forgiving to Operator Error
- “Fail Safe” in Low Water Condition
- No Cold Water Shock
- Few Proprietary Spare Parts

STANDARD FEATURES AND ACCESSORIES

• ASME Section I, Part PEB, pressure vessel with Manufacturer's Data Report & National Board Registration	• Feedwater Control, Stop and Check Valves with three-valve bypass
• Pressure vessel Factory-insulated with 4" nominal thickness fiberglass and skid-mounted in an enameled sheet metal enclosure.	• Automatic Surface Blow-off, with air-operated valve, strainer & bleed valve (activated by Conductivity Control)
• Water Column with Low & High Water Cutoffs and Progressive Alarms	• Quick-opening and slow-opening bottom Blowdown Valves
• External Boiler Circulation Pump with Mechanical Seal	• Water Level Sight and Steam Pressure Gauges
• VFD to Drive Circulation Pump Motor	• Integral, lockable 15KV terminal enclosure.
• ASME Safety Valves	• Conductivity Control with Low & High Set points with alarm
• Proportional Pressure, KW and Level Controls	• Steam Pressure & Water Level Transmitters
• Manual & Auto reset High Pressure Cutouts w/Alarms	• Standby Immersion Heater
• Auto and Manual Vent Valves	• Steam Stop & Check Valves
• Junction Box for single point wiring controls/instruments	• Back Pressure Control Valve
• Bypass Feeder for Electrolyte (w/funnel and valves)	• Sample Cooler w/ Valves (316 SS)

PRECISION BOILERS



1 – Bottom Blowdown Valves
2 - Pump Removal Clearance
3 - Circulation Pump w/VFD
4 - Check Valve
(for multiple pumps only)
5 - Conductivity Cell
6 - Sheet Metal Enclosure
7 - Insulation
8 - Safety Valves (2)
9 - Electrode Terminal Enclosure
10 - Conduit Entrance Panel
11 - Header Removal Clearance
12 - Conductor Rod
13 - High Voltage Insulators
14 - Back Pressure Regulator
15 - Steam Outlet
16 - Non-Return Valve
17 - Insulator Shields
18 - Electrode/Strike Plate
19 - Nozzle Header Assembly
20 - Counter Electrode
21 - Pressure Manifold & Gage
22 - Water Column & Gage
23 - Surface Blowoff Valve
24 - Standby Heater
25 - Feedwater Valve w/Bypass
26 - Manhole

PRECISION BOILERS

MODEL HVJ-228-200
ELECTRODE STEAM BOILER

	Maximum Rating in MW**			Maximum Rating in PPH**			Dimensions (inches)							Weight (lbs)***	
	4160V	6.9kV	12.4 kV	4160V	6.9kV	13.2 kV	Dia.	OAL	H	H1	H2	P	Ship	Operate
HVJ-228			11.3			37,576	72	190	221	7	24	32	16,000	23,200

**Boiler Maximum Ratings are for peak operation at 150 psi (10 bar) with 220°F (104°C) feedwater. ***Weights are for boiler built to 175 psi (12 bar) design pressure.

		Model 228
Guaranteed Performance Operating at 140 psi Working Pressure with 220°F Feedwater Supply and 12.4 kV Power Supply	Maximum Output Rating @ 12.4kV	11.3 MW 37,576 PPH
	90% Continuous Duty Rating @ 12.4kV	10.2 MW 33,818 PPH
Configuration	No. of Electrodes	6
Recirculation Pump	Quantity @ HP	1 @ 40 HP
	VFD HP	40
Feedwater	Flow (gpm)	80
Tank Capacity	Operating (gal)	900
	Flooded (gal)	2,450
Standby Heater	Rating (kW)	36
	Time Req'd (hrs)	8
Connection Sizes	Steam Output	6-inch Flange
	Feedwater	2-inch FLG
	Bottom Blowdown	1-1/2-inch NPT
	Surface Blowoff	1-inch NPT
	Air Release	1-inch NPT
	Riser Pipe	10-inch
Weight (Lbs)	Tank***	16,000 lbs
	Circulation Pump	1,500 lbs

PRECISION BOILERS

Model HVJ-438-200
ELECTRODE STEAM BOILER

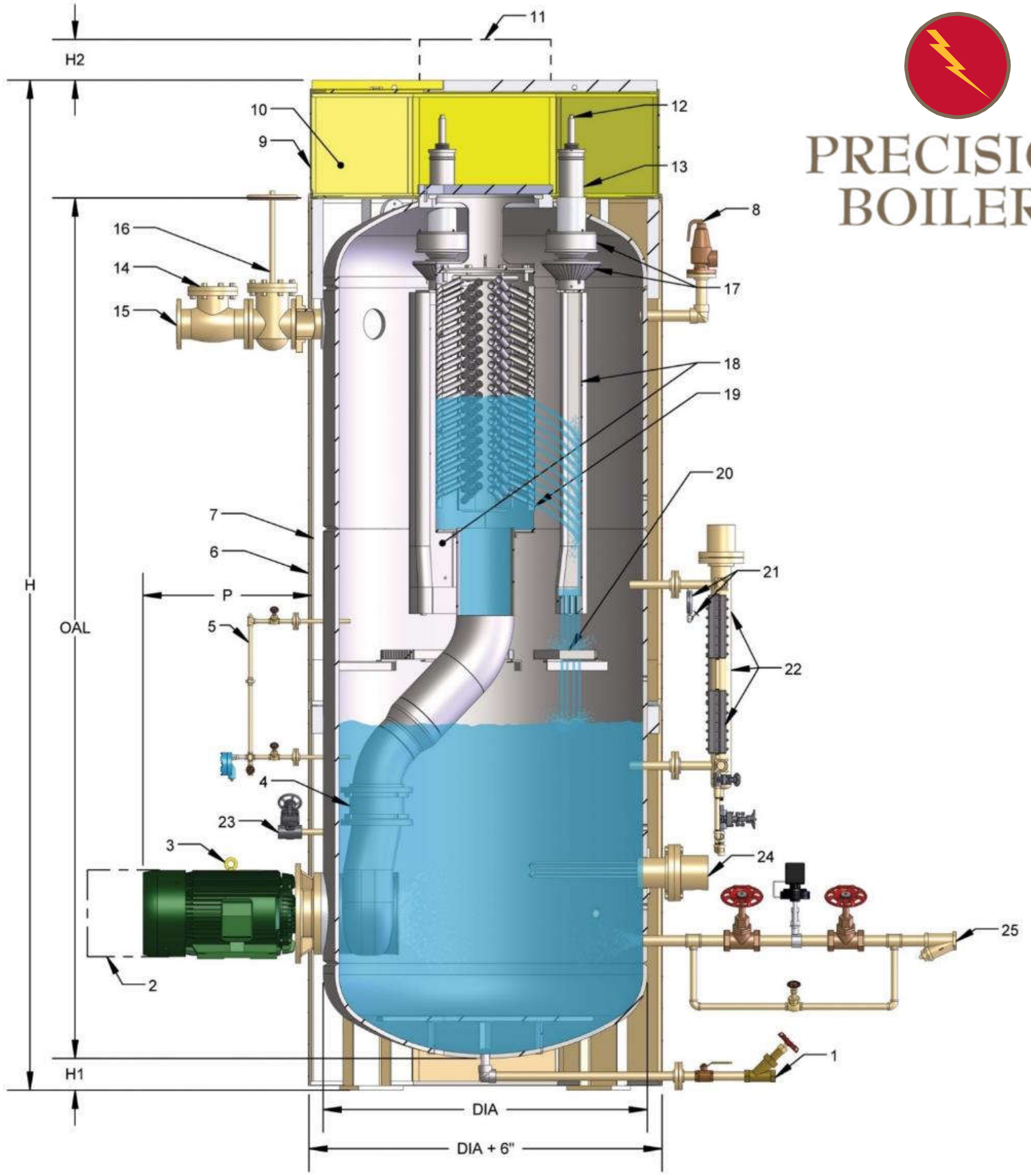
DESIGN ADVANTAGES

- Highest Efficiency - 99.5%
- Zero Emissions
- No Emission Permitting Required
- Full Modulation (0% to 100%) Output
- Lower Total Installed Capital Cost
- Best Steam Quality > 99.9% Pure
- Lower Maintenance Cost
- Lower Insurance Cost
- Less Chemical Usage
- Higher Reliability
- More Forgiving to Operator Error
- "Fail Safe" in Low Water Condition
- No Cold Water Shock
- Few Proprietary Spare Parts

STANDARD FEATURES AND ACCESSORIES

• ASME Section I, Part PEB, pressure vessel with Manufacturer's Data Report & National Board Registration	• Feedwater Control, Stop and Check Valves with three-valve bypass
• Pressure vessel Factory-insulated with 4" nominal thickness fiberglass and skid-mounted in an enameled sheet metal enclosure.	• Automatic Surface Blow-off, with air-operated valve, strainer & bleed valve (activated by Conductivity Control)
• Water Column with Low & High Water Cutoffs and Progressive Alarms	• Quick-opening and slow-opening bottom Blowdown Valves
• External Boiler Circulation Pump with Mechanical Seal	• Water Level Sight and Steam Pressure Gauges
• VFD to Drive Circulation Pump Motor	• Integral, lockable 15KV terminal enclosure.
• ASME Safety Valves	• Conductivity Control with Low & High Set points with alarm
• Proportional Pressure, KW and Level Controls	• Steam Pressure & Water Level Transmitters
• Manual & Auto reset High Pressure Cutouts w/Alarms	• Standby Immersion Heater
• Auto and Manual Vent Valves	• Steam Stop & Check Valves
• Junction Box for single point wiring controls/instruments	• Back Pressure Control Valve
• Bypass Feeder for Electrolyte (w/funnel and valves)	• Sample Cooler w/ Valves (316 SS)

PRECISION BOILERS



1 – Bottom Blowdown Valves
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13 - High Voltage Insulators
14 - Back Pressure Regulator
15 - Steam Outlet
16 - Non-Return Valve
17 - Insulator Shields
18 - Electrode/Strike Plate
19 - Nozzle Header Assembly
20 - Counter Electrode
21 - Pressure Manifold & Gage
22 - Water Column & Gage
23 - Surface Blowoff Valve
24 - Standby Heater
25 - Feedwater Valve w/Bypass
26 - Manhole

PRECISION BOILERS

MODEL HVJ-438-200 ELECTRODE STEAM BOILER

	Maximum Rating in MW**			Maximum Rating in PPH**			Dimensions (inches)						Weight (lbs)***	
	4160V	6.9kV	12.4 kV	4160V	6.9kV	13.2 kV	Dia.	OAL	H	H1	H2	P	Ship	Operate
HVJ-438			31			103,773	102	229	262	7	51	32	34,000	57,000

**Boiler Maximum Ratings are for peak operation at 150 psi (10 bar) with 220ºF (104ºC) feedwater. ***Weights are for boiler built to 175 psi (12 bar) design pressure.

<table>
<tr><th></th><th></th><th>Model 438</th></tr>
<tr><td>Guaranteed Performance
Operating at 140 psi Working Pressure with 220^{O}F Feedwater Supply and 12.4 kV Power Supply</td><td>Maximum Output Rating @ 12.4kV</td><td>31
MW
103,773 PPH</td></tr>
<tr><td></td><td>90% Continuous Duty Rating @ 12.4kV</td><td>27.9 MW
93,396 PPH</td></tr>
<tr><td>Configuration</td><td>No. of Electrodes</td><td>12</td></tr>
<tr><td rowspan="2">Recirculation Pump</td><td>Quantity @ HP</td><td>2 @ 60 HP</td></tr>
<tr><td>VFD HP</td><td>75</td></tr>
<tr><td>Feedwater</td><td>Flow (gpm)</td><td>220</td></tr>
<tr><td rowspan="2">Tank Capacity</td><td>Operating (gal)</td><td>2900</td></tr>
<tr><td>Flooded (gal)</td><td>6800</td></tr>
<tr><td rowspan="2">Standby Heater</td><td>Rating (kW)</td><td>90</td></tr>
<tr><td>Time Req'd (hrs)</td><td>16</td></tr>
<tr><td rowspan="6">Connection Sizes</td><td>Steam Output</td><td>10-inch Flange</td></tr>
<tr><td>Feedwater</td><td>3-inch FLG</td></tr>
<tr><td>Bottom Blowdown</td><td>2-inch NPT</td></tr>
<tr><td>Surface Blowoff</td><td>1-1/4-inch NPT</td></tr>
<tr><td>Air Release</td><td>1-1/4-inch NPT</td></tr>
<tr><td>Riser Pipe</td><td>12-inch</td></tr>
<tr><td rowspan="2">Weight (Lbs)</td><td>Tank***</td><td>30,000 lbs</td></tr>
<tr><td>Circulation Pump</td><td>1,500 lbs</td></tr>
</table>

Appendix No. 7 – ROM Electrode Boiler Maintenance Cost

HVJ 128 **Preliminary - Budgetary Only** **Recommended Spare Parts**

	P/N	Description	Quantities Total Unit	Quantities Spare *	Price Unit **	Price Extension	# Expected Life (Yrs)	Availability (Weeks)	## Annual Cost / Expec Life
1	14156	Insulator, Inner (<175 psi)	3	1	$1,848	$1,848	5	1-2	$370
2	10157	Insulator, Outer	3	1	$468	$468	20	1-2	$70
3	10158	Insulator, Thru	3	1	$2,932	$2,932	10	1-2	$880
4	10120	Nozzle Jet	84	18	$28	$504	10	1-2	$235
5	10168	Gasket, Outer Insulator	6	6	$23	$138	5	1-2	$28
6	10169	Gasket, Inner Insulator	6	6	$36	$216	5	1-2	$43
7	10170	Gasket, Thru Insulator	3	1	$6	$6	5	1-2	$4
9	10184	Gasket, Header	2	2	$522	$1,044	1	1-2	$1,044
10	5104.1	Gasket Manhole (12 *16)	1	3	$241	$723	1	1-2	$241
11	10167	Spring, Outer	9	3	$18	$54	5	1-2	$32
12	10166	Spring, Inner	6	2	$18	$36	5	1-2	$22
13	Job Specific	Seal, Mechanical-Double	1	1	$7,500	$7,500	2	8	$3,750
14	10125	Rod, Conductor	3	1	$1,356	$1,356	20	6	$203
15	10122	Nut, Coupling	3	1	$140	$140	20	6	$21
16	804140	Spring Washer, Belleville	15	5	$24	$120	5	1-2	$72
17		Nut, Hex-Plated (1-1/2-12)	3	2	$8	$16	10	1-2	$5
18	10142	Strike Plate	3	1	$250	$250	10	2	$75
					TOTAL	$17,351			$7,094 Annual Cost

* Quantity of Spares recommended for 3 year operation

** Prices are budgetary only

The Life Expectancy refers to the suggested replacement frequency and not to the parts life (expected failure)

Annual Cost over expected life is based on replacing the total unit quantity at the expected life.

Typical Annual Parts Cost various sizes			
20K LBH	Size 1		$ 7,094
40K LBH	Size 2		$ 8,868
80K LBH	Size 4		$ 14,188

Electrode Boiler
Model CEJS

Installation, Operation, and Maintenance

750-272
10/2017

⚠WARNING

DO NOT OPERATE, SERVICE, OR REPAIR THIS EQUIPMENT UNLESS YOU FULLY UNDERSTAND ALL APPLICABLE SECTIONS OF THIS MANUAL.

DO NOT ALLOW OTHERS TO OPERATE, SERVICE, OR REPAIR THIS EQUIPMENT UNLESS THEY FULLY UNDERSTAND ALL APPLICABLE SECTIONS OF THIS MANUAL.

FAILURE TO FOLLOW ALL APPLICABLE WARNINGS AND INSTRUCTIONS MAY RESULT IN SEVERE PERSONAL INJURY OR DEATH.

TO: Owners, Operators and/or Maintenance Personnel

This operating manual presents information that will help to properly operate and care for the equipment. Study its contents carefully. The unit will provide good service and continued operation if proper operating and maintenance instructions are followed. No attempt should be made to operate the unit until the principles of operation and all of the components are thoroughly understood. Failure to follow all applicable instructions and warnings may result in severe personal injury or death.

It is the responsibility of the owner to train and advise not only his or her personnel, but the contractors' personnel who are servicing, repairing or operating the equipment, in all safety aspects.

Cleaver-Brooks equipment is designed and engineered to give long life and excellent service on the job. The electrical and mechanical devices supplied as part of the unit were chosen because of their known ability to perform; however, proper operating techniques and maintenance procedures must be followed at all times. Although these components afford a high degree of protection and safety, operation of equipment is not to be considered free from all dangers and hazards inherent in handling and firing of fuel.

Any "automatic" features included in the design do not relieve the attendant of any responsibility. Such features merely free him of certain repetitive chores and give him more time to devote to the proper upkeep of equipment.

It is solely the operator’s responsibility to properly operate and maintain the equipment. No amount of written instructions can replace intelligent thinking and reasoning and this manual is not intended to relieve the operating personnel of the responsibility for proper operation. On the other hand, a thorough understanding of this manual is required before attempting to operate, maintain, service, or repair this equipment.

Because of state, local, or other applicable codes, there are a variety of electric controls and safety devices which vary considerably from one boiler to another. This manual contains information designed to show how a basic burner operates.

Operating controls will normally function for long periods of time and we have found that some operators become lax in their daily or monthly testing, assuming that normal operation will continue indefinitely. Malfunctions of controls lead to uneconomical operation and damage and, in most cases, these conditions can be traced directly to carelessness and deficiencies in testing and maintenance.

It is recommended that a boiler room log or record be maintained. Recording of daily, weekly, monthly and yearly maintenance activities and recording of any unusual operation will serve as a valuable guide to any necessary investigation. Most instances of major boiler damage are the result of operation with low water. We cannot emphasize too strongly the need for the operator to periodically check his low water controls and to follow good maintenance and testing practices. Cross-connecting piping to low water devices must be internally inspected periodically to guard against any stoppages which could obstruct the free flow of water to the low water devices. Float bowls of these controls must be inspected frequently to check for the presence of foreign substances that would impede float ball movement.

The waterside condition of the pressure vessel is of extreme importance. Waterside surfaces should be inspected frequently to check for the presence of any mud, sludge, scale or corrosion.

It is essential to obtain the services of a qualified water treating company or a water consultant to recommend the proper boiler water treating practices.

The operation of this equipment by the owner and his or her operating personnel must comply with all requirements or regulations of his insurance company and/or other authority having jurisdiction. In the event of any conflict or inconsistency between such requirements and the warnings or instructions contained herein, please contact Cleaver-Brooks before proceeding.

CONTENTS

1 - INTRODUCTION

This manual contains descriptive, maintenance, operating, and parts information for the Cleaver-Brooks Electrode Steam Boiler Model CEJS. The CEJS is a three-phase four-wire high voltage steam-producing boiler with automatic control and limiting functions.

1.1-Description

The CEJS Electrode Steam Boiler is several systems integrated into a single unit to function as a heating system. The several systems making up the boiler are:

- The electrodes
- The circulating system (piping)
- The pressure vessel
- The control system

1.2-Operating principles

Electrode boilers utilize the conductive and resistive properties of water to carry electric current and generate steam. The electric current flows between the energized electrode and the two neutral points, the nozzle stock and the counter electrodes. The water streams are the conductors.

Since water has electrical resistance, this current flow generates heat directly in the water itself. As current flow increases, more heat is generated and more steam is produced.

Figure 1 is a typical boiler configuration, It is shown for the purpose of this explanation only. The actual configuration of your model will be found on the drawings which accompany the boiler.

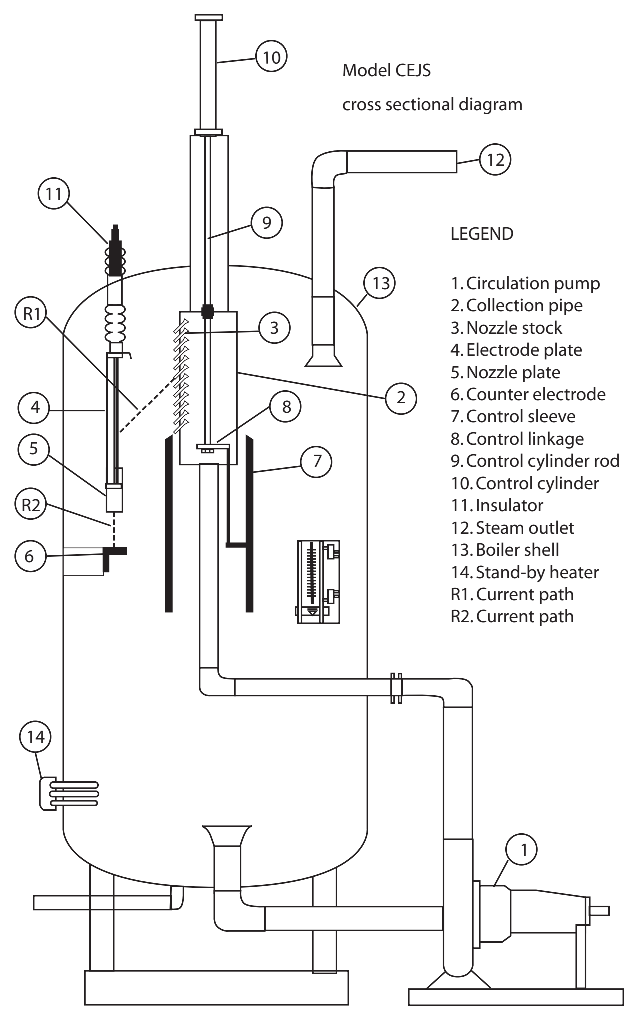


Figure 1 - Model CEJS Cutaway View

Basic Principles

The Model CEJS High Voltage Steam Boiler generates heat by passing electrical current through the boiler water and uses the water as the resistor. In the cutaway view of the boiler, water is drawn from the bottom part of the boiler drum by the circulating pump (1) and forced up the center collection pipe (2) to the nozzle stock (3) where it is discharged through multiple nozzles with sufficient velocity to strike the electrode plate (4).

Electrical current now flows through R1, the streams of water, to the nozzle stock. The rate of flow is greatly in excess of the steaming rate, and water which is not vaporized from the nozzle streams falls to the bottom or collector portion of the electrode and drains through the nozzle plate (5) which forms the bottom of the electrode. As the water falls from the electrode, it strikes the counter electrode (6) and a second current path R2 is established.

Since both the nozzle stock and the counter electrode are in contact with the boiler shell, they form the common connection points of a "Y” connected load.

At maximum power output with proper conductivity of the water all of the nozzles of the nozzle stock are discharging to the electrode plate at a constant rate. In order to regulate the output to match changes in system demand, and to maintain constant steam pressure, the regulating shield is positioned by a hydraulic cylinder. Vertical movement of the regulating shield results in a nearly linear change in power output (current flow) relative to the number of streams of water allowed to strike the electrodes. The change is not exactly linear because the flow rate from the nozzles varies according to the static head at the nozzle inlet. The time for full travel of the regulating shield can be 20 seconds or longer and varies according to required operating conditions.

Starting and stopping of the boiler is done by starting and stopping of the pump. The electrodes can remain energized when the pump is off, since no current can flow unless the pump is running. This mode of operation provides a 'soft start' and 'soft stop' feature.

In some cases, a standby heater is included. The standby heater is an immersion element type used to keep the boiler just below the minimum operating pressure during periods when steam production is not required. When the standby heater is used, the boiler can start producing steam in a much shorter time after a period of inactivity, as the water temperature has been maintained at a higher level. Keeping the boiler at temperature is also beneficial to the insulators and gasketed joints.

The boiler works in conjunction with other components within the same system, such as a deaerator or condensate return tank, which serve as a reservoir for the boiler feedwater. Condensate from the steam system is recovered at these points and chemical additives are added if needed. The treated makeup water is fed into the boiler by the feedwater pump through a modulating control valve.

Boiler water conductivity is tested during boiler operation by automatically drawing off small samples and passing them through a conductivity measuring cell. The conductivity signal is connected to the automatic conductivity controller. If conductivity is low, the chemical feed pump will be activated to add the necessary chemicals to bring up the conductivity. If conductivity is high, a solenoid bleed valve will be activated to evacuate the necessary amount of water and replace it with fresh makeup water.

The water level controller and level gauge are mounted on the water column. The gauge visually shows the level of water in the pressure vessel. The high and low water limits are mounted in the vessel. These devices are sensors for the automatic control system.

Regulating Steam Production

The electrical control system automatically positions the regulating shield to maintain the steam pressure of the boiler at the set point by matching steam output to the load on the steam system. Should the demand for steam exceed the boiler 's rated capacity, the boiler 's steam output is restricted by a current monitoring system in the electrical controls. Steam production may be automatically controlled by a pressure control, or manually by selecting the output desired using the 'POWER LIMIT' function on the boiler control panel overview screen.

The boiler control system operates primarily to regulate the boiler output to maintain constant steam pressure, but incorporates also a current monitoring system to prevent the boiler electrical demand from exceeding the design value - i.e. full load. The 'POWER LIMIT' is provided to enable the operating engineer to manually limit the boiler to less than full rated MW if necessary. The load regulating system uses the boiler MW as the controlled variable, and the system is therefore insensitive to changes in conductivity as long as adequate conductivity is maintained.

1.3-Advantages/performance benefits

100% of the electrical energy is converted into heat with no heat transfer or stack losses. Since the water has electrical resistance, this current flow generates heat directly in the water itself. The more current (amps) that flows, the more heat (BTU) that is generated and the more steam that is produced.

Low water protection is absolute since the absence of water prevents current from flowing and the electrode boiler from producing steam.

Unlike conventional electric boilers or fossil fuel boilers, nothing in the electrode boiler is at a higher temperature than the water itself (with the exception of the standby heater when the boiler is not in operation).

If scaling should occur in the boiler, it will electrically insulate the electrodes, reducing current flow and boiler output. There will be no loss in conversion efficiency. Cleaning the electrodes will restore capacity. There will be no heat buildup in the electrodes, no electrode burnout, and no danger to the boiler itself.

The efficient utilization of electrical energy enables the CEJS to provide a very high steam output within a small physical space.

2 - Installation

Installing the CEJS involves these major steps:

1. Installation of Piping
2. Mechanical installation of circulation pump, electrodes, and hydraulics
3. Wiring the electrical supply and interconnections
4. Preparation for startup
5. Initial startup and checkout procedures

Refer to the boiler drawings for exact details, measurements, and dimensions for the following instructions.

