FINAL

TECHNICAL MEMORANDUM – POWER GENERATION STATION RELIABILITY IMPROVEMENTS EVALUATION

SD-413 PGS Reliability Improvements Phase 3

EBMUD PROJECT SD-413

BV PROJECT NO. 405542

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PREPARED FOR

East Bay Municipal Utility District

DECEMBER 17, 2020

BLACK & VEATCH

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1.0 Purpose

The East Bay Municipal Utility District (EBMUD) Main Wastewater Treatment Plant (MWWTP) is located in Oakland, California. In May 2020, EBMUD entered into an agreement with Black & Veatch (B&V) to prepare a Power Generation Station (PGS) Reliability Improvements Evaluation Technical Memorandum (SD-413). This project was undertaken to improve the power generation station's reliability and provide recommendations for the design of facility improvements.

This Technical Memorandum (TM) will evaluate risks and budget costs for reliability improvements determined for power generation equipment and associated support systems, including those associated with the digester gas, heat recovery, and cooling systems. From this information EBMUD can select PGS improvements based on risk and cost that fit within their available budget and can be included in the design phase of the project.

In addition, an evaluation will be performed that will look at alternatives to eliminate the use of plant effluent as cooling water for PGS1 and PGS2.

A separate technical memorandum has been prepared that provides recommendations for the low-pressure gas holder (LPGH).

2.0 Background

The Power Generation Station (PGS) at the MWWTP is comprised of PGS1, engine-generator system and PGS2, turbine generator system. In 2018 a reliability and assessment study identified the PGS as a critical facility required for emergency preparedness and in need of various improvements.

PGS1 was installed in 1986, and consists of three, 2.1 megawatt (MW) reciprocating internal combustion engine-generators; three, 2-stage reciprocating gas compressors; two waste heat exchangers; a plant effluent water cooling system; a diesel fuel system; a lube oil system; and a compressed air system. PGS1 was modified in 1993 and 2005. The diesel fuel storage capacity was increased, radiators were added to cool at least one engine-generator in the event plant effluent water was interrupted, cooling loop heat exchangers and pumps, and a boiler were added.

PGS2 was installed in 2012 and consists of one 4.6 MW turbine generator, a gas conditioning skid, a gas compressor skid, cooling loop heat exchangers and pumps, and an effluent water cooling system for the turbine oil and compressor.

The engine-generator units use digester gas and diesel fuel for fuel and the turbine generator uses digester gas as fuel. The electrical energy produced from these units is utilized within the facility. Typically, two engine-generator units operate at one time with one unit held in reserve as a standby maintenance unit. The turbine generator is generally in operation at all times. Any modifications to the digester gas and plant effluent cooling system assumes all three units are in operation.

Two high capacity flares, to burn excess digester gas, have been recently installed. These flares have a total capacity of 3,000 scfm. Four existing low capacity flares also have the capability to burn excess digester gas and have a total capacity of 2,200 scfm.

This evaluation includes a review of the following specific items;

- Cooling water evaluation – this system has been identified as requiring upgrade to provide full capacity of the PGS at all times and has been specifically reviewed herein.
- Equipment associated with the overall PGS

Cost and project prioritization is also provided in this technical memorandum.

3.0 Cooling Water Evaluation

The first step in assessing the Cooling Water System (CWS) is to gain a thorough understanding of the existing system, including the original design criteria, modifications to the system, operational intent, and the actual operation and performance. Data provided by EBMUD for the CWS was reviewed in detail to gain an understanding of the original system's design and operation.

Currently, the CWS operates using three different cooling loops: the engine cooling loop, the intercooler cooling loop, and the turbine cooling loop. Each of these cooling loops are cooled by pumping plant effluent (3W) to interface heat exchangers. Radiators were installed in the engine and intercooler loop to allow at least one engine-generator to operate during times when plant effluent was not available. During this time the turbine generator cannot be operated.

The CWS is being assessed to determine ways to eliminate the use of plant effluent as the means of cooling. Portions of the existing CWS have been in service since PGS1 was installed and are at the end of their operation life. The existing system as well as alternate cooling options which do not rely on plant effluent as the source of cooling will be evaluated.

3.1 EXISTING SYSTEM DESCRIPTION

The existing 3W system cools the engine cooling loop, intercooler cooling loop, and the turbine cooling loop through redundant waste heat exchangers, PGS1 cooling loop heat exchangers, and PGS2 cooling loop heat exchangers. The water is pumped out of the effluent channel using, one set of three 60 horsepower (hp) pumps supplying water to the waste heat exchanger and the PGS1 cooling loop heat exchanger and another set of two 15 hp pumps supplying water to the PGS2 cooling loop heat exchanger. After going through the heat exchangers, the 3W is then sent back to the effluent channel.

3.1.1 Engine Cooling Loop

The engine cooling loop was designed and constructed as a part of project SD135 in 1986 and uses the cold side of the plant heating hot water (HHW) system to cool the engine lube oil and engine jacket water shell and tube heat exchangers. By cooling these, a maximum of 0.91 million British thermal units per hour (Btuh) and 3.10 million Btuh, respectively, is added to the HHW system. The HHW then goes through the engine exhaust heat recovery unit to gain an additional 3.92 million Btuh as needed. When no heat is needed in the HHW system all the heat produced by the engines is removed using a shell and tube waste heat exchanger having a design cooling capacity of 11.0 million Btuh by using 3W as the cooling medium. To be able to cool all three engines operating together, the cooling load will be 12.0 million Btuh and will be used for sizing cooling equipment for the cooling system evaluation.

In 1991 as a part of project SD189 a remote radiator with dedicated pumps was added to the engine cooling loop to provide a maximum of 12.4 million Btuh of cooling. This is enough for all three engines, when no heat is needed in the HHW system and no 3W is available. However, due to the size of the intercooler remote radiator installed at the same time only one engine can operate, when no 3W is available. In 2005, as a part of project SD 275, a boiler capable of providing a maximum of 16.7 million Btuh and two dedicated pumps were added to the HHW system at PGS1 to provide supplemental heat to the HHW system. In 2010, as a part of project SD317, a turbine exhaust heat recovery unit with its own dedicated pump was added to provide additional 13.25 million Btuh of heat to the HHW system.

3.1.2 Intercooler Cooling Loop

The intercooler cooling loop was designed and constructed as a part of project SD135 in 1986 and used 3W directly to cool the engines' intercoolers and the digester gas compressors' shell and tube intercoolers and aftercoolers. The heat load from each heat exchanger is 1.35 million Btuh, 0.2 million Btuh, and 0.13 million Btuh, respectively. Later the cooling loop was modified by the addition of two shell and tube cooling loop heat exchangers. Cooling was provided to the heat exchangers by a closed loop cooling water instead of using 3W directly. The new cooling loop heat exchangers were then cooled by 3W and are capable of cooling a maximum of 3.41 million Btuh. In 1991, as a part of project SD189, a remote radiator was added to the closed loop to provide a maximum of 2.6 million Btuh of cooling, enough for cooling one engine when 3W is not available. The cooling loop heat exchangers were later modified as a part of SD275 in 2005 by extending the length from 10 feet to 15 feet and increasing both the 3W and closed loop water flow rates for a new cooling rate of 5.12 million Btuh.

Each engine-generator and compressor require a minimum of 1.68 million Btuh of cooling. To operate all three engine-generators a total of 5.04 million Btuh of cooling will be required and will be used for sizing cooling equipment for the cooling system evaluation.

3.1.3 Turbine Cooling Loop

The turbine generator cooling loop was designed and constructed as a part of project SD317 in 2010 and uses closed loop cooling water to cool the turbine digester gas compressor and the turbine lube oil system. The closed loop water is then cooled by a shell and tube cooling loop heat exchanger using 3W and is capable of cooling a maximum of 4.11 million Btuh. This cooling load will be used for sizing cooling equipment for the cooling system evaluation.

3.1.4 Cooling Load Summary

Table 3-1 provides a summary of the cooling loads for sizing the new cooling system to replace the 3W cooling system.

Table 3-1 Cooling Load Summary

ITEM	NUMBER OF UNITS	COOLING LOADS, EACH, MILLION BTUH	TOTAL COOLING, MILLION BTUH
Engine Cooling Loop			
Engine Jacket Water Heat Exchanger	3	3.10	9.30
Lube Oil Cooler	3	0.91	2.73
Intercooler Cooling Loop			
Engine Intercooler	3	1.35	4.05
Compressor Intercooler	3	0.20	0.60
Compressor Aftercooler	3	0.13	0.39
Turbine Cooling Loop	1	4.11	4.11
Total Cooling Load			**21.18**

3.2 COOLING OPTIONS

Several options were evaluated for replacing the existing plant effluent cooling water system. Cooling towers, fluid coolers, adiabatic coolers, and radiators are the best candidates for replacing 3W and each have their pros and cons. The existing 3W system can also be rehabilitated and allow it to continue to operate as it currently does.

Below is a description of how each option works and how it will integrate into the existing system. In using any option that does not rely on plant effluent the existing engine cooling loop radiator and engine intercooler loop radiator will both become redundant and can be removed entirely. Design criteria for sizing the cooling water equipment is to provide a minimum cooling load of 21.18 million Btuh at a maximum supply temperature of 80 degrees Fahrenheit (F). A redundant unit will be provided for each cooling option.

3.2.1 Base Case – Status Quo

The existing CWS needs repairs to maintain the use of plant effluent and current operation of the system. The major equipment needing repair are the Waste Heat Exchanger and the Cooling Loop Heat Exchanger. To rehabilitate these heat exchangers the tube bundles, seals, and gaskets of each will need to be replaced. The buried 18 inch W3 pipe used to supply plant effluent water to PGS1 needs to be entirely replaced.

The disadvantage of repairing the existing CWS is the retained dependence on 3W from the effluent channel. This dependence on effluent flow limits the equipment that can operate during non-ideal operating conditions and in the worst case only allows for the guaranteed operation of a single engine-generator. At this time none of the pumps in the existing CWS are new and will also need to be repaired or replaced in the future. This future cost was not included in the cost analysis.

3.2.2 Option 1 - Cooling Towers

Cooling towers are a simple and effective design for cooling that has seen a wide variety of use across many industries. The implementation of cooling towers would keep the existing system largely the same, with the only change being that the 3W loop would be replaced with a closed loop system. Cooling towers operate by spraying recirculated water over a wet deck and drawing air over the wet deck cooling the water and causing the water to evaporate. As the water evaporates, the remaining water is cooled. Pumps would circulate the cooled water to the interface heat exchanger and back to the cooling tower.

This new cooling tower system would be comprised of three new pumps and three cooling towers in a two duty, one standby configuration. The main drawback of a cooling tower is that the water is exposed to open air and site conditions as it passes over the wet deck. Exposure to open air can introduce particulates and contaminants into the system meaning the cooling tower water cannot be used to cool the existing equipment directly, requiring the existing heat exchangers to remain. However, due to their age, the existing waste heat exchanger and the PGS1 cooling loop heat exchanger tubes will need to be replaced. Figure 1 shows a diagram of a cooling tower.

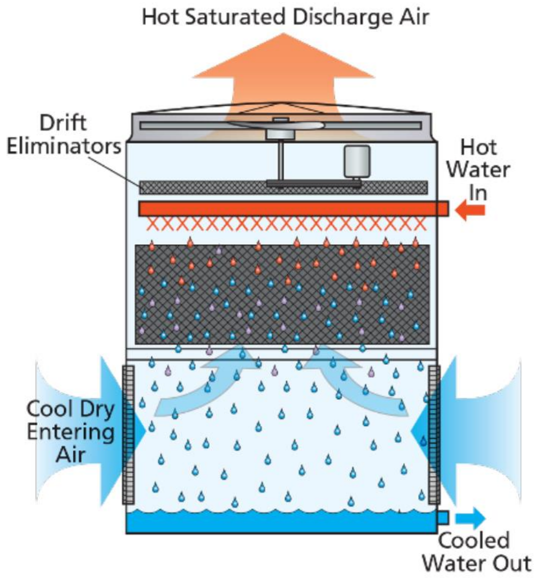

Figure 1 Cooling Tower Diagram (Figure by Evapco)

3.2.3 Option 2 - Fluid Coolers

Fluid coolers are more complex and more expensive than a traditional cooling tower but operate on a similar principal. A fluid cooler works by spraying water and drawing air over a cooling coil. Similar to the cooling tower, a small portion of the spray water will evaporate, however, unlike the cooling tower, the spray water is contained within the fluid cooler. The cooling water recirculates through the cooling coil in a closed loop and replaces the 3W cooling water going to the heat exchangers.

Since the cooling water in a fluid cooler is contained within a cooling coil, the water does not come into contact with open air. Therefore, the cooling water can directly circulate through the individual process heat exchangers. The waste heat exchangers, PGS1 cooling loop heat exchangers, and PGS2 cooling loop heat exchangers, can all be eliminated.

This new cooling system would be comprised of three new pumps and three fluid coolers in a two duty, one standby configuration. A drawback of removing the cooling heat exchanges when using the fluid cooler is that additional controls in the form of flow, pressure, and temperature instruments and control valves are required to guarantee operating conditions of existing equipment. Figure 2 shows a diagram of a fluid cooler.

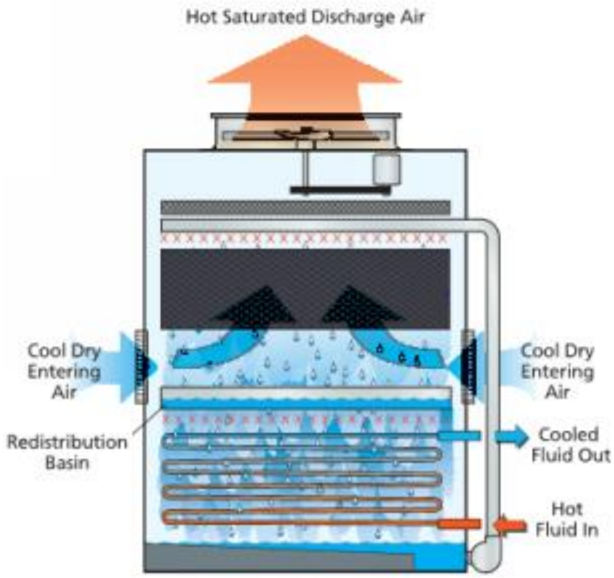

Figure 2 Fluid Cooler Diagram (Figure by Evapco)

3.2.4 Option 3 - Adiabatic Coolers

Adiabatic coolers are more complex and more expensive than a cooling tower but operate similarly to a fluid cooler. An adiabatic cooler works by wetting fibrous pads and drawing air through them and over a cooling coil. Like the fluid cooler, the spray water is contained within the adiabatic cooler. The water from the fibrous pad is evaporated into the air causing the air to cool and increase the efficiency of the cooling coil. The water passing through the cooling coil is the water that is used to replace the 3W cooling water.

Since the cooling water in an adiabatic cooler is contained within a cooling coil, the cooling water does not come into contact with open air. Therefore, similar to the fluid cooler, the cooling water can be directly circulated through the individual process heat exchangers. The waste heat exchangers, PGS1 cooling loop heat exchangers, and PGS2 cooling loop heat exchangers, can all be eliminated.

Because of size limitations, the new adiabatic cooling system would be comprised of five new pumps and five adiabatic coolers in a four duty, one standby configuration. A drawback of removing the existing cooling heat exchangers when using the adiabatic cooler is that additional controls in the form of flow, pressure, and temperature instruments and control valves will be required to guarantee operating conditions of existing equipment. Figure 3 shows a diagram of an adiabatic cooler.

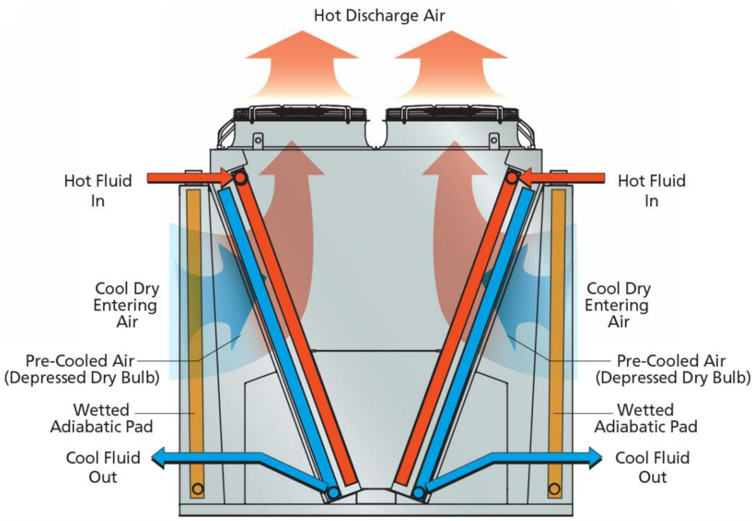

Figure 3 Adiabatic Cooler Diagram (Figure by Evapco)

3.2.5 Option 4 - Radiators

Radiators are a reliable way to cool water by only using air. A radiator works by drawing air over a cooling coil. The air absorbs the heat and the hot air discharges the unit. Currently, there are two radiators on site, that are used to provide limited cooling at PGS1 when 3W is not available. Radiators used to replace 3W cooling water would be similar to the radiators on site. The radiators would then tie into the equipment side of the existing cooling loop similar to the existing engine cooling radiator.

Since the cooling water is contained within a cooling coil in the radiator, the cooling water does not come into contact with open air. Therefore, similar to the fluid and adiabatic coolers, the cooling water can be directly circulated through the individual process heat exchangers. The waste heat exchangers, PGS1 cooling loop heat exchangers, and PGS2 cooling loop heat exchangers, can all be eliminated.

Without the additional assistance of evaporation, radiators cannot match the cooling water supply temperatures of the other cooling water alternatives and the existing 3W design temperatures. This should not be an issue for the process heat exchangers for jacket water and lube oil cooling, since they operate at higher temperatures. But since the PGS1 cooling loop process heat exchangers and PGS2 process cooling loop heat exchangers operate at lower temperatures, these individual process heat exchangers will need to be evaluated to confirm they can provide sufficient cooling at the higher design temperature, when functioning on the hottest days.

A new radiator system would be comprised of five new pumps and five radiators in a four duty, one standby configuration. A drawback of removing the heat exchangers is that additional controls in the form of flow, pressure, and temperature instruments and control valves will be required to guarantee operating conditions of existing equipment. Figure 4 shows a diagram of a radiator.

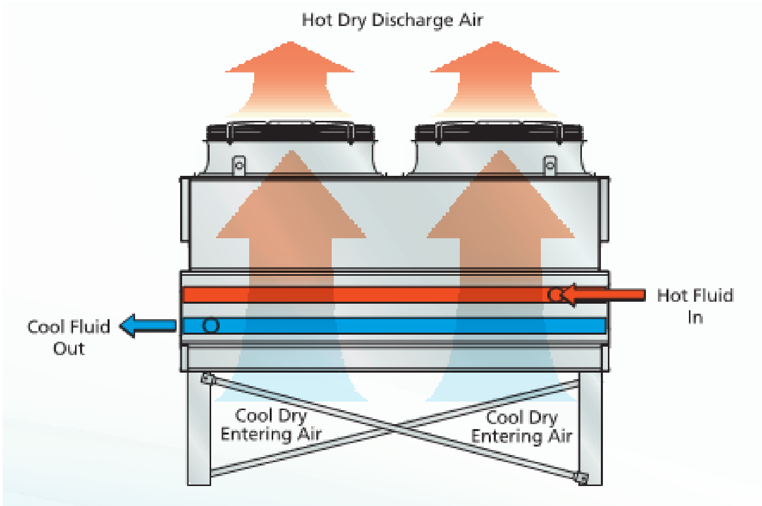

Figure 4 Radiator Diagram (Figure by Evapco)

3.2.6 Cooling Options Summary

Table 3-2 provides a summary of the equipment for the cooling options. Table 3-3 provides a summary of all the equipment being replaced, eliminated, and kept for the Base Case and effluent replacement Options. Equipment being removed in conjunction with cooling options 2, 3, and 4 can be seen on the PGS Cooling Water System Diagram in Appendix D. A site plan of the cooling towers and fluid coolers are provided in Appendix D. There is not enough space where the existing radiators are located for the adiabatic coolers and radiator options.

