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Newfoundland & Labrador Hydro

Hydro Plant Corrosion / Fouling Study 2002

Bay D'Espoir Generating Station Unit 7

SERVICE WATER SYSTEM

Newfoundland & Labrador Hydro

Bay D'Espoir Generating Station Powerhouse #2

Unit 7
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 Bay D'Espoir Unit 7 was performed to evaluate the fouling problem for the system and produce recommendations to improve the reliability of the system.

The first section of the study focuses on the background into the system. This includes a summary of the current state of the system, specifications of the existing equipment and an explanation of the system operations. Next, research was performed to evaluate the past work history of the system. 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 within the system.

A number of options were considered and discussed for solutions to the fouling problems within the system. 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 performed for each of the options to evaluate them over the life of the plant.

Also, the economics of converting the cooling water supply from the penstock to the tailrace was evaluated. The purpose of this is to identify cost saving from using the cooling water for generation and pumping water from the tailrace for the cooling system. This analysis involved estimating the initial capital cost of the conversion as well as the operating costs due to pumping and equipment maintenance.

There are two main recommendations from this study. It was recommended to replace the piping with corrosion resistant piping, as replacement of each section is required. Also, due to the significant saving associated with the conversion of the cooling water source it was recommended to prepare a detailed design for the conversion of the cooling water source from the penstock to the tailrace.

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Background for Service Water System

Introduction

The service water system has been in operation since construction of the plant in 1977. 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. 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. The maintenance on this system has been lower compared to units 1-6, this is due to several reasons; the plant is approximately 10 years newer, more stainless steel is used for the piping and the system has less equipment.

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.

This report also contains a review of the economics of converting the supply for the service water system from the penstock to the tailrace.

General Information

The cooling water supply is tapped off the top of the makeup piece between the pressure conduit and the spiral case. The header rises directly up through the floor at elevation 12'-2" and the supply is then teed off through two gate valves, one for the bearing supply and the other for the surface air coolers. The bearing supply is common to both turbine guide bearing and the generator guide/thrust bearing. The turbine shaft seal water supply is also provided from this same source.

Each of the two supplies, bearings and air coolers, are equipped with two stages of pressure reduction. The first stage reduces the 250 PSI penstock supply to 125 – 150 PSI, the second stage reduces the pressure to 45-50 PSI. Between each of the two stages of pressure reduction there is a duplex or twin basket filter. There is also a third pressure reduction and filter in the branch that supplies the shaft seal; there the pressure is reduced to 30 PSI. Each of the two supplies is equipped with a pressure relief valve, set to operate at 60 PSI and a rupture disc as backup that is set at 65 PSI. The following table summarizes the pressure setting throughout the system.

Location	Pressure
Penstock Supply	250 PSI
First Stage Reduction	125-150 PSI
Second Stage Reduction	45-50 PSI
Pressure Relief Valve	60 PSI
Rupture Disc	65 PSI

Table 1: System Pressure Set Points

The service water system has one main function, that is unit cooling. There are three main areas that require service water for cooling. The sketch below is a simplified flow diagram for the system that shows the basic equipment and layout of the system. A detailed version of the system flow diagram is attached in Appendix A.