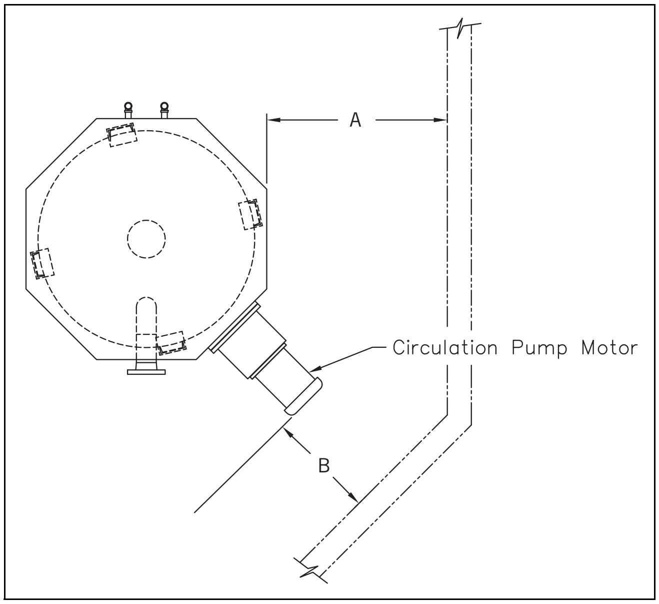
2.1-Location

Position the boiler on its pad and level it. Provide adequate clearances on all sides for maintenance and operation space (see Table 1).

Locate the control cabinet adjacent to the boiler so that the operator can observe boiler operation as necessary.

Table 1: Model CEJS Minimum Clearances.

Model Number	Minimum Clearances	
	A	B
CEJS-200	60”	30”
CEJS-400	60”	36”
CEJS-600	60”	36”
CEJS-900	60”	48”
CEJS-1200	60”	48”
CEJS-1800	60”	48”
CEJS-2400	60”	48”
CEJS-3000	60”	55”
CEJS-3600	60”	55”
CEJS-4200	60”	70”
CEJS-5000	60”	70”



2.2-Piping

For field installed piping refer to Figure 3 and the piping schematic for your boiler. Install all piping shown by dotted lines and all piping external to the boiler package. Components normally included as standard with CEJS boilers are described below.

Note: Different piping configurations are possible depending on boiler capacity. The diagram shows a typical application. Consult the piping diagram provided with your boiler for details specific to your installation.

Vent Line

It is necessary to vent air from the system during initial startup, filling, and draining of the boiler. From the top of the vessel a one inch vent pipe and easily accessible valve should be plumbed to within two (2) inches of the floor, in a location where escaping steam will not endanger those operating the boiler. This valve is opened at startup and is left open to allow air and a small amount of steam to escape. When the boiler reaches 100 psi, the vent valve should be closed and not opened again as long as positive pressure remains in the boiler.

Figure 2 - Water Column

Water column and gauge glass

The water column is a cylindrical chamber located on the outside of the boiler, usually in front. Two pipes connect it to the pressure vessel, one below the water line and one above. Thus, the water column duplicates the water level condition inside the boiler. The column is provided with a level gauge glass and a drain. The drain must be piped to a safe point of discharge such as a blowdown tank or outside drain, as the hot water evacuated will flash to steam under normal atmospheric conditions. The water column should be blown down once a day to clear out accumulated sediment (see Section 8 - Maintenance). During normal operation the water column drain should be closed.

The High Water and High High Water limit probes are located in the boiler vessel. These probes should be checked at installation. The lower probe is High Water and the upper probe is High High Water. Note which probe is which and tag them to make wiring easier.

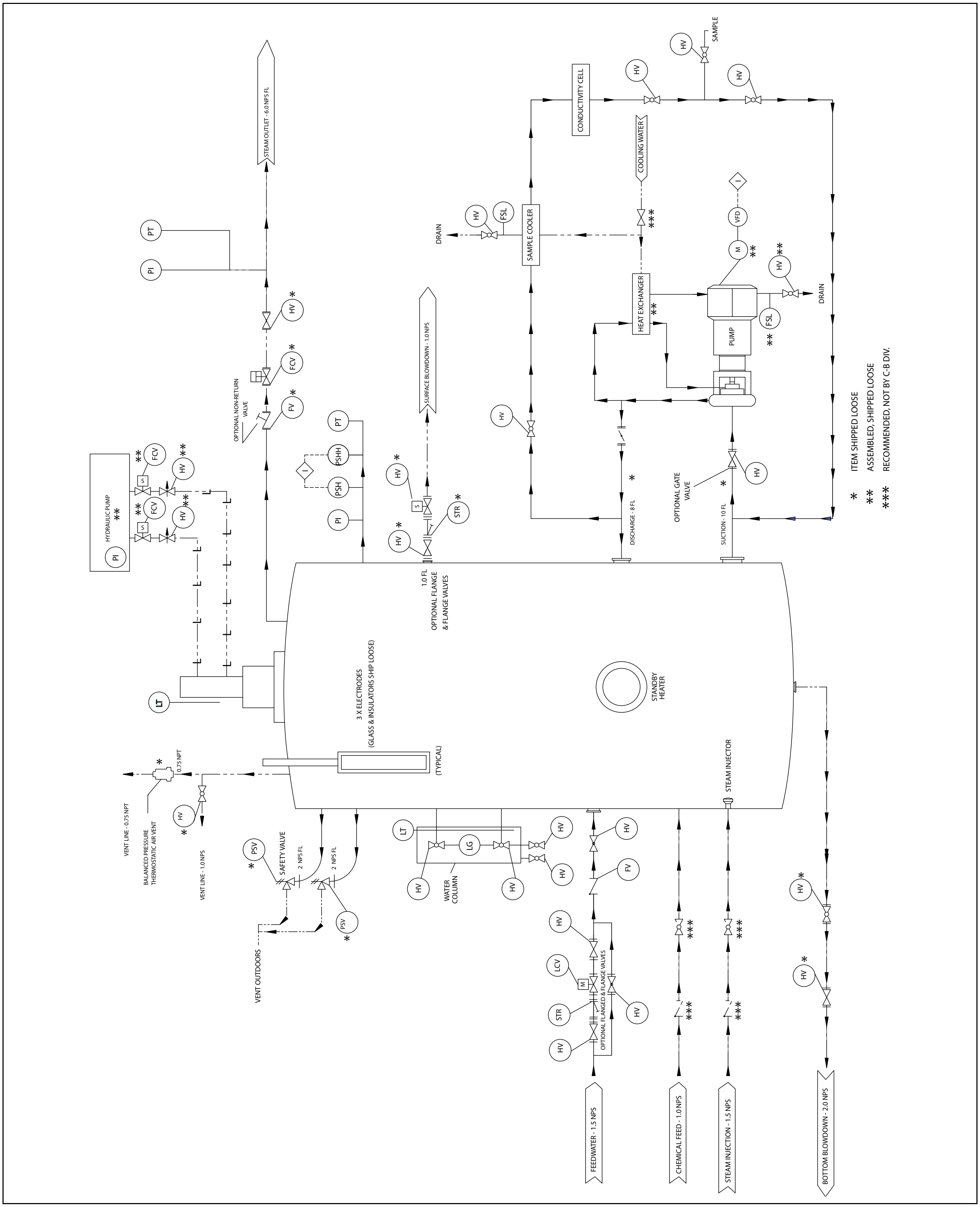


Figure 3 - Typical piping configuration

Feedwater and water level controller

Feedwater is piped into the boiler near the base of the pressure vessel. The feedwater regulating valve, check valve, and gate valve are normally furnished with the boiler.

A bypass (requiring three valves) may be installed around the feed water regulating valve to facilitate valve replacement.

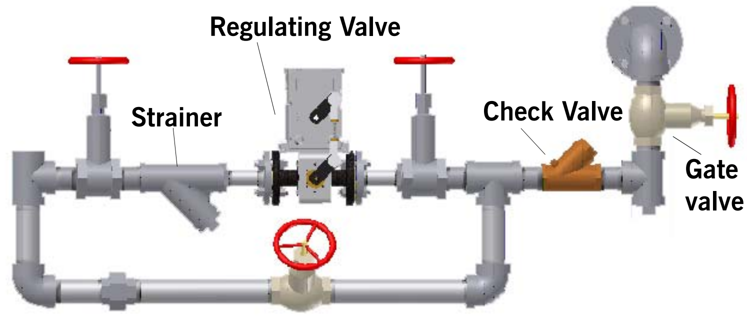


Figure 4 - Feedwater piping w/3-valve bypass

The water level transmitter

mounted on the water column is a modulating 4-20 mA type. In order to maintain a consistent water level in the system, the transmitter signal opens the feedwater valve when the boiler drops below the acceptable operating level and closes it again when water level rises. Feedwater may also be added manually through the customer bypass.

Pressure controls

A boiler pressure gauge, pressure transmitter, and high pressure limit control are piped to a manifold with unions for each branch. The manifold is piped to a coupling in the steam space of the boiler (above the waterline). The piping schematic shows actual configuration for each boiler.

A system pressure gauge and transmitter are installed downstream of the steam outlet back-pressure valve. Their function is to give a comparative reading between vessel pressure and pressure in the pipes downstream of the boiler steam valves.

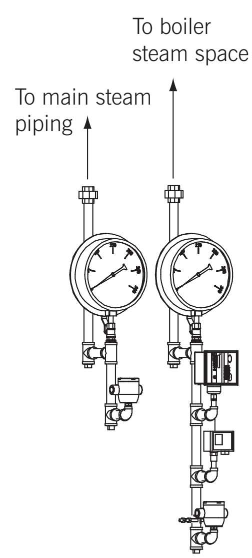


Figure 5 - Pressure controls

Pressure vessel blowdown

Connect the blowdown valves as shown on the piping schematic. Usually there will be two valves in series. For pressure vessel blowdown procedures see Section 9-2, Daily Maintenance.

⚠ Caution

The discharge from the blowdown piping is extremely hot and must be piped to a safe point of discharge.

A blowdown tank (optional) may be used as a means of safe disposal of blowdown discharge. The blowdown pipe between the valves and blowdown tank should provide for connection of additional hot water from the surface blowdown line, water column drain, etc.

Sampling system and surface blowdown

The piping schematic will show the specific details of these lines. The most common configuration of the sample line is a gate valve at the vessel, a sample cooler, and sometimes a flow control metering valve to a fitting holding the conductivity cell. From the conductivity cell, the water is piped back to the boiler. The sample flow should be at the minimum that will give an accurate measurement.

The conductivity cell takes a reading of the conductivity of the boiler water and feeds the signal to the conductivity controller. The conductivity controller automatically oversees the conductivity of the boiler water, keeping it within the limits acceptable for proper operation (see 4.3 - Boiler Control Circuits).

The surface blowdown line usually contains a gate valve, solenoid valve, and a flow control metering valve. It operates when the conductivity of the water is too high, drawing off some of the water from the vessel so that fresh makeup may be added to dilute the conductivity. It is a blowdown line and must be piped to drain in a safe area such as a blowdown tank.

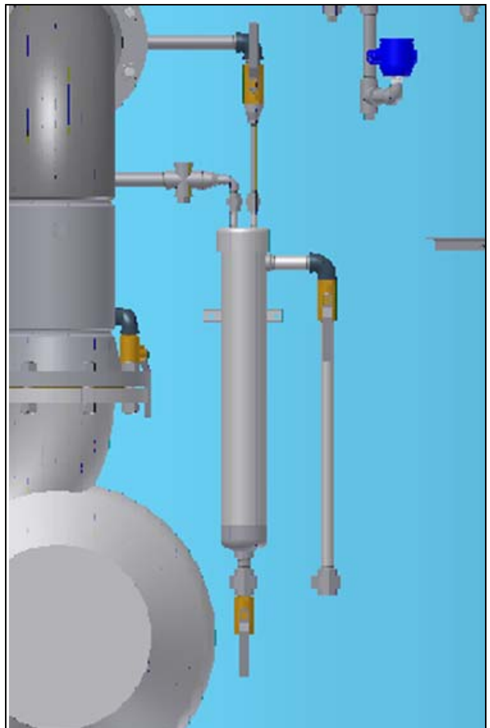


Figure 6 - Sample cooler

Safety Valves

Safety valves are standard with this boiler The valve discharge must be piped and vented to the atmosphere outside the boiler room at a location that is safe for persons in the area. These valves must be piped in such a manner that they will not hinder access to any of the boiler controls. Use a gravity drain for condensate near the safety valves, and at any low points below the valve seats. Small condensate drain valves may be used if they are left open during operation and are piped to drain in a safe location.

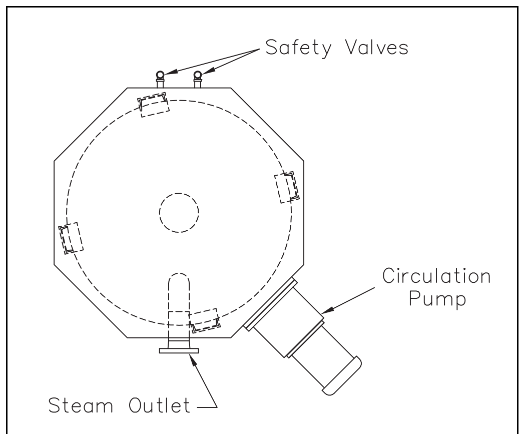


Figure 7 - Safety valves & steam outlet

Steam outlet

The steam outlet size is determined by the boiler 's capacity and operating pressure. The piping schematic will give the actual size. Usually, there will be a gate valve directly outside the boiler, and a back pressure regulating valve with its controller.

Chemical feed pump

The chemical feed pump is not part of the standard boiler package, but can be added as part of a completely automatic conductivity control system. The pump is actuated by a signal from the conductivity control circuit if a low conductivity condition is sensed in the boiler water. It pumps chemical into the boiler to bring the conductivity to the correct level for operation. The pump starter may be located in the medium voltage compartment.

2.3-Mechanical

Circulation pump

The circulation pump is a pre-assembled unit. Installation consists of bolting it in the mounting flange with gaskets and tightening the bolts on the discharge manifold and pump flange. The pump contains a mechanical seal which in some installations may require the connection of a cooling water inlet and drain.

Install the pump wiring and check:

1.The voltage rating on the motor against the supply voltage.

2.The rotation of the pump motor. The proper direction is marked on the motor mount. If the motor rotates backwards, reverse any two wires.

Figure 8 - Circulation Pump

Electrode Installation

Assemble high voltage cage. Electrode installation includes installing the electrode lead-through and the electrode housing, positioning the electrode housing, and positioning the counter electrode. The electrode housing must be installed squarely and at equal distances from the nozzles, and so that the water streams discharged from the nozzles strike the center of the electrode target plate.

Install the electrode rod assembly through the electrode nozzle in the vessel with connected electrode box and target plates. Adjust connection bolts until the electrode plates are positioned at an equal distance from the nozzle stock. After ensuring the electrode boxes are properly positioned, tighten the electrode rod nuts to 500 ft lb of torque. This will compress the spring washer to almost fully flat.

Hydraulic system

Install hydraulic lift tower assembly and hydraulic cylinder. Connect hydraulic cylinder to control rod using the supplied adapter sleeve (see Figures 9 & 10).

The hydraulic pump should be conveniently located for service access and piping run to the hydraulic cylinder.

The regulating shield is positioned by the hydraulic system. There are two hydraulic lines from the flow control valves on the hydraulic pump to the hydraulic cylinder mounted on top of the boiler. The hydraulic pump should be mounted securely with the mounting feet down. Wire the motor according to the instructions on the wiring diagram in the terminal compartment of the motor. Be sure to obtain proper rotation.

The travel speed of the regulating head is controlled by the hydraulic pump. Travel time from 0% to 100% should be about 20 seconds. To check for correct hydraulic pressure for this travel, close both flow control valves and read the hydraulic pressure gauge. The reading should not exceed 1000 psig. If necessary, correct the pressure by rotating the relief valve and adjusting. When finished, re-open the flow control valves.

Bleed the air out of the system by cracking the line fittings. Cycle the unit under no pressure until all air is removed. Keep checking the reservoir level and top off as needed. Most foreign material will flush to the reservoir after two or three days of operation. The reservoir should then be drained, the strainer cleaned, and the fluid replaced.

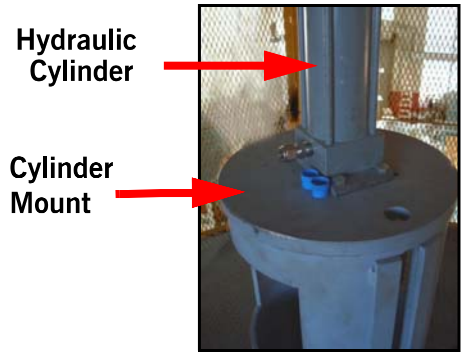


Figure 9 - Hydraulic cylinder mount

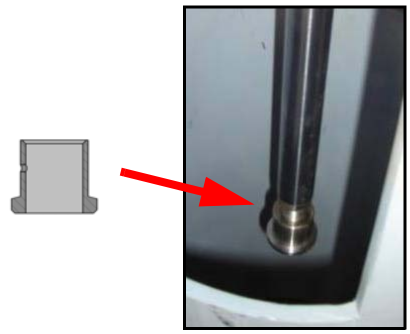


Figure 10 - Install adapter sleeve

2.4-Electrical

Install the field power supply wiring, shown in dotted lines on the power wiring schematic. A general description of the power circuits is given in Section 4, Electrical Systems. Install all 120V control wiring, shown in dotted lines on the control wiring schematic.

Electrical installation should be in strict accord with the boiler wiring schematic, the National Electric Code, and local electrical codes. Also check all existing electrical connections in the boiler for tightness. Vibration during transit sometimes loosens these connections.

2.5-Boiler Preparation

After the circulation pump and electrodes have been installed, the boiler piped into the system, and the electrical system wired in, the boiler must be cleaned and prepared for operation.

Read Section 6, Before Startup, before starting the boiler for the first time.

2.6-First startup and checkout

When starting the boiler for the first time, the different systems must be monitored in order to test their performance. Read Section 7, Startup and Operation, before attempting to start the boiler for the first time.

POWER UNIT STARTUP

1. To properly perform the dual function of lubrication and transmission of power, we recommend the use of a good quality SAE 10 Grade Hydraulic Oil for systems having an operating temperature range from 0 deg F minimum to 160 deg F maximum, or an SAE 20 Grade Hydraulic Oil for 32 deg F Minimum to 200 deg F maximum temperature range. Operation at fluid temperature below 160 deg F is recommended to obtain maximum unit and fluid life.

2. Connect the motor to the proper electrical source, checking the motor nameplate for proper wiring of dual voltage motors. Jog the motor to check rotation. Poly-phase motors are bi-directional and proper rotation can be established by reversing any two phases.

⚠ Caution

Simultaneously energizing both solenoids on double solenoid valves will cause coil burnout.

3. System pressure should be set as low as possible to prevent unnecessary fluid heating; on some applications this setting may be from 600 to 1,000 psi as needed to overcome dynamic pressure drop or to achieve proper acceleration and lift load control components.

4. Pump noise and 'crackle' is most often caused by air entering the pump suction. The tightening of suction fittings will usually eliminate such problems. If pump fails to prime, vent pump discharge to atmosphere to establish fluid flow.

5. The fluid level should be maintained so that fluid is always visible in the sight gauge.

6. After the first few hours of operation, any foreign material from the system plumbing will be flushed to the reservoir. It is good practice to drain and replace the initial filling, and to clean the reservoir and suction strainer.

7. For most industrial applications, an operating temperature of 150 deg F is considered maximum. At higher temperatures difficulty is often experienced in maintaining reliable and consistent hydraulic control, component service life is reduced, hydraulic fluid deteriorates, and a potential danger to operating personnel is created.

8. At least once a year or every 4,000 operating hours the reservoir, suction strainer, and air vent filter should be cleaned. At this time, check the entire system for possible future difficulties. Some application or environmental conditions may dictate such maintenance be performed more frequently.

3 - Water Treatment

The KW output of the boiler is determined by the conductivity of the water in the system. Water conductivity is determined by its chemical makeup. General water hardness, pH, alkalinity, iron, oxygen, and total dissolved solids all have an effect on boiler operation. The water required for CB boilers should be non-scale forming, non-corrosive, non-foaming, and should have the following chemical characteristics:

- pH of boiler water should be between 8.5 and 11.0
- Total alkalinity of boiler water should not exceed 400 ppm
- Oxygen content of feedwater should not exceed 0.005 ppm
- Iron content of boiler water should not exceed 0.5 ppm
- Makeup water hardness should not exceed 0.5 ppm - preferably 0 ppm
- Boiler water hardness should be 0 ppm

Correct conductivity varies with the boiler voltage and temperature. This information is supplied by CB for each boiler installation. Conductivity must be high enough to allow development of the required KW output of the boiler at its designed operating pressure, and should not exceed that amount by more than 10%.

Important

In electrode steam boilers, water conductivity must be carefully controlled. If conductivity is allowed to increase without limits, it will result in damage to the boiler shell and electrodes and could also result in high voltage surface arc-over in the boiler itself.

The control of alkalinity and CO2 content of the steam or hot water is important because these factors can affect the porcelain insulators which are used as lead-through bushings to bring the electric power into the boiler. With porcelain insulators, total alkalinity should be held below 400 ppm.

It is normally recommended that boiler water conductivity be kept as low as will enable the boiler to continue at full load operation without being unduly sluggish. Chemical additives commonly used in electrode steam boilers include sodium hydroxide, sodium sulfite, sodium sulfate, sodium tri-phosphate, and hydrazine for oxygen control. There are of course other compounds which could be used in the boiler for various purposes - for example, control of sludge fluidity. Each additive would need to be evaluated on an individual basis with attention to its effect on conductivity as well as to its intended purpose.

Caution

Any chemicals or compounds which tend to induce foaming should be avoided. Particularly in high voltage boilers, foaming will cause boiler shutdowns and could lead to serious disruptions of supply circuits and switchgear. Impurities or contaminants from elsewhere in the system should also be avoided.

⚠ Caution

Before any water treatment program is implemented, a complete water analysis should be provided to Cleaver-Brooks for review.

4 - Electrical Systems

The three electrical systems are described in this section, which gives a general outline of the basic circuits and their functions. The power supply circuits (high and medium voltage) are diagrammed on the power wiring schematic in the boiler drawings, and the boiler control circuits are diagrammed on the 120V control wiring schematic.

4.1-High voltage power supply

The high voltage power supply, to be connected by the customer, is a three-phase, four-wire 'Y' connected configuration. A full sized insulated and shielded neutral is required in this circuit, as it must be of adequate capacity to take a sizeable amount of current in the case of a large phase unbalance or fault condition. This circuit must include a high voltage main circuit breaker, current transformers (one per phase for supply monitoring), and an isolating switch or mechanism, as required by the National Electrical Code and local codes which may apply. The main circuit breaker must include a common trip device which may be actuated to open the circuit breaker in response to supply circuit supervisory relays or boiler limit circuits. Potential transformers are required for voltage monitoring. The breaker must also have a normally open auxiliary contact for connection to the boiler control circuits. If the main circuit breaker is located some distance from the boiler, local codes may require the installation of a high voltage isolating switch at or near the boiler for local isolation.

Main connection

From the main circuit breaker, the four-wire voltage supply circuit is brought to the boiler by the customer and terminated at the electrodes and at the neutral lug on the boiler shell inside the electrode terminal enclosure. The ground lug is on the bottom of the casing ring. The boiler ground should have the same capacity as the supply conductors. Access to the terminal enclosures must be interlocked with the customer 's main circuit breaker and/or isolating switches to prevent access to the electrodes when the power supply circuit is energized.

High voltage supply circuit supervisory relays

Proper monitoring of the high voltage supply circuit requires the use of a supervisory metering system. This system monitors signals from the supply circuit current transformers and actuates the common trip device on the customer's main circuit breaker in the event of ground fault, over-current, loss of phase, or phase unbalance.

Notice

If unbalance, ground fault, or overcurrent occurs, the supervisory relay system may also signal the limit circuit and shut the boiler down. The supervisory system is a required part of a boiler installation and must be included (either factory-installed in the boiler control panel and/or included with the customer supplied and wired high voltage switchgear)

4.2-Medium voltage power supply

Four terminals are provided for connection of the three-phase medium voltage power supply. Three terminals are for phase A, B, and C, and the control cabinet lug is for the ground. From the medium voltage terminal connections, this circuit is wired to provide power to:

- The control panel
- The circulating pump
- The hydraulic pump
- The chemical feed pump (if used)

All circuits indicated by dotted lines on the power wiring schematic must be connected in the field by the customer.

4.3-120V Boiler control circuits

The control circuits oversee the automatic functioning of the boiler during normal operation. The control circuits are briefly described in the following section as they typically appear in a standard CEJS boiler. Actual configuration may vary.

120V power supply

The primary leads of the control transformer are fused. The transformer secondary white wire is a grounded neutral, and the black wire goes through a circuit breaker switch to the boiler control circuits.

Master start/stop circuit

This circuit initiates the start signal to the boiler when the <Auto-Run> or <Test> mode is activated. The circuit also shuts the boiler off when the <Off> mode is enabled. Remote Start and Stop control is available.

High pressure limit circuit

In a high pressure condition this circuit is initiated by a signal from the high pressure limit switch (mounted on the pressure control piping). It will shut the boiler down in the high pressure condition and activate a high pressure alarm through the PLC. Manual reset of the pressure switch may be required prior to restarting the boiler.

High and low water limit circuits

If these circuits become operational, a feedwater problem is indicated; the water level has become too high. Two separate probes, located in the vessel, areu sed to sense water level. The High-High water probe will initiate a boiler shutdown. If either limit condition exists, the appropriate alarm ("High Water" or "High-High Water") will activate in the PLC.

Limit circuit

The limit circuit is the control function which actually gives the signal for boiler shutdown in any limit condition. For example, if the High-High Water circuit senses a High-HIgh water condition, it will open the limit circuit.

The limit circuit is normally energized. If the circuit is interrupted by a signal from one of its ancillary limit circuits, it will stop the pump and sound the alarm. The boiler will shut down. When the alarm is cleared, this circuit will be reset.

Alarm circuit

The alarm works in tandem with the limit circuit. When a protective limit is reached, the boiler will shut down and the alarm will sound. When the <Acknowledge> button is pushed, the alarm is silenced.

High voltage feedback circuit

This circuit shows whether the high voltage circuit breaker is open or closed by lighting either the "HIGH VOLTAGE ON" or "OFF" light on the boiler control panel. It also performs an ancillary control logic function (see control wiring schematic).

Conductivity controller and control circuit

During normal boiler operation the conductivity controller will continuously sample the conductivity of the boiler water. The conductivity is sensed by the conductivity cell as the sample water passes from the sample cooler, and reads out on the conductivity transmitter in micromho/cm. Conductivity high and low are set to the desired levels. If a high or low limit is reached, the conductivity control circuit will activate the "HIGH CONDUCTIVITY" or "LOW CONDUCTIVITY" alarm in the PLC. If the high conductivity limit is reached, the circuit will also open the surface blowdown line and bleed off some water so that the water in the system can be diluted with makeup water to bring conductivity down. In a low conductivity condition, the conductivity control circuit will signal the addition of the appropriate amount of chemicals to the water in order to bring the conductivity up.

