Newfoundland & Labrador Hydro

Hydro Plant Corrosion / Fouling Study 2002

Bay D'Espoir Generating Station Units 1-6

SERVICE WATER SYSTEM

Newfoundland & Labrador Hydro

Bay D'Espoir Generating Station Powerhouse #1

Units 1 – 6
SERVICE WATER SYSTEM

Piping
Strainer
Supply Pumps
Control Valves
Heat Exchangers

Prepared for: Newfoundland & Labrador Hydro
Hydro Generation

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Summary

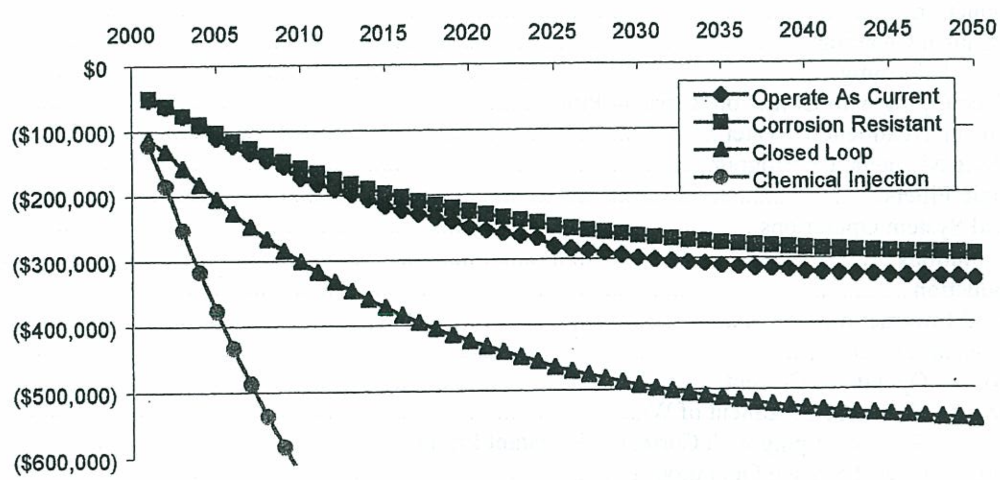
A study on the service water system for Units 1-6 Bay D'Espoir was performed to evaluate the fouling problem and produce recommendations to improve the reliability of the system.

The first section of the study focuses on the background. This includes a summary of the current state of the system, specifications of the existing equipment and explanation of operations. Next, research was performed to evaluate the past work history. This provides insight into how the system has been modified; it identifies high maintenance equipment and re-occurring problems. Test samples for the water and pipe deposits were analyzed to provide details for the cause of the fouling. Also, trend monitoring was performed to highlight operating trends.

A number of options were considered and discussed for solutions to the fouling problems. The options were reduced to four and developed further. The four options considered for economic analysis were:

- Operate as Current
- Chemical Treatment of Water
- Replace Piping with Corrosion Resistant Piping
- Closed System Operation

Cost estimates were prepared for each of these options; this included projected operating costs as well as initial capital costs. The economic analysis was based on the net present worth of the cost. The results of the analysis are displayed in the graph below.



By evaluating the options a recommendation was prepared. The main recommendation from the study was to continue with the replacement of the piping with corrosion resistant materials.

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Background for Service Water System

Introduction

The service water system has been in operation since construction of the plant in 1967. The reliability of this system is critical since system failure results in forced outages for the unit. The main problems experienced with the system have been a result of fouling. During the initial stages of operation the fouling problems were more frequent, however the problem has become less frequent in recent years. The fouling problem is identified when it causes problems with heat transfer in the coolers during the summer months. Also, corrosion within the system has caused water leaks into the bearings and pipe failures. The maintenance on this system has been high; most of the components of the system have been replaced since original construction, including pumps, piping, meters and coolers.

The purpose of this report is to provide a review of the existing system, how it has been operated, and the types of problems experienced. Also included in this report is a description and economic analysis of several solutions for improving the reliability of the system and reducing the maintenance costs.

General Information

The general layout of the system has been simplified in the sketch below. The system consists of six pumps, each discharging to a common header that supplies the units. Connections to the penstock serve as a backup supply system during pump failure.

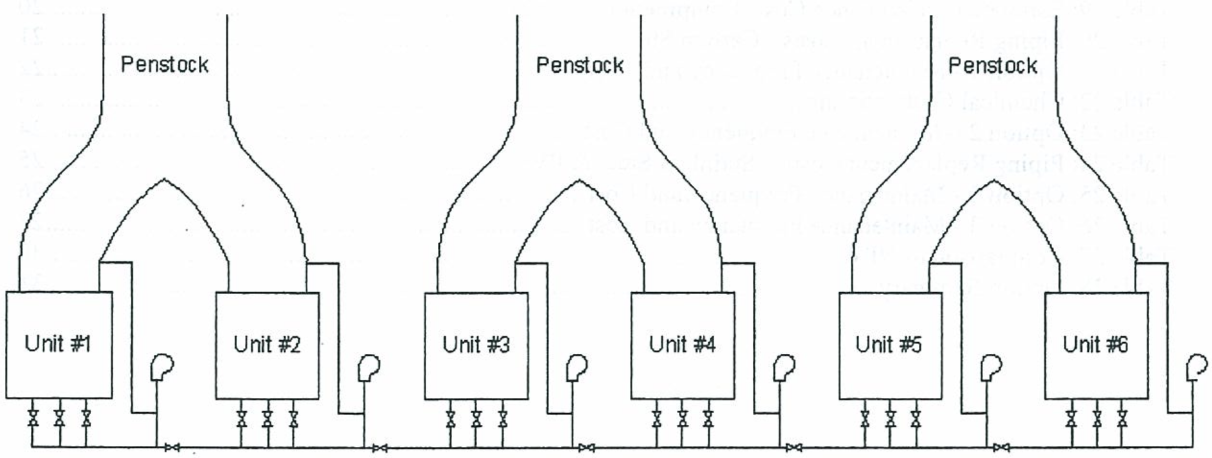


Figure 1: Simplified System Flow Diagram

The system contains the flexibility to supply each unit by each pump. A copy of the actual system flow diagram is attached in Appendix A.

The service water system has several functions; it supplies the repair shop, laundry service and provides backup for the firewater header however the main function of the service water system is unit cooling. For each unit there are three main areas that require service water for cooling. The sketch below is used to describe how the unit is supplied and a detailed version of this sketch is attached in Appendix A:

- Surface Air Coolers (SAC). There are four SAC that are supplied from two locations to cool the stator windings. A temperature control valve located on the common discharge line controls the flow through these coolers.
- Generator Bearing Coolers. There are three generator bearing coolers that function to cool the oil used in the thrust / guide bearing. These coolers are supplied from the main header and the flow is controlled through a temperature control valve on the discharge line.
- Turbine Bearing Cooler. The single turbine bearing cooler and shaft seal is supplied through a separate branch that contains a pressure reducer and strainer.

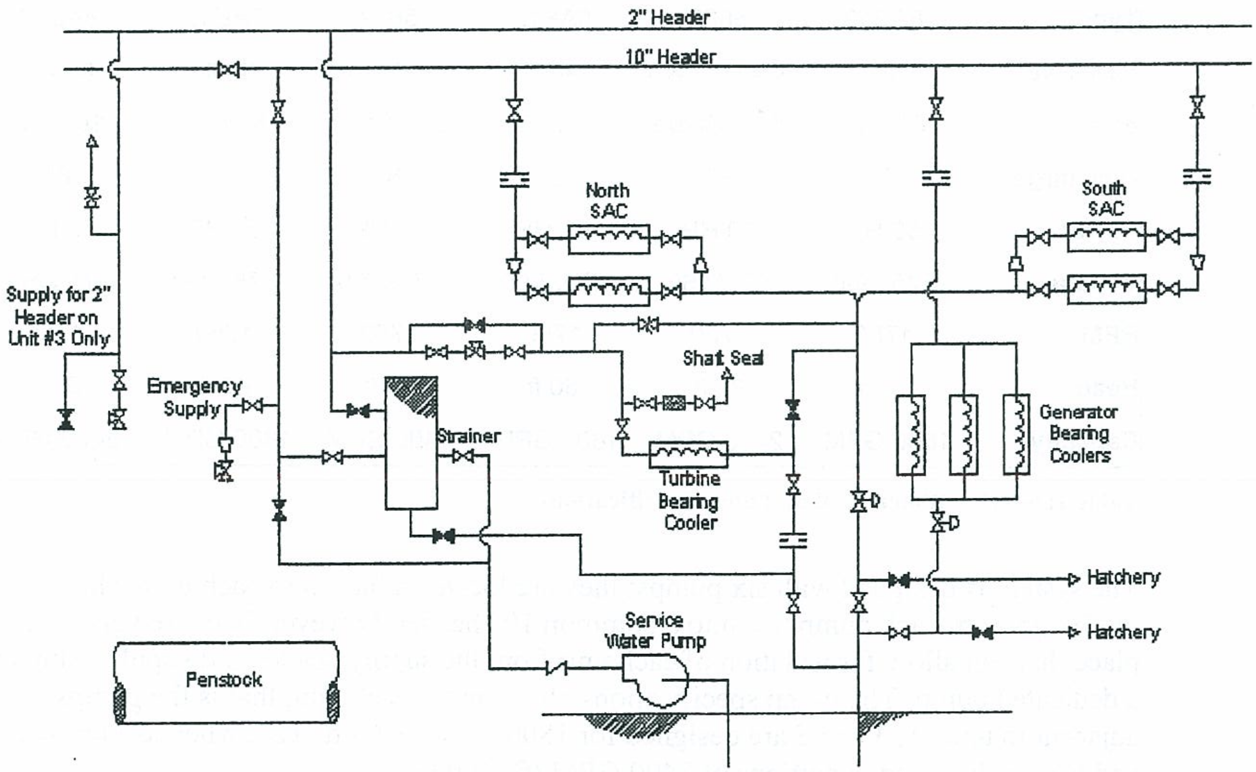


Figure 2: Unit Flow Diagram

The discharge from the service water system is routed to the tailrace, however there is an option to direct the warm water to the fish hatchery when requested.

Main Equipment

The following section of the report describes each component of the service water system. This information was compiled from the operating and maintenance manuals, generation support files, drawings, site visit, nameplate information and conversations with Bay D'Espoir personnel. Pictures of the equipment can be found in Appendix B.

Pumps

All the original service water pumps that were installed have been replaced since construction. The following table provides the specifications for the current pumps used in the system.

	Unit #1	Unit #2	Unit #3	Unit #4	Unit #5	Unit #6
Manufacturer	Peerless Pump	Fairbank Morse	Peerless Pump	Fairbank Morse	Peerless Pump	Peerless Pump
Type	8AE12	5822	8AE12	5822	8AE12	8AE13
Serial No.	115612	K2M1041804-1	148656	K2M1041804-2	485391	508704
Size	8" x 8"	8 - 1 Stage	8" x 8"	8 - 1 Stage	8" x 8"	10" x 8"
Discharge	8"	8"	8"	8"	8"	8"
Power	50 HP	60 HP	50 HP	60 HP	50 HP	75 HP
Voltage	575/3/60	575/3/60	575/3/60	575/3/60	575/3/60	575/3/60
RPM	1750	1750	1750	1750	1750	1750
Head	60 ft	80 ft	60 ft	80 ft	60 ft	85 ft
Capacity	1800 GPM	2400 GPM	1800 GPM	2400 GPM	1800 GPM	2400 GPM

Table 1: Service Water Cooling Pump Specifications

The system is designed with six pumps; they are located adjacent to each unit. The discharge from each pump ties into a common 10" header, however there are valves in place that can allow for isolation of each unit from the supply header and supply a unit as a dedicated pump. The pump specifications alternate for each unit, that is the pumps adjacent to units 1, 3 and 5 are designed for 1800 GPM @ 60 ft head, whereas pumps 2, 4 and 6 have designed conditions of 2400 GPM @ 80 ft head.

All pumps are split case, horizontal, single stage pumps. The suction for the pumps is piped to the fresh water sump through a ten-inch suction line. The suction is equipped with a foot valve. The pump curves for each of these pumps are located in Appendix C.

Strainers

The discharge from each pump is routed through a strainer to remove particulate from the water entering the system. The strainers are all peacock rotary type basket strainers. There are two different models; an 8" model and a 9" model, however the design is identical. The strainers are equipped with a 2" backwashing connection for cleaning the filter media and a manual drive to rotate the filter basket assembly. The available details for the strainers are shown in the table below.

	Unit #1	Unit #2	Unit #3	Unit #4	Unit #5	Unit #6
Manufacturer	Peacock	Peacock	Peacock	Peacock	Peacock	Peacock
Serial Number	66141	66142	66143	68092	N/A	68093
Design Pressure	188 PSI	188 PSI	188 PSI	188 PSI	188 PSI	188 PSI
MAWP	100 PSI	100 PSI	100 PSI	100 PSI	100 PSI	100 PSI
Size	8"	8"	8"	9"	8"	9"

Table 2: Strainer Specifications

Flow Meters

Each unit has four flow meters that are used to measure the water flow to the various cooling equipment. The flow rate is used for reporting, trend monitoring and system alarms. The flow rate is not used for flow control; the flow is controlled by the temperature control valves located in the discharge line. The four flow meters are located at the following locations:

- The vertical sections of the supply lines to the SAC, one in each branch.
- The horizontal section on the supply line to the generator bearing coolers.
- The vertical section of the discharge line from the turbine bearing coolers.

The flow meters used are pressure differential type meters with a Bailey pressure transducer, which produces a 4-20 mA output from the pressure differential over an orifice. The following table shows the details of these flow meters orifices.

Line Location	Line Size	Orifice Size
Surface Air Coolers		
Units 1 – 6	6"	4.148"
Generator Bearing Coolers:		
Units 1 – 6	3"	1.9583"
Turbine Bearing Coolers:		
Units 1,2,4	1"	Not Available
Unit 3	1"	0.6146"
Units 5,6	1"	0.7636"

Table 3: Flow Meter Orifice Sizes

Service Water System Coolers

There are three types of coolers used in the service water system; surface air coolers, generator bearing coolers and turbine bearing coolers. The table below details the available specifications for each of the three types of coolers used in the system.

	Surface Air Coolers	Generator Bearing Coolers	Turbine Bearing Cooler
Max Allowable Pressure:	Not Available	250 PSI	250 PSI
Total Flow Rate:	1150 IGPM	90 IGPM	15 IGPM
Number of Coolers	4	3	1
Number of Tubes:	132	20	12
Number of Passes:	2	4	12
Tube Outside Diameter:	0.750"	0.875"	0.875"
Tube Wall Thickness:	0.045"	0.049"	0.065"

Table 4: Cooler Specifications

Surface Air Coolers

There are four surface air coolers located around the exterior of the stator windings for cooling of the generator. The coolers are constructed of seamless copper tubes with 1 ¾" aluminum fins (9 fins per inch). These coolers have the highest flow demand for the system and are supplied by 4" lines. Fouling in these coolers will cause high temperatures for the stator. These coolers are constructed with carbon steel water jackets at either end of the cooler and have a two-pass configuration. Although all the specifications are the same, the cooler lengths vary for Units1-4 from Units 5-6. The tube length for Units 1-4 is 85.5" whereas for Units 5-6 it is 98".

Generator Bearing Coolers

There are three generator bearing coolers for each unit. These coolers are located in the oil reservoir for the generator thrust / guide bearing. The three coolers are positioned around the bearing to form a circular bank of tubes that surrounds the circumference of the bearing. The coolers are constructed of copper-nickel finned tubes. A failure of these coolers will result in water entering the bearing oil and causing a high bearing temperature alarm or high oil level alarm. These coolers were recently replaced on all units.

Turbine Bearing Coolers

There is one turbine bearing cooler for each unit. It is located in the oil reservoir of the turbine bearing. This cooler is constructed of Seamless 90/10 Cupronickel tubes that are bent to form a continuous circular bank around 255° of the circumference of the bearing. This cooler has the lowest flow rate of all the coolers and has a separate supply at a slightly higher pressure than the other two bearings.

Main Control Valves

Cooler Control Valves

The same model of temperature control valve controls the surface air coolers and the generator bearing coolers. One valve is located on the discharge line for the generator bearing coolers and one on the common drain line for the two branches of the surface air coolers. The specifications for this type of valve are shown in the table below.

Temperature Discharge Valve	
Manufacturer	Fisher
Model	Type 8550 – 1051
Size	6"
Action	Spring to Close
Supply Pressure	35 PSI
Output Pressure	6-30 PSI

Table 5: Temperature Discharge Valve Specifications

Downstream of the temperature control valves there are sets of pneumatic valves in both the surface air cooler drain and the generator bearing cooler drain. These valves are used to control the flow of water to either the tailrace drain or the fish hatchery. The valves are positioned for normal operation such that water flow is directly to the tailrace drain, however when requested the discharge cooling water can be diverted to the fish hatchery.

Backwashing Reducing Valve

A separate source supply is used for the 2" header that runs parallel to the 10" main supply header. This line is used to supply the backwash water for the strainers and supply for the turbine bearing cooler and shaft seal. This line operates at a higher pressure than the rest of the service water system. This water is supplied directly from the penstock through a pressure-reducing valve and is protected by a pressure relief valve. The set points of these valves are shown below.

Set points	Pressure
Pressure Reducing Valve:	
Inlet Pressure	250 PSI
Outlet Pressure	75 PSI
Pressure Safety Valve:	
Safety Valve Set point	110 PSI

Table 6: High Pressure Supply Valve

Turbine Bearing / Shaft Seal Reducing Valves

On each branch for supplying the turbine bearing cooler and shaft seal there is a further pressure reducer that decreases the pressure before supplying the cooler. This reduces the flow to the cooler and the shaft seal. Downstream from the reducing valve is a safety relief valve that prevents over pressurizing the cooler. The table below displays the set points for both of these valves.

Set points	Pressure
Pressure Reducing Valve:	
Inlet Pressure	75 PSI
Outlet Pressure	40 PSI
Pressure Safety Valve:	
Safety Valve Set point	45 PSI

Table 7: Pressure Set Points for Turbine Bearing Supply

Emergency Penstock Supply Valves

The service water pumps are backed up by an emergency supply from the penstock. The valve is a normally closed valve that opens on low flow condition as indicated by the flow switch on the suction to the service water pump. The valve will only operate if it is in "auto" mode and the flow switch doesn't indicate the presence of flow. When the valve is initiated it operates as a reducing valve to reduce the pressure from 250 PSI to the system pressure of 35 PSI. The details of the valve are shown in the table below.

Emergency Cooling Water	
Manufacturer	Masoneilan
Model	48-2115
Cv	110
Size	3"
Action	Air to Open
Supply Pressure	20 PSI
Output Pressure	7-25 PSI

Table 8: Emergency Supply Reducing Valve Specifications

History of Service Water System

Introduction

This section of the report details the past work performed on the service water system. It details the main equipment that was replaced, major maintenance performed, trend monitoring and past tube velocity calculations.

Work History

Equipment History

For information on the work history for the service water system a search of the JD Edwards work order system was performed. The system contains information on work performed on the system since 1995. This research was complemented by information from the Engineering Files and conversations with site personnel. From this a timeline of the work history was produced to provide a general overview.

	Unit 1	Unit 2	Unit 3	Unit 4	Unit 5	Unit 6
1987		CWP Replaced		CWP Replaced		
1990			1 SAC Replaced	1 SAC Replaced		
1991			1 SAC Replaced			
1992	1 SAC Installed	1 SAC Retubed				
1993			1 SAC Replaced			
1994						
1995	CWP Replaced				4 SAC Cleaned	4 SAC Cleaned
1996	4 SAC Cleaned SAC Pipe Clean	SAC Pipe Clean	SAC Pipe Clean	SAC Pipe Clean	SAC Pipe Clean	SAC Pipe Clean
1997			CWP Replaced			
1998						1 TBC Leak Repaired
1999	1 SAC Retubed	2 GBC Installed	3 GBC Installed TBC Replaced		1 TBC Replaced	
2000		3 GBC Installed 1 TBC Replaced		3 GBC Installed 1 TBC Replaced	3 GBC Installed	3 GBC Installed CWP Replaced
2001			4 SAC Clean Ext.			1 SAC Plugged
2002						

Legend: SAC – Surface Air Cooler; TBC – Turbine Bearing Cooler; GBC – Generator Bearing Cooler; CWP – Cooling Water Pumps

Table 9: Work History Timeline

Equipment Replacement

From the timeline it can be seen that there has been considerable equipment replacement over the past four years. This included the replacement of the generator bearing coolers and turbine bearing coolers. There are plans to purchase spare surface air coolers such that a plan can be initiated to remove and retube all the surface air coolers on a rotational basis. Further to this, three service water pumps were recently replaced and there are plans to replace the strainers in the near future.

Piping Replacement

There is currently a program underway for piping replacement. The following is a description of completed and planned work for sections of piping in the system:

- 10" Supply Header. Has been replaced from Units 1 to 4 during the summer 2001 and plan to replace the remainder of the header during summer 2002. Original and Replacement Material – Carbon Steel.
- 2" Backwash / Turbine Bearing Supply Header. Has been replaced in the past 5 years. Original Material – Carbon Steel with threaded fittings. Replacement Material – Carbon Steel with victaulic fittings.
- Generator Bearing Cooler Piping. One Unit has been replaced during summer 2001. Plans to replace three more units during summer 2002. Original Material – Marine brass and mixture of fittings including homemade brass fittings. Replacement Material – Stainless Steel.
- Turbine Bearing Cooler and Shaft Seal Piping. Piping located outside the generator was replaced on all units. Replacement Material – Stainless Steel. Piping located inside the Generator Pit has been replaced on 4 units with the other 2 units planned for summer 2002. Replacement Material – Stainless Steel and Flexible Hose.

Stainless Steel was used for all the piping replacement due to its non-corrosive properties, however the 10" header was replaced with carbon steel. This was due to two reasons; the high cost of stainless steel and the arrangement of pipe supports didn't allow for replacement with PVC.

Discussions were conducted last year to arrive at the decision of replacement of the above piping with stainless steel. These sections have been or will be completed in the near future and therefore they will not be considered as future work within the context of this study. For the purpose of this study the following sections will be considered as the remaining piping to be replaced:

- Surface Air Cooler Piping.
- Emergency Supply Backup Piping.
- Pump and Strainer Piping.

Test Samples

In August 2001 water samples and pipe deposits from the Bay D'Espoir plant were sent to BetzDearborn for analysis. The water sample is directly from the penstock supply and the deposits are from the 10" supply header. The table below shows the composition of the water sample. As one can see the pH level of 6.2 tells us that the water is acidic in nature. This type of water is very aggressive and will corrode piping and equipment.

Composition	Sample
pH	6.2
Specific Conductance @ 25C, μmhos	13.7
Alkalinity "P" as $CaCO_3$, ppm	0
Alkalinity "M" as $CaCO_3$, ppm	2.1
Sulfur Total as SO_4, ppm	< 5
Chloride as CL, ppm	3.7
Hardness Total as $CaCO_3$, ppm	3.8
Calcium Hardness Total as $CaCO_3$, ppm	2.3
Magnesium Hardness Total as $CaCO_3$, ppm	1.6
Copper Total as Cu, ppm	< 0.05
Iron Total as Fe, ppm	0.08
Sodium as Na, ppm	1.1
Phosphate Total Inorganic as Po_4, ppm	< 0.2
Phosphate Filtered Ortho- as Po_4, ppm	< 0.2
Silica Total as SiO_2, ppm	1.0
Carbon. Total Organic as C, ppm	4.7
Color, Apparent, Color Units (APHA)	10.0

Table 10: Water Test Sample Results

The table below shows the composition of the deposit taken from the 10" supply header. As one can see the sample deposits are mainly composed of metal oxides. These metal oxides are from the pipe wall, which is being corroded by the acidic water. Loss on ignition (LOI) refers to the organics within the sample.

Composition	Sample
Iron $Fe_2O_3 + Fe_3O_4$	81%
Loss on Ignition (LOI)	13%
Manganese MnO_2	5%
Aluminum Al_2O_3	1%

Table 11: Pipe Deposit Sample Results

The complete BetzDearborn analysis of the water and pipe samples can be found in Appendix D.

Trend Monitoring

Trend Monitoring readings are taken weekly by operations for all hydro generating stations except Snooks Arm and Venams Bight. With knowledge of the work history performed on the generating station coupled with the trend monitoring readings one can develop a picture of how the generating station has operated over the last few years.

The trend monitoring readings are now being stored in a database using Microsoft Access. A hard copy of the weekly readings is being kept on site for backup. The Microsoft Access Trend Monitoring program now allows quick graphing of operating parameters to help us determine the efficiency of the unit. The program is user friendly and allows operations to view the units operating parameters over an extended period of time.

The data used for the trend monitoring for Bay D'Espoir was taken from the past two years. This data was imported into the database from excel spreadsheets that were previously used. Additional data is available in hard copy form. All the graphs from the trend monitoring exercise are located in Appendix E.

To highlight the main trends for the six units, the graphs are grouped together by each type of cooler. For each cooler the temperature reading as well as the flow rate was reviewed.

Surface Air Coolers Trending

The surface air cooler graphs displayed in the Appendix have a page for each different unit; the top graph shows the flow rate for both the north and south surface air coolers. Both of these meters follow the same trends and map the same values. The lower graph displays the water temperature for the inlet and outlet of the surface air coolers.

The results from the graphs can be summarized into three main trends:

- The water flow rate cycles from summer to the winter. During the summer the flow rate averages around 2500 LPM. During the winter the flow rate averages around 1200 LPM. This cycle is a result of the increase in water temperature during the summer months. Since the temperature increases the flow has to be increased to provide the same heat transfer rate.
- For several units the peak flow rate has increased from summer of 2000 to the summer of 2001. This may be due to higher water temperatures last summer or due to fouling within the cooler, it is not possible to tell without additional data.
- The inlet water temperature varies from approximately 4°C in the winter to 20°C in the summer, however the rise in water temperature from the inlet to the outlet of the cooler is approximately 3°C in the winter to 1°C in the summer.

The surface air cooler flow rate is temperature controlled at the discharge of the coolers. The temperature control valves in many cases are manual opened full and by-passed during the summer to increase the flow rate to the coolers. There are no temperature alarms associated with the surface air coolers, the system alarms are based on the flow rate; the table below describes the alarm set points for the coolers. The temperatures are monitored and recorded but do not have alarms associated with them.

	Unit #1 - #6
Surface Air Coolers:	
Flow Range	0 – 3121 LPM
Low Alarm	500 LPM
High Alarm	3000 LPM

Table 12: Surface Air Cooler Flow Alarms

Generator Guide / Thrust Bearing Coolers Trending

The generator bearing cooler graphs are displayed in a similar way as the surface air coolers, each page describes a different unit; the top graph shows the flow rate for the coolers and the lower graph displays the water temperature for the inlet and outlet water as well as the two bearing temperatures. The following table displays the bearing temperature alarm set points. These alarms are sometimes slightly adjusted depending on operating conditions.

	Guide Bearing	Thrust Bearing
Alarm	70 °C	80 °C
Trip Unit Off Line	80 °C	90 °C

Table 13: Temperature Alarm Set Points for Generator Bearing

The results from the graphs can be summarized into four main trends:

- The water flow rate cycles from summer to the winter. During the summer the flow rate averages around 550 to 650 LPM. During the winter the flow rate averages around 350 to 450 LPM. This cycle is a result of the increase in water temperature during the summer months. Since the temperature increases the flow has to be increased to provide the same heat transfer rate.
- For several units the peak flow rate has increased from summer of 2000 to the summer of 2001. This may be due to higher water temperatures last summer or due to fouling within the cooler, it is not possible to tell without additional data.
- The inlet water temperature varies from approximately 4°C in the winter to 20°C in the summer, however the rise in water temperature from the inlet to the outlet of the cooler is approximately 5°C in the winter to 3°C in the summer.

- The bearing temperature data provides information for the effect of cooling. From the graphs, it can be seen that the bearing temperature is maintained below the alarm set points. However, Unit #4 and #5 show peak summer temperatures on the thrust bearing of approximately 85°C, this is above the alarm set point of 80°C. This may be due to low flow rates or high water temperatures.

Turbine Bearing Cooler Trending

The trending data displayed in the Appendix is arranged with each page for a different unit; the top graph shows the flow rate for the cooler and the lower graph displays the turbine bearing temperature. The following table displays the bearing temperature alarm set points. These alarms are sometimes slightly adjusted depending on operating conditions.

	Unit #1 - #6
Turbine Bearing	
Alarm	60 °C
Trip Unit Off Line	70 °C

Table 14: Temperature Alarm Set Points for Turbine Bearing

The results from the graphs can be summarized into three main trends:

- The water flow rate ranges a great deal from unit to unit. From as low as 15 LPM to as high as 30 LPM.
- The flow rate is constant. There is an absence of cycles from summer to the winter as was seen in the surface air coolers and generator bearing coolers. This is due to the flow control. That is, it is not temperature controlled; the reducing valve located in the supply line controls the flow rate. The effects of adjustments or replacements of the reducing valve can be seen on the trending graphs.
- The turbine bearing temperature is constant at approximately 44°C to 55°C and is below the alarm set point of 60°C for the data available.

Tube Velocity

Another important aspect of the service water system is the water velocity in the coolers. When the tube velocity is too low the particulates in the water can settle out. The result of this can cause fouling of the cooler and reduce the heat transfer rate. Also, if the tube velocity is excessively high, the life of the cooler can become compromised due to erosion. The tube velocity is calculated using the following formulae:

$$V = \frac{Q}{A_{flow}} \qquad A_{flow} = \frac{A_{tube} \cdot N_{total}}{N_{pass}}$$

V = Tube Velocity, m/sec
Q = Flow per Cooler, m^3/sec
A_{flow} = Flow Area, m^2

A_{tube} = Flow Area of One Tube, m^2
N_{total} = Total Number of Tubes
N_{pass} = Number of Passes

The following table displays the design conditions for each of the three types of coolers used in units 1-6 in the Bay D'Espoir Plant. The table contains the tube velocity at the design condition of maximum flow. Also, the calculations were repeated using actual values from the trend monitoring information. Since the values vary throughout the year, the maximum and minimum values were used to obtain an accurate representation of the actual tube velocities.

	Surface Air Coolers	Generator Brg Coolers	Turbine Brg Coolers
Cooler Specifications:			
Number of Tubes:	132	20	12
Number of Passes:	2	4	12
Number of Tubes in Flow:	66	5	1
Tube Area (m2):	0.00022	0.00031	0.00028
Total Flow Area (m2):	0.01457	0.00153	0.00028
Design Velocity:			
Flow Rate / Cooler (LPS):	21.8	2.3	1.1
Velocity (m/s):	1.50	1.49	4.04
Velocity (fps):	4.91	4.88	13.26
Actual Maximum Flow Rate:			
Flow Rate / Cooler (LPS):	23.3	4.2	1.0
Velocity (m/s):	1.60	2.72	3.56
Velocity (fps):	5.26	8.94	11.67
Actual Minimum Flow Rate:			
Flow Rate / Cooler (LPS):	8.3	1.7	0.2
Velocity (m/s):	0.57	1.09	0.59
Velocity (fps):	1.88	3.57	1.94

Table 15: Cooler Tube Velocity

A report was prepared in May of 2000 that identified the minimum tube velocity that is recommended to eliminate maintenance cleaning for surface air coolers. The study compared the existing design tube velocities to the past cleaning frequency for each hydro plant. The plants included in the study along with their maximum design velocity are listed in the table below.

Plant	Maximum Design Velocity
CFLCO (CGE Units)	10.0 ft/sec
CFLCO (MIL Units)	7.00 ft/sec
BDE (1 to 6)	4.48 ft/sec*
Hind's Lake	3.45 ft/sec
BDE (Unit 7)	2.96 ft/sec
Cat Arm	4.32 ft/sec
Upper Salmon	2.81 ft/sec

* Should be 4.91 ft/sec, 132 tubes/cooler not 148.

Table 16: Maximum Design Velocity Comparison

The main recommendation that was made from the study was to identify the minimum **design** velocity for the surface air cooler tubes. This value was recommended at a minimum of 4.5 feet per second for any future modified stator coolers or for installations of new systems.

The design velocity for Bay D'Espoir Units 1-6 is 4.91 ft/sec. This is above the minimum recommended velocity of 4.5 ft/sec. However during the summer the increased flow rate to the coolers results in actual tube velocities of 5.26 ft/sec and during the winter, when the flow rate is reduced, it can fall as low as 1.88 ft/sec. The actual velocities for the tubes were not considered in the study as all the units were compared on the basis of the maximum design velocity only. Also noted in the study was the surface air coolers for Bay D'Espoir Units 1-6 did not require cleaning and had velocities that *"are significantly high enough to maintain efficiency of the coolers without cleaning."* Therefore these surface air coolers do not require modifications to increase the tube velocities.

Alternative Solutions

Introduction

The fouling problem with regard to the cooling water system is being caused by a combination two possible problems; corrosion of the piping system and organic build up.

- The acidic water supply is causing the piping system to corrode and the organics are then attaching themselves to the corrosion deposits. Over time the organics build up and are able to clog the pipe.
- As the cooling water passes through the coolers the suspended organics in the water settle out. This then causes the discharge piping to become clogged with organics and choke off the flow. A decreased flow rate allows for more organics to settle within the cooling water system. Eventually the entire cooling water system will become clogged with organics.

The following is a list of alternative solutions that were considered to combat these problems. A brief description of each proposed solution is discussed below.

1. Mechanical cleaning of the system.
2. Chemical cleaning of the system.
3. Replace the piping with corrosion resistant pipe.
4. Chemically treat the water.
5. Develop a flushing maintenance program.
6. Incorporate organic filters.
7. Convert the system to a closed loop operation.

Mechanical Cleaning

Mechanical cleaning of the cooling water system will require a maintenance cleaning program if this solution is going to be considered. Without a maintenance cleaning program the reliability of the service water system will be compromised and forced unit outages will happen.

Mechanically cleaning the service water system will require a cleaning maintenance crew and scheduled plant outages to perform the work. The piping and heat exchangers have to be removed from service and physically cleaned by hand. This hand cleaning decreases the life expectancy of both the piping and heat exchangers. The hand cleaning of piping and cooler tubes is done with rotating nylon brushes that physically scrape the pipe walls of organic build up. Also the possibility of mechanical damage is increased when man handling the piping and heat exchangers.

Chemical Cleaning

Chemical cleaning of the service water system requires a maintenance cleaning program to be established. Without a maintenance cleaning program the reliability of the service water system will be compromised and forced unit outages will occur.

Chemically cleaning the service water system will require a cleaning maintenance crew and scheduled plant outages to perform the work. The piping and heat exchangers don't have to be removed from the system. Instead isolation valves upstream and downstream are closed and mechanical branch connections are attached to the piping system in both upstream and downstream locations. The chemical mixture is then pumped through the system to dissolve any organic build up. Chemical treatment is harsh on the piping and heat exchangers and decreases their life expectancy. The chemical leaves the metal in an unpassivated state and corrosion will occur very rapidly after returning the system to service.

Replace Piping with Corrosion Resistant Piping

Currently the piping material is mild steel schedule 40. Two different piping materials have been considered for replacement of the mild steel pipe, they are 316 stainless steel pipe schedule 10 and polyvinyl chloride (PVC) pipe schedule 80. The 316 stainless steel schedule 10 pipe is considered because of its corrosion resistance and mechanical properties. The stainless steel pipe will be placed in high traffic areas or in areas where the piping is likely to be hit to prevent damage. The PVC schedule 80 pipe is considered because of its corrosion resistance, mechanical properties, and thermal properties. Schedule 80 will be more durable when compared with schedule 40. Due to PVC's excellent thermal properties there will be no need to insulate the pipe as compared to stainless steel. The PVC pipe will be placed in low traffic areas where the probability of the pipe being damaged is remote. The PVC pipe is less costly to purchase as well as install.

Chemical Treatment of Water

The water can be chemically treated to reduce the acidity by raising the pH level, which will reduce corrosion and help keep all organic materials in a suspended state. The treatment chemical would be constantly injected at the entrance to the system. The existing service water system is a once through operation and will require large amounts of chemical and therefore carry high chemical costs. It is important to note that the fish hatchery utilizes the water from the discharge and the fish will be sensitive to the chemical additives. Also, there are possible future environmental considerations with the use of this product, although the chemical is currently environmentally acceptable.

Flushing Maintenance Program

Flushing each cooler individually to remove any organic build up will help keep the service water system clear. Flushing is performed when all water flow is directed through one particular cooler for a predetermined amount of time. Any lose organic material will be forced out of the cooler and washed away. This would delay but not prevent the blockage of the pipe since the corrosion would still continue.

If a flushing program was implemented it would reduce the amount of organic build up within the service water system. The program would consist of flushing the coolers every four weeks starting in the spring and continuing over the summer.

Organic Filters

Organic filters can be incorporated at the beginning of the service water system to remove the organics from the water. Sand filters are an effective method of removing organics from water. Typical flow rates for sizing a sand filter are 3-6 GPM for every square foot of surface area. The smallest sand filter for Bay D'Espoir would be around 18 ft in diameter to allow for 1500 GPM. Each unit would require it's own filter. Space would then become a problem with this solution.

Closed System Operations

By adding another heat exchanger to the existing service water system one can create a closed system. There are various heat exchangers that can be implemented into the system such as water-to-water, air-to-water, or chemical-to-water. Water-to-water would be the most practical in this situation due to the amount of heat that is being transferred through the exchanger. An air-to-water heat exchanger would have a very large surface area in order to remove the quantity of heat within the system, making this solution not practical. Using a chemical medium within the closed circuit system is not necessary considering the temperatures that we are dealing with.

This additional heat exchanger will require pumps, piping and valves in order to be incorporated into the service water system. In addition the style and location of this new heat exchanger will be incorporated into the design of the new system so that maintenance will be easier. Also this system will have 100% capacity back up so that cleaning of the heat exchanger will not require any unit outages.

The use of a cooling pond to supply water to the service water system can be considered a closed loop system. The water in the cooling pond can be chemically treated to ensure that it remains neutral. Again space would be a restriction with this type of solution.

Viable Solutions

Introduction

Four alternative solutions were considered viable and were developed further to the point of an economic review:

- Operate as Current
- Chemical Treatment of Water
- Replace Piping with Corrosion Resistant Piping
- Closed System Operation

The economic review is based on the net present worth of each of the solutions rather than only a comparison of capital costs, this way the true cost of the option can be evaluated over the life of the plant. All the costs discussed in this section are on a per unit basis, this is to produce a common baseline for the analysis.

General Information

The piping costs for each option were required. The materials for the piping were estimated using quoted prices from EMCO distribution. The labor costs were estimated using the labor installation time and crew type from RSMeans Mechanical Cost Data 2002. The hourly rates that were used for the personnel are shown in the table below.

Personnel	Hourly Rate
Plumber	$ 21.56
Plumber Apprentice	$ 21.56
Welder	$ 21.56
Supervisor (+10%)	$ 23.72
Overhead	63%

Table 17: Hourly Rates for Labor Costs

The crew type and day rates for each type of installation were calculated and are shown in the table below. The full details for each piping estimate can be found in Appendix F.

Crew Type:	1 Plum	Q1	Q2	Q15	Q16
Plumber	1	1	2	1	2
Plumber Apprentice	-	1	1	1	1
Welder	-	-	-	1	1
Supervisor	0.333	0.333	0.333	0.333	0.333
Day Rate ($/Day)	**$ 384.12**	**$ 665.27**	**$ 946.41**	**$ 946.41**	**$ 1,227.55**

Table 18: Day Rate for Crew Types

For the net present worth analysis it was necessary to set a constant annual escalation rate and annual discount rate. The annual escalation for the analysis is 2% and the annual discount rate is 8.5%. The analysis was performed over a 50 year time period to capture all reoccurring costs with each option. The full details of the analysis for each option are shown in Appendix G.