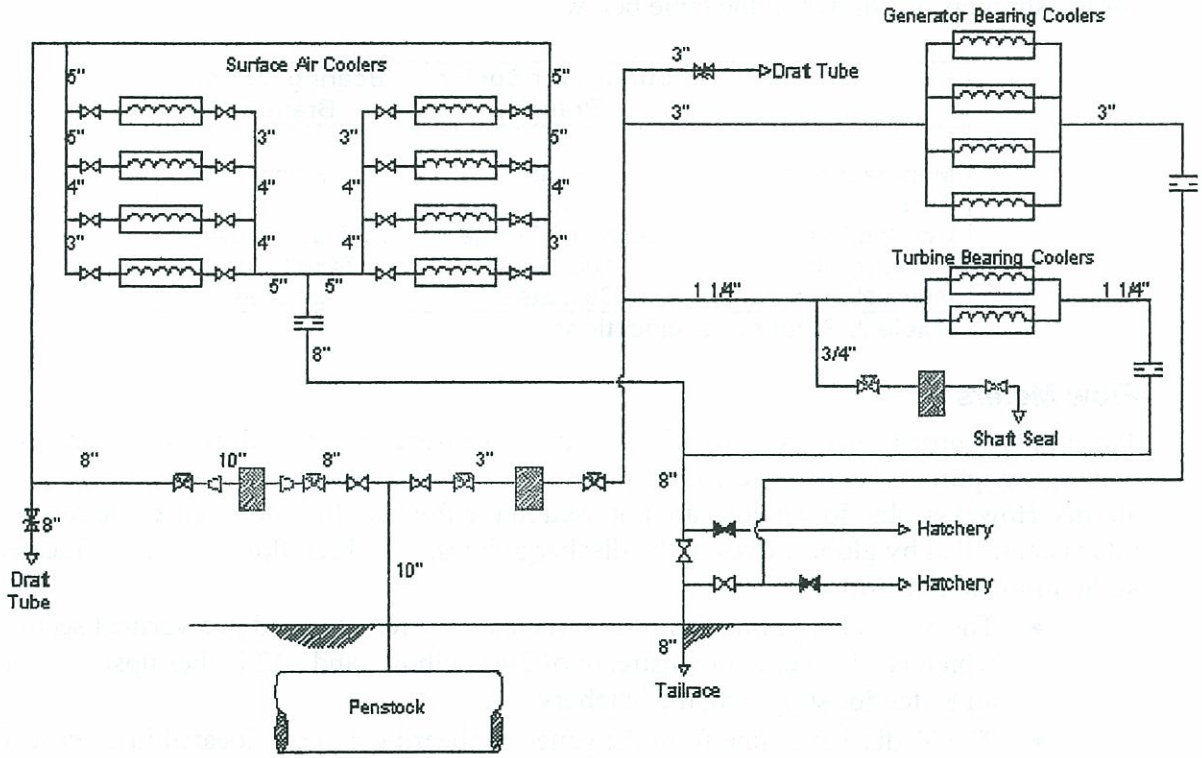


Figure 1: Unit Flow Diagram

It is important to notes that 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.

Strainers

Between the stages of pressure reduction in each branch there are strainers that remove the particles from the water before entering the system. The strainers are duplex (twin basket) models. They are equipped with a transfer valve that can direct the flow to either side of the strainer. Also, a bypass line with a "Y" type strainer is provided to allow for isolation and maintenance of the strainer without unit outage. The available specifications for the strainers are shown in the table below.

	Surface Air Cooler Branch	Bearing Cooler Branch
Manufacturer	Plenty	Plenty
Size	10"	3"
Connection	ASA 300 Flange	ASA 300 Flange
Drawing No.	10D-G-13	748030201
Material	Cast Steel	Cast Steel

Table 2: Strainer Specifications

Flow Meters

The unit has three flow meters, which function to measure the water flow to the various cooling equipment. The flow rate is used for reporting, trend monitoring and system alarms. However, the flow meters are not used in the flow control loop, rather the flow rate is controlled by globe valves in the discharge lines. The three flow meters are located at the following locations:

- The 8" discharge line from the surface air coolers, located in a vertical section which is ~12 inches downstream of 2-45^{o} elbows and ~12 inches upstream of an 8" tee for supplying the hatchery.
- The 3" discharge line from the generator bearing coolers, located in a vertical section with 3' of unobstructed flow both upstream and downstream.
- The 1-1/4" discharge line from the turbine bearing coolers, located midway in a 4' horizontal run with 90^{o} elbows located at either end.

Recently the displays for the three flow meters were changed from analog to digital. This involved the removal of the analog gauges and replacing them with pressure transducers and digital displays. The flow meter plates and orifices were not changed. The readings from the flow meters are known to be incorrect. It is believed that this is due to turbulence in the lines due to poor positioning.

Service Water System Coolers

The table below details the available specifications for each of the three types of coolers used in the system. The design of the surface air coolers has been modified to increase the tube velocity; both the original and modified cooler specifications are included.