Load and pressure control circuits

These circuits handle the main load and pressure control functions, checks, and limits in the boiler. The primary logic circuits are incorporated here. Current feedback is monitored in these circuits.

A current transformer in the high voltage power circuit measures the current being drawn and feeds that information back to the load control as an indication of boiler power drawn. If the system demand for steam is higher than output, an instruction is sent to the control circuit to lower the regulating shield for the output needed. If a lower output is required, the load control raises the regulating shield for the lower demand.

The load control also allows the circulating pump and load control system to be tested with the high voltage power off. On the boiler control panel, the "Test" function allows the load control to drive the regulating shield to its minimum position and permits the circulating pump to be activated. The regulating shield can then be manually moved to the maximum load position. If the pump and load control system are functioning properly, the test is complete and mode may be returned to 'Auto-Run'.

Standby control circuit

This circuit will place the boiler in Standby mode. The regulating shield will drive to minimum load position and the circulating pump will stop. The "STANDBY" banner on the boiler touch screen will come on, as will the standby heater (if present). The regulating shield will stay in the minimum load position as long as the boiler is in standby. This circuit uses the control pressure transmitter and is set at the desired standby pressure.

Circulating pump control circuit

If the boiler is ready for operation and placed into 'Test' or 'Auto-Run' mode, this circuit supplies power to the circulating pump.

Hydraulic system control circuit

This circuit is controlled by the load control and is directly responsive to system steam demand. When the signal for more steam is given, the PLC energizes the hydraulic solenoid valve to drive the regulating shield to a position which allows more water flow to the electrodes.

When steam production and demand are balanced, the hydraulic solenoid valve is de-energized. When less steam is required, the hydraulic pump is started and the solenoid valve is energized to drive the regulating shield to a position allowing less water flow to the electrodes. Time delays are used in these circuits to prevent cycling of the pump motor starter.

5 - Water Level Control Systems

CB electrode high voltage steam boilers are designed to operate with constant water levels. During operation, feedwater must be added to compensate for steam production and surface blowdown. A modulating valve is used to admit feedwater to the boiler in proportion to the rate of water consumption. The feedwater control system may consist of one, two, or three elements depending upon the degree of instrumentation desired and/or the nature of the steam load.

Single element (water level only)

For most CB applications a single element (water level only) control system is satisfactory. The water level transmitter on the water column senses water level deviation from the set point and modulates the feedwater valve in order to match feedwater flow to actual water consumption. By proportioning feedwater flow to water level deviation from set point, this deviation is reduced and water level is maintained.

Two element (water level and steam flow)

When steam requirements are very irregular and involve large and/or rapid changes in boiler steaming, a multiple element feedwater control system may be needed.

The two element system uses both water level and steam flow signals to position the feedwater control valve. The water level transmitter measures level deviation from the set point. The steam flow transmitter measures the rate of steam flow. Feedwater flow is adjusted to compensate both for level deviation and for changes in rate of steam flow.

Three element (water level, steam flow, and water flow)

If the boiler is large and steam requirements fluctuate widely and rapidly, a three element feedwater control system may be used to provide smoother control than would be obtainable with a two element system.

The three element system uses feedwater flow rate as well as steam flow and water level signals to modulate the feedwater control valve. The water flow and steam flow signals are integrated to assure that water flow fluctuations are no more severe than actual steam flow fluctuations as feedwater flow is varied to compensate for water level deviation and changes in rate of steam flow.

6 - Before Startup

6.1-Boiler Cleanout

General - Before first startup, inspect the entire boiler for loose objects (metal scraps, dust, dirt, paper, etc.) which may have accumulated during construction or shipping. Check also for wetness, moisture, or rust on the electrode circuitry. The boiler must be thoroughly clean and dry before startup. The entire system must be cleaned and flushed to remove fabrication oil, welding slag, piping compounds, sand or clays from the jobsite, etc.

Rinsing out - Clean bottom of vessel and remove pump inlet plug. Verify condition of all manholes and ports.

Boiler must be thoroughly rinsed three times to remove all contaminants prior to conducting a water test. Rinse once with 80 deg C water and twice with cold water.

⚠ Important

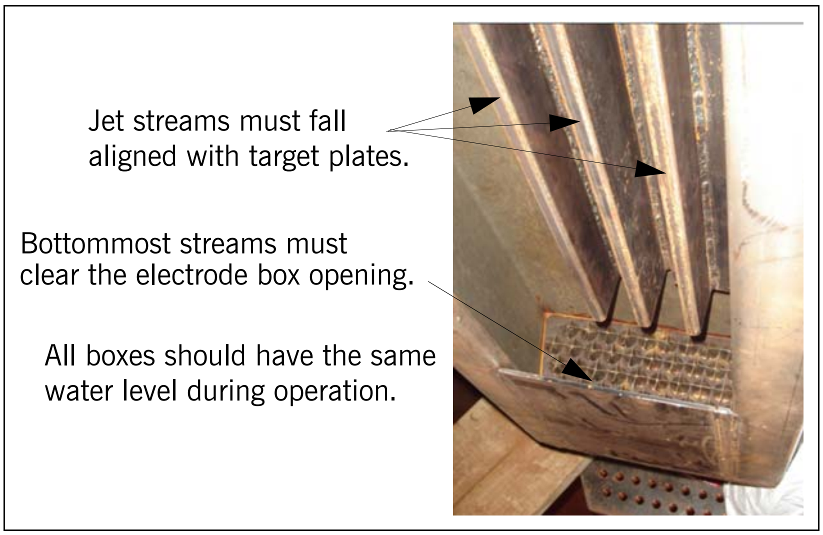
CB will not be responsible for damage incurred at startup unless the preceding precautions are taken.

6.2-Water Test

Verify correct positioning and alignment of jets by running the circulation pump and observing jet shapes. Check for excessive splashing at the top of stroke; optional splash guards may be installed. Eliminate any leaks or spraying.

Check for clogged nozzles. ALL nozzles must flow.

Coordinate incremental skirt lowering with workers outside boiler while monitoring jets.



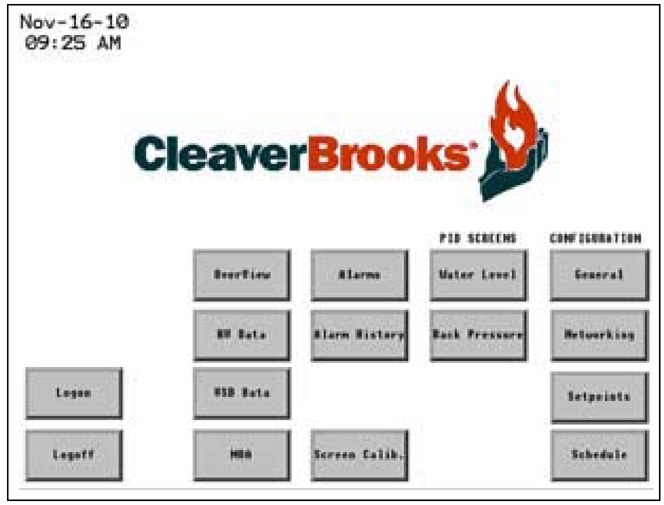
During water test, record pressure reading at pump inlet and outlet. Compare DP to specified value. Before Startup, run a water level high limit check.

7 - Boiler Controls

CEJS boilers feature an integral control panel housing the PLC -based control system components and the touchscreen HMI. The HMI screens are described below.

7.1- Main Menu

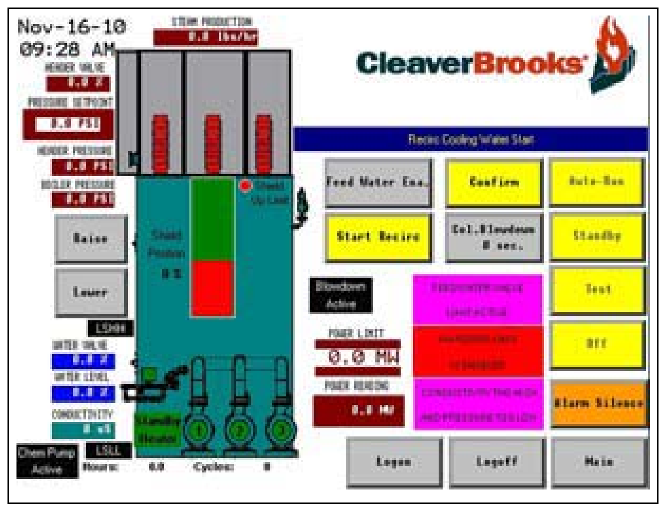
The **Main Menu** appears on power-up. This screen allows user login for access to password-protected features and serves to navigate to other control screens.



7.2-Overview

The **Overview** screen monitors critical data during boiler operation, and is the primary control screen for commissioning and starting up the boiler. This screen contains operating controls, status messages, and transmitter data including a graphic/ numeric indicator to show control shield position and numeric displays for:

- Steam pressure and water level
- Steam header valve and water valve position
- Water conductivity
- Power output to the electrodes
- Power limit
- Steam Production

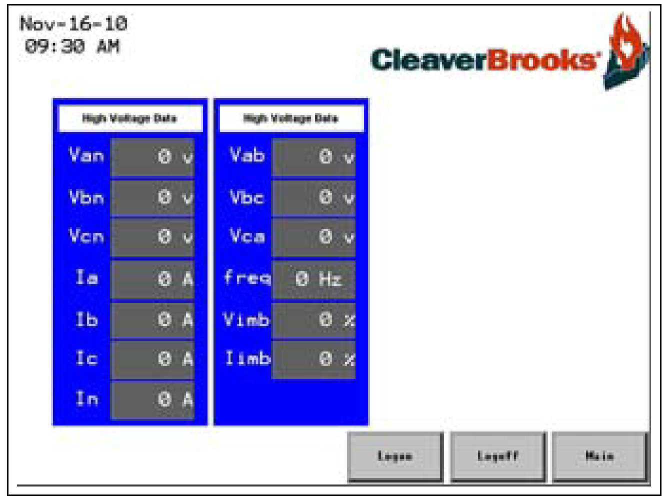


In "Test" mode, the position of the shield can be adjusted by pressing the "Raise" button to elevate and the "Lower" button to descend. The "Col. Blowdown" button allows the user to set a timer to inhibit the low level alarm while a column blowdown is being performed. Other on-screen indicators are as follows:

- Feedwater Valve Limit Active - Indicates that the pressure setting to limit the feedwater valve position is enabled. See Operating Setpoints, Press to Limit FW Vlv%, or Software Switch Setpoints, PSLL settings for more details.
- MH Power Limit Is Enabled - Indicates that the Power Limit setpoint on the Operating Setpoints screen has been enabled.
- Conductivity Too High and Pressure Too Low - Indicates that the conductivity level is too high in comparison to the pressure level of the boiler. The conductivity level is below the lower limit for start-up. See Software Switch Setpoints, CSL setting for more details.

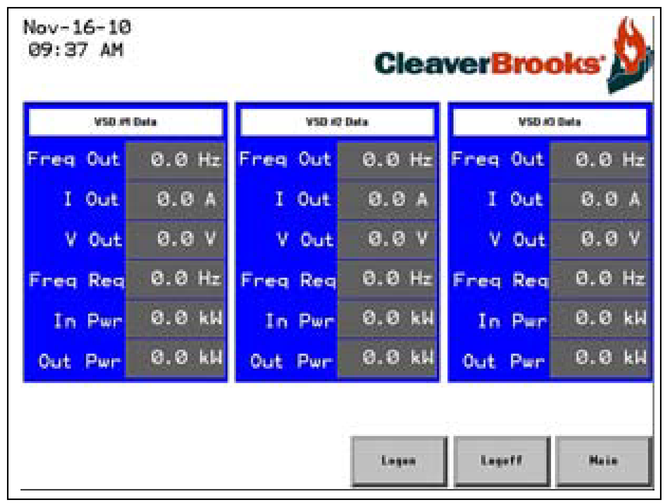
7.3-HV Data

The **HV Data** screen monitors the boiler's 3-phase high voltage power via the power meter. This screen shows the real-time voltages and currents for each phase (including current to neutral) along with the frequency and voltage/current imbalances.



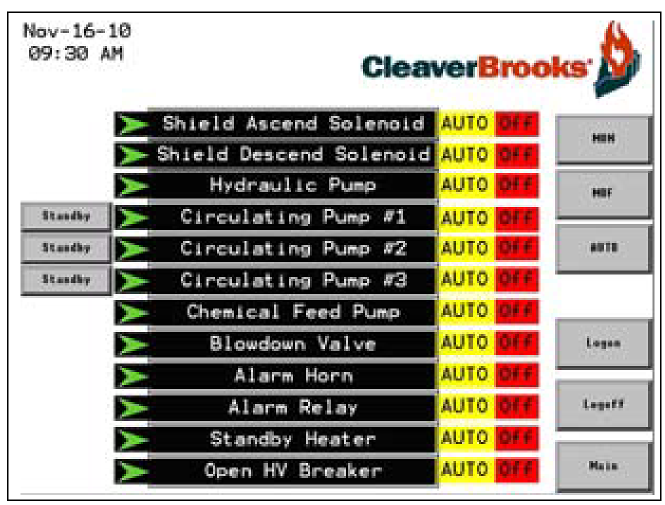
7.4-VSD Data

The **VSD Data** screen monitors the status of each circulation pump variable speed drives as required. This screen displays the output voltage, current, and frequency. Also shown is the input and output power in kilowatts.



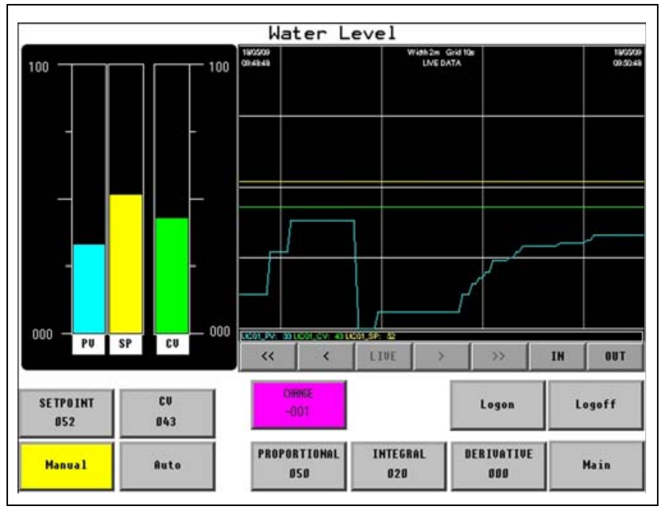
7.5-MOA

The **MOA** (Manual/Auto) screen allows all boiler control devices with digital outputs to be placed under manual control and provides on/off and auto/manual status for all digital points. Selections include MON (Manual On), MOF (Manual Off), or AUTO. This screen can also be used to select the standby pump, if applicable. Pressing the Standby button places the corresponding active pump in standby mode. This in return moves the former standby pump into active position. This screen also allows the operator to monitor the status of each device during startup or while troubleshooting.



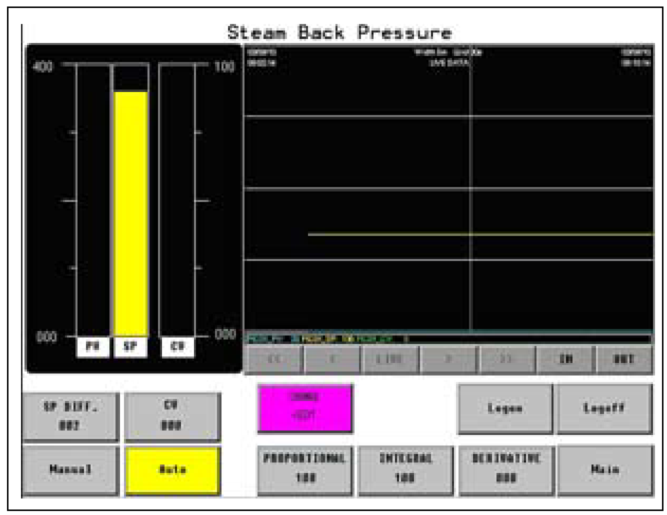
7.6-Water Level PID

The **Water Level PID** screen allows for the setting of the system setpoints controlling Proportional, Integral, and Derivative values (password-protected). The user must be logged in to access the Manual operations. While in manual mode, the user can use the "CV" button to enter a value for the PID loop output to manually control the valve. This screen allows for PID control of water level control valve including loop tuning and setpoint entry with manual override for loop control. This screen monitors the process variable, setpoint, and control output in a bar graph and in a real-time trending window.



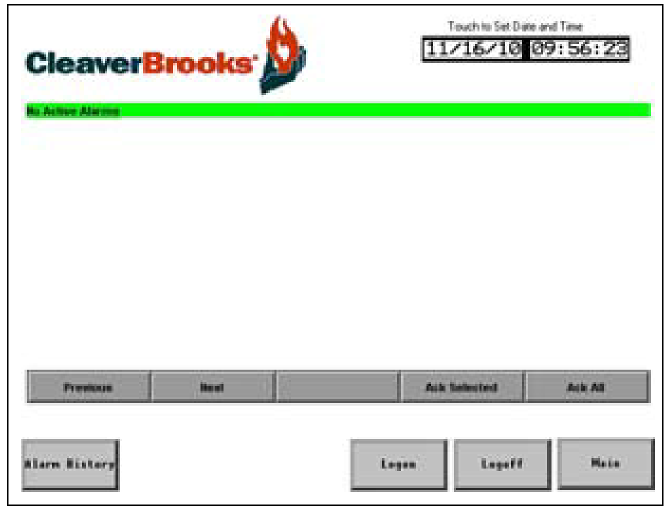
7.7-Back Pressure PID

The **Back Pressure PID** screen allows for the setting of the system setpoints controlling Proportional, Integral, and Derivative values (password-protected). The user must be logged in to access the Manual operations. While in manual mode, the user can use the "CV" button to enter a value for the PID loop output to manually control the valve. This screen allows for PID control of the back-pressure valve and allows loop tuning and setpoint entry with manual override for loop control. The setpoint is entered as a differential from the operating pressure of the boiler. This screen monitors the process variable, setpoint, and control output in a bar graph and in a real-time trending window.



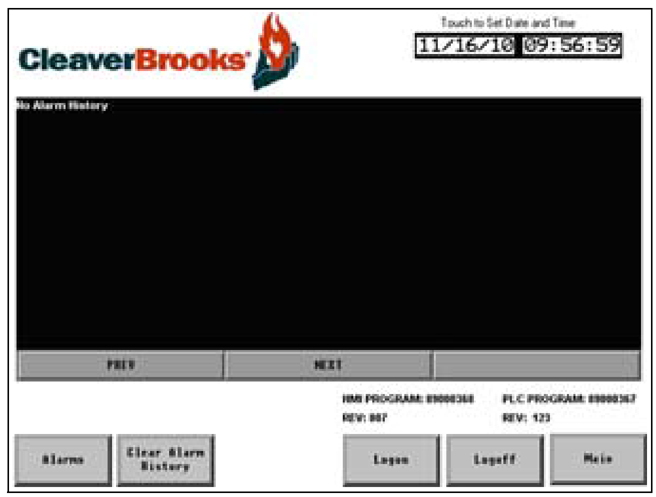
7.8-Alarm

The **Alarm** screen is used to acknowledge alarms. Once acknowledged, an alarm may be cleared from the Alarm History screen. When acknowledging an alarm, investigate and correct the cause of the alarm before re-starting the boiler.



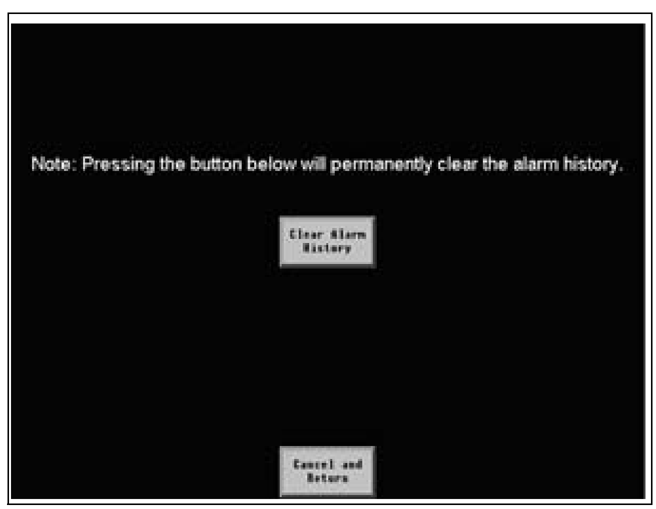
7.9-Alarm History

The **Alarm History** screen displays a record of alarms logged by the system with a date/time stamp and brief description for each. From this screen, the user can advance to Clear Alarm History screen to remove all previous alarm notifications. The user must be logged on to clear the alarm history.



Clear Alarm History

The **Clear Alarm History** screen is used to permanently delete the alarm history once an acknowledgement of the alarms has been selected from the Alarm screen.



7.10-General Configuration

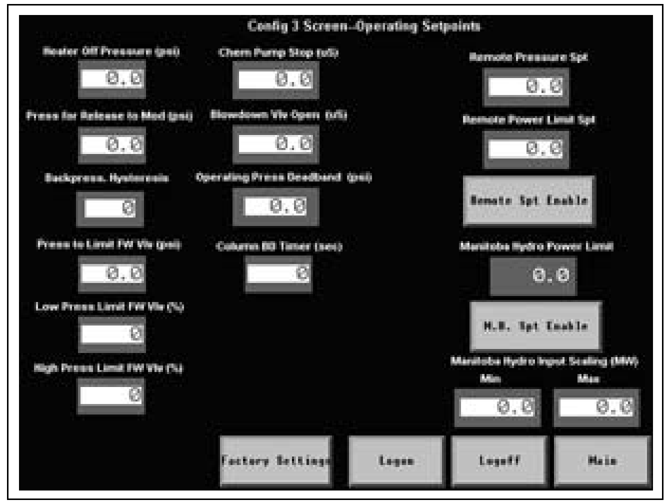
The **General Configuration** screen contains general information about the boiler in addition to contact information for the local Cleaver Brooks representative. The user must be logged on to change these values.

7.11-Networking Configuration

The **Networking** configuration screen allows the user to set the IP address for the HMI and allows for the option of automatic alarm notifications via e-mail. The user must be logged on to modify these values.

7.12-Operating Setpoints Configuration

The **Operating Setpoints** configuration screen allows the user to enter specific setpoints for normal boiler operations. The remote pressure and power limit setpoints as well as the power limit and scaling factors can be set/enabled from this screen. These operating setpoints are typically determined at startup. The user must be logged on to modify operating setpoints. Factory Settings can be accessed from this screen.



The following is a descriptive list of the operating setpoint variables:

- Heater Off Pressure (psi)

  Defines the pressure setting at which the back-up heating elements turn-off.

- Press for Release to Mod (psi)

  Defines the pressure setting to allow the shield to modulate and control to setpoint after start-up. Until this setpoint is reached, the shield ramp is moved incrementally based on the setpoints on the Factory Settings screen. This sepoint is duplicated on the Software Switch Settings (Soft Switch SPs) screen as the PSL setting.

- Backpress. Hysteresis

  Defines the value at which the back-pressure valve begins to modulate into a closed position. The valve starts closing when the pressure drops below the setpoint value minus the "Backpress. Hysteresis" value. This creates a deadband/buffer zone for the modulated closing of the valve.

- Press to Limit FW Vlv (psi)

  Defines the pressure setting that limits the feedwater valve position during start-up. This setpoint is duplicated on the Software Switch Settings (Soft Switch Sps) screen as the PSLL setting. When the boiler pressure is below this set point, the travel of the feed water valve is limited to the High Press Limit FW Vlv (psi) setpoint value on the Operating Setpoints screen.

- Low Press Limit FW Vlv (%)

  Defines the percentage in which the feedwater valve is opened when the boiler pressure is below the feedwater valve pressure limit setting.

- High Press Limit FW Vlv (%)

  Defines the percentage in which the feedwater valve is opened when the boiler pressure is above the feedwater valve pressure limit setting.

- Chem Pump Stop (s)

  Defines the upper conductivity limit at which the chemical pump stops supplying chemicals to the system.

- Blowdown Vlv Open (s)

  Defines the upper conductivity limit at which the blowdown valve opens to purge the system.

- Operating Press Deadband (psi)

  Defines the deadband range (psi) to eliminate shield "hunting" when the pressure does not exactly match the operating pressure setpoint.

- Column BD Timer (sec)

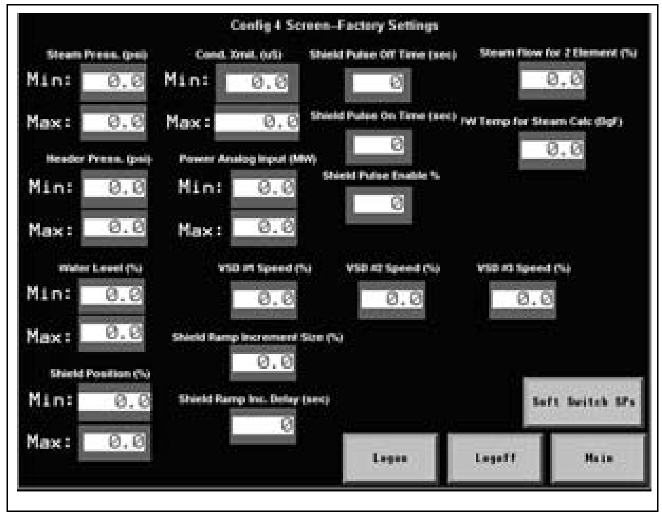
  Defines the time that the level alarms and associated feedback are disabled during a blowdown sequence.

7.12a - Factory Settings Warning

The **Warning** screen appears when attempting to access the Factory Settings screen. The user should select "Continue" only if the operator is qualified and authorized to make changes to these parameters. The user must be logged on to access and modify the factory settings.

7.12b - Factory Settings

The **Factory Settings** configuration screen allows the setting of crutial setpoints during the initial startup of the boiler. These setpoints are typically determined at startup and are not changed in the normal course of boiler operation. These parameters are set by Cleaver Brooks and should only be changed by qualified and authorized personnel. The user must be logged on to modify these factory setpoints. This screen is accessed from the Operating Setpoints configuration screen. Software Switch SetPoints (Soft Switch SPs) can be accessed from the Factory Settings screen.



The following is a descriptive list of the factory setpoint variables:

- Steam Press. (psi)

  Defines the scaled range for the steam pressure values of the system.

- Header Press. (psi)

  Defines the scaled range for the header pressure values of the system.

- Water Level (%)

  Defines the scaled range for the water level of the system.