Maintenance Costs

To evaluate the maintenance costs for the service water system estimates were prepared. Each maintenance work plan was considered separately. That is, the cost of cleaning each type of cooler was outlined. The following is the breakdown of the assumptions that were made to determine these costs:

Minimum Work Crew:

- 3 Workers (2 workers on floor, 1 worker operating the crane)
- 1 Supervisor (1/3 time charged, normally supervising more than one job)

Crew Labor Costs:

- Workers: ($21.56 / hr) x 3 = $64.68 / hr
- Supervisor: $23.72 / hr (Worker x 10% x 1/3) = $7.90 / hr
- Crew Labor Rate: $72.58 / hr

Overhead Costs:

- Total over head costs: Salary x 63%
- Total Labor Rate: $118.30

Cleaning Time for Equipment:

- Surface Air Coolers: (8hrs / Cooler) x (4 Coolers) = 32 hrs
- Surface Air Cooler Piping: 3 days = 24 hrs
- Generator Coolers: (16 hrs / Cooler) x (3 Coolers) = 48 hrs
- Generator Cooler Piping: 3 days = 24 hrs

The following table contains the results of the cost estimates for cleaning the equipment:

Equipment	Time	Rate	Total Cost
Surface Air Coolers	32 hrs	$118.30	**$ 3785.64**
Surface Air Cooler Piping	24 hrs	$118.30	**$ 2839.23**
Generator Coolers	48 hrs	$118.30	**$ 5678.46**
Generator Cooler Piping	24 hrs	$118.30	**$ 2839.23**

Table 19: Estimated Maintenance Cost (Equipment Cleaning)

Option 1 - Operate as Current

The basis for this option is to operate the system as in the past, without any design modifications. By evaluating this option we are setting a baseline. This option will allow a comparison of the existing long-term, high maintenance option to the other options, which include an initial capital cost but have reduced maintenance costs.

The net present worth analysis of this option involves the following costs:

- Initial replacement of pipe with carbon steel pipe.
- Replacement of the piping on a regular basis.
- Service water pump operating costs.
- Maintenance costs estimated at a high frequency.

The following table details the material and labor cost associated with replacement of the piping with carbon steel as in the original design. The piping currently requires replacement as it is at the end of its life. The piping that has been replaced or is planned for replacement this summer will not be considered in the cost analysis as that spending is already committed. The estimated piping costs are $33,476.

Piping Section	Materials	Labor	Total
Surface Air Cooler	$ 5,249	$ 6,735	**$ 11,984**
Emergency Supply	$ 569	$ 3,009	**$ 3,577**
Pump and Strainer Piping	$ 4,831	$ 8,718	**$ 13,548**
Contingency 15%	$ 1,597	$ 2,769	**$ 4,366**
Total	**$ 12,245**	**$ 21,231**	**$ 33,476**

Table 20: Piping Replacement Costs - Carbon Steel

This option assumes that the piping will require replacement on a regular basis. This frequency is estimated at 25 years to maintain reasonable reliability of the system.

The service water pump operating costs are determined by the power usage. The pump power requirement alternates between 50 HP and 60 HP for the different pumps in the system, since this analysis is based on a per unit basis the power requirement is averaged to 55 HP. This power rating produces an approximate annual operating cost of $18,000. The equation below details the calculation:

$$\text{Cost} = (55\,\text{HP} \times 0.7457\frac{\text{kW}}{\text{HP}}) \times (0.05\frac{\$}{\text{kW}\cdot\text{hr}} \times 8760\frac{\text{hr}}{\text{yr}}) = \$17{,}964/\text{yr}$$

The maintenance cost associated with this option is based on the estimate prepared earlier in this report. The frequency for the maintenance was estimated at a high rate since the corrosion will increases cleaning requirements. The table below shows the estimated frequency and cost used in the analysis.

Equipment	Frequency	Total Cost
Surface Air Coolers	5 years	$ 3,785.64
Surface Air Cooler Piping	10 years	$ 2,839.23
Generator Coolers	5 years	$ 5,678.46
Generator Cooler Piping	10 years	$ 2,839.23

Table 21: Option 1 - Maintenance Frequency and Cost

These costs were used to obtain the net present worth of this option. The following chart displays the results. The total net present worth for the cost of this option is estimated at $334,343.

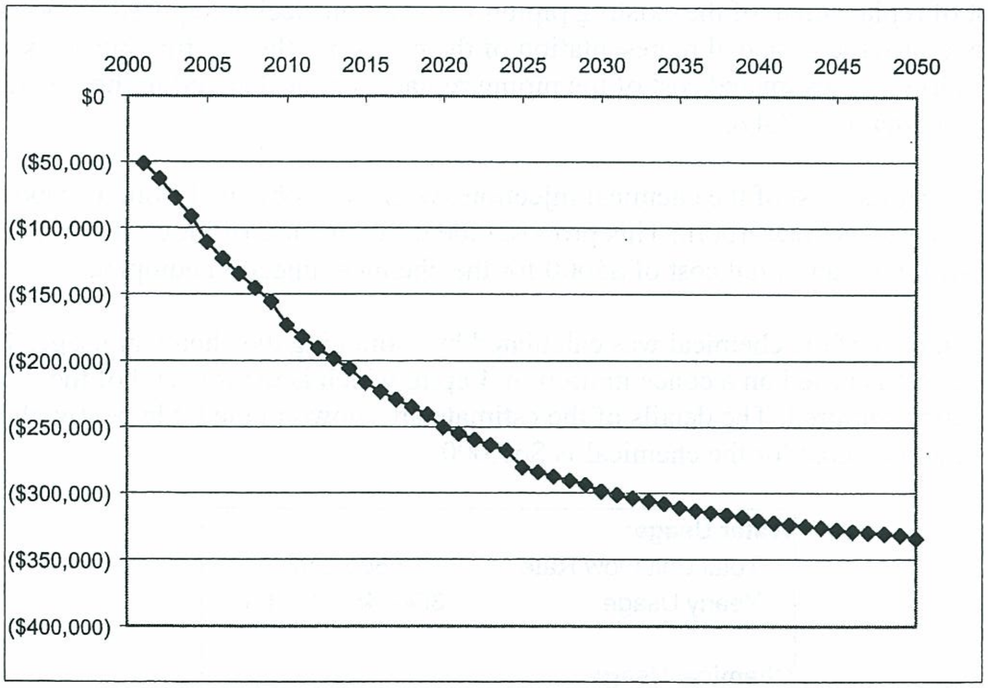


Figure 3: NPW – Option 1

Option 2 - Chemical Treatment of Water

This option involves the use of a once through chemical treatment that will reduce corrosion within the piping and fouling of the equipment. The benefit of this option is the reduced frequency of maintenance and pipe replacement. However, this option has the added operating cost of the chemical and previously identified environmental sensitivities for the fish hatchery as well as possible future emission controls.

The net present worth analysis of this option involves the following costs:

- Cost of replacement of the existing piping with carbon steel pipe.
- Initial capital cost of the chemical injection system
- Annual cost of bulk chemical.
- Service water pump operating cost.
- Maintenance costs estimated at a reduced frequency.

The cost of replacement of the existing piping with carbon steel is required in the estimate to provide an actual representation of the cost since the existing piping is at the end of its life. The estimated cost of the piping replacement is detailed in the previous section; the total is $33,476.

The initial capital cost of the chemical injection system was obtained from a proposal that was prepared by BetzDearborn. This proposal identified the use of Flogard POT6101 as the chemical with an initial cost of $5000 for the chemical injection equipment.

The annual cost of the chemical was calculated by estimating the chemical usage. The estimated cost is based on a concentration of 4 ppm, which is the low end of the concentration required. The details of the estimate are shown in the table below, the estimated annual cost for the chemical is $65,600.

Water Usage:	
Total Unit Flow Rate	5800 L/min
Yearly Usage	3048.48×10^6 L/yr
Chemical Usage:	
Desired Concentration	4 ppm
Volume Consumption	12194 L/yr
Density of Chemical	1398 kg/m^3
Mass Consumption	17047 kg/yr
Chemical Cost:	
Bulk Unit Cost	$3.85 /kg
Total Annual Cost	$65,631.34

Table 22: Chemical Cost Estimate

The service water pump operating costs were determined in the previous section. The same estimate was used for this option, as the pump requirements are constant. The approximate annual operating cost of the pump was estimated at $18,000.

The maintenance costs associated with this option are based on the estimate prepared earlier in this report. The frequency for the maintenance was estimated at a reduced rate since the corrosion will be inhibited by the use of the chemical. The frequency was increased five times that of the original option. The table below shows the estimated frequency and cost used in the analysis.

Equipment	Frequency	Total Cost
Surface Air Coolers	25 years	**$ 3,785.64**
Surface Air Cooler Piping	50 years	**$ 2,839.23**
Generator Coolers	25 years	**$ 5,678.46**
Generator Cooler Piping	50 years	**$ 2,839.23**

Table 23: Option 2 – Maintenance Frequency and Cost

These costs were used to obtain the net present worth of this option. The following chart displays the results. The total net present worth of the cost for this option is estimated at $1,265,207.

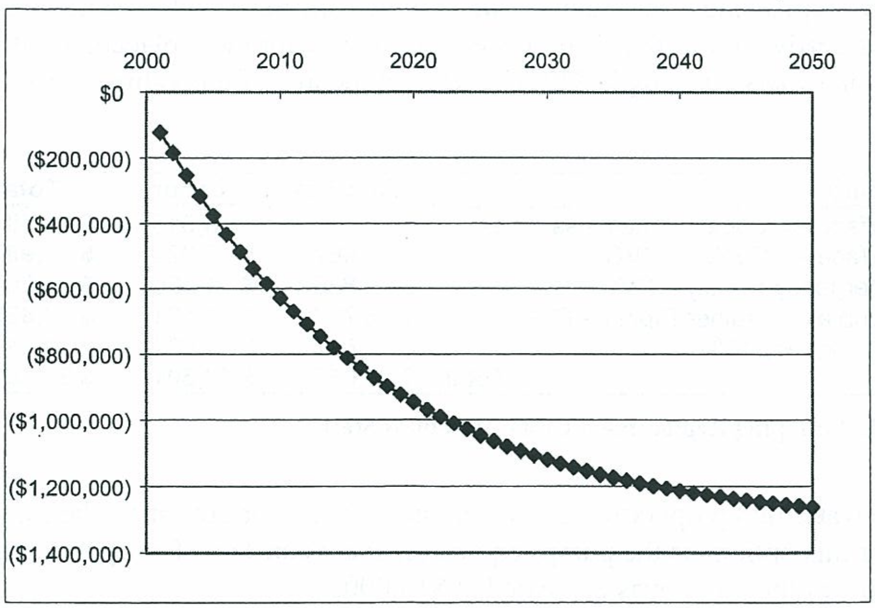


Figure 4: NPW – Option 2

Option 3 – Replace Piping with Corrosion Resistant Piping

This option involves replacing the existing piping with corrosion resistant piping. The idea with this option is to reduce the corrosion of the piping and therefore reduce the fouling within piping and coolers. This option has the benefit of reducing maintenance costs however there is an increased capital cost. The corrosion resistant piping specified for this option would be PVC piping outside the generator housing and Stainless Steel inside the generator housing.

The net present worth analysis of this option involves the following costs:

- Initial replacement of pipe inside the generator with Stainless Steel.
- Initial replacement of pipe outside the generator with PVC.
- Service water pump operating costs.
- Maintenance costs estimated at a reduced frequency.

The following table details the material and labor cost associated with replacement of the piping with non-corrosive piping. Inside the generator housing the piping used will be schedule 10 Stainless Steel with victaulic couplings. Outside the generator housing, schedule 80 PVC pipe with socket connection fittings will be used. Connections to the existing equipment will be made using PVC flanges. Although the stainless steel piping is more expensive than the existing carbon steel there is a significant savings with using PVC in the material costs as well as the labor costs. The piping that has been replaced or is planned for replacement this summer will not be considered in the estimate as that spending is already committed. The total estimated cost for the replacement of the piping with corrosion resistant piping is $32,562. The full details of this estimate can be found in Appendix F.

Piping	Materials	Labor	Total
Surface Air Cooler – Stainless Steel	$ 9,888	$ 3,516	**$ 13,404**
Surface Air Cooler – PVC	$ 962	$ 2,024	**$ 2,987**
Emergency Supply – PVC	$ 836	$ 1,230	**$ 2,066**
Pump and Strainer Piping – PVC	$ 5,757	$ 4,101	**$ 9,858**
Contingency 15%	$ 2,617	$ 1,631	**$ 4,247**
Total	**$ 20,061**	**$ 12,501**	**$ 32,562**

Table 24: Piping Replacement Costs – Stainless Steel & PVC

The service water pump operating costs were determined for option 1. The same estimate was used for this option, as the pump requirements are constant. The approximate annual operating cost of the pump was estimated at $18,000.

The maintenance costs associated with this option are based on the estimate prepared earlier in this report. The frequency for the maintenance was estimated at a reduced rate since the pipe corrosion problem will be eliminated. The frequency was increased five times that of the first option. The table below shows the estimated frequency and costs used in the analysis.

Equipment	Frequency	Total Cost
Surface Air Coolers	25 years	$ 3,785.64
Surface Air Cooler Piping	50 years	$ 2,839.23
Generator Coolers	25 years	$ 5,678.46
Generator Cooler Piping	50 years	$ 2,839.23

Table 25: Option 3 - Maintenance Frequency and Cost

These costs were used to obtain the net present worth of this option. The following chart displays the results. The total net present worth for the cost of this option is estimated at $296,499.

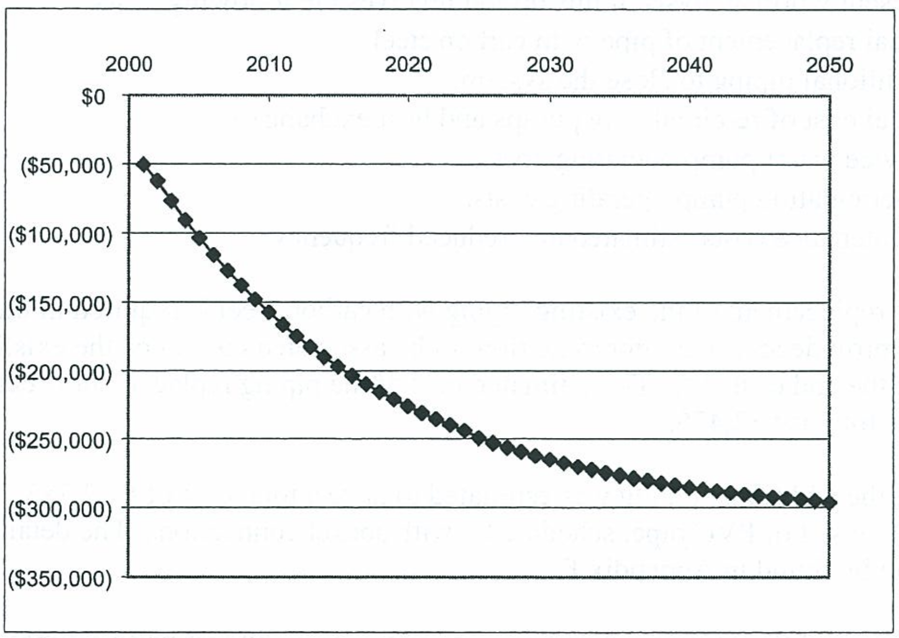


Figure 5: NPW – Option 3

Option 4 - Closed System Operation

This option involves converting the system to a closed loop system. The idea behind this option is to utilize a corrosion-inhibited cooling medium that circulates throughout the system. A sketch is attached in Appendix H that describes the layout of the system. The surface air coolers and the generator bearing coolers would be included in the loop. The turbine bearing and shaft seal water is currently supplied from a separate source and would not be included in the closed loop. The existing service water pumps would be used to cool the inhibited medium through a heat exchanger and the waste heat could be diverted to the fish hatchery from the exit of the heat exchanger. This option has the benefit of reducing maintenance costs by minimizing corrosion. The costs for this option include the installation of a re-circulating pump and heat exchanger as well as additional piping to close the loop.

The net present worth analysis of this option involves the following costs:

- Initial replacement of pipe with carbon steel
- Additional piping to close the system.
- Initial cost of re-circulating pumps and heat exchangers.
- Service water pump operating costs.
- Re-circulation pump operating costs.
- Maintenance costs estimated at a reduced frequency.

The cost of replacement of the existing piping with carbon steel is required in the estimate to provide an actual representation of the associated cost since the existing piping is at the end of its life. The estimated cost of the piping replacement is detailed in option 1 the total is $33,476.

The cost of the additional piping was estimated to have a total cost of $ 12,783. The piping will consist of PVC pipe, schedule 80 with socket connections. The details of this estimate can be found in Appendix F.

The capital cost of the new equipment was estimated using budget price estimates from manufactures. The details of the equipment used for the estimates are attached in Appendix H. The pump used for the estimate has a capacity of 1500 GPM at 70 ft; the budget estimate is $10,000. The heat exchanger used for the estimate was a plate-to-plate type with a capacity of 1500 GPM and a temperature change of 5-10 °C; the budget estimate is $25,000.

The service water pump operating costs were determined for option 1. These pumps will be used in this option to pump the cooling water for the heat exchangers. Therefore the same estimate was used for this option, as the pump requirements are constant. The approximate annual operating cost of the pump was estimated at $18,000.

The re-circulating pump operating costs were determined by the same means as the service water pump. The pump power requirement is 40 HP. The equation below produces an approximate annual operating cost of $13,000.

$$\text{Cost} = (40\ \text{HP} \times 0.7457 \frac{\text{kW}}{\text{HP}}) \times (0.05 \frac{\$}{\text{kW} \cdot \text{hr}} \times 8760 \frac{\text{hr}}{\text{yr}}) = \$13{,}065/\text{yr}$$

The maintenance cost associated with this option was based on the estimate prepared earlier in this report. The frequency for the maintenance was estimated at a reduced rate since the pipe corrosion problem will be eliminated. The frequency was increased five times that of the first option. The table below shows the estimated frequency and cost used in the analysis.

Equipment	Frequency	Total Cost
Surface Air Coolers	25 years	$ 3,785.64
Surface Air Cooler Piping	50 years	$ 2,839.23
Generator Coolers	25 years	$ 5,678.46
Generator Cooler Piping	50 years	$ 2,839.23

Table 26: Option 3 - Maintenance Frequency and Cost

These costs were used to obtain the net present worth of this option. The following graph displays the results. The total net present worth for the cost of this option is estimated at $547,904.

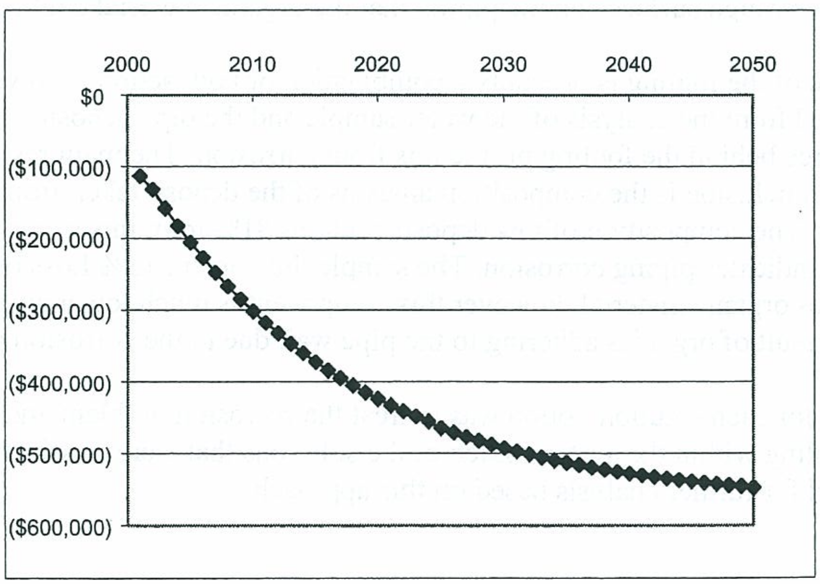


Figure 6: NPW - Option 4

Conclusions and Recommendations

Introduction

This section includes the conclusions and recommendations for the study. The process of researching for the study highlighted advantages and disadvantages for each of the options that could not be quantified financially. Therefore, the recommendations made in this section are based on the economics of the options as well as past work history, trending information, and individual considerations for each option.

Root Cause

In order to recommend a solution for the fouling problem in the system it is important to consider the root cause of the problem. The higher equipment temperatures experienced within the system during the summer months are a direct result of fouling in the coolers and piping. The question is what is causing this fouling?

The root cause of the fouling was approached from two possible positions:

1. The fouling could be caused by the presence of organic material that is suspended in the water that precipitates out at low velocities. This could be causing increased corrosion by producing stagnate pockets of water under the organic material on the internal surfaces of the piping.
2. The fouling could be caused by corrosion due to the high acidic nature of the water within the system. This could lead to iron deposits within the coolers and produce rough surfaces on the piping that the organic material could adhere to.

The root cause of the fouling is probably a combination of both actions. However the results obtained from the analysis of the water sample and the pipe deposit suggests that the driving force behind the fouling problem is from corrosion. The main result that points to this conclusion is the composition analysis of the deposit taken from the 10" supply header. The composition of this deposit contains 81% iron; this iron is from the pipe wall and indicates piping corrosion. The sample did contain 13% Loss on Ignition which indicates organic material, however this component is much lower and is considered a result of organics adhering to the pipe wall due to the corrosion process.

The approach for each solution option was to treat the corrosion problem and therefore reduce the fouling within the system. Each of the solutions that were considered viable was developed for further analysis based on this approach.

Conclusions

Of the four options evaluated in this study the option for replacement of the piping with corrosion resistant material has the lowest cost analysis. The table below shows a comparison of the four options discussed in the previous section. The second option has an extremely high cost associated with it; this is due to the large operating cost for the yearly purchasing of chemical.

Option	Cost NPW
1. Operate as Current	$ 334,343
2. Chemical Treatment	$ 1,265,207
3. Corrosion Resistant Piping	$ 296,499
4. Closed System	$ 547,904

Table 27: Comparison of NPW

The figure below shows the net present worth for the two best options. From this figure we can compare the operating costs, capital cost and overall net present worth for the options over the evaluation period. It is apparent from the graph that the "Corrosion Resistant Piping" option has a lower initial capital cost and lower operating costs over the "Operate As Current" option. The final point for the series represents the net present worth of the cost of the option for the evaluation period. As shown by the figure, the cost of the "Corrosion Resistant Piping" option is lower compared to the "Operate As Current" option.

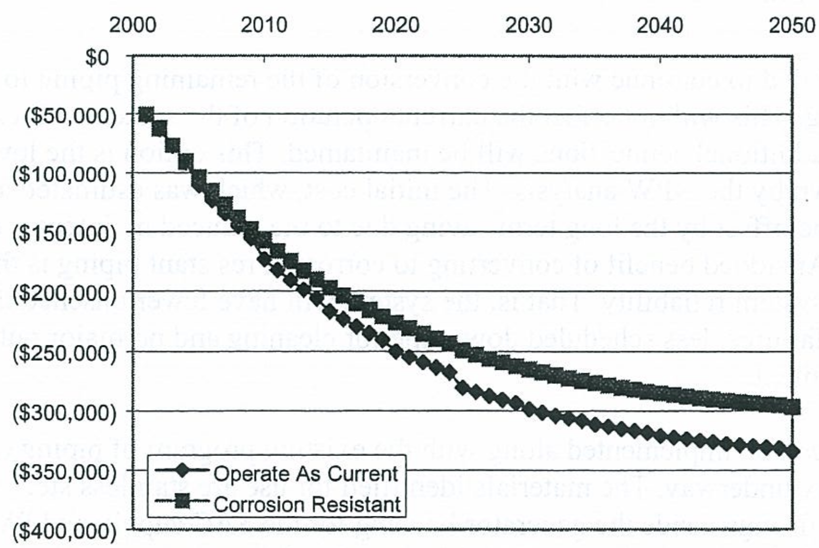


Figure 7: NPW Comparison of Options

Recommendations

The following table summarizes the advantages and disadvantages of each of the viable options developed in the study.

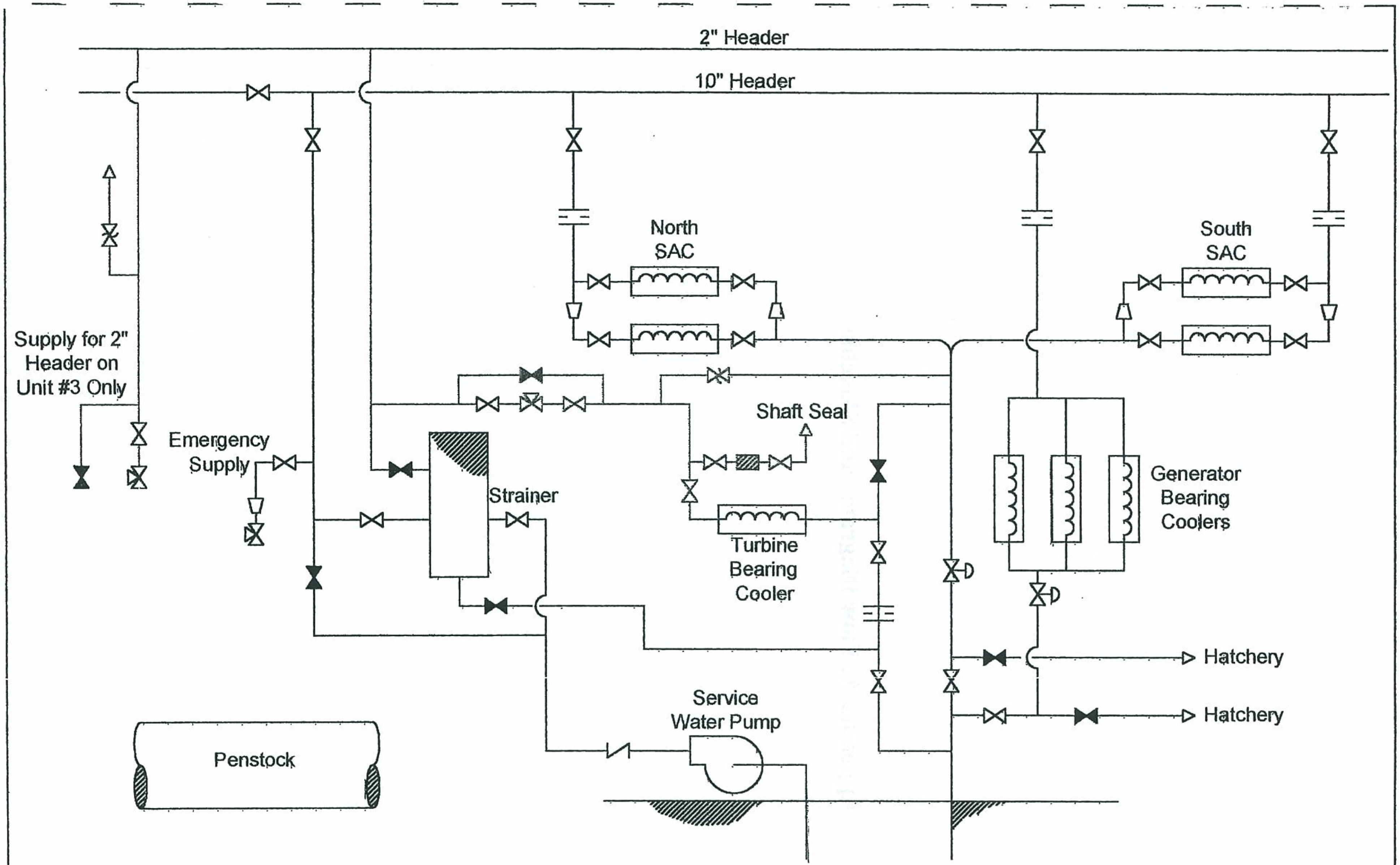
Option	Advantages	Disadvantages
Operate as Current	• Existing design unchanged • No effect on other supplies (Firewater, Repair Shop)	• Reduced system reliability • Future piping replacements • Downtime for mntc.
Chemical Treatment	• Reduce corrosion	• Highest cost solution • High chemical costs • Environmental risk • Lose supply to other areas
Non-Corrosive Piping	• Eliminate corrosion • Some piping converted • Lowest cost solution - NPW • Increases system reliability • Existing design unchanged • No effect on other supplies (Firewater, Repair Shop)	
Closed Loop System	• Temperature control • Reduce corrosion	• Added equipment mntc. • Reduced system flexibility • Don't address turbine brg. • Lose supply to other areas

Table 28: Option Summary

It is recommended to continue with the conversion of the remaining piping to corrosion resistant piping. This will not effect the current operation of the system. All existing branches and additional connections will be maintained. This option is the lowest cost option as shown by the NPW analysis. The initial cost, which was estimated at $32,562 per unit, will be offset by the long term saving due to the reduced maintenance and piping replacement. An added benefit of converting to corrosion resistant piping is the increase in the overall system reliability. That is, the system will have fewer unscheduled outages due to piping failures, less scheduled downtime for cleaning and no major outages for piping replacement.

This solution can be implemented along with the existing program of piping replacement that is currently underway. The materials identified for use are stainless steel schedule 10 with victaulic fittings inside the generator housing for the SAC supply and PVC schedule 80 pipe and fittings outside the generator housing, for the emergency supply and all drains.

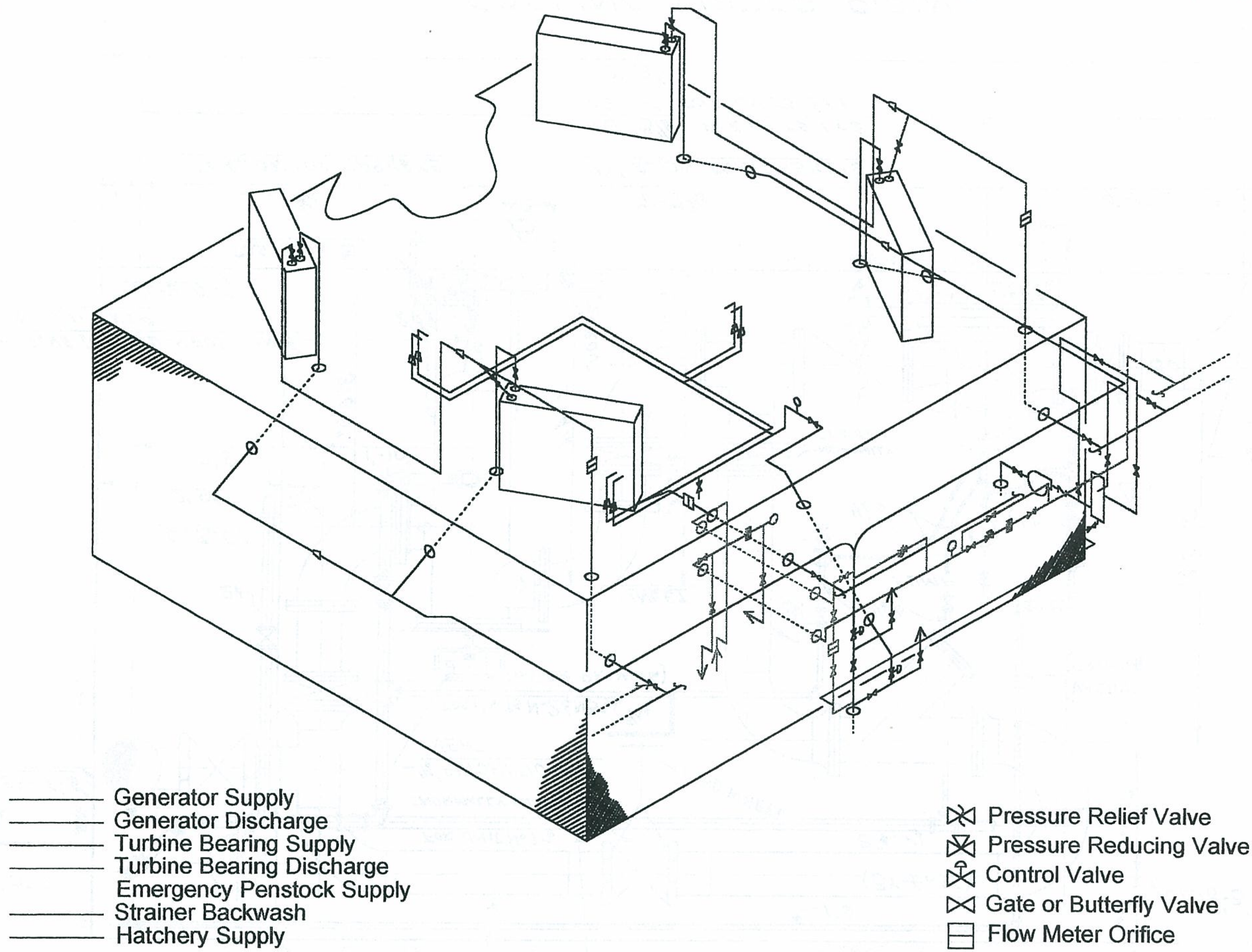
Appendix A: Flow Diagrams and Sketches

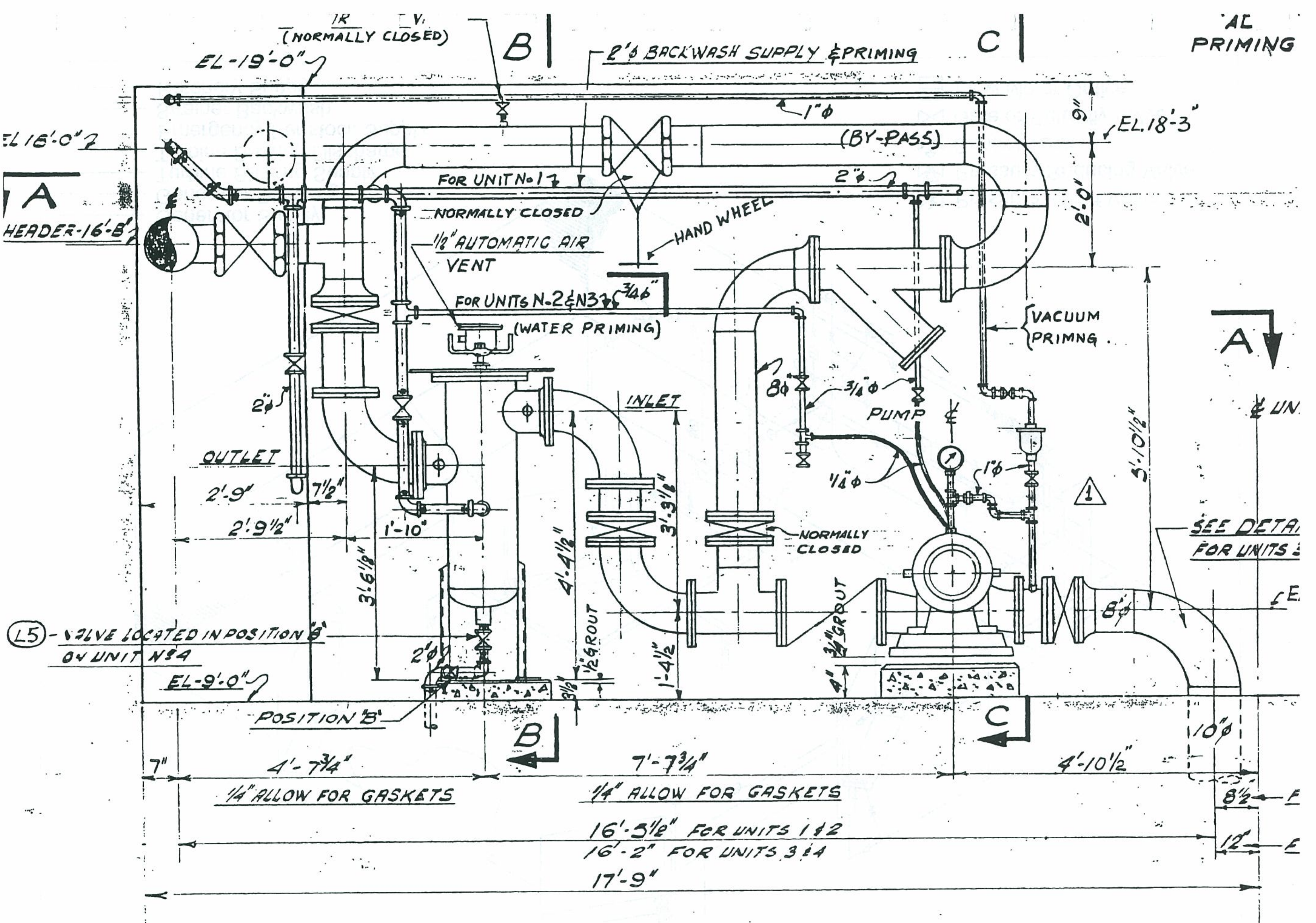


Pump Discharge 35 PSI	Isolation Valve
Turbine / Shaft Seal 40 PSI	Reducing Valve
Backwashing 75 PSI	Temperature Control Valve
Penstock 250 PSI	Safety Valve
Drain Lines to Tailrace	Flow Meter Orifice
	Strainer

Unit Flow Diagram
Existing Service Water System
Bay D'Espoir Powerhouse #1

Service Water Piping





COOLING WATER PIPING ARRANGEMENT

c.- FOXB... THERMOMETER WITH ALARM AND SHUTDOWN CONTACTS ... ONE (1) IN COOLING WATER SUPPLY, ONE (1) IN COOLING WATER DRA...

d.- THERMOSTAT. G.E. 6A426G.202 FOR 125 V. D.C. OPERATION. RANGE 60-25... ONE (1) ON EACH COOLER IN INCOMING AIR.

7- INSTRUMENT SCALES WILL HAVE WHITE GRADUATIONS ON A BLACK BACKGROU... FLOWMETER READING IN I.G.P.M. AND TEMP. GAUGE READING IN DEGREES F.

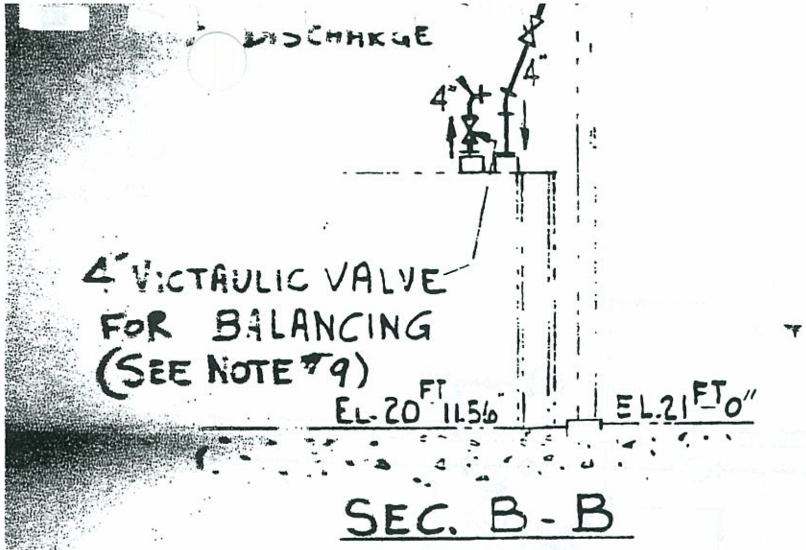
8- 'M' AND 'N' REQUIRED FOR MAXIMUM FLOWMETER ACCURACY. (SEE DIAGRAM).