	Surface Air Coolers Original	Surface Air Coolers Modified	Generator Bearing Coolers	Turbine Bearing Coolers
Total Flow Rate (IGPM):	1600	1600	110	35
Number of Coolers	8	8	4	2
Number of Tubes per Cooler:	156	156	36	6
Number of Passes:	2	4	6	2
Tube Outside Diameter (in):	0.75	0.75	0.875	0.625
Tube Wall Thickness (in):	0.049	0.049	0.049	0.049
Tube Inside Diameter (in):	0.652	0.652	0.777	0.527
Number Fins per Inch	9	9	7	8
Fin Outside Diameter	1-3/4	1-3/4	1-7/8	1-5/16
Hydrostatic Pressure Test	250 PSI	250 PSI	250 PSI	200 PSI
Tube Material	Arsenical Cu	90/10 Cu-Ni	90/10 Cu-Ni	Stainless Steel
Fin Material	Extruded Al	Extruded Al	Extruded Al	Aluminum

Table 3: Cooler Specifications

Surface Air Coolers

There are eight surface air coolers located around the exterior of the stator windings for cooling of the generator. These coolers have the highest flow demand for the system and are supplied by two 5" branches from the main 8" surface air cooler supply header. Fouling in these coolers will cause high temperatures for the stator. These coolers originally had a two-pass configuration, which is in the process of being changed to a four pass configuration as each cooler is re-tubed.

Generator Bearing Coolers

There are four generator bearing coolers for this unit. These coolers are located in the oil reservoir for the generator thrust / guide bearing. The four coolers are positioned around four sides of the circumference of the bearing. 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.

Turbine Bearing Coolers

There are two turbine bearing coolers for this unit. They are located in the oil reservoir of the turbine bearing. Each cooler is constructed of stainless steel tubes that are bent to form a continuous circular bank around 135° of the circumference of the bearing. These coolers have the lowest flow rate of the system.

Main Control Valves

Supply Pressure Reducing Valves

The flow is controlled by pressure reducing valves located in the main supply header. There are two 8" valves located in the surface air cooler branch and two 3" valves located in the bearing supply branch. The available details for the valves are displayed in the table below.

	SAC Supply		Bearing Supply	
	First Stage	Second Stage	First Stage	Second Stage
Drawing Ref #	ACR1	ACR2	BCR1	BCR2
Manufacturer	Singer	Singer	Singer	Singer
Model	106 PR	106 PR	106 PR	106 PR
Size	8"	8"	3"	3"
Connection	Flanged	Flanged	Flanged	Flanged
Material	Cast Iron	Cast Iron	Cast Iron	Cast Iron
Class	250 #	250 #	250 #	250 #
Inlet Pressure	250 PSI	150 PSI	250 PSI	150 PSI
Output Pressure	150 PSI	50 PSI	150 PSI	50 PSI

Table 4: Pressure Reducing Valve Specifications

Shaft Seal Pressure Reducing Valves

The supply branch for the shaft seal contains another stage of pressure reduction. The supply is taken from the 50 PSI turbine bearing supply and is reduced to 30 PSI. Originally a reducing valve functioned to moderate the downstream to 30 PSI regardless of the upstream pressure. However this valve had small internal components that caused problems due to frequent plugging. Therefore it was recently removed from service and replaced with a globe valve that is manually throttled to provide the desired downstream pressure.

Pressure Relief Valves

Two pressure relief valves are used to protect the supply header. These valves are located downstream of the reducing stations and are set to open at 60 PSI. The discharge from these valves is routed to the draft tube. Rupture discs are installed in parallel with the pressure relief valves; these act as a backup for the relief valves, they are rated to rupture at 65 PSI.

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, test sample results, trend monitoring and tube velocity calculations.

Work History

JD Edwards Search

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 as early as 1990. All the work orders were researched and they were categorized into four groups:

- Shaft Seal Supply
- Surface Air Cooler and Piping
- Generator Bearing Cooler and Piping
- Turbine Bearing Cooler and Piping

Shaft Seal Supply

The following table describes the work history on the shaft seal supply piping. For this piping the work history shows that the main problem experienced with this section of piping is cleaning of the strainer and regulating valve. This was required due to plugging of the line. Other work performed included replacement of the control valve and plans to replace the strainer in 2002.

WO #	Date	Work Description
25751	Oct-1991	Strainer Cleaned
33212	Mar-1996	Strainer and Reducing Valve Plugged - Cleaned
37399	Dec-1997	Strainer and Reducing Valve Cleaned
39094	Dec-1998	Strainer Blocked - Cleaned
120303	Jan-2000	Reducing valve plugged - Cleaned
120452	Jan-2000	Reducing valve - Cleaned
143733	Apr-2000	Strainer Blocked - Cleaned
138270	Jul-2000	Replace Isolation Valves
143837	Jul-2000	New flow control valve installed
188515	Dec-2000	Flow meter cleaned
258143	Jan-2002	Plan to replace Strainer

Table 5: Work History for Shaft Seal Supply

Surface Air Coolers

The following table describes the work history on the surface air coolers and piping. For the surface air coolers the work history consists mostly of cleaning. The cooler tubes were cleaned in 1993, 1997 and 2002. This shows a cleaning frequency of approximately 5 years. Most other work orders for the system are the result of flow choked off due to plugging of the lines or strainer requiring cleaning. Recently a spare cooler has been purchased to allow for removal of each of the coolers for cleaning and modification to a 4-pass configuration from the existing 2-pass configuration. Also recently problems have been experienced with the flow meter readings.

WO #	Date	Work Description
24551	Oct-1990	Investigate flow through relief valve
28435	Sep-1993	High Temperature
28431	Dec-1993	(7) Surface Air Coolers Cleaned 1 Done Next Annual
30218	Jul-1994	Air Temperature alarms checked and adjusted
30556	Feb-1995	Copper lines to reducing valve replaced - leaking
30824	Apr-1995	Cleaned Pipe, flow choked off
25450	Jun-1996	Cleaned Orifice
36732	Aug-1997	8 Coolers - Tubes Cleaned and cleaned Outside
23948	May-1999	Clean Filters for SAC
213961	May-2001	Purchase Spare Cooler
186475	Sep-2001	Replace Flow meter
210807	Sep-2001	Orifice Plates Replaced
226209	Sep-2001	Strainer cleaned and coolers inspected
229673	Sep-2001	Increased air temperature alarm
240287	Oct-2001	Flow meter Problem
118394	Jan-2002	Retubed spare cooler
257769	Jan-2002	Modify Spare cooler for 4 pass
236679	Sep-2002	Cleaned all 8 Coolers
247218	Nov-2002	Low Flow Rate on Meter when supplying hatchery

Table 6: Work History for Surface Air Coolers

Generator Bearing Coolers

The following table describes the work history on the generator bearing coolers and piping. For the generator bearing coolers the work history shows two main problems with the system. The flow meter accounts for the majority of the work orders on this system, they are in the form of adjustment problems and orifice cleaning. The other main problem is with the cooler themselves, that is, the coolers were found to have leaks in 1990, replaced in 1991 and are showing leaks again in 2001 with plans to replace the coolers in 2002. The life of the cooler is significantly lower than expected.

WO #	Date	Work Description
24681	Oct-1990	Water in Bearing Oil - Cooler Repaired
25602	Nov-1991	New Coolers Installed
25735	Dec-1991	Cleaned Orifice
26584	Feb-1992	Flow meter Adjusted
27264	Nov-1992	Flow meter Alarm Reset
27416	Dec-1992	Temp calibrated and alarm / trip points checked
29900	Apr-1994	Valve Leaks - Repaired
34789	Jun-1996	Adjusted Flow Rate
37322	Oct-1997	Low flow rate investigated
38375	May-1998	Cleaned Orifice
72416	Aug-1999	Flow meter Piping Plugged
141168	Apr-2000	Check Flow meter, No Problems
232020	Aug-2001	Water in Bearing Oil - Cooler Repaired
186475	Sep-2001	Replace flow meter
210807	Sep-2001	Orifice Plates Replaced
258142	Jan-2002	Plan to Repair Coolers

Table 7: Work History for Generator Bearing Coolers

Turbine Bearing Coolers

The following table describes the work history on the turbine bearing coolers and piping. This work history shows no major problems until the past 3 years of service. The work orders range from water leaks, plans to replace the cooler in 2002, replacement and erroneous readings from the flow meter and leak and replacement of the supply strainer. Also it is important to note that in 1998 the turbine bearing supply was re-routed. During the relocation the piping was converted from stainless steel to carbon steel, the reason is unknown

WO #	Date	Work Description
26584	Feb-1992	Flow meter Adjusted
59982	Aug-1995	Replace Temperature Meter
34789	Jun-1996	Adjusted Flow Rate
38501	Sep-1998	Replace SS pipe with CS
38603	Sep-1998	Replace SS pipe with CS
24883	May-1999	Flow meter Reading Error
92727	Jul-1999	Increased Temperature Alarms
89704	Aug-1999	Water in Bearing Oil
90898	Aug-1999	Duplex Strainer Leak
91053	Jul-2000	Duplex Strainer Replace
161804	Aug-2000	Flow meter incorrect reading
186475	Sep-2001	Replace Flow meter
210807	Sep-2001	Orifice Plates Replaced and location changed
248860	Nov-2001	Plan to Replace Turbine Cooler

Table 8: Work History for Turbine Bearing Coolers

Piping Replacement

During the design of the cooling water system for unit 7 the corrosion and fouling problems that were experienced with units 1-6 were considered. From this it was noted that it would be beneficial to use stainless steel piping for the cooling water system where possible. Therefore several sections of piping were constructed with stainless steel originally however some of the larger diameter piping was left as carbon steel. The following table lists the piping material used in each section of the system.

Piping Section	Material
Generator Bearing Supply	Stainless Steel
Generator Bearing Discharge	Stainless Steel
Turbine Bearing / Shaft Seal Supply	Carbon Steel (Originally S.S)
Turbine Bearing Discharge	Stainless Steel
Surface Air Cooler Supply	Carbon Steel
Surface Air Cooler Discharge	Carbon Steel
Main Supply Header	Carbon Steel
Main Discharge Header	Carbon Steel

Table 9: Existing Piping Material

Within this study the piping costs will be evaluated for several options. However, the sections of piping that are currently constructed of stainless steel do not require replacement and therefore will not be included in the economic analysis within this study. The following is a list of those sections of piping that will be considered for replacement within the scope of this study:

- Turbine Bearing / Shaft Seal Supply
- Surface Air Cooler Supply
- Surface Air Cooler Discharge
- Main Supply Header
- Main Discharge Header

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 of powerhouse #1. This sample is comparable to powerhouse #2 since the water is taken from the same source. 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 deposit samples were not taken for powerhouse #2, however the reports from the plant personnel expressed that the deposits found were similar to those from powerhouse #1. That is, it is believed that the material is not organic in nature; rather it is described as a harder substance similar to the oxide deposits that were found in powerhouse #1. The table below shows the composition of the deposit taken from the 10" supply header at powerhouse #1. 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. The complete BetzDearborn analysis can be found in Appendix C.

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

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.

Cooling Water Temperature

The following figure shows the trend monitoring information for the cooling water inlet and outlet temperatures. The inlet temperature varies from 0°C in the winter to 18°C in the summer. Also, the increase in water temperature across the SAC and the generator bearing cooler is approximately 10°C in the winter and 5°C in the summer.

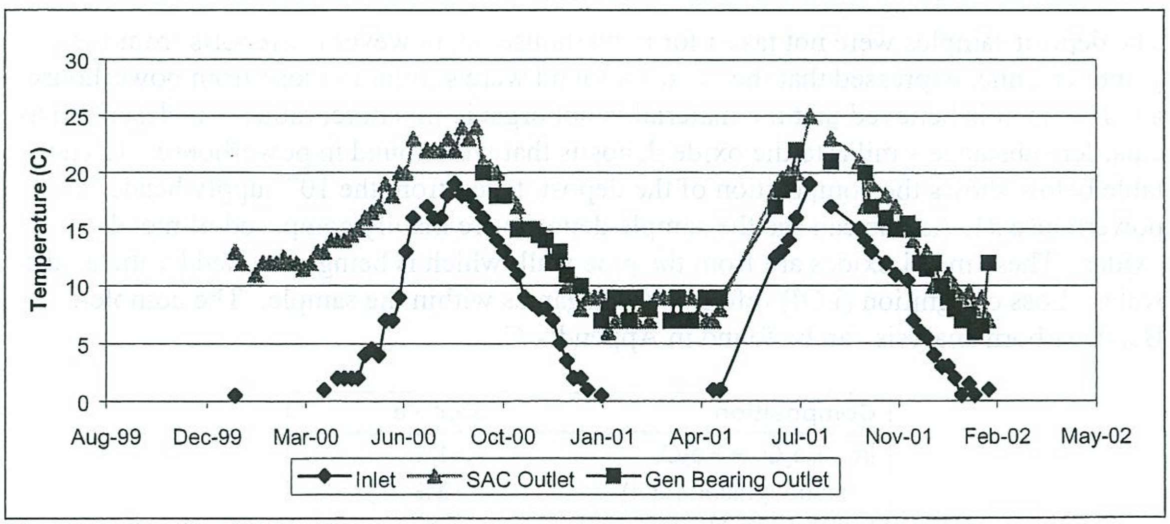


Figure 2: Cooling Water Temperatures

Bearing Temperature

The bearing temperatures are trended in this section to determine the effectiveness of the generator bearing coolers and the turbine bearing coolers. High bearing temperatures can indicate insufficient cooling. The table below displays the alarm and trip set points for the three bearings.

	Generator Guide Bearing	Generator Thrust Bearing	Turbine Guide Bearing
Alarm	80	82	80
Trip Unit Off Line	85	87	85

Table 12: Bearing Temperature Alarm Set Points

The figure below shows the trended information for the three bearings over the past two years. From this trending the following notes were highlighted:

- All the bearing temperatures vary by approximately 16°C from winter to summer.
- The generator guide bearing is consistently below the alarm set point.
- The generator thrust bearing and turbine guide bearing approach the alarm set point for these bearings during the summer.
- The trend shows an increase in the bearing temperatures for the turbine bearing for the summer of 2001 over the readings for the summer of 2000. This may be a result of slightly warmer inlet water temperatures or fouling within the turbine bearing coolers.

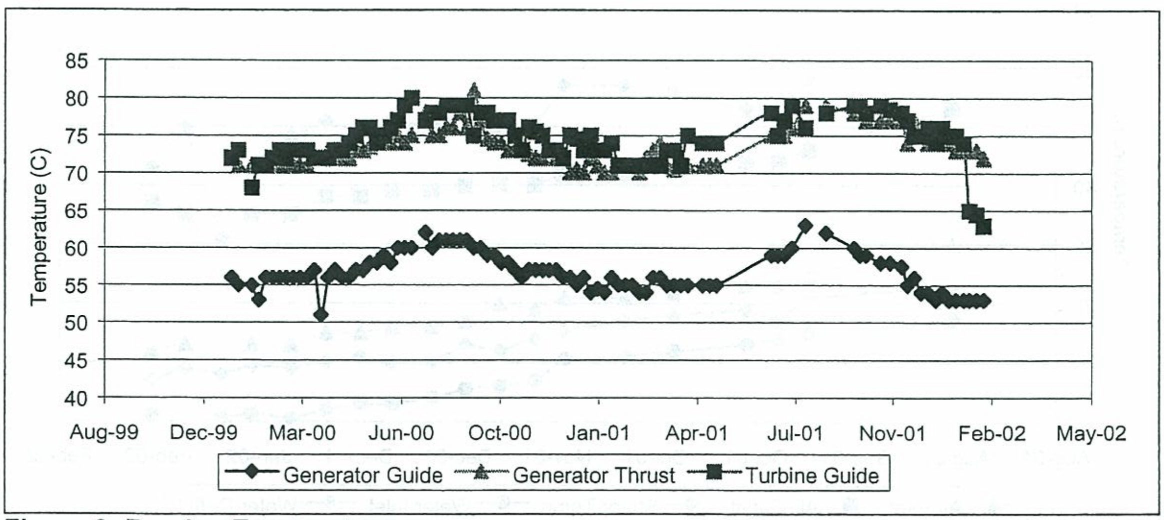


Figure 3: Bearing Temperatures

Stator Temperature

The stator temperature is trended in this section to determine the effectiveness of the surface air coolers. High stator temperatures can indicate insufficient cooling by the SAC. The table below displays the alarm and trip set points for the stator temperature.

	Set Point
Cold Air Alarm:	40
Warm Air Alarm:	
1 Temperature Meter	56
7 Thermostats (Average)	60

Table 13: Stator Temperature Alarm Set Points

The figure below shows the trended information for the stator temperatures. The air inlet and outlet temperature were only available for the past eight months. Also included are the water inlet and outlet temperatures to show their effect on the air inlet temperature. Since the information is not available for a complete year cycle very little can be drawn from the data. The trends that were highlighted are:

- The change in air temperature as it passes over the surface air coolers is constant at approximately 23°C.
- The stator temperature and air temperatures are all closely related to the cooling water inlet temperature.