- Shield Position (%)

  Defines the scaled range for the shield position transmitter from "Full-Down" to "Full-Up" position of the shield.

- Cond. Xmit. (s)

  Defines the conductivity range for the conductivity transmitter.

- Power Analog Input (MW)

  Defines the scaled range of the analog power input in megawatts (MW).

- VSD #1/#2/#3 Speed (%)

  Defines the scaled speed of each of the pump VSDs.

- Shield Ramp Increment Size (%)

  Defines the percentage-based increment at which the shield travels during start-up mode when the boiler pressure is below the "Press for Release to Mod (psi)" setpoint located on the Operating Setpoints screen.

- Shield Ramp Inc. Delay (sec)

  Defines the time delay before moving to the next shield increment during start-up mode when the boiler pressure is below the "Press for Release to Mod (psi)" setpoint located on the Operating Setpoints screen.

- Shield Pulse Off Time (sec)

  Defines the amount of time the hydraulic shield contactor remains de-energized (Off) during the shield pulse.

- Shield Pulse On Time (sec)

  Defines the amount of time the hydraulic shield contactor remains energized (On) during the shield pulse.

- Shield Pulse Enable (%)

  Defines the percentage of the MW limit in which to enable the shield to begin pulsing. Shield pulsing allows for fine tuning as the boiler nears the set MW limit. Setting this value to 0% always enables the shield to pulse. Setting this value to 100% never enables the shield to pulse.

  Example: If the output limit is set to 10 MW and the Shield Pulse Enable% setpoint is established to be 90%, then the shield pulse will be enabled at 9 MW output.

- Steam Flow for 2 Element (%)

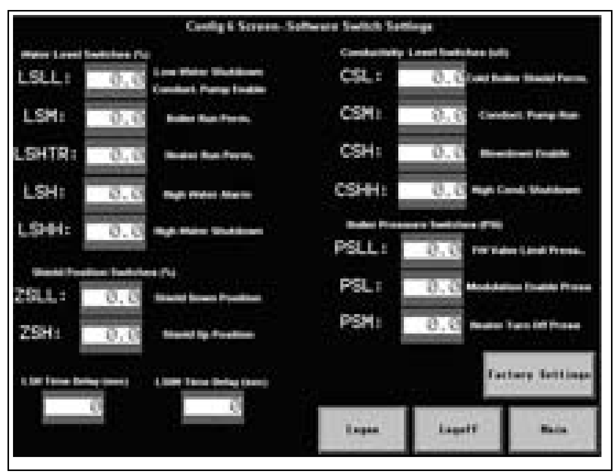
  Defines the steam flow output percentage limit at which the two element feedwater system is enabled. The two element feedwater system is based on the water level and calculated steam output determined from the MW reading.

- FW Temp for Steam Calc (DgF)

  Defines the temperature value (degress Fahrenheit) used to calculate steam flow based on the current MW reading of the boiler. This value is used when there is no temperature input to the system.

7.12c - Software Switch SetPoints

The **Software Switch SetPoints** (Soft Switch SPs) screen allows the user to adjust the setpoints for the various transmitter driven functions of the boiler. These parameters are set by Cleaver Brooks and should only be changed by qualified and authorized personnel. The user must be logged on to modify these factory setpoints. This screen is accessed from the Factory Settings screen.



The following is a descriptive list of the software switch setpoint variables:

- Water Level Switches (%)

  LSLL: Low water limit which triggers the low water boiler shutdown.

  LSM: Median water limit which allows the boiler to start-up after this level is achieved.

  LSHTR: Low water limit which disables the operation of the heater when the water level drops below this setpoint.

- Water Level Switches (%) (cont.)

  LSH: High water limit which triggers the high water alarm.

  LSHH: High-High water limit which triggers the high water boiler shutdown and opening of the HW breaker.

- LSH Time Delay (sec)

  Defines the amount of time delay between the triggering of the high water limit (LSH) and the sounding of the high water alarm to alleviate momentary or nuisance trips.

- LSHH Time Delay (sec)

  Defines the amount of time delay between the triggering of the high-high water limit (LSHH) and the shutdown of the boiler to alleviate momentary or nuisance trips.

- Shield Position Switches (%)

  ZSLL: Setpoint which limits the "Full-Down" position of the shield during normal boiler operation.

  ZSH: Setpoint which limits the "Full-Up" position of the shield during normal boiler operation.

- Conductivity Level Switches (s)

  CSL: Low conductivity limit which defines the conductivity threshold level that will allow the shield to lower and the boiler to operate during cold start-up.

  CSM: Median conductivity setpoint which enables/disables the chemical feed pump. When the boiler is running, the chemical feed pump will be enabled when the conductivity level is below this setpoint and disabled when the conductivity level is above this setpoint.

  CSH: High conductivity limit which triggers the automatic blowdown valve to open.

  CSHH: High-High conductivity limit which triggers an automatic boiler shutdown.

- Boiler Pressure Switches (psi)

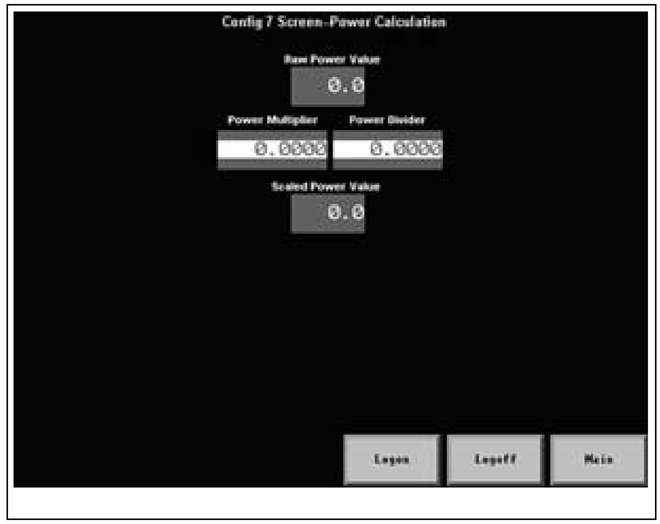
  PSLL: Defines the pressure setting that limits the feedwater valve position. This setpoint is duplicated on the Operating Setpoints screen as the Press to Limit FW Vlv (psi) setting. When the boiler pressure is below this set point, the travel of the feed water valve is limited to the High Press Limit FW Vlv (psi) setpoint value on the Operating Setpoints screen.

  PSL: Defines the pressure setting to allow the shield to modulate and control to setpoint after start-up. Until this setpoint is reached, the shield ramp is moved incrementally based on the setpoints on the Factory Settings screen. This setpoint is duplicated on the Operating Setpoints screen as the Press to Release to Mod (psi) setting.

  PSM: Pressure limit which disables the heater when this pressure setpoint is achieved in standby mode only.

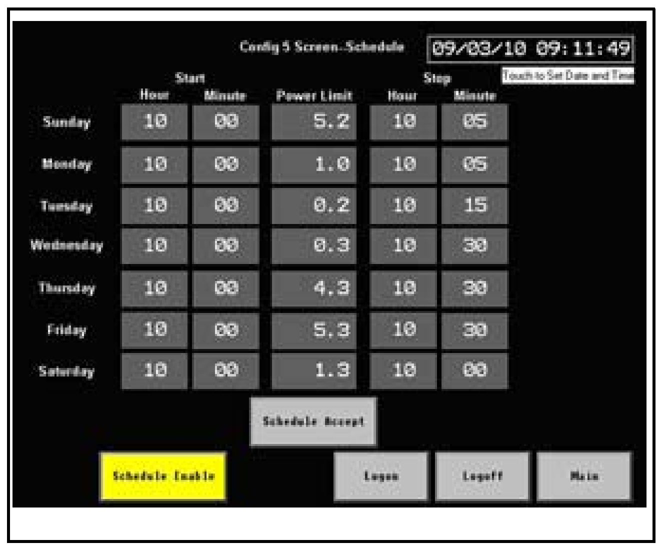
7.12d - Power Calculation

The **Power Calculation** screen allows for the scaling of the raw power reading from the power meter by adjusting scaling parameters to produce the desired scaled power value. These parameters are set by Cleaver Brooks and should only be changed by qualified and authorized personnel. The user must be logged on to modify these factory setpoints. This screen is accessed by pressing a "hidden" button located in the top right-hand corner of the **Software Switch Settings** screen.



7.13-Schedule

The **Schedule** configuration screen allows the user to program the boiler's daily start and stop times along with a power limit for individual days. This seven day schedule is repeated as a weekly schedule.



8 - Startup and Operation

When starting the CEJS boiler for the first time, observe the deaerator or condensate tank, sight glass, and chemical feed pump to monitor their performance until the control systems have been tested. After the pressure is up for the first time, check the safety valve operation and settings. The boiler pressure should be at least 75% of the safety valve setting when the test handles are lifted. The valve should be allowed to snap shut to assure a good seat. ***Note: Boiler should not be heated/cooled quicker than 3-5 ºF per minute to protect the porcelain insulators and glass tubes.***

8.1-Prestart

1.Open the following valves: Feedwater, Conductivity Sample, Steam Outlet, Manual Air Vent, Chemical

Feed, and Cooling Water to the circulating pump (if applicable).

2.Close the following valves: Water Column Blowdown and Feedwater Bypass Valve

3.Adjust pressure setpoint in PLC. Pressure switches are set as shown on control schematic

4.Open the high voltage switchgear.

5.Inside the control cabinet, check fuses and close the circuit breaker for the medium voltage circuits, the pump, and the hydraulic system motors.

6. Go to the Overview screen on the HMI. Enable "Test" mode.

7.Press <Feed Water Enable> at the HMI. Start the feedwater pump and fill the boiler with water. The water should stop automatically when it reaches the right level.

8.Once the water level reaches the set-point and the regulating shield has driven to the no load position, the shield position indicator should be at 100% and the circulating pump should start.

9.Manually adjust the regulating shield downward and upward. Return to "Auto-Run" when movement goes freely to both stops and speed of movement has been adjusted.

10.Adjust the sample flow and cooling water flow. Allow the conductivity sample to stabilize. If necessary, increase the conductivity by allowing chemicals to be pumped into the boiler. Conductivity for startup should not exceed 100 to 800 μS.

8.2-Startup (Manual Mode)

Note: "Automatic Mode" is recommended for typical startup. "Manual Mode" should only be used in limited circumstances. Cleaver-Brooks recommends using "Manual Mode" operation during initial startup of boiler to ensure proper functionality of controls and integration with system.

1.Raise the shield to the 'No Load' position.

2.Close the high voltage switchgear.

3.Enable "TEST" Mode. Press <Feed Water Enable>. Select <Start Recirculation>..

5.Manually monitor conductivity pump. A maximum conductivity of 600 S should be allowed. The conductivity pump can be manually turned on and off from the "MOA" screen.

6.Lower shield at a maximum rate of 5% increments approximately every 5 minutes. Continue this process until the boiler pressure reaches 100 psig. When the steam pressure reaches 40 psi, close the manual air vent. The boiler pressure will need to exceed the level required to open the back pressure valve, and be slightly above the pressure in the steam main, before the boiler will begin to feed steam into the system. Adjust the back pressure valve control set point until the desired back pressure is maintained, and the passage of steam into the system will begin.

7.Check the boiler steam pressure gauge. Generally, there will only be a negligible pressure drop through the back pressure valve.

8.Enable "AUTO-RUN" mode.

9.Adjust "Power Limit" setting to the desired output. The boiler is now in operation and is free to modulate as required.

8.3-Startup (Automatic Mode)

1.Raise the shield to the 'No Load' position.

2.Close the high voltage switchgear.

3.Enable "AUTO RUN" mode.

4.The circulating pump will start and the regulating shield will go to the full-load position. Allow the boiler to heat up and begin to make steam. When boiler steam pressure reaches 40 psi, close the manual air vent. The boiler pressure will need to exceed the level required to open the back pressure valve, and be slightly above the pressure in the steam main, before the boiler will begin to feed steam into the system. Adjust the back pressure valve control set point until the desired back pressure is maintained, and the passage of steam into the system will begin.

5.Check the boiler steam pressure gauge. Generally, there will only be a negligible pressure drop through the back pressure valve.

6.Adjust "Power Limit" setting to the desired output. The boiler is now in operation and is free to modulate as required.

8.4-Emergency shutdown

1.Push the large red "STOP" button on the boiler control panel. The boiler will go to OFF mode and the circulating pump will stop. The regulating shield will stay in the position it was in when the STOP button was pushed. The high voltage switchgear will be opened when the emergency stop is pushed.

2.To restart the boiler after an emergency shutdown, ensure the stop button is returned to the operating position and follow the normal startup procedure outlined in Section 7.2 above.

8.5-Standby and shutdown

Standby

Enable "STANDBY" mode. The regulating shield will drive to the no-load position and the Standby banner will turn yellow. The circulation pump will stop and the standby heater (if included) will energize to keep the boiler hot.

Shutdown

Enable "OFF" mode. The regulating shield will move to the no-load position and the circulating pump will stop. The PLC may be turned off using the control power switch on the panel.

8.6-Normal operation

The CEJS boiler has completely automatic operating controls, feedback, and limiting functions. The only attention it will need during normal operation is a periodic check of the ammeter. The "POWER LIMIT" may be adjusted at any time.

8.7-List of Alarms

The following is a full list of alarm codes/names with corresponding descriptions of each.

ALM001 Water Level High High (Probe) - High High Water Probe or LSHH in Software. Shuts down the boiler and opens HV breaker.

ALM002 Water Level High (Probe) - High Water Probe or LSH in Software.

ALM003 VSD#1 Fault - VSD fault switches operation to standby pump. If standby pump is not available, a VSD fault shuts down boiler.

ALM004 Modbus Comms Fault - Comms loss to Nexus for 30 seconds.

ALM005 E-Stop Pressed - Shuts down boiler & opens HV breaker.

ALM006 Hydraulic Pump Fault - Aux. contacts on hydraulic pump contactor are not functioning properly.

ALM007 Shield Down Position Fault - Down solenoid on for 120 seconds, shield position not down.

ALM008 Shield Up Position Fault - Up solenoid on for 120 seconds, shield position not up.

ALM009 Low Low Water Fault - Shuts down boiler.

ALM010 Boiler Pressure High High - Input slot 2, channel 1. Pressure input shuts down boiler.

ALM011 HV Breaker Control Power Loss - Input slot 2, channel 10. Control power is Off on HV breaker.

ALM012 N/A

ALM013 Device in Manual Override Mode - At least one (1) device on MOA screen is in manual mode.

ALM014 Phase Imbalance Fault - 10% or greater phase imbalance for 10 seconds.

ALM015 Current Imbalance Fault - 10% or greater current imbalance for 10 seconds.

ALM016 Analog Input Limit Failure - One of the analog inputs is out of range.

ALM017 High Voltage Breaker Open - Slot 2, channel 5 input loss. Alarms only when boiler is in operation.

ALM018 High Voltage Safety Contact Fault - Slot 2, channel 4 input. Safety Contact in HV breaker tripped.

ALM019 N/A

ALM020 Boiler Pressure High - Slot 2, channel 12 input.

ALM021 VSD# 2 Fault - See ALM003 VSD#1 Fault above for more details.

ALM022 VSD# 3 Fault - See ALM003 VSD#1 Falut above for more details.

ALM023 High Conductivity - CSHH in Software - Raises shield.

ALM024 Water Level High High (Transmitter) - High High Water Transmitter or LSHH in Software. Shuts down the boiler & opens HV breaker.

ALM025 Water Level High (Transmitter) - High Water Transmitter or LSH in Software.

9 - Maintenance

Since the boiler 's operation is usually supervised by its automatic controls, conscientious preventative maintenance should be practiced at all times. Keep the electrical circuitry clean and dry, and all contacts tight, especially on the magnetic contactors. Do not allow dust or dampness to accumulate anywhere in the control cabinet. Do not allow the temperature in the control cabinet to exceed 120 deg F. Watch for irregularities in operation and try to catch developing problems early. Perform the periodic maintenance listed in the following sections at the times given.

Important

Allow only qualified personnel to do maintenance work on this equipment.

9.1-Shift maintenance

1.At some point during each shift, the gauge glass on the water column must be blown down to clear out any accumulated sediment. Blowdown should be performed during boiler operation.

Gauge glass blowdown

A.Close both top and bottom valves to the gauge fully. B.Open the drain valve on the bottom of the gauge glass.

C.Open the top valve just enough to lift the disk from its seat, but not enough to cause the ball check inside the valve to seat.

D.At this point, live steam will be blowing down through the gauge glass and out the drain. Let blowdown continue for a few seconds (until it becomes apparent that all sediment has been dislodged from the glass), then fully close the top valve.

E.Close the bottom gauge glass drain.

F.Open the top valve again, just enough to allow a slow passage of pressure. When the flow stops, open this valve fully.

G.Open the bottom valve to the glass (not the drain) just enough to allow a slow passage of water into the glass.

H.Let the seepage continue until the water level stabilizes, then slowly open this valve fully.

The above procedure assures a true reading of the gauge glass with both top and bottom valves open. It is important to make sure that the ball checks in the valves to the gauge glass do not accidentally seat. If a ball check seats, the gauge glass will no longer reflect the true water volume.

If the boiler shuts down on a high or low water limit and the gauge glass level and all other conditions are normal, one or both of these ball checks has seated or one of the lines to the gauge glass has clogged.

2.Blow down the gauge glass of the condensate return tank.

3.Check all hand-operated valves for packing leaks. Check to see that the boiler blowdown, air vent, condensate tank feed, and drain valves are closed and all others are open.

4.Check the regulating shield travel for responsiveness to hydraulic pump direction change. If it is sluggish or unstable, correct the hydraulic pressure.

5.Check to see if the desired pressure is being maintained in the system and boiler.

9.2-Daily maintenance

1.Clean the strainers in the water supply, cooling, feedwater pump, and blowdown cooling lines.

2.Check each open valve for freedom of operation.

3.Blow down the water column by opening the drain on the bottom. Allow two to ten seconds for blowdown, then close the valve fully.

4.Blow down the boiler to clear out any sludge accumulation in the pressure vessel. Generally, five to ten seconds will be sufficient. Experience and observation will indicate the proper duration of blowdown. The color of the water is a good indicator of the amount of accumulated sludge. The murkier the water is, the longer blowdown should continue or the more often the boiler should be blown down.

Boiler blowdown

A.Open the blowdown valve nearest the boiler, fully.
B.Open the second valve as quickly as possible to minimize valve seat erosion.
C.The boiler will be blowing down at this point. When blowdown has continued long enough, fully close the valve furthest from the boiler.
D.When the flow stops, close the nearest valve to ensure a tight shutoff.

5.Check the levels in the chemical feed and hydraulic fluid reservoirs and top off as needed. If the hydraulic fluid level is abnormally low, check the hydraulic system for leaks.

6.Check for steam leaks at the electrode insulators and the control rod packing. If necessary, replace gaskets and/or packing. Refer to Section 9.6 for more information on the packing of the gland housing for the control rod. Control rod packing should be checked for leaks within 2-4 weeks of initial operation after the gland is packed.

7.Check mechanical seal on circulating pump for significant leakage.

9.3-Monthly maintenance

1.Shut the boiler down and turn off the power supply. Check all electrical connections for tightness. Be particularly careful during the first few months of service. Check contacts for discoloration, corrosion, or pitting.

2.Make an instantaneous check of the safety valves. Allow them to slam shut to ensure good seating.

3.Check the elements of the standby heater with a megohmmeter. Test the lead wire to ground. A reading of 25000 ohms or more is satisfactory. Below 25000 ohms indicates a defective element, which should be replaced at the next scheduled boiler annual inspection.

Standby heater replacement

A.Sketch the wiring hookup of the element head and busses. Identify each wire.

B.Disconnect the wire and remove the element flange bolts. A tapped hole is provided to assist in breaking the gasket free.

C.Pull the flange and element bundle straight out. Handle the element gently.

D.Remove the faulty element from bundle. Replace with a new element and ferrule.

E.Re-insert element bundle and install with a new gasket and seal. Torque the bolts to 115ft-lb. Re-wire the elements and busses according to sketch made at beginning

4.The air supply filters (if present) on the feedwater controller and back pressure regulating valve should be removed and cleaned on a regular basis. Experience will determine the maintenance interval. It is recommended to periodically remove any condensate in the bowl of the regulator.

5.Check the conductivity cell. Abnormal conductivity readings usually indicate that the cell needs cleaning or replatinization. If there are any foreign substances on the cell (oil, grease, rust, sediment, etc.) it must be cleaned. Do not scrape or clean mechanically, as this may remove the coating. The cell should be dipped into a solution of 10% hydrochloric acid in water and left to soak for five to ten minutes, as needed. Afterwards, rinse thoroughly in running tap water.

6.Check the entire piping system for leaks.

7.Check the boiler auxiliary equipment.

9.4-Annual maintenance

1.Shut the boiler down, drain the water from the system, and clean out all accumulated scale buildup, corrosion, and sludge from the pressure vessel.

2.Check for electrode deterioration and erosion of the electrodes, counter electrodes, and stripper of the regulating shield.

3.Check for erosion of nozzles. Check the nozzle stock for erosion and remove any scale buildup.

4.Check the general mechanical condition of the boiler assembly, paying particular attention to the reg- ulating shield operating equipment.

5.Check all pressure gauges for accuracy.

6.Remove the circulating pump(s) and inspect for wear of the shaft bearings and pump impeller.

7.Have an approved safety valve service agency check the safety valves for wear and correct settings.

8.Inspect the blowdown valves for seat erosion.

9.Clean the hydraulic pump reservoir, air filter, and suction strainer.

9.5-Replacement of porcelain insulators

1.Turn off all power to the boiler, drain the pressure vessel completely, and allow it to cool. Boiler should not be heated/cooled quicker than 3-5 F per minute to protect the porcelain insulators from damage.

2.Securely support the electrode box inside the vessel. Remove the high voltage cable(s) and loosen the electrode rod nut. Remove the rod assembly carefully, taking care not to crack or chip the insulators or damage the assembly in any way (details in the following pages).

3.Clean and inspect the Pyrex tube for cracks and replace if necessary.

4.Replace the damaged porcelain insulator and reassemble the electrode with new gaskets.

5.Replace the electrode in the boiler and reinstall the shield and the electrode plate and housing inside the vessel, again taking care not to damage the electrode. Check the clearances and dimensions for the assembly against the boiler drawings to ensure that the electrode has been positioned properly. Tighten the electrode rod nut to 500 ft-lb, making sure the rod does not rotate. See Figures 11 and 12 for electrode components and order of assembly.

⚠ Caution

Take extreme care when handling electrode components. Use gloves when handling.

Prior to re-assembly, clean all parts with a **NON-PETROLEUM** based solvent.

Note: A cold boiler must be filled slowly and with return water from the mains no hotter than 140 Deg F. This is to ensure that the porcelain insulators and glass tubes are not heated too quickly. If the boiler is still hot, the feed water temperature should not be lower than the boiler temperature. Also, the boiler should not be heated/cooled quicker than 3-5 F per minute to protect the porcelain insulators from damage.

Lower Electrode Assembly

1. Electrode Housing
2. Copper Gasket (Triangular)
3. Electrode Bracket
4. Copper Gasket (Round)
5. Bracket Adapter*
6. Electrode Rod*
7. Graphite Gasket
8. Sponge Gasket 2-1/2” x 1-3/4”
9. Lower Centering Ring
10. Sponge Gasket 2-1/2” x 1-3/4”
11. Sponge Gasket 2-1/2” x 1-3/4”
12. Quartz Tube
13. Sponge Gasket 2-1/2” x 1-3/4”
14. Porcelain Insulator
15. Graphite Gasket
16. Drip Shield**

*Tighten electrode rod to bracket adapter to approx. 100 ft-lb.

Do not use any lubrication. High temperatures will evaporate lubricants and cause electrical shorts.

**Place drip shield loosely over completed electrode assembly and proceed to electrode installation.

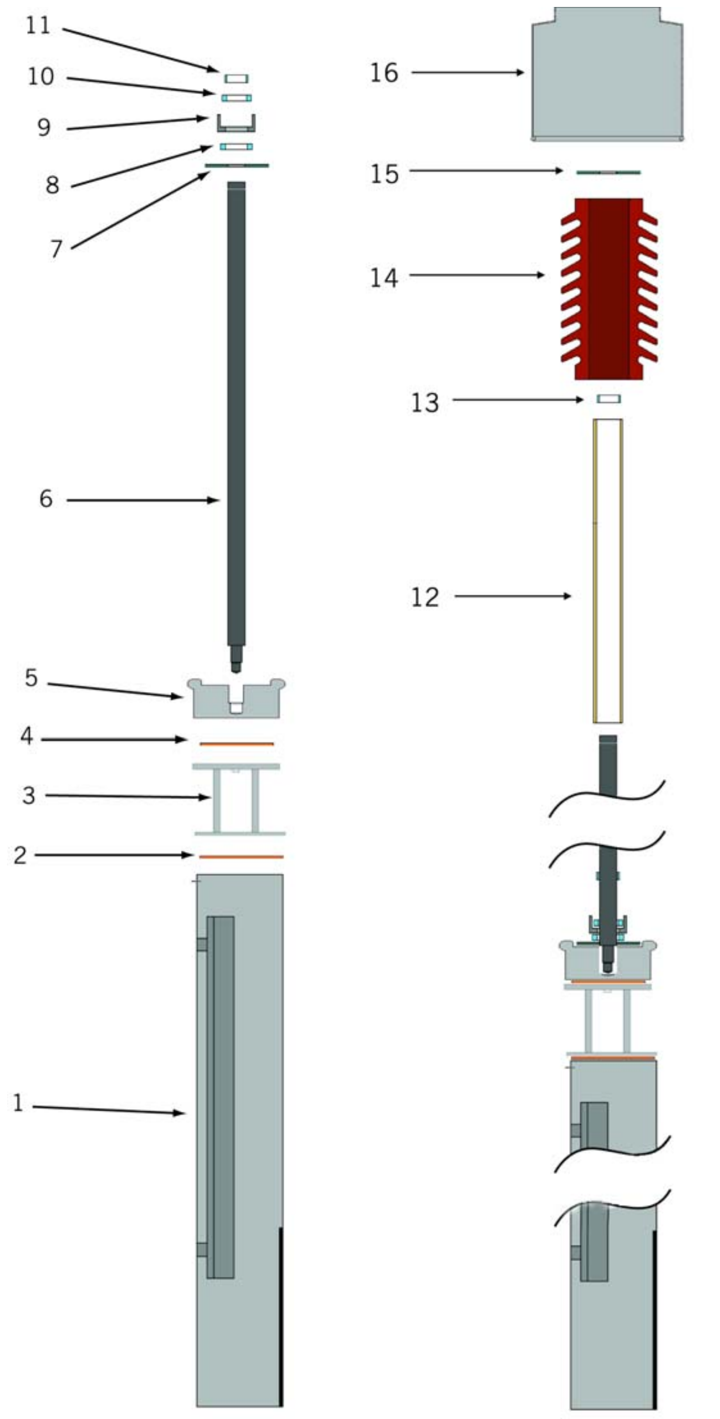


Figure 11 - Lower Electrode Assembly

Electrode Installation

- Install lifting eye-hook onto electrode shaft.
- Hoist the completed lower electrode assembly up through the boiler 's electrode fitting. Hoisting procedure will require careful handling of electrode by workers inside the boiler.