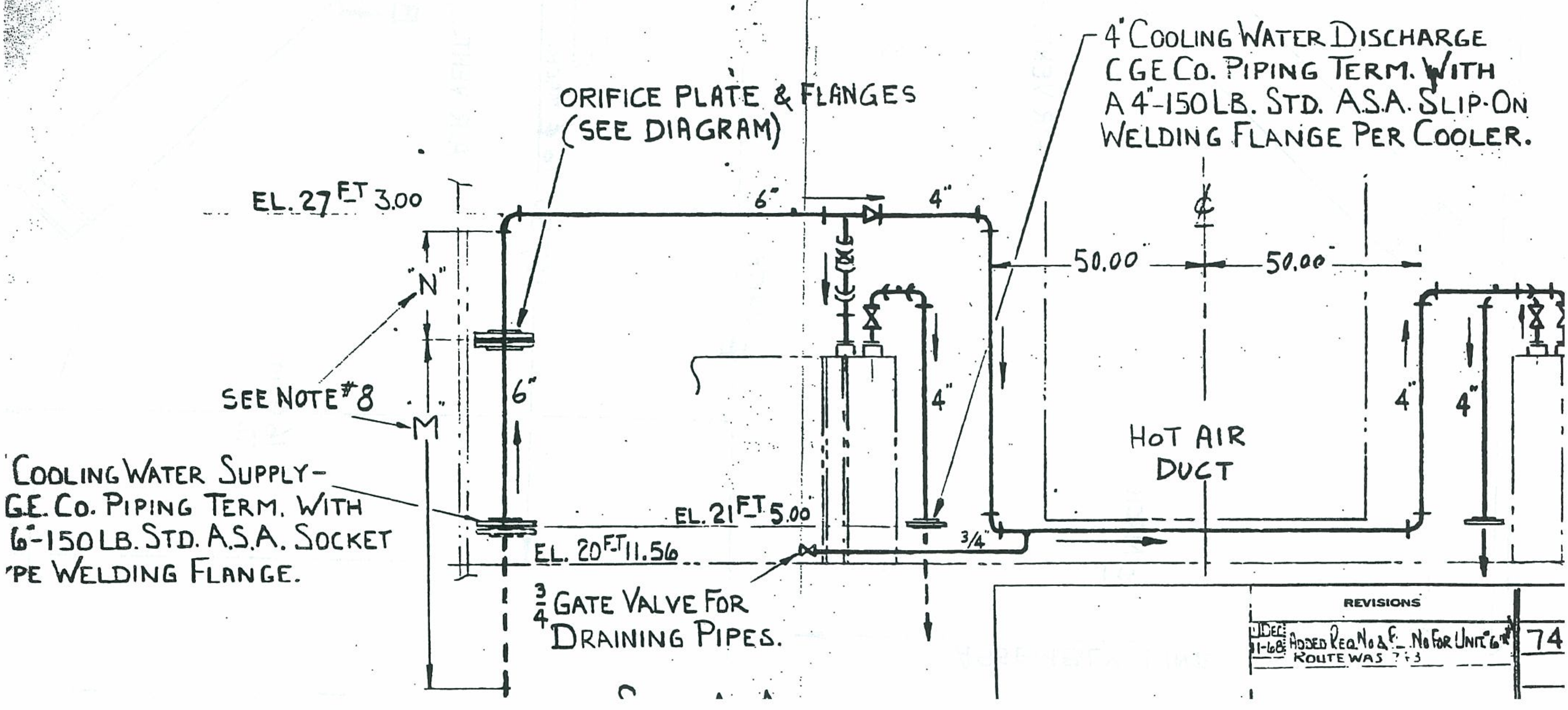
9- TO OBTAIN UNIFORM FLOW THROUGH THE COOLERS AT STATIO... PRESSURE:

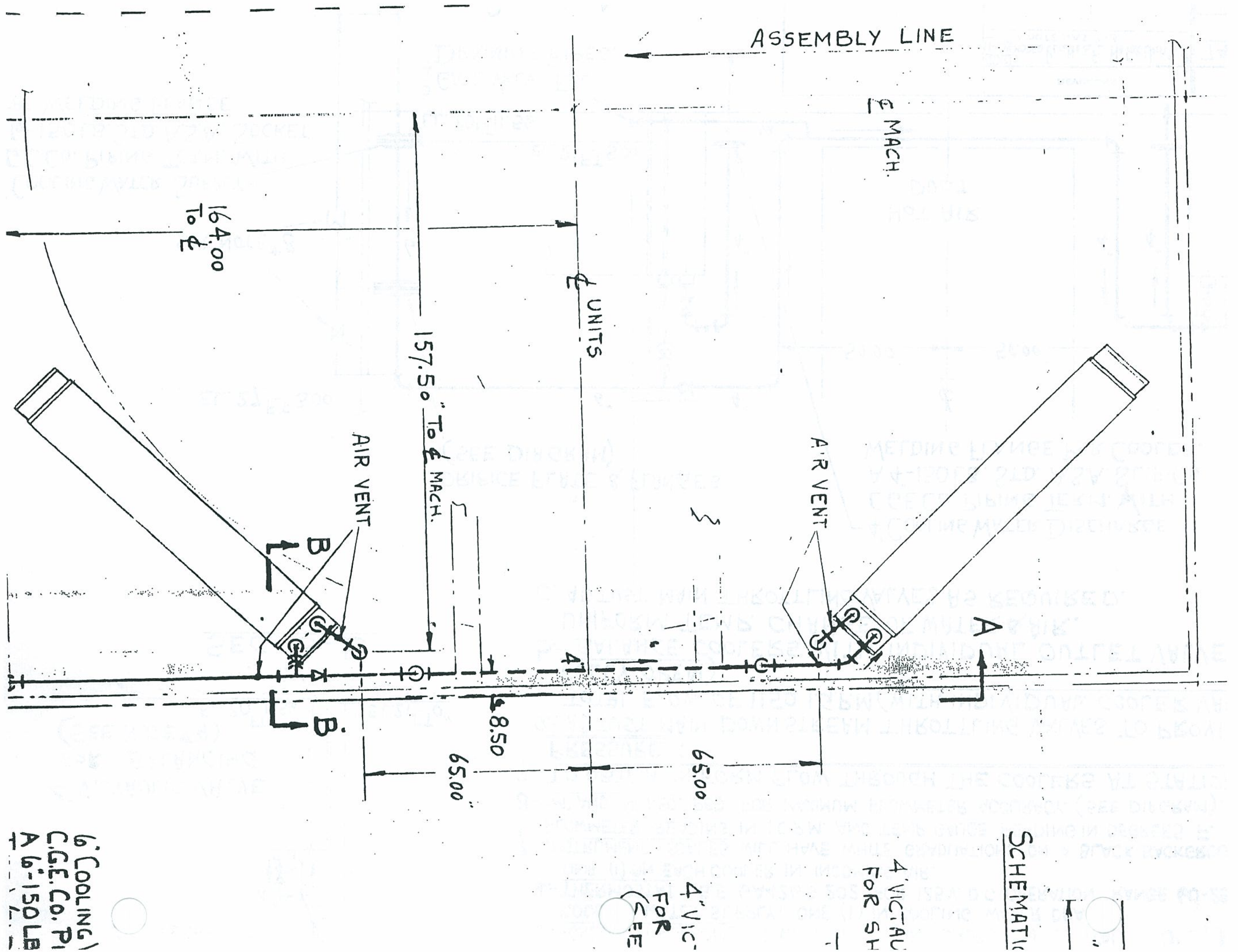
a- ADJUST MAIN DOWNSTREAM THROTTLING VALVES TO PROVI... TOTAL FLOW OF 1150 I.G.P.M (WITH INDIVIDUAL COOLER VA... FULLY OPEN).

b- BALANCE COOLERS WITH INDIVIDUAL OUTLET VALVE... UNIFORM TEMP. CHANGE OF WATER & AIR.

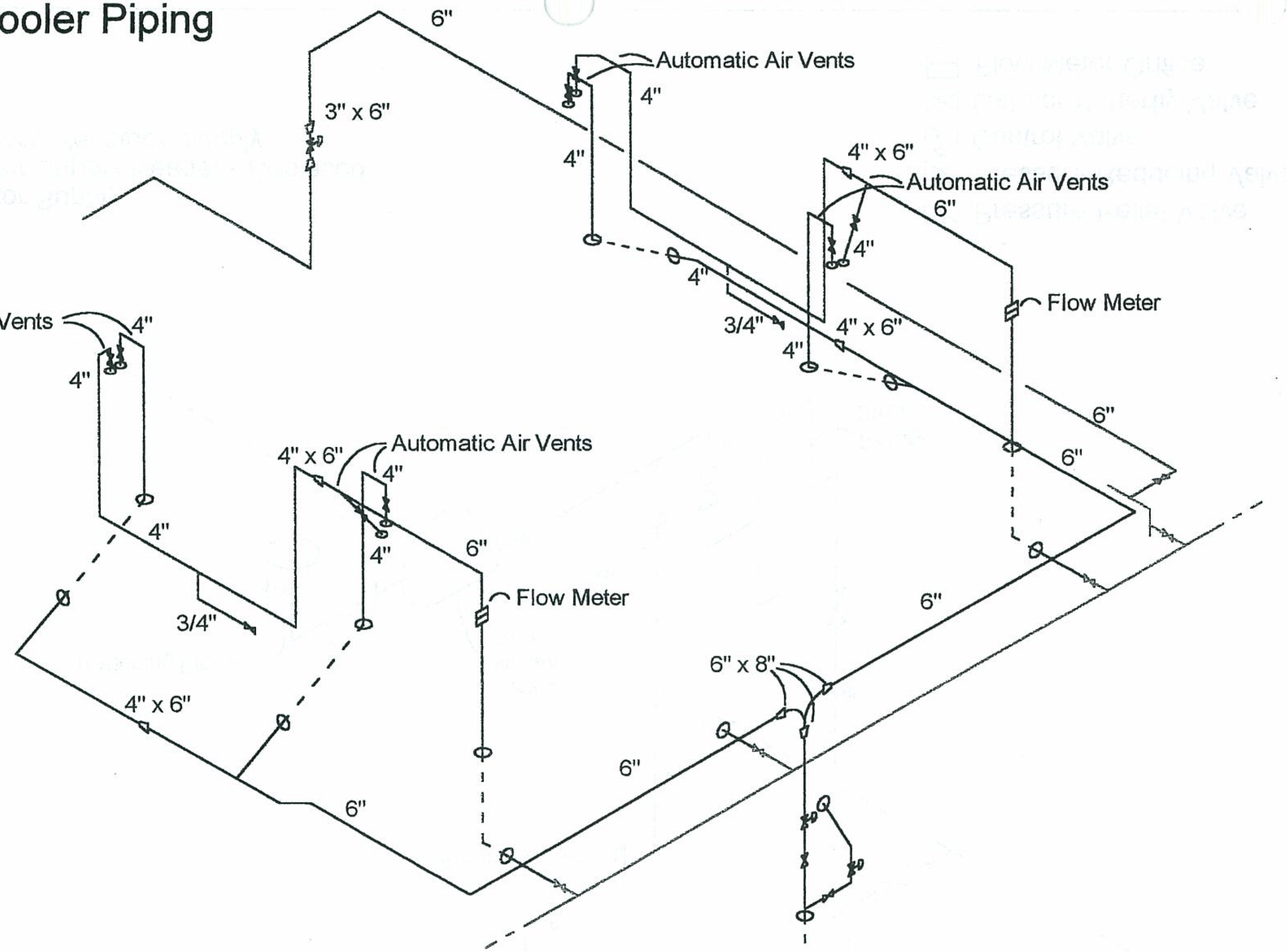
c- ADJUST MAIN THROTTLING VALVES AS REQUIRED.






ASSEMBLY LINE
℄ MACH.
164.00 To ℄
℄ UNITS
157.50" To ℄ MACH.
AIR VENT
AIR VENT
B
B.
A
8.50
65.00"
65.00
SCHEMATI
4" VICTAU
FOR SH
4" VIC
FOR
(SEE
6" COOLING
C.G.E. Co. P
A 6-150LB

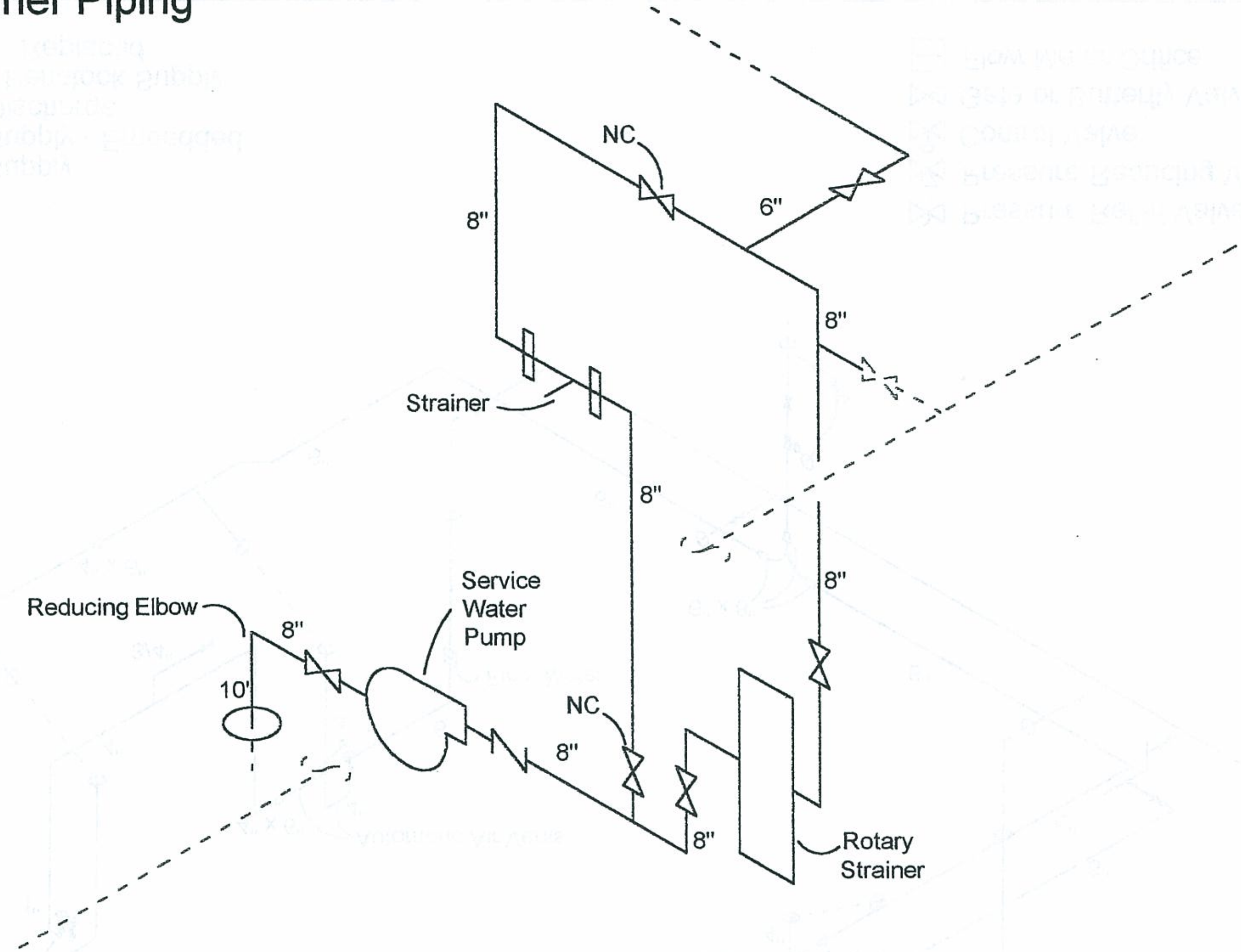
Surface Air Cooler Piping



- Generator Supply
- Generator Supply - Embedded
- Generator Discharge
- Emergency Penstock Supply
- 10" Header - Replaced

- Pressure Relief Valve
- Pressure Reducing Valve
- Control Valve
- Gate or Butterfly Valve
- Flow Meter Orifice

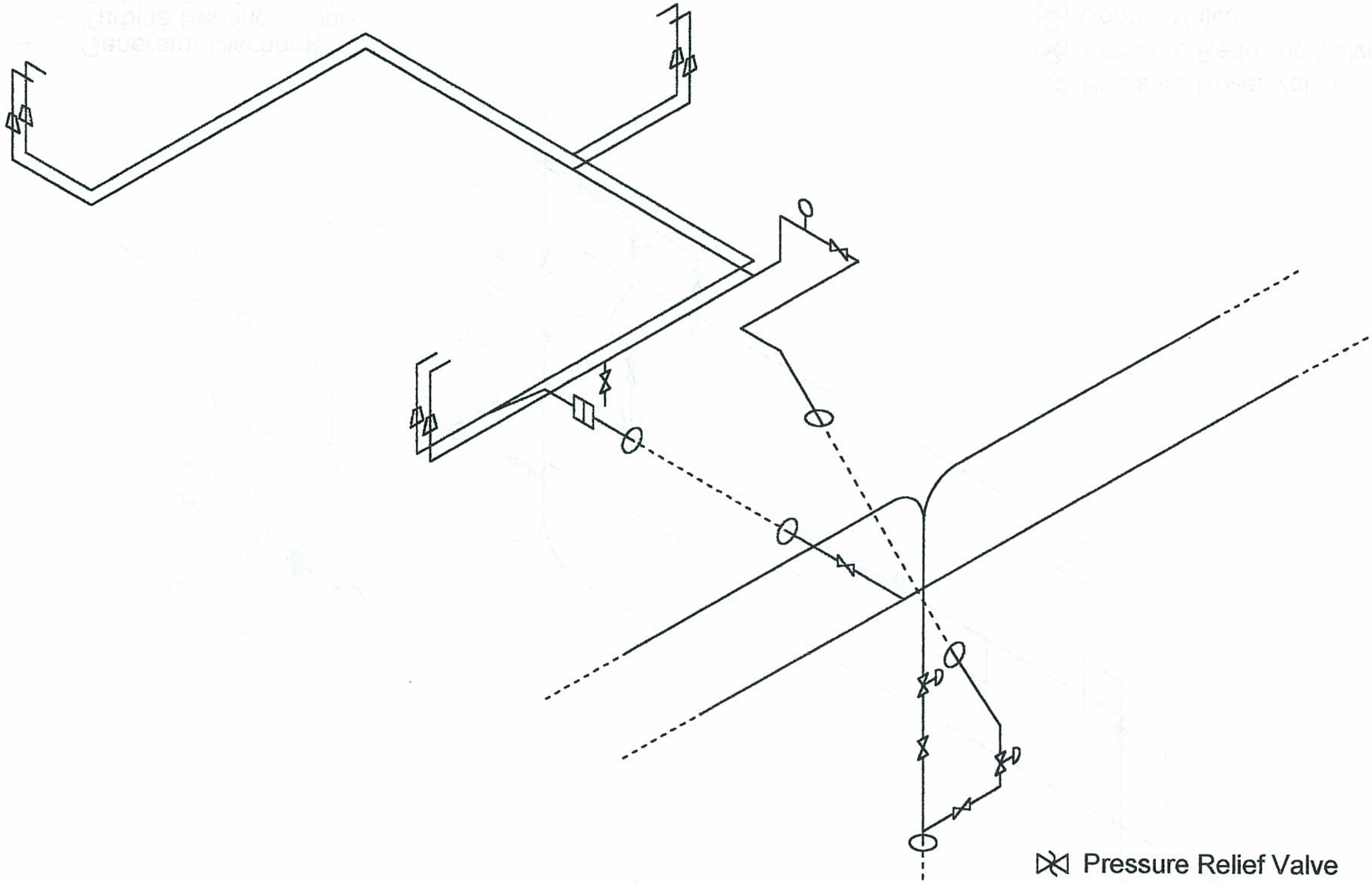
Pump and Strainer Piping



Generator Supply
Generator Supply Header - Replaced
Emergency Penstock Supply

Pressure Relief Valve
Pressure Reducing Valve
Control Valve
Gate or Butterfly Valve
Flow Meter Orifice

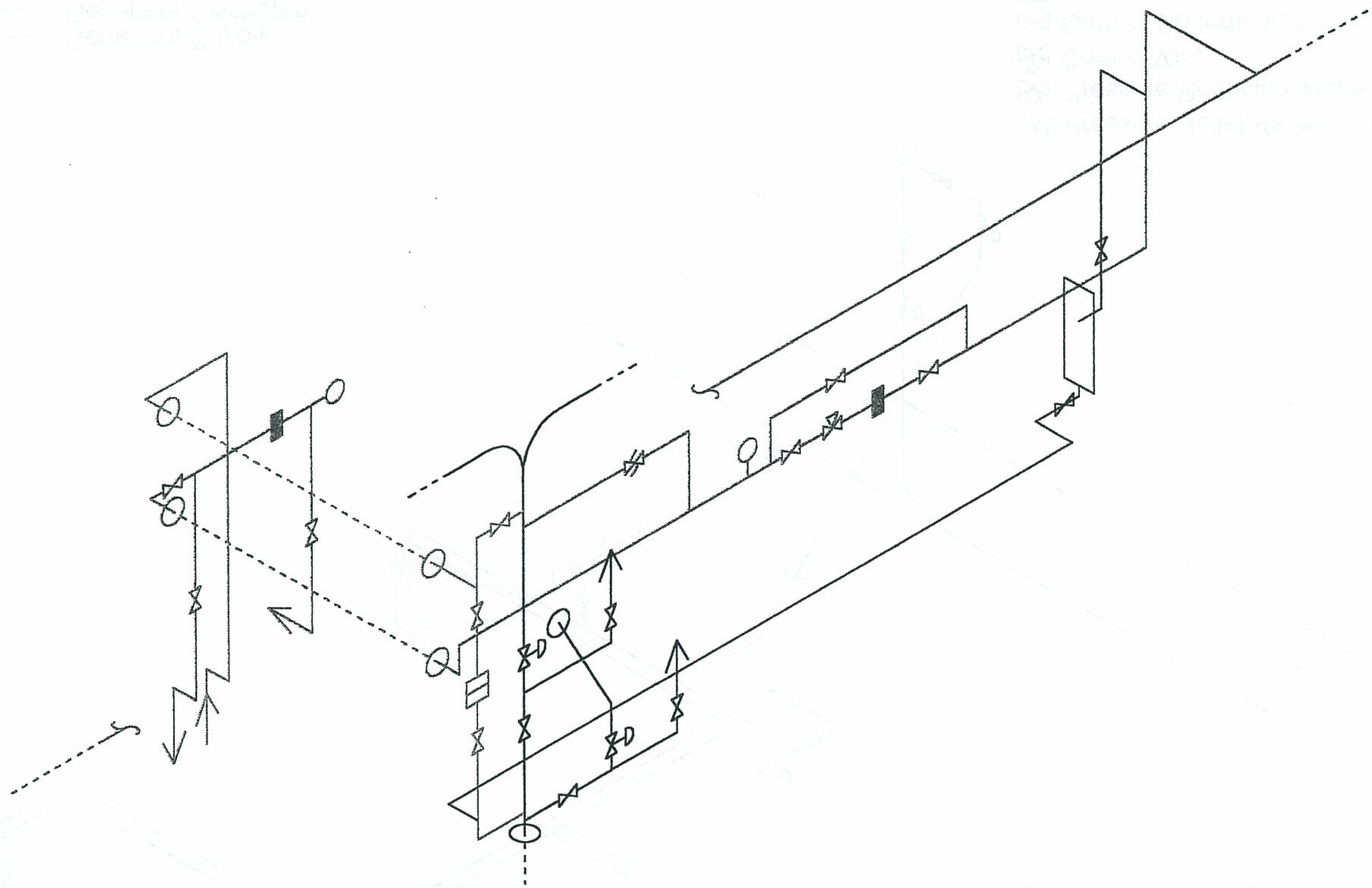
Generator Bearing Cooler Pipi



Generator Supply
Generator Discharge

Pressure Relief Valve
Pressure Reducing Valve
Control Valve
Gate or Butterfly Valve
Flow Meter Orifice

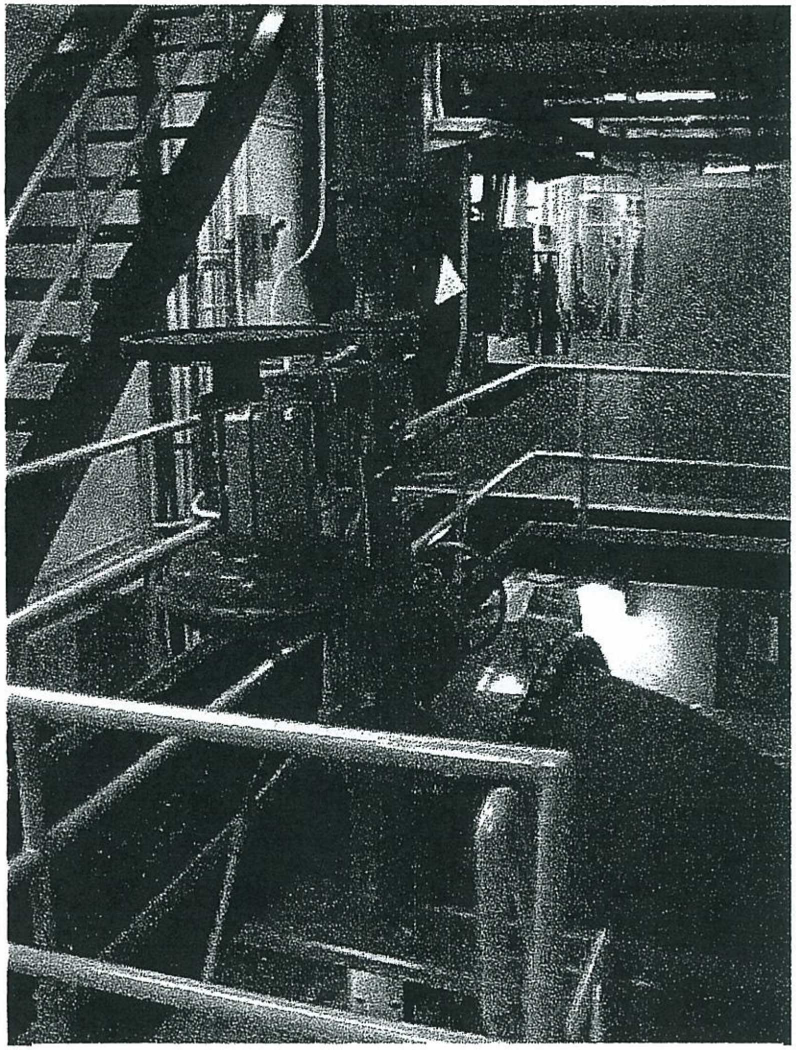
Turbine Bearing Cooler and Shaft Seal Piping



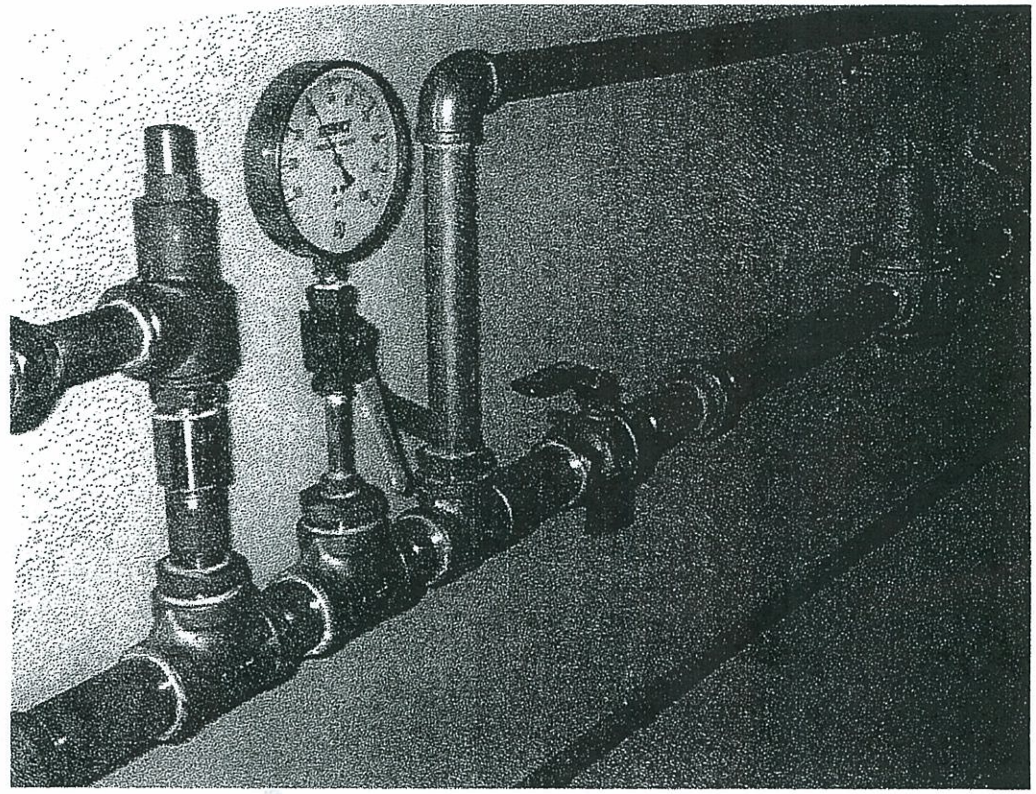
———	Generator Discharge
———	Turbine Bearing Supply
———	Turbine Bearing Discharge
———	Strainer Backwash
———	Hatchery Supply

⋈	Pressure Relief Valve
⋈	Pressure Reducing Valve
⋈	Control Valve
⋈	Gate or Butterfly Valve
⊟	Flow Meter Orifice

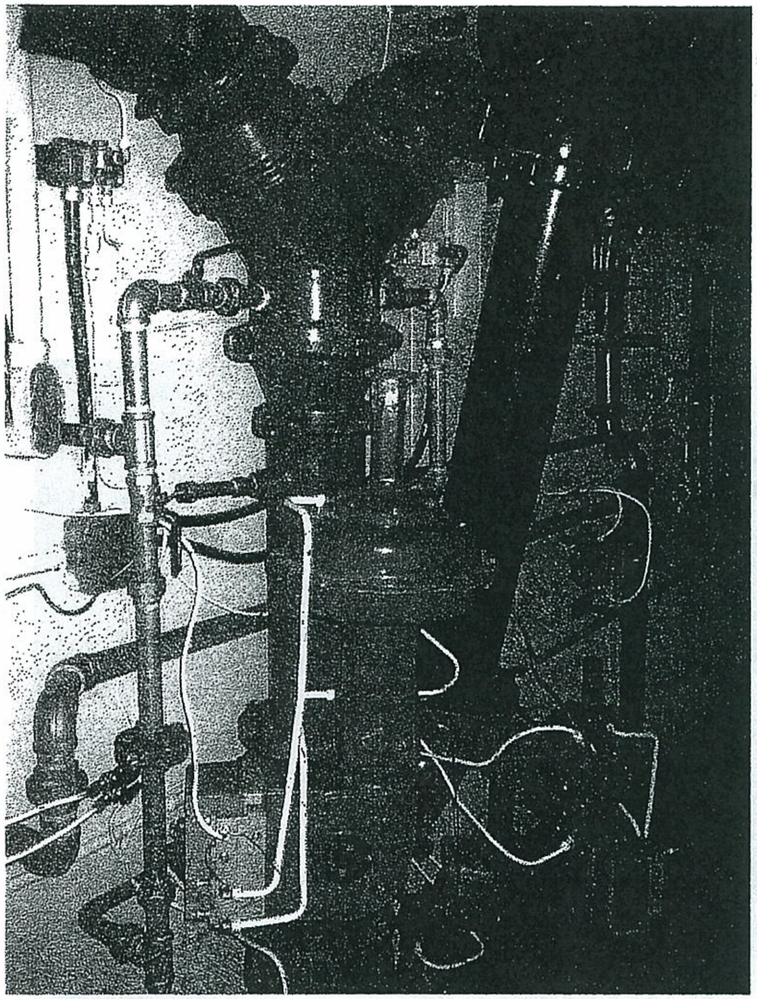
Appendix B: Equipment Pictures



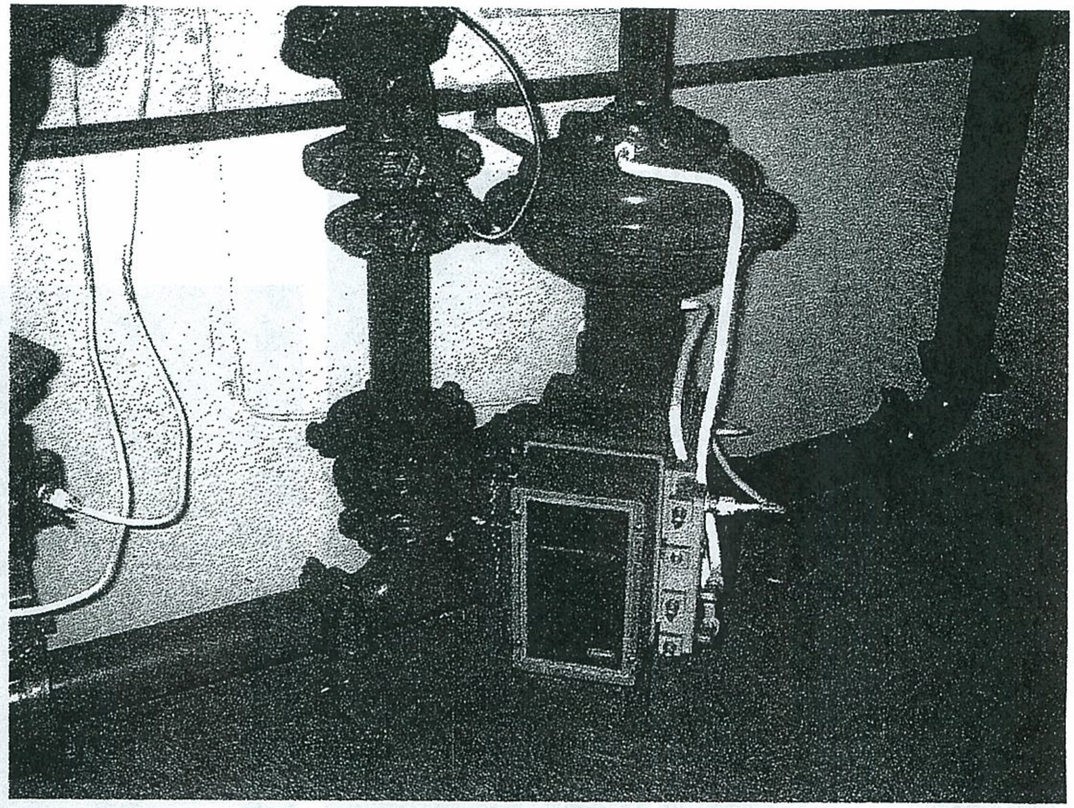
Emergency Penstock Supply Control Valve



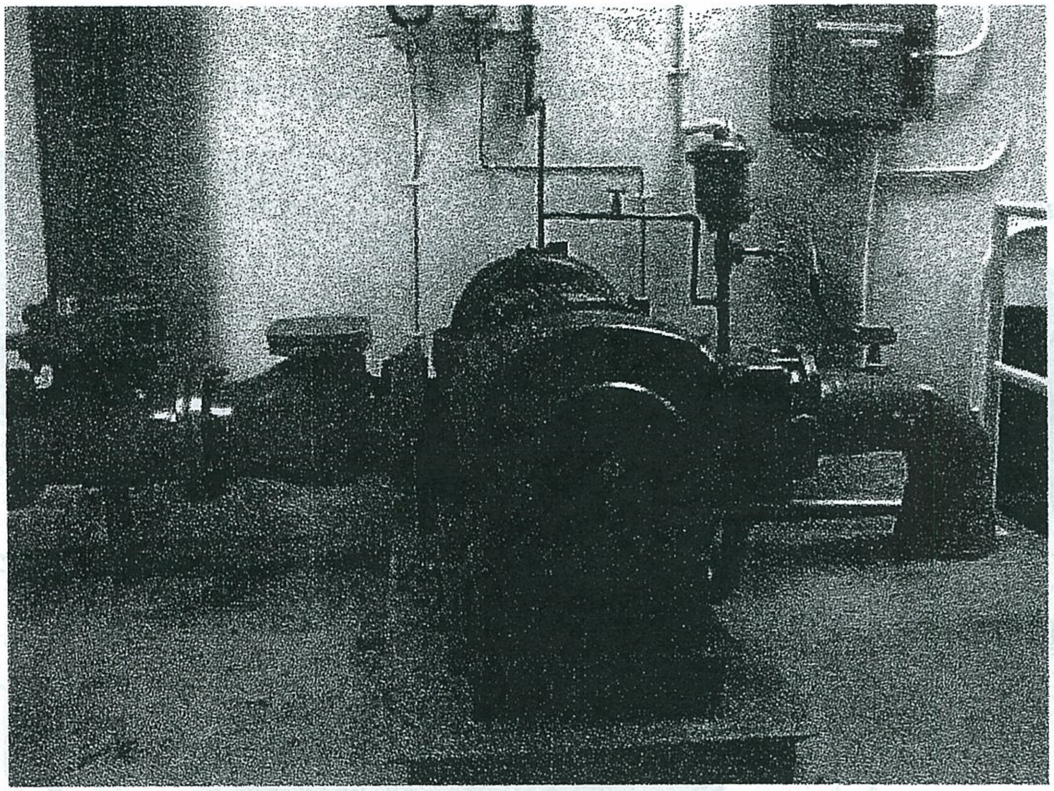
Turbine Bearing / Shaft Seal Reducing Valve



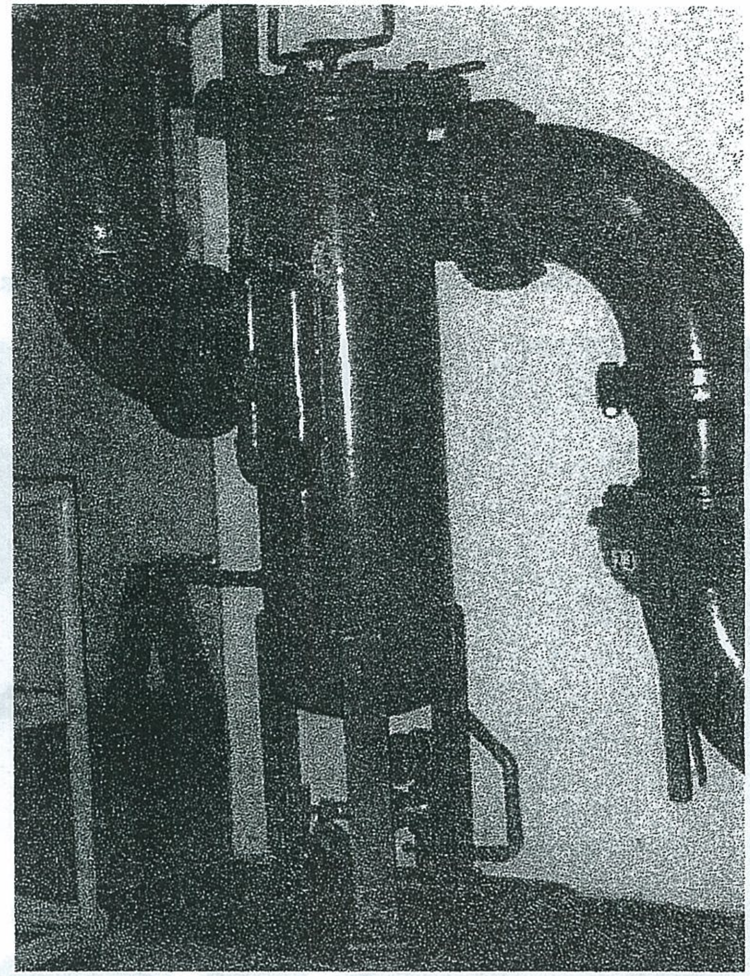
SAC Temperature Control Valve



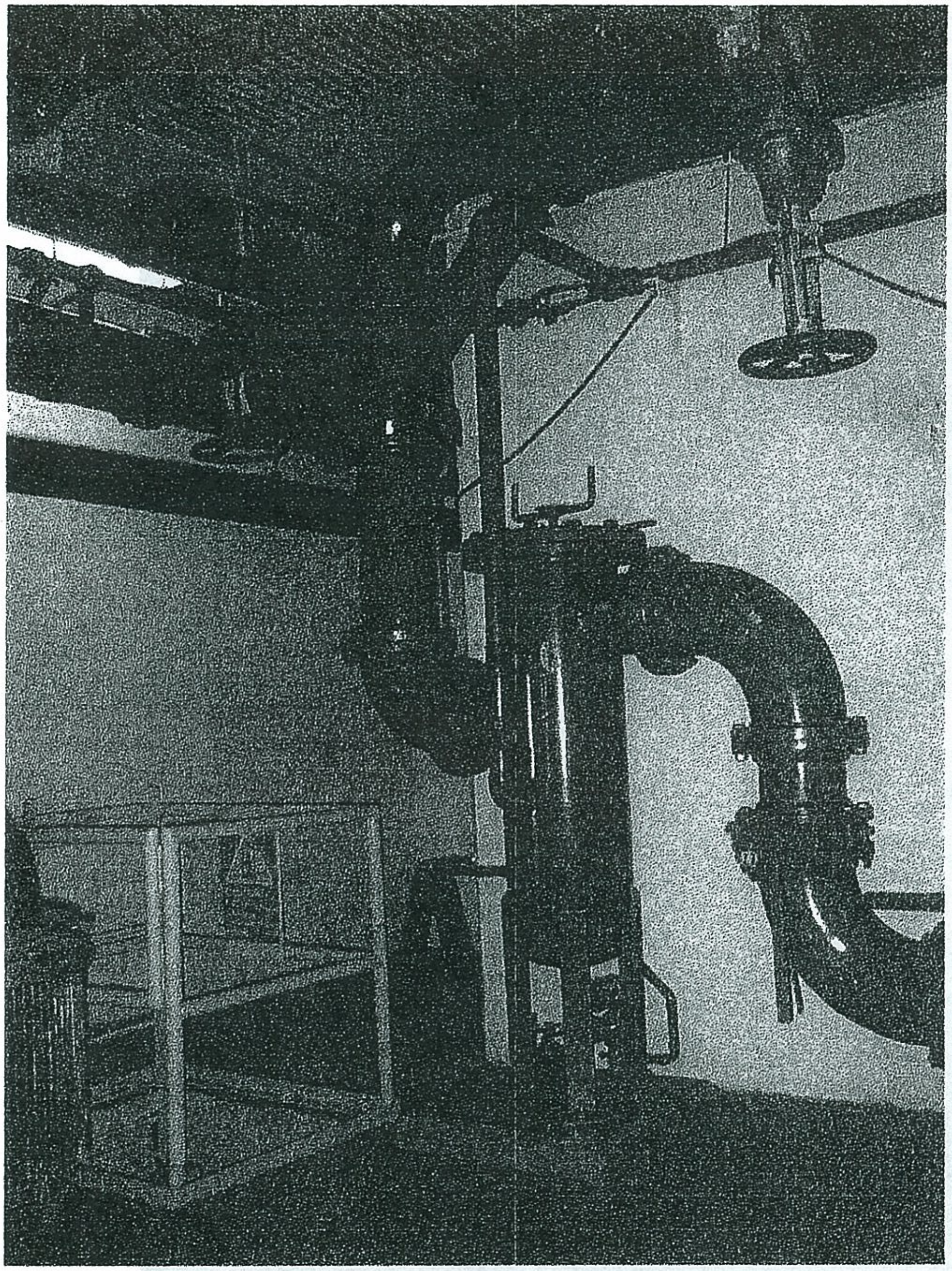
Generator Bearing Temperature Control Valve