Table 3-2 Cooling System Options Summary

	OPTION 1 COOLING TOWERS	OPTION 2 FLUID COOLERS	OPTION 3 ADIABATIC COOLERS	OPTION 4 RADIATORS
Number of Cooling Units (Duty/Standby)	3 (2/1)	3 (2/1)	5 (4/1)	5 (4/1)
Total Water Flow, gpm	2,590	2,590	2,590	1,344
Temperature In, F	97	97	97	125
Temperature Out, F	80	80	80	90
Temperature, Wet Bulb, F	66	66	66	NA
Evaporation Rate, gpm	35.2	17.6	28.4	NA
No of Fans, per unit	1	1	6	6
Motor, hp, each	25	50	10	10
No of Spray Pumps	NA	2	NA	NA
Pump Motor, hp each	NA	7.5	NA	NA

	OPTION 1 COOLING TOWERS	OPTION 2 FLUID COOLERS	OPTION 3 ADIABATIC COOLERS	OPTION 4 RADIATORS
Footprint, feet, each	11.8 x 12	11.8 x 22.4	9.1 x 40.2	7.8 x 40.2
Circulating Pumps (Duty/Standby)	3 (2/1)	3 (2/1)	5 (4/1)	5 (4/1)
Flowrate, gpm, each.	1,295	1,295	650	335
Motor, hp each	50	50	25	15

Table 3-3 Cooling System Existing Equipment Summary

	BASE CASE STATUS QUO	OPTION 1 COOLING TOWERS	OPTION 2 FLUID COOLERS	OPTION 3 ADIABATIC COOLERS	OPTION 4 RADIATORS
PGS1 3W Pumps	Replace	Eliminate	Eliminate	Eliminate	Eliminate
PGS2 3W Pumps	Keep	Keep	Keep	Keep	Keep
Engine Radiators	Replace	Eliminate	Eliminate	Eliminate	Eliminate
Waste Heat Exchanger	Replace Tubes	Replace Tubes	Eliminate	Eliminate	Eliminate
PGS1 Cooling Loop Heat Exchanger	Replace Tubes	Replace Tubes	Eliminate	Eliminate	Eliminate
PGS2 Cooling Loop Heat Exchanger	Keep	Keep	Keep	Keep	Keep

3.3 LIFE CYCLE COST ANALYSIS

This section describes the life-cycle cost analysis for the cooling water options including the methodology, inputs, and assumptions.

3.3.1 Evaluation Assumptions

A life-cycle cost analysis performed considered the initial capital cost of each cooling system option and the energy and water costs for the equipment. In order to perform a life-cycle cost for the different options, certain assumptions were made. The primary assumptions were:

- Maintenance costs for all options will be the similar and will have little effect on the life cycle costs.
- Utility power will cost $0.05 per kW/hr.
- Make up water will cost $0.007 per gallon.
- The total life cycle costs are determined over a 20-year project life using an interest rate of 3 percent and are based on 2020 dollars.

3.3.2 Project Capital Costs

The project capital costs include costs for contractor mobilization, demolition, facilities modifications, site work, new equipment, and equipment installation. Equipment costs are based on budget quotes provided by equipment suppliers or based on engineering experience.

Contractor markups and general requirements are costs required by the contractor to do the work. Market conditions are an allowance for doing work in the Bay Area.

The cost factors listed in Table are used to generate the total expected project capital costs.

Table 3-4 Construction and Design Cost Factors

ITEM	COST FACTORS
Equipment Installation	40%
Electrical & Instrumentation	15%
Site Work	5%
Contractor's Markups	20%
General Requirements	25%
Market Conditions	15%
Contingencies	35%

The opinion of probable capital and operation costs presented in Table 3-5 include the following:

- General requirements include the costs for mobilization, temporary facilities, equipment rental, and supervision.
- Electrical and instrumentation and control (I&C) systems for each cooling system and other ancillary equipment are also included in the costs. Equipment costs include the capital cost of the equipment plus an allowance for installation.
- Costs for the cooling systems were based on budgetary equipment costs received from equipment suppliers.
- The electrical and water costs were based on operating the facilities 24 hours per day, seven days per week for 20 years at an average percent of total capacity.

Detailed capital costs for each option are presented in Appendix A.

Table 3-5 Opinion of Probable Capital, Operation, and Life Cycle Costs

	BASE CASE SATSUS QUO	OPTION 1 COOLING TOWERS	OPTION 2 FLUID COOLERS	OPTION 3 ADIABATIC COOLERS	OPTION 4 RADIATORS
Cooling System Capital Costs	$1,006,400	$1,666,700	$1,740,700	$2,624,200	$2,523,900
Contractor's Markups (20%)	$201,300	$333,300	$348,100	$524,800	$504,800

	BASE CASE SATSUS QUO	OPTION 1 COOLING TOWERS	OPTION 2 FLUID COOLERS	OPTION 3 ADIABATIC COOLERS	OPTION 4 RADIATORS
General Requirements (25%)	$251,600	$416,700	$435,200	$656,000	$631,000
Market Conditions (15%)	$151,000	$250,000	$261,100	$393,600	$378,500
Contingencies (35%)	$510,700	$845,900	$883,400	$1,331,800	$1,280,900
Total Project Capital Cost	***$2,121,000***	***$3,512,600***	***$3,668,600***	***$5,530,400***	***$5,319,100***
Annual Electrical Cost[1]	$40,800	$36,800	$43,300	$52,300	$39,200
Annual Water Cost[2]	NA	$100,000	$89,800	$209,100	NA
Present Worth Electrical Cost[3]	$607,400	$546,700	$643,900	$777,500	$583,100
Present Worth Water Cost[3]	NA	$1,484,600	$1,335,900	$3,110,200	NA
Total Project Life Cycle Cost	**$2,728,400**	**$5,543,900**	**$5,648,300**	**$9,418,100**	**$5,902,200**

[1] Energy consumption is based on quotes received from equipment suppliers.

[2] Water consumption is based on quotes received from equipment suppliers.

[3] Total Energy and Water present worth cost is calculated based on total life cycle of 20 years using a 3 percent interest rate and presented in 2020 dollars.

3.4 RECOMMENDATIONS

The following can be summarized based on the life cycle cost analysis:

- Base case or Status Quo has the lowest capital cost and the lowest overall present worth.
- The cooling tower option has the lowest capital costs and the lowest overall present worth cost of all the options for replacing the existing 3W cooling system. This is followed closely with the fluid cooler option.
- The adiabatic coolers and radiators options have the highest capital costs and life cycle costs, and because of the number and size of the units will not fit on the site.
- Capital costs for the cooling towers are the lowest out of all the options, but it requires keeping the existing interface waste and cooling heat exchangers. Since the waste heat exchanger and the PGS1 cooling heat exchanger tubes need to be replaced, those costs were included for this option.
- Cooling towers and fluid coolers have lower capital cost than the adiabatic cooler and radiators due to the number of new cooling equipment needed. Compared to the other options three cooling towers or fluid coolers and three pumps are needed, whereas the adiabatic cooler and radiator options would require five units.

It is recommended that EBMUD install Option 1, new cooling towers, to replace the existing 3W cooling system, since the cooling tower option has the lowest capital costs, lowest life cycle costs, and will fit the best on site where the existing radiators are located. If the District decides to keep using 3W for cooling, additional modifications, including replacing the buried 18 inch piping and waste and the cooling loop heat exchangers will need to be modified by replacing tube bundles, seals, and gaskets for each.

4.0 Equipment Assessment

A system condition assessment was performed to develop an understanding of the current condition of the existing equipment. The major components of the overall PGS systems were assessed to establish the system's current level of performance and reliability. Any risks, deficiencies, upgrades, or repairs were identified and were summarized in the recommendations section of this report.

4.1 ASSESSMENT METHODOLOGY

An evaluation and visual inspection of all major equipment was conducted. The following section provides a brief description of the assessment criteria and how equipment was evaluated. This evaluation includes data collection and field investigations, assessment of probability of failure (POF), assessment of consequence of failure (COF), and business risk exposure (BRE) analysis.

4.1.1 Data Collection and Operator Information

The condition assessment process began with visual inspection and photographing of key process equipment. A data request was prepared by B&V and EBMUD staff provided electronic copies of requested data. Due to restrictions on travel, the scheduled in person interviews with O&M staff were completed via online workshops.

Once all requested data was obtained from EBMUD, an extensive review of the original PGS system design was performed. Data reviewed included all available original design documents, equipment O&M manuals, and equipment maintenance records. Using this information, an inventory of relevant assets was developed and was used as a guide for data collection. Updates were made to the data inventory as new information became available or as actual field conditions were observed. Appendix B provides a summary of data collected for all equipment to be evaluated.

Once the asset data inventory was established, ratings were developed using the rating criteria described below. Preliminary ratings were provided for equipment and categories where adequate information was available to make such ratings. Once preliminary ratings were completed, they were sent to EBMUD staff for review and comment. A total of 70 assets were assessed and a ranking of risk level was assigned to each asset. The business risk exposure for each piece of equipment was determined based on the product of the ranking of the POF and COF, as described below.

4.2 ASSESSMENT OF PROBABILITY OF FAILURE

The following list of criteria was used to assess the probability of failure and criteria for ratings:

- **Condition** – Determine condition of equipment through visual/photos and staff interviews.
  - 1 - Brand new or essentially new equipment.
  - 3 - Older equipment runs acceptably with only typical preventative maintenance required.
  - 5 - Equipment requiring significant maintenance and replacement of parts.
- **Reliability** – Maximo info and staff interviews to determine maintenance frequency.
  - 1 – Minimal equipment scheduled preventative maintenance.
  - 2 - Equipment only requires scheduled preventative maintenance.
  - 3 - More than scheduled preventive maintenance is required.
  - 4 - Significantly more than scheduled preventive maintenance is required.
  - 5 - Equipment is not usable.

- **Capacity** – Compare capacity with design capacity.
  - 1 - If the equipment has excess capacity.
  - 3 - Equipment capacity matched the capacity required to perform its function.
  - 5 - Equipment does not meet its required capacity.
- **Functionality** – Does equipment function as intended.
  - 1 - Equipment performs its function adequately.
  - 3 – Equipment performs function but may need adjustment.
  - 5 - Equipment fails to achieve its function.
- **Financial Efficiency** – Other ways to accomplish function that could be more efficient
  - 1 - There are very few (if any) better ways to perform the function.
  - 3 - Equipment is a proper fit for its function, with no better ways to perform the function.
  - 5 - There are better ways to perform the function, such as newer technology.

4.3 ASSESSMENT OF CONSEQUENCE OF FAILURE

The following list of criteria was used to assess the consequence of failure and criteria for ratings:

- **Health and Safety** – Equipment will be evaluated on the potential for human harm in the event of failure.
  - 1 – Does not result in injury or illness.
  - 2 - Potential for minor injury or illness.
  - 3 - Potential for serious injury.
  - 4 - Potential of serious injury likely.
  - 5 - Potential for loss of live.
- **Social Impact** – Equipment will be evaluated on potential to cause violations of the plant's permit as well as on the plant's ability to be a "good neighbor".
  - 1 - No or minimal impact.
  - 2 - Localized complaints only.
  - 3 - Broader complaints, make local news, potential regulatory violations.
  - 4 - Violation expected.
  - 5 - Possible fines and prosecution.
- **Difficulty of Repair** – Equipment will be evaluated based on how long it takes to repair piece of equipment.
  - 1 - Repair takes less than a day and can be done by staff, spare parts are readily available.
  - 2 - Repair takes up to a week and can be done by staff, spare parts available.
  - 3 - Repair takes up to a month, outside technicians may be required, spare parts are not readily available.
  - 4 - Repair takes up to 3 months, outside technicians will be required, spare parts are not available.
  - 5 - Repair takes more than 3 months, outside technicians will be required, spare parts are not available, shutdowns may be required.

- **<u>Redundancy</u>** – Redundancy will be determined by considering the number of pieces of equipment required to operate under normal operating conditions with the number of pieces of spare equipment available.
  - 1 - 100% redundancy of equipment in place.
  - 2 - 50% redundancy of equipment in place.
  - 3 - 33% redundancy of equipment in place.
  - 4 - 25% redundancy of equipment in place.
  - 5 - No redundancy of equipment in place.

4.4 BUSINESS RISK EXPOSURE ANALYSIS AND RANKING

Once the individual POF and COF ratings were determined through the assessment activities for each asset, an overall business risk exposure rating was determined by the product of the overall POF and COF ratings. The overall BRE rating can be visualized by identifying where the risk rating falls within the risk signature as indicated in Figure 5.

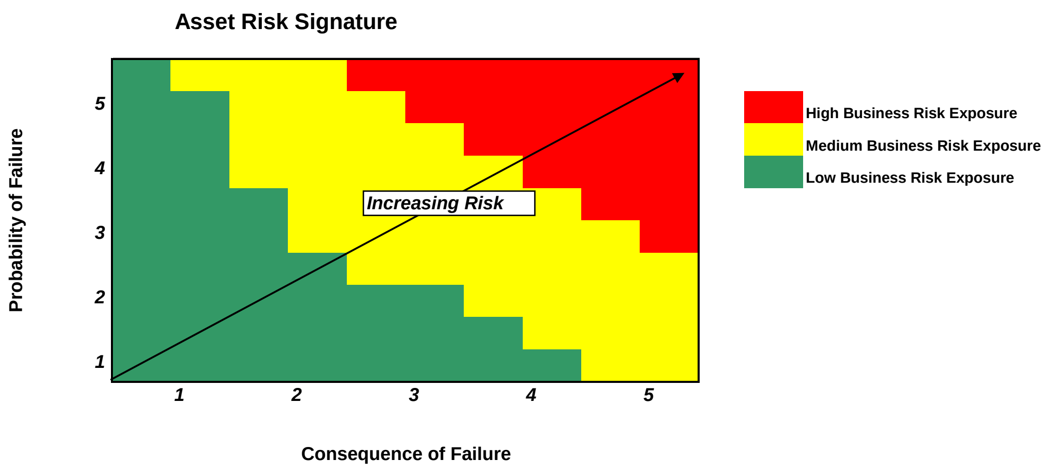

Figure 5 Asset Risk Signature

The results of the POF, COF, and BRE ratings for assets which have the highest BRE rating are indicated in Table 4-1. Detailed rankings of all equipment evaluated are presented in Appendix B.

Table 4-1 Equipment Business Risk Exposure Ranking

EQUIPMENT DESCRIPTION	POF	COF	BUSINESS RISK EXPOSURE
Low Pressure Gas Holder	4.4	4.3	18.9
Plant Effluent Cooling Water System	4.2	3.5	14.7
Slop Oil Storage Tanks	3.0	4.3	12.9
Diesel Storage Tank	3.0	4.3	12.9
Gas Treatment System	3.6	3.5	12.6
Engine Cooling Radiators and Engine Intercooler Radiator	3.4	3.5	11.9
Gas Treatment Blower	3.6	3.3	11.9
Gas Treatment Heat Exchangers	3.4	3.3	11.2
PGS1 Digester Gas Compressor Intercoolers and Aftercoolers	3.6	3.0	10.8
Engine Lube Oil, Jacket Water, and Intercooler Heat Exchangers	3.6	3.0	10.8
Compressed Air System Air Dryer	3.8	2.8	10.6
Engine Lube Oil Tank Heater	3.8	2.8	10.6
High Capacity Flares	2.8	3.3	9.2
Digester Gas Surge Tank	2.8	3.3	9.2
Boiler Gas Blower	2.8	3.3	9.2
Waste Heat Exchanger	4.0	2.3	9.2
Starting Air Compressors	4.2	2.0	8.4
Gas Treatment Chiller	2.8	3.0	8.4
PGS1 Digester Gas Compressor	2.8	3.0	8.4
PGS Boiler	3.0	2.8	8.4
PGS1 Cooling Loop Heat Exchanger	4.0	2.0	8.0
Engine Heat Recovery Pump	2.4	3.3	7.9
PGS1 Engine Room HVAC Fans	4.2	1.8	7.6
Engine-Generator Silencers	2.2	3.3	7.3

5.0 Project Capital Costs

Project capital costs were developed for items in Table 4-1 similar to the way that the 3W replacement cooling options were developed. This included costs for contractor mobilization, demolition, facilities modifications, new equipment, and equipment installation. Costs factors for equipment installation, electrical and instrumentation, and site work, were adjusted based on the task requirements.

Based on the BRE rankings presented in Table 4-1, tasks were developed for each piece of equipment based on specific improvements required to improve overall equipment reliability. This may include modifying the equipment, adding a redundant unit, or complete replacement of the unit. Additional tasks, not associated with an asset, were developed based on requests by EBMUD. Table 5-1 presents the task description, along with an associated task number for each modification. For each task in Table 5-1, the associated opinion of capital costs, along with the BRE is presented. The low pressure gas holder assessment was presented in a separate TM. Detailed capital costs of all assets evaluated are presented in Appendix A.

Table 5-1 Task Cost to Construct

TASK NUMBER	TASK DESCRIPTION	BRE	COST ($000)
TASKS SCOPED TO BE ASSESSED			
1	LPGH – Refer to separate LPGH Technical Memorandum for complete evaluation and recommendation. Costs include short term modifications to add valves and long term modifications to eliminate LPGH and provide two gas conditioning blowers at higher pressure.	18.9	2,573
2	Eliminate use of plant effluent in cooling water system by the use of Cooling Towers for cooling.	14.7	3,513
3	Remove two slop/waste oil tanks and replace with one aboveground tank.	12.9	405
4	Remove diesel tank and replace with aboveground tank.	12.9	1,063
5	Provide complete redundancy for digester gas treatment system gas blower, heat exchangers, and chiller; separate HV & LV in control panel.	12.6	4,317
6	Replace existing radiators in kind. Not required if 3W cooling system is replaced. See Task 2.	11.9	976
7	Provide redundant digester gas treatment blower and separate HV & LV in control panel.	11.9	1,624
8	Provide redundant digester gas treatment heat exchangers.	11.2	2,155
9	Replace compressor intercoolers and aftercoolers in kind.	10.8	750
10	Replace engine lube oil and jacket water heat exchanger tubes and replace intercooler heat exchangers in kind.	10.8	1,252
11	Replace existing compressed air system air dryer with a higher capacity dryer and provide redundant unit.	10.6	24

TASK NUMBER	TASK DESCRIPTION	BRE	COST ($000)
12	Replace lube oil heater in engine lube oil storage tank with a higher capacity heater.	10.6	21
13	Replace high capacity flare ignition rod and add weather hood.	9.2	35
14	Replace digester gas surge tank safety relief valve and clean tank.	9.2	19
15	Replace boiler gas blower in kind.	9.2	402
16	Replace existing waste heat exchanger tubes.	9.2	652
17	Replace starting air compressors in kind.	8.4	43
18	Add redundancy to digester gas treatment chiller.	8.4	1,009
19	Replace existing PGS1 piston type gas compressors with rotary screw type gas compressors similar to PGS2 gas compressor.	8.4	7,877
20	Modify boiler stack and add weather protection to control panel.	8.4	64
21	Replace PGS1 cooling loop heat exchanger tubes.	8.0	1,064
22	Increase engine HRU pump pressure.	7.9	19
23	Modify PGS1 engine room fans and ducting.	7.6	44
24	Replace engine-generator silencers on roof.	7.3	522
TASKS NOT ASSOCIATED WITH EVALUATED EQUIPMENT			
25	Incorporate engine detonation monitoring and adjustment system.		1,090
26	Modify Main Interface Panel (MIP) – to have false floor to protect wiring and ease entrance.		64
27	Relocate low pressure & medium pressure digester gas PITs to be closer to ground level.		11
28	Migrate controls and tie alarms from PGS MIP to the plant DCS.		700
29	Add load bank connections at PGS1.		148
30	Replace PGS2 compressor discharge pipe from buried to above ground.		196
31	Seismic improvements to PGS2 building and stack as recommended in Seismic study.		500
32	Replace existing standby engine-generator with a larger unit.		1,558
33	Add new radiator for cooling turbine lube oil.		264

Note, some of the tasks listed above are related to one another. These include tasks associated with the cooling system: Task 2, use fluid coolers for cooling, and Task 6, replace radiators; Task 16, replace waste heat exchanger tubes; and Task 21, replace PGS1 cooling heat exchanger tubes. Also, tasks associated with the gas conditioning system: including Task 1, LPGH; Task 5, redundant gas conditioning train; and Task 7, redundant gas conditioning blower; Task 8, redundant gas conditioning heat exchangers; and Task 18, redundant gas conditioning chiller.

6.0 Project Prioritization

Project prioritization is a process by which all tasks are compared based on project cost, POF, COF, BRE, and relation to other tasks to determine which tasks can be done in a single project. This is necessary because the total project construction cost as indicated in the Request for Proposal was $8.5 million, and the total for all tasks listed in Table 5-1 exceeds $34 million. Therefore, not all tasks identified in Table 5-1 will be completed under a single construction project.