- Once the electrode is seated against the electrode bushing, use a bottle jack to support the assembly.
- Disengage the winch and begin upper electrode assembly (see Figure 12).
- Temporarily hand-tighten retaining nut and proceed to electrode positioning.

Upper Electrode Assembly

1. Graphite Gasket
2. Porcelain Insulator
3. Sponge Gasket 2-1/2” x 1-3/4”
4. Graphite Gasket
5. Upper Centering Ring
6. Spring Washers (see Figure 13 on pg. 38)
7. Spacer
8. Bearing
9. Retaining Nut

⚠ Caution

Check for required space between quartz and top of insulator.

Gaskets and centering ring must be snug but not over-tightened.

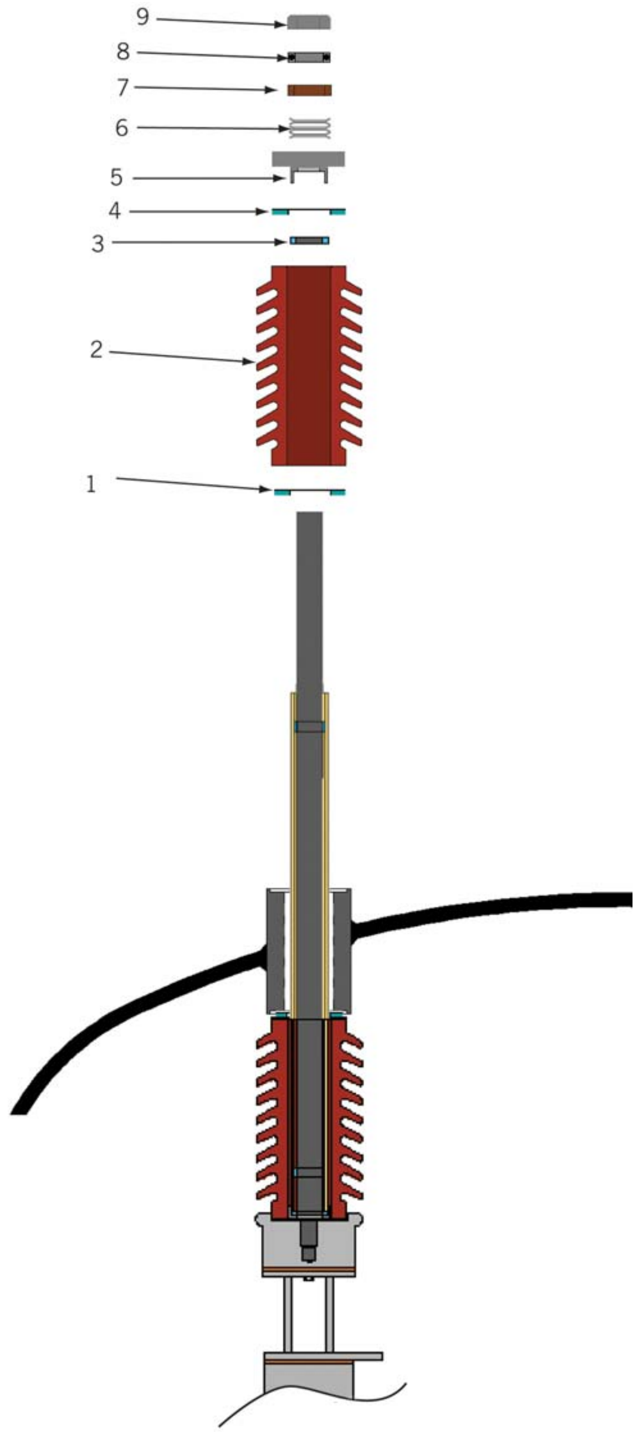


Figure 12 - Upper Electrode Assembly

Electrode positioning

- Space and center each of the electrode housings. The bottom plate of the electrode bracket is fitted with slots for front-back adjusting. Verify the electrode housing is squarely facing the nozzle plates.

- Tighten electrode retaining nut to 500 ft-lb torque. With non-lubricated threads, compression from cold free-height of the spring washer stack (5 concave mirrored pairs as shown in Figure 13) should measure a difference of approximately 0.5”. While tightening, have an assistant inside the boiler verify that the electrode boxes do not move. If boxes turn, check rod threads for damage or nut binding. DO NOT forcefully restrain boxes during tightening.

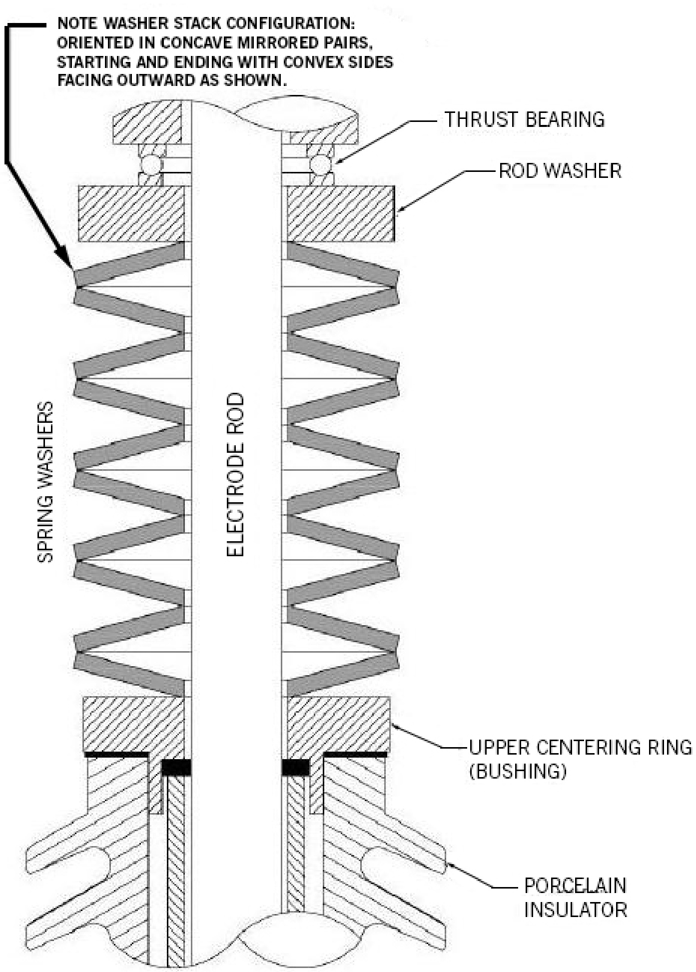
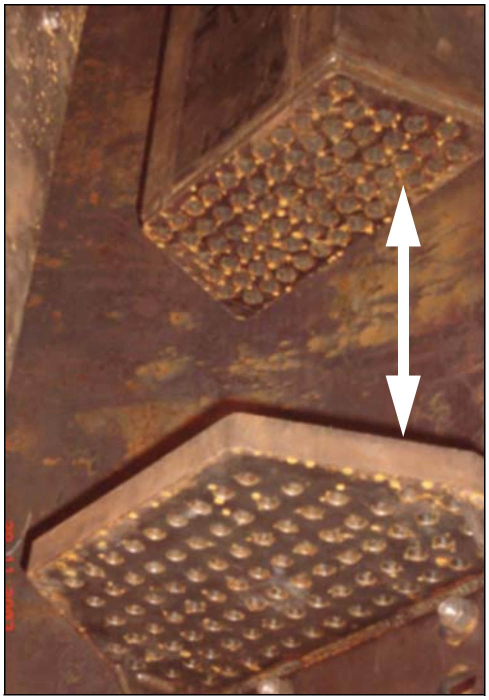


Figure 13 - Spring Washer Loading

Electrode positioning (continued)

- Measure and adjust distance between bottom of electrode boxes and counter electrodes.



- Measure and adjust the distance from each electrode box to the center water column nozzle plates. Each electrode box should be aligned perfectly parallel to the center column to ensure to the nozzle openings align precisely with the target plates.

- After positioning electrodes, attach the drip shield to electrode bushing.

9.6-Packing of gland housing assembly for control rod

The control rod gland housing packing must be replaced/repaired once a steam leak is realized. The packing can be tightened without completely replacing all material every time. Refer to the steps below for details to ensure the gland housing is properly packed and to minimize the risk associated with improper packing techniques. Figure 14 also shows a detailed drawing of the gland housing assembly to further assist with this procedure. The gland housing for the control rod should be checked for leaks within 2-4 weeks of initial operation after the gland housing assembly has been packed.

1.Begin by tightening the Gland Sleeve nuts (Item 6) to easily resolve the leaking steam issue. Proceed to Step 2-4 below if the tightening of this nut does not remedy the steam leak. CAUTION: Alleviate all pressure in boiler before attempting to remove any component of gland housing assembly.

2.To access the packing material, remove the Gland Sleeve (Item 1). This is accomplished by removing the Gland Sleeve nuts (Item 6), spring washers (Item 9), and stud bolts (Item 4).

NOTE: Two different types of packing material are used in this process. Please notice that the firmer round Carbon Braid packing (Item 7) is used on the outside (top & bottom) of the packing assembly. The 5 to 7 inner layers are comprised of softer square Graphite packing (Item 8) to ensure a better air-tight seal.

3.Remove the top-most round Carbon Braid packing (Item 7). Add sufficient layers of the square Graphite packing (Item 8), alternating the locations of the seam with each layer. Add a fresh layer of round Carbon Braid packing (Item7) to top of packing assembly.

NOTE: If all packing material must be replaced, begin with a fresh bottom layer of round Carbon Braid packing (Item 7). Add 5 to 7 middle layers of square Graphite packing (Item 8). A top layer of round carbon Braid packing is needed to finish the packing “sandwich”. See Figure 14 for reference. To ensure the best possible seal, cut ends of square Graphite packing (Item 8) to meet flush at 45 degree angles.

4.Replace the Gland Sleeve (Item 1), spring washers (Item 9), and stud bolts (Item 4). Tighten the Gland Sleeve nuts (Item 6) to pack the material. There are no certain torque specifications for this procedure as the compression of the packing is never constant. Be sure to leave a ½” to ¾” gap between the gland sleeve (Item 1) and the gland housing (Item 3) to allow for future compression when the assembly is initially packed.

NOTE: Spring washer (Item 9) stack configuration should be oriented in concave mirrored pairs, starting and ending with convex sides facing outward; three pairs of washers should be used with each stud bolt (Item 4) and Gland Sleeve nut (Item 6). Packing of gland housing assembly for control rod should be checked for leaks within 2-4 weeks of initial operation after the gland is packed. Tighten Gland Sleeve nuts (Item 6) as necessary.

ITEM	DESCRIPTION
1	GLAND SLEEVE
2	GLAND BUSHING, BRONZE
3	GLAND HOUSING
4	STUD BOLT
5	GASKET RING (GARLOCK)
6	NUT, HEX
7	PACKING, CARBON BRAID (ROUND)
8	PACKING, GRAPHITE (SQUARE)
9	WASHER, SPRING

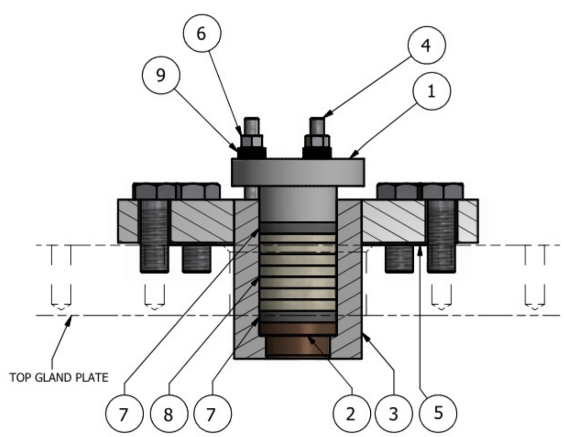


Figure 14 - Gland Housing

10 - Layup

At times it is desirable to shut the boiler down for an extended period ("Layup"). The preparation method used depends on the duration of layup and on how much time it is convenient to take in placing the boiler back into service.

For short-term shutdown (up to one or two months) the boiler may be left on standby with the standby heater keeping the boiler hot and under some pressure. This will keep all gaskets tight and will leave the boiler ready for use.

If the boiler is to be shut down and allowed to cool off, the water left in the boiler should be treated with hydrazine (100 ppm). The steam space should be filled with nitrogen to a pressure of 1 or 2 psi.

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PRECISION BOILERS

Installation and Operating Instructions

MODEL HVJ

ELECTRODE BOILER

(Revision: April 30, 2014)

PRECISION BOILERS

Installation and Operating Instructions

MODEL HVJ

ELECTRODE BOILER

This manual supplies information on the application, installation and operation of Model HVJ Electrode Boilers. Review all application and installation procedures completely before proceeding with the installation. Consult the Precision Local Factory Representative with any problems or questions regarding this equipment. Experience has shown that improper installation causes most operation problems.

RETAIN THESE INSTRUCTIONS NEAR THE EQUIPMENT FOR READY REFERENCE

WARNING

Improper installation, adjustment, alteration, service or maintenance can cause injury or property damage. **Read this manual thoroughly and follow the instructions herein.** The HVJ Boilers shall be installed according to the procedures detailed in this manual, or the Precision Boilers Limited Warranty may be voided. The installation must conform to the requirements of the local jurisdiction having authority. Any modifications to the boiler or its controls may void the warranty. If field installation requires modifications, consult either the local HVJ Electrode Boilers' Representative or the Factory.

TABLE OF CONTENTS

1.0 INSTALLATION GUIDELINES

1.1 Introduction

This Installation Manual is intended to supplement the experience and ability of qualified personnel in the installation, operation and maintenance of the boiler system.

1.1.1 General

All equipment supplied per this contract is intended for inside installation in a non-hostile environment. Complete installation shall be in compliance with all local codes and regulations.

1.1.2 Civil

Each piece of equipment shall be mounted in accordance with the respective dimensional drawing. Floor mounted equipment shall be adequately anchored to withstand that applicable Seismic requirements (6 degrees). Clearances for adequate service and maintenance shall be provided per shipment specifications / drawings. All equipment shall be adequately shimmed and grouted to assure the equipment to be level and / or plumb.

1.1.3 Mechanical

References to the system P&ID, in addition to detail piping drawings and the equipment dimensional drawings, should be made for the mechanical installation of each piece of equipment. Particular attention should be made in routing pipes both to allow for thermal expansion and to facilitate maintenance of equipment.

1.1.4 Electrical

The equipment should be wired per both the respective wiring diagrams and the overall system diagram. Care should be made to assure all conduits are routed to allow for equipment maintenance and away from both hot surfaces and areas of possible water or steam leakage. All analog instrument wiring should utilize shielded cable. High voltage cabling shall comply with the United States National Electrical Code (Part V of Article 490) and shall be routed to allow for sufficient ventilation.

1.2 Description of Boiler Operation

Refer to High Voltage Jet (HVJ) Electrode Steam Boiler, Figure 1. In the high voltage jet (HVJ) electrode boiler, water from the lower part of the boiler shell is pumped by the circulating pump(s) by the circulating pump(s) to the nozzle header and flows through the jets to strike an electrode, thus creating a path for the electric current. Primary voltage connections are made directly to the electrode terminals. As the unevaporated portion of the water, which is approximately 98% of total flow, flows from an electrode to a counter electrode, a second path for current is created.

Regulation of the boiler output is accomplished by a variable speed circulation pump, which varies the amount circulation pump, which varies the amount pump speed is set by the boiler pressure control system to hold the steam pressure constant.

NOTE: All size 1 boilers have standard ANSI pumps mounted external to the vessel. Size 2 and larger boilers have external circulation pumps. Size 338 and larger and have multiple internal pumps.

The conductivity of the water is important to boiler operation. In almost all instances, the conductivity of the boiler water tends to increase because make-up water adds salts to the boiler water (unless the make-up water is completely demineralized) which remain in the boiler since carryover of salt in the steam is negligible. To negate this trend of increasing conductivity, an automatic conductivity control senses water conductivity and, if too high, signals an automatic valve to allow a small amount of highly conductive water to be blown out of the boiler. This water is then replaced with less-conductive make-up water.

The boiler water level is controlled via a proportioning-type feedwater control. High and low water cutoffs are also provided as separate switches, and are connected into the boiler safety circuit. All boiler safety circuitry is connected directly to the circulation pump control and the boiler is effectively shut down.

A standby heater is provided to raise the boiler pressure to the minimum-operating limit (50 psi) on start-up or to maintain this or a higher pressure for short durations when the boiler is in the standby mode.

The high voltage power supply must be from a 'wye' system, as depicted in Figure 2, and must be installed in compliance with the *National Electrical Code (Part V of Article 490).*

The high voltage power supply must be from a 'wye' system, as depicted in Figure 2, and must be installed in compliance with the *National Electrical Code (Part V of Article 490).*

Figure 1a: High Voltage Jet (HVJ) Electrode Steam Boiler

Legend
3. Circulation Pump w/ VFD
12. Conductor Rod
18. Electrode / Strike Plate
19. Nozzle Header

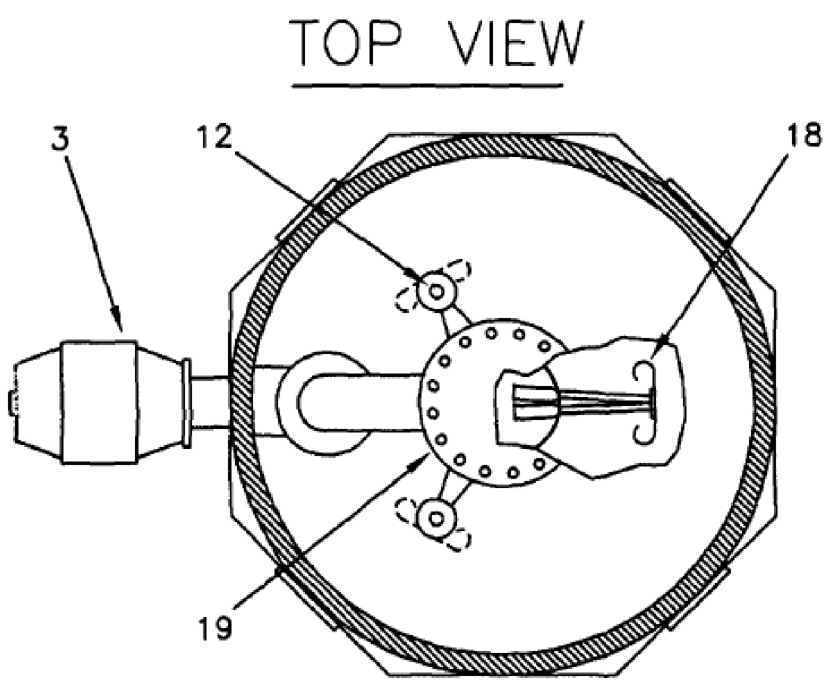


Figure 1b: High Voltage Jet (HVJ) Electrode

Steam Boiler

Figure 1 – Legend

1. Blowdown Valves
2. Pump Removal Clearance
3. Circulation Pump w/ VFD
4. Check valve
   (For multiple pumps only)
5. Conductivity Cell
6. Sheet Metal Enclosure
7. Insulation
8. Safety Valves (2)
9. Electrode Terminal Enclosure
10. Conduit Entrance Panel
11. Header Removal Clearance
12. Conductor Rod
13. High Voltage Insulators
14. Back Pressure Regulator
15. Steam Outlet
16. Non-Return Valve
17. Insulator Shields
18. Electrode / Strike Plate
19. Nozzle Header
20. Counter Electrode
21. Pressure Manifold & Gage
22. Water Column & Gage
23. Surface Blowoff
24. Standby Heater
25. Feedwater Valve w/ Bypass
26. Manhole

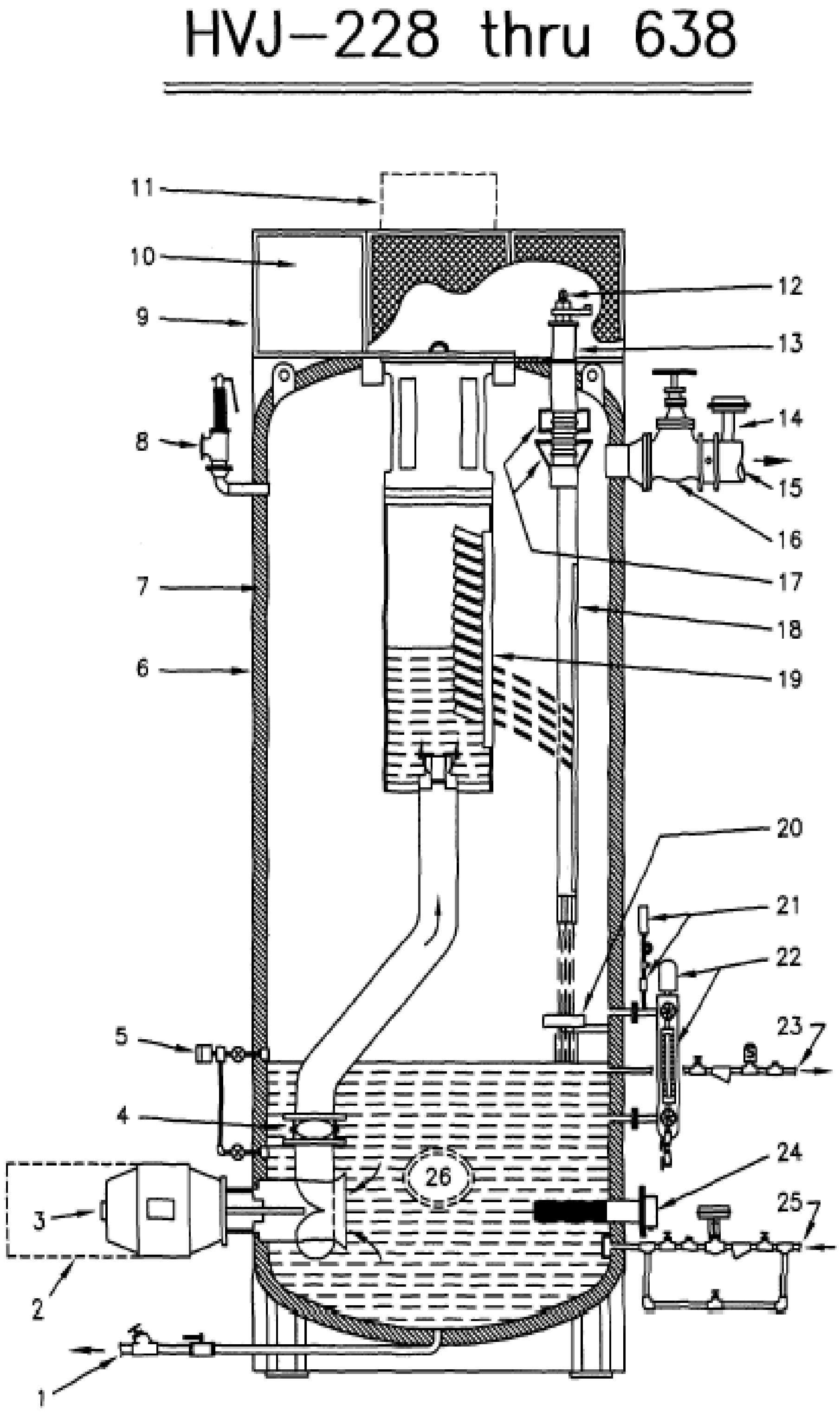
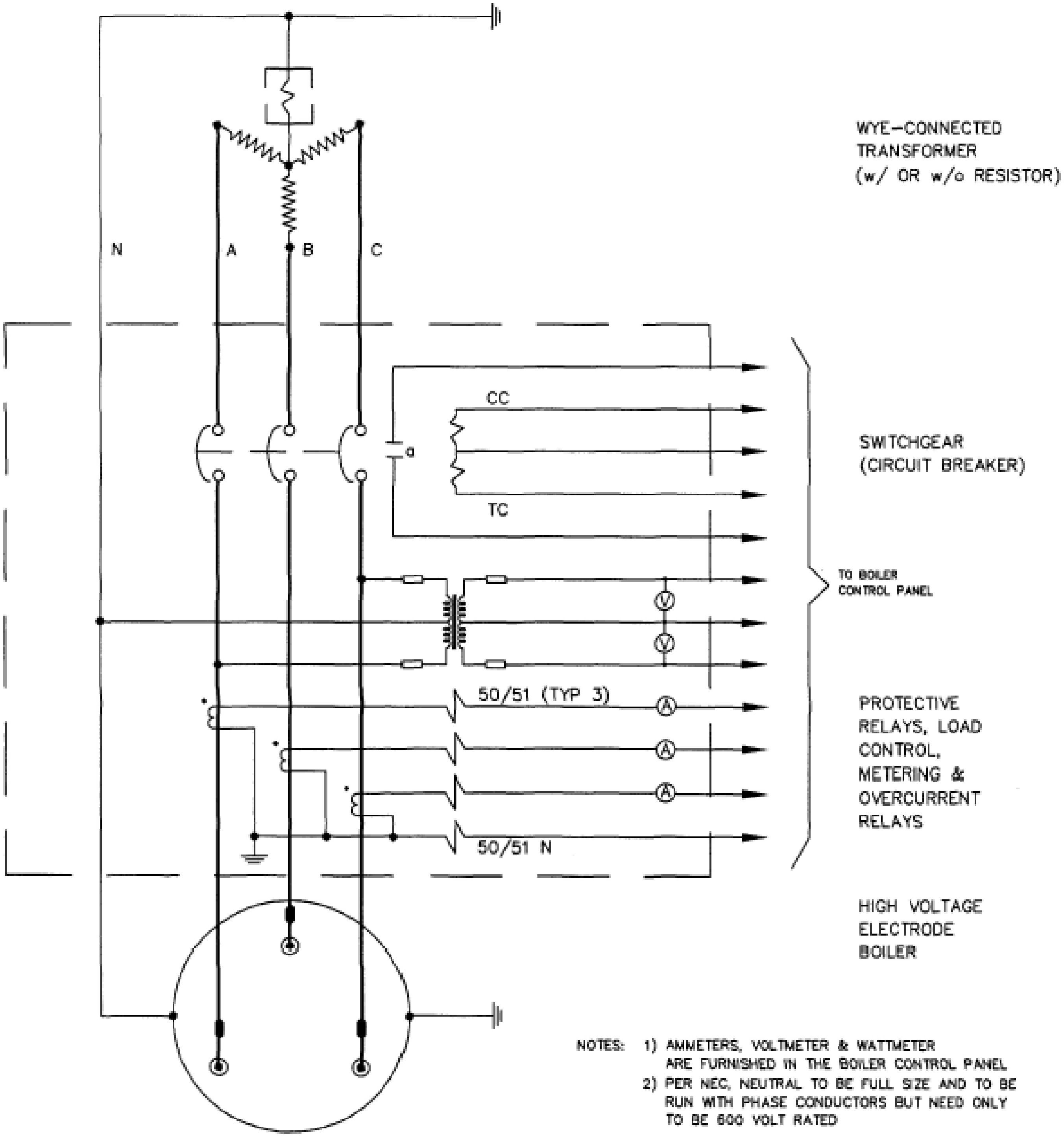


Figure 2: Typical Wiring Schematic
TYPICAL WIRING SCHEMATIC FOR MODEL 'HVJ' HIGH VOLTAGE ELECTRODE BOILER

2.0 HANDLING AND STORAGE



2.1 Shipping

2.1.1 Boiler

Boiler vessel will be shipped lying on its back supported by temporary shipping support beams. Lifting lugs located on the upper exposed side and top provide pickup points for removal from the container, and for later righting the boilers above their foundation pads.