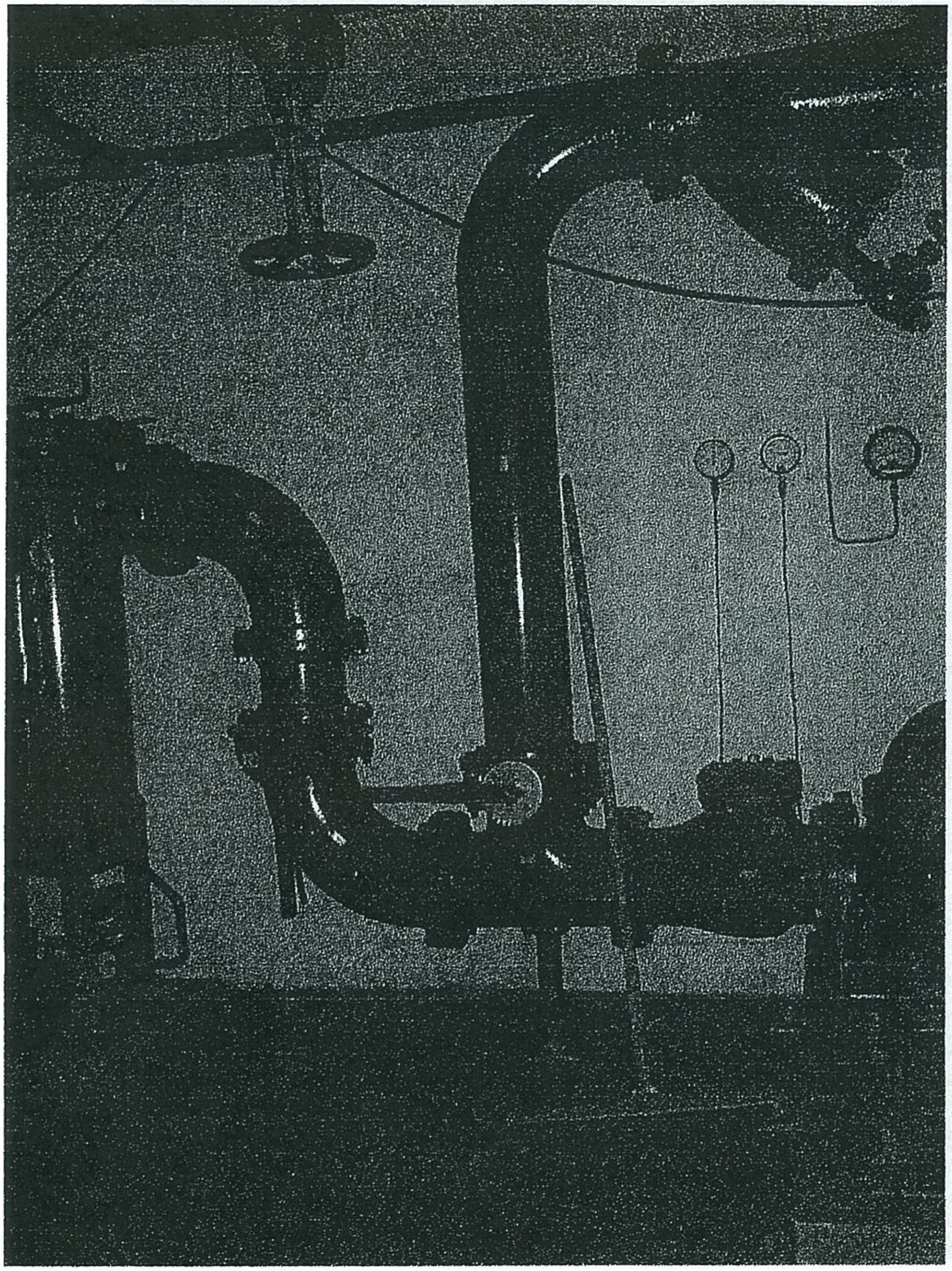


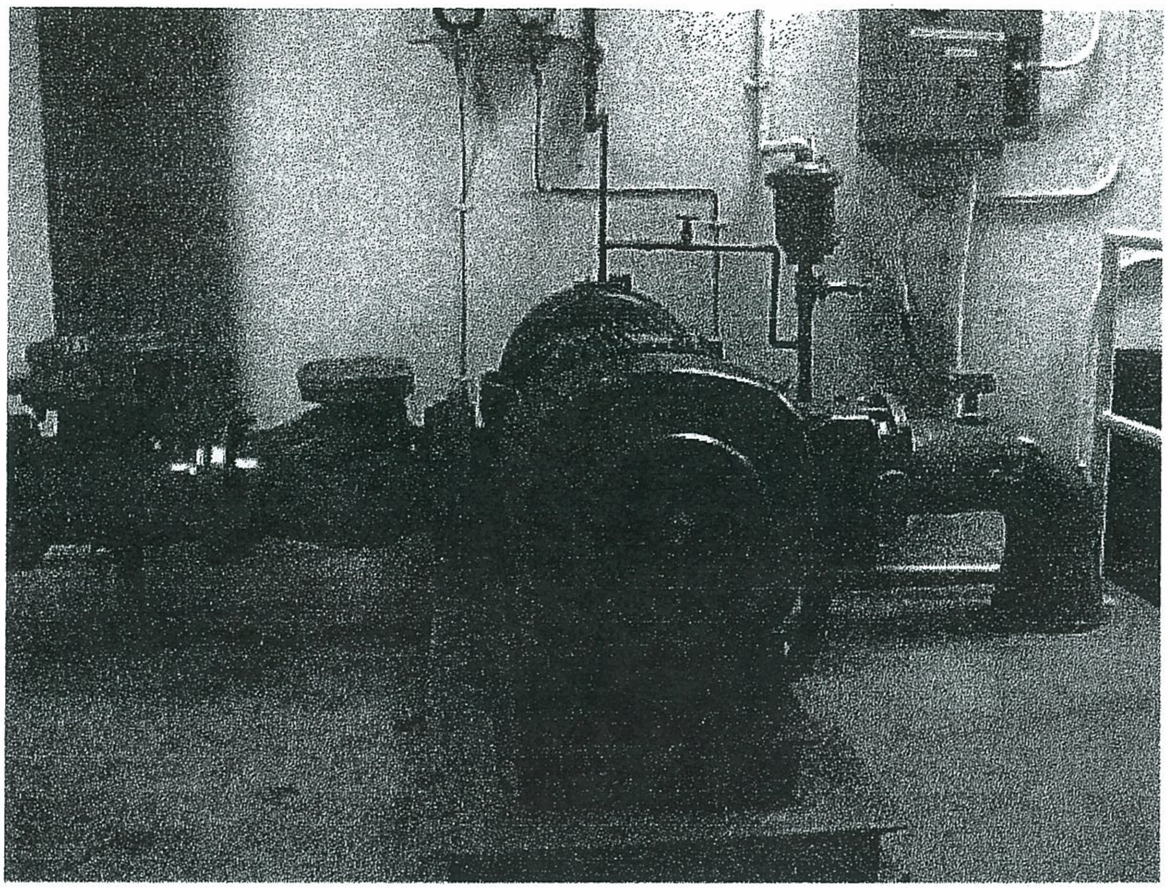
Service Water Pump



Rotary Strainer

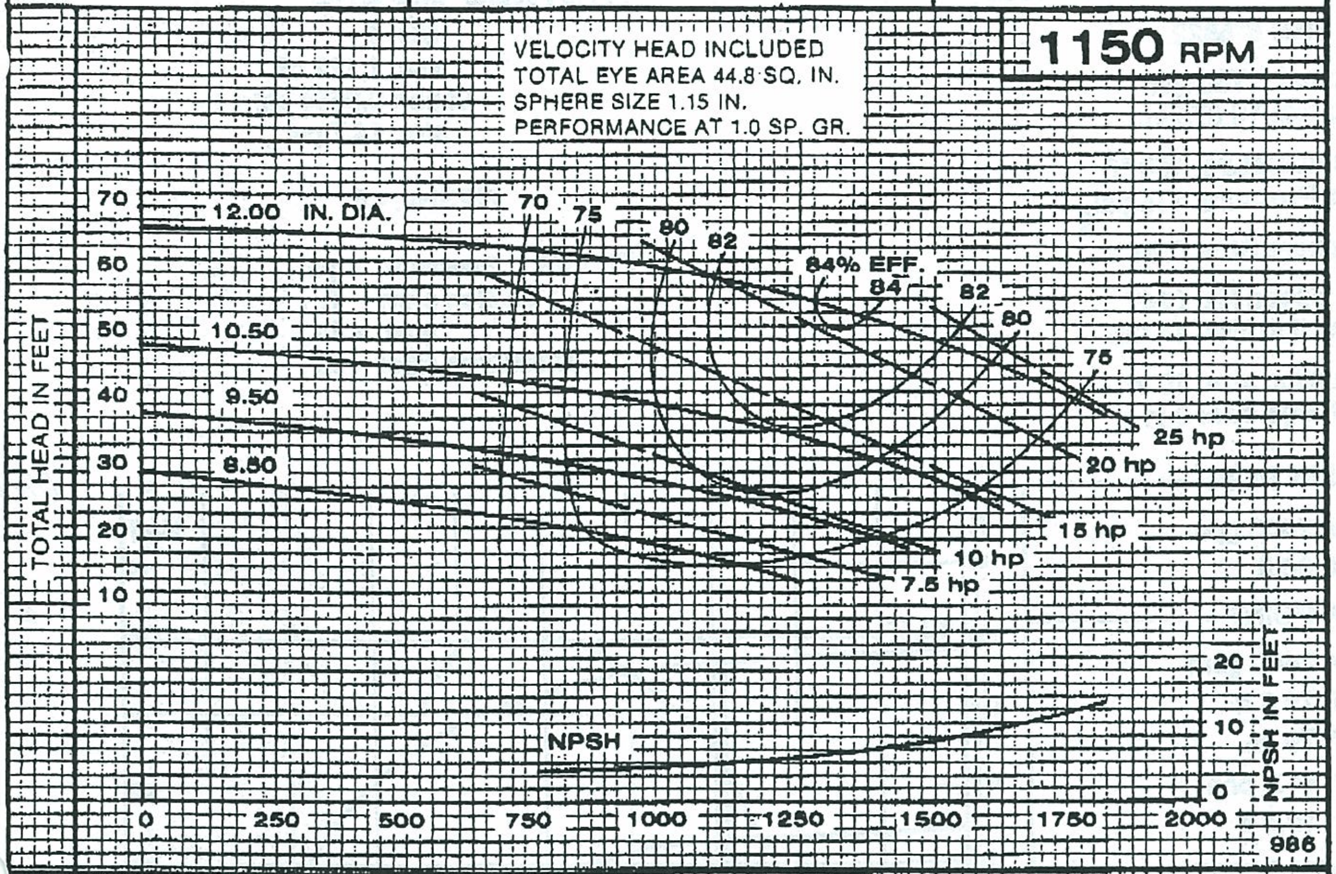




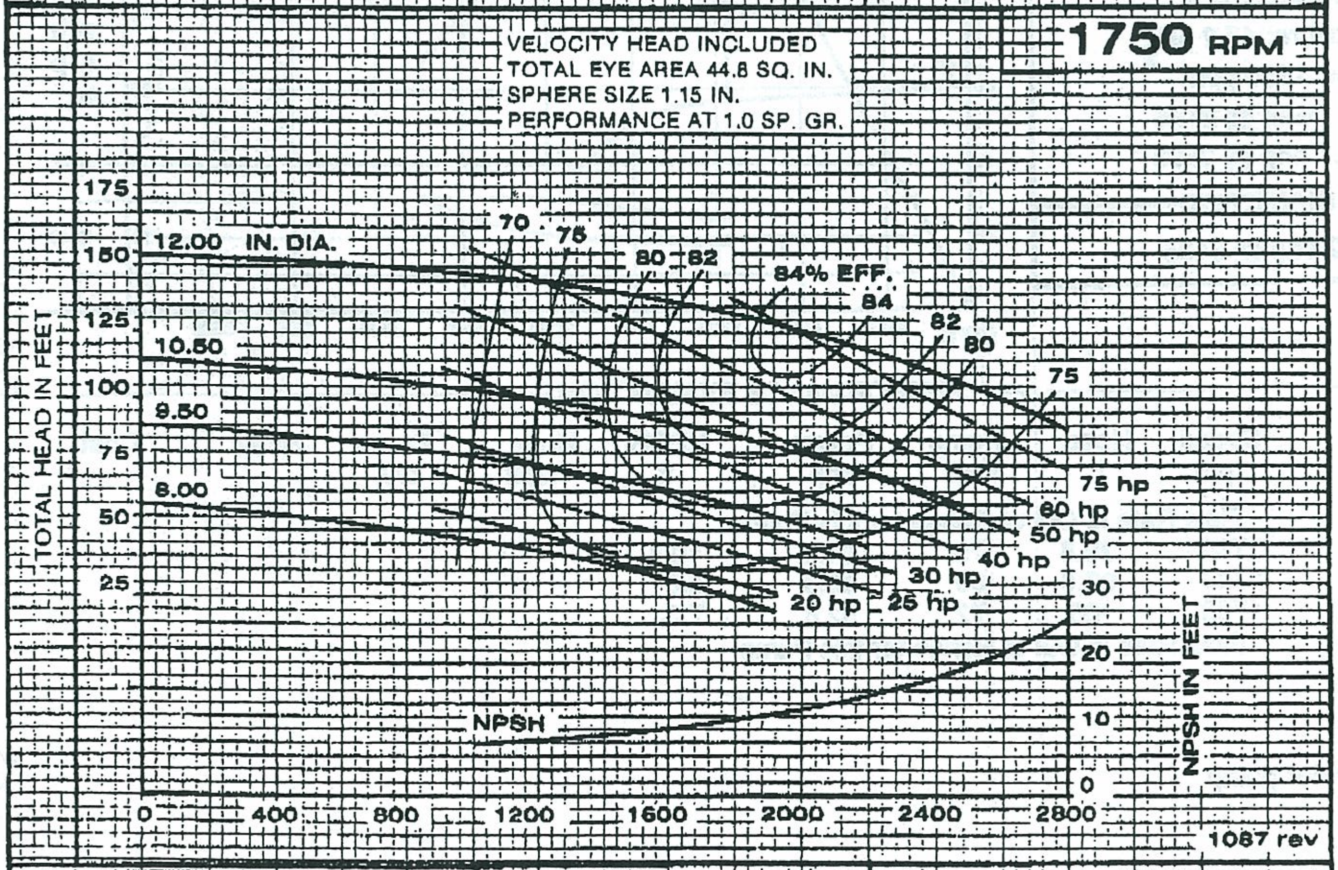


Appendix C: Pump Curves

Peerless Pump Company Indianapolis, IN 46207-7026	HORIZONTAL SPLIT CASE PUMPS Type 8AE12 Size 8x8x12.00	SECTION 1240



IMPELLER 2692806 | U.S. GALLONS PER MINUTE | CURVE 3132019



UNIT #1 #3, #5

IMPELLER 2692806 | U.S. GALLONS PER MINUTE | CURVE 3132017

April 26, 1999

PUMP DATA SHEET

Fairbanks Morse Pumps, 60 Hz

Catalog: FMCENT60 v. 2.0

...20604R

... - SPEED: 5800-HSC - 1800

PUMP Size: 8"5822

Speed: 1780 rpm
Imp dia: 10.875 in

Max Temperature: 160 °F
Max Pressure: 175 psi_g

Max Sphere Size: 0.94 in

Specific Speed Ns: 2247
Suction Nss: 14735

Suction size: 10 in
Discharge size: 8 in

FLUID Water tmp: 60 °F
SG: 1
vsc: 1.122 cP
vapor: 0.2568 psi
atm: 14.7 psi

NPSHa: - ft

PIPING Pressure: - psi
Suction elev: - ft
size: - in
Discharge size: - in

DESIGN POINT

Flow: 2400 gpm
Head: 80 ft

DATA POINT

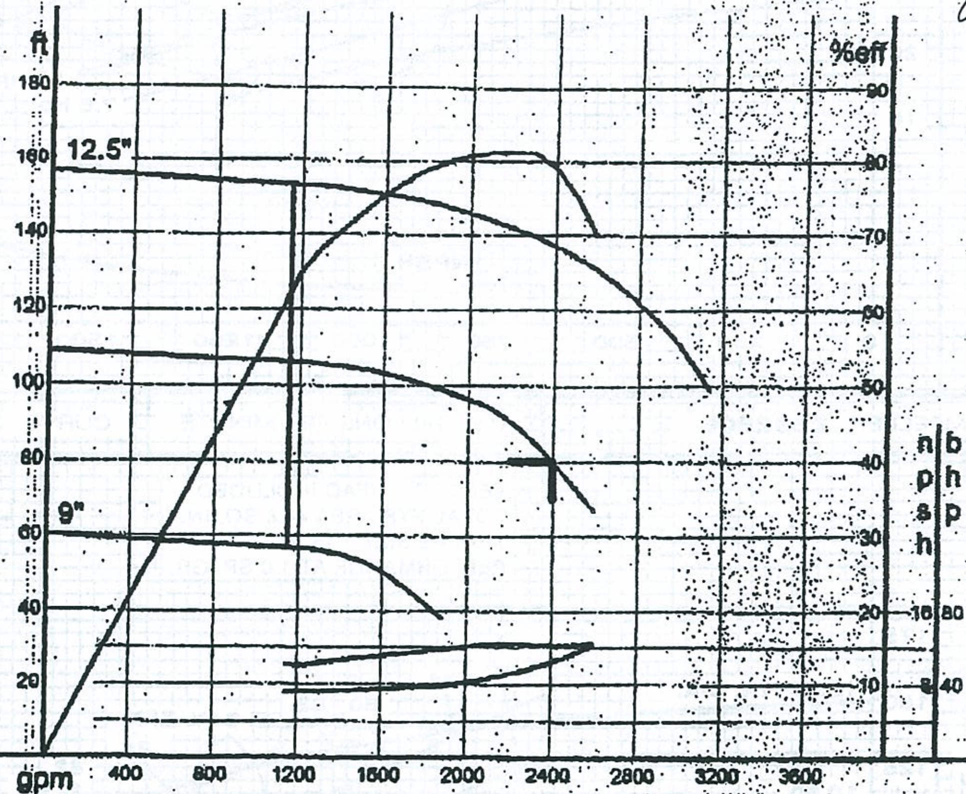
Flow: 2400 gpm
Head: 79.8 ft
Eff: 79 %
Power: 61.2 bhp
NPSHr: 10.4 ft

DESIGN CURVE

Shutoff Head: 109 ft
Pressure: 47.2 psi_g
Min Flow: 1150 gpm
BEP: 81 %eff @ 2156
Max: 62.7 bhp @ 2593

MAX DIAMETER

Max: 112 bhp @ 3135

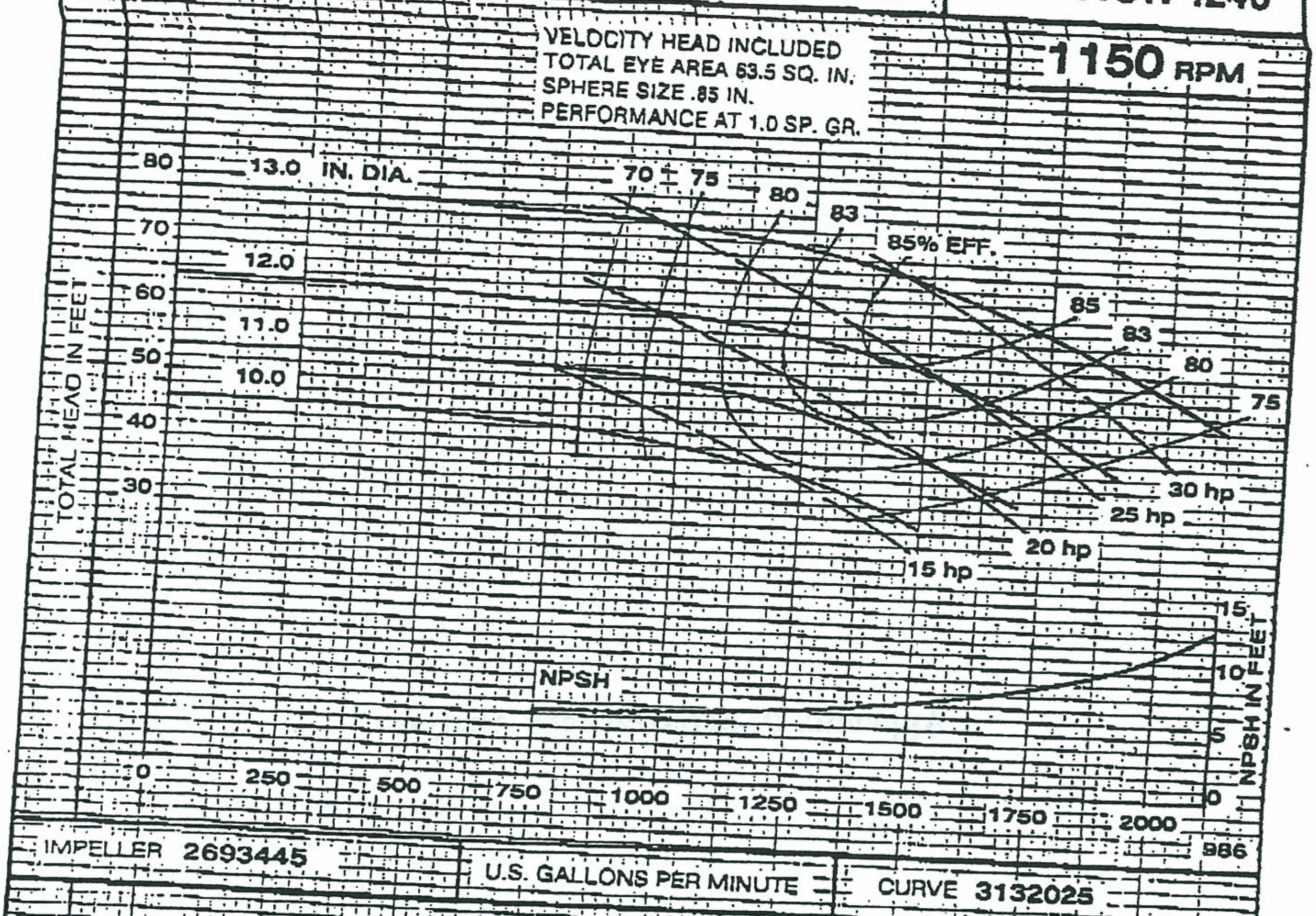


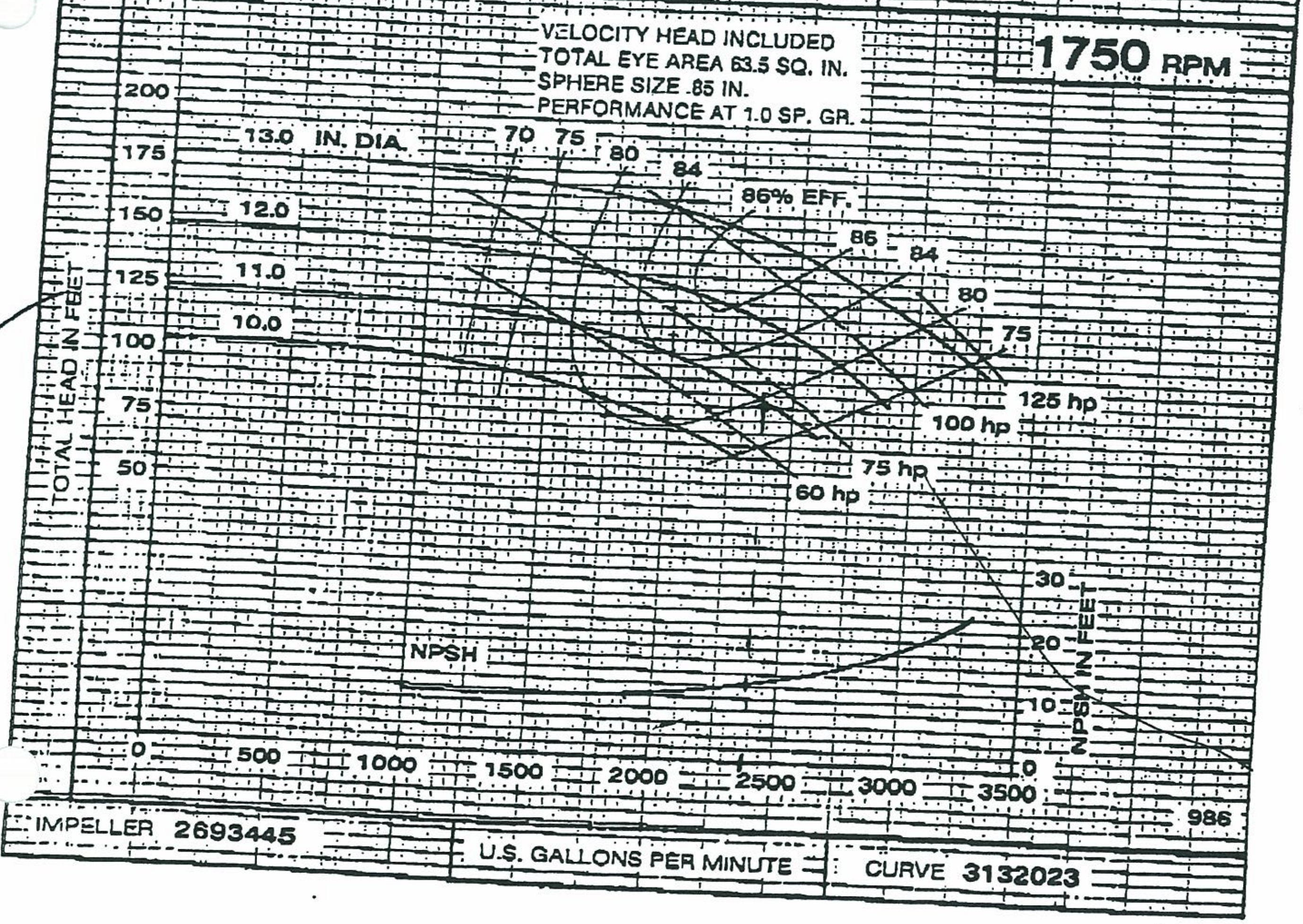
UNIT #2
#4

PERFORMANCE EVALUATION

Flow gpm	Speed rpm	Head ft	Pump %eff	Power bhp	NPSHr ft	Motor %eff	Power kW	Hrs/yr	Cost
2880	Flow Rate is Out of Range for this Pump								
2400	1780	79.8	79	61.2	10.4				
1920	1780	97.9	80	59.3	8.0				
1440	1780	105	72	52.8	7.3				
960	Flow Rate is Out of Range for this Pump								

cooling water pump


VELOCITY HEAD INCLUDED
TOTAL EYE AREA 63.5 SQ. IN.
SPHERE SIZE .85 IN.
PERFORMANCE AT 1.0 SP. GR.
1150 RPM
TOTAL HEAD IN FEET
13.0 IN. DIA.
12.0
11.0
10.0
70
75
80
83
85% EFF.
85
83
80
75
30 hp
25 hp
20 hp
15 hp
NPSH
NPSH IN FEET
0
250
500
750
1000
1250
1500
1750
2000
986
IMPELLER 2693445
U.S. GALLONS PER MINUTE
CURVE 3132025


VELOCITY HEAD INCLUDED
TOTAL EYE AREA 63.5 SQ. IN.
SPHERE SIZE .85 IN.
PERFORMANCE AT 1.0 SP. GR.
1750 RPM
TOTAL HEAD IN FEET
13.0 IN. DIA.
12.0
11.0
10.0
70
75
80
84
86% EFF.
86
84
80
75
125 hp
100 hp
75 hp
60 hp
NPSH
NPSH IN FEET
0
500
1000
1500
2000
2500
3000
3500
986
IMPELLER 2693445
U.S. GALLONS PER MINUTE
CURVE 3132023

UNIT #6

Appendix D: BetzDearborn Analysis

: port of deposit analysis. Deposit removed from 10 inch diam cooling water header at Bay
: Espoir

BetzDearborn

INORGANIC ANALYSIS REPORT

4000018855
NEWFOUNDLAND & LABRADOR HYDRO
[redacted]

Laboratory ID: 68943.2

Sampled: 29-JUN-2001
Reported: 20-JUL-2001
Field Rep: Finn, Edward
91000078

Sample Description:
Once thru cooling system

PRIMARY COMPOSITION (%)

Iron, Fe_2O_3 + Fe_3O_4	81
Loss on Ignition LOI	13
Silicon, SiO_2	5
Aluminum, Al_2O_3	1

X-ray fluorescence detects elements between fluorine and uranium in atomic number. Any of these elements not reported are below detection limits.

Stan Kasper, Laboratory Supervisor

BDE

BetzDearborn

WATER ANALYSIS REPORT

4000018855
NEWFOUNDLAND & LABRADOR HYDRO
[redacted]

Sampled: 21-AUG-2001
Reported: 27-AUG-2001
Field Rep: Finn, Edward
91000078

	JMO/BDE L0823124
pH	6.2
Specific Conductance, at 25°C, µmhos	13.7
Alkalinity, "P" as $CaCO_3$, ppm	0
Alkalinity, "M" as $CaCO_3$, ppm	2.1
Sulfur, Total, as SO_4, ppm	< 5
Chloride, as Cl, ppm	3.7
Hardness, Total, as $CaCO_3$, ppm	3.8
Calcium Hardness, Total, as $CaCO_3$, ppm	2.3
Magnesium Hardness, Total, as $CaCO_3$, ppm	1.6
Copper, Total, as Cu, ppm	< 0.05
Iron, Total, as Fe, ppm	0.08
Sodium, as Na, ppm	1.1
Phosphate, Total Inorganic, as PO_4, ppm	< 0.2
Phosphate, Ortho-, as PO_4, ppm	I
Phosphate, Filtered Ortho-, as PO_4, ppm	< 0.2
Silica, Total, as SiO_2, ppm	1.0

BDE

BetzDearborn

WATER ANALYSIS REPORT

4000018855
NEWFOUNDLAND & LABRADOR HYDRO
[redacted]

Sampled: 21-AUG-2001
Reported: 27-AUG-2001
Field Rep: Finn, Edward
91000078

	JMO/BDE
	L0823124
Carbon, Total Organic, as C, ppm	4.7
Color, Apparent, Color Units (APHA)	10.0

BDE

BetzDearborn

WATER ANALYSIS REPORT

4000018855
NEWFOUNDLAND & LABRADOR HYDRO
[redacted]

Sampled: 21-AUG-2001
Reported: 27-AUG-2001
Field Rep: Finn, Edward
91000078

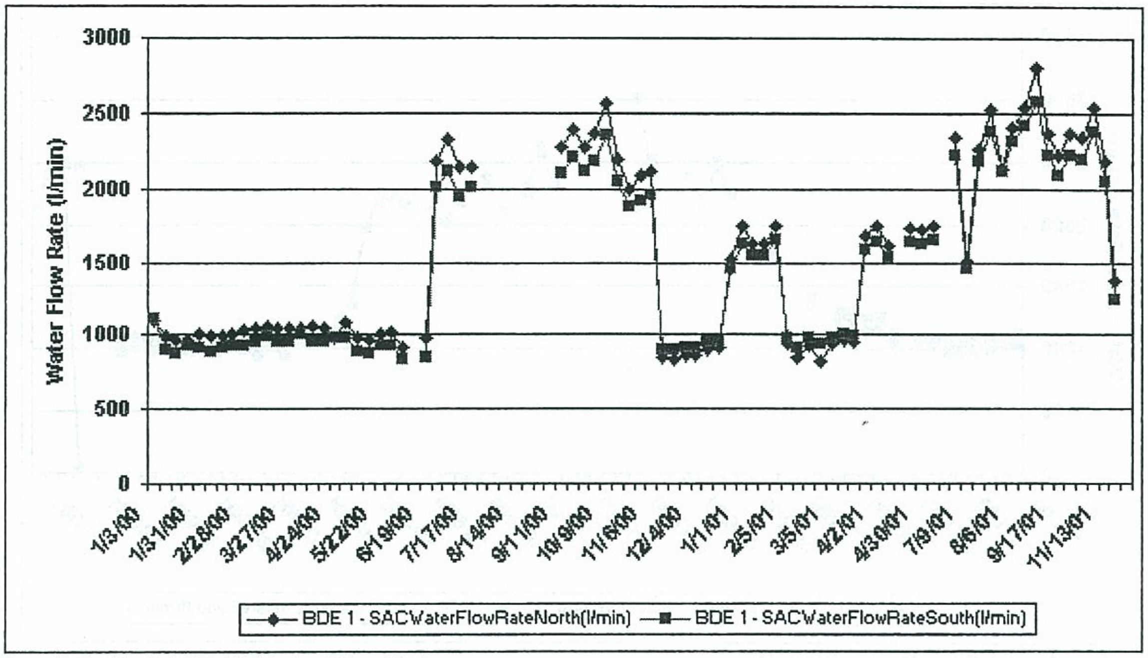
Result Legend

I - A chemical or physical interference prevented the labs ability to perform this test.