The process for selecting priority projects starts by deciding what high cost and high BRE task will be included in the project. **Table 6-1** presents a list of priority project tasks and associated capital costs that could be completed and together would be near to the project budget.

Table 6-1 Equipment Business Risk Exposure Ranking and Costs

TASK NUMBER	TASK DESCRIPTION	BUSINESS RISK	COST ($000)
1	LPGH – Refer to separate LPGH Technical Memorandum for complete evaluation and recommendation.	18.9	2,573
2	Eliminate use of plant effluent in cooling water system by the use of cooling towers.	14.7	3,513
3	Remove slop oil tank and replace with aboveground tank.	12.8	405
4	Remove diesel tank and replace with aboveground tank.	12.8	1,063
10	Replace engine lube oil and jacket water heat exchanger tubes and replace intercooler heat exchangers in kind.	10.8	1,252
11	Replace existing compressed air system air dryer with a higher capacity dryer and add a redundant unit.	10.6	24
12	Replace lube oil heater in engine lube oil storage tank with a higher capacity heater.	10.6	21
13	Replace high capacity flare ignition rod replacement and add weather hood.	9.2	35
17	Replace two starting air compressors in kind.	8.4	43
20	Modify boiler stack and add weather protection to control panel.	8.4	64
22	Increase engine HRU pump pressure.	7.9	19
23	Modify PGS1 engine room fans and ducting.	7.6	44
25	Engine detonation monitoring and adjustment system.		1,090
26	Modify Main Interface Panel (MIP) – to have false floor to protect wiring and ease entrance.		64
27	Relocate low pressure and medium pressure digester gas PITs to ground level.		11
28	Migrate controls and tie alarms from PGS MIP to the plant DCS.		700
29	Add load bank connections at PGS1.		148

TASK NUMBER	TASK DESCRIPTION	BUSINESS RISK	COST ($000)
30	Replace PGS2 compressor discharge pipe from buried to above ground.		196
31	Seismic improvements to PGS2 building.		500
32	Replace existing standby engine-generator with a larger unit.		1,558
33	Add new radiator for cooling turbine lube oil.		264
21 Tasks	**Total Project Construction Cost**		**13,587**

In total 21 tasks potentially can be constructed as a part of this project for a total project construction cost of a little over the $13.5 million, which is much more than what was originally budgeted however it allows for several tasks to be a part of a single project. The total project cost is 1.8 times greater than the total project construction cost.

As discussed herein B&V recommends Option 1, the use of cooling towers for replacing the 3W cooling water system and these costs were included.

Task 28, migrating controls and alarms from PGS1 MIP to the DCS and Task 31, Seismic improvement to the PGS2 building was not provided with detailed enough scope to cost out, so allowances was provided for these tasks. Additional focus meetings will be required to accurately provide costs.

The main tasks not included in the list are as follows:

- Task 5, not providing complete redundancy for the complete digester gas treatment system. It was felt redundancy for the gas blower was most critical in the treatment system and redundancy for the heat exchangers and chillers were not as necessary. Heat exchangers do not have moving parts and have less chance for failure. The chillers have redundancy built in by having multiple refrigeration circuits.
- Tasks 9, replacing heat exchangers for the engine-generator gas compressors. To replace in kind all the heat exchangers for the engine-generators and gas compressors cooling would cost around $0.75 million. Because of this high cost, they were not included in the recommended project tasks. If it is felt that individual more critical heat exchangers need to be replaced, they may be included in the project.
- Task 19, to replace PGS1 gas compressors, was not included due to its high cost.

The remaining tasks were chosen to maximize the total number of tasks to be included in the project to increase reliability and to address ongoing issues that affect the operation of the plant.

7.0 Summary and Recommendations

Many pieces of equipment and some entire systems are nearing the end of their original design life and are in immediate need of repairs, improvements, and modifications in order to restore the reliability and efficiency it was designed for. EBMUD has already begun to make updates, improvements, and repairs in order to keep all systems operational. However, there continue to be operational challenges. This has resulted in undesired operation and in some instances shutdowns. For these reasons, immediate investments need to be made to improve operations and reliability of the systems.

The main issues facing PGS1 and PGS2 is a lack of redundancy and aging equipment. To determine what equipment is the most at risk an equipment assessment was performed. The equipment assessment used information gathered on site and through data provided by EBMUD to evaluate the probability of failure, consequence of failure, and business risk exposure for all equipment. Equipment together in a single system were grouped and those systems along with remaining individual equipment were reviewed to determine the best solution to increase reliability and redundancy of PGS1 and PGS2. Equipment vendors were contacted and the opinion of probable construction costs to complete each task were determined.

During the review, it became clear that the any modification related to the LPGH would be complex and therefore it was evaluated in a separate technical memorandum. From that TM, a recommendation of replacing and adding a redundant blower with higher discharge pressures and the addition of valves to dampen the high fluctuations in gas pressures was provided. The total cost for this work is approximately $2.6M and can either be included in this project due to the high business risk score or can be handled separately at the District's discretion.

Another system with various options to consider were changes that needed to be made to the digester gas treatment system, which has never operated the way EBMUD has desired. To improve reliability, a redundant blower was recommended, along with providing a separate control panel for the high and low voltage power.

Another system to be reviewed was replacing the existing 3W cooling system which compared multiple technologies to determine which would be best for EBMUD. For replacing the 3W system Option 1, which uses a cooling tower to replace 3W, requires the least amount of changes to the existing cooling system however it requires the replacement of the tubes in the existing waste heat exchanger and PGS1 cooling loop heat exchanger, which makes it more expensive. Options 2, adding fluid coolers; Option 3, adding adiabatic coolers; and 4 adding radiators all require some changes to the existing system including removal of the waste heat exchanger, PGS1 and PGS2 cooling loop heat exchangers. Of these four options, Option , cooling towers, has the lowest total project capital cost, the lowest project life cycle cost, and least number of units. Installation of cooling towers to replace the existing 3W cooling system is therefore recommended and included in the project costs.

The project construction cost is expected to be approximately $13.5 million with the tasks in Table 6-1 being combined into a single project.

Appendix E lists the tasks that EBMUD requested to be carried forward and developed as part of the Basis of Design Report (BODR). In the BODR, each task will be developed in more detail and the opinion of probable construction costs will be updated for the specific tasks listed in Appendix E.

Appendix A. Opinion of Probable Construction Costs

EBMUD - PGS Reliability

Task 2: Base Case - Status Quo

Description: Continue use of 3W to cool PGS. Replace existing 18 inch 3W supply pipe between effluent channel and PGS1. Replace Waste Heat Exchanger and PGS1 Cooling Loop heat exchanger tubing and seals.

Capital Costs

		Status Quo Option		
Description	Cost Factors	Cost per unit	No.	Total Cost
Equipment Costs				
Waste Heat Exchanger		$ 91,000	2	$ 182,000
PGS1 Cooling Loop Heat Exchanger		$ 157,500	2	$ 315,000
Equipment Total				**$ 497,000**
Demolition		$ 20,000	4	$ 80,000
Misc Piping and Valves		$ 600	305	$ 182,700
Total				$ 759,700
Total Equipment Costs				**$ 759,700**
Installation - % of Equip Costs	40%			$ 198,800
Total with Installation				**$ 958,500**
Electrical & I&C	5%			$ 47,925
Site Work	0%			$ -
Total Capital Cost w/o markups				**$ 1,006,425**
Contractor Markups	20%			$ 201,285
General Requirements	25%			$ 251,606
Market Conditions	15%			$ 150,964
Contingencies	35%			$ 510,732
Total Capital Cost w/markups				**$ 2,121,012**

Electricity Costs		
Electricity Usage Pumping	kW	93
Annual Electricity Usage	kW/yr	816,555
Annual Electricity Cost	**$/yr**	**$ 40,828**
Present Worth Electricity Cost	$	607,414
Total Project Cost		**$ 2,728,425**

EBMUD - PGS Reliability

Task 2: Cooling Option 1 - Cooling Towers

Description: Eliminate 3W cooling and use Cooling Towers to cool the waste heat exchanger, PGS1 cooling loop heat exchanger, and PGS2 cooling loop heat exchanger. New dedicated Cooling Tower pumps will be added. Replace piping and valves as necessary to connect Cooling Towers. Tasks 16 and 21 will be completed.

Capital Costs

		Cooling Tower Option				
Description	Cost Factors	Cost per unit		No.	Total Cost	
Equipment Costs						
Cooling Tower (2 duty/1 standby)		$	80,000	3	$	240,000
Pumps		$	8,000	3	$	24,000
Water Treatment System		$	10,000	3	$	30,000
Waste Heat Exchanger		$	91,000	2	$	182,000
PGS1 Cooling Loop Heat Exchanger		$	157,500	2	$	315,000
Equipment Total					**$**	**791,000**
Radiator Demolition		$	25,000	2	$	50,000
Heat Exchanger Demolition		$	10,000	4	$	40,000
Concrete Pad		$	750	25	$	18,500
Concrete Pile		$	14,000	10	$	140,000
Cooling Tower Misc Piping and Valves		$	30,000	3	$	90,000
Heat Exchanger Misc Piping and Valves		$	10,000	4	$	40,000
Total					$	1,169,500
Total Equipment Costs					**$**	**1,169,500**
Installation - % of Equip Costs	40%				$	316,400
Total with Installation					**$**	**1,485,900**
Cooling Tower Electrical & I&C	15%				$	106,515
Heat Exchanger Electrical & I&C	5%				$	38,790
Cooling Tower Site Work	5%				$	35,505
Total Capital Cost w/o markups					**$**	**1,666,710**
Contractor Markups	20%				$	333,342
General Requirements	25%				$	416,678
Market Conditions	15%				$	250,007
Contingencies	35%				$	845,855
Total Capital Cost w/markups					**$**	**3,512,591**

Electricity Costs			
Electricity Usage Coolers	kW		19
Electricity Usage Pumping	kW		75
Annual Electricity Usage	kW/yr		734,899
Annual Electricity Cost	**$/yr**	**$**	**36,745**
Water Costs			
Water Usage	gal/min		18
Annual Water Usage	gal/yr		9,255,816
Annual Water Treatment Cost	$/yr		35,000
Annual Water Cost	**$/yr**	**$**	**99,791**
Present Worth Electricity Cost	$		546,672
Present Worth Water Cost	$		1,484,634
Total Project Cost		**$**	**5,543,897**

EBMUD - PGS Reliability

Task 2: Cooling Option 2 - Fluid Cooler

Description: Eliminate 3W cooling and use Fluid Coolers to directly cool exiting equipment. New dedicated Fluid Cooler pumps will be added. Replace piping and valves as necessary to connect Fluid Coolers.

Capital Costs

		Fluid Cooler Option		
Description	Cost Factors	Cost per unit	No.	Total Cost
Equipment Costs				
Fluid Cooler (2 duty/1 standby)		$ 227,500	3	$ 682,500
Pumps		$ 8,000	3	$ 24,000
Water Treatment System		$ 8,333	3	$ 25,000
Equipment Total				**$ 731,500**
Demolition		$ 25,000	2	$ 50,000
Concrete Pad		$ 750	46	$ 34,500
Concrete Pile		$ 14,000	18	$ 252,000
Misc Piping and Valves		$ 30,000	3	$ 90,000
Total				$ 1,158,000
Total Equipment Costs				**$ 1,158,000**
Installation - % of Equip Costs	40%			$ 292,600
Total with Installation				**$ 1,450,600**
Electrical & I&C	15%			$ 217,590
Site Work	5%			$ 72,530
Total Capital Cost w/o markups				**$ 1,740,720**
Contractor Markups	20%			$ 348,144
General Requirements	25%			$ 435,180
Market Conditions	15%			$ 261,108
Contingencies	35%			$ 883,415
Total Capital Cost w/markups				**$ 3,668,567**

Electricity Costs		
Electricity Usage Coolers	kW	48
Electricity Usage Pumping	kW	75
Annual Electricity Usage	kW/yr	865,548
Annual Electricity Cost	**$/yr**	**$ 43,277**
Water Costs		
Water Usage	gal/min	18
Annual Water Usage	gal/yr	9,255,816
Annual Water Treatment Cost	$/yr	25,000
Annual Water Cost	**$/yr**	**$ 89,791**
Present Worth Electricity Cost	$	643,859
Present Worth Water Cost	$	1,335,859
Total Project Cost		**$ 5,648,285**

EBMUD - PGS Reliability

Task 2: Cooling Option 3 - Adiabatic Cooler

Description: Eliminate 3W cooling and use Adiabatic Coolers to directly cool existing equipment. New dedicated Adiabatic Cooler pumps will be added. Replace piping and valves as necessary to connect Adiabatic Cooler.

Capital Costs

		Adiabatic Cooler Option			
Description	**Cost Factors**	**Cost per unit**	**No.**		**Total Cost**
Equipment Costs					
Adiabatic Cooler (4 duty/1 standby)		$ 205,000	5	$	1,025,000
Pumps		$ 5,000	5	$	25,000
Equipment Total				**$**	**1,050,000**
Demolition		$ 25,000	2	$	50,000
Concrete Pad		750	103	$	76,875
Concrete Pile		$ 14,000	40	$	560,000
Misc Piping and Valves		$ 25,000	5	$	125,000
Total				$	1,861,875
Total Equipment Costs				**$**	**1,861,875**
Installation - % of Equip Costs	40%			$	420,000
Total with Installation				**$**	**2,281,875**
Electrical & I&C	15%			$	342,281
Site Work	0%			$	-
Total Capital Cost w/o markups				**$**	**2,624,156**
Contractor Markups	20%			$	524,831
General Requirements	25%			$	656,039
Market Conditions	15%			$	393,623
Contingencies	35%			$	1,331,759
Total Capital Cost w/markups				**$**	**5,530,409**

Electricity Costs			
Electricity Usage Coolers	kW		89
Electricity Usage Pumping	kW		75
Annual Electricity Usage	kW/yr		1,045,190
Annual Electricity Cost	**$/yr**	**$**	**52,260**
Water Costs			
Water Usage	gal/min		57
Annual Water Usage	gal/yr		29,864,592
Annual Water Cost	**$/yr**	**$**	**209,052**
Present Worth Electricity Cost	$		777,490
Present Worth Water Cost	$		3,110,168
Total Project Cost		**$**	**9,418,067**

EBMUD - PGS Reliability

Task 2: Cooling Option 4 - Radiator

Description: Eliminate 3W cooling and use Radiators to directly cool existing equipment. New dedicated Radiator pumps will be added. Replace piping and valves as necessary to connect new Radiators.

Capital Costs

		Radiator Option				
Description	Cost Factors	Cost per unit		No.	Total Cost	
Equipment Costs						
Radiator (4 duty/1 standby)		$	195,000	5	$	975,000
Pumps		$	4,000	5	$	20,000
Equipment Total					**$**	**995,000**
Demolition		$	25,000	2	$	50,000
Concrete Pad		$	750	89	$	66,667
Concrete Pile		$	14,000	40	$	560,000
Misc Piping and Valves		$	25,000	5	$	125,000
Total					$	1,796,667
Total Equipment Costs					**$**	**1,796,667**
Installation - % of Equip Costs	40%				$	398,000
Total with Installation					**$**	**2,194,667**
Electrical & I&C	15%				$	329,200
Site Work	0%				$	-
Total Capital Cost w/o markups					**$**	**2,523,867**
Contractor Markups	20%				$	504,773
General Requirements	25%				$	630,967
Market Conditions	15%				$	378,530
Contingencies	35%				$	1,280,936
Total Capital Cost w/markups					**$**	**5,319,072**

Electricity Costs			
Electricity Usage Coolers	kW		89
Electricity Usage Pumping	kW		45
Annual Electricity Usage	kW/yr		783,893
Annual Electricity Cost	**$/yr**	**$**	**39,195**
Present Worth Electricity Cost	$		583,117
Total Project Cost		**$**	**5,902,189**

EBMUD - PGS Reliability

Task 3: Waste (Slop) Oil Tank Replacement

Description: Replace buried slop tank at maintenance building and PGS1 with one new 4,000 gallon aboveground tank. Existing PGS1 buried tank has a diameter of 6.2 ft and is 13.3 ft long. The new tank will be have a diameter of 7.5 ft and will be 14.6 ft long. The new tank will be located on concrete slab, directly above the existing tank.

Capital Costs

		Waste (Slop) Tank Replacement		
Description	Cost Factors	Cost per unit	No.	Total Cost
Equipment Costs				
New above ground tank		$ 24,730	1	$ 24,730
Misc accessories		$ 5,000	1	$ 5,000
Drum Lift		$ 5,000	1	$ 5,000
Equipment Total				**$ 34,730**
Demolition		$ 15,000	1	$ 15,000
Concrete Pad		$ 750	10	$ 7,367
Concrete Pile		$ 14,000	6	$ 84,000
Misc Piping and Valves		$ 5,000	1	$ 5,000
Total				$ 146,097
Total Equipment Costs				**$ 146,097**
Installation - % of Equip Costs	40%			$ 13,892
Total with Installation				**$ 159,989**
Electrical & I&C	15%			$ 23,998
Site Work	5%			$ 7,999
Total Capital Cost w/o markups				**$ 191,986**
Contractor Markups	20%			$ 38,397
General Requirements	25%			$ 47,997
Market Conditions	15%			$ 28,798
Contingencies	35%			$ 97,433
Total Capital Cost w/markups				**$ 404,611**

EBMUD - PGS Reliability

Task 4: Diesel Tank Replacement

Description: Replace Buried tank with new Aboveground tank. Existing tank has a diameter of 10 ft and is 46 ft long. The new tank will have a diameter of 10.6 ft and will be 43.1 ft long. The new tank will be located on concrete slab, directly above the existing tank. Will need to rent a smaller temporary tank during construction

Capital Costs

		Diesel Tank Replacement		
Description	Cost Factors	Cost per unit	No.	Total Cost
Equipment Costs				
New above ground tank		$ 110,170	1	$ 110,170
Fill Box		$ 15,000	1	$ 15,000
Misc accessories		$ 6,000	1	$ 6,000
Tank Heater		$ 15,000	1	$ 15,000
Equipment Total				**$ 146,170**
Demolition		$ 50,000	1	$ 50,000
Concrete Pad		$ 750	47	$ 35,448
Concrete Pile		$ 14,000	8	$ 112,000
Misc Piping and Valves		$ 10,000	1	$ 10,000
Total				$ 353,618
Total Equipment Costs				**$ 353,618**
Installation - % of Equip Costs	40%			$ 58,468
Total with Installation				**$ 412,086**
Electrical & I&C	15%			$ 61,813
Tank Rental				$ 10,000
Site Work	5%			$ 20,604
Total Capital Cost w/o markups				**$ 504,503**
Contractor Markups	20%			$ 100,901
General Requirements	25%			$ 126,126
Market Conditions	15%			$ 75,675
Contingencies	35%			$ 256,035
Total Capital Cost w/markups				**$ 1,063,240**

EBMUD - PGS Reliability

Task 5: Add Digester Gas Treatment Train for Redundancy

Description: Add a second train of gas booster, gas drying HEX and chiller, and new piping and valves to connect skids. Separate exiting low voltage components from high voltage components in existing panel.

Capital Costs

		Add Gas Treatment Redundancy		
Description	Cost Factors	Cost per unit	No.	Total Cost
Equipment Costs				
Add Gas Blower		$ 300,000	1	$ 300,000
Add Heat Exchangers		$ 600,000	1	$ 600,000
Add Chiller		$ 280,000	1	$ 280,000
Equipment Total				**$ 1,180,000**
Demolition		$ 5,000	1	$ 5,000
Misc Piping and Valves		$ 50,000	1	$ 50,000
Total				$ 1,235,000
Total Equipment Costs				**$ 1,235,000**
Installation - % of Equip Costs	40%			$ 472,000
Total with Installation				**$ 1,707,000**
Electrical & I&C	15%			$ 256,050
Site Work	5%			$ 85,350
Total Capital Cost w/o markups				**$ 2,048,400**
Contractor Markups	20%			$ 409,680
General Requirements	25%			$ 512,100
Market Conditions	15%			$ 307,260
Contingencies	35%			$ 1,039,563
Total Capital Cost w/markups				**$ 4,317,003**

EBMUD - PGS Reliability

Task 6: Radiator Replacement

Description: Replace existing radiators for cooling a single Engine Generator. New engine cooling radiator will cool the jacket water and lube oil heat exchangers. New intercooler radiator will cool the engine intercooler and digester gas compressor intercooler and aftercooler.