2.1.2 Components

All loose components and trim, and the control enclosure will be shipped in crates and should be handled by a fork truck for removal from the containers.

2.2 Storage

Electrical equipment can be damaged if exposed to adverse weather. **The boiler and all accessories should be stored inside with temperatures held at 70°F + 20°F and humidity held to 60% + 20%.** The electrical panel and controls must be covered with plastic throughout all construction to avoid accumulation of dust and moisture on the controls and load components. Relays, contactors and switches can be damaged by dust in the mechanism.

2.3 Uncrating

Care must be given not to damage controls or to deform the boiler sheet metal during removal from the container. If using pry bars or forklifts, be certain to support the boiler weight on the temporary shipping skids.

3.0 INSTALLATION AND ASSEMBLY

3.1 Boiler

3.1.1 Primary Boiler Assembly

3.1.1.1 Setting the Boiler

3.1.1.1.1 Position boiler in proper location and then shim boiler bearing plates to assure that boiler is plumb using boiler top cover flange as reference.

3.1.1.1.2 Attach the boiler bearing plates to the floor using the appropriate anchor bolts. The anchor bolt holes are oversized to allow for thermal growth when the boiler is put in operation.

3.1.1.1.3 Grout the bearing plates to assure boiler remains plumb.

CAUTION: Grout beneath bearing plates only to allow some lateral movement per Section 3.1.1.1.2.

3.1.1.2 Top Platform*

3.1.1.2.1 Place the two pieces of painted grating within the angle iron supports on top of the boiler.

3.1.1.2.2 Bolt grating in place temporarily using the appropriate cap screws and flat washers (these bolts will be removed later when mounting the electrode terminal enclosure).

3.1.2 Assembly of Internal Components

3.1.2.1 Bottom Platform*

3.1.2.1.1 Place the three remaining pieces of grating upon the support studs on the inside bottom of the boiler. Position so that the pieces are joined together over the support studs.

3.1.2.1.2 Bolt grating to studs using the appropriate machine bolts and flat washers.

3.1.2.2 Counter Electrodes

Attach the counter electrodes to the support brackets using the appropriate machine bolts and nuts. Position electrodes with the angle iron brackets facing up.

3.1.2.3 Conductor Rod Assemblies

Refer to **Figure 3** and to the *Electrode Assembly Drawing Appendix B.*

3.1.2.3.1 Install upper insulator shields* into the plates welded to the bushings extended through the top of the tank.

NOTE: Upper insulator shields may be lowered later to assure proper location of upper inner insulator gasket.

3.1.2.3.2 Install (3 each) shorting springs* (outer) onto the outside face of the (3) bushings extending through the top of the tank using the appropriate machine screws.

3.1.2.3.3 Assemble (2) shorting springs* (inner) to each conductor rod using the appropriate machine screws.

3.1.2.3.4 Screw the conductor rods* into the coupling nuts and tighten securely.

NOTE: It is important that this joint be as tight as possible.

3.1.2.3.5 Assemble the lower insulator shields* to the coupling nuts using the appropriate machine screws. Do not tighten at this time.

NOTE: From past experience, it has been found to be easier to complete the electrode assembly inside the boiler. Pass the components of the conductor rod assemblies into the boiler through the manhole.

IMPORTANT: Avoid touching the silver oxide coating of the thru insulator. It is very important that this surface remains clean.

3.1.2.3.6 Slip (1 each) 1-3/4” x 3” thru gasket over each conductor rod (DO NOT USE GASKET CEMENT)

3.1.2.3.7 Slip (1 each) thru insulator over each conductor rod being careful not to disrupt short springs.

NOTE: Handle Insulators carefully. Insulators must be free of all grease and oil. To clean insulators, use hot soapy water and a soft brush. Chipped ends are only a concern on the inner steam side (ribbed) insulator. **Do not touch the silver oxide coating on the thru insulator.**

3.1.2.3.8 Slip (1 each) 4” x 5-5/8” conductive inner gasket over each conductor rod – do not use gasket cement. Make sure groove in coupling nut if free of dirt. Position gasket within the rabbit on the coupling nut.
3.1.2.3.9 Slip (1 each) inner (ribbed) insulator over each conductor rod.

IMPORTANT: Clean coupling nut and bushing in top of boiler prior to assembling insulators.

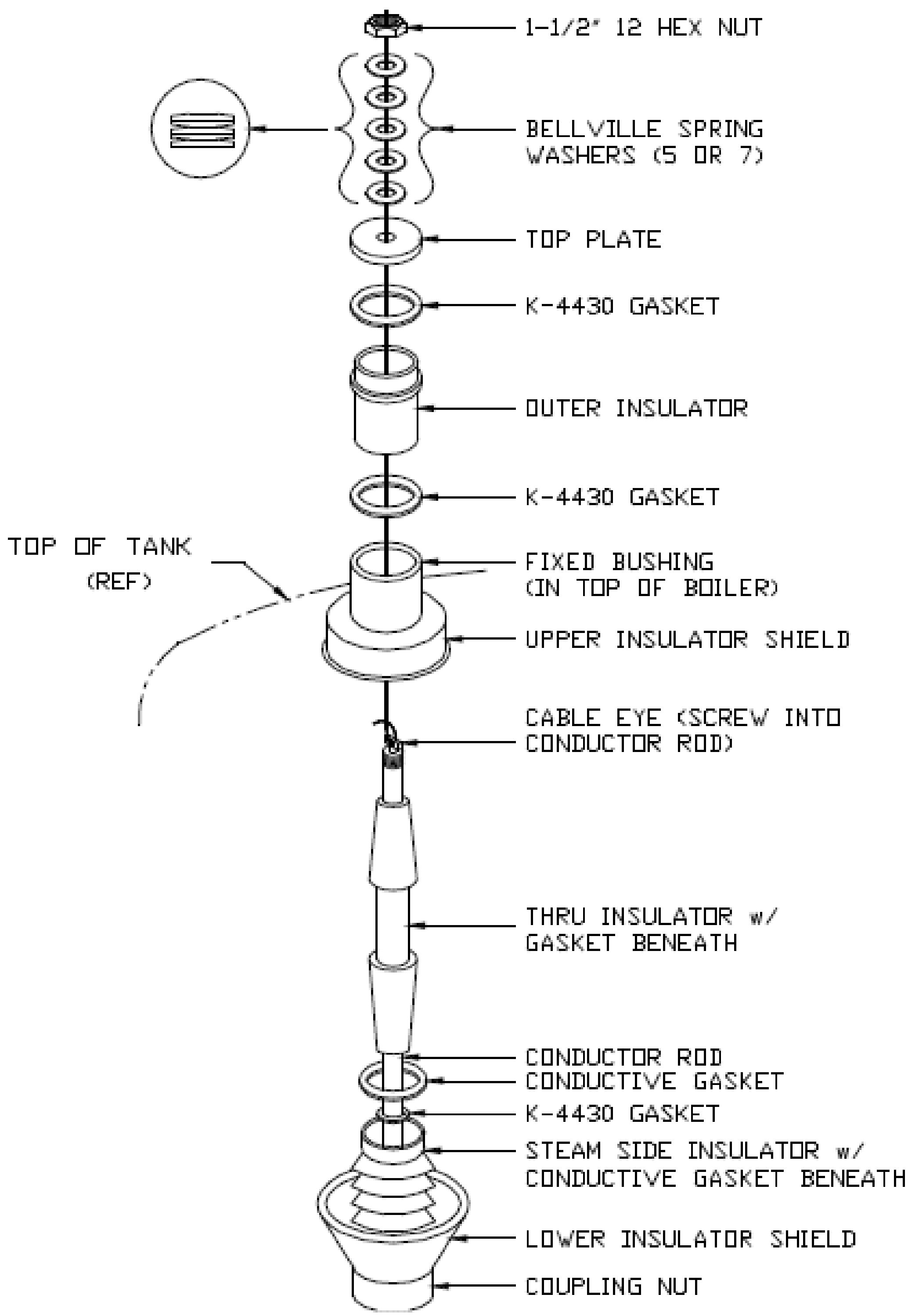
3.1.2.3.10 While on top of the boiler, thread the 3/16” lifting cable (supplied” through the following items (in order): Refer to *Assembly Installation, **Figure 3**.*

- 1-1/2 – 12 hex nuts
- (5) Belleville spring washers – first (2) pairs to be opposed as shown on ***Figure 3.***
- Top plate
- 4” x 5-5/8” outer gasket
- Outer insulator
- 4” x 5-5/8” outer gasket
- Fixed bushing in top of boiler

3.1.2.3.11 Screw the lifting hook, attached to the lifting cable, into the end of the conductor rod assembly and hoist assembly up through the tank bushing..

IMPORTANT: Exercise care to assure both the safety of the thru insulator and the proper function of the outer shorting springs. Thumb pressure may be required on the shorting springs to guide them during their compression along the insulator surface.

FIGURE 3 – CONDUCTOR ROD ASSEMBLY INSTALLATION



3.1.2.3.12 Screw the 1-1/2 – 12 hex nut onto the conductor rod until it is just snug. Orient the assembly so that the bolt hole in the bottom of the electrode coupling nut closest to the center of the nut faces radially inward.

3.1.2.3.13 After assuring the proper alignment of all gaskets and insulators, tighten the tie-nut approximately one full turn after hand tight (final tightening instructions to follow).

3.1.2.3.14 Repeat steps Paragraph 3.1.2.4.11 – 3.1.2.4.14 for the remaining conductor rod assemblies.

3.1.2.3.15 Adjust the lower insulator shields to that there is 1-3/4" + 1/8" gap between the rings of the upper and lower insulator shields. Tighten securely.

3.1.2.3.16 Pass the electrodes into the boiler through the manhole. Attached to the coupling nut using the appropriate machine screws and a triangular 3-hole electrode clamp plate.

3.1.2.3.17 Test the insulating resistance of each bushing with a meggar; each must be at least 1.5 megohms. If a meggar is not available, hi-pot each conductor rod at the phase-to-neutral voltage + 100% for AC, +200% for DC.

3.1.2.4 Nozzle header*

3.1.2.4.1 Apply a thin film of non-hardening gasket cement on the inside shoulder of the tank cover flange and then place the appropriate 1/8" top flange gasket on this surface.

3.1.2.4.2 Hoist the lower part of the nozzle header assembly up and onto the top flange opening. Lower the assembly into the boiler and support assembly on top flange using the rod extending through the header support pipe.

3.1.2.4.3 Hoist the upper part of the nozzle header assembly up and onto the lower part and orient so that the locating pin in the lower assembly fits into the locating hole in the upper assembly.

3.1.2.4.4 Join together the two nozzle header assemblies using the appropriate machine bolts as required. Tighten securely.

NOTE: If adequate over-head space is available, this assembly may be fitted together at floor level and then hoisted fully assembled to the top of boiler for installation.

3.1.2.4.5 Using the inside lifting eye, first raise the whole assembly enough to remove the support rod, then lower the assembly into the boiler; orient so that the locating pin in the top plate lines up with the slot in the boiler flange.

NOTE: During this step, one needs to be inside the boiler to ensure that the circulation pipe properly slips into the nozzle header.

3.1.2.4.6 At this time, snug up the bolts fastening the riser pipe to the pump discharge flange.

3.1.2.5 Dimensional Checks

Before leaving the inside of the boiler, make sure that the critical dimensions comply with those tabulated in *Assembly Dimensions*, *Figure 4*. A threaded 'T-rod' has been supplied to facilitate checking the alignment of the electrodes and the distance ‘a’. This rod should be screwed into the threaded hole at the bottom of each nozzle plate. The bolts of the electrode fastenings have adequate play (+ 3/4” circumferentially) to correct small deviations in the electrode locations. The electrodes must also be square to the T-rod and plumb to the axis of the nozzle header.

NOTE: If the distance ‘a’ cannot be exactly attained on all electrodes, then the objective is to obtain a distance that is most uniform for all of the electrodes within the tolerance limits per *Assembly Dimensions, Figure 4*.

3.1.2.6 Final Tightening

Being careful not to turn the conductor rod assemblies by using the flats on the top of the conductor rods to prevent rotation, tighten the 1-1/2 – 12 tie rod nuts an additional turn or more to result in a 3/64” (approximately the thickness of a US dime) gap between the edges of the Belleville washers.

3.1.3 Assembly of External Components

3.1.3.1 Standby Heater*

3.1.3.1.1 Locate the standard flange gasket and attach it to the standby heater flange using gasket cement.

3.1.3.1.2 Apply gasket cement to the standby heater flange and insert the heater into the boiler. Fasten securely using the appropriate machine bolt and hex nuts as required.

NOTE: For electric heaters, orient heater so that conduit connection either faces the right or left, depending on the accessibility to the electrical connection.

FIGURE 4: Assembly Dimensions

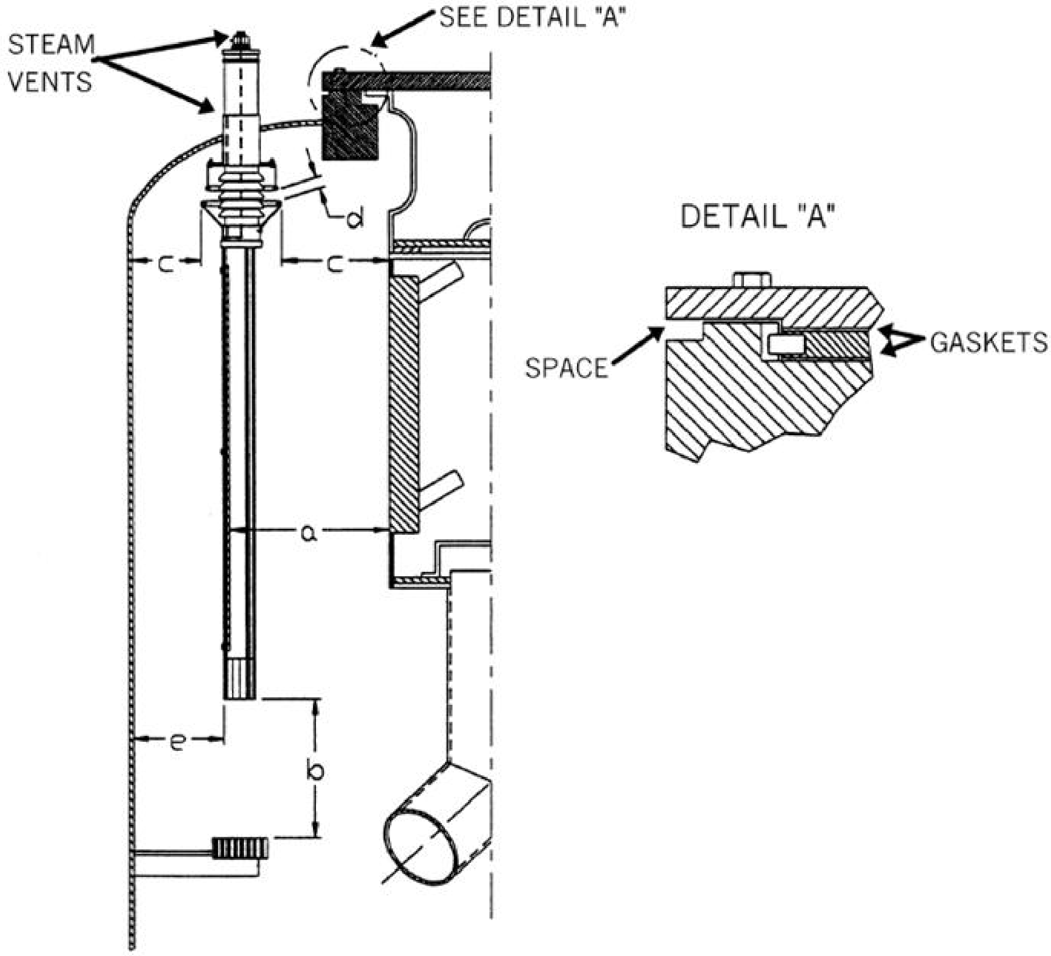


Figure 4: Table of Assembly Dimensions					
KV	a (+/- ¼")	b (+/- ¼")	c (Minimum)	d (Minimum)	e (Minimum)
4.16	7	9-1/2	1-1/4	1-1/4	3
6.6	7-1/2	11	1-1/4	1-1/4	4
6.9	8	11-1/2	1-3/8	1-1/4	4
11	11	15-1/2	2	1-1/2	5
1205	12	16-1/2	2	1-9/16	6
13.2	12-1/2	17	2-1/8	1-5/8	6
13.8	12-3/4	17-1/2	2-1/8	1-5/8	6-1/4
14.4	13	17-3/4	2-1/4	1-3/4	6-1/2
20	17	22	2-=3/4	2	7
22.5	19	24-1/4	3	2-1/2	7-1/2
25	21	26-1/2	3-1/2	3	8

3.1.3.2 Circulating Pump(s) (boilers with internal pump(s) only)

NOTE: Exercise caution when handling the circulation pump to prevent damaging the exposed impeller.

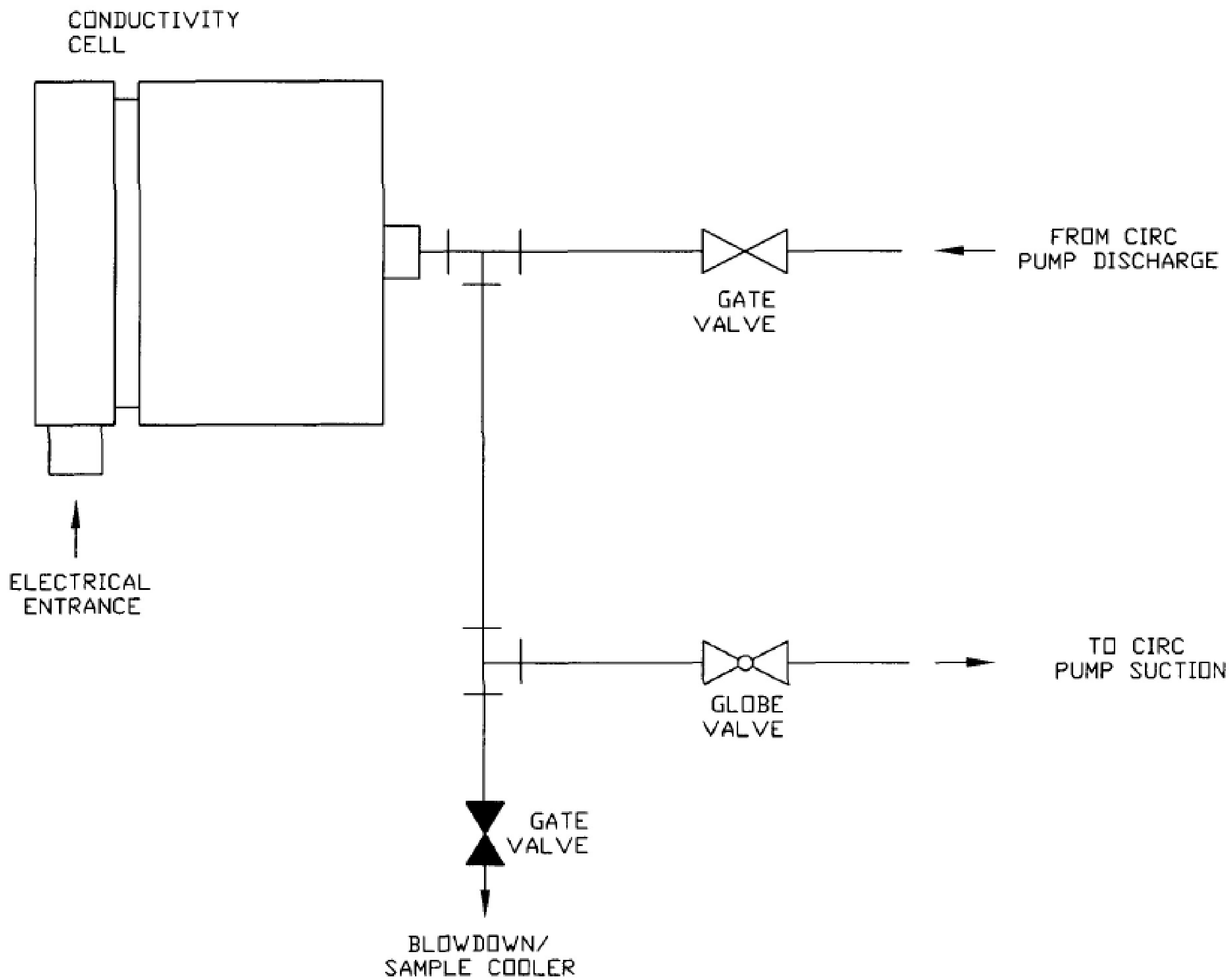
3.1.3.2.1 Screw into the pump flange the (12) 1-8 x 5 – 1/2 mounting studs and tighten securely.
3.1.3.2.2 Locate the outer pump gasket (18" OD) and fit it to the outer pump flange.
3.1.3.2.3 Prior to pump installation; ascertain proper rotation per *Lawrence Pumps Operations & Maintenance Manual, Vendor Supplied Material,* ***Appendix E*.**
(Note: Impeller unscrews clockwise).
3.1.3.2.4 Hoist pump assembly using lifting eye on motor and insert into side of tank through flange and fasten securely using the appropriate nuts; make sure pump turns freely and check for uniform impeller clearance from inside the boiler. Torque nuts to 250 ft-lbs.
3.1.3.3 Electrode Terminal Enclosure
3.1.3.3.1 Hoist the electrode terminal enclosure onto the angle-iron from the top of the boiler. Orient enclosure so that the solid panel is in the direction from which the high voltage power supply will come
3.1.3.3.2 At the (4) corners of the octagon under which plates with threaded holes are welded to the T-iron frame, thread the appropriate cap screws into the most accessible holes.
3.1.3.3.3 Attach the solid panel of the enclosure securely to the T-iron from by drilling holes* and then bolting the panel to the frame using the appropriate cap screws, washers and hex nuts.

3.1.4 Piping Assembly
Refer to Boiler *Dimensional Drawing* ***(DD - ____)*** *and P & ID,* ***Appendix A.***
3.1.4.1 Blowdown*
3.1.4.1.1 Per the dimensional drawing, install and connect the bottom blowdown fittings and piping per installation and local code requirements, and pipe to the blowdown tank or separator.
3.1.4.1.2 Install the surface blowdown fittings (stop valve, strainer, solenoid valve and check valve) per the installation drawing and pipe to the blowdown tank or separator.

NOTE: The solenoid valve should be in a horizontal section of pipe with the solenoid oriented vertically up.

3.1.4.2 Conductivity Cell and Sample Cooler*
Refer to *Conductivity Piping, Figure 5*

Figure 5: Conductivity Piping



3.1.4.2.1 Using the fittings supplied, attach the pre-piped conductivity cell assembly to the boiler as shown.
3.1.4.2.2 Attach the sample cooler to the boiler skin near the conductivity cell.
3.1.4.2.3 Pipe the process inlet of the sample cooler to the valve on the conductivity cell drain piping.
3.1.4.2.4 Connect cooling water supply to the bottom shell connection of the sample cooler.
3.1.4.2.5 Pipe the cooling water discharge to the drain manifold with visible flow provision.

NOTE: For boilers operating above 250 psi, the sample water to the conductivity cell must be cooled per the following:

For 250 psi Operating Pressure, 400°F Max Cell Temperature
For 275 psi Operating Pressure, 370°F Max Cell Temperature
For 300 psi Operating Pressure, 340°F Max Cell Temperature

The sample cooler can be used for this purpose with the process discharge used as the supply to the conductivity cell.

3.1.4.3 Feedwater

Refer to *Feedwater Piping,* ***Figure 6.***

3.1.4.3.1 The feedwater system should be sized to allow for a 10 – 15 psi pressure drop across the modulating feedwater control valve. The pipe size may be 1 or 2 sizes larger than the control valve body size.

3.1.4.3.2 Pipe the feedwater to the boiler as shown in ***Figure 6***. A 3 – valve bypass is recommended as shown. The chemical fill inlet (quill) should be located as close to the boiler as possible.