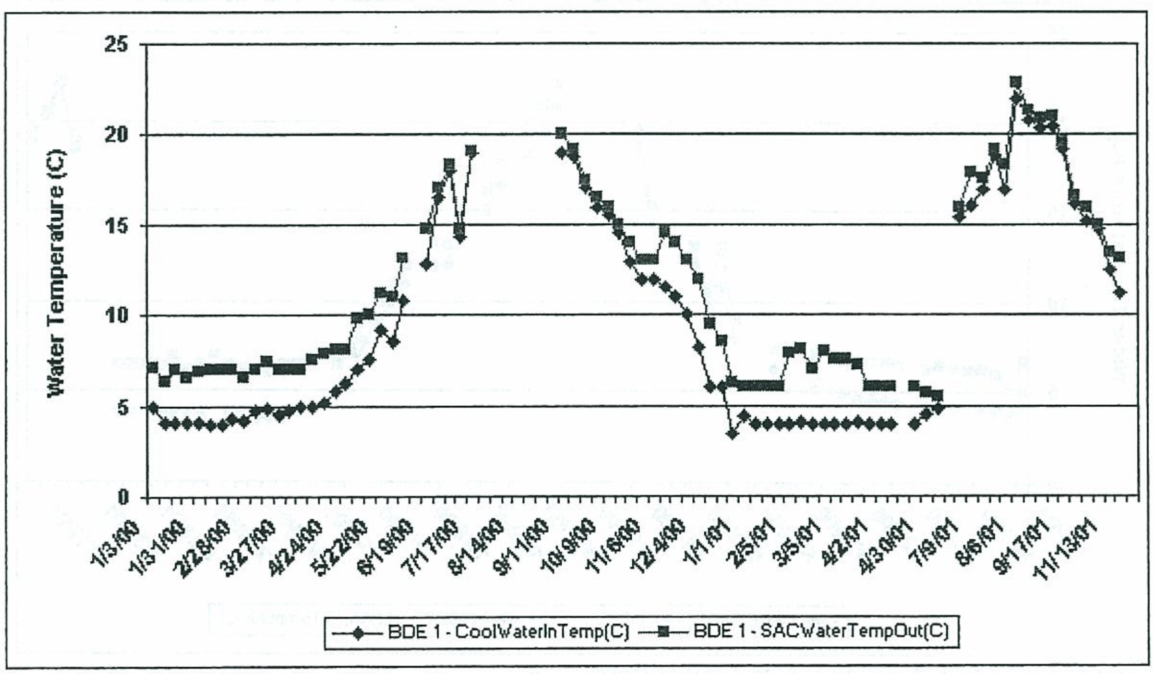
Appendix E: Trend Monitoring Graphs

Table of Contents

Unit 1 Surface Air Coolers

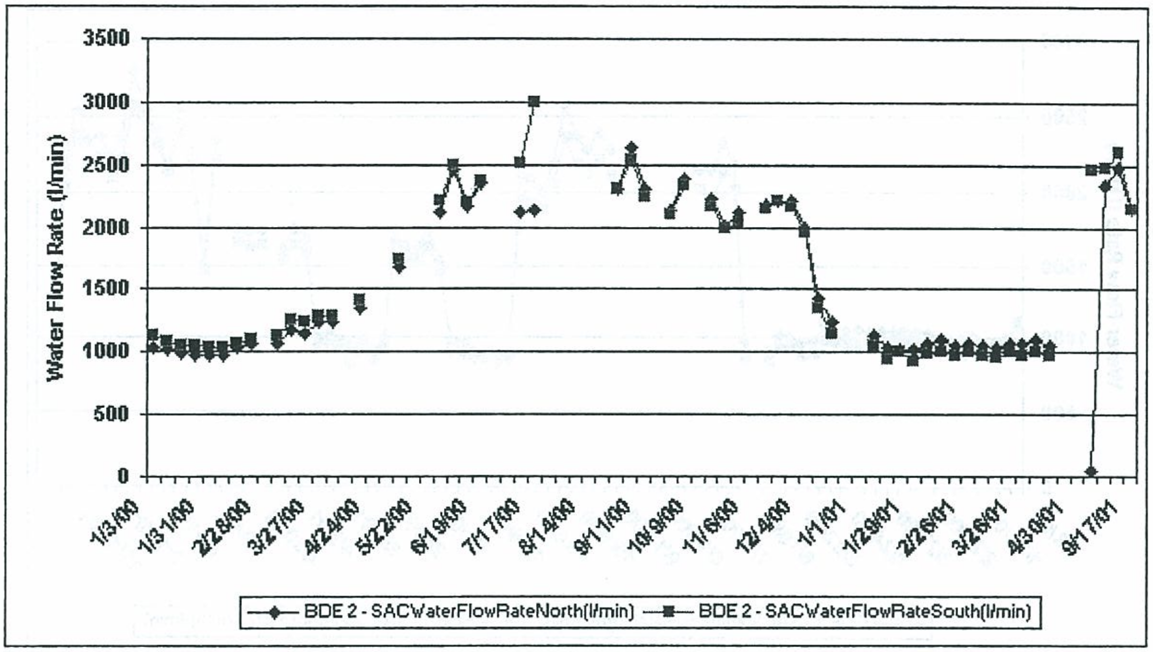


Graph 1: Unit 1 SAC Water Flow Rate

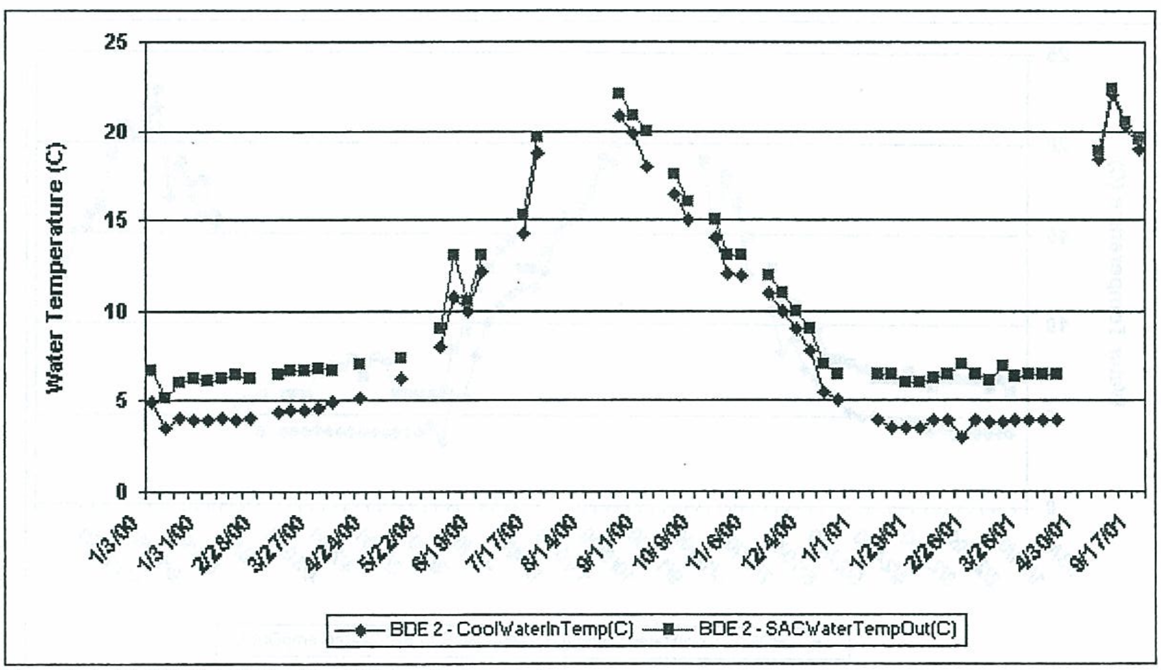


Graph 2: Unit 1 SAC Cooling Water Temperature

Unit 2 Surface Air Coolers

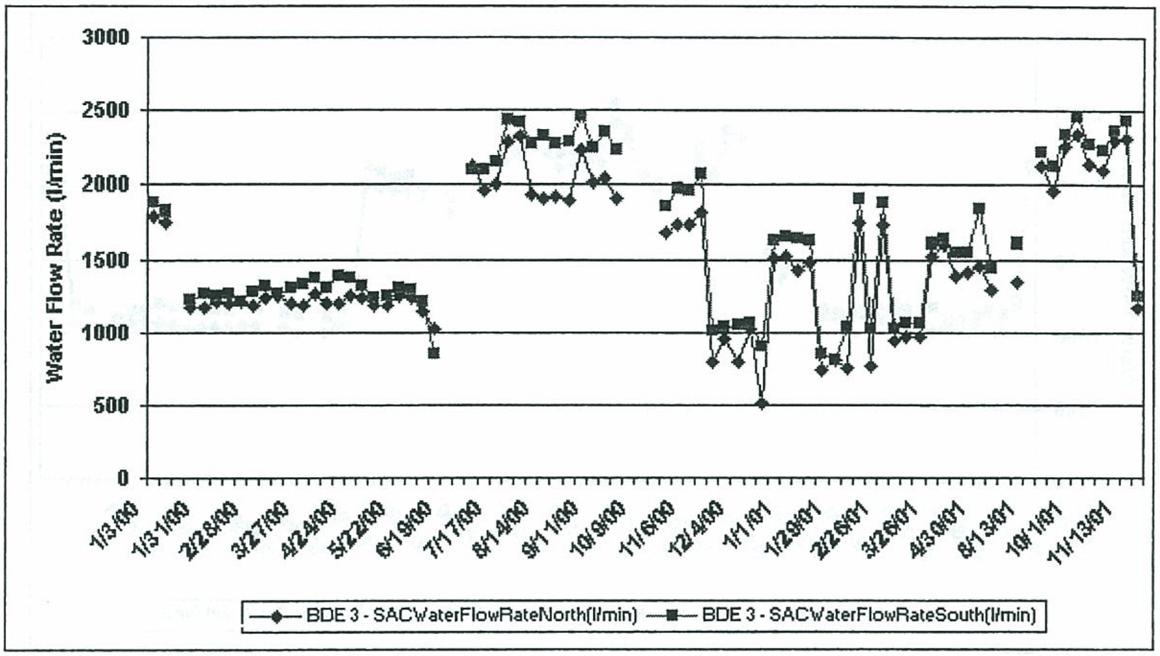


Graph 3: Unit 2 SAC Water Flow Rate

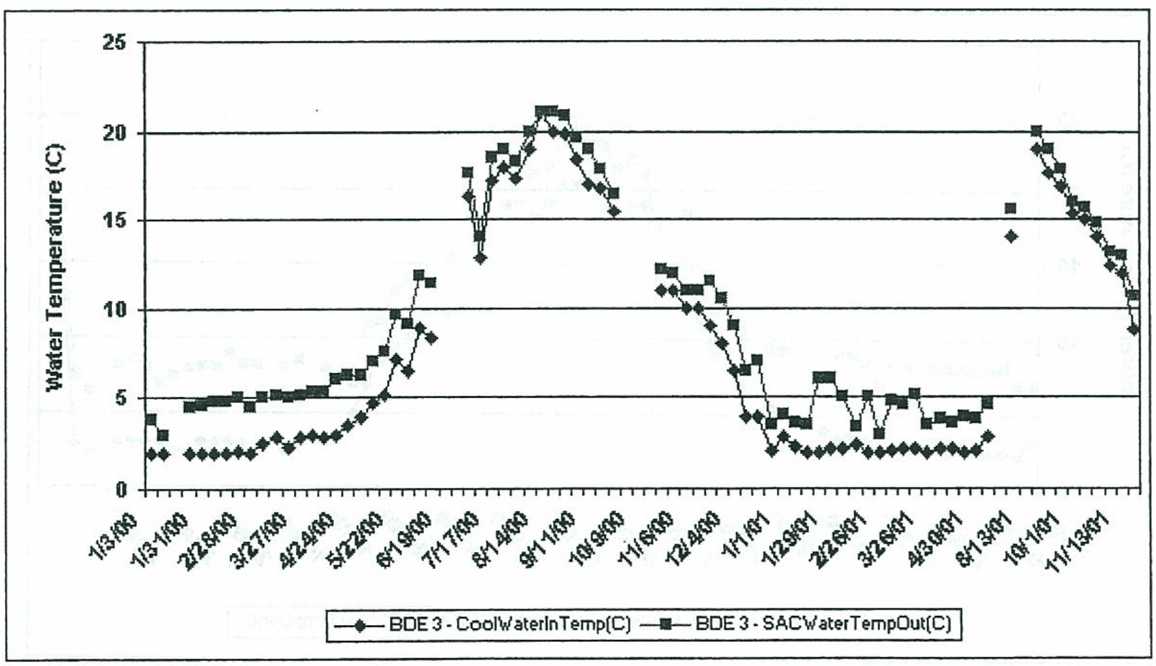


Graph 4: Unit 2 SAC Cooling Water Temperature

Unit 3 Surface Air Coolers

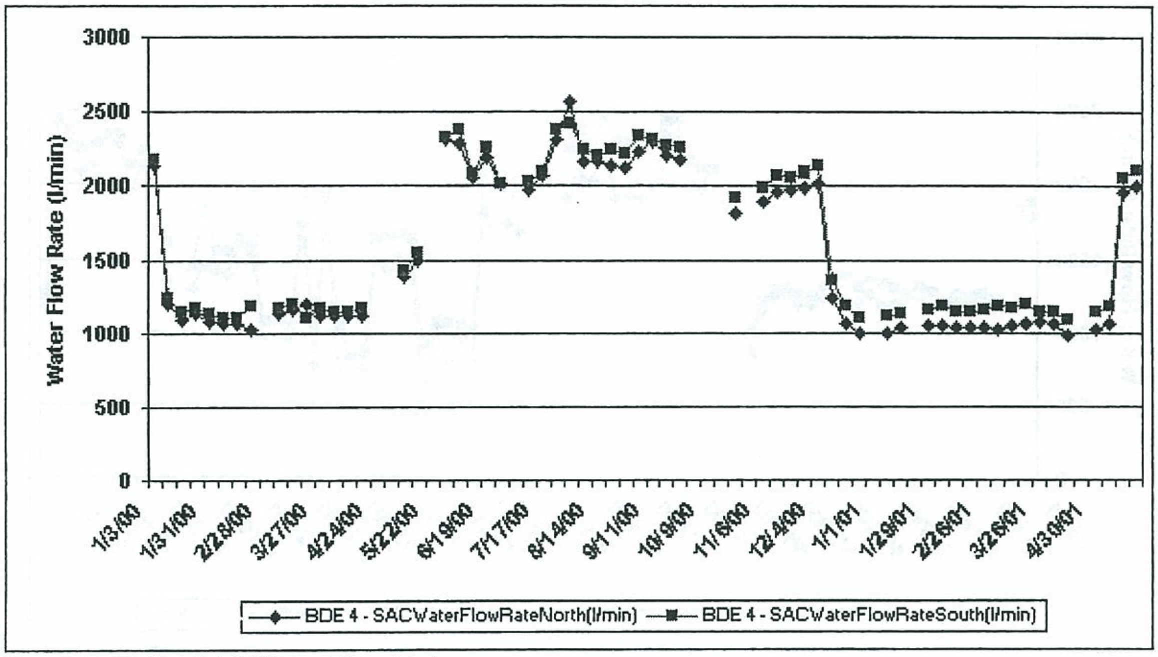


Graph 5: Unit 3 SAC Water Flow Rate

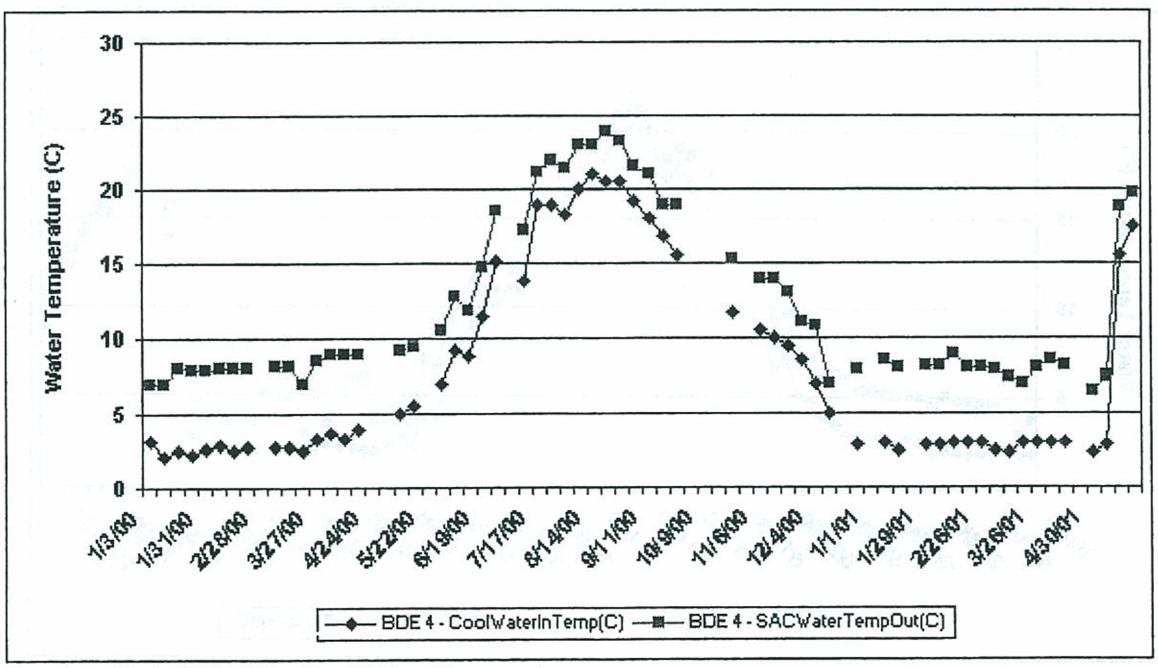


Graph 6: Unit 3 SAC Cooling Water Temperature

Unit 4 Surface Air Coolers

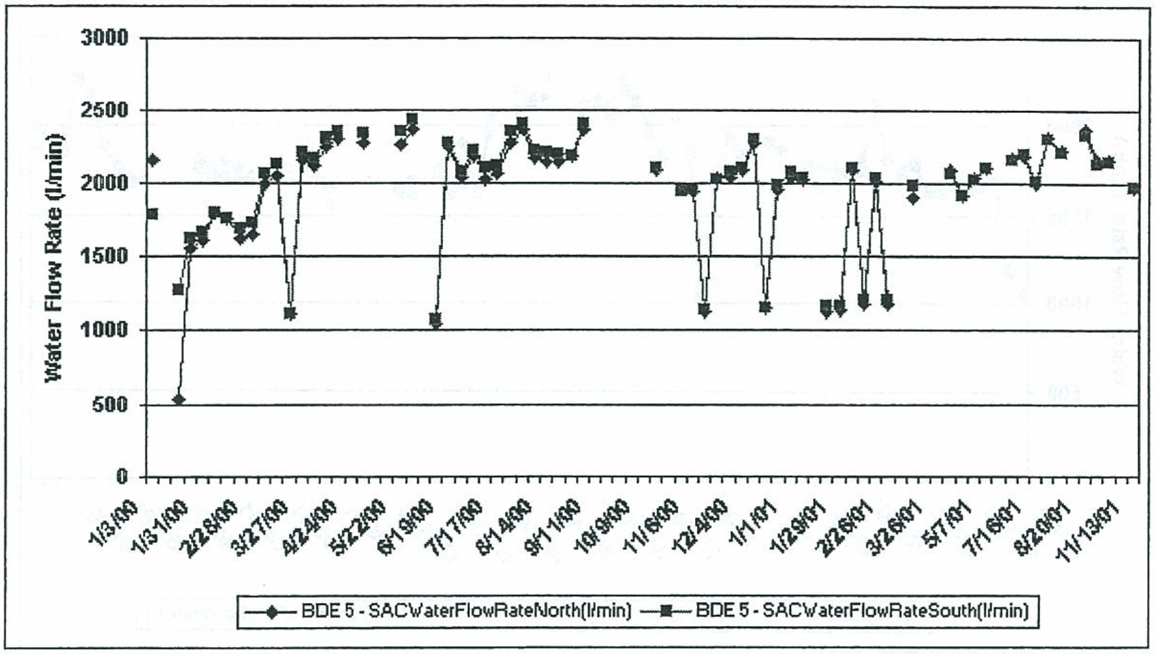


Graph 7: Unit 4 SAC Water Flow Rate

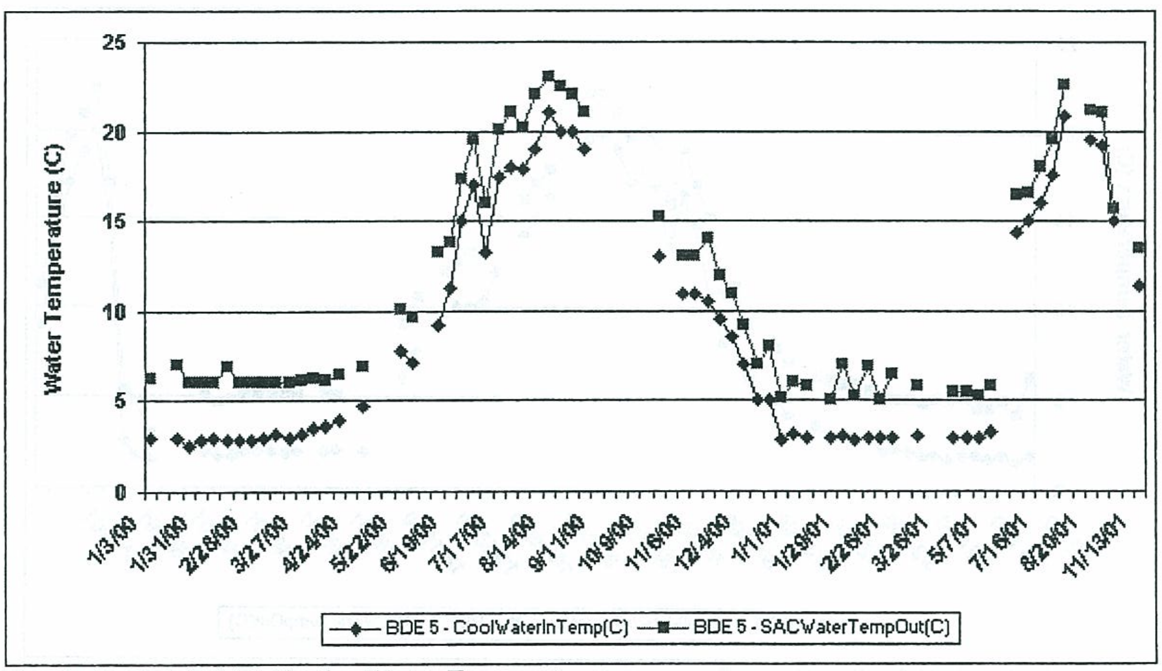


Graph 8: Unit 4 SAC Cooling Water Temperature

Unit 5 Surface Air Coolers

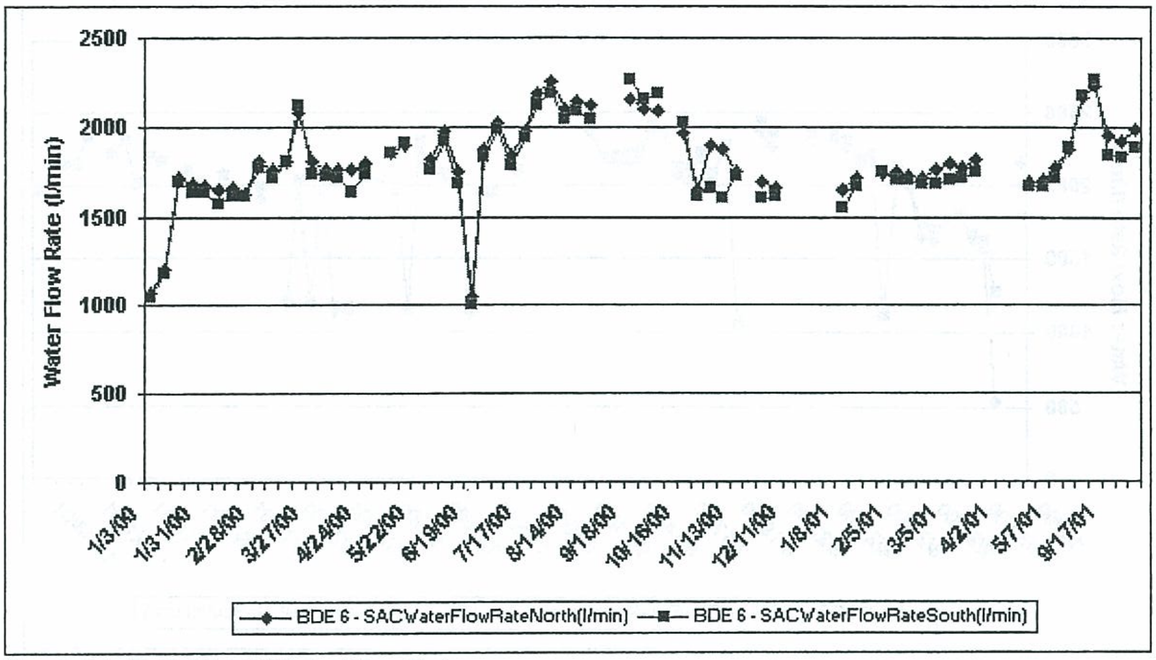


Graph 9: Unit 5 SAC Water Flow Rate

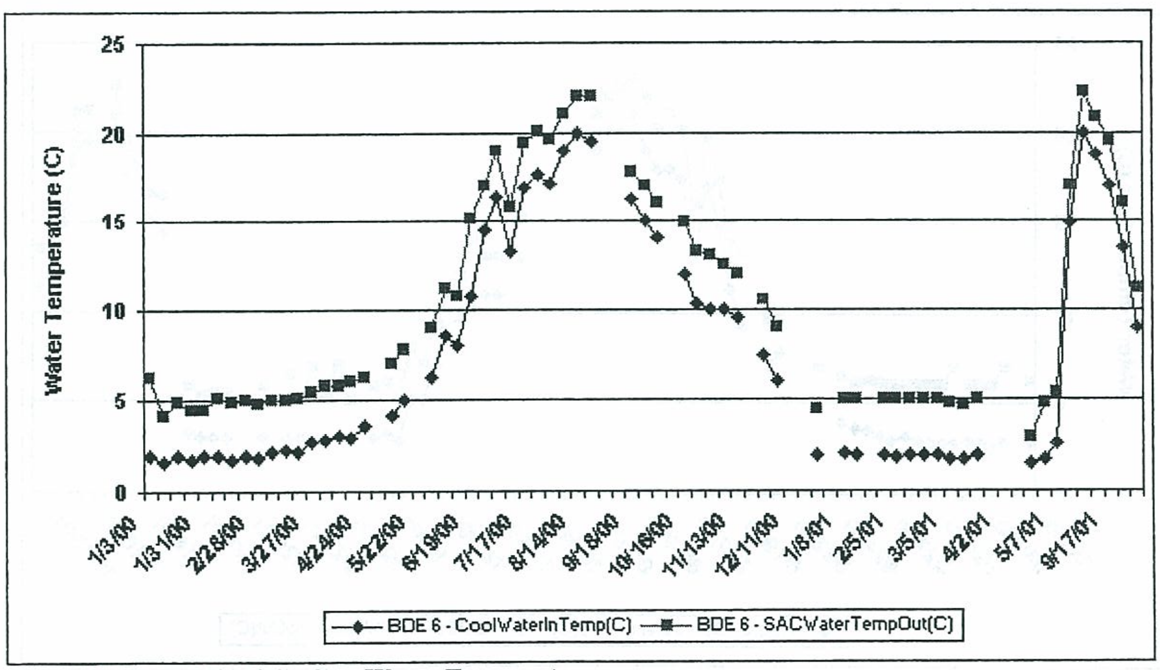


Graph 10: Unit 5 SAC Cooling Water Temperature

Unit 6 Surface Air Coolers

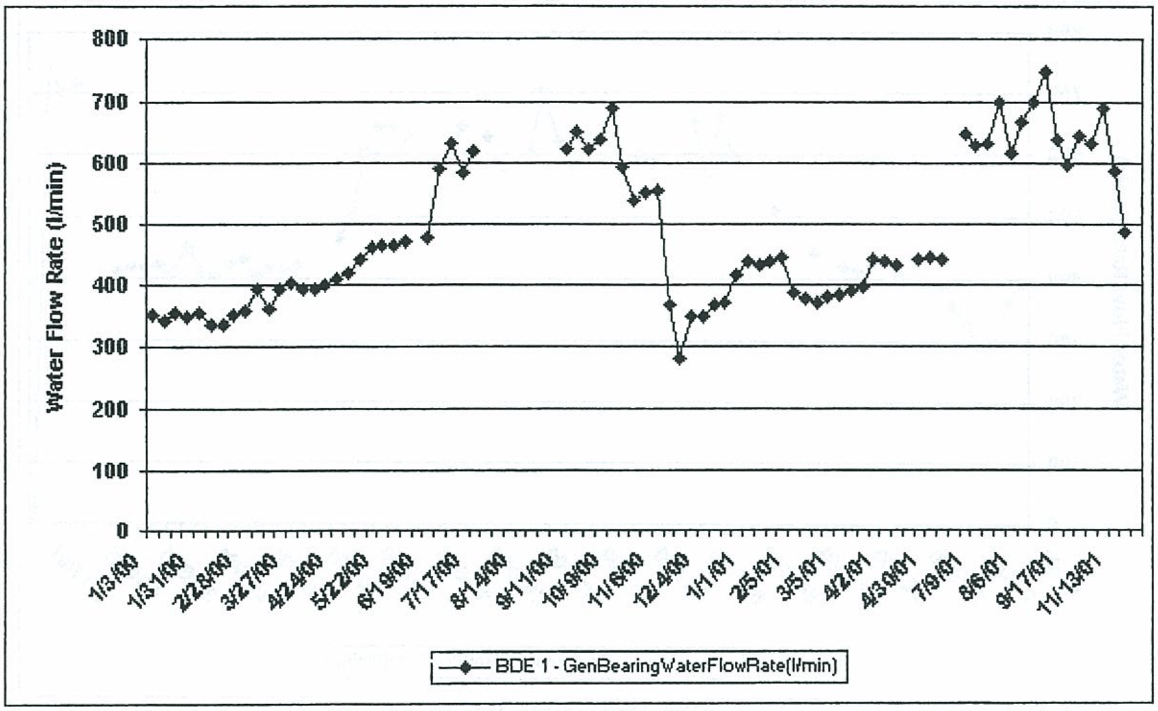


Graph 11: Unit 6 SAC Water Flow Rate

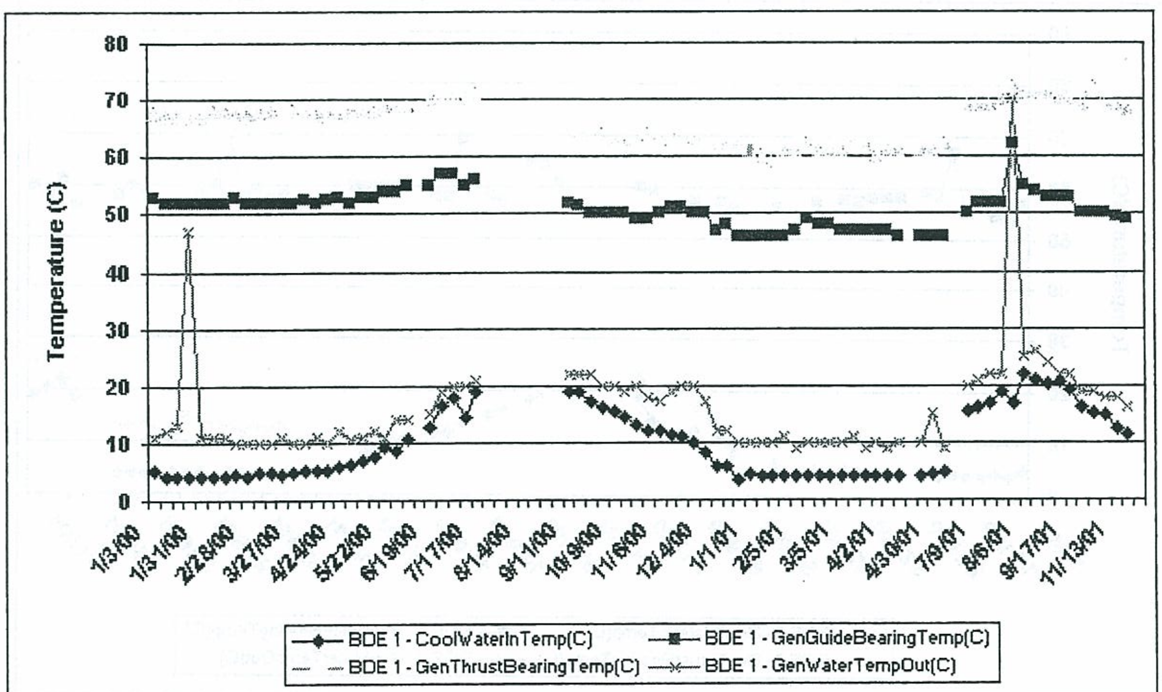


Graph 12: Unit 6 SAC Cooling Water Temperature

Unit 1 Generator Guide / Thrust Bearing Coolers

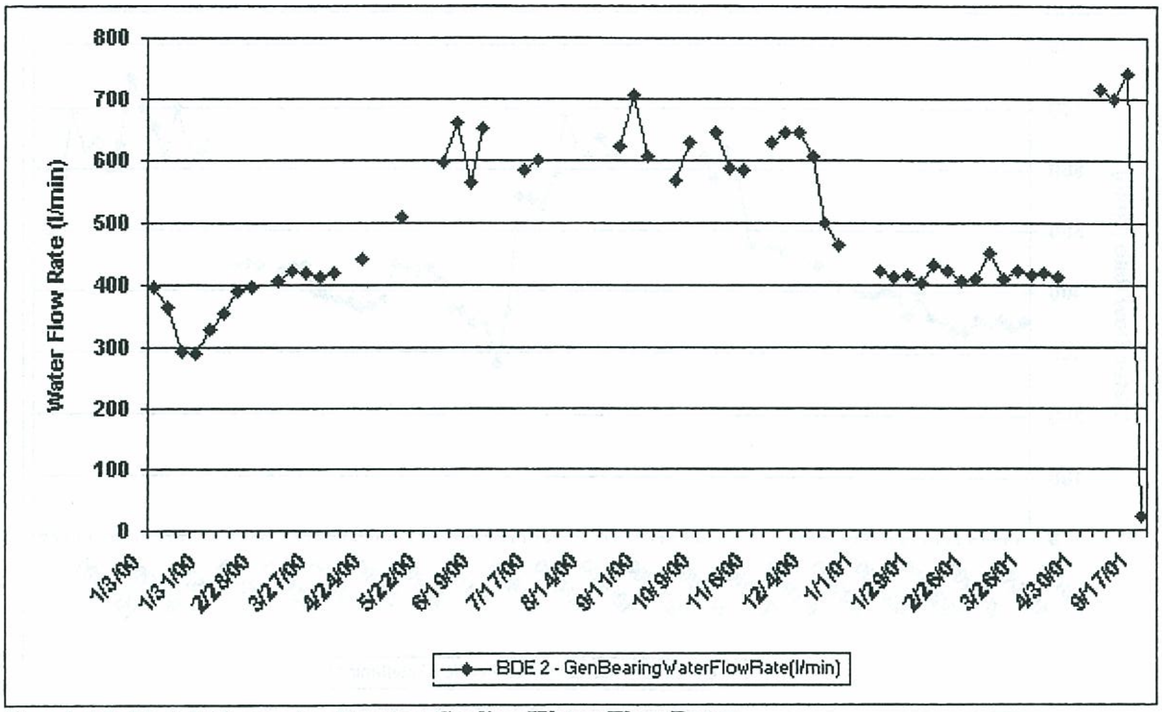


Graph 13: Unit 1 Generator Bearing Cooling Water Flow Rate

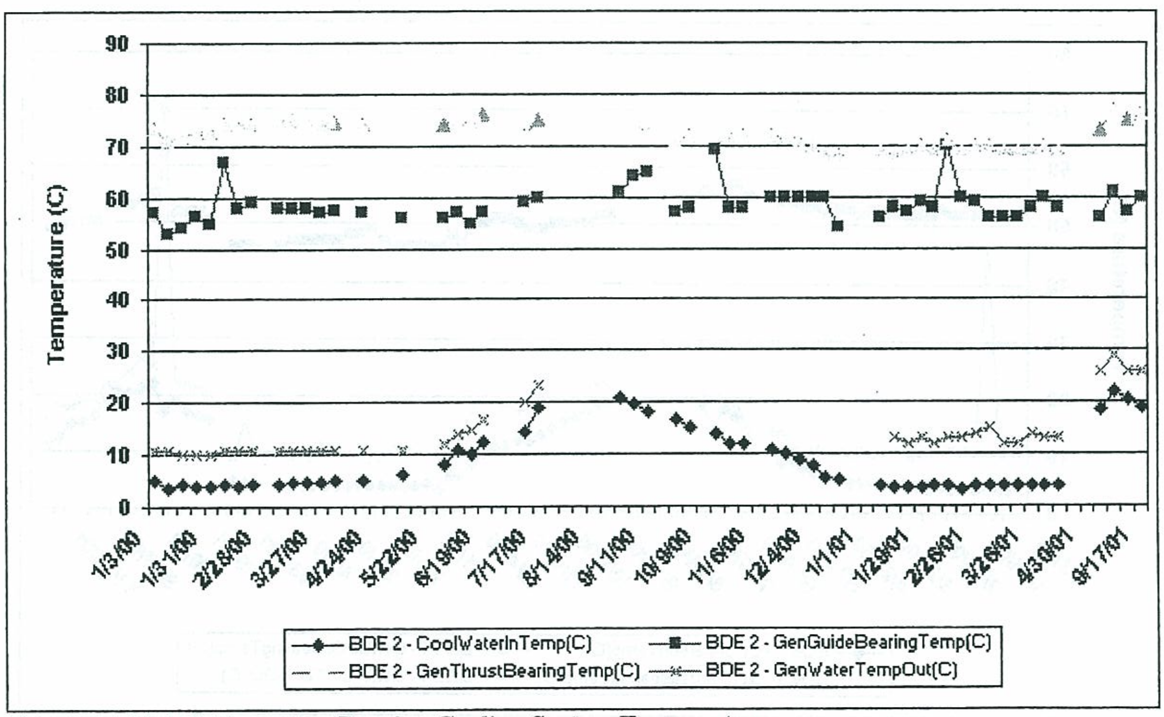


Graph 14: Unit 1 Generator Bearing Cooling System Temperatures

Unit 2 Generator Guide / Thrust Bearing Coolers

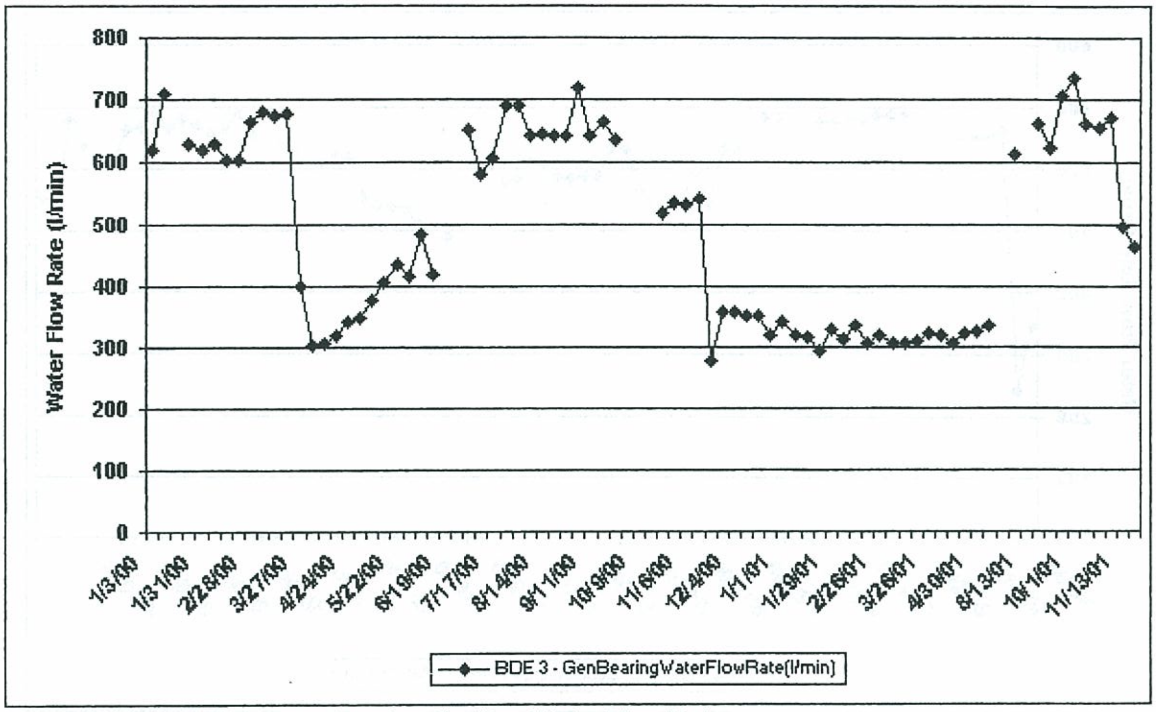


Graph 15: Unit 2 Generator Bearing Cooling Water Flow Rate

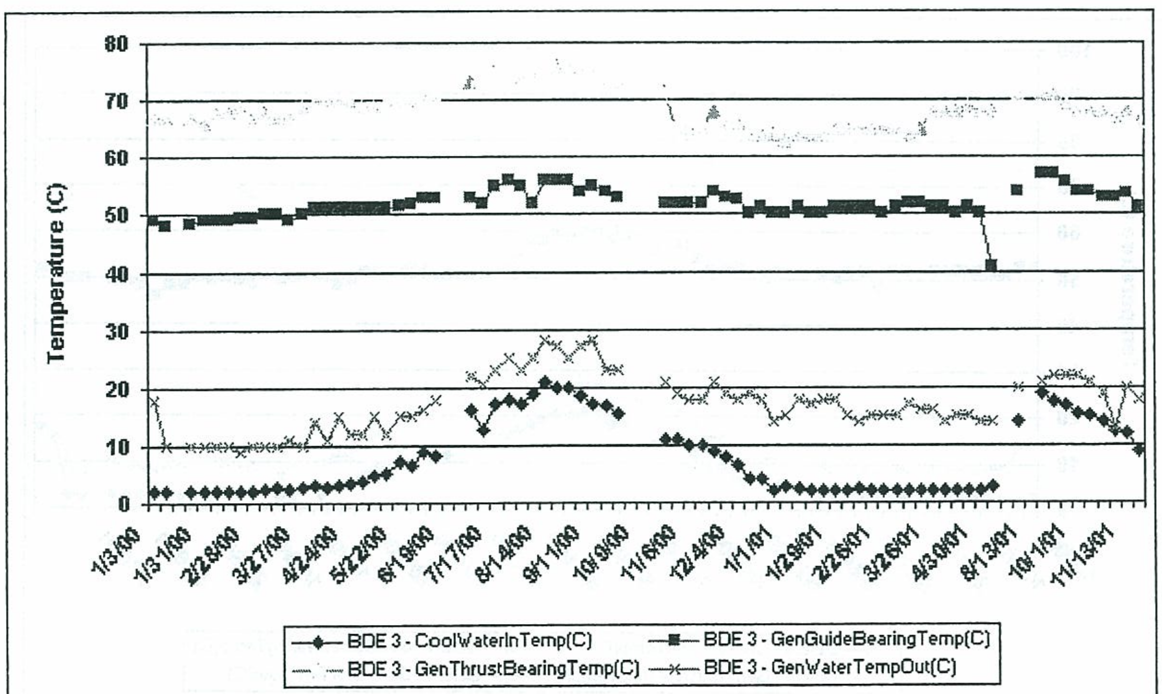


Graph 16: Unit 2 Generator Bearing Cooling System Temperatures

Unit 3 Generator Guide / Thrust Bearing Coolers

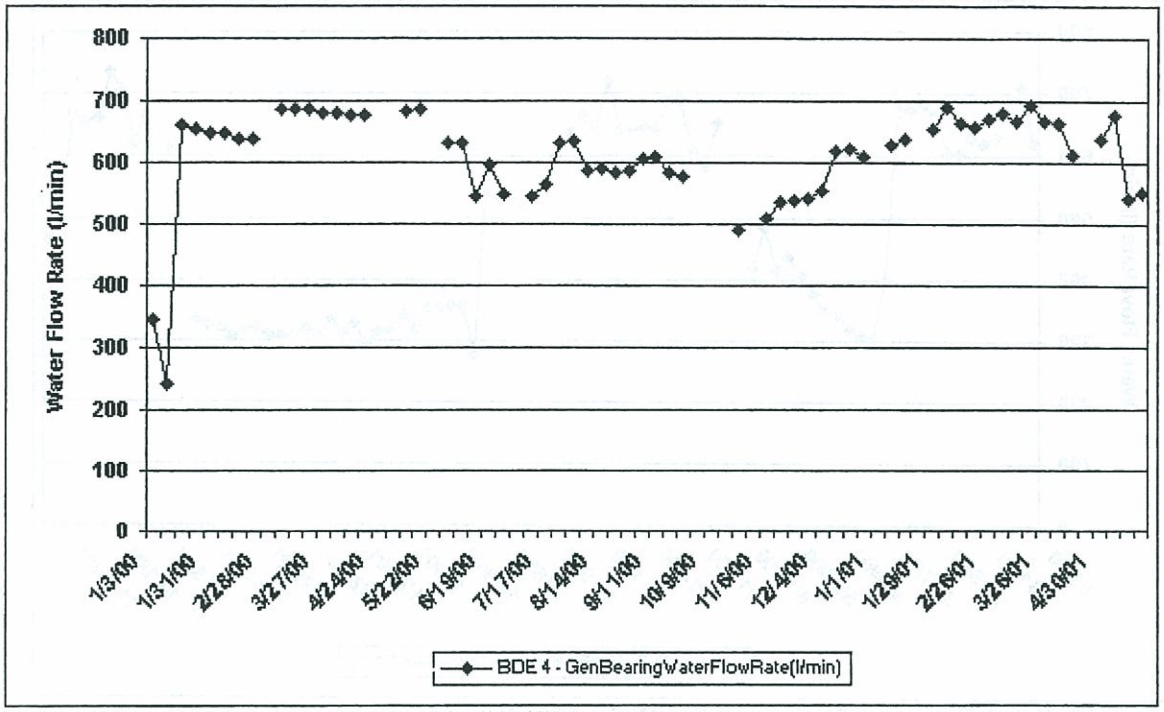


Graph 17: Unit 3 Generator Bearing Cooling Water Flow Rate

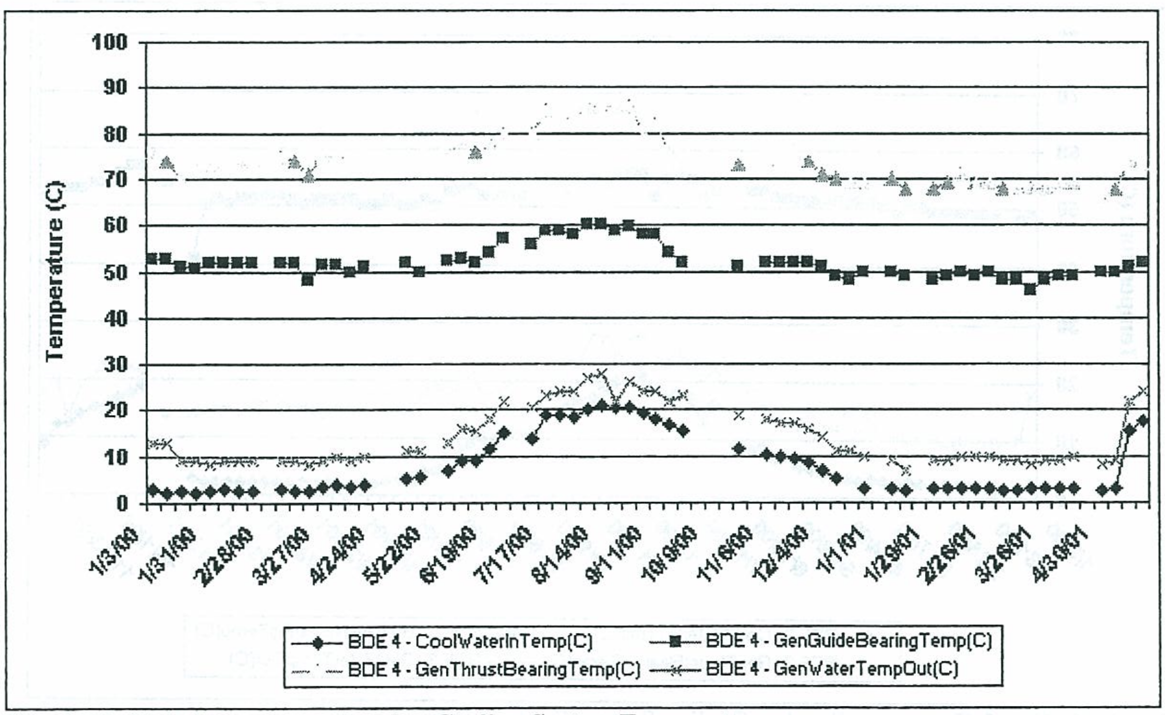


Graph 18: Unit 3 Generator Bearing Cooling System Temperatures

Unit 4 Generator Guide / Thrust Bearing Coolers

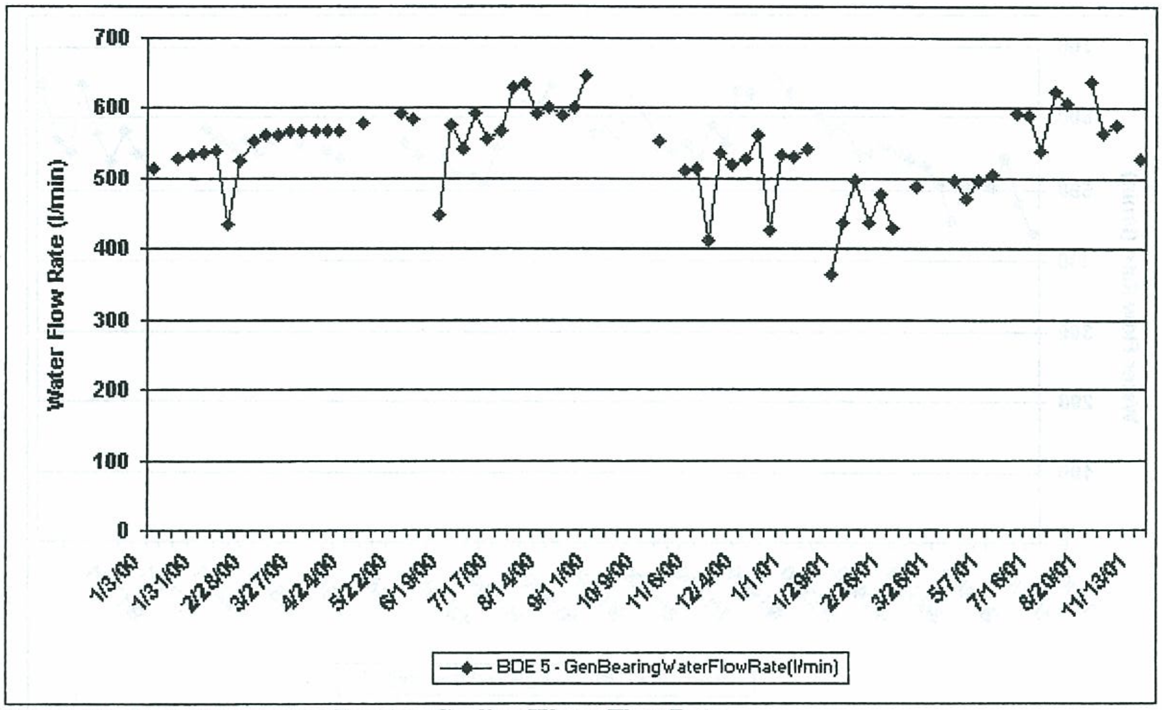


Graph 19: Unit 4 Generator Bearing Cooling Water Flow Rate

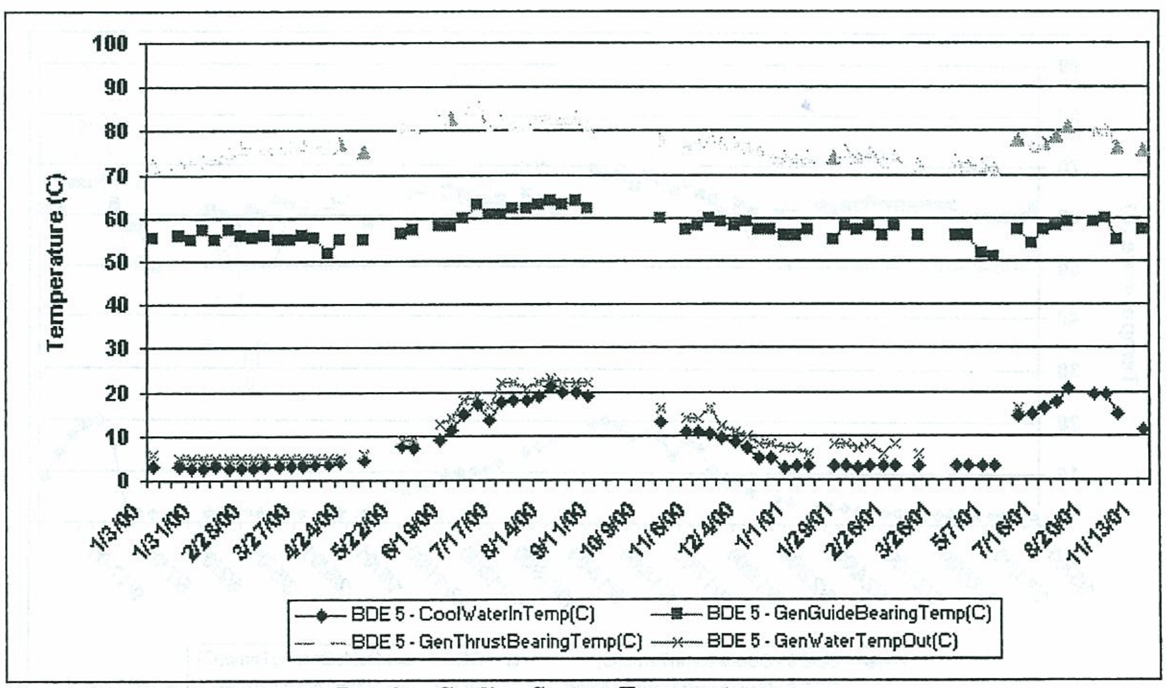


Graph 20: Unit 4 Generator Bearing Cooling System Temperatures

Unit 5 Generator Guide / Thrust Bearing Coolers

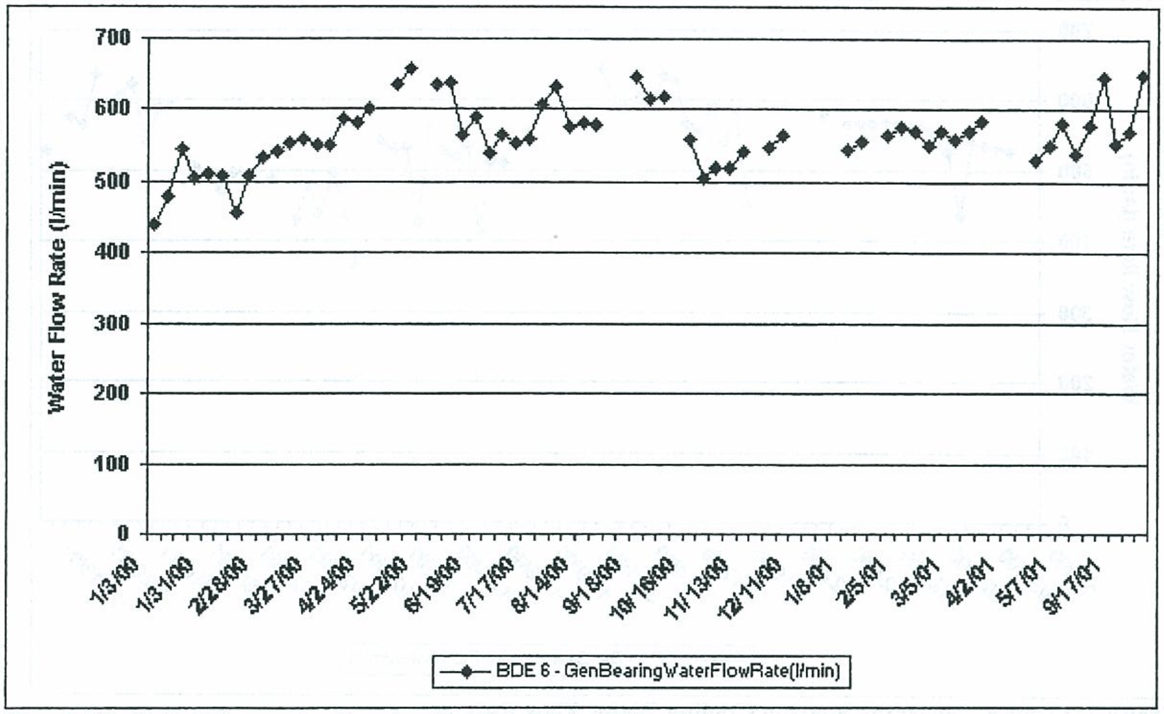


Graph 21: Unit 5 Generator Bearing Cooling Water Flow Rate

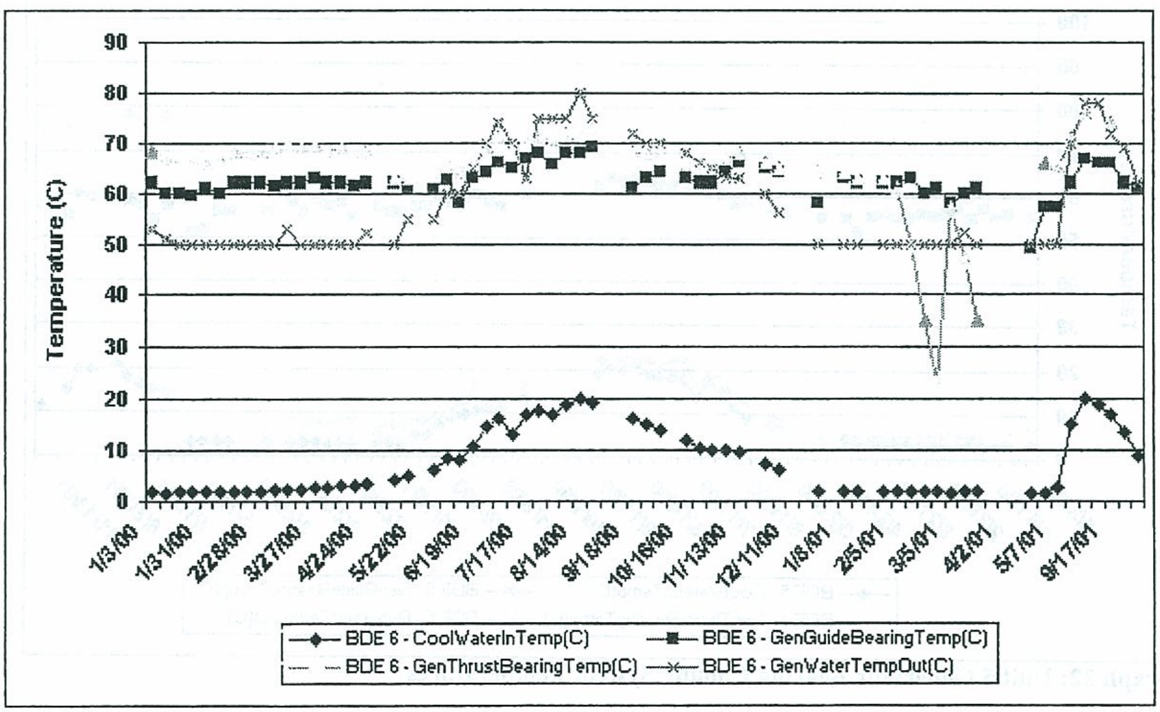


Graph 22: Unit 5 Generator Bearing Cooling System Temperatures

Unit 6 Generator Guide / Thrust Bearing Coolers

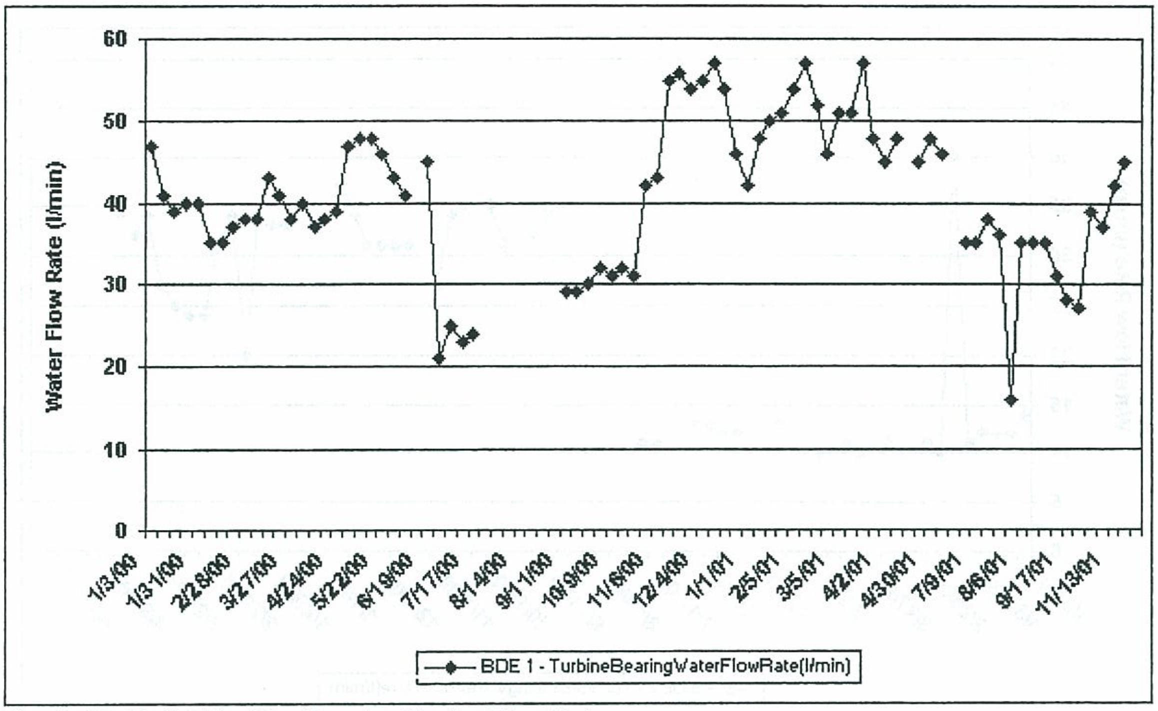


Graph 23: Unit 6 Generator Bearing Cooling Water Flow Rate

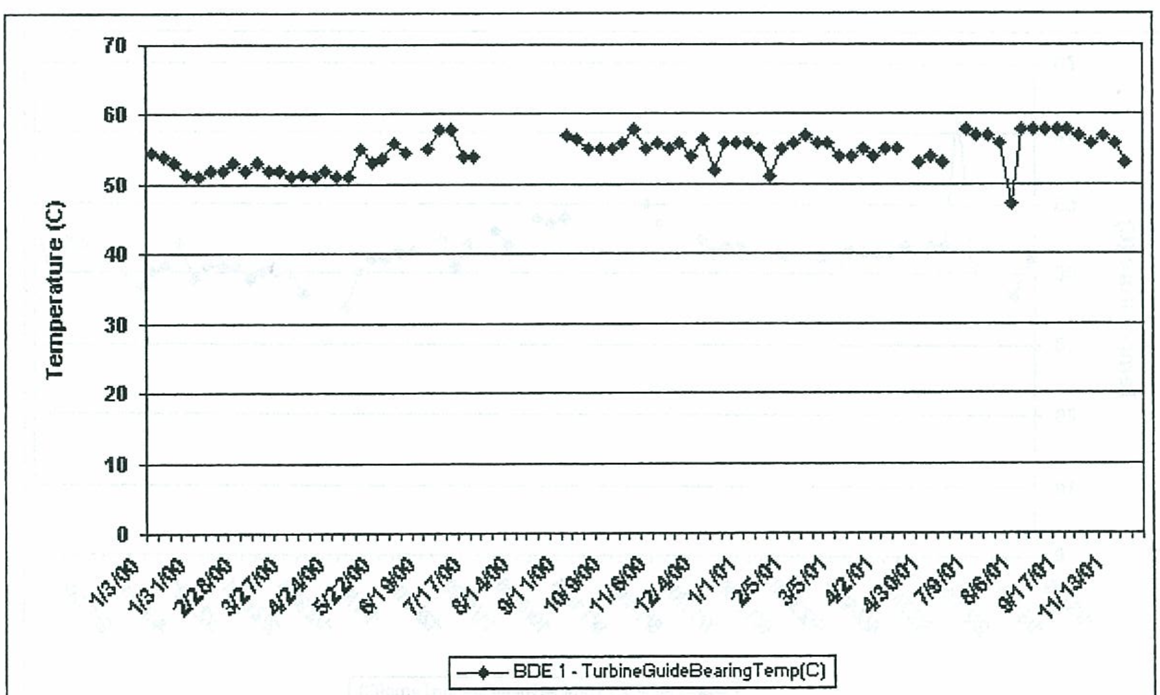


Graph 24: Unit 6 Generator Bearing Cooling System Temperatures

Unit 1 Turbine Bearing Cooler

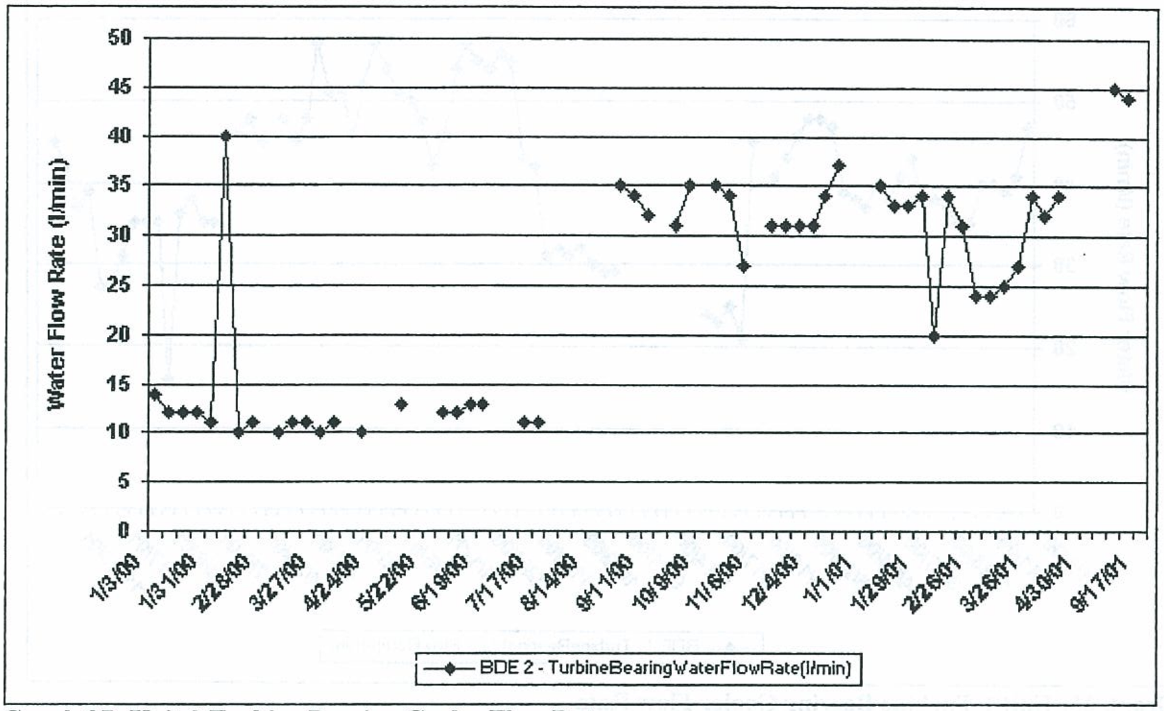


Graph 25: Unit 1 Turbine Bearing Cooler Flow Rate

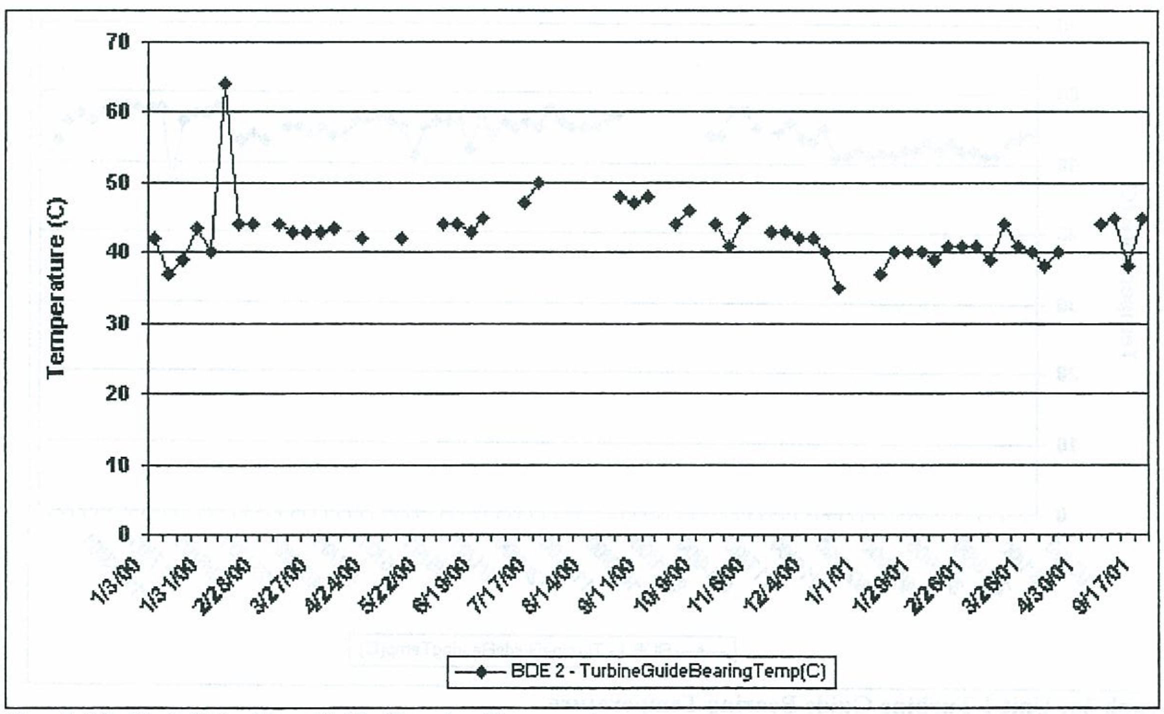


Graph 26: Unit 1 Turbine Guide Bearing Temperature

Unit 2 Turbine Bearing Cooler

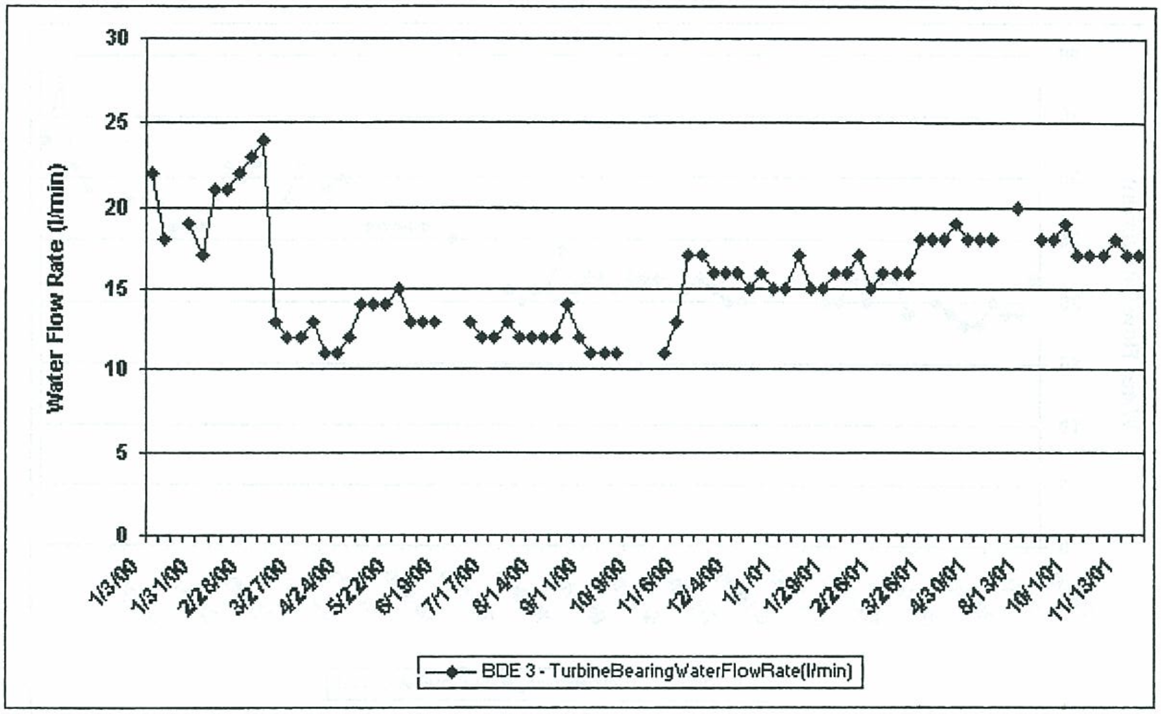


Graph 27: Unit 2 Turbine Bearing Cooler Flow Rate

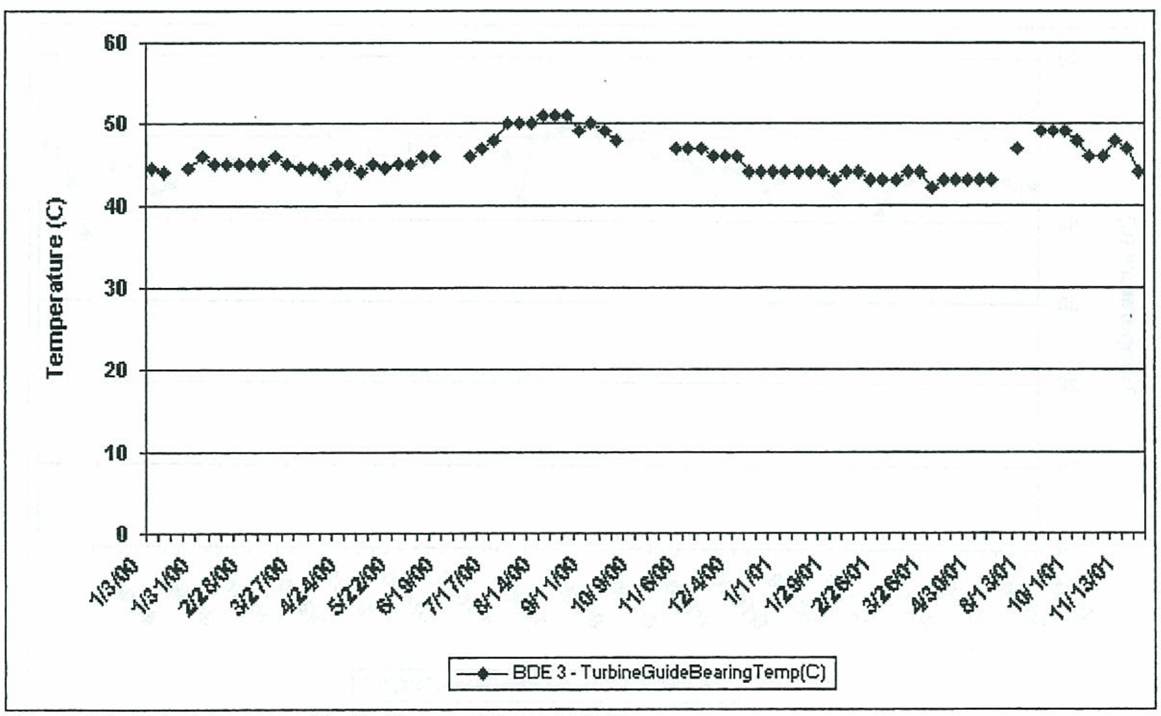


Graph 28: Unit 2 Turbine Guide Bearing Temperature

Unit 3 Turbine Bearing Cooler

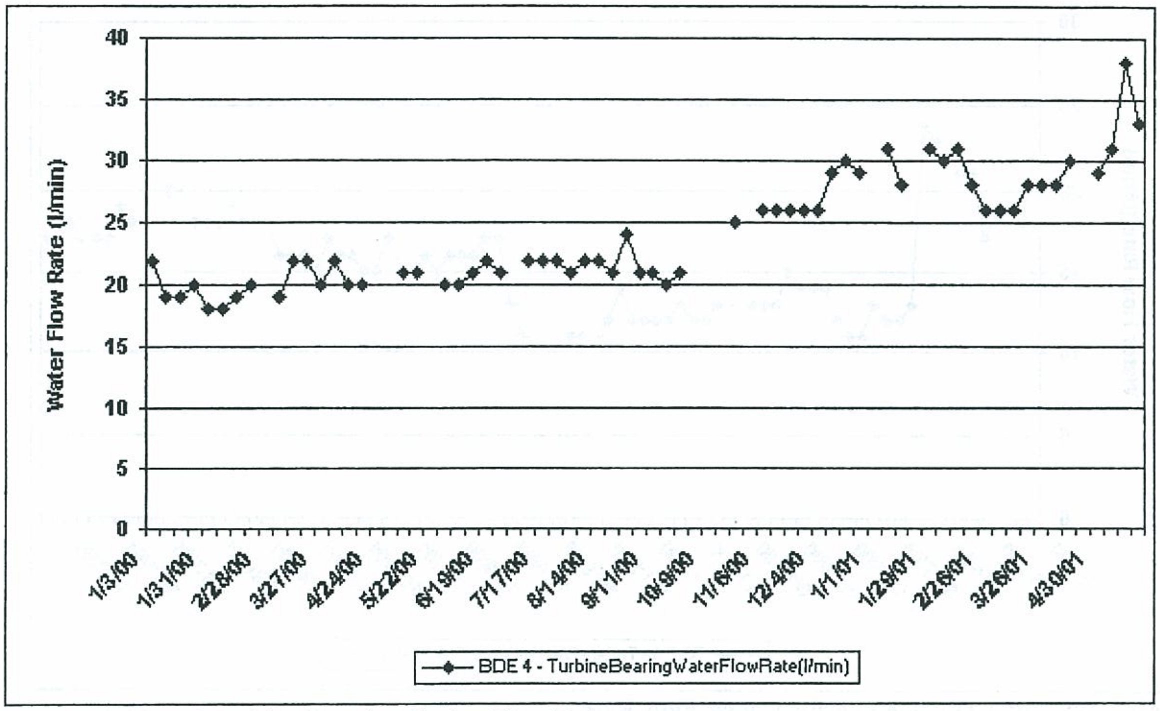


Graph 29: Unit 3 Turbine Bearing Cooler Flow Rate

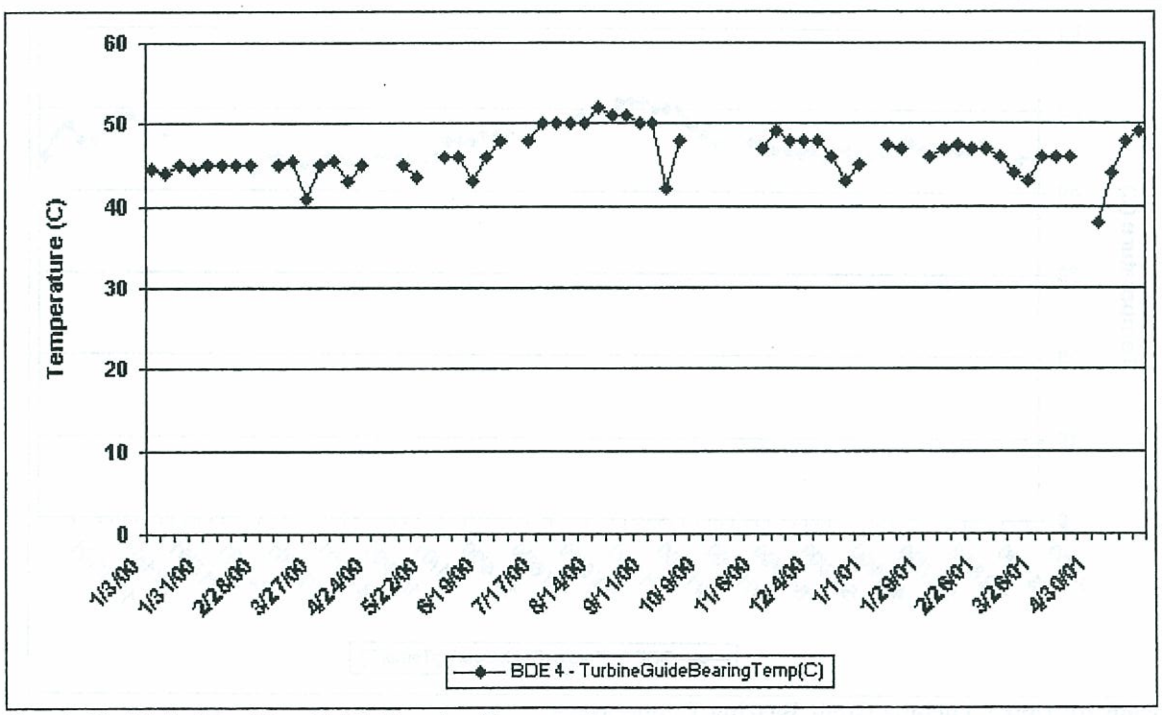


Graph 30: Unit 3 Turbine Guide Bearing Temperature

Unit 4 Turbine Bearing Cooler

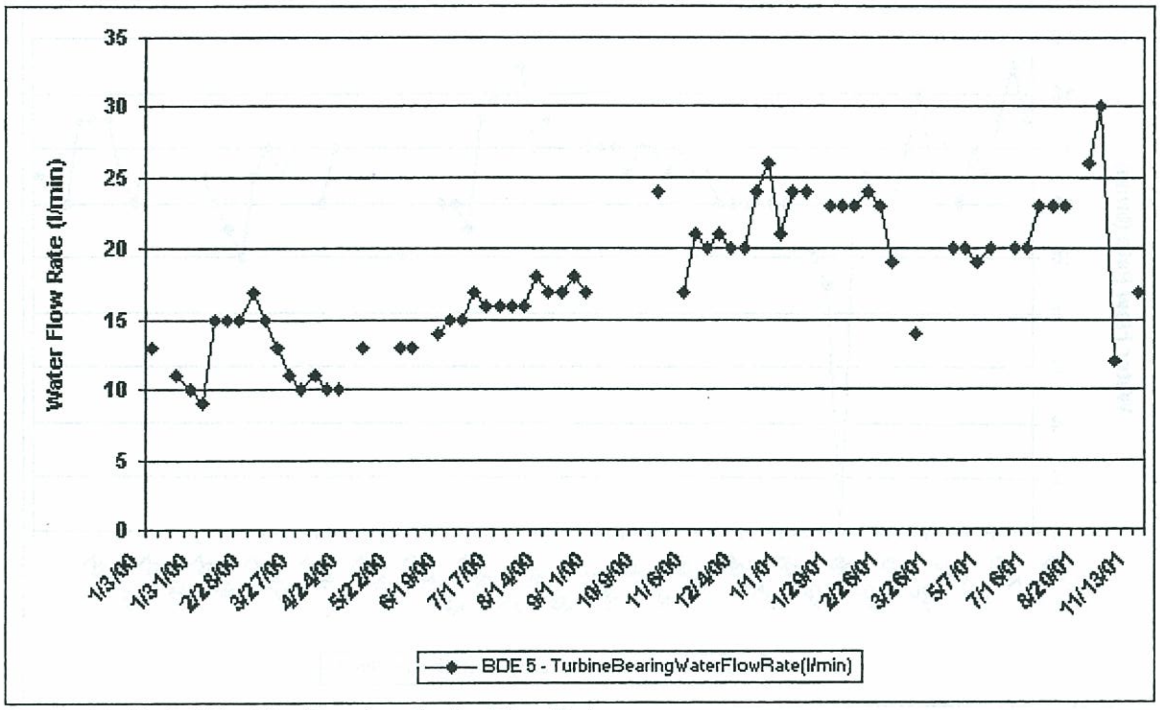


Graph 31: Unit 4 Turbine Bearing Cooler Flow Rate

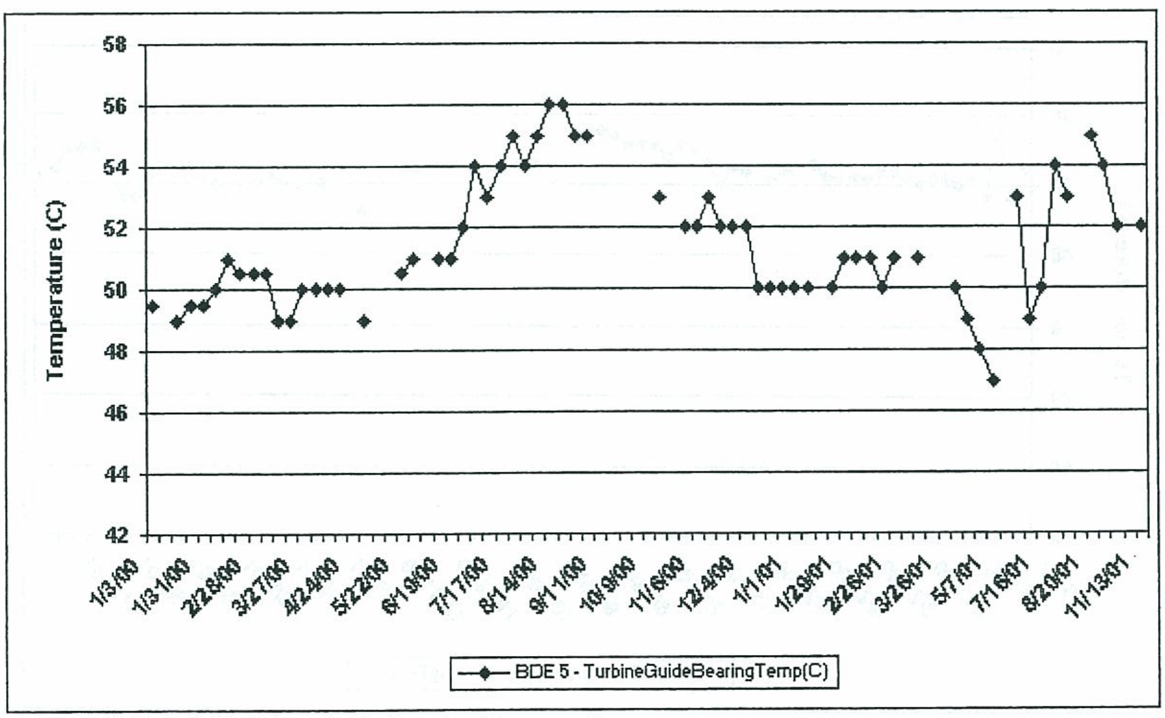


Graph 32: Unit 4 Turbine Guide Bearing Temperature

Unit 5 Turbine Bearing Cooler

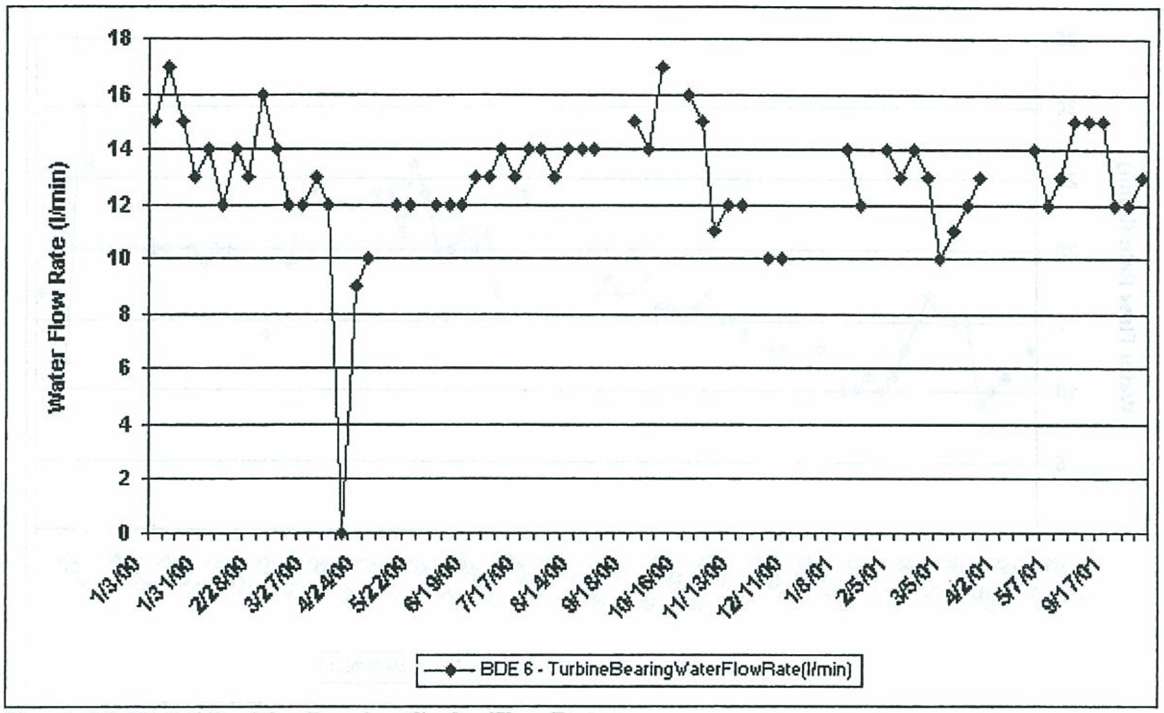


Graph 33: Unit 5 Turbine Bearing Cooler Flow Rate

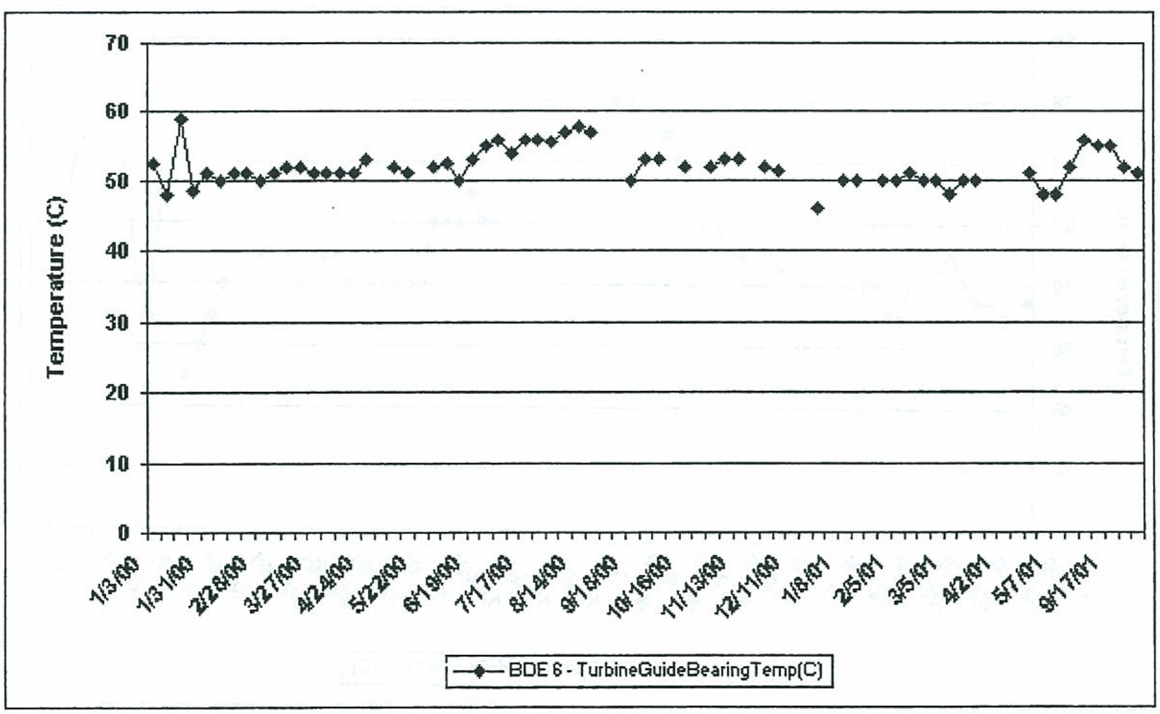


Graph 34: Unit 5 Turbine Guide Bearing Temperature

Unit 6 Turbine Bearing Cooler



Graph 35: Unit 6 Turbine Bearing Cooler Flow Rate



Graph 36: Unit 6 Turbine Guide Bearing Temperature

Appendix F: Estimated Piping Costs

Breakdown of Labor Crew Costs

Employee Rates:

RSMeans Personnel	Hydro Equivalent	Rate
Plumber	Mech. Main A	$ 21.56
Plumber App.	Mech. Main A	$ 21.56
Welder	Mech. Main A	$ 21.56
Supervisor	Mech. Main A + 10%	$ 23.72
Overhead		63%

Labor Crews for RSMeans Piping Cost Estimates:

	Crew "1Plum"		Crew "Q1"		Crew "Q2"		Crew "Q15"		Crew "Q16"	
	Quantity	Cost	Quantity	Cost	Quantity	Cost	Quantity	Cost	Quantity	Cost
Plumber	1	$ 21.56	1	$ 21.56	2	$ 43.12	1	$ 21.56	2	$ 43.12
Plumber Apprentice	0	$ -	1	$ 21.56	1	$ 21.56	1	$ 21.56	1	$ 21.56
Welder	0	$ -		$ -		$ -	1	$ 21.56	1	$ 21.56
Supervisor	0.333	$ 7.90	0.333	$ 7.90	0.333	$ 7.90	0.333	$ 7.90	0.333	$ 7.90
Overhead (63%)		$ 18.56		$ 32.14		$ 45.72		$ 45.72		$ 59.31
Crew Rate per Hour		**$ 48.02**		**$ 83.16**		**$ 118.30**		**$ 118.30**		**$ 153.44**
Crew Rate per Day		**$ 384.12**		**$ 665.27**		**$ 946.41**		**$ 946.41**		**$ 1,227.55**

Labor Crew for Maintenance Cost Estimates:

	Cleaning Crew	
	Quantity	Cost
Mechanical Main "A"	3	$ 64.68
Supervisor	0.333	$ 7.90
Overhead (63%)		$ 45.72
Crew Rate per Hour		**$ 118.30**

Equipment	Hours	Cost
Surface Air Coolers	32	**$ 3,785.64**
Surface Air Cooler Pipe	24	**$ 2,839.23**
Generator Coolers	48	**$ 5,678.46**
Generator Cooler Pipe	24	**$ 2,839.23**

Item	Quantity (ea. ft.)	Unit Cost ($/ea.)	Material Cost ($)	Crew Type	Crew Capacity (/day)	Install Time (days)	Crew Cost ($/day)	Labor Cost ($)	Total Cost ($)

Replacement of Original with Carbon Steel

Item	Quantity (ea. ft.)	Unit Cost ($/ea.)	Material Cost ($)	Crew Type	Crew Capacity (/day)	Install Time (days)	Crew Cost ($/day)	Labor Cost ($)	Total Cost ($)
Surface Air Cooler (Carbon Steel)									
3/4" Carbon Steel Pipe Schd 40	10	0.74	7.40	1 Plum	61	0.16	384.12	62.97	70.37
4" Carbon Steel Pipe Schd 40	100	4.75	475.00	Q1	45	2.22	665.27	1478.37	1953.37
6" Carbon Steel Pipe Schd 40	100	7.46	746.00	Q2	42	2.38	946.41	2253.36	2999.36
4" 90 Elbow - Victaulic - Standard	20	19.27	385.40	Q1	25	0.80	665.27	532.21	917.61
6" 90 Elbow - Victaulic - Standard	4	22.24	88.96	Q2	25	0.16	946.41	151.43	240.39
4" 45 Elbow - Victaulic - Standard	6	23.84	143.04	Q1	25	0.24	665.27	159.66	302.70
6" 45 Elbow - Victaulic - Standard	2	59.14	118.28	Q2	25	0.08	946.41	75.71	193.99
6" x 6" x 4" Tee - Victaulic - Standard	4	97.24	388.96	Q2	18	0.22	946.41	210.31	599.27
8" Tee - Victaulic - Standard	1	168.26	168.26	Q2	14	0.07	946.41	67.60	235.86
4" Butterfly Valves - Victaulic - Standard	8	204.01	1632.08	Q1	38	0.21	665.27	140.06	1772.14
3/4" Bronze Gate Valve - Treaded	2	21.46	42.92	1 Plum	20	0.10	384.12	38.41	81.33
4" x 6" Reducer - Victaulic - Standard	4	30.25	121.00	Q2	26	0.15	946.41	145.60	266.60
6" x 8" Reducer - Victaulic - Standard	3	49.91	149.73	Q2	23	0.13	946.41	123.44	273.17
4" Flange - Slip On Weld - 150	4	12.11	48.44	Q15	6	0.67	946.41	630.94	679.38
6" Flange - Socket Weld - 150	2	16.68	33.36	Q16	6	0.33	1227.55	409.18	442.54
3/4" Automatic Air Vent	8	87.47	699.76	1 Plum	12	0.67	384.12	256.08	955.84