Engine Radiator: 4.0 mmBtuh, 300 gpm, 190-140°F

Intercooler Radiator: 1.7 mmBtuh, 650 gpm, 95-90°F

Capital Costs

		Radiator Replacement		
Description	Cost Factors	Cost per unit	No.	Total Cost
Equipment Costs				
JW Radiator		$ 95,000	1	$ 95,000
Intercooler Radiator		$ 100,000	1	$ 100,000
Equipment Total				**$ 195,000**
Demolition		$ 5,000	2	$ 10,000
Concrete Pad		$ 750	21	$ 16,000
Concrete Pile		$ 14,000	8	$ 112,000
Misc Piping and Valves		$ 5,000	2	$ 10,000
Total				$ 343,000
Total Equipment Costs				**$ 343,000**
Installation - % of Equip Costs	40%			$ 78,000
Total with Installation				**$ 421,000**
Electrical & I&C	10%			$ 42,100
Site Work	0%			$ -
Total Capital Cost w/o markups				**$ 463,100**
Contractor Markups	20%			$ 92,620
General Requirements	25%			$ 115,775
Market Conditions	15%			$ 69,465
Contingencies	35%			$ 235,023
Total Capital Cost w/markups				**$ 975,983**

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Task 7: Add Redundant Digester Gas Treatment Blower

Description: Add new blower in parallel with existing blower to create redundancy. Increase HEX capacity. Separate exiting low voltage components from high voltage components in existing panel.

Capital Costs

		Add Redundant Blower				
Description	Cost Factors	Cost per unit		No.	Total Cost	
Equipment Costs						
Add Redundant Gas Blower		$	300,000	1	$	300,000
New HEX		$	150,000	1	$	150,000
Equipment Total					**$**	**450,000**
Demolition		$	2,000	1	$	2,000
Misc Piping and Valves		$	10,000	1	$	10,000
Total					$	462,000
Total Equipment Costs					**$**	**462,000**
Installation - % of Equip Costs	40%				$	180,000
Total with Installation					**$**	**642,000**
Electrical & I&C	15%				$	96,300
Site Work	5%				$	32,100
Total Capital Cost w/o markups					**$**	**770,400**
Contractor Markups	20%				$	154,080
General Requirements	25%				$	192,600
Market Conditions	15%				$	115,560
Contingencies	35%				$	390,978
Total Capital Cost w/markups					**$**	**1,623,618**

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Task 8: Add Redundant Digester Gas Treatment Heat Exchangers

Description: Add new heat exchangers in parallel with existing heat exchangers to create redundancy.

Capital Costs

		Add Redundant HEXs		
Description	Cost Factors	Cost per unit	No.	Total Cost
Equipment Costs				
Add Redundant HEXs		$ 600,000	1	$ 600,000
Equipment Total				**$ 600,000**
Demolition		$ 2,000	1	$ 2,000
Misc Piping and Valves		$ 10,000	1	$ 10,000
Total				$ 612,000
Total Equipment Costs				**$ 612,000**
Installation - % of Equip Costs	40%			$ 240,000
Total with Installation				**$ 852,000**
Electrical & I&C	15%			$ 127,800
Site Work	5%			$ 42,600
Total Capital Cost w/o markups				**$ 1,022,400**
Contractor Markups	20%			$ 204,480
General Requirements	25%			$ 255,600
Market Conditions	15%			$ 153,360
Contingencies	35%			$ 518,868
Total Capital Cost w/markups				**$ 2,154,708**

EBMUD - PGS Reliability

Task 9: PGS1 Digester Gas Compressor Heat Exchanger Replacement

Description: Replace exiting PGS1 digester gas compressor intercooler and aftercooler heat exchangers on three existing gas compressors. The heat exchangers are mounted on the existing compressor package. Piping and valves will be replaced as necessary to connect new heat exchangers.

Intercooler: 0.205 mmBtuh, 10 gpm 80 to 121°F, 625 SCFM 230 to 90°F

Aftercooler: 0.127 mmBtuh, 10 gpm 80 to 105.6°F, 625 SCFM 205 to 90°F

Capital Costs

		Compressor Intercooler HEX Replacement		
Description	Cost Factors	Cost per unit	No.	Total Cost
Equipment Costs				
New Intercooler HEX		$ 40,000	3	$ 120,000
New Aftercooler HEX		$ 30,000	3	$ 90,000
Equipment Total				**$ 210,000**
Demolition		$ 2,500	6	$ 15,000
Misc Piping and Valves		$ 5,000	6	$ 30,000
Total				$ 255,000
Total Equipment Costs				**$ 255,000**
Installation - % of Equip Costs	40%			$ 84,000
Total with Installation				**$ 339,000**
Electrical & I&C	5%			$ 16,950
Site Work	0%			$ -
Total Capital Cost w/o markups				**$ 355,950**
Contractor Markups	20%			$ 71,190
General Requirements	25%			$ 88,988
Market Conditions	15%			$ 53,393
Contingencies	35%			$ 180,645
Total Capital Cost w/markups				**$ 750,165**

EBMUD - PGS Reliability

Task 10: Engine-Generator Heat Exchanger Replacement

Description: Replace tubes and seals for existing Jacket Water and Lube oil heat exchangers and replace existing Engine Intercooler heat exchanger. Piping and valves will be replaced as necessary to connect new heat exchangers.

Jacket Water: 3.1 mmBtuh, 300 gpm 146 to 167°F, 600 gpm 185 to 175°F

Lube Oil: 0.915 mmBtuh, 300 gpm 140 to 146°F, 275 gpm 175 to 158°F

Engine Intercooler: 1.36 mmBtuh, 400 gpm 80 to 87°F, 625 gpm 300 to 100°F

Capital Costs

		Engine JW HEX Replacement		
Description	Cost Factors	Cost per unit	No.	Total Cost
Equipment Costs				
New JW HEX		$ 75,600	2	$ 151,200
New LO HEX		$ 30,800	3	$ 92,400
New Intercooler HEX		$ 40,000	3	$ 120,000
Equipment Total				**$ 363,600**
Demolition		$ 5,000	9	$ 45,000
Misc Piping and Valves		$ 10,000	9	$ 90,000
Total				$ 498,600
Total Equipment Costs				**$ 498,600**
Installation - % of Equip Costs	40%			$ 145,440
Total with Installation				**$ 644,040**
Electrical & I&C	3%			$ 19,321
Site Work	0%			$ -
Total Capital Cost w/o markups				**$ 663,361**
Contractor Markups	20%			$ 132,672
General Requirements	25%			$ 165,840
Contingencies	35%			$ 290,221
Total Capital Cost w/markups				**$ 1,252,094**

EBMUD - PGS Reliability

Task 11: Compressed Air Dryer Replacement and Added Redundancy

Description: Replace existing compressed air dryer with two new air cooled refrigerant type compressed air dryers capable of drying 200 scfm at 100 psig.

Capital Costs

		Air Compressor Dryer Replacement		
Description	Cost Factors	Cost per unit	No.	Total Cost
Equipment Costs				
Air Dryers		$ 3,550	2	$ 7,100
Misc Access, traps, filters		$ 500	2	$ 1,000
Equipment Total				**$ 8,100**
Demolition		$ 500	1	$ 500
Concrete Pad		$ 750	1	$ 444
Misc Piping and Valves		$ 500	1	$ 500
Total				$ 9,544
Total Equipment Costs				**$ 9,544**
Installation - % of Equip Costs	40%			$ -
Total with Installation				**$ 9,544**
Electrical & I&C	20%			$ 1,909
Site Work	0%			$ -
Total Capital Cost w/o markups				**$ 11,453**
Contractor Markups	20%			$ 2,291
General Requirements	25%			$ 2,863
Market Conditions	15%			$ 1,718
Contingencies	35%			$ 5,813
Total Capital Cost w/markups				**$ 24,138**

EBMUD - PGS Reliability
Task 12: Lube Oil Tank Heater Replacement
Description: Replace exiting 4.5 kW lube oil tank heater with new 6 kW heater.

Capital Costs

		Lube oil tank heater replacement			
Description	Cost Factors	Cost per unit	No.		Total Cost
Equipment Costs					
LO Heater		$ 5,883	1	$	5,883
Equipment Total				**$**	**5,883**
Demolition		$ 500	1	$	500
Misc Piping and Valves					
Total				$	6,383
Total Equipment Costs				**$**	**6,383**
Installation - % of Equip Costs	40%			$	2,353
Total with Installation				**$**	**8,736**
Electrical & I&C	15%			$	1,310
Site Work	0%			$	-
Total Capital Cost w/o markups				**$**	**10,047**
Contractor Markups	20%			$	2,009
General Requirements	25%			$	2,512
Market Conditions	15%			$	1,507
Contingencies	35%			$	5,099
Total Capital Cost w/markups				**$**	**21,173**

EBMUD - PGS Reliability

Task 13: Replace Flare Igniter and Add Weather Hood

Description: Replace existing flare igniter rod with new igniter rod and add weather protection hood.

Capital Costs

		Flare Igniter Replacement		
Description	Cost Factors	Cost per unit	No.	Total Cost
Equipment Costs				
Igniter		5000	2	$ 10,000
Equipment Total				**$ 10,000**
Demolition		$ 1,000	1	$ 1,000
Misc Piping and Valves				
Total				$ 11,000
Total Equipment Costs				**$ 11,000**
Installation - % of Equip Costs	40%			$ 4,000
Total with Installation				**$ 15,000**
Electrical & I&C	10%			$ 1,500
Site Work	0%			$ -
Total Capital Cost w/o markups				**$ 16,500**
Contractor Markups	20%			$ 3,300
General Requirements	25%			$ 4,125
Market Conditions	15%			$ 2,475
Contingencies	35%			$ 8,374
Total Capital Cost w/markups				**$ 34,774**

EBMUD - PGS Reliability

Task 14: Digester Gas Surge Tank Safety Valve Replacement and Clean Tank

Description: Replace existing safety valve with new safety valve on DG Surge tank. Inspect and clean tank interior.

Capital Costs

		DG Surge Tank Safety Valve Replacement		
Description	Cost Factors	Cost per unit	No.	Total Cost
Equipment Costs				
Safety relief valve		5000	1	$ 5,000
Equipment Total				**$ 5,000**
Clean tank		$ 1,000	1	$ 1,000
Misc Piping and Valves				
Total				$ 6,000
Total Equipment Costs				**$ 6,000**
Installation - % of Equip Costs	40%			$ 2,000
Total with Installation				**$ 8,000**
Electrical & I&C	10%			$ 800
Site Work	0%			$ -
Total Capital Cost w/o markups				**$ 8,800**
Contractor Markups	20%			$ 1,760
General Requirements	25%			$ 2,200
Market Conditions	15%			$ 1,320
Contingencies	35%			$ 4,466
Total Capital Cost w/markups				**$ 18,546**

EBMUD - PGS Reliability
Task 15: Boiler Gas Blower Replacement
Description: Replace exiting boiler digester gas blower with new gas blower.

Capital Costs

		Boiler Gas Blower Replacement		
Description	Cost Factors	Cost per unit	No.	Total Cost
Equipment Costs				
Gas Blower		$ 115,000	1	$ 115,000
Equipment Total				**$ 115,000**
Demolition		$ 5,000	1	$ 5,000
Concrete Pad				
Misc Piping and Valves				
Total				$ 120,000
Total Equipment Costs				**$ 120,000**
Installation - % of Equip Costs	40%			$ 46,000
Total with Installation				**$ 166,000**
Electrical & I&C	15%			$ 24,900
Site Work	0%			$ -
Total Capital Cost w/o markups				**$ 190,900**
Contractor Markups	20%			$ 38,180
General Requirements	25%			$ 47,725
Market Conditions	15%			$ 28,635
Contingencies	35%			$ 96,882
Total Capital Cost w/markups				**$ 402,322**

EBMUD - PGS Reliability

Task 16: Waste Heat Exchanger Replacement

Description: Replace tubes and seals for existing Waste Heat Exchangers. Replace piping and valves as necessary to connect new heat exchangers.

Waste Heat Exchanger: 11 mmBtuh, 450 gpm 80 to 130°F, 450 gpm 190 to 140°F

Capital Costs

		Waste Heat HEX Replacement		
Description	Cost Factors	Cost per unit	No.	Total Cost
Equipment Costs				
Waste Heat HEX		$ 91,000	2	$ 182,000
Equipment Total				**$ 182,000**
Demolition		$ 5,000	2	$ 10,000
Misc Piping and Valves		$ 15,000	2	$ 30,000
Total				$ 222,000
Total Equipment Costs				**$ 222,000**
Installation - % of Equip Costs	40%			$ 72,800
Total with Installation				**$ 294,800**
Electrical & I&C	5%			$ 14,740
Site Work	0%			$ -
Total Capital Cost w/o markups				**$ 309,540**
Contractor Markups	20%			$ 61,908
General Requirements	25%			$ 77,385
Market Conditions	15%			$ 46,431
Contingencies	35%			$ 157,092
Total Capital Cost w/markups				**$ 652,356**

EBMUD - PGS Reliability

Task 17: Starting Air Compressor Replacement

Description: Replace exiting air compressors with two new 15 hp reciprocating compressors capable of 45 acfm at 250 psig.

Capital Costs

		Starting Air Compressor Replacement		
Description	Cost Factors	Cost per unit	No.	Total Cost
Equipment Costs				
Air Compressors		$ 6,767	2	$ 13,534
Misc accessories Filters, Moist Sep		$ 1,000	2	$ 2,000
Equipment Total				**$ 15,534**
Demolition		$ 1,000	1	$ 1,000
Concrete Pad		$ 750	1	$ 889
Misc Piping and Valves		$ 1,000	1	$ 1,000
Total				$ 18,423
Total Equipment Costs				**$ 18,423**
Installation - % of Equip Costs	40%			$ -
Total with Installation				**$ 18,423**
Electrical & I&C	10%			$ 1,842
Site Work	0%			$ -
Total Capital Cost w/o markups				**$ 20,265**
Contractor Markups	20%			$ 4,053
General Requirements	25%			$ 5,066
Market Conditions	15%			$ 3,040
Contingencies	35%			$ 10,285
Total Capital Cost w/markups				**$ 42,709**

EBMUD - PGS Reliability

Task 18: Add Redundant Digester Gas Treatment Chiller

Description: Add new chiller in parallel with existing chiller to create redundancy.

Capital Costs

		Add Redundant Chiller		
Description	Cost Factors	Cost per unit	No.	Total Cost
Equipment Costs				
Add Redundant Chiller		$ 280,000	1	$ 280,000
Equipment Total				**$ 280,000**
Demolition		$ 2,000	1	$ 2,000
Misc Piping and Valves		$ 5,000	1	$ 5,000
Total				$ 287,000
Total Equipment Costs				**$ 287,000**
Installation - % of Equip Costs	40%			$ 112,000
Total with Installation				**$ 399,000**
Electrical & I&C	15%			$ 59,850
Site Work	5%			$ 19,950
Total Capital Cost w/o markups				**$ 478,800**
Contractor Markups	20%			$ 95,760
General Requirements	25%			$ 119,700
Market Conditions	15%			$ 71,820
Contingencies	35%			$ 242,991
Total Capital Cost w/markups				**$ 1,009,071**

EBMUD - PGS Reliability
Task 19: PGS1 Gas Compressor Replacement

Description: Replace three exiting digester gas compressors at PGS1 with oil flooded rotary screw type gas compressors. Replace piping and valves as necessary to connect new compressors.
Oil Flooded Rotary Screw: 625 scfm, 70 psig, 150 hp

Capital Costs

		Gas Compressor Replacement		
Description	Cost Factors	Cost per unit	No.	Total Cost
Equipment Costs				
Gas Compressor		$ 798,310	3	$ 2,394,930
Equipment Total				**$ 2,394,930**
Demolition		$ 5,000	3	$ 15,000
Misc Piping and Valves		$ 10,000	3	$ 30,000
Total				$ 2,439,930
Total Equipment Costs				**$ 2,439,930**
Installation - % of Equip Costs	40%			$ 957,972
Total with Installation				**$ 3,397,902**
Electrical & I&C	10%			$ 339,790
Site Work	0%			$ -
Total Capital Cost w/o markups				**$ 3,737,692**
Contractor Markups	20%			$ 747,538
General Requirements	25%			$ 934,423
Market Conditions	15%			$ 560,654
Contingencies	35%			$ 1,896,879
Total Capital Cost w/markups				**$ 7,877,186**

EBMUD - PGS Reliability

Task 20: Modify Boiler Stack & Add Control Panel Cover

Description: Replace boiler stack and add drain. Provide weather cover over control panel.

Capital Costs

		Boiler Stack & CP Cover			
Description	Cost Factors	Cost per unit	No.		Total Cost
Equipment Costs					
		$ -		$	-
Equipment Total				**$**	**-**
Demolition		$ 2,500	1	$	2,500
CP Weather Cover		2,500	1	$	2,500
Boiler Stack Modification		$ 25,000	1	$	25,000
Total				$	30,000
Total Equipment Costs				**$**	**30,000**
Installation - % of Equip Costs	40%			$	-
Total with Installation				**$**	**30,000**
Electrical & I&C	0%			$	-
Site Work	0%			$	-
Total Capital Cost w/o markups				**$**	**30,000**
Contractor Markups	20%			$	6,000
General Requirements	25%			$	7,500
Market Conditions	15%			$	4,500
Contingencies	35%			$	15,225
Total Capital Cost w/markups				**$**	**63,225**

EBMUD - PGS Reliability

Task 21: PGS1 Cooling Loop Heat Exchanger Replacement

Description: Replace tubes and seals for exiting cooling loop heat exchangers. Replace piping and valves as necessary.

Capital Costs

		Cooling HEX Replacement		
Description	Cost Factors	Cost per unit	No.	Total Cost
Equipment Costs				
Cooling HEX		$ 157,500	2	$ 315,000
Equipment Total				**$ 315,000**
Demolition		$ 10,000	2	$ 20,000
Misc Piping and Valves		$ 10,000	2	$ 20,000
Total				$ 355,000
Total Equipment Costs				**$ 355,000**
Installation - % of Equip Costs	40%			$ 126,000
Total with Installation				**$ 481,000**
Electrical & I&C	5%			$ 24,050
Site Work	0%			$ -
Total Capital Cost w/o markups				**$ 505,050**
Contractor Markups	20%			$ 101,010
General Requirements	25%			$ 126,263
Market Conditions	15%			$ 75,758
Contingencies	35%			$ 256,313
Total Capital Cost w/markups				**$ 1,064,393**

EBMUD - PGS Reliability

Task 22: Increase Engine Heat Recovery Pump Pressure

Description: Increase the engine heat recovery pump pressure by replacing pump motor and sheaves to meet new operating conditions.

Capital Costs

		EG HR Pump Mods		
Description	Cost Factors	Cost per unit	No.	Total Cost
Equipment Costs				
Pump modifications		$ 2,000	3	$ 6,000
Equipment Total				**$ 6,000**
Demolition		$ -		$ -
Misc Piping and Valves				
Total				$ 6,000
Total Equipment Costs				**$ 6,000**
Installation - % of Equip Costs	40%			$ 2,400
Total with Installation				**$ 8,400**
Electrical & I&C	5%			$ 420
Site Work	0%			$ -
Total Capital Cost w/o markups				**$ 8,820**
Contractor Markups	20%			$ 1,764
General Requirements	25%			$ 2,205
Market Conditions	15%			$ 1,323
Contingencies	35%			$ 4,476
Total Capital Cost w/markups				**$ 18,588**

EBMUD - PGS Reliability

Task 23: Modify PGS1 Basement HVAC Ductwork

Description: Extend ductwork in the basement of PGS1 to improve heat removal.

Capital Costs

		HVAC Duct Modifications Replacement		
Description	Cost Factors	Cost per unit	No.	Total Cost
Equipment Costs				
		$ -		$ -
Equipment Total				**$ -**
Demolition		$ 1,000	1	$ 1,000
Duct modifications		$ 20,000	1	$ 20,000
Total				$ 21,000
Total Equipment Costs				**$ 21,000**
Installation - % of Equip Costs	40%			$ -
Total with Installation				**$ 21,000**
Electrical & I&C	0%			$ -
Site Work	0%			$ -
Total Capital Cost w/o markups				**$ 21,000**
Contractor Markups	20%			$ 4,200
General Requirements	25%			$ 5,250
Market Conditions	15%			$ 3,150
Contingencies	35%			$ 10,658
Total Capital Cost w/markups				**$ 44,258**

EBMUD - PGS Reliability

Task 24: Engine Exhaust Silencer Replacement

Description: Replace exiting engine exhaust silencers with new hospital grade stainless steel exhaust silencers.

Capital Costs

		Engine Silencer Replacement		
Description	Cost Factors	Cost per unit	No.	Total Cost
Equipment Costs				
Silencers		$ 50,400	3	$ 151,200
Equipment Total				**$ 151,200**
Demolition		$ 2,500	3	$ 7,500
Misc Piping and Valves		$ 2,000	3	$ 6,000
Total				$ 164,700
Total Equipment Costs				**$ 164,700**
Installation - % of Equip Costs	40%			$ 60,480
Total with Installation				**$ 225,180**
Electrical & I&C	10%			$ 22,518
Site Work	0%			$ -
Total Capital Cost w/o markups				**$ 247,698**
Contractor Markups	20%			$ 49,540
General Requirements	25%			$ 61,925
Market Conditions	15%			$ 37,155
Contingencies	35%			$ 125,707
Total Capital Cost w/markups				**$ 522,024**

EBMUD - PGS Reliability

Task 25: Install Engine Detonation Monitoring System

Description: EBMUD provided a quote to provide detonation monitoring. The system monitors cylinder pressure to detect detonation and shuts down the engine before damage. AETC will provide and install and wiring will be done by the contractor.

Capital Costs

		Detonation Control		
Description	Cost Factors	Cost per unit	No.	Total Cost
Equipment Costs				
Detonation Control Quote		$ 125,000	3	$ 375,000
Options		$ 25,000	3	$ 75,000
Equipment Total				**$ 450,000**
Demolition				
Misc Piping and Valves				
Total				$ 450,000
Total Equipment Costs				**$ 450,000**
Installation - % of Equip Costs	0%			$ -
Total with Installation				**$ 450,000**
Electrical & I&C	15%			$ 67,500
Site Work	0%			$ -
Total Capital Cost w/o markups				**$ 517,500**
Contractor Markups	20%			$ 103,500
General Requirements	25%			$ 129,375
Market Conditions	15%			$ 77,625
Contingencies	35%			$ 262,631
Total Capital Cost w/markups				**$ 1,090,631**

EBMUD - PGS Reliability

Task 26: Retrofit MIP Wiring Cabinet With False Floor

Description: Retrofit MIP wiring cabinet with false floor to protect wiring.

Capital Costs

		MIP Cabinet Floor				
Description	Cost Factors	Cost per unit		No.	Total Cost	
Equipment Costs						
		$	-		$	-
Equipment Total					**$**	**-**
Demolition - Cutting holes concrete.		$	-		$	20,000
Total					$	20,000
Total Equipment Costs					**$**	**20,000**
Installation - % of Equip Costs	40%				$	-
Total with Installation					**$**	**20,000**
Electrical & I&C					$	10,000
Site Work	0%				$	-
Total Capital Cost w/o markups					**$**	**30,000**
Contractor Markups	20%				$	6,000
General Requirements	25%				$	7,500
Market Conditions	15%				$	4,500
Contingencies	35%				$	15,225
Total Capital Cost w/markups					**$**	**63,225**

EBMUD - PGS Reliability

Task 27: Relocate Pressure Transmitters

Description: Relocate two pressure indicator transmitters in digester gas piping closer to grade.

Capital Costs

		Relocate PITs in DG Piping				
Description	Cost Factors	Cost per unit		No.	Total Cost	
Equipment Costs						
		$	-		$	-
Equipment Total					**$**	**-**
Demolition		$	500	2	$	1,000
Piping mods		$	1,000	2	$	2,000
Total					$	3,000
Total Equipment Costs					**$**	**3,000**
Installation - % of Equip Costs	40%				$	-
Total with Installation					**$**	**3,000**
Electrical & I&C					$	2,000
Site Work	0%				$	-
Total Capital Cost w/o markups					**$**	**5,000**
Contractor Markups	20%				$	1,000
General Requirements	25%				$	1,250
Market Conditions	15%				$	750
Contingencies	35%				$	2,538
Total Capital Cost w/markups					**$**	**10,538**

EBMUD - PGS Reliability

Task 28: Migrate Controls and Alarms from PGS MIP to DCS

Description: Modify existing controls and alarms to interface with and be controlled by the DCS instead of PGS MIP.

Capital Costs

		MIP to DCS Control/Alarms Migration		
Description	Cost Factors	Cost per unit	No.	Total Cost
Equipment Costs				
		$ -		$ -
Equipment Total				**$ -**
Demolition		$ -		$ -
Piping mods				
Total				$ -
Total Equipment Costs				**$ -**
Installation - % of Equip Costs				
Total with Installation				**$ -**
Electrical & I&C				$ 330,000
Site Work	0%			$ -
Total Capital Cost w/o markups				**$ 330,000**
Contractor Markups	20%			$ 66,000
General Requirements	25%			$ 82,500
Market Conditions	15%			$ 49,500
Contingencies	35%			$ 167,475
Total Capital Cost w/markups				**$ 695,475**

EBMUD - PGS Reliability

Task 29: Add Load Bank Connection

Description: Add load bank connection to help when testing of the engine generators, and add new cubical in switchgear.

Capital Costs

		Load Bank Connection				
Description	Cost Factors	Cost per unit		No.	Total Cost	
Equipment Costs						
New Breaker		$	50,000	1	$	50,000
Equipment Total					**$**	**50,000**
Demolition		$	-		$	-
Piping mods						
Total					$	50,000
Total Equipment Costs					**$**	**50,000**
Installation - % of Equip Costs	40%				$	20,000
Total with Installation					**$**	**70,000**
Electrical & I&C	Included				$	-
Site Work	0%				$	-
Total Capital Cost w/o markups					**$**	**70,000**
Contractor Markups	20%				$	14,000
General Requirements	25%				$	17,500
Market Conditions	15%				$	10,500
Contingencies	35%				$	35,525
Total Capital Cost w/markups					**$**	**147,525**

EBMUD - PGS Reliability
Task 30: Replace Buried HPDG at PGS2

Description: Replace existing buried HPDG piping from PGS2 digester gas compressor to PGS2 turbine-generator with above ground 6" schedule 40, stainless steel pipe.

Capital Costs

		HPDG Pipe Replacement				
Description	Cost Factors	Cost per unit		No.	Total Cost	
Equipment Costs						
Pipe Flexibility		$	5,000	2	$	10,000
Auto Condensate Trap		$	5,000	1	$	5,000
Equipment Total					**$**	**15,000**
Demolition		$	20,000	1	$	20,000
Concrete Pad		$	750	10	$	7,500
Misc Piping and Valves		$	40,000	1	$	40,000
Total					$	82,500
Total Equipment Costs					**$**	**82,500**
Installation - % of Equip Costs	40%				$	6,000
Total with Installation					**$**	**88,500**
Electrical & I&C	0%				$	-
Site Work	5%				$	4,425
Total Capital Cost w/o markups					**$**	**92,925**
Contractor Markups	20%				$	18,585
General Requirements	25%				$	23,231
Market Conditions	15%				$	13,939
Contingencies	35%				$	47,159
Total Capital Cost w/markups					**$**	**195,839**

EBMUD - PGS Reliability
Task 31: PGS Building Seismic Modifications
Description: PGS building will be seismicly modified based on 10% design by Consultant.

Capital Costs

		PGS Building Seismic Modifications		
Description	Cost Factors	Cost per unit	No.	Total Cost
Equipment Costs				
Building Modifications		$ 170,000	1	$ 170,000
Equipment Total				**$ 170,000**
Demolition		$ -		$ -
Concrete Pad				
Misc Piping and Valves				
Total				$ 170,000
Total Equipment Costs				**$ 170,000**
Installation - % of Equip Costs	40%			$ 68,000
Total with Installation				**$ 238,000**
Electrical & I&C	0%			$ -
Site Work	0%			$ -
Total Capital Cost w/o markups				**$ 238,000**
Contractor Markups	20%			$ 47,600
General Requirements	25%			$ 59,500
Market Conditions	15%			$ 35,700
Contingencies	35%			$ 120,785
Total Capital Cost w/markups				**$ 501,585**

EBMUD - PGS Reliability

Task 32: Standby Engine-Generator Replacement

Description: New generator shall be sized to start one Engine-Generator. Existing electrical equipment is limited to 800 kW. New unit will be located in the same location as the existing unit.

Capital Costs

		New Standby Generator				
Description	Cost Factors	Cost per unit		No.	Total Cost	
Equipment Costs						
Standby Diesel Generator		$	375,000	1	$	375,000
Equipment Total					**$**	**375,000**
Demolition		$	1,000	1	$	1,000
Concrete Pad		$	750	5	$	4,000
Concrete Pile		$	14,000	6	$	84,000
Misc Piping and Valves		$	2,000	1	$	2,000
Total					$	466,000
Total Equipment Costs					**$**	**466,000**
Installation - % of Equip Costs	40%				$	150,000
Total with Installation					**$**	**616,000**
Electrical & I&C	15%				$	92,400
Site Work	5%				$	30,800
Total Capital Cost w/o markups					**$**	**739,200**
Contractor Markups	20%				$	147,840
General Requirements	25%				$	184,800
Market Conditions	15%				$	110,880
Contingencies	35%				$	375,144
Total Capital Cost w/markups					**$**	**1,557,864**

EBMUD - PGS Reliability

Task 33: Add Turbine Generator Lube Oil Radiator

Description: Add new radiator for cooling a the Turbine Generator Lube Oil. New lube oil radiator will cool the lube oil when needed.

Lube Oil Radiator: 0.502 mmBtuh, 60 gpm, 183-150°F

Capital Costs

		Lube Oil Radiator Addition				
Description	Cost Factors	Cost per unit		No.	Total Cost	
Equipment Costs						
Lube Oil Radiator		$	25,000	1	$	25,000
Equipment Total					**$**	**25,000**
Demolition		$	5,000	2	$	10,000
Concrete Pad		$	750	4	$	2,722
Concrete Pile		$	14,000	4	$	56,000
Misc Piping and Valves		$	5,000	2	$	10,000
Total					$	103,722
Total Equipment Costs					**$**	**103,722**
Installation - % of Equip Costs	40%				$	10,000
Total with Installation					**$**	**113,722**
Electrical & I&C	10%				$	11,372
Site Work	0%				$	-
Total Capital Cost w/o markups					**$**	**125,094**
Contractor Markups	20%				$	25,019
General Requirements	25%				$	31,274
Market Conditions	15%				$	18,764
Contingencies	35%				$	63,485
Total Capital Cost w/markups					**$**	**263,637**

Appendix B. Equipment Data Summary

EQUIPMENT DATA								
EQUIPMENT NAME	LOCATION	TAG NO'S	EQUIPMENT DESCRIPTION	MANUFACTURER	MODEL	DATE/PROJECT INSTALLED	Equipment Design and Operation Parameters	NOTES
Engine Generators								
Engine No. 1	PGS1	W-28-ENG-001-01		Delaval Enterprise	DGSR-46	Dec 1983/SD135	Power Output: 2,153 kW Voltage: 4,160 Phase: 3 Frequency: 60 Hz Speed: 450 RPM Specific Fuel Consumption at 100% Load: 6,450 BTU/BHP-hr DG Consumption at 100% Load: 521 cfm Air Consumption at 100% Load: 6,000 scfm Maximum DG Consumption: 620 scfm Maximum Waste Heat: 11,259,000 BTU/hr Bore: 17" Stroke: 21" Power: 2,980.3 hp @ 450 rpm	Out of scope
Jacket Water Heat Exchanger No. 1	PGS1-Basement	W-28-HEX-001-01		American Standard Heat Transfer Division	5-046-15-162-004	Dec 1983/SD135	Shell Side/Tube Side: 600/300 gpm Temperature in: 185/146°F Temperature Out: 175/167°F Heat Exchange Rate: 3,100,000 BTU/HR Maximum Temperature: Shell Side/Tube Side: 300°F/300°F Maximum Pressure: Shell Side/Tube Side: 125 psig/125 psig Shell ID: 15 inch Lube Length: 162 inches	
Intercooler No. 1	PGS1					Dec 1983/SD135	Shell Side/Tube Side: 400 gpm/6,250 cfm Temperature in: 80/300°F Temperature Out: 90/100°F Heat Exchange Rate: 1,350,000 BTU/HR	Failing. Need replaced.
Lube Oil Cooler No. 1	PGS1-Basement	W-28-HEX-001-03		American Standard Heat Transfer Division	5-046-12-162-007	Dec 1983/SD135	Shell Side/Tube Side: Flow: 275/300 gpm Temperature in: 175/140°F Temperature Out: 158/146°F Maximum Temperature: 300°F/300°F Maximum Pressure: 125 psig/125 psig Heat Exchange Rate:914,600 BTU/HR Shell ID: 12 inch Lube Length: 162 inches	Retubed in 2014/2015. HEX failing
Lube Oil (Before & After) Pump No. 1	PGS1			Transamerican Delaval INC	G3DH-128	Dec 1983/SD135	Speed: 1150 RPM Flows: 415 gpm @ 150 SSU & 44.7 gpm @ 5000 SSU Power: 1.4 BHP @ 150 SSU & 4.2 BHP @ 5000 SSU Rotation: Clockwise Motor Size: 5 hp	
Exhaust Heat Recover No. 1	PGS1			Maxim Silencer Inc.	WVS 3365-24	Dec 1983/SD135	Air Side/Tube Side: ?/300 gpm Temperature in: 900/167°F Temperature Out: 350-364/190-205°F Heat Exchange Rate: 3,566,600 BTU/HR - 3,923,000 BTU/HR Maximum Pressure & Temp: 60 psi @ 500°F Minimum Metal Temp: 10°F @ 60 psig Diameter: 275 inch	Replaced in 2013. OK
Hot Water Circulating Pump No. 1	PGS1		Horizontal, single-stage, end-suction	Ingersoll-Dresser Pumps, Worthington	D 814 4x3x8	Dec 1983/SD135	Speed: 1750 RPM Flow: 300 gpm TDH: 55 feet Minimum Efficiency: 75% Maximum Temp: 200°F Motor Size: 7.5 hp Maximum Pressure: 175 psig Suction/Discharge: 4 inch/3 inch Impeller: 8 inch	Higher pressure size installing HRU. Upsize pump by replacing impeller and motor.
Exhaust Silencer 1				Maxim Silencer Inc.	MT-31	Dec 1983/SD135	Type: End in/End out Inlet/Outlet Size: 24/24 inch Diameter: 5 ft Length: 13 ft - 6 inch	No internals

EQUIPMENT DATA								
EQUIPMENT NAME	LOCATION	TAG NO'S	EQUIPMENT DESCRIPTION	MANUFACTURER	MODEL	DATE/PROJECT INSTALLED	Equipment Design and Operation Parameters	NOTES
Engine No. 2	PGS1	W-28-ENG-002-01		Delaval Enterprise	DGSR-46	12/15/1982 SD 135	Power Output: 2,153 kW Voltage: 4,160 Phase: 3 Frequency: 60 Hz Speed: 450 RPM Specific Fuel Consumption at 100% Load: 6,450 BTU/BHP-hr DG Consumption at 100% Load: 521 cfm Air Consumption at 100% Load: 6,000 scfm Maximum DG Consumption: 620 scfm Maximum Waste Heat: 11,259,000 BTU/hr Bore: 17" Stroke: 21" Power: 2,980.3 hp @ 450 rpm	Out of scope
Jacket Water Heat Exchanger No. 2	PGS1	W-28-HEX-002-01		American Standard Heat Transfer Division	5-046-15-162-004	Dec 1983/SD135	Shell Side/Tube Side: 600/300 gpm Temperature in: 185/146°F Temperature Out: 175/167°F Heat Exchange Rate: 3,100,000 BTU/HR Maximum Temperature: Shell Side/Tube Side: 300°F/300°F Maximum Pressure: Shell Side/Tube Side: 125 psig/125 psig Shell ID: 15 inch Lube Length: 162 inches	
Intercooler No. 2	PGS1					Dec 1983/SD135	Shell Side/Tube Side: 400 gpm/6,250 cfm Temperature in: 80/300°F Temperature Out: 90/100°F Heat Exchange Rate: 1,350,000 BTU/HR	Failing. Need Replaced
Lube Oil Cooler No. 2	PGS1			American Standard Heat Transfer Division	5-046-12-162-007	Dec 1983/SD135	Shell Side/Tube Side: Flow: 275/300 gpm Temperature in: 175/140°F Temperature Out: 158/146°F Maximum Temperature: 300°F/300°F Maximum Pressure: 125 psig/125 psig Heat Exchange Rate:914,600 BTU/HR Shell ID: 12 inch Lube Length: 162 inches	Needs to be retubed HEX Failing
Lube Oil (Before & After) Pump No. 2	PGS1			Transamerican Delaval INC	G3DH-128	Dec 1983/SD135	Speed: 1150 RPM Flows: 415 gpm @ 150 SSU & 44.7 gpm @ 5000 SSU Power: 1.4 BHP @ 150 SSU & 4.2 BHP @ 5000 SSU Rotation: Clockwise Motor Size: 5 hp	
Exhaust Heat Recover No. 2	PGS1			Maxim Silencer Inc.	WVS 3365-24	Dec 1983/SD135	Air Side/Tube Side: ?/300 gpm Temperature in: 900/167°F Temperature Out: 350-364/190-205°F Heat Exchange Rate: 3,566,600 BTU/HR - 3,923,000 BTU/HR Maximum Pressure & Temp: 60 psi @ 500°F Minimum Metal Temp: 10°F @ 60 psig Diameter: 275 inch	Replaced in 2013. OK
Hot Water Circulating Pump No. 2	PGS1			Ingersoll-Dresser Pumps, Worthington	D 814 4x3x8	Dec 1983/SD135	Speed: 1750 RPM Flow: 300 gpm TDH: 55 feet Minimum Efficiency: 75% Maximum Temp: 200°F Motor Size: 7.5 hp Maximum Pressure: 175 psig Suction/Discharge: 4 inch/3 inch Impeller: 8 inch	Higher pressure size installing HRU. Upsize pump by replacing impeller and motor.
Exhaust Silencer 2				Maxim Silencer Inc.	MT-31	Dec 1983/SD135	Type: End in/End out Inlet/Outlet Size: 24/24 inch Diameter: 5 ft Length: 13 ft - 6 inch	No internals

EQUIPMENT DATA								
EQUIPMENT NAME	LOCATION	TAG NO'S	EQUIPMENT DESCRIPTION	MANUFACTURER	MODEL	DATE/PROJECT INSTALLED	Equipment Design and Operation Parameters	NOTES
Engine No. 3	PGS1	W-28-ENG-003-01		Delaval Enterprise	DGSR-46	Dec 1983/SD135	Power Output: 2,153 kW Voltage: 4,160	Out of scope
Jacket Water Heat Exchanger No. 3	PGS1	W-28-HEX-003-01		American Standard Heat Transfer Division	5-046-15-162-004	Dec 1983/SD135	Shell Side/Tube Side: 600/300 gpm Temperature in: 185/146°F Temperature Out: 175/167°F Heat Exchange Rate: 3,100,000 BTU/HR Maximum Temperature: Shell Side/Tube Side: 300°F/300°F Maximum Pressure: Shell Side/Tube Side: 125 psig/125 psig Shell ID: 15 inch Lube Length: 162 inches	Recent tube leaks. Sent out for repair. Plug leaking tubes
Intercooler No. 3	PGS1					Dec 1983/SD135	Shell Side/Tube Side: 400 gpm/6,250 cfm Temperature in: 80/300°F Temperature Out: 90/100°F Heat Exchange Rate: 1,350,000 BTU/HR	Failing. Need replaced.
Lube Oil Cooler No. 3	PGS1			American Standard Heat Transfer Division	5-046-12-162-007	Dec 1983/SD135	Shell Side/Tube Side: Flow: 275/300 gpm Temperature in: 175/140°F Temperature Out: 158/146°F Maximum Temperature: 300°F/300°F Maximum Pressure: 125 psig/125 psig Heat Exchange Rate:914,600 BTU/HR Shell ID: 12 inch Lube Length: 162 inches	Needs to be retubed. HEX Failing
Lube Oil (Before & After) Pump No. 3	PGS1			Transamerican Delaval INC	G3DH-128	Dec 1983/SD135	Speed: 1150 RPM Flows: 415 gpm @ 150 SSU & 44.7 gpm @ 5000 SSU Power: 1.4 BHP @ 150 SSU & 4.2 BHP @ 5000 SSU Rotation: Clockwise Motor Size: 5 hp	
Exhaust Heat Recover Silencer No. 3	PGS1			Maxim Silencer Inc.	WVS 3365-24	Dec 1983/SD135	Air Side/Tube Side: ?/300 gpm Temperature in: 900/167°F Temperature Out: 350-364/190-205°F Heat Exchange Rate: 3,566,600 BTU/HR - 3,923,000 BTU/HR Maximum Pressure & Temp: 60 psi @ 500°F Minimum Metal Temp: 10°F @ 60 psig Diameter: 275 inch	Replaced in 2013
Hot Water Circulating Pump No. 3	PGS1			Ingersoll-Dresser Pumps, Worthington	D 814 4x3x8	Dec 1983/SD135	Speed: 1750 RPM Flow: 300 gpm TDH: 55 feet Minimum Efficiency: 75% Maximum Temp: 200°F Motor Size: 7.5 hp Maximum Pressure: 175 psig Suction/Discharge: 4 inch/3 inch Impeller: 8 inch	Higher pressure size installing HRU. Upsize pump by replacing impeller and motor.
Exhaust Silencer 3				Maxim Silencer Inc.	MT-31	Dec 1983/SD135	Type: End in/End out Inlet/Outlet Size: 24/24 inch Diameter: 5 ft Length: 13 ft - 6 inch	No internals
Standby Engine-Generator	Outdoors					Nov 1991/SD189A	Voltage: 480 Phase: 3 Frequency: 60 hz Power Output: 150 kW/187.5 kVA Power Factor: 0.8	Out of scope

EQUIPMENT DATA								
EQUIPMENT NAME	LOCATION	TAG NO'S	EQUIPMENT DESCRIPTION	MANUFACTURER	MODEL	DATE/PROJECT INSTALLED	Equipment Design and Operation Parameters	NOTES
Engine Accessories								
Air Compressor 1 (Starting)	PGS1		Vertical Two-stage Single Acting Air Cooled	Original: Ingersoll-Rand New: Quincy	Original: New: 390	Original: Dec 1983/SD135 New: Nov 1991/SD189A	Original: Maximum Discharge Pressure: 250 psig Minimum Flow: 14 scfm Compressor Speed: 600 rpm Belt Service Factor: 1.5 Minimum Motor Size: 7.5 hp New: Motor Size: 20 hp Flow: 45 ACFM Pressure: 250 psig Speed: 1760 rpm Size: 7.5x4x4	No major overhaul, repaired failed head, replace.
Air Compressor 2 (Starting)	PGS1		Vertical Two-stage Single Acting Air Cooled	Original: Ingersoll-Rand New: Quincy	Original: New: 390	Original: Dec 1983/SD135 New: Nov 1991/SD189A	Original: Maximum Discharge Pressure: 250 psig Minimum Flow: 14 scfm Compressor Speed: 600 rpm Belt Service Factor: 1.5 Minimum Motor Size: 7.5 hp New: Motor Size: 20 hp Flow: 45 ACFM Pressure: 250 psig Speed: 1760 rpm Size: 7.5x4x4	No major overhaul, repaired failed head, replace.
Air Receiver 1 (Starting)		AR-1	Vertical, Steel	Roy E. Hanson Jr. MFG.	RT-4	Dec 1983/SD135	Material: Steel ASTM A 516 Capacity: 250 gal Volume: 33 ft3 Gross Volume: 240 gal Diameter: 33 inch Height: 7 ft Operating Pressure: 250 psig Maximum Pressure: 275 psig Maximum Temp: 450°F Shell: 0.3125 SA515-70 Head: 0.3125 SA515-70	Inspected every 5 years. No issues
Air Receiver 2 (Starting)		AR-2	Vertical, Steel	Roy E. Hanson Jr. MFG.	RT-4	Dec 1983/SD135	Material: Steel ASTM A 516 Capacity: 250 gal Volume: 33 ft3 Gross Volume: 240 gal Diameter: 33 inch Height: 7 ft Operating Pressure: 250 psig Maximum Pressure: 275 psig Maximum Temp: 450°F Shell: 0.3125 SA515-70 Head: 0.3125 SA515-70	Inspected every 5 years. No issues
Air Receiver 3 (Starting)		AR-3					Capacity: 400 gallon Operating Pressure: 250 psig	
Air Receiver 4 (Starting)		AR-4				Nov 1991/SD189A	Capacity: 1350 gallon Operating Pressure: 250 psig Diameter: 5 ft - 6 in Height: 9'-0"	
Compressed Air Dryer								Air not dry, dryer is too small. Needs upgraded.
PGS1 Bldg Ventilation						Dec 1983/SD135	Fan Speed: 1,100 RPM Minimum Capacity: 30,000 cfm Static Pressure: 2.5 in wc Number of Fans: 4 Maximum Motor Size: 25 hp Motor Voltage: 460 V Phase: 3 Frequency: 60 hz Motor Speed: 1,800 RPM Basement Register Flow: 1,440 CFM Number of Basement Registers: 9	Not enough ventilation in basement, often gets hot.

EQUIPMENT DATA								
EQUIPMENT NAME	LOCATION	TAG NO'S	EQUIPMENT DESCRIPTION	MANUFACTURER	MODEL	DATE/PROJECT INSTALLED	Equipment Design and Operation Parameters	NOTES
Turbine Generator	PGS2	W28-TRB-101				Jan 2009/SD 317A		Not is scope
Heat Recovery Unit No. 1	PGS2					Jan 2009/SD 317A	Air Side/Tube Side: Flow: 143,366-127,688/265,000 lb/hr Ambient Temp: 59-100°F Temperature in: 724-756/140°F Temperature Out: 350-364/190°F Pressure Loss: 12 in wc/6 psig Heat Exchange Rate: 13,250,000 BTU/HR	Leak at joints when stopped
Hot Water Pump No. 1	PGS2	W28-HWP-PMP-101	ANSI Horizontal End Suction	Flowserve	MK3 STD 2K6X4-13ARV/12.25	Jan 2009/SD317A	Speed Maximum/Minimum:1800 RPM/1150 RPM Flow: 550 gpm TDH: 105 feet NPSHa: 27 feet Minimum Efficiency: 67% Suction/Discharge: 6 inch/4 inch Material: Ductile Iron Drive: Direct Coupled Motor Motor Size: 20 hp Maximum Pressure: 250 psig Maximum Impeller: 13 inch Actual Impeller: 12.25 inch Material: Ductile Iron Motor Speed: 1180 RPM	No redundancy
Turbine Generator Oil Cooler	PGS2	W28-CWS-HXR-L01				Jan 2009/SD 317A		No issues, ordered a new unit.
Turbine Compressor Oil Cooler	PGS2	W28-CWS-HXR-L01				Jan 2009/SD 317A	Shell Side/Tube Side: Temperature in: ?/85-125°F Temperature Out: ?/95-135°F Maximum Pressure Loss: 5/5 psi Heat Exchange Rate: 127,815 BTU/HR	

EQUIPMENT DATA								
EQUIPMENT NAME	LOCATION	TAG NO'S	EQUIPMENT DESCRIPTION	MANUFACTURER	MODEL	DATE/PROJECT INSTALLED	Equipment Design and Operation Parameters	NOTES
Boiler	Outdoors	W28-HHW-BLR-B01	Firetube Boiler	Cleaver Brooks	4WI-700-500-125HW CB-LE	Jan 2005/SD-275	Maximum Fuel Consumption: 20,925,000 BTU/HR Gross Output: 16,000,000 BTU/HR Digester Gas HHV: 500-600 BTU/ft3 Maximum Pressure: 125 psig Blower Motor: 30 hp Hot Water Output: 16,736,000 BTU/HR Boiler Capacity: 500 hp Water Flow: 640 gpm Water Temperature In/Out: 148°F/198°F Pressures Design/Operating/Rated: 60 psig/35 psig/50 psig Burner Turndown: 4 to 1 Minimum Efficiency: 81% Noise @ 5 ft: 84 dBA Exhaust emissions as NOx: 15 ppm	Gas train safety valve failure. Boiler has leaking issue. Pneumatic valve won't fully close and cause an after burn. Need to close valve manually. Control panel needs protection from weather. Add weather hood.
Boiler Hot Water Recirculation Pump	Outdoors	W28-HHW-PMP-BO1 (P01010)	Flex Coupled End Suction Centrifugal	American March	300 3X4-7RE	Original: May 2003/SD274 New: Jan 2005/SD275	Original: Flow: 400 gpm TDH: 35 ft NPSHa: 30 ft Maximum Temperature Range: 150-220°F Minimum Efficiency: 77% Suction/Discharge: 4 inch/3 inch Maximum Speed: 1800 RPM Maximum Motor Size: 5 hp New: Speed: 1750 RPM Motor Size: 7.5 hp Impeller Diameter: 6.75 inch	
Boiler Hot Water Recirculation Pump	Outdoors	W28-HHW-PMP-BO2 (P01020)	Flex Coupled End Suction Centrifugal	American March	300 3X4-7RE	Original: May 2003/SD274 New: Jan 2005/SD275	Original: Flow: 400 gpm TDH: 35 ft NPSHa: 30 ft Maximum Temperature Range: 150-220°F Minimum Efficiency: 77% Suction/Discharge: 4 inch/3 inch Maximum Speed: 1800 RPM Maximum Motor Size: 5 hp New: Speed: 1750 RPM Motor Size: 7.5 hp Impeller Diameter: 6.75 inch	

EQUIPMENT DATA								
EQUIPMENT NAME	LOCATION	TAG NO'S	EQUIPMENT DESCRIPTION	MANUFACTURER	MODEL	DATE/PROJECT INSTALLED	Equipment Design and Operation Parameters	NOTES
PGS1 Effluent Cooling (3W)								
Cooling Loop (Heat Loop) Pump No. 1	PGS1	W28-CCL-PMP-P01 (W-28-PMP-001-10)		Bell & Gossett	Series 80 5x5x9.5	Original: SD179 New: Jan 2005/SD275	Original: Speed: 1750 RPM Suction/Discharge:5 inch/5 inch Flow: 650 gpm New: Flow: 975 gpm Motor Size: 20 hp Pump Speed: 1750 RPM Maximum Pressure: 175 psig Maximum Motor Speed: 1765 RPM	Installed 1989 and modified in 2005
Cooling Loop (Heat Loop) Pump No. 2	PGS1	W28-CCL-PMP-P02 (W-28-PMP-002-10)		Bell & Gossett	Series 80 5x5x9.5	Original: SD179 New: Jan 2005/SD275	Original: Speed: 1750 RPM Suction/Discharge:5 inch/5 inch Flow: 650 gpm New: Flow: 975 gpm Motor Size: 20 hp Pump Speed: 1750 RPM Maximum Pressure: 175 psig Maximum Motor Speed: 1765 RPM	Installed 1989 and modified in 2005
PGS Cooling Loop Heat Exchanger No. 1	PGS1	W28-CCL-HEX-H01 (W-28-HEX-001-05)	Shell and tube with straight tubes, two pass	Bell & Gossett	Original: OC 2810-28 PN 5-045-28-125-001 New: OC 2815-28 PN 5-045-28-185-001	Original: SD179 New: Jan 2005/SD275	Original Diameter: 28 inch Tube Length: 10'-0" Shell Side/Tube Side: Flow: 650 gpm/940 gpm Inlet Temperature: 101°F/80°F Outlet Temperature: 90.5°F/87°F Heat Load: 3,412,500 BTU/HR New Diameter: 28 inch Tube Length: 15'-0" Shell Side/Tube Side: Flow: 975 gpm/? gpm Inlet Temperature: 101°F/80°F Outlet Temperature: 90.5°F/87°F	Installed 1989 and modified in 2005; Short Circuiting
PGS Cooling Loop Heat Exchanger No. 2	PGS1	W28-CCL-HEX-H02 (W-28-HEX-002-05)	Shell and tube with straight tubes, two pass	Bell & Gossett	Original: OC 2810-28 PN 5-045-28-125-001 New: OC 2815-28 PN 5-045-28-185-001	Original: SD179 New: Jan 2005/SD275	Original Diameter: 28 inch Tube Length: 10'-0" Shell Side/Tube Side: Flow: 650 gpm/940 gpm Inlet Temperature: 101°F/80°F Outlet Temperature: 90.5°F/87°F Heat Load: 3,412,500 BTU/HR New Diameter: 28 inch Tube Length: 15'-0"	Installed 1989 and modified in 2005; Short Circuiting
No. 3 Water Cooling Pumps No. 1	PGS1 Basement	W-28-3W-PMP-P01 (W-28-PMP-001-03)	Horizontal Split Case	American-Marsh Pumps	HD RH 6X8-12	Original: Dec 1983/SD135 New: Jan 2005/SD275	Speed: 1750 RPM Flow: 1500 gpm TDH: 110 feet NPSH: 39 feet Minimum Efficiency: 73% Suction/Discharge: 8 inch/6 inch Motor Size: 60 hp	Installed 1985 and replaced in 2005
No. 3 Water Cooling Pumps No. 2	PGS1 Basement	W-28-3W-PMP-P02 (W-28-PMP-002-03)	Horizontal Split Case	American-Marsh Pumps	HD RH 6X8-12	Original: Dec 1983/SD135 New: Jan 2005/SD275	Speed: 1750 RPM Flow: 1500 gpm TDH: 110 feet NPSH: 39 feet Minimum Efficiency: 73% Suction/Discharge: 8 inch/6 inch Motor Size: 60 hp	Installed 1985 and replaced in 2005

EQUIPMENT DATA								
EQUIPMENT NAME	LOCATION	TAG NO'S	EQUIPMENT DESCRIPTION	MANUFACTURER	MODEL	DATE/PROJECT INSTALLED	Equipment Design and Operation Parameters	NOTES
No. 3 Water Cooling Pumps No. 3	PGS1 Basement	W-28-3W-PMP-P03 (W-28-PMP-003-03)	Horizontal Split Case	American-Marsh Pumps	HD RH 6X8-12	Original: Dec 1983/SD135 New: Jan 2005/SD275	Speed: 1750 RPM Flow: 1500 gpm TDH: 110 feet NPSH: 39 feet Minimum Efficiency: 73% Suction/Discharge: 8 inch/6 inch Motor Size: 60 hp	Installed 1985 and replaced in 2005
Waste Heat Exchanger No. 1	PGS1 Basement	W-28-HEX-001-04	Shell and tube with straight tubes	Basco	20216-2 pass, Type: OP (TEMA AEW)	Dec 1983/SD135 replace in 2004	Shell Side/Tube Side: 450/450 gpm Temperature in: 190/80°F Temperature Out: 140/130°F Maximum Temperature: 300°F Minimum Temperature: -20°F Pressure drop: 6.7/1.5 psi Maximum Pressure: 125 psig Heat Exchange Rate: 10,957,000 BTU/HR Fouling Factor: 0.001/0.002	Installed 1985 and replaced in 2005; Past their useful life.
Waste Heat Exchanger No. 2	PGS1 Basement	W-28-HEX-002-04	Shell and tube with straight tubes	Basco	20216-2 pass, Type: OP (TEMA AEW)	Dec 1983/SD135 replace in 2006	Shell Side/Tube Side: 450/450 gpm Temperature in: 190/80°F Temperature Out: 140/130°F Maximum Temperature: 300°F Minimum Temperature: -20°F Pressure drop: 6.7/1.5 psi Maximum Pressure: 125 psig Heat Exchange Rate: 10,957,000 BTU/HR Fouling Factor: 0.001/0.002	Installed 1985 and replaced in 2005; Past their useful life.
Engine Remote Radiator, RT-1	PGS1 Outdoors	RT-1	Horizontal core vertical air flow radiator	Young	SP-HC316V50 PN XM13170	SD 189A (1993)	Air Side/Tube Side: Flow: 140,500 scfm/300 gpm Temperature in: 85-70/190°F Temperature Out: ?/140°F Heat Exchange Rate: 12,384,000-10,675,860 BTU/HR Motor size: 50 hp Motor Voltage: 460 Motor Phase: 3 Motor Frequency: 60 hz Type: TEFC	Leaking
Intercooler Remote Radiator, RT-2	PGS1 Outdoors	RT-2	Horizontal core vertical air flow radiator		SP-HC316V50 PN XM13170	Nov 1991/SD189A	Air Side/Tube Side: Flow: 140,500 scfm/650 gpm Temperature in: 85-70/95°F Temperature Out: ?/91.5°F Heat Exchange Rate: 2,580,000-1,016,750 BTU/HR Motor size: 50 hp Motor Voltage: 460 Motor Phase: 3 Motor Frequency: 60 hz Type: TEFC	Replaced 4-5 years ago. Leak last couple of weeks. Bullet hole fixed.
Engine Cooling Radiator Pump (Cooling Water Pump) No. 1, CWP-1	PGS1 Outdoors	CWP-1	Horizontal, single-stage, end-suction	Peerless Pump	F1 1025AM	Nov 1991/SD189A	Capacity: 300 gpm Head: 85 ft $NPSH_A$: 6 ft Fluid Temp: 190°F Motor Speed: 1760 RPM Motor Voltage: 460 Motor Phase: 3 Motor Frequency: 60 hz Type: TEFC Motor Size: 10 hp	
Engine Cooling Radiator Pump (Cooling Water Pump) No. 2, CWP-2	PGS1 Outdoors	CWP-2	Horizontal, single-stage, end-suction	Peerless Pump	F1 1025AM	Nov 1991/SD189A	Capacity: 300 gpm Head: 85 ft $NPSH_A$: 6 ft Fluid Temp: 190°F Motor Speed: 1760 RPM Motor Voltage: 460 Motor Phase: 3 Motor Frequency: 60 hz Type: TEFC Motor Size: 10 hp	

EQUIPMENT DATA								
EQUIPMENT NAME	LOCATION	TAG NO'S	EQUIPMENT DESCRIPTION	MANUFACTURER	MODEL	DATE/PROJECT INSTALLED	Equipment Design and Operation Parameters	NOTES
PGS2 Effluent Cooling (3W)								
Cooling Water Loop Pump No. 1	Outdoors	W28-CWS-PMP-102	ANSI Horizontal End Suction	Flowserve	MK3 STD 2K4X3-13RV/11.00	Jan 2009/SD317A	Flow Rated/Minimum: 375 gpm/113.9 gpm TDH Rated/Maximum: 105 ft/111.2 ft NPSHr: 4.9 ft NPSHa: 27 ft Motor Size: 20 hp Maximum Pressure: 247.8 psig Impeller Diameter Rated/Maximum/Minimum: 10.63 in/13.0 in/9.5 in Pump Speed: 1750 RPM Suction/Discharge: 4 in/3 in Material: Ductile Iron Maximum Motor Speed: 1,765 RPM Drive: Direct Coupled Motor Efficiency at Rated Flow: 65%	
Cooling Water Loop Pump No. 2	Outdoors	W28-CWS-PMP-202	ANSI Horizontal End Suction	Flowserve	MK3 STD 2K4X3-13RV/11.00	Jan 2009/SD317A	Flow Rated/Minimum: 375 gpm/113.9 gpm TDH Rated/Maximum: 105 ft/111.2 ft NPSHr: 4.9 ft NPSHa: 27 ft Motor Size: 20 hp Maximum Pressure: 247.8 psig Impeller Diameter Rated/Maximum/Minimum: 10.63 in/13.0 in/9.5 in Pump Speed: 1750 RPM Suction/Discharge: 4 in/3 in Material: Ductile Iron Maximum Motor Speed: 1,765 RPM Drive: Direct Coupled Motor Efficiency at Rated Flow: 65%	
PGS 2 Cooling Loop Heat Exchanger No. 1	Outdoors	W28-CWS-HEX-101	Shell and Tube 2 Pass Straight-Tube	Bell & Gossett	C(3)2412-312	Jan 2009/SD317A	Maximum Pressure: 150 psig Maximum Temperature: 375°F Minimum Temperature: -20°F Shell Side/Tube Side: Flow: 752.1 gpm/825 gpm Temperature In: 106°F/80°F Temperature Out: 95°F/90°F Velocity: 3.3/3.4 ft/sec Pressure Drop: 7.5 psi/1.2 psi Heat Load: 4,105,401 BTU/HR Fouling Factor: 0.001/0.002	
PGS 2 Cooling Loop Heat Exchanger No. 2	Outdoors	W28-CWS-HEX-201	Shell and Tube 2 Pass Straight-Tube	Bell & Gossett	C(3)2412-312	Jan 2009/SD317A	Maximum Pressure: 150 psig Maximum Temperature: 375°F Minimum Temperature: -20°F Shell Side/Tube Side: Flow: 752.1/825 gpm Temperature In: 106/80°F Temperature Out: 95/90°F Velocity: 3.3/3.4 ft/sec Pressure Drop: 7.5/1.2 psi Heat Load: 4,105,401 BTU/HR Fouling Factor: .001/.002	

EQUIPMENT DATA								
EQUIPMENT NAME	LOCATION	TAG NO'S	EQUIPMENT DESCRIPTION	MANUFACTURER	MODEL	DATE/PROJECT INSTALLED	Equipment Design and Operation Parameters	NOTES
PGS2 No. 3 Water Pumps No. 1	PGS1	W28-CWS-PMP-101	ANSI Horizontal End Suction	Flowserve	MK3 STD 2K6X4-10HRV/7.75	Jan 2009/SD317A	Flow Rated/Minimum: 825 gpm/171.2 gpm TDH Rated/Maximum: 45 ft/57.2 ft NPSHr: 13.9 ft NPSHa: 22 ft Motor Size: 15 hp Maximum Pressure: 250 psig Impeller Diameter Rated/Maximum/Minimum: 7.69 in/10.0 in/6.5 in Suction/Discharge: 6 inch/4 inch Motor Speed: 1,765 RPM Minimum Efficiency: 72% Material: Ductile Iron Drive: Motor with VFD Maximum Pressure: 250 psig	
PGS2 No. 3 Water Pumps No. 2	PGS1	W28-CWS-PMP-201	ANSI Horizontal End Suction	Flowserve	MK3 STD 2K6X4-10HRV/7.75	Jan 2009/SD317A	Flow Rated/Minimum: 825 gpm/171.2 gpm TDH Rated/Maximum: 45 ft/57.2 ft NPSHr: 13.9 ft NPSHa: 22 ft Motor Size: 15 hp Maximum Pressure: 250 psig Impeller Diameter Rated/Maximum/Minimum: 7.69 in/10.0 in/6.5 in Suction/Discharge: 6 inch/4 inch Motor Speed: 1,765 RPM Minimum Efficiency: 72% Material: Ductile Iron Drive: Motor with VFD Maximum Pressure: 250 psig	

EQUIPMENT DATA								
EQUIPMENT NAME	LOCATION	TAG NO'S	EQUIPMENT DESCRIPTION	MANUFACTURER	MODEL	DATE/PROJECT INSTALLED	Equipment Design and Operation Parameters	NOTES
Digester Gas System								
Gas Conditioning System		W28-DG-CHD-001		ESC Corporation		Jan 2009/SD317A	Flow Maximum/Minimum:3,000/1,200 scfm Pressure Loss Inlet/Outlet:1.8/10 psi Inlet Conditions: Specific Gravity: 0.7-0.9 Methane: 60-70% CO2: 36-40% VOCs Non-Methane: 7.5 ppmv H2S Maximum/Avg: 200/100 ppmv Siloxane Total/D4/D5: 4,500/350/4,100 ppbv Temperature Range/Normal: 60-135/130°F Moisture: Saturated Pressure: 2-6 in wc Outlet Conditions: Siloxanes: <0.3 mg/m3 Moisture: <40% RH @ 75°F Pressure Out: 6 in wc VOCs non-methane: <5 ppmv Inlet Filter/Moisture Separator: 98% solids ≥ 5 micron, 99% liquid droplets ≥ 10 micron Siloxane Media Life: 150 days	When there is an issue with the gas conditioning system and is offline the turbine cannot run and a 36" valve needs to open for the engines run.
Gas Blower	Outdoors	W28-DG-BLW-101	Direct Drive Multistage Centrifugal	HIS (Atlas Copco)	SM 12606	Jan 2009/SD317A	Flow Maximum/Rated @ Pressure Standard: 5100 scfm @ 4.5 psid/3000 scfm @ 6.6 psid Flow Maximum/Rated @ Pressure Maximum: 3900 scfm @ 3.8 psid/3000 scfm @ 5 psid Speed: 3600 RPM Motor Size: 125 hp Flow Maximum/Minimum: 3,000/1,200 scfm Temperature Range/Normal: 60-135/130°F Moisture: Saturated Volts: 230/460 V Motor Speed: 3566 RPM Frequency: 60 Hz Blower Serial NO. 0515022	Flow is not sufficient to run all engines and the turbine. Control panel has 480 V and 120 V which is likely causing issues with noise making it hard to control the blower. According to Maximo in Oct. 2019 the oil seals and bearings needed to be repaired which required the use of a spare new blower.
Economizer-HEX	Outdoors				N/A	Jan 2009/SD317A		High pressure loss restricts higher flows.
Glycol HEX	Outdoors				N/A	Jan 2009/SD317A		High pressure loss restricts higher flows.
Chiller	Outdoors	W28-DG-CHU-001		Johnson Thermal Systems	RT125AA-AC	Jan 2009/SD317A		Does not reduce temperature enough to remove all moisture before the pipe goes underground. However pipe is being rerouted above ground.
Siloxane Vessels (typ of 4)	Outdoors	W28-DG-TNK-101, 102, 201, 202			N/A	Jan 2009/SD317A		
Gas Compressor C-1	PGS1		Two-Stage Double-Acting Water-Cooled Reciprocating Horizontal Crosshead V-belt Driven Balanced-opposed	Ingersoll-Rand	PHE2	Dec 1983/SD135	Capacity: 625 scfm @ 70 psig Inlet Pressure: 14.7 psia Power: 150 hp Compressor Speed: 600 RPM Motor Speed: 1800 RPM Motor Voltage: 460 V Inlet Temp: 90-95°F Inlet Temp: 95°F Maximum Piston Speed: 750 ft/min Bore: 17.5 inch Stroke: 6 inch Discharge Pressure Normal/Rated/Maximum: 23.5/190/210 psig Maximum Temp: 450°F Hydro Test Pressure: 315 psig Maximum Coolant Pressure: 75 psig Displaced flow at 555 RPM Frame/Outer/Total: 457.5/463.5/921	Rebuilt, took 7 months. Future replacement with higher eff units.
Gas Compressor C-1 Intercooler	PGS1					Dec 1983/SD135	Shell Side/Tube Side:10 gpm/625 scfm Temperature in: 80/230°F Temperature Out: 121/90°F Operating Pressure: 40-45 psig/38.2 psia Heat Exchange Rate: 205,000 BTU/HR Pressure Drop: 1/0.3 PSI	
Gas Compressor C-1 Aftercooler	PGS1					Dec 1983/SD135	Shell Side/Tube Side: 10 gpm/625 scfm Temperature in: 80/205°F Temperature Out: 105.6/90°F Operating Pressure: 40-45 psig/84.7 psia Heat Exchange Rate: 127,815 BTU/HR Pressure Drop: 1/0.4 PSI	

EQUIPMENT DATA								
EQUIPMENT NAME	LOCATION	TAG NO'S	EQUIPMENT DESCRIPTION	MANUFACTURER	MODEL	DATE/PROJECT INSTALLED	Equipment Design and Operation Parameters	NOTES
Gas Compressor C-2	PGS1		Two-Stage Double-Acting Water-Cooled Reciprocating Horizontal Crosshead V-belt Driven Balanced-opposed	Ingersoll-Rand	PHE2	Dec 1983/SD135	Capacity: 625 scfm @ 70 psig Inlet Pressure: 14.7 psia Power: 150 hp Compressor Speed: 600 RPM Motor Speed: 1800 RPM Motor Voltage: 460 V Inlet Temp: 90-95°F Inlet Temp: 95°F Maximum Piston Speed: 750 ft/min Bore: 17.5 inch Stroke: 6 inch Discharge Pressure Normal/Rated/Maximum: 23.5/190/210 psig Maximum Temp: 450°F Hydro Test Pressure: 315 psig Maximum Coolant Pressure: 75 psig Displaced flow at 555 RPM Frame/Outer/Total: 457.5/463.5/921	Rebuilt, took 7 months. Future replacement with higher eff units.
Gas Compressor C-2 Intercooler	PGS1					Dec 1983/SD135	Shell Side/Tube Side:10 gpm/625 scfm Temperature in: 80/230°F Temperature Out: 121/90°F Operating Pressure: 40-45 psig/38.2 psia Heat Exchange Rate: 205,000 BTU/HR Pressure Drop: 1/0.3 PSI	
Gas Compressor C-2 Aftercooler	PGS1					Dec 1983/SD135	Shell Side/Tube Side: 10 gpm/625 scfm Temperature in: 80/205°F Temperature Out: 105.6/90°F Operating Pressure: 40-45 psig/84.7 psia Heat Exchange Rate: 127,815 BTU/HR Pressure Drop: 1/0.4 PSI	
Gas Compressor C-3	PGS1	W-28-GCP-003-01	Two-Stage Double-Acting Water-Cooled Reciprocating Horizontal Crosshead V-belt Driven Balanced-opposed	Ingersoll-Rand	PHE2	Dec 1983/SD135	Capacity: 625 scfm @ 70 psig Inlet Pressure: 14.7 psia Power: 150 hp Compressor Speed: 600 RPM Motor Speed: 1800 RPM Motor Voltage: 460 V Inlet Temp: 90-95°F Inlet Temp: 95°F Maximum Piston Speed: 750 ft/min Bore: 17.5 inch Stroke: 6 inch Discharge Pressure Normal/Rated/Maximum: 23.5/190/210 psig Maximum Temp: 450°F Hydro Test Pressure: 315 psig Maximum Coolant Pressure: 75 psig Displaced flow at 555 RPM Frame/Outer/Total: 457.5/463.5/921	Rebuilt, took 7 months. Future replacement with higher eff units.
Gas Compressor C-3 Intercooler	PGS1					Dec 1983/SD135	Shell Side/Tube Side:10 gpm/625 scfm Temperature in: 80/230°F Temperature Out: 121/90°F Operating Pressure: 40-45 psig/38.2 psia Heat Exchange Rate: 205,000 BTU/HR Pressure Drop: 1/0.3 PSI	
Gas Compressor C-3 Aftercooler	PGS1					Dec 1983/SD135	Shell Side/Tube Side: 10 gpm/625 scfm Temperature in: 80/205°F Temperature Out: 105.6/90°F Operating Pressure: 40-45 psig/84.7 psia Heat Exchange Rate: 127,815 BTU/HR Pressure Drop: 1/0.4 PSI	
Gas Compressor (Turbine)	Outdoors	W28-DG-CMP-101	Sliding Vane	Vilter	VSG 1851 VVRGHPEMD36SHNECSTGL	Jan 2009/SD317A	Flow Normal/Maximum/Minimum: 1200/1300/0 scfm Maximum Outlet Temperature Normal/Emergency: 125/165°F Maximum Speed: 3550 RPM Motor Size: 1000 hp Maximum Suction Pressure: 6 in wc Outlet Pressure: 250 psig Maximum Motor Size: 600 Maximum Temperature: 300°F Minimum Temperature: -20°F Maximum Pressure: 600 psig	No issues. Oil cooling using W3 water.

EQUIPMENT DATA								
EQUIPMENT NAME	LOCATION	TAG NO'S	EQUIPMENT DESCRIPTION	MANUFACTURER	MODEL	DATE/PROJECT INSTALLED	Equipment Design and Operation Parameters	NOTES
Blower (BLW-B01) (Boiler)	Outdoors	W28-DG-BLW-B01	Hermetic Centrifugal Gas Booster Blower	The Spencer Turbine Co.	GH 3015 H-MOD	Jan 2005/SD275	Motor Speed: 3525 RPM Motor Size: 20 hp Flow: 598 ICFM Inlet Temp: 100°F Inlet Pressure: 14.86 psia Outlet Pressure: 17.7 psia Specified Outlet Pressure: 5.5 psig	Failed many times. Staff adding bypass from gas compressor for a redundant gas supply.
Flare (F-1H) High Capacity	Outdoors			ABUTEC	HTF 18.5 MW			Ignition weather proofing required
Flare (F-2H) High Capacity	Outdoors			ABUTEC	HTF 18.5 MW			Ignition weather proofing required
Low Pressure Gas Holder	Outdoors	W-28-TKS-LPG-01	Dry Seal Gas Holder	Pittsburgh-Des Moines Steel Company	N/A	Dec 1983/SD135	Diameter: 40 ft Capacity: 15,000 ft^3 Design Pressure: 4" wc Inside Diameter: 40'-0" Piston Height: 6'-6" Roof Travel: 13'-0" Diaphragm Material: Buna-n or Nylon Flame Arrester: Varec Figure No. 50, 12" Ø Pressure-Vacuum Valve: Varec Fig. 2010-51, 8" Ø, pressure set 2 3/4 oz & 1/2 vac Tank Gage: Varec Fig. 2502 Volume Control Valve: 75,000 ft3/hr @ 4 in wc Inlet/Outlet Size: 18/18 inch	One cable broken. Possible leak in diaphragm.
High Pressure Digester Gas Surge Tank	Outdoors		Digester Gas Surge Tank	California Tank & Mfg. Corp.	N/A	Dec 1983/SD135	Vessel Size: 144 in ID x 120 in SL Head Size: 144 in ID x 123 in DR Design/Test Pressure: 75/113 psig Design Temperature: 120°F Minimum Capacity: 1,500 ft3 Pressure Relief Valve Full Open/Closed/Maximum Pressure: 70/67/75 psig	Relieve valve never change. Possible accumulation of crud.

EQUIPMENT DATA								
EQUIPMENT NAME	LOCATION	TAG NO'S	EQUIPMENT DESCRIPTION	MANUFACTURER	MODEL	DATE/PROJECT INSTALLED	Equipment Design and Operation Parameters	NOTES
Tanks								
Diesel Oil Storage Tank, TK-1	PGS1 Buried	W-28-TKS-DOS-01	Fiberglass tank	Owens Corning	N/A	Original: Dec 1983/SD135 New: Nov 1991/SD189A	Capacity: 25,000 gallon Inside Diameter: 10 ft - 6 in Length: 45 ft	No issues. Replaced 20 years ago. Consider replacement with aboveground tank
Waste (Slope) Oil Tank	PGS1 Buried		Fiberglass tank	Owens Corning	N/A	Original: Dec 1983/SD135 New: Nov 1991/SD189A	Capacity: 2,500 gallon Diameter: 6'-3.5" Length: 13'-5.75"	Consider replacement with aboveground tank. Confirm no of tanks. One by PGS1 to be replaced. Another by oil shed replaced?
Lube Oil Tank			Steel Tank	Ace Tank	N/A	Dec 1983/SD135	Capacity: 2,000 gallon Diameter: 7 ft Height: 7 ft	No issues
Lube Oil Tank Heater						Dec 1983/SD135	Heating Capacity: 4.5 kW Voltage: 460 Frequency: 60 hz Type: Horizontal Heating Element Location: 4 inch above bottom Minimum Temperature: 60°F	Need to be replaced.
PGS1 Gas Compressor Lube Oil Tank			Steel Tank		N/A	Dec 1983/SD135	Capacity: 110 gallon	

Appendix C. Business Risk Exposure Rankings

EQUIPMENT LIST	ASSESSMENT - PROBABILITY OF FAILURE						ASSESSMENT - CONSEQUENCE OF FAILURE					BUSINESS RISK EXPOSURE RATING	NOTES
EQUIPMENT NAME	CONDITION	RELIABILITY	CAPACITY	FUNCTIONALITY	FINANCIAL EFFICIENCY	AVERAGE SCORE	HEALTH & SAFETY	SOCIAL IMPACT	DIFFICULTY OF REPAIR	REDUNDANCY	AVERAGE SCORE		
Engine Generators													
Engine No. 1													Out of scope
Jacket Water Heat Exchanger No. 1	5	4	3	3	3	3.6	2	1	4	5	3.0	10.8	Original w/EG, Recent tube leaks. Sent out for repair. Plug leaking tubes
Intercooler No. 1	5	4	3	3	3	3.6	2	1	4	5	3.0	10.8	Original w/EG, Staff indicated failing. Need Replaced
Lube Oil Cooler No. 1	5	4	3	3	3	3.6	2	1	4	5	3.0	10.8	Original w/EG, Staff indicated failing, Needs to be retubed
Lube Oil (Before & After) Pump No. 1	3	2	3	1	1	2.0	2	1	2	5	2.5	5.0	
Exhaust Heat Recover No. 1	2	2	3	1	4	2.4	2	1	4	5	3.0	7.2	Replaced in 2013. Condition is OK
Hot Water Circulating Pump No. 1	2	2	4	2	2	2.4	2	1	5	5	3.3	7.9	Higher pressure after replacing HRU. Upsize pump by repacing impeller and motor.
Exhaust Silencer 1	3	2	1	2	3	2.2	2	2	4	5	3.3	7.3	No internals, should be replaced
Engine No. 2													Out of scope
Jacket Water Heat Exchanger No. 2	5	4	3	3	3	3.6	2	1	4	5	3.0	10.8	Original w/EG, Recent tube leaks. Sent out for repair. Plug leaking tubes
Intercooler No. 2	5	4	3	3	3	3.6	2	1	4	5	3.0	10.8	Original w/EG, Staff indicated failing. Need Replaced
Lube Oil Cooler No. 2	5	4	3	3	3	3.6	2	1	4	5	3.0	10.8	Original w/EG, Staff indicated failing, Needs to be retubed
Lube Oil (Before & After) Pump No. 2	3	2	3	1	1	2.0	2	1	2	5	2.5	5.0	
Exhaust Heat Recover No. 2	2	2	3	1	4	2.4	2	1	4	5	3.0	7.2	Replaced in 2013. Condition is OK
Hot Water Circulating Pump No. 2	2	2	4	2	2	2.4	2	1	5	5	3.3	7.9	Higher pressure after replacing HRU. Upsize pump by repacing impeller and motor.
Exhaust Silencer 2	3	2	1	2	3	2.2	2	2	4	5	3.3	7.3	No internals, should be replaced
Engine No. 3													Out of scope
Jacket Water Heat Exchanger No. 3	5	4	3	3	3	3.6	2	1	4	5	3.0	10.8	Original w/EG, Recent tube leaks. Sent out for repair. Plug leaking tubes
Intercooler No. 3	5	4	3	3	3	3.6	2	1	4	5	3.0	10.8	Original w/EG, Staff indicated failing. Need Replaced
Lube Oil Cooler No. 3	5	4	3	3	3	3.6	2	1	4	5	3.0	10.8	Original w/EG, Staff indicated failing, Needs to be retubed
Lube Oil (Before & After) Pump No. 3	3	2	3	1	1	2.0	2	1	2	5	2.5	5.0	
Exhaust Heat Recover No. 3	2	2	3	1	4	2.4	2	1	4	5	3.0	7.2	Replaced in 2013. Condition is OK
Hot Water Circulating Pump No. 3	2	2	4	2	2	2.4	2	1	5	5	3.3	7.9	Higher pressure after replacing HRU. Upsize pump by repacing impeller and motor.
Exhaust Silencer 3	3	2	1	2	3	2.2	2	2	4	5	3.3	7.3	No internals, should be replaced
Engine Accessories													
Engine Cooler Radiator, RT-2	4	3	3	3	4	3.4	2	2	5	5	3.5	11.9	Replaced 4-5 years ago. Leak last couple of weeks. Bullet hole fixed.
Air Compressor 1 (Starting)	5	4	4	4	4	4.2	2	1	4	1	2.0	8.4	No major overhaul, repaired failed head, replace.
Air Compressor 2 (Starting)	5	4	4	4	4	4.2	2	1	4	1	2.0	8.4	No major overhaul, repaired failed head, replace.
Air Receiver 1 (Starting)	3	2	3	2	2	2.4	2	1	2	1	1.5	3.6	Inspeced every 5 years. No issues
Air Receiver 2 (Starting)	3	2	3	2	2	2.4	2	1	2	1	1.5	3.6	Inspected every 5 years. No issues
Compressed Air Dryer	5	4	3	4	3	3.8	2	1	3	5	2.8	10.6	Air not dry, dryer is too small. Needs upgraded.
PGS1 Bldg Ventilation	4	5	5	3	4	4.2	2	1	2	2	1.8	7.6	
Turbine Generator													Out of Scope
Heat Recovery Unit No. 1	3	2	3	2	1	2.2	2	1	5	5	3.3	7.3	Leak at joints when stopped
Hot Water Pump No. 1	3	4	2	2	2	2.6	2	1	2	5	2.5	6.5	No redundacy
Turbine Generator Oil Cooler	2	2	3	1	1	1.8	2	1	3	5	2.8	5.0	No issues, ordered a new unit.

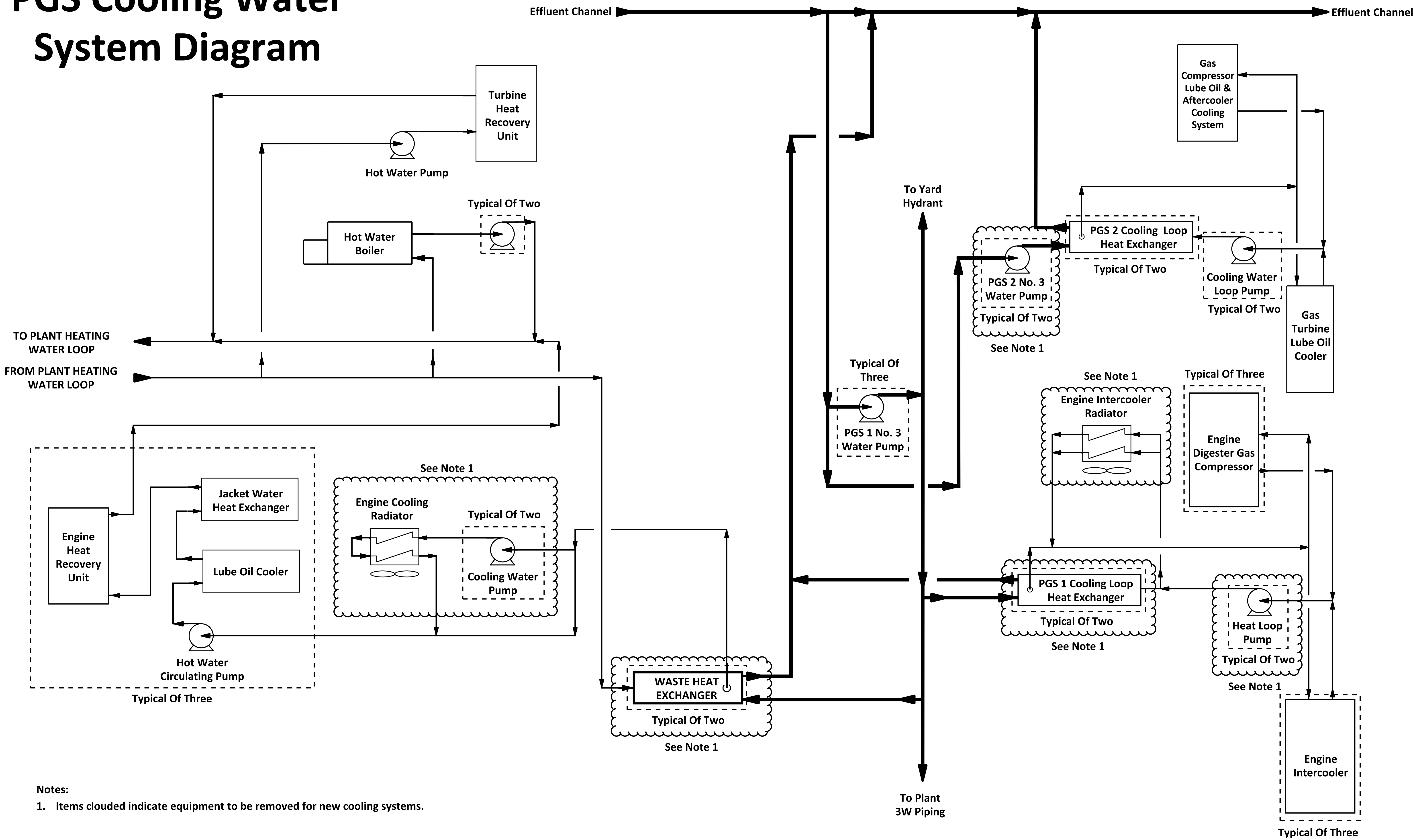
EQUIPMENT LIST	ASSESSMENT - PROBABILITY OF FAILURE						ASSESSMENT - CONSEQUENCE OF FAILURE					BUSINESS RISK EXPOSURE RATING	
EQUIPMENT NAME	CONDITION	RELIABILITY	CAPACITY	FUNCTIONALITY	FINANCIAL EFFICIENCY	AVERAGE SCORE	HEALTH & SAFETY	SOCIAL IMPACT	DIFFICULTY OF REPAIR	REDUNDANCY	AVERAGE SCORE		NOTES
Boiler	4	3	3	3	2	3.0	2	1	3	5	2.8	8.4	Gas train safety valve failure. Boiler has leaking issue. Pneumatic valve won't fully close and cause an after burn. Need to close valve manually. Control panel needs protection from weather. Add weather hood.
Boiler Hot Water Recirculation Pump	3	2	3	2	1	2.2	1	1	2	1	1.3	2.9	
Boiler Hot Water Recirculation Pump	3	2	3	2	1	2.2	1	1	2	1	1.3	2.9	
PGS1 Effluent Cooling (3W)	5	4	3	4	5	4.2	2	2	5	5	3.5	14.7	Overall cooling system not reliable when run out of plant
Heat Loop Pump No. 1	3	2	3	1	2	2.2	1	1	2	1	1.3	2.9	Installed 1989 and modified in 2005
Heat Loop Pump No. 2	3	2	3	1	2	2.2	1	1	2	1	1.3	2.9	Installed 1989 and modified in 2005
PGS 1 Cooling Loop Heat Exchanger No. 1	5	3	3	4	5	4.0	1	1	5	1	2.0	8.0	Installed 1989 and modified in 2005; Short Circuiting
PGS 1 Cooling Loop Heat Exchanger No. 2	5	3	3	4	5	4.0	1	1	5	1	2.0	8.0	Installed 1989 and modified in 2005; Short Circuiting
No. 3 Water Cooling Pumps No. 1	3	3	3	4	5	3.6	1	1	2	2	1.5	5.4	Installed 1985 and replaced in 2005
No. 3 Water Cooling Pumps No. 2	3	3	3	4	5	3.6	1	1	2	2	1.5	5.4	Installed 1985 and replaced in 2005
No. 3 Water Cooling Pumps No. 3	3	3	3	4	5	3.6	1	1	2	2	1.5	5.4	Installed 1985 and replaced in 2005
Waste Heat Exchanger No. 1	5	3	3	4	5	4.0	2	1	5	1	2.3	9.2	Installed 1985 and replaced in 2005; Past their useful life.
Waste Heat Exchanger No. 2	5	3	3	4	5	4.0	2	1	5	1	2.3	9.2	Installed 1985 and replaced in 2005; Past their useful life.
Engine Intercooler Radiator, RT-1	4	3	3	3	4	3.4	2	2	5	5	3.5	11.9	Installed 1989; Leaking
PGS2 Effluent Cooling (3W)													
Cooling Water Loop Pump No. 1	2	3	2	3	2	2.4	1	1	3	4	2.3	5.5	
Cooling Water Loop Pump No. 2	2	3	2	3	2	2.4	1	1	3	4	2.3	5.5	
PGS 2 Cooling Loop Heat Exchanger No. 1	2	1	3	2	2	2.0	1	1	3	4	2.3	4.6	
PGS 2 Cooling Loop Heat Exchanger No. 2	2	1	3	2	2	2.0	1	1	3	4	2.3	4.6	
No. 3 Water Pumps No. 1	2	2	3	3	2	2.4	2	1	3	4	2.5	6.0	
No. 3 Water Pumps No. 2	2	2	3	3	2	2.4	2	1	3	4	2.5	6.0	

EQUIPMENT LIST	ASSESSMENT - PROBABILITY OF FAILURE						ASSESSMENT - CONSEQUENCE OF FAILURE					BUSINESS RISK EXPOSURE RATING	
EQUIPMENT NAME	CONDITION	RELIABILITY	CAPACITY	FUNCTIONALITY	FINANCIAL EFFICIENCY	AVERAGE SCORE	HEALTH & SAFETY	SOCIAL IMPACT	DIFFICULTY OF REPAIR	REDUNDANCY	AVERAGE SCORE		NOTES
Digester Gas System													
Gas Conditioning System	3	4	4	4	3	3.6	3	2	4	5	4	12.6	Installed with gas turbine. When there is an issue with the gas conditioning system and is offline the turbine cannot run and a 36" valve needs to open for the engines run. System components need redundacy to make more reliable.
Gas Blower	3	4	4	4	3	3.6	3	2	3	5	3.3	11.9	Flow is not sufficient to run all engines and the trubine. Control pannel has 480 V and 120 V which is likely causing issues with noise making it hard to control the blower. According to
Economizer-HEX	3	2	4	4	4	3.4	2	2	4	5	3.3	11.2	High pressure loss restricts higher flows.
Glycol HEX	3	2	4	4	4	3.4	2	2	4	5	3.3	11.2	High pressure loss restricts higher flows.
Chiller	3	3	3	3	2	2.8	1	2	4	5	3.0	8.4	Does not reduce temperature enough to remove all moisture before the pipe goes underground. However pipe is being rerouted above ground.
Siloxane Vessels (typ of 4)	2	2	3	2	2	2.2	2	2	2	4	2.5	5.5	
Gas Compressor C-1	3	3	2	2	4	2.8	3	2	5	2	3.0	8.4	Rebuilt, took 7 months. Future replacement with high eff units.
Intercooler No. 1	5	3	3	3	4	3.60	3	1	3	5	3.00	10.8	
Aftercooler No. 1	5	3	3	3	4	3.60	3	1	3	5	3.00	10.8	
Gas Compressor C-2	3	3	2	2	4	2.8	3	2	5	2	3.0	8.4	Rebuilt, took 7 months. Future replacement with high eff units.
Intercooler No. 2	5	3	3	3	4	3.60	3	1	3	5	3.00	10.8	
Aftercooler No. 2	5	3	3	3	4	3.60	3	1	3	5	3.00	10.8	
Gas Compressor C-3	3	3	2	2	4	2.8	3	2	5	2	3.0	8.4	Rebuilt, took 7 months. Future replacement with high eff units.
Intercooler No. 3	5	3	3	3	4	3.60	3	1	3	5	3.00	10.8	
Aftercooler No. 3	5	3	3	3	4	3.60	3	1	3	5	3.00	10.8	
Gas Compressor (Turbine)	2	2	2	2	1	1.8	3	2	5	5	3.8	6.8	No issues. Oil cooling using W3 water.
Blower (BLW-B01) (Boiler)	4	4	2	2	2	2.8	3	2	3	5	3.3	9.2	Failed many times. Staff adding bypass from gas compressor for a redundant gas supply.
Flare (F-1H) High Capacity	2	4	3	3	2	2.8	4	4	3	2	3.3	9.2	Ignition weather proofing required
Flare (F-2H) High Capacity	2	4	3	3	2	2.8	4	4	3	2	3.3	9.2	Ignition weather proofing required
Low Pressure Gas Holder	5	4	5	4	4	4.4	4	4	4	5	4.3	18.9	One cable broken. Possible leak in diaphragm.
High Pressure Gas Holder (Surge)	4	3	3	2	2	2.8	3	2	3	5	3.3	9.2	Relieve valve never change. Possible accumulation of crud.

Tanks													
Diesel Oil Storage Tank	4	2	3	2	4	3.0	2	5	5	5	4.3	12.9	No issues. Replaced 20 years ago. Consider replacement with aboveground tank
Waste (Slope) Oil Tank	4	2	3	2	4	3.0	2	5	5	5	4.3	12.9	Consider replacement with aboveground tank
Lube Oil Tank	2	2	3	2	2	2.2	2	2	2	5	2.8	6.2	No issues
Lube Oil Tank Heater	5	5	3	4	2	3.8	2	1	3	5	2.8	10.6	Need to be replaced.

Appendix D. Diagrams and Drawings

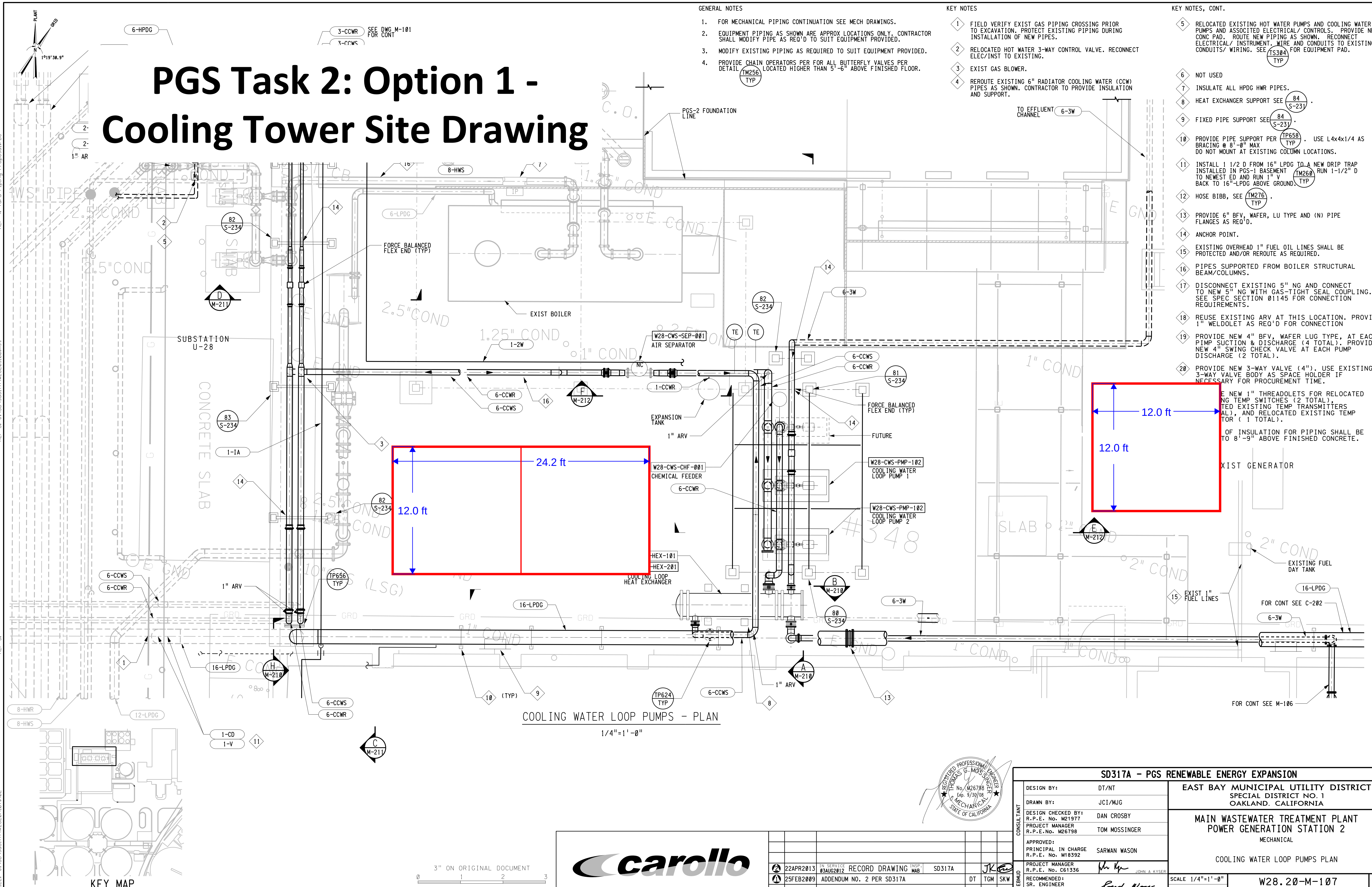
PGS Cooling Water System Diagram



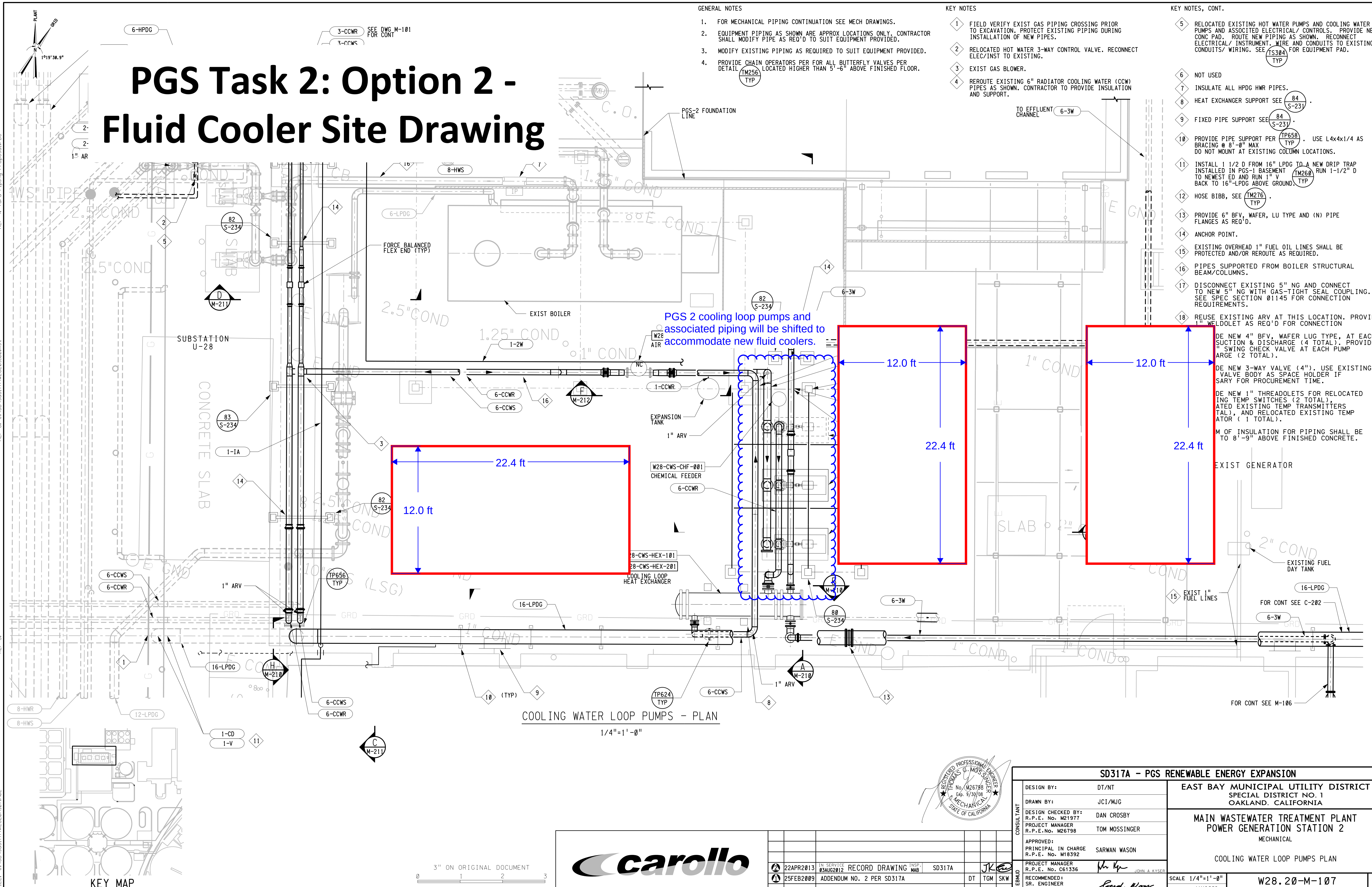
Notes:

1. Items clouded indicate equipment to be removed for new cooling systems.

PGS Task 2: Option 1 - Cooling Tower Site Drawing



PGS Task 2: Option 2 - Fluid Cooler Site Drawing



Appendix E. Carry Forward Task List

Task Number	Task Description
Tasks Scoped for BODR	
2	Eliminate use of plant effluent in cooling water system by the use of Cooling Towers for cooling. (to 10%)
3	Remove two slop/waste oil tanks and replace with aboveground tanks.
4	Remove diesel tank and replace with aboveground tank.
7	Provide HV/LV separation for gas conditioning system and give space/provisions in new panels for future blower only
10/16/21	Replace tubes/rebuild following heat exchangers: engine lube oil, jacket water, engine intercooler, waste, and cooling loop heat exchangers.
11/17	Replace existing air compressors and air dryer. Dryer replacement to be higher capacity and provide redundant unit.
12	Replace lube oil heater in engine lube oil storage tank with a higher capacity heater.
13	Replace high capacity flare ignition rod and add weather hood.
20	Modify boiler stack and add weather protection to control panel.
22	Increase engine HRU pump pressure. Typ of 3 units. Replace impeller/motor
23	Modify PGS1 engine room fans and ducting. Ducting and fans on the roof that doesn't work. Engine room gets really hot. Basement smells like oil. Leave basement alone.
25	Incorporate engine detonation monitoring and adjustment system.
26	Modify Main Interface Panel (MIP) – to have false floor to protect wiring and ease entrance. Use fiberglass panel for separation.
27	Relocate low pressure & medium pressure digester gas PITs to be closer to ground level.
28	Migrate controls and tie alarms from PGS MIP to the plant DCS.
29	Add load bank connections at PGS1. (to 10%)
31	Seismic improvements to control room and bridge crane as recommended in Seismic study. (to 10%)
32	Replace existing standby engine-generator with a larger unit. (to 10%) Finalize sizing of generators during 10% design.
New	Replace air filter with upgraded unit on Turbine.