3.1.4.3.3 If a feedwater pressure gauge is provided, install it in the feedwater line upstream of the control valve.

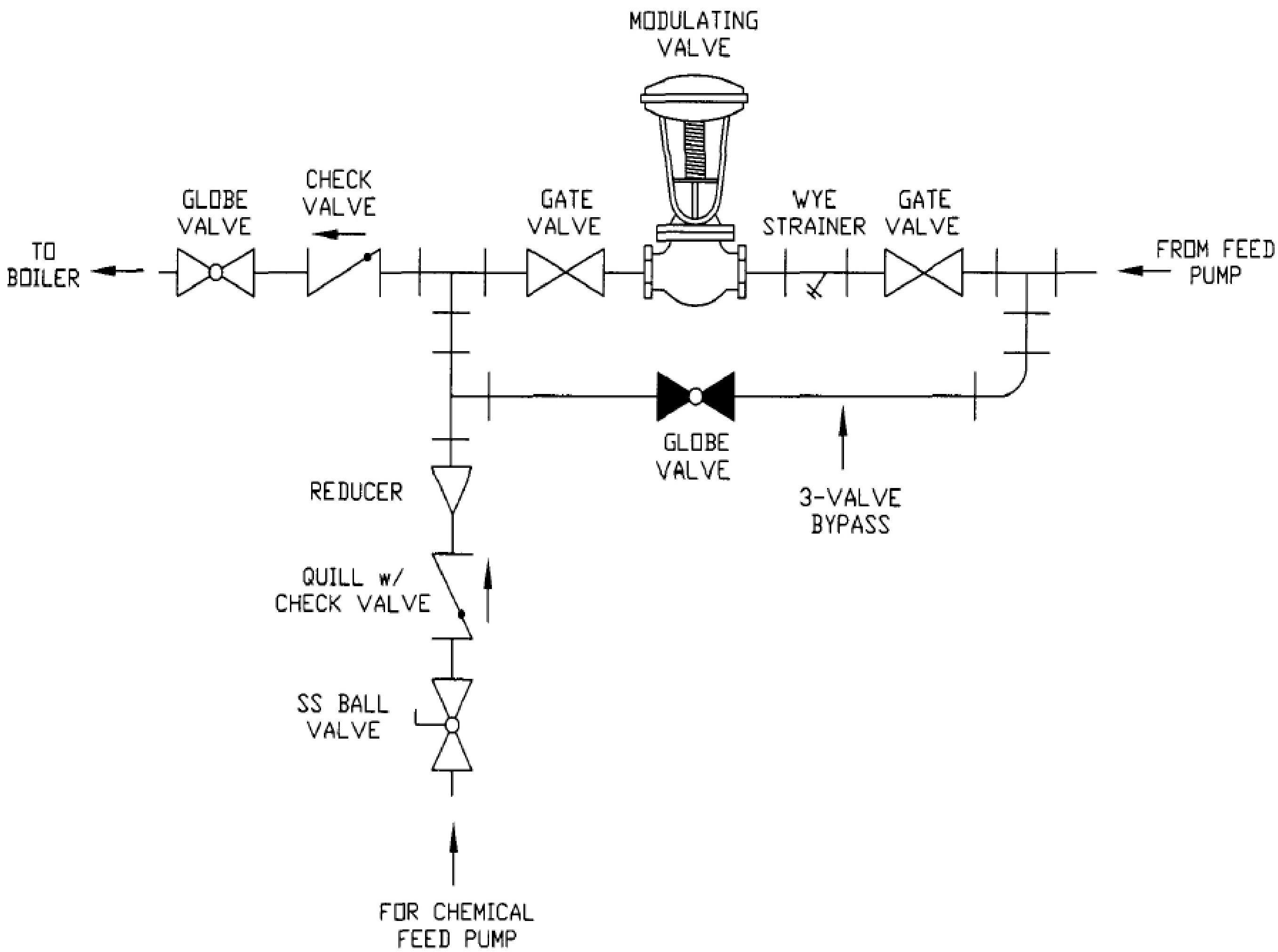
3.1.4.4 Water Column and Pressure Sensing Manifold*

3.1.4.4.1 Locate the pre-piped pressure sensing manifold and mount it to the top outlet of the water column assembly. Alternately, this assembly may be factory-mounted on a sub-panel to be attached to the boiler sheet metal. In this case, piping must be installed to connect the sensing manifold to the upper water column connection.

3.1.4.4.2 Mount the water column assembly to the 1” flanges on the boiler using gaskets and the appropriate machine bolts.

3.14.4.3 Screw the drain valve* into the drain outlet and pipe it to the floor drain.

FIGURE 6: Feedwater Piping



NOTE: At this time make sure that balancing pendulums (if provided) in both pressure limits indicate that they are level. Make plumbing adjustments if necessary to assure their levelness.

3.1.4.5 Air Release*

Install the air release globe valve on the nipple extending from the boiler approx 5' above the floor (this actually runs from the top of the boiler behind the lagging) and pipe to approximately 1" above a drain receiver and in sight of the air release valve.

3.1.4.6 Circulation Pump Connection*

Refer to the pump drawing, *Vendor Supplied Material,* ***Appendix C.***

3.1.4.6.1 Using a 1/2" minimum pipe, pipe cooling water to the 1/2" connection for the pump oil and seal cooling. Include the 1/2" flow switch and check ball valves provided in this line. (The flow switch must mount in a horizontal pipe.)

NOTE: For ease of pump removal / disassembly, the final connections to the pump should be made with stainless steel tubing.

3.1.4.6.2 Using 1/2" pipe, pipe the cooling water discharge (upper connection) to the open drain manifold. Include the 1/2" needle valve provided in this line.

NOTE: For prolonged seal performance, the cooling water should be both softened and filtered.

3.1.4.7 Safety Valves*

3.1.4.7.1 Using the pipe fittings required / provided, install the safety valves to the (2) vessel connections per the dimensional drawing.

3.1.4.7.2 Pipe the safety valve discharges to atmosphere using drip pan elbows per code requirements. The discharge pipe cross-sectional area shall be the total area of the valves discharging thereunto, shall be as short and straight as possible, and shall be carried from running boards and platforms.

3.1.4.8 Steam Stop and Check Valves

Install the stop and check valves on the steam outlet flange per installation requirements.

3.1.4.9 Back Pressure Regulator

Install the backpressure regulator (to be set at slightly below normal operating pressure) in the stream outlet valve train per installation requirements.

3.1.4.10 Manual Vent Valve

If other boilers discharge into a common header, then both a header gat valve and 1" vent valve, located between the gate valve and the non-return or stop valve, are normally required (check local code requirements).

3.1.4.10 Auto Vent Valve

Assemble the automatic vent valve assembly to the 1/2" NPT tapping in the top cover plate.

3.1.5 Electrode Assembly

Refer to Boiler *Electrical Wiring Diagram* ***(WD-____),*** *Appendix A.*

3.1.5.1 High Voltage Wiring

3.1.5.1.1 Make the high voltage conduit connection through the solid panel (removable) on the electrode terminal enclosure.

3.1.5.1.2 Using the appropriate cop screw and star type lock washer, attach an equipment ground lug (minimum size per electrical schematic) to the NEMA ground pad on the base of the boiler (2 provided).

3.1.5.1.3 Using the appropriate cap screw a star-type lock washer, attach a neutral lug to one of the tapped holes in the boiler cover plate. This will be used later for the grounded conductor (neutral).

3.1.5.1.4 Attach one bus bar to each electrode terminal.

CAUTION: When tightening the jam nuts, do not allow the conductor rod assembly to turn. Hold conductor rod via flatted sides at top.

3.1.5.1.5 Attach phase conductors to each electrode terminal per installation requirements. Route the wires to facilitate later installation requirements. Route the wires to facilitate later installation or removal of the boiler cover plate, and so that they do not come in contact with hot boiler surfaces.

NOTE: If complete assembly is to be meggered, refer to Paragraph 3.1.2.4.18.

3.1.5.2 Control Wiring

3.1.5.2.1 Anchor the control cabinet to the floor per installation requirements.

3.1.5.2.2 Run the 480 VAC branch circuit to the boiler control cabinet per the electrical schematic.

3.1.5.2.3 Attach an equipment ground (minimum size per the wiring schematic) to the grounding lug in the control enclosure.

3.1.5.2.4 Make the field wiring connections between the control cabinet and the external electrical components per the wiring drawing. Use AWG #14 wire minimum (except for 480 Volt circuitry) and shielded control cables. For shielded wire cables, use the AWG #20 multi-conductor cable as provided. The shields should be terminated at one end only.

3.1.5.3 Grounding

After completing the above electrical connections, be certain that the following components are solidly grounded:

- Boiler enclosure
- Circulation pump motor casing
- Control cabinet

3.1.6 Pneumatic Assembly

Refer to Boiler *Loop Diagram* ***(____- LOOP)****, Appendix B.*

3.1.6.1 Feedwater Control Valve*

Install the assembled air loader, filter, and gauge assembly to control air supply (1/4” NPT / 35 psi min) and tube (3/8” OD copper tubing min. – typical for all tubing) to the ‘Supply’ port of the feedwater valve positioner.

3.2 Feedwater Pumps

Install the feedwater pumps per the *P & ID* and the respective Operation & Maintenance Manual located in *Vendor Supplied Material, Appendix C.*

NOTE: Most boiler feed pumps require a relief valve or orifice with a bypass loop back to the feedwater receiver. Check the requirements of the specified feed pump being used.

NOTE: Make certain that the continuous recirc / vent connection is made at the top of the pump stack. This will eliminate the accumulation of air at the top of the pump.

NOTE: Schedule 80 pipe should be used for the pump discharge piping (check with local code requirements).

3.3 Blowdown Tank

3.3.1 Erection

3.3.1.1 Position the blowdown tank in its proper position and then shim the bearing plates to assure the tank is plumb using the vessel sides as reference.

3.3.1.2 Attach bearing plates to the floor using the appropriate anchor bolts.

3.3.1.3 Grout the bearing plates to assure the tank remains plumb.

3.3.2 Assembly of External Components

Refer to Blowdown *Dimensional Drawing* ***(DD-)****, Appendix A.*

3.3.2.1 Gauges*

Install the temperature, pressure and sight gauges in their proper location.

Valves*

Install the cold-water quench and drain valves in their proper location.

3.4 Electrolyte Feed System

3.4.1 Erection

3.4.1.1 Position the electrolyte feed system in its proper location and then shim the bearing plates to assure the tank is plumb using the vessel sides as reference.

3.4.1.2 Attach the bearing plates to the floor using the appropriate anchor bolts.

3.4.1.3…Grout the bearing plates to assure the system remains plumb.

3.4.2 Assembly of External Components

Refer to *Electrolyte Feed Dimensional Drawing* ***(DD-___), Appendix A****.*

3.4.2.1 Make-Up Valve*

Install the make-up valve to the open fitting on the upper part of the tank.

3.4.2.2 Agitator*

Clamp the agitator to the C-channel extension.

3.4.3 Piping Assembly

3.4.3.1 Make-up Water

Pipe make-up water to the make-up globe valve previously installed.

3.4.3.2 Discharge

Pipe the pump discharge to the boiler quill assembly per the Piping Layout Drawing using stainless steel pipe or tubing.

3.4.3.3 Drain

Run a drain line from the tank drain valve to a suitable floor drain.

3.4.4 Electrical Connection

Refer to *Electrolyte Feed Wiring Diagram* ***(WD-____), Appendix A.***

Wire the electrolyte feed system to the boiler control cabinet per the referenced wiring diagram.

3.5 Chemical Feed System

3.5.1 Erection

3.5.1.1 Position the chemical feed system in its proper location and then shim the bearing plates to assure the tank is plumb using the vessel sides as reference.

3.5.1.2 Attach the bearing plates to the floor using the appropriate anchor bolts. Grout the bearing plates to assure the system remains plumb.

3.5.2 Assembly of External Components

Refer to *Chemical Feed Dimensional Diagram* ***(DD-____), Appendix A***.

3.5.2.1 Make-Up Valve*

Install the make-up valve to the open fitting on the upper part of the tank.

3.5.2.2 Agitator*

Clamp the agitator to the C-channel extension.

3.5.3 Piping Assembly

3.5.3.1 Make-Up Water

Pipe make-up water to the make-up globe valve previously installed.

3.5.3.2 Discharge

Pipe the pump discharge to the boiler quill assembly per the Piping Layout Drawing using stainless steel pipe or tubing.

3.5.3.3 Drain

Run a drain line from the tank drain valve to a suitable floor drain.

3.5.4 Electrical Connection

Refer to *Chemical Feed Wiring Diagram* ***(WD-____), Appendix A***.

Wire the chemical feed system to the boiler control cabinet per the referenced wiring diagram.

4.0 OPERATION

4.1 Preliminary Checks and Adjustments

4.1.1 Boiler

4.1.1.1 Pressure Check

4.1.1.1.1 Place the top cover on the boiler using a thin film of non-hardening gasket cement on both sides of the appropriate gasket (this cover will be removed later to permit observation of the water flow pattern).

4.1.1.1.2 Fasten the cover down using the appropriate high stress hex nuts.

4.1.1.1.3 Install the manhole cover.

4.1.1.1.4 Install gags on the safety valves or, alternatively, blanking plates (pans) in the safety valve connections.

4.1.1.1.5 Tightly close valves farthest from the boiler on all valve trains intended to be pressurized.

4.1.1.1.6 Perform a hydrostatic test on the entire system. Use the pipe plug on the boiler top cover as a vent and, if the steam outlet train is included in the test, use the 1” vent valve to vent the steam outlet train.

4.1.1.1.7 Drain water from boiler and remove safety valve gags or pans.

4.1.1.1.8 Refill boiler to proper water level (+1”).

4.1.1.2 Electrical Checks

4.1.1.2.1 Switch on the 480VAC power to the control console.

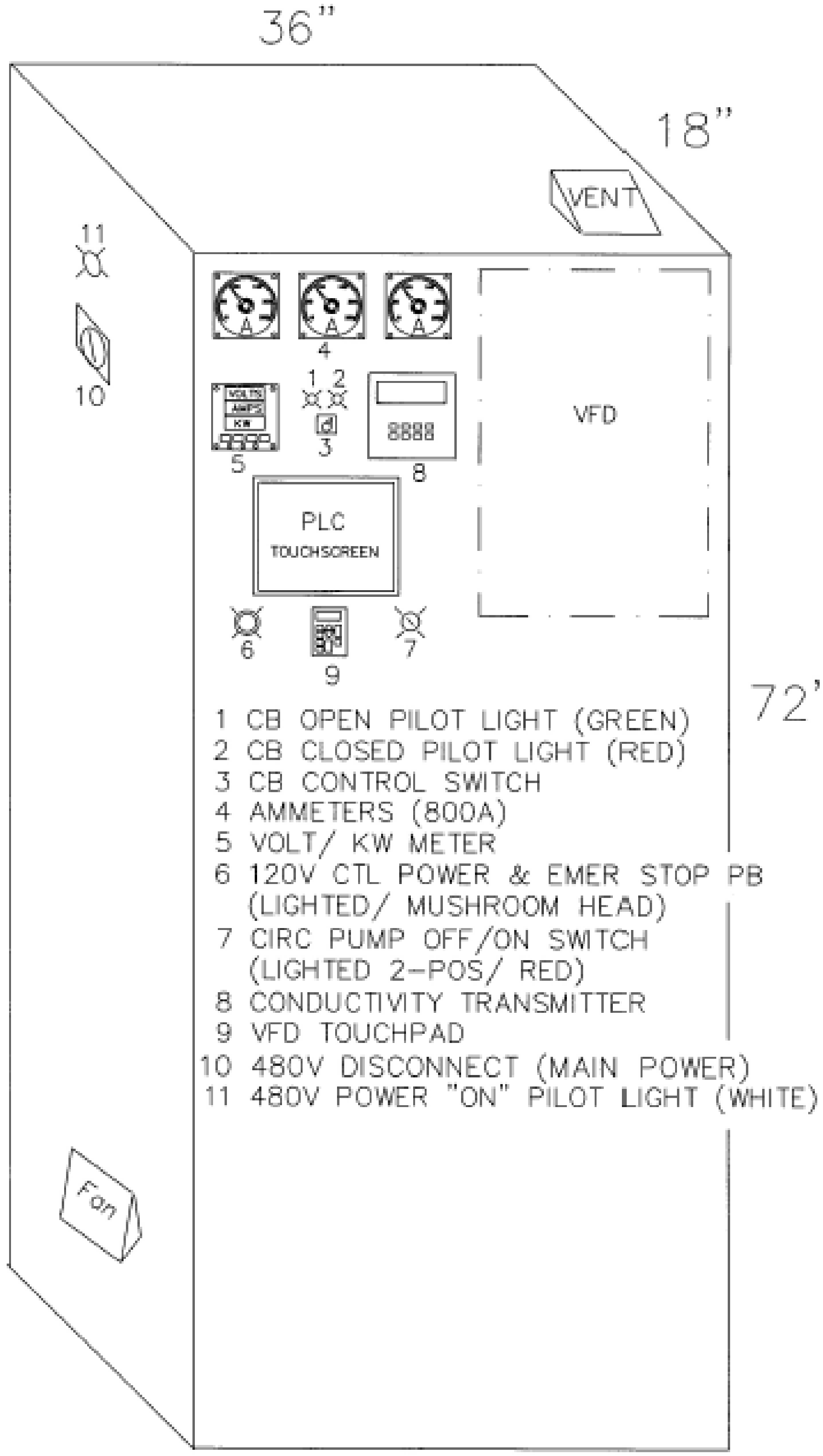
4.1.1.2.2 Switch on the 480VAC ‘CONTROL POWER’ at the control panel. The ‘480VAC On’ (amber) light should illuminate.

4.1.1.2.3 Switch on the ‘120VAC’ power at the control panel. The audible alarm (if provided) should sound and the following should light:

(Refer to *Control Panel,* ***Figure 7****.)*

- 120VAC ‘CONTROL POWER’ Lighted Switch
- High Voltage Switchgear ‘Open’ Pilot Light
- Touch screen Panel (HMI)
- Conductivity Control

Figure 7 CONTROL PANEL



4.1.1.2.4 Silence the audible alarm by pushing the 'alarm silence' button. (HMI)
4.1.1.2.5 Attempt to reset the alarms by depressing the 'reset' button on the HMI. All alarm points should reset except low water.
4.1.1.2.6 Circulation Pump
4.1.1.2.6.1 Check that the pump turns freely by hand and that the gland cooling water is turned sufficiently on (approx 1.5 gpm).

NOTE: The pump will not operate unless at least 0.5 gpm of cooling water is flowing. Cooling water discharge temperate should be approx. 110°F.

4.1.1.2.6.2 Select the 'HAND' mode at the VFD unit and decrease output (speed) to 0.
4.1.1.2.6.3 Switch the 'CIRCULATION PUMP' pilot switch to 'ON/AUTO' – the red 'PUMP ON' pilot light should not light (the high voltage switchgear must be closed for normal pump operation).
4.1.1.2.6 4 Enable the password protected 'SWITCHGEAR INTERLOCK OVERRIDE' by pressing the 'CIRCULATION PUMP' button (HMI) and pressing the 'SWITCHGEAR BYPASS' (HMI). Enter the code and press enter – the red 'PUMP ON' symbol should light on the touchscreen.
4.1.1.2.6.5 If not previously done, check proper rotation of the circulation pump. From the VFD unit, barely increase output (speed) to check for correct pump rotation.

CAUTION: Reverse rotation could cause impeller to unscrew and jam against the pump casing with possible motor damage resulting.

4.1.1.3 Water Flow Check & VFD Characterization
4.1.1.3.1 Remove boiler top cover.
4.1.1.3.2 Using the VFD hand / auto station and with the switchgear interlock in the 'BYPASS' position observe, from the top of the boiler, the water flow at various pump speeds through the 'windows' in the nozzle header extension. The water jets should be a solid stream with minimal spray, and should impinge the strike plates in the middle (+ 1/2"). If the jet streams are more than 1/2" off center, the electrode must be adjusted circumferentially at its attachment to the coupling nut.
4.1.1.3.3 Characterize the VFD's by establishing the no-flow speed for pump operation. The full flow operation is when water just reaches the top nozzle.

NOTE: Refer to the VFD Operation and Maintenance Manual, Vendor Supplied Material, Appendix C, on how to characterize.

4.1.1.3.4 Replace boiler top cover (with gasket) and tighten bolts.
4.1.1.4 Standby Heater

4.1.1.4.1 The standby heater pressure control (HMI) should be set at 50 psi with a differential setting of approximately 10 psi.
4.1.1.4.2 Depress the standby heater 'ON' button (HMI). The standby heater symbol should light (red).

NOTE: The standby heater 'red' symbol will not light if either the boiler pressure is above the standby heater set point or the low water alarm is not reset.

4.1.1.5 Pneumatic Checks
4.1.1.5.1 Check that operating air is available at the boiler feedwater control valve and adjust the air set to a pressure of 35 psi.
4.1.1.5.2 Check that operating air is available at the boiler back-pressure control valve and adjust the operating air to 35 psi.

NOTE: Refer to the appropriate Operation and Maintenance Manual, Vendor Supplied Material, Appendix C, if the valve controls malfunction or require adjustment.

4.1.1.6 Conductivity Control System
The Conductivity control menu is accessed by pressing the Conductivity display button (HMI), then pressing the 'ON' button (HMI).
Refer to the Conductivity Analyzer Operation and Maintenance Manual, *Vendor Supplied Material,* ***Appendix C****, for information on the conductivity control used relative to adjustment and calibration procedures.*
4.1.1.6.1 Check the alarm point settings by accessing the menus in the conductivity controller. The high alarm set point is factory set at 2000 umho. Above the high set point, the Blowdown solenoid valve should be energized. Below the low set point, the electrolyte feed circuit should be energized.
4.1.1.6.2 Select the 'AUTO' mode for the 'SURFACE BLOWOFF' function (HMI). The red light (on the Surface Blowoff Valve symbol) should not illuminate since the conductivity is well below the factory preset limit.
4.1.1.6.3 Select the 'HAND' mode for the 'SURFACE BLOWOFF' function (HMI). The red light (on the Surface Blowoff Valve symbol) should illuminate and the solenoid valve at the boiler should energize.
4.1.1.6.4 Select the 'AUTO' mode for the 'ELECTROLYTE FEED PUMP' function (HMI). The red light (on the Electrolyte Feed Pump symbol) should illuminate and the pump will turn on if power is available to the electrolyte feed system, since conductivity is well below the preset level.
4.1.1.7 Historic Data Acquisition
From the HMI 'HOME' screen, touch the 'HISTORY' button. The history can be viewed for all listed parameters for the past several weeks by using the arrow keys to scroll.
4.1.1.8 Water Level Switches
4.1.1.8.1 With the boiler empty, depress the 'HIGH WATER' 'RESET' button (HMI). The 'HIGH WATER' alarm should clear.
4.1.1.8.2 Depress the 'LOW WATER' 'RESET' button (HMI). The 'LOW WATER' alarm should clear.

4.1.1.8.3 Manually fill the boiler to normal water level (center of the sight gauge).
4.1.1.8.4 Depress the 'LOW WATER' 'RESET' button (HMI). The 'LOW WATER' alarm should clear.
4.1.1.8.5 Manually fill the boiler above normal water level. The 'HIGH WATER' should alarm when the water level reaches the set limit.
4.1.1.8.6 Manually blow down the boiler below the normal water level – 'LOW WATER' should alarm when the water level reaches the set limit.

4.1.1.9 Conductivity Cell

Check that the (2) conductivity cell flow valves are open. The globe type flow valve on the discharge should be opened one turn only to maintain positive pressure on the cell to preclude the cell from becoming vapor-locked.

4.1.1.10 Pressure Settings

4.1.1.10.1 Pressure Limit Cutout – Manual Reset (located on control manifold near the pressure gauge). This switch is normally set to trip the circuit breaker at a pressure 5% less than the lowest safety valve set pressure. This switch has a button located on the top of the switch.

4.1.1.10.2 Pressure Limit – Auto Reset (located on the control manifold near the pressure gauge). Set the pressure limit at approximately 10% below the lowest safety valve set pressure.

4.1.1.10.3 Standby Heater

The standby heater is set via the HMI. Pressing the Standby Heater symbol will pop up a set point menu. This pressure is normally set at 50 psi (+ 5 psi).

4.1.1.11 Kilowatt & Pressure Control

The HMI touch screen accesses all set points, PID parameters, and automatic / manual functions. The back-pressure control valve is controlled by the lower output signal (low select) of the boiler pressure and kilowatt limit. The circulation pump is controlled by the boiler pressure.

4.1.1.11.1 Back-pressure Control Valve

Pressing the Back-pressure Control Valve (BCV) symbol on the HMI will pop up a screen that contains both the boiler pressure and MW limit set points. Pressing the set point display box will pop up a keypad or pressing the arrows will increase or decrease the set points incrementally. PID settings are password protected and can be changed by pressing the 'PID' button. Pressing the 'AUTO / MANUAL' button will cycle the control of each loop from AUTO to MANUAL. Pressing the 'OFF' BUTTON will stop all output.

4.1.1.11.2 Circulation Pump Control

Pressing the Circulation Pump symbol (CP) on the HMI will pop up a screen that allows the set point to be changed. Pressing the set point display box will pop up a keypad or pressing the up / down arrow keys will allow the set point to be changed. PID settings are password protected and can be changed by pressing the 'PID' button. Pressing the 'AUTO / MANUAL' button will cycle the control of each loop from AUTO to MANUAL. Pressing the 'OFF' button will stop all output.

4.1.1.12 Cleaning Boiler Interior

Prior to start-up, the boiler interior should be thoroughly cleaned to remove oil, mill scale and other construction and installation contaminants. A commercial boiler 'Boil Out' compound should be used, per their procedure, with the boiler completely flooded. In lieu of a commercial boil out compound, the following mix of chemicals can be used for every 250 gallons of water:

- 30 lbs. tri-sodium phosphate (Na_3PO_4)
- 5 lbs. caustic soda (NaOH)
- 2 lbs. ordinary detergent

These chemicals should be dissolved in warm water prior to their addition to the boiler. The boil out can be accomplished per the following procedure:

1) Remove all tools, rags, etc. from the boiler. Remove boiler top cover.

2) Fill boiler to just below the manhole with feedwater.

3) Add the chemical solution.

4) Close manhole.

5) Fill boiler until water level is at the top of electrodes (IE: below coupling nut).

6) Operate standby heater to raise temperature.

7) Upon achieving 210°F water temperature, operate circulation pump in manual mode, with speed at approximately 600 rpm, for about 5 minutes.

8) Allow boiler to boil for 3 hours minimum, 24 hours maximum.

9) Repeat instructions number 8.

10) Drain boiler.

11) Open manhole.

12) Rinse all walls and surfaces thoroughly with a garden hose.

4.1.2 Condensate Feedwater System
N/A (Supplied by others)

4.1.3 Feedwater Pumps
Refer to the appropriate manufacturer's O & M Manual provided in ***Appendix C***.

4.1.3.1 Make sure the pumps are flooded and that the orifice isolation valves are open.
4.1.3.2 Check that the pumps turn freely by hand and are properly aligned.
4.1.3.3 Make sure the pump control switches are in the 'OFF' position.
4.1.3.4 Close the 480v disconnect to the feedwater pump control panel.
4.1.3.5 'Bump' the feedwater pumps individually by briefly switching their pilot switches to 'HAND' – the red 'PUMP ON' pilot lights should light momentarily.
4.1.3.6 Correct the pump rotation if reverse.

4.1.4 Blowdown Tank

Pressure Check

4.1.4.1 Place blanking plates (pans) between the vent flanges and outlet (discharge) flanges.
4.1.4.2 Close blowdown tank quench and drain valves, and boiler blowdown valves.
4.1.4.3 Perform hydrostatic test at 75 psi on the entire system.

NOTE: Loosen the vent flange bolts to vent air from the tank.

4.1.4.4 Drain water from the tank and remove flange blanking plates (pans).

4.1.5 Electrolyte Feed System

4.1.5 1 Pressure Check

4.1.5.1.1 Close the ball valve upstream of the boiler quill.
4.1.5.1.2 Remove the pump discharge relief valve and use this connection for hydrostatic test connection.
4.1.5 1.3 Perform a hydrostatic test at 75 psi on the electrolyte feed discharge line. Use the ball valve at the boiler quill as a vent.
4.1.5.1.4 Drain discharge line and re-install relief valve.

4.1.6 Chemical Feed System

4.1.6.1 Pressure Check

4.1.6.1.1 Close the ball valve upstream of the boiler quill.
4.1.6.1.2 Remove the pump discharge relief valve and use this connection for hydrostatic test connection.
4.1.6.1.3 Perform a hydrostatic test at 75 psi on the chemical feed discharge line. Use the ball valve at the boiler quill as a vent.
4.1.6.1.4 Drain discharge line and re-install relief valve.

4.1.6.2 Electrical Checks

4.1.6.2.1 Make sure local control switches are in the 'OFF' position, and then switch 'ON' the 120VAC 'POWER SUPPLY' at the boiler control panel (HMI).
4.1.6.2.2 Check that the 120VAC is available at the chemical feed control panel.

4.2 Start-Up Procedure

4.2.1 Boiler

CAUTION: The possibilities of 'arcs' in the boiler can be minimized if the following points are heeded:

• Avoid sudden pressure drops.
• Do not allow water conductivity to exceed the value required for maximum boiler output by more than 10%.
• Do not add any chemicals to a shutdown boiler since water conductivity is also a function of temperature.

• Be sure boiler is free of organic or other substances which could cause foaming inside the boiler

• Limit iron content in boiler water to less than the recommended maximum of 2.0 ppm.

4.2.1.1 Start-Up From a Hot Condition (NORMAL START-UP)

4.2.1.1.1 Check that both the air release and stream valve are fully closed, and that the cooling water to the pump stuffing box is sufficiently open.

4.2.1.1.2 To minimize the possibility of arcs, it is always best to start the boiler from the hot condition (50 psig or greater).

4.2.1.1.2.1 Standby Heater

It is best to start the boiler using the standby heater to bring the boiler up to 50 psi.

4.2.1.1.2.2 Existing Steam Source

It is possible to bring the boiler above 50 psi by bleeding steam in from another source while circulating the water with the high voltage switchgear open. This starting method, while being appreciably more rapid than the previous method, also requires more attention than when using the standby heater.

4.2.1.1.3 Upon attaining 50 psi boiler pressure, carefully open the air release valve until all of the entrapped air is blown out. (IE: until steam is present).

4.2.1.1.4 Set the kW limit (HMI) to the desired limit.

4.2.1.1.5 Check that the 'SWITCHGEAR INTERLOCK OVERRIDE' switch is in the 'NORMAL' position (HMI), and that the circulation pump pilot switch is 'OFF'.

4.2.1.1.6 Close the high voltage switchgear using the CB control switch.

4.2.1.1.7 Select the 'manual' mode at the pressure control (HMI) and set the output to 0%.

4.2.1.1.8 Switch the 'CIRCULATION PUMP' pilot switch 'ON' – the red 'POWER ON' should light and the pump should start.

NOTE: Pump cavitation is probable when there is rapid drop in the boiler pressure. For occurrence of cavitation from a rapid loss of boiler pressure, switch to "MANUAL" pressure control and decrease the output (pump speed) until flow (output) is re-established. Manually bring the boiler up to pressure and then switch to 'AUTO' operation.

4.2.1.1.9 Through manual speed control (HMI), attempt to bring the boiler up to the appropriate operating pressure.

NOTE: The boiler output at this time is wholly dependant on the conductivity of the boiler feedwater and could realistically be immeasurable.

NOTE: As a rule of thumb, in bringing the boiler up to operating pressure, manually adjust the output so that its percentage numerically equals or is slightly less than the boiler pressure.

4.2.1.1.10 If after 30 minutes, the boiler fails to reach normal operating pressure, switch 'ON' the power supply to the electrolyte feed pump (HMI) and allow chemicals (NA_3PO_4 is recommended mixed at approximately 20 lbs. / 25 gal) to enter the boiler.

NOTE: If the chemical connection is in the feedwater line, manual blowdown may have to be effected to permit the entrance of feedwater into the boiler.

IMPORTANT: No foaming chemical may be added to the boiler for any reason! This includes Amines and ‘anti-foam’ chemicals.

4.2.1.1.11 When the boiler reaches normal operating pressure, switch the pressure control to the ‘AUTO’ mode (HMI) and gradually open the steam outlet valve.

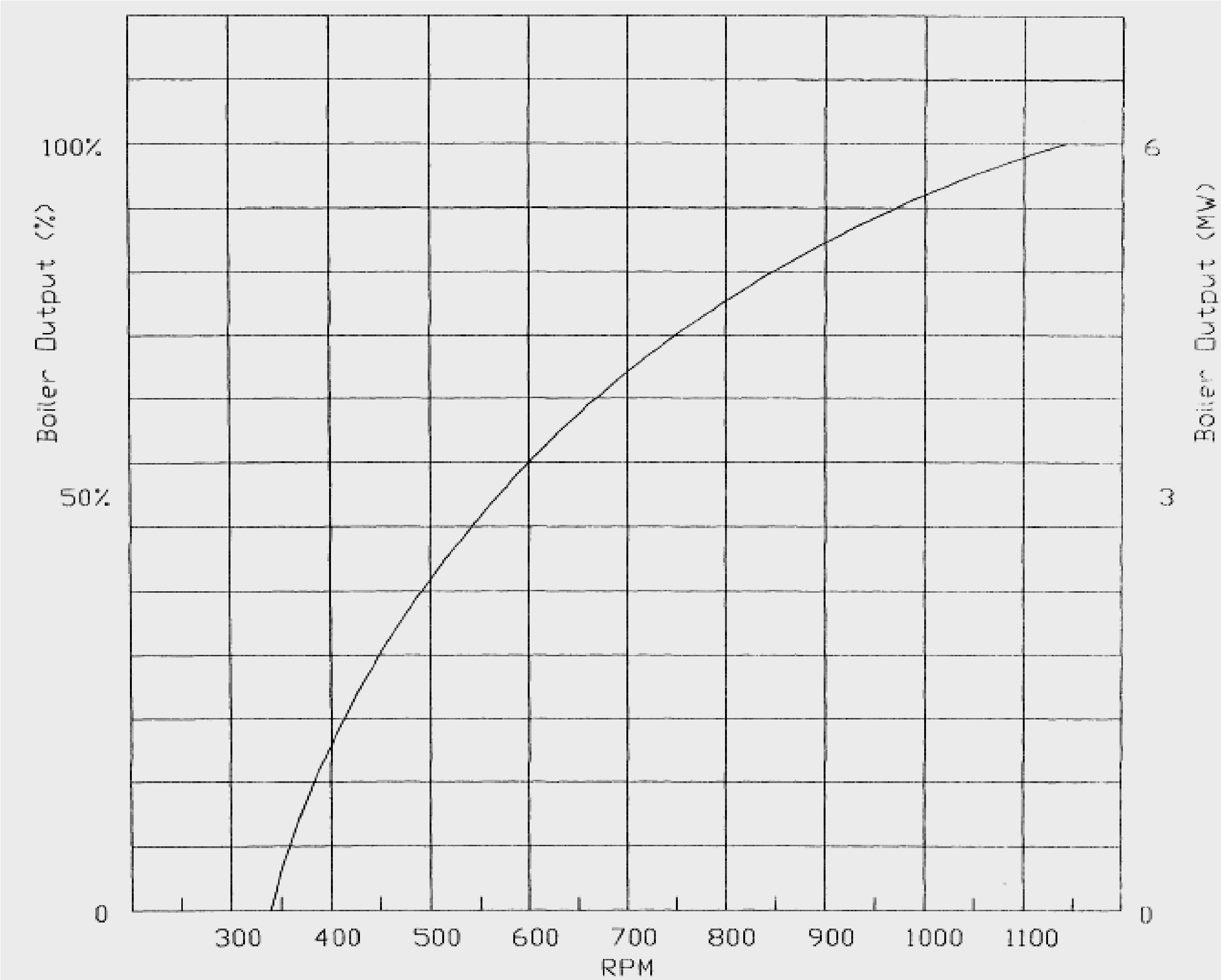
NOTE: It is preferred to slightly exceed the operating set pressure before switching to the ‘AUTO’ mode to permit a bumpless transfer.

4.2.1.1.12 With the pump at maximum flow speed, full rated boiler output should be attained. ***NOTE***: The conductivity control is factory set at approximately the correct value for the rated boiler output. Although the control has automatic temperature compensation, the control may have to be calibrated to correct for actual water composition. A portable conductivity sensor should be used for a periodic ‘bench test’ to assure proper calibration of the conductivity control. Refer to HVJ Characteristic Curve, **Figure 8**, for the approximate pump characteristic curve to aid in properly setting the conductivity control for boiler operation at less than full output. Refer to the conductivity controller Operation and Maintenance Manual, Vendor Supplied Material, **Appendix C**, if the conductivity control requires further adjustment.

4.2.1.2 Start-Up from a Cold Condition (EMERGENCY START-UP)

NOTE: This procedure is not recommended except in an emergency requiring a quick start-up.
4.2.1.2.1 Close all valves leading to and from the boiler.
4.2.1.2.2 Check that the cooling water to the pump stuffing box is sufficiently open.
4.2.1.2.3 Open the air release to assure no vacuum, and then re-close.
4.2.1.2.4 If boiler is empty, fill the boiler to normal water level – this should raise the boiler pressure to 10 – 15 psig.
4.2.1.2.5 Close the high voltage switchgear.
4.2.1.2.6 Decrease the output to the VFD using the ‘MANUAL” mode at the HMI.
4.2.1.2.7 Start the circulation pump (HMI).
IMPORTANT: In bringing the boiler up to pressure from a cold state, the pump speed should never exceed 20% of its no-flow speed until the boiler pressure is observed to increase and the air is released from the boiler.
4.2.1.2.8 When the boiler has risen to approximately 50 psi, bleed the entrapped air off through the air release.
4.2.1.2.9 Proceed per ***Sections 4.2.1.1.4 – 4.2.1.1.12***.

Figure 8: Typical HVJ Characteristic Curve for a 6 MW Rated Boiler



4.2.2 Feedwater Pumps (if installed with the system)

4.2.2.1 Before starting pumps, rotate several revolutions by hand to get oil on bearings.

4.2.2.2 If not previously done, check pump rotation.

4.2.2.3 Switch on each pump using the 'HAND' position of the 'FEEDPUMP #1' and'FEEDPUMP #2' control switches (HMI). Observe that the pumps come up to speed smoothly and, with the bypass relief valve or orifice isolation valve closed, achieve no-flow discharge pressure. The no-flow discharge pressure should be noted to verify the pump performance curve.

CAUTION: Do not operate the pumps in no-flow condition for more than 2 minutes to avoid overheating.

4.2.2.4 Open bypass isolation valves and observe pressure drops to a point on the curve providing the necessary minimum pump flow per the pump specifications. If relief valves are provided, adjust accordingly.

NOTE: Refer to the appropriate relief valve Operation and Maintenance Manual, *Vendor Supplied Material,* ***Appendix D*** *for adjustment instructions*.

4.2.3 Blowdown Tank

4.2.3.1 Using the quench valve, fill tank to point of overflow (level with bottom of discharge pipe).

4.2.3.2 Small Automatic Discharges

Normal drip trap discharges and boiler surface blowdowns do not require manual attention.

4.2.3.3 Large Manual Discharges

To accommodate boiler bottom blowdown operation, the quench valve on the blowdown tank must be opened prior to the blowdown operation, and then closed after the blowdown is complete. If the quench valve is automatic, make sure the stop valve is in the open position.

4.2.4 Electrolyte Feed System (IF supplied)

CAUTION: Be sure pump gear box is properly filled with hydraulic fluid. Refer to the appropriate Operation and Maintenance Manual, *Vendor Supplied Material,* ***Appendix C***.

4.2.4.1 Using the glove valve on the water supply line, fill tank with water.

4.2.4.2 Check manual operation of the agitator by placing the H-O-A switch (HMI) in the 'HAND' position. Return H-O-A switch to the 'OFF' position.

4.2.4.3 Check timer operation of the agitator by turning the timer knob (local panel) clockwise. Return timer knob to the 'OFF' (CCW) position.

4.2.4.4 Check automatic operation of the agitator by placing the H-O-A switch (HMI) in the 'AUTO' position and properly adjusting the interval timer.

4.2.4.5 Open both ball valves on pump discharge and the valve on the pump suction.

4.2.4.6 Make certain the pumping chamber is flooded by loosening the discharge valve cap approximately 2 to 3 turns, allowing solution to appear. Tighten discharge valve cap. This procedure will also allow air to vent from pumping chamber. The 'DIA-PUMP' will not function if air is trapped in the hydraulic fluid or liquid pump chambers.

4.2.4.7 Set the capacity control knob to approximately 30 – 40% of maximum capacity.

4.2.4.8 On initial start-ups: Switch the H-O-A switch (HMI) to 'HAND' and run the pump for 10-20 seconds, then stop for 20 – 30 seconds. Repeat a few times. During these short runs, listen for any abnormal motor or crank noises. If present, refer to the appropriate Operation and Maintenance Manual, *Vendor Supplied Material,* ***Appendix C****.*

4.2.4.9 Run pump for 1/2 to 1–1/2 hours to warm up oil. Check discharge line for indication of flow.

4.2.4.10 Once discharge flow is observed, proceed to next step. If no flow, repeat steps in Sections 4.2.4.8 – 4.2.4.9 until discharge flow is achieved.

4.2.4.11 Increase capacity adjustment setting to 70% of maximum capacity and operate for 10 – 20 minutes.

4.2.4.12 Reduce capacity adjustment setting to 30 – 40% of maximum capacity and operate for several minutes, then increase capacity adjustment back to 100% for approximately 10 minutes. Repeat several times to insure that the air is bled from both the hydraulic fluid and liquid sides.

4.2.4.13 Drain the tank and refill with properly mixed water treatment solution.

4.2.5 Chemical Feed System Perform the same procedure as for the Electrolyte Feed System (Sections 4.2.4.1 – 4.2.4.13).

4.3 Shut-Down Procedure

4.3.1 Normal Shut-Down

4.3.1.1 Reduce the steam demand to 0, by gradually closing the steam outlet back-pressure control valve (HMI).
4.3.1.2 Switch off the circulation pump.
4.3.1.3 Open the high voltage switchgear.
4.3.1.4 Close the feedwater stop valve.
4.3.1.5 Switch off both the chemical and boiler feed pumps (HMI).
4.3.1.6 If the boiler is to be down for several days or is to be drained, the standby heater power should also be switched off, as well as the control power (120VAC and 480VAC).

4.3.2 Emergency Shut-Down

4.3.2.1 Trip the high voltage switchgear via either the switchgear control switch or the 'EMERGENCY STOP' pushbutton. This also de-energizes the circulation pump.
4.3.2.1 Close the steam header stop valve.
4.3.2.2 Proceed per *Sections 4.3.1.2 – 4.3.1.6 as required.*

4.3.3 Moth Ball Procedure

(When boiler is taken out of service for a lengthy period of time.)
4.3.3.1 Close steam stop and header gate valves; open 1" header vent valve.
4.3.3.2 Blowdown boiler under pressure to remove sludge.
4.3.3.3 Drain boiler completely, including water column and conductivity cell.
4.3.3.4 Remove manhole cover.
4.3.3.5 Rinse boiler to further aid in sludge removal.
4.3.3.6 Assure good ventilation of the boiler interior and that steam or condensate does not leak into the boiler. To insure that vessel interior remains dry, place a small heat source inside the boiler to slightly elevate the internal temperature.

RETORQUE FLANGE BOLTS – After the initial boiler start-up and with the boiler start-up and with the boiler including the top cover bolts, should be retorqued.

5.0 BOILER WATER

5.1 Properties of Feedwater

Municipal water used for feeding boilers is never pure. It contains various impurities detrimental to operation, and therefore, must be treated before being introduced to the boiler. By far the greatest proportion of these impurities consists of inorganic combinations in solutions: calcium, magnesium and sodium salts. Also present at times are organic impurities.

The salts form scale in the boiler; organic matter causes foaming which could short the electrodes.

Generally, hard water is classified as that which contains large quantities of calcium and magnesium salts in solution; soft water is that which contains none of these salts, but can contain sodium salts which are not detrimental to the boiler operation. However, if excessive amounts of sodium salts enter the boiler they will cause frequent blowdowns resulting in decreased boiler efficiency.

5.2 Feedwater Treatment

Refer to *Recommended Feedwater & Boiler Water Properties, **Table 1***.

In most instances it is recommended that the makeup water be softened, using a zeolite softener. In this system, usually referred to as the 'sodium-cycle base exchange', the calcium, magnesium, and iron ions are exchanged for sodium ions, thus eliminating 99.9% of the hardness. In most instances, it is also recommended that a deaerator be used which will eliminate most of the oxygen and carbon dioxide and thus minimize system corrosion. If iron in the condensate becomes a problem, re-evaluate the water treatment program as this indicates system corrosion and is detrimental to the boiler operation. The addition of sodium sulfite directly to the boiler is recommended to eliminate any free oxygen from being in the boiler water. A sulfite residual of at least 20 ppm should be maintained in the boiler at all times.

IMPORTANT: We recommend that **only** the (3) following generic chemicals be added directly to the boiler as needed: **Caustic (NaOH); Sodium-Sulfite; Tri-Sodium- Phosphate**. Amines should be added to the steam header.

Table 1: Recommended Feedwater & Boiler Water Properties

FEEDWATER						
TYPE OF BOILER	Hardness (ppm)	pH	Alkalinity (ppm-total)	Fe + Cu* (ppm)	Oxygen (cc/l)	Conductivity (pmho)
RESISTANCE -						
Hot Water	0-10	7.5-9.5	25-400	0-5	4	0-600
Steam	0-5	7.5-9	1-50	0-1	0.03	0-500
ELECTRODE STEAM -						
High Voltage @ 6.9KV	0-2	7.5-9	1-50	0-1	0.005	0-300
High Voltage @ 13.2 KV	0-2	7.5-9	1-50	0-1	0.005	0-250
High Voltage @ 22.5 KV	0-2	7.5-9	1-50	0-1	0.005	0-200

BOILER WATER						
TYPE OF BOILER	Hardness (ppm)	pH	Alkalinity (ppm-total)	Fe + Cu* (ppm)	Oxygen (cc/l)	Conductivity (pmho)
RESISTANCE -						
Hot Water	0-10	7.5-9.5#	25-600	0-50	0	0-6000
Steam	0	7.5-9.5#	25-600	0-20	0 ##	0-4500
ELECTRODE STEAM -						
High Voltage @ 6.9KV	0	7.5-10.5	100-350	0-15	0 ##	500-2600
High Voltage @ 13.2KV	0	7.5-10.5	100-350	0-10	0 ##	500-2400
High Voltage @ 22.5 KV	0	7.5-10.5	100-350	0-7	0 ##	500-2000

* Total Iron (ie, $FE+FE_2O_3+FE_3O_4$) plus total Copper (ie, Cu+CuO)

\# This limit should be reduced to 9 ½ max if copper elements are used

\## If hydrazine is used to scavenge oxygen, the maximum hydrazine residual recommended is 0.2 ppm unless boiler is "bronze free"

Any additional concern in regard to the boiler feedwater is alkalinity control. Alkalinity control, or more specifically the amount of hydroxide present (usually indicated by the pH reading), is important because too little alkalinity concentration may result in corrosion or the formation of objectionable sludge or scale; whereas too high a level of alkalinity may result in foaming and deterioration of the insulators.

In a system with 100% makeup, a complete water analysis is definitely recommended to ensure that proper treatment of the boiler feedwater is administered. We suggest that a qualified water treatment firm be consulted for recommendations regarding your particular application. Such organizations as Bets, Calgon, Culligan, Dearborn, or Mogul can assist you in this matter. We do, however, caution against over-feeding chemicals and so not recommend the use of chelants. If hydrazine is used for oxygen scavenging, the residual level should be kept below 0.2 ppm to minimize corrosion to any bronze used in the boiler. This level can be raised to 1.0 ppm if the boiler is supplied ‘bronze free”. In all cases, magnetite (Fe_3O_4) should be avoided since it will cause rapid erosion of nozzles and electrode strike plates.

5.3 Water Conductivity

5.3.1 Adjustments

The conductivity of the boiler water is the prime determinant of boiler output and is controlled by the conductivity control by either signaling for automatic blowdown or electrolyte feed. The conductivity control should be so adjusted that the rated boiler output is attained with the pump at full flow speed. Refer to the appropriate Operation and Maintenance Manual, *Vendor Supplied Material,* ***Appendix C*** for the method of adjustment.

5.3.2 Conductivity Range

The typical conductivity range is from 700 umho to 2200 umho. See Table 1 above for details

CAUTION: Do not exceed the rated maximum conductivity of 3000 umho at any time!

5.3.3 Low-Output Operation
If the boiler is to be operated at partial load for any length of time, the water conductivity should be decreased so as to effect greater water flow to the electrodes and, thus, to provide for better load control and lower carryover. Operation at a lower conductivity will also lessen the erosion of both the jet nozzles and electrodes.

5.4 Electrolyte Feed
Both a shot feeder and an automatic electrolyte feed system are supplied for increasing the water conductivity. The shot feeder is used for initial boiler startup to quickly increase the water conductivity. The automatic system is used for conductivity maintenance when the condensate return is greater 90%, or where the feedwater has a very low conductivity (less than 50 umho). For the electrolyte, a solution of tri-sodium phosphate (Na_3PO_4) is recommended because it is basic, forms a soft sludge, and has a relatively stable conductivity throughout the operating temperature range of the boiler.

NOTE: Approximately 1/2 lb. of Na_3PO_4 will raise the boiler water conductivity 1000 umho per 100 gallons.

For conductivity maintenance, a mixture of caustic, sodium sulfite, and tri-sodium phosphate is used depending on actual water conditions. In any event, it is recommended that a small amount of sodium sulfite be continually fed to the boiler to establish a sulfite residual of at least 20 ppm for oxygen scavenging.

5.5 Blowoff
5.5.1 Automatic Blowoff
All PRESCISION Model HVJ Boilers are supplied with an automatic surface blowdown, in conjunction with the conductivity control, to limit the boiler conductivity to the desired maximum level.
5.5.2 Response Adjustment
Overall response of the blowdown system is controlled by a cycle timer within the conductivity control by increasing or decreasing the ‘in process’ portion of the blowdown cycle.

6.0 ROUTINE MAINTENANCE

6.1 Boiler
6.1.1 Manual Blowdown
6.1.1.1 Bottom Blowdown
The boiler should be subjected to a periodic short manual bottom blowdown depending on system requirements. A daily blowdown is highly recommended to remove any sludge that may have formed.
6.1.1.2 Surface Blowoff
It is essential to skim off the water surface at least once a month because the jet-type boiler does not form steam beneath the water surface and thus does not have carryover from the water surface, and because foaming on the water surface could create arcing from the bottom

of the electrodes. With the circulating pump off and the feedwater stop valve closed, manually perform a surface blowoff until the water level is below the level of the surface blowoff tapping.

6.1.2 Automatic Blowoff

The strainer of the automatic blowoff should be periodically cleaned depending on system requirements. This cleaning should be carried out at least weekly.

6.1.3 Water Column

Both water column and sight gauge should undergo a brief daily blowdown.

6.1.4 Conductivity Chamber

The conductivity chamber should be blown down weekly. Turn off conductivity control. Shut off inlet flow valve to perform this blowdown to cause a 'back flush' of the conductivity cell.

6.1.5 Conductivity Cell

The conductivity cell should be removed and inspected at least bi-monthly (or as experience dictates). Refer to the appropriate Operation and Maintenance Manual, *Vendor Supplied Material – **Appendix C**,* for inspection procedures.

6.1.6 Valve Actuators

Bi-monthly visual checks should be made to assure proper stroking of the control valves.

6.1.7 Feedwater Strainer

The feedwater strainer should be cleaned periodically depending on feedwater contamination. This should be performed at least monthly.

6.1.8 Conductor Rod Insulators / Gaskets

Refer to the *Conductor Rod Assembly Installation, **Figure 3**.*

6.1.8.1 Gasket Deterioration

The sealing gaskets between the inner insulator and both the tank mounting bushing and the coupling nut deteriorate over a period of time. The PRECISION Electrode Boiler is provided with steam 'tell-tale' vents, which indicate when the gaskets need replacing. Leaking steam is channeled to these vents from collecting grooves located on the sealing surfaces.

6.1.8.2 Gasket Replacement

All steam vents should be checked daily for evidence of gasket deterioration. Upon noticing leaking steam, a boiler overhaul should be scheduled within a week to replace the sealing gaskets and to examine the insulators for deterioration.

NOTE: The sealing gaskets are made of a special conductive gasket material in order to obtain uniform voltage across the entire insulator face. Failure to replace these gaskets can allow steam leakage into the interior of the insulator and cause flashover, which will destroy the thru insulator. During gasket replacement, make sure that all steam leakage passages are clean and clear of obstruction.

6.1.8.3 Insulators
Insulators returned to service should be free of scale and dirt. To clean insulators, use hot soapy water and a soft brush. The shorting springs are provided to eliminate static discharges and should be thoroughly cleaned.

6.1.9 Back Pressure Regulator
The packing gland of the back-pressure regulator should be subjected to periodic inspection, tightening, and repacking. If the regulator is self-contained with a piston operator, the operator should also undergo periodic checks to assure it is free of dirt and operates smoothly.

6.1.10 Nozzles
6.1.10.1 Blockage
The nozzles should be inspected annually or more often if it is found that the water conductivity has to be gradually increased over the months of service to attain full rated output. In this occurrence, the boiler will eventually have to be shut down for nozzle cleaning. A 1" reamer can be used to loosen hardened deposits on the nozzle ID. A stiff wire brush should be used to remove the remaining contamination from within the nozzles.

6.1.10.2 Flow Check
After each boiler overhaul, perform a water flow check per Section 4.1.1.3.

6.1.11 Safety Valves
The safety valves should be periodically checked per local code requirements.

6.2 Condensate Feedwater System
Refer to the appropriate Operation and Maintenance Manual, *Vendor Supplied Material,* ***Appendix C****,* for required pump maintenance, motor lubrication, and mechanical seal maintenance.

6.3 Circulating Pumps
Refer to the appropriate Operation and Maintenance Manual, *Vendor Supplied Material,* ***Appendix C****,* for required pump maintenance, motor lubrication, and mechanical seal maintenance.

6.4 Feedwater Pumps
Precision Boilers

6.5 Chemical Feed Pumps
Refer to the appropriate Operation and Refer to the appropriate Operation and *Material,* ***Appendix C****,* for required pump maintenance.