Surface Air Cooler Total:			5248.59			8.60		6735.35	11983.94
Emergency Supply (Carbon Steel)									
6" Carbon Steel Pipe Schd 40	40	7.46	298.40	Q16	36	1.11	1227.55	1363.95	1662.35
6" 90 Elbow - Butt Weld - Schd 40	3	22.24	66.72	Q16	5	0.60	1227.55	736.53	803.25
3" x 6" Reducer - Butt Weld - Schd 40	1	14.21	14.21	Q16	6	0.17	1227.55	204.59	218.80
6" Butterfly Valve - Wafer - 150	1	146.76	146.76	Q2	5	0.20	946.41	189.28	336.04
6" Flange - Socket Weld - 150	2	16.68	33.36	Q16	6	0.33	1227.55	409.18	442.54
3" Flange - Socket Weld - 150	1	9.27	9.27	Q15	9	0.11	946.41	105.16	114.43
Emergency Supply Total:			568.72			2.52		3008.69	3577.41

Item	Quantity (ea. ft.)	Unit Cost ($/ea.)	Material Cost ($)	Crew Type	Crew Capacity (/day)	Install Time (days)	Crew Cost ($/day)	Labor Cost ($)	Total Cost ($)
Pump and Strainer Piping (Carbon Steel)									
8" Carbon Steel Pipe Schd 40	20	12.48	249.60	Q16	29	0.69	1227.55	846.59	1096.19
8" 90 Elbow - Butt Weld - Schd 40	4	44.48	177.92	Q16	3.75	1.07	1227.55	1309.39	1487.31
8" 90 Elbow - Flanged - Class 150	3	121.08	363.24	Q2	8	0.38	946.41	354.90	718.14
8" Tee - Butt Weld - Schd 40	1	104.35	104.35	Q16	2.5	0.40	1227.55	491.02	595.37
8" Tee - Flanged - Class 150	1	219.25	219.25	Q2	5	0.20	946.41	189.28	408.53
8" x 8" x 6" Tee - Butt Weld - Schd 40	1	104.35	104.35	Q16	2.5	0.40	1227.55	491.02	595.37
8" x 10" Reducer - Butt Weld - Schd 40	2	27.49	54.98	Q16	4	0.50	1227.55	613.78	668.76
8" Flange - Socket Weld - 150	9	25.95	233.55	Q16	5	1.80	1227.55	2209.59	2443.14
10" Flange - Socket Weld - 150	2	42.00	84.00	Q16	4	0.50	1227.55	613.78	697.78
8" Butterfly Valve - Wafer - 150	4	248.12	992.48	Q2	4.5	0.89	946.41	841.25	1833.73
8" Gate Valve - Flanged - 150	1	1134.00	1134.00	Q2	2.5	0.40	946.41	378.56	1512.56
8" Check Valve - Flanged - 150	1	1112.95	1112.95	Q2	2.5	0.40	946.41	378.56	1491.51
Pump and Strainer Piping Total:			4830.67			7.62		8717.73	13548.40
Subtotal:			10648			19		18462	29110
15% Contingency:			1597			3		2769	4366
Piping Cost (Carbon Steel):			**12245**			**22**		**21231**	**33476**

Item	Quantity (ea. ft.)	Unit Cost ($/ea.)	Material Cost ($)	Crew Type	Crew Capacity (/day)	Install Time (days)	Crew Cost ($/day)	Labor Cost ($)	Total Cost ($)

Replacement of Piping with Corrosion Resistant Piping

Item	Quantity (ea. ft.)	Unit Cost ($/ea.)	Material Cost ($)	Crew Type	Crew Capacity (/day)	Install Time (days)	Crew Cost ($/day)	Labor Cost ($)	Total Cost ($)
Surface Air Cooler Inside (Stainless Steel)									
3/4" Stainless Steel Pipe Schd 10	10	3.08	30.80	1 Plum	61.5	0.16	384.12	62.46	93.26
4" Stainless Steel Pipe Schd 10	80	16.11	1288.80	Q1	49	1.63	665.27	1086.15	2374.95
6" Stainless Steel Pipe Schd 10	40	25.63	1025.20	Q2	46	0.87	946.41	822.96	1848.16
4" 90 Elbow - SS - Victaulic - Standard	18	134.92	2428.56	Q1	25	0.72	665.27	478.99	2907.55
6" 90 Elbow - SS - Victaulic - Standard	2	340.96	681.92	Q2	25	0.08	946.41	75.71	757.63
4" 45 Elbow - SS - Victaulic - Standard	4	104.27	417.08	Q1	25	0.16	665.27	106.44	523.52
6" x 6" x 4" Tee - SS - Victaulic - Standard	2	344.64	689.28	Q2	18	0.11	946.41	105.16	794.44
4" Butterfly - Steel/Rubber Lined - Victaulic	8	202.25	1618.00	Q1	38	0.21	665.27	140.06	1758.06
4" x 6" Reducer - SS - Victaulic - Standard	4	199.97	799.88	Q2	26	0.15	946.41	145.60	945.48
4" Victaulic - Flange Adapter - SS	4	100.00	400.00	Q1	23	0.17	665.27	115.70	515.70
6" Victaulic - Flange Adapter - SS	2	150.00	300.00	Q2	23	0.09	946.41	82.30	382.30
3/4" Stainless Steel Gate Valve - Treaded	2	21.02	42.04	1 Plum	20	0.10	384.12	38.41	80.45
3/4" Automatic Air Vent - PVC Chemline	8	20.85	166.80	1 Plum	12	0.67	384.12	256.08	422.88
Surface Air Cooler Inside Total:			9888.36			5.13		3516.03	13404.39
Surface Air Cooler Outside (PVC)									
4" PVC Pipe Schd 80	20	5.00	100.00	Q1	46	0.43	665.27	289.25	389.25
6" PVC Pipe Schd 80	60	7.90	474.00	Q1	38	1.58	665.27	1050.42	1524.42
4" 90 Elbow - PVC - Schd 80 - Socket	2	9.69	19.38	Q1	16.5	0.12	665.27	80.64	100.02
6" 90 Elbow - PVC - Schd 80 - Socket	2	27.53	55.06	Q1	10.1	0.20	665.27	131.74	186.80
6" 45 Elbow - PVC - Schd 80 - Socket	2	33.10	66.20	Q1	10.1	0.20	665.27	131.74	197.94
6" x 6" x 4" Tee - PVC - Schd 80 - Socket	2	48.74	97.48	Q1	6.7	0.30	665.27	198.59	296.07
8" Tee - PVC - Schd 80 - Socket	1	116.81	116.81	Q2	6.2	0.16	946.41	152.65	269.46
6" x 8" Reducer - PVC - Schd - Socket	3	44.51	133.53	Q2	10.2	0.29	946.41	278.36	411.89
Surface Air Cooler Outside Total:			962.46			2.85		2024.12	2986.58

Item	Quantity (ea. ft.)	Unit Cost ($/ea.)	Material Cost ($)	Crew Type	Crew Capacity (/day)	Install Time (days)	Crew Cost ($/day)	Labor Cost ($)	Total Cost ($)
Emergency Supply (PVC)									
6" PVC Pipe Schd 80	40	7.90	316.00	Q1	38	1.05	665.27	700.28	1016.28
6" 90 Elbow - PVC - Schd 80 - Socket	3	27.53	82.59	Q1	10.1	0.30	665.27	197.60	280.19
3" x 6" Reducer - PVC - Schd 80 - Socket	1	18.30	18.30	Q1	11.1	0.09	665.27	59.93	78.23
6" Butterfly Valve - Chemline	1	362.00	362.00	Q2	5	0.20	946.41	189.28	551.28
6" Vanstone Flange - PVC - Socket	2	22.87	45.74	Q1	18.5	0.11	665.27	71.92	117.66
3" Flange - PVC - Schd 80 - Socket	1	11.49	11.49	Q1	60.6	0.02	665.27	10.98	22.47
Emergency Supply Total:			836.12			1.76		1230.00	2066.12
Pump and Strainer Piping (PVC)									
8" PVC Pipe Schd 80	20	12.06	241.20	Q2	47	0.43	946.41	402.73	643.93
8" 90 Elbow - PVC - Schd 80 - Socket	7	75.90	531.30	Q2	9.3	0.75	946.41	712.35	1243.65
8" Tee - PVC - Schd 80 - Socket	2	116.81	233.62	Q2	6.2	0.32	946.41	305.29	538.91
8" x 8" x 6" Tee - PVC - Schd 80 - Socket	1	116.81	116.81	Q2	6.2	0.16	946.41	152.65	269.46
8" x 10" Reducer - PVC - Schd 80 - Socket	2	139.40	278.80	Q2	10.1	0.20	946.41	187.41	466.21
8" Flange - PVC - Socket - 150	14	40.91	572.74	Q2	17.1	0.82	946.41	774.84	1347.58
10" Flange - PVC - Socket - 150	2	328.79	657.58	Q2	14	0.14	946.41	135.20	792.78
8" Butterfly Valve - Steel/Rubber Lined	5	390.04	1950.20	Q2	4.5	1.11	946.41	1051.57	3001.77
8" Check Valve - Chemline - Wafer	1	1174.87	1174.87	Q2	2.5	0.40	946.41	378.56	1553.43
Pump and Strainer Piping Total:			5757.12			4.33		4100.60	9857.72
Subtotal:			17444			14		10871	28315
15% Contingency:			2617			2		1631	4247
Piping Cost (Corrosion Resistant):			**20061**			**16**		**12501**	**32562**

Additional Piping Required for Closed Loop System

Item	Quantity (ea. ft.)	Unit Cost ($/ea.)	Material Cost ($)	Crew Type	Crew Capacity (/day)	Install Time (days)	Crew Cost ($/day)	Labor Cost ($)	Total Cost ($)
Additional Piping for Closed Loop (PVC)									
4" PVC Pipe Schd 80	10	5.00	50.00	Q1	46	0.22	665.27	144.62	194.62
6" PVC Pipe Schd 80	10	7.90	79.00	Q1	38	0.26	665.27	175.07	254.07
8" PVC Pipe Schd 80	40	12.06	482.40	Q2	47	0.85	946.41	805.46	1287.86
6" 90 Elbow - PVC - Schd 80 - Socket	2	27.53	55.06	Q1	10.1	0.20	665.27	131.74	186.80
8" 90 Elbow - PVC - Schd 80 - Socket	12	75.90	910.80	Q2	9.3	1.29	946.41	1221.17	2131.97
6" x 8" Reducer - PVC - Schd - Socket	2	44.51	89.02	Q2	10.2	0.20	946.41	185.57	274.59
8" Flange - PVC - Socket - 150	16	40.91	654.56	Q2	17.1	0.94	946.41	885.53	1540.09
8" Check Valve - IPEX SC - Wafer	1	1174.87	1174.87	Q2	2.5	0.40	946.41	378.56	1553.43
8" Butterfly Valve - Steel/Rubber Lined	6	390.04	2340.24	Q2	4.5	1.33	946.41	1261.88	3602.12
8" x 8" x 6" Tee - PVC - Schd 80 - Socket	2	116.81	233.62	Q2	6.2	0.32	946.41	305.29	538.91
Subtotal:			5941			6		5175	11116
15% Contingency:			891			1		776	1667
Total Estimated Piping Cost:			**6832**			**6**		**5951**	**12783**

Appendix G: Net Present Worth Analysis

Net Present Worth Analysis

Case Details

Option Name:	Operate As Current
Annual Escalation:	2.0%
Annual Discount Rate:	8.5%

Capital Costs:

Piping - Carbon Steel:	$ (33,476.22)

Piping Replacement:

Replacement Freq. (yr):	25
Replacement Cost:	$ (33,476.22)

Operating Costs:

Pump:

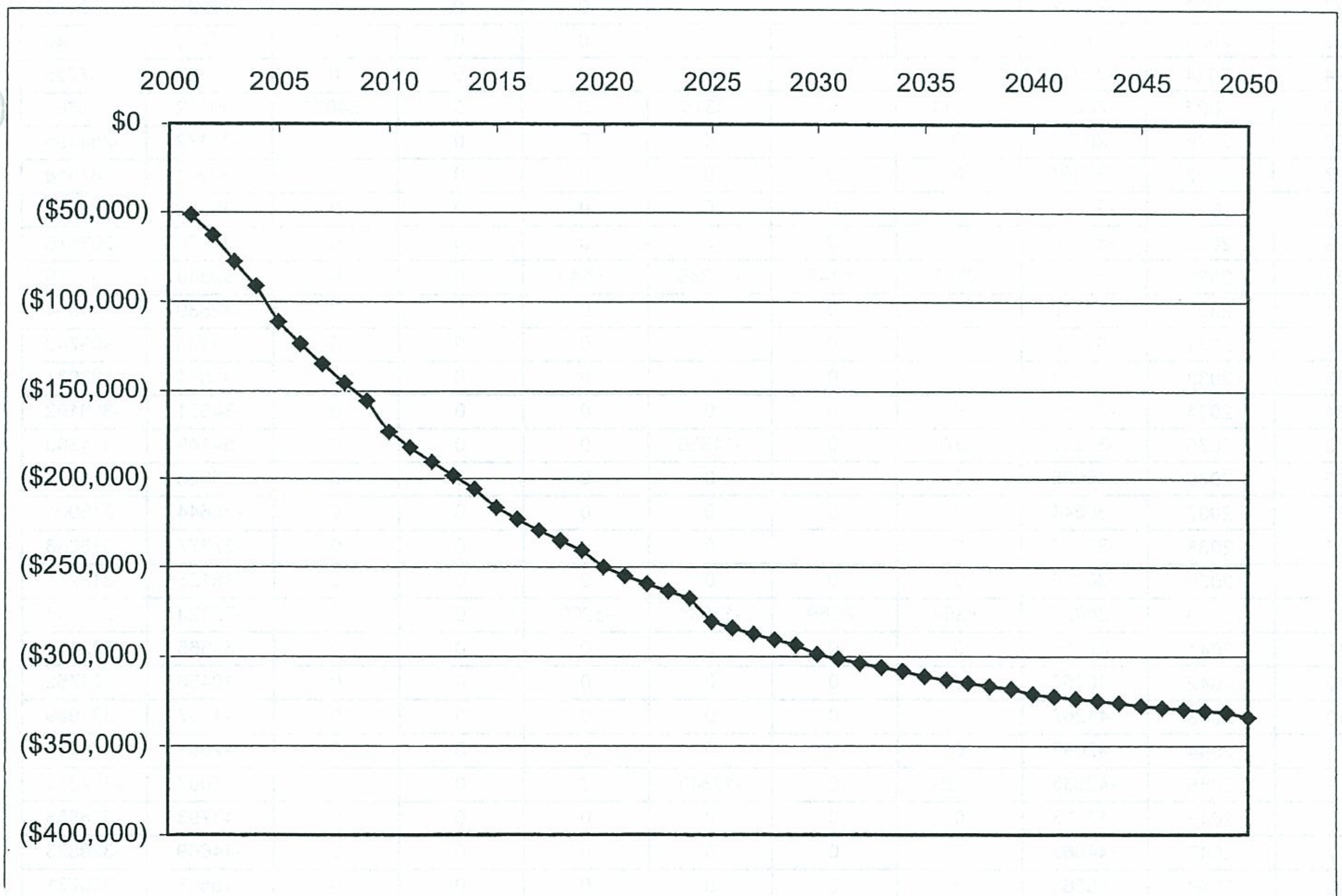
Pump Rating (hp):	55
Pump Rating (kW):	41.01
Electrical Cost ($/kWh):	0.05
Yearly Pump Cost:	$ (17,963.91)

System Maintenance Costs:

SAC Frequency (yr):	5
SAC Cost:	$ (3,785.64)
SAC Pipe Freq. (yr):	10
SAC Pipe Cost:	$ (2,839.23)
Gen. Brg Freq. (yr)	5
Gen. Brg. Cost:	$ (5,678.46)
Gen. Brg. Pipe Freq.:	10
Gen. Brg. Pipe Cost:	$ (2,839.23)

Additional Operating Costs:

None:	$ -



Net Present Worth: **($334,343)**

NPW Data Table for the Option: Operate As Current

No.	Year	Pump	SAC	SAC Pipe	Gen Brg.	Gen Pipe	Additional	Capital	Cash Flow	NPW
1	2001	-17964	0	0	0	0	0	-33476	-51440	-51440
2	2002	-18323	0	0	0	0	0	0	-18323	-62975
3	2003	-18690	0	0	0	0	0	0	-18690	-77607
4	2004	-19063	0	0	0	0	0	0	-19063	-91363
5	2005	-19445	-4180	0	-6269	0	0	0	-29894	-111244
6	2006	-19834	0	0	0	0	0	0	-19834	-123401
7	2007	-20230	0	0	0	0	0	0	-20230	-134829
8	2008	-20635	0	0	0	0	0	0	-20635	-145573
9	2009	-21048	0	0	0	0	0	0	-21048	-155674
10	2010	-21469	-4615	-3461	-6922	-3461	0	0	-39927	-173333
11	2011	-21898	0	0	0	0	0	0	-21898	-182259
12	2012	-22336	0	0	0	0	0	0	-22336	-190651
13	2013	-22783	0	0	0	0	0	0	-22783	-198540
14	2014	-23238	0	0	0	0	0	0	-23238	-205956
15	2015	-23703	-5095	0	-7642	0	0	0	-36440	-216675
16	2016	-24177	0	0	0	0	0	0	-24177	-223229
17	2017	-24661	0	0	0	0	0	0	-24661	-229391
18	2018	-25154	0	0	0	0	0	0	-25154	-235183
19	2019	-25657	0	0	0	0	0	0	-25657	-240629
20	2020	-26170	-5625	-4219	-8438	-4219	0	0	-48671	-250149
21	2021	-26693	0	0	0	0	0	0	-26693	-254962
22	2022	-27227	0	0	0	0	0	0	-27227	-259486
23	2023	-27772	0	0	0	0	0	0	-27772	-263740
24	2024	-28327	0	0	0	0	0	0	-28327	-267738
25	2025	-28894	-6211	0	-9316	0	0	-54921	-99342	-280662
26	2026	-29472	0	0	0	0	0	0	-29472	-284195
27	2027	-30061	0	0	0	0	0	0	-30061	-287518
28	2028	-30662	0	0	0	0	0	0	-30662	-290641
29	2029	-31276	0	0	0	0	0	0	-31276	-293576
30	2030	-31901	-6857	-5143	-10286	-5143	0	0	-59330	-298710
31	2031	-32539	0	0	0	0	0	0	-32539	-301304
32	2032	-33190	0	0	0	0	0	0	-33190	-303743
33	2033	-33854	0	0	0	0	0	0	-33854	-306037
34	2034	-34531	0	0	0	0	0	0	-34531	-308192
35	2035	-35221	-7571	0	-11356	0	0	0	-54149	-311308
36	2036	-35926	0	0	0	0	0	0	-35926	-313213
37	2037	-36644	0	0	0	0	0	0	-36644	-315004
38	2038	-37377	0	0	0	0	0	0	-37377	-316688
39	2039	-38125	0	0	0	0	0	0	-38125	-318271
40	2040	-38887	-8359	-6269	-12538	-6269	0	0	-72323	-321038
41	2041	-39665	0	0	0	0	0	0	-39665	-322437
42	2042	-40458	0	0	0	0	0	0	-40458	-323752
43	2043	-41267	0	0	0	0	0	0	-41267	-324989
44	2044	-42093	0	0	0	0	0	0	-42093	-326151
45	2045	-42935	-9229	0	-13843	0	0	0	-66007	-327831
46	2046	-43793	0	0	0	0	0	0	-43793	-328858
47	2047	-44669	0	0	0	0	0	0	-44669	-329823
48	2048	-45563	0	0	0	0	0	0	-45563	-330731
49	2049	-46474	0	0	0	0	0	0	-46474	-331585
50	2050	-47403	-10189	0	-15284	0	0	-90104	-162981	-334343

Net Present Worth Analysis

Case Details

Option Name:	Chemical Injection	
Annual Escalation:	2.0%	
Annual Discount Rate:	8.5%	

Capital Costs:

Piping - Carbon Steel	$	(33,476.22)
Injection Facility	$	(5,000.00)
Total:	$	(38,476.22)

Piping Replacement:

Replacement Freq. (yr):		100
Replacement Cost:	$	-

Operating Costs:

Pump:

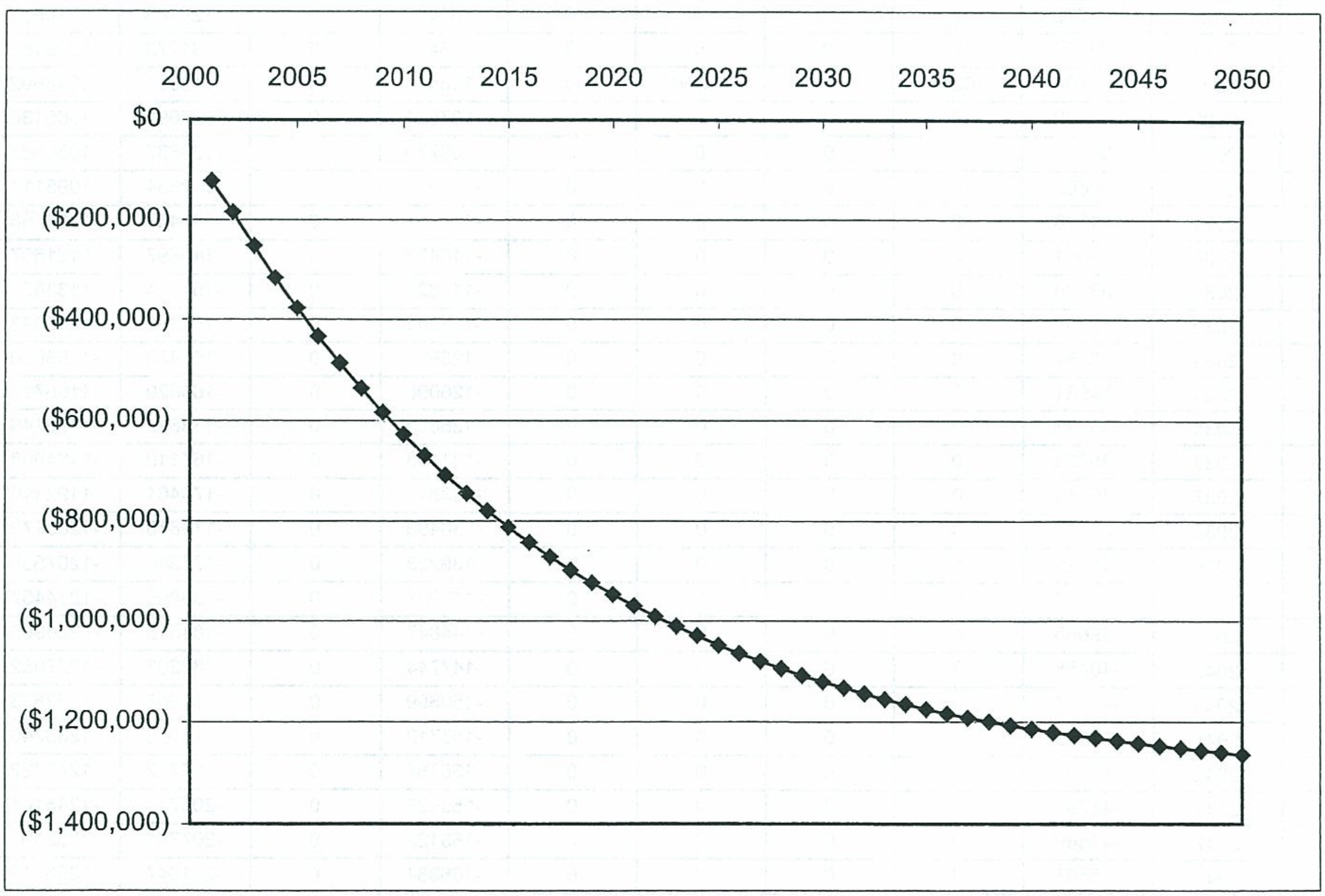
Pump Rating (hp):		55
Pump Rating (kW):		41.01
Electrical Cost ($/kWh):		0.05
Yearly Pump Cost:	$	(17,963.91)

System Maintenance Costs:

SAC Frequency (yr):		25
SAC Cost:	$	(3,785.64)
SAC Pipe Freq. (yr):		50
SAC Pipe Cost:	$	(2,839.23)
Gen. Brg Freq. (yr)		25
Gen. Brg. Cost:	$	(5,678.46)
Gen. Brg. Pipe Freq.:		50
Gen. Brg. Pipe Cost:	$	(2,839.23)

Additional Operating Costs:

Chemical Costs:	$	(65,600.00)



Net Present Worth: **($1,265,207)**

NPW Data Table for the Option: Chemical Injection

No.	Year	Pump	SAC	SAC Pipe	Gen Brg.	Gen Pipe	Additional	Capital	Cash Flow	NPW
1	2001	-17964	0	0	0	0	-65600	-38476	-122040	-122040
2	2002	-18323	0	0	0	0	-66912	0	-85235	-184883
3	2003	-18690	0	0	0	0	-68250	0	-86940	-252949
4	2004	-19063	0	0	0	0	-69615	0	-88679	-316937
5	2005	-19445	0	0	0	0	-71008	0	-90452	-377092
6	2006	-19834	0	0	0	0	-72428	0	-92261	-433643
7	2007	-20230	0	0	0	0	-73876	0	-94107	-486806
8	2008	-20635	0	0	0	0	-75354	0	-95989	-536785
9	2009	-21048	0	0	0	0	-76861	0	-97908	-583769
10	2010	-21469	0	0	0	0	-78398	0	-99867	-627938
11	2011	-21898	0	0	0	0	-79966	0	-101864	-669462
12	2012	-22336	0	0	0	0	-81565	0	-103901	-708498
13	2013	-22783	0	0	0	0	-83197	0	-105979	-745195
14	2014	-23238	0	0	0	0	-84861	0	-108099	-779694
15	2015	-23703	0	0	0	0	-86558	0	-110261	-812126
16	2016	-24177	0	0	0	0	-88289	0	-112466	-842615
17	2017	-24661	0	0	0	0	-90055	0	-114715	-871278
18	2018	-25154	0	0	0	0	-91856	0	-117010	-898223
19	2019	-25657	0	0	0	0	-93693	0	-119350	-923555
20	2020	-26170	0	0	0	0	-95567	0	-121737	-947368
21	2021	-26693	0	0	0	0	-97478	0	-124172	-969755
22	2022	-27227	0	0	0	0	-99428	0	-126655	-990801
23	2023	-27772	0	0	0	0	-101416	0	-129188	-1010586
24	2024	-28327	0	0	0	0	-103445	0	-131772	-1029186
25	2025	-28894	-6211	0	-9316	0	-105513	0	-149934	-1048692
26	2026	-29472	0	0	0	0	-107624	0	-137095	-1065130
27	2027	-30061	0	0	0	0	-109776	0	-139837	-1080583
28	2028	-30662	0	0	0	0	-111972	0	-142634	-1095111
29	2029	-31276	0	0	0	0	-114211	0	-145487	-1108768
30	2030	-31901	0	0	0	0	-116495	0	-148397	-1121607
31	2031	-32539	0	0	0	0	-118825	0	-151364	-1133677
32	2032	-33190	0	0	0	0	-121202	0	-154392	-1145023
33	2033	-33854	0	0	0	0	-123626	0	-157480	-1155690
34	2034	-34531	0	0	0	0	-126098	0	-160629	-1165718
35	2035	-35221	0	0	0	0	-128620	0	-163842	-1175146
36	2036	-35926	0	0	0	0	-131193	0	-167119	-1184008
37	2037	-36644	0	0	0	0	-133817	0	-170461	-1192340
38	2038	-37377	0	0	0	0	-136493	0	-173870	-1200172
39	2039	-38125	0	0	0	0	-139223	0	-177348	-1207535
40	2040	-38887	0	0	0	0	-142007	0	-180895	-1214457
41	2041	-39665	0	0	0	0	-144847	0	-184512	-1220965
42	2042	-40458	0	0	0	0	-147744	0	-188203	-1227082
43	2043	-41267	0	0	0	0	-150699	0	-191967	-1232833
44	2044	-42093	0	0	0	0	-153713	0	-195806	-1238240
45	2045	-42935	0	0	0	0	-156787	0	-199722	-1243322
46	2046	-43793	0	0	0	0	-159923	0	-203717	-1248101
47	2047	-44669	0	0	0	0	-163122	0	-207791	-1252592
48	2048	-45563	0	0	0	0	-166384	0	-211947	-1256815
49	2049	-46474	0	0	0	0	-169712	0	-216186	-1260785
50	2050	-47403	-10189	-7642	-15284	-7642	-173106	0	-261267	-1265207

Net Present Worth Analysis

Case Details

Option Name:	Corrosion Resistant
Annual Escalation:	2.0%
Annual Discount Rate:	8.5%

Capital Costs:

Piping - Non Corrosive:	$ (32,562.03)

Piping Replacement:

Replacement Freq. (yr):	100
Replacement Cost:	$ -

Operating Costs:

Pump:

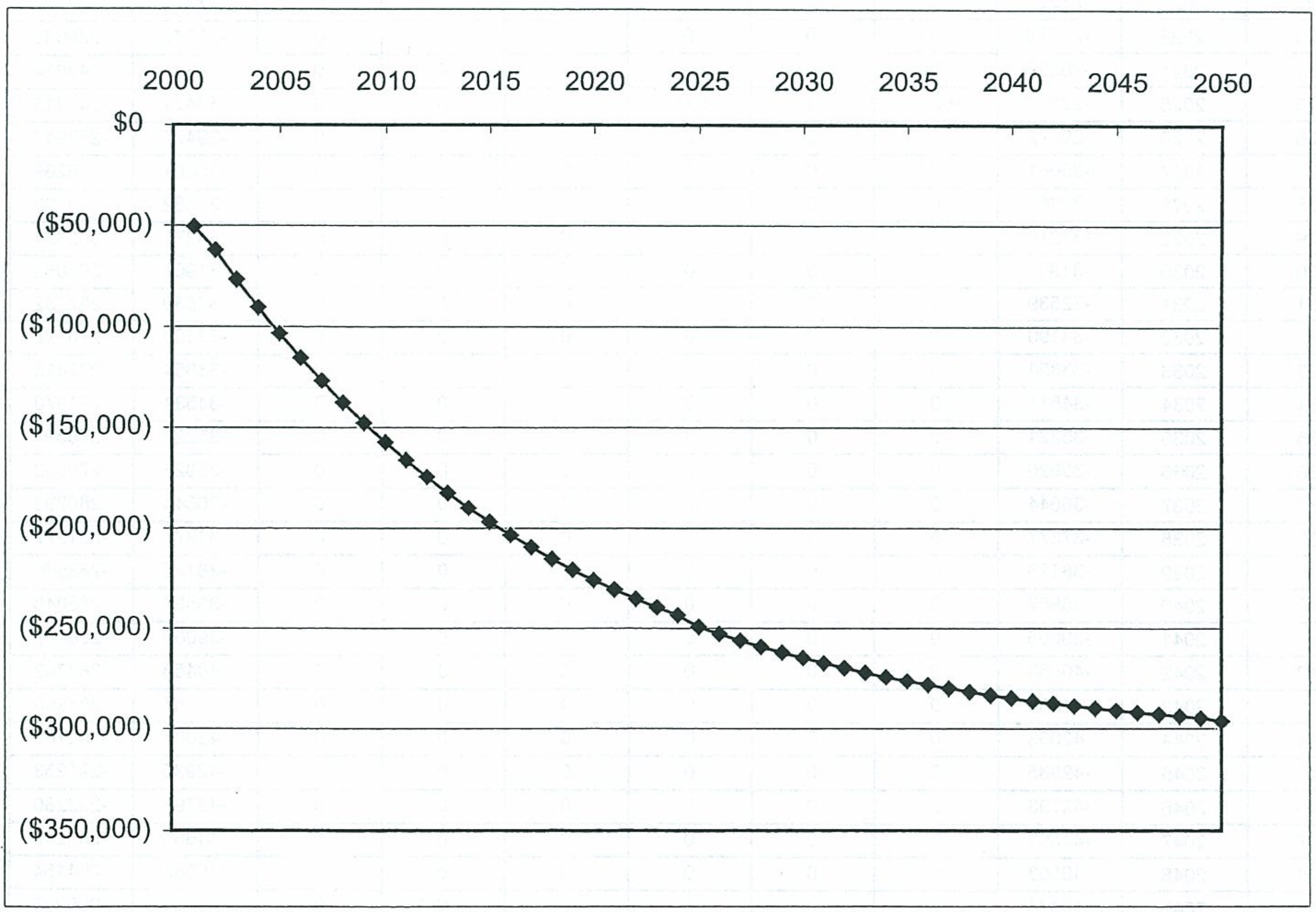
Pump Rating (hp):	55
Pump Rating (kW):	41.01
Electrical Cost ($/kWh):	0.05
Yearly Pump Cost:	$ (17,963.91)

System Maintenance Costs:

SAC Frequency (yr):	25
SAC Cost:	$ (3,785.64)
SAC Pipe Freq. (yr):	50
SAC Pipe Cost:	$ (2,839.23)
Gen. Brg Freq. (yr)	25
Gen. Brg. Cost:	$ (5,678.46)
Gen. Brg. Pipe Freq.:	50
Gen. Brg. Pipe Cost:	$ (2,839.23)

Additional Operating Costs:

None:	$ -



Net Present Worth: **($296,499)**

NPW Data Table for the Option: Corrosion Resistant

No.	Year	Pump	SAC	SAC Pipe	Gen Brg.	Gen Pipe	Additional	Capital	Cash Flow	NPW
1	2001	-17964	0	0	0	0	0	-32562	-50526	-50526
2	2002	-18323	0	0	0	0	0	0	-18323	-62132
3	2003	-18690	0	0	0	0	0	0	-18690	-76765
4	2004	-19063	0	0	0	0	0	0	-19063	-90520
5	2005	-19445	0	0	0	0	0	0	-19445	-103452
6	2006	-19834	0	0	0	0	0	0	-19834	-115609
7	2007	-20230	0	0	0	0	0	0	-20230	-127038
8	2008	-20635	0	0	0	0	0	0	-20635	-137781
9	2009	-21048	0	0	0	0	0	0	-21048	-147882
10	2010	-21469	0	0	0	0	0	0	-21469	-157377
11	2011	-21898	0	0	0	0	0	0	-21898	-166303
12	2012	-22336	0	0	0	0	0	0	-22336	-174695
13	2013	-22783	0	0	0	0	0	0	-22783	-182584
14	2014	-23238	0	0	0	0	0	0	-23238	-190000
15	2015	-23703	0	0	0	0	0	0	-23703	-196972
16	2016	-24177	0	0	0	0	0	0	-24177	-203527
17	2017	-24661	0	0	0	0	0	0	-24661	-209688
18	2018	-25154	0	0	0	0	0	0	-25154	-215481
19	2019	-25657	0	0	0	0	0	0	-25657	-220926
20	2020	-26170	0	0	0	0	0	0	-26170	-226046
21	2021	-26693	0	0	0	0	0	0	-26693	-230858
22	2022	-27227	0	0	0	0	0	0	-27227	-235382
23	2023	-27772	0	0	0	0	0	0	-27772	-239636
24	2024	-28327	0	0	0	0	0	0	-28327	-243634
25	2025	-28894	-6211	0	-9316	0	0	0	-44421	-249413
26	2026	-29472	0	0	0	0	0	0	-29472	-252947
27	2027	-30061	0	0	0	0	0	0	-30061	-256269
28	2028	-30662	0	0	0	0	0	0	-30662	-259392
29	2029	-31276	0	0	0	0	0	0	-31276	-262328
30	2030	-31901	0	0	0	0	0	0	-31901	-265088
31	2031	-32539	0	0	0	0	0	0	-32539	-267682
32	2032	-33190	0	0	0	0	0	0	-33190	-270122
33	2033	-33854	0	0	0	0	0	0	-33854	-272415
34	2034	-34531	0	0	0	0	0	0	-34531	-274570
35	2035	-35221	0	0	0	0	0	0	-35221	-276597
36	2036	-35926	0	0	0	0	0	0	-35926	-278502
37	2037	-36644	0	0	0	0	0	0	-36644	-280293
38	2038	-37377	0	0	0	0	0	0	-37377	-281977
39	2039	-38125	0	0	0	0	0	0	-38125	-283560
40	2040	-38887	0	0	0	0	0	0	-38887	-285048
41	2041	-39665	0	0	0	0	0	0	-39665	-286447
42	2042	-40458	0	0	0	0	0	0	-40458	-287762
43	2043	-41267	0	0	0	0	0	0	-41267	-288998
44	2044	-42093	0	0	0	0	0	0	-42093	-290160
45	2045	-42935	0	0	0	0	0	0	-42935	-291253
46	2046	-43793	0	0	0	0	0	0	-43793	-292280
47	2047	-44669	0	0	0	0	0	0	-44669	-293246
48	2048	-45563	0	0	0	0	0	0	-45563	-294154
49	2049	-46474	0	0	0	0	0	0	-46474	-295007
50	2050	-47403	-10189	-7642	-15284	-7642	0	0	-88161	-296499

Net Present Worth Analysis

Case Details

Option Name:	Closed Loop
Annual Escalation:	2.0%
Annual Discount Rate:	8.5%

Capital Costs:

Piping - Carbon Steel	$	(33,476.22)
Additional Piping Loop	$	(12,783.14)
Pump & Heat Exchanger	$	(35,000.00)
Total:	$	(81,259.36)

Piping Replacement:

Replacement Freq. (yr):		100
Replacement Cost:	$	-

Operating Costs:

Pump:

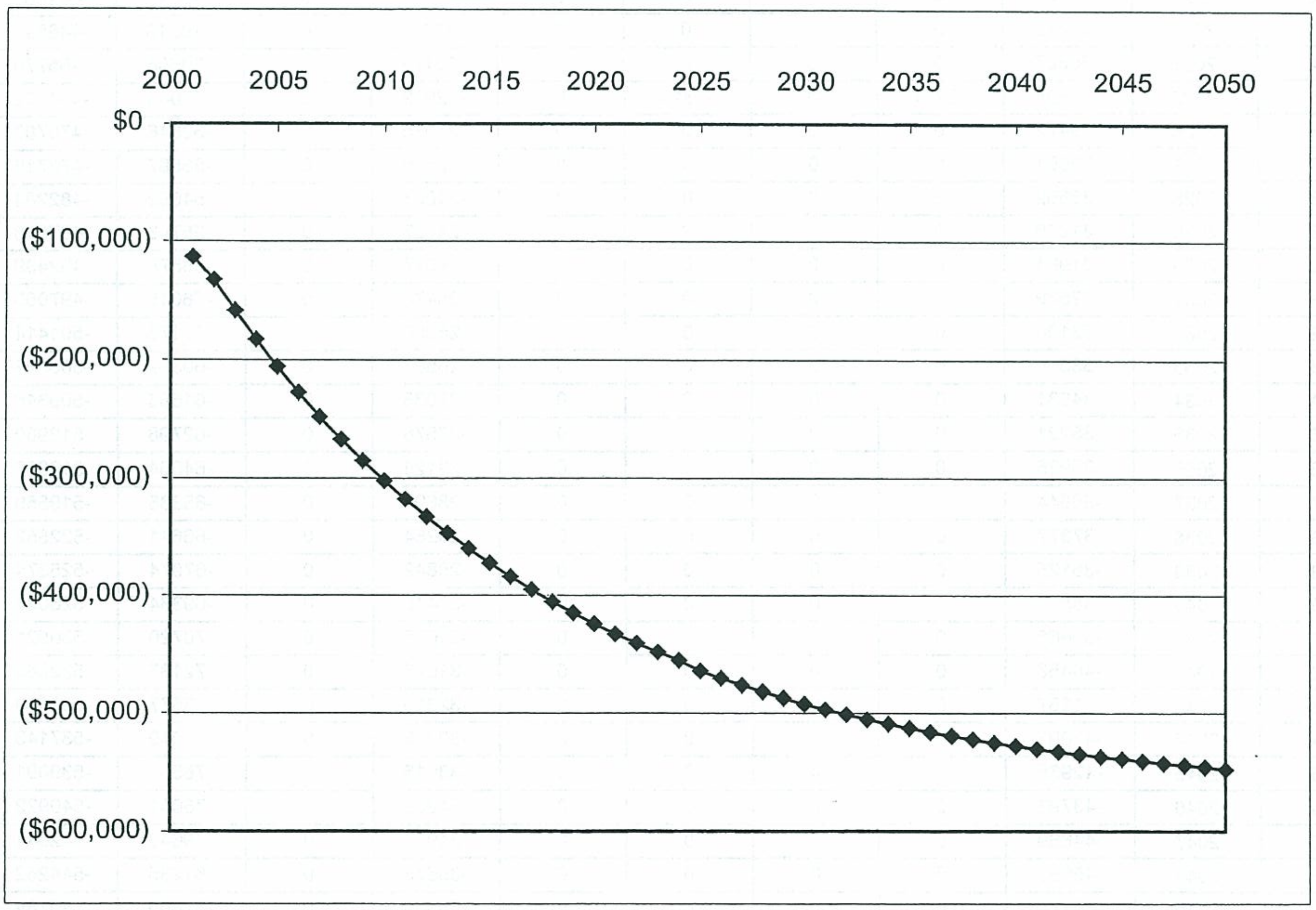
Pump Rating (hp):		55
Pump Rating (kW):		41.01
Electrical Cost ($/kWh):		0.05
Yearly Pump Cost:	$	(17,963.91)

System Maintenance Costs:

SAC Frequency (yr):		25
SAC Cost:	$	(3,785.64)
SAC Pipe Freq. (yr):		50
SAC Pipe Cost:	$	(2,839.23)
Gen. Brg Freq. (yr)		25
Gen. Brg. Cost:	$	(5,678.46)
Gen. Brg. Pipe Freq.:		50
Gen. Brg. Pipe Cost:	$	(2,839.23)

Additional Operating Costs:

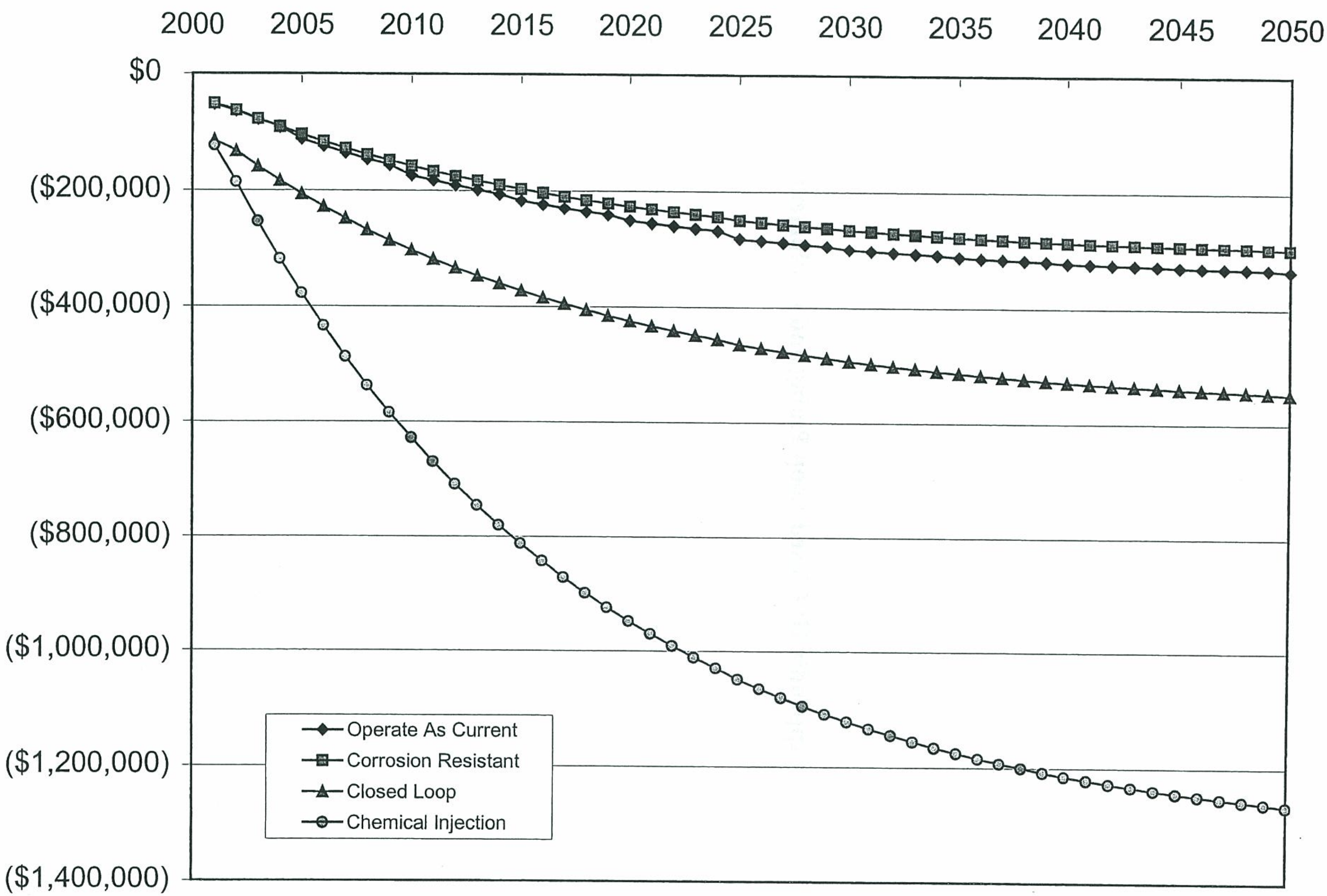
Heat Exchanger Maintenance	$	(1,000.00)
Re-circulating Pump	$	(13,064.66)
Total :	$	(14,064.66)



Net Present Worth: **($547,904)**

NPW Data Table for the Option: Closed Loop

No.	Year	Pump	SAC	SAC Pipe	Gen Brg.	Gen Pipe	Additional	Capital	Cash Flow	NPW
1	2001	-17964	0	0	0	0	-14065	-81259	-113288	-113288
2	2002	-18323	0	0	0	0	-14346	0	-32669	-132164
3	2003	-18690	0	0	0	0	-14633	0	-33323	-158252
4	2004	-19063	0	0	0	0	-14926	0	-33989	-182778
5	2005	-19445	0	0	0	0	-15224	0	-34669	-205834
6	2006	-19834	0	0	0	0	-15529	0	-35362	-227509
7	2007	-20230	0	0	0	0	-15839	0	-36069	-247886
8	2008	-20635	0	0	0	0	-16156	0	-36791	-267042
9	2009	-21048	0	0	0	0	-16479	0	-37527	-285050
10	2010	-21469	0	0	0	0	-16809	0	-38277	-301979
11	2011	-21898	0	0	0	0	-17145	0	-39043	-317894
12	2012	-22336	0	0	0	0	-17488	0	-39824	-332856
13	2013	-22783	0	0	0	0	-17837	0	-40620	-346922
14	2014	-23238	0	0	0	0	-18194	0	-41432	-360144
15	2015	-23703	0	0	0	0	-18558	0	-42261	-372575
16	2016	-24177	0	0	0	0	-18929	0	-43106	-384261
17	2017	-24661	0	0	0	0	-19308	0	-43968	-395247
18	2018	-25154	0	0	0	0	-19694	0	-44848	-405575
19	2019	-25657	0	0	0	0	-20088	0	-45745	-415284
20	2020	-26170	0	0	0	0	-20490	0	-46660	-424411
21	2021	-26693	0	0	0	0	-20899	0	-47593	-432992
22	2022	-27227	0	0	0	0	-21317	0	-48545	-441058
23	2023	-27772	0	0	0	0	-21744	0	-49516	-448641
24	2024	-28327	0	0	0	0	-22179	0	-50506	-455770
25	2025	-28894	-6211	0	-9316	0	-22622	0	-67043	-464492
26	2026	-29472	0	0	0	0	-23075	0	-52546	-470793
27	2027	-30061	0	0	0	0	-23536	0	-53597	-476716
28	2028	-30662	0	0	0	0	-24007	0	-54669	-482284
29	2029	-31276	0	0	0	0	-24487	0	-55763	-487518
30	2030	-31901	0	0	0	0	-24977	0	-56878	-492439
31	2031	-32539	0	0	0	0	-25476	0	-58015	-497065
32	2032	-33190	0	0	0	0	-25986	0	-59176	-501414
33	2033	-33854	0	0	0	0	-26505	0	-60359	-505503
34	2034	-34531	0	0	0	0	-27036	0	-61566	-509346
35	2035	-35221	0	0	0	0	-27576	0	-62798	-512960
36	2036	-35926	0	0	0	0	-28128	0	-64054	-516357
37	2037	-36644	0	0	0	0	-28690	0	-65335	-519550
38	2038	-37377	0	0	0	0	-29264	0	-66641	-522552
39	2039	-38125	0	0	0	0	-29849	0	-67974	-525374
40	2040	-38887	0	0	0	0	-30446	0	-69334	-528027
41	2041	-39665	0	0	0	0	-31055	0	-70720	-530521
42	2042	-40458	0	0	0	0	-31676	0	-72135	-532866
43	2043	-41267	0	0	0	0	-32310	0	-73577	-535070
44	2044	-42093	0	0	0	0	-32956	0	-75049	-537143
45	2045	-42935	0	0	0	0	-33615	0	-76550	-539091
46	2046	-43793	0	0	0	0	-34288	0	-78081	-540922
47	2047	-44669	0	0	0	0	-34973	0	-79643	-542644
48	2048	-45563	0	0	0	0	-35673	0	-81235	-544262
49	2049	-46474	0	0	0	0	-36386	0	-82860	-545784
50	2050	-47403	-10189	-7642	-15284	-7642	-37114	0	-125275	-547904



2000
2005
2010
2015
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($200,000)
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($800,000)
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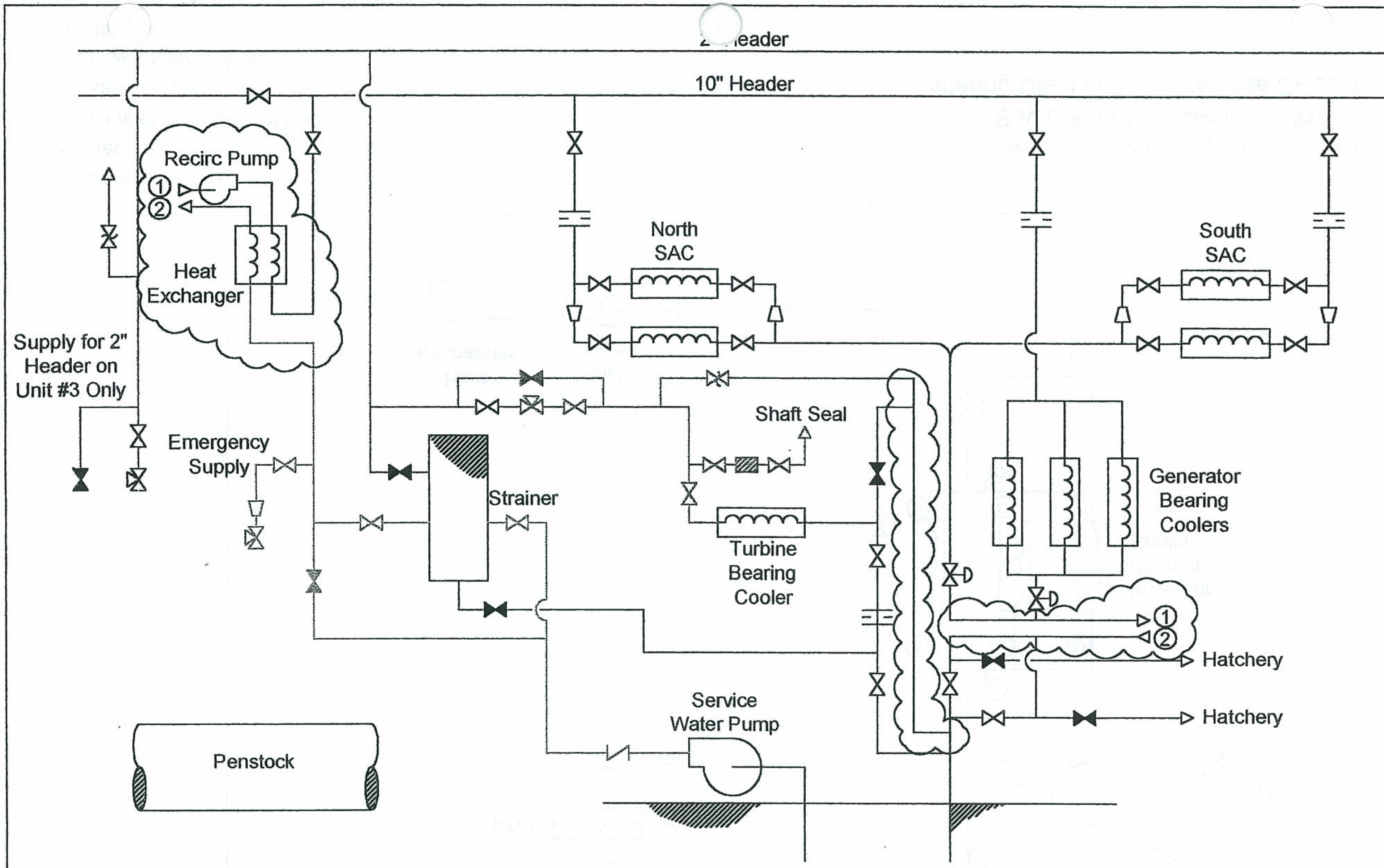
($1,200,000)
($1,400,000)
Operate As Current
Corrosion Resistant
Closed Loop
Chemical Injection

Appendix H: Closed Loop Piping and Equipment

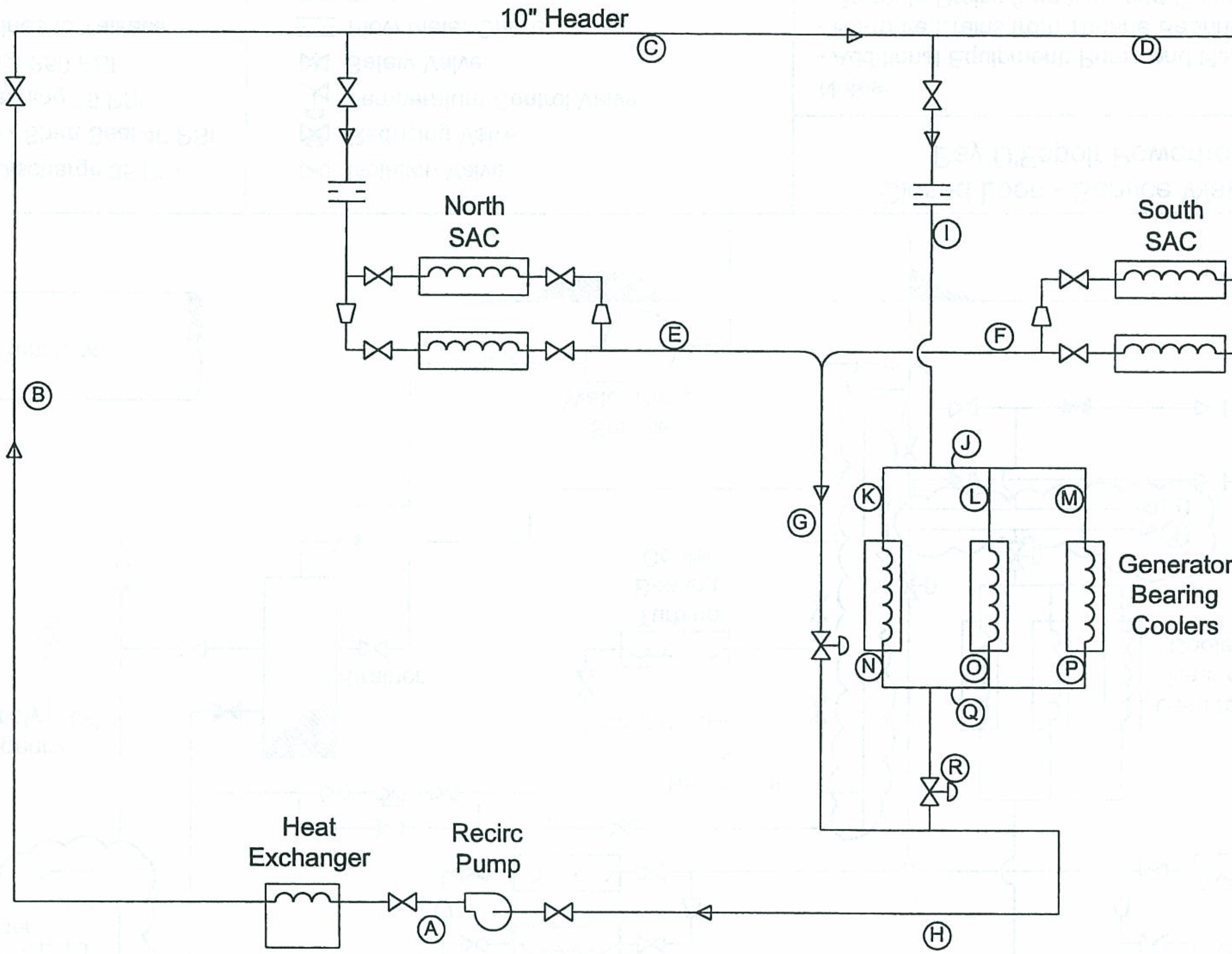


Pump Discharge 35 PSI
Turbine / Shaft Seal 40 PSI
Backwashing 75 PSI
Penstock 250 PSI
Drain Lines to Tailrace
Closed Loop

Isolation Valve
Reducing Valve
Temperature Control Valve
Safety Valve
Flow Meter Orifice
Strainer

Closed Loop - Service Water System
Bay D'Espoir Powerhouse #1

Notes:
- Additional Equipment: Pump and Heat Exchanger.
- Re-route Drains from Turbine Bearing Downstream.
- Re-route Drains from SAC and Generator Bearing.



- Isolation Valve
- Reducing Valve
- Temperature Control Valve
- Safety Valve
- Flow Meter Orifice
- St[illegible]r

Closed Loop - Service Water System
Bay D'Espoir Powerhouse #1
Lettering Used in Pressure Loss Calculation

Pump Sizing of Re-circulation Pump for BDE 1-6 Closed Loop

Flow Rate:

SAC North	691	GPM
SAC South	691	GPM
Gen Brg Cooler	108	GPM
Total	**1489**	**GPM**

Frictional Pressure Loss for each Section of Piping

Section	Flow Rate *(GPM)*	Pipe Size *(in)*	Length *(ft)*	Fittings Equivalent Length (ft)												Total Length *(ft)*	Pressure Loss *(PSI/100ft)*	Pressure Loss *(PSI)*
				Elbows		Tee St.		Tee Br.		Reducer		Valves		Other				
				Qt.	*(ft)*	*Qt.*	*(ft)*	*Qt.*	*(ft)*	*Qt.*	*(ft)*	*Qt.*	*(ft)*	*Qt.*	*(ft)*			
A	1489	8	10									1	30	1	33	73.2	1.5	1.098
B	1489	8	20	4	20							1	30			129.9	1.5	1.949
C	800	10	10			1	17	1	50			1	29			106	0.18	0.191
D	691	10	15	1	25	1	17					1	29			86	0.14	0.120
E	691	6	30	1	15	1	10			2	16					87.3	1.6	1.397
F	691	6	30	1	15	1	10			2	16					87.3	1.6	1.397
G	1381	8	10	2	20	1	13	1	40			1	30			133.1	1.5	1.997
H	1489	8	10			1	13					1	30			53.2	1.5	0.798
I	108	3	10	2	7.7			1	15	1	7	1	12			59.14	1.6	0.946
J	72	3	11	1	7.7	2	5.1									28.89	0.75	0.217
K	36	2	5	2	5.2	1	3.5			1	5					23.79	1.8	0.428
L	36	2	7	2	5.2			1	10	1	5					32.64	1.8	0.588
M	36	2	15	4	5.2	1	3.5			1	5					44.13	1.8	0.794
N	36	2	15	2	5.2					1	5					30.34	1.8	0.546
O	36	2	7	2	5.2					1	5					22.34	1.8	0.402
P	36	2	12	4	5.2					1	5					37.68	1.8	0.678
Q	72	3	5			1	5.1	1	15							25.41	0.75	0.191
R	108	3	10	4	7.7	1	5.1					1	12			57.29	1.6	0.917
Gen Brg	7.2	0.75	27.5	6	2			2	4							47.5	7	3.325

Determine Frictional Pressure Drop for Pump

Notes:

- Static Head Neglected since system is a Closed Loop
- Pressure Drop for SAC Branches quoted on drawing number 499C143DF as 23 ft
- Subtract 6 ft static pressure loss from SAC Branches = 17 ft = 7.5 PSI
- Pressure Loss for SAC Branch including Pipe: 7.5 PSI
- Typical Pressure Loss for Plate Heat Exchangers: 10 PSI
- Pressure Loss in Generator Bearing Cooler Estimated as piping branches:

Path with the Highest Frictional Pressure Drop

Path 1

Section A	1.098
Heat Exch	10
Section B	1.949
North SAC	7.5
Section E	1.397
Section G	1.997
Section H	0.798
Total	**24.74**

Path 2

Section A	1.098
Heat Exch	10
Section B	1.949
Section C	0.191
Section D	0.12
South SAC	7.5
Section F	1.397
Section G	1.997
Section H	0.798
Total	**25.05**

Path 3

Section A	1.098
Heat Exch	10
Section B	1.949
Section C	0.191
Section I	0.946
Section K	0.428
Gen Brg	3.325
Section N	0.546
Section R	0.917
Section H	0.798
Total	**20.2**

Path 4

Section A	1.098
Heat Exch	10
Section B	1.949
Section C	0.191
Section I	0.946
Section J	0.217
Section L	0.588
Gen Brg	3.325
Section O	0.402
Section Q	0.191
Section R	0.917
Section H	0.798
Total	**20.62**

Path 5

Section A	1.098
Heat Exch	10
Section B	1.949
Section C	0.191
Section I	0.946
Section J	0.217
Section M	0.794
Gen Brg	3.325
Section P	0.678
Section Q	0.191
Section R	0.917
Section H	0.798
Total	**21.1**

Maximum Frictional Pressure Drop 25 PSI
Add 20% Safety Factor for Sizing: 30 PSI

Pump Requirements

Flow Rate: 1489 GPM
Head: 69 ft

Model:3196/HT3196	Size:6X8-13	Group:	60 Hz	RPM:1780	Stages:1

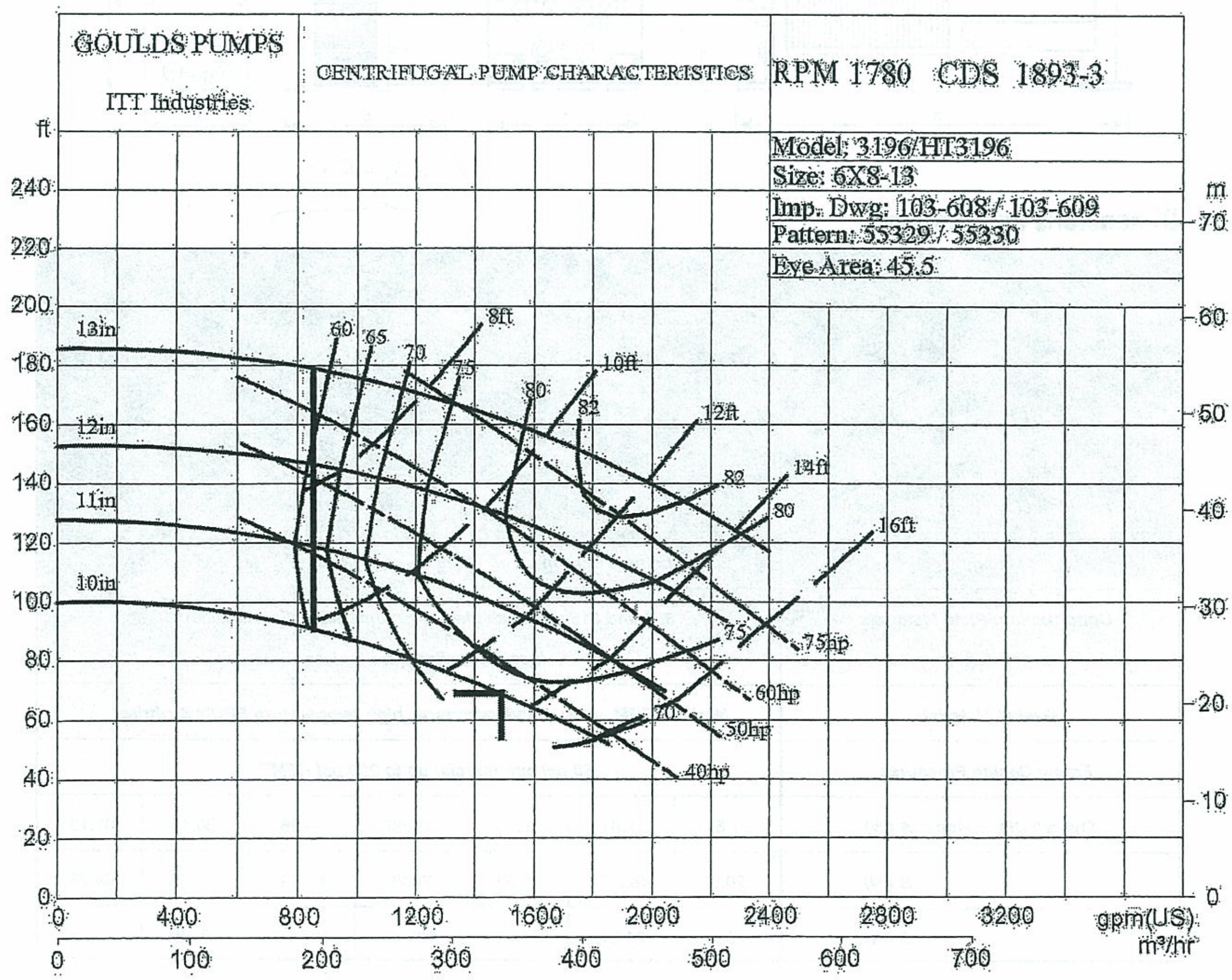
Purchaser:
User:
Item/Equip.No:
Service:

Date: 2/4/02
Certified By: ____________________

Operating Conditions				Pump Performance	
Liquid:	Water	Rated Efficiency:	74 %	Suction Specific Speed:	12153 (gpm(US) , ft)
Temp.:	70 °F	Rated Pump Power:	36.6 hp	Min. Cont. Stable Flow:	850 gpm(US)
Sp. Heat:		Mech/Dyn Seal Loss:	0 hp	Min. Cont. Thermal Flow:	
S.G./Visc.:	1	Other Power Loss:	0 hp		
Flow:	1500 gpm(US)	Rated Total Power:	36.6 hp	Non-Overloading Power:	36.7 hp
TDH:	70 ft	Impeller Dia. 1st stage:	10.125 in	Addt'l stages:	
NPSHa:		NPSHr:	13.1 ft		
		Shut off Head:	103.2 ft	Mag. Drive Circuit Flow:	
Max Dia. Solids:				Max Drive Power:	
% Solids:				Max Drive Temp:	
Vapor Press:				Max Motor Size:	

Notes: 1. Mechanical seal increased drag effect on power and efficiency is not included. 2. Magnetic drive eddy current and viscous effect on power and efficiency is not included. 3. Elevated temperature effects on performance are not included.

$10,000

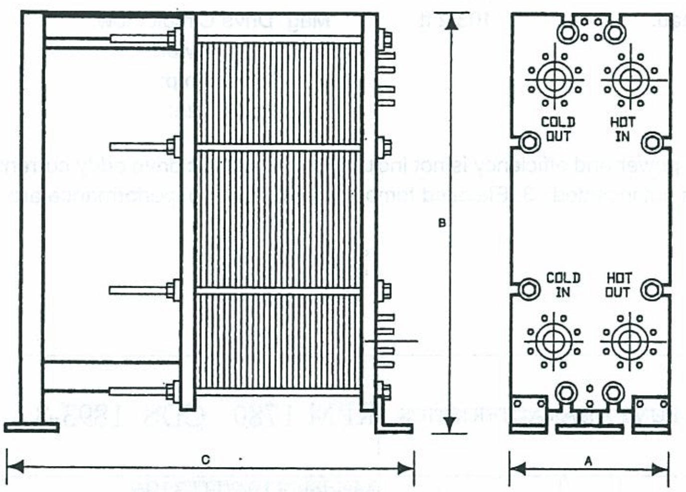


Integrity.

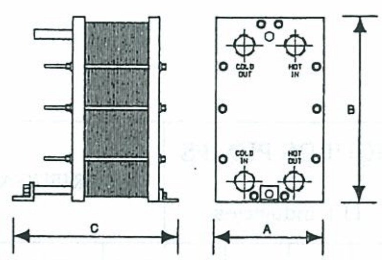
Easily incorporated.

The uncomplicated nature of the Plateflow exchanger yields connections at the same location and on the same plane for a given model. This yields simple and accurate results when laying out these heat exchangers into your system.

Models PF25-PF85



Models PF8-PF21



$ 25,000

Dimensions and Details

[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Performance: Maximum Flowrate (GPM)	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Max. Heat Transfer Area (FT²)	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Connections: NPT Nozzles—Size (IN)	[illegible]	2	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
ANSI Studded Connections—Size (IN)	[illegible]	[illegible]	4	6	6	8	[illegible]
Materials	Epoxy painted carbon steel, stainless steel, titanium, Hastelloy, rubber						
Construction: Plate Materials	304 and 316 stainless steel, titanium, SMO 254, Hastelloy, Incolloy, palladium-titanium						
Gasket Materials	Nitrile, EPDM, viton, butyl, neoprene, high temperature EPDM & nitrile						
Frame Design Pressures	50 psi commercial up to 300 psi ASME						
Overall Dimensions: A (IN)	7.5	11.81	18.13	25.59	28.38	30.13	31.13
B (IN)	20.9	32.13	38.63	76.25	81.69	64.38	89.75
C (IN)	20.1	24.81	87.81	129.40	137.50	101.81	114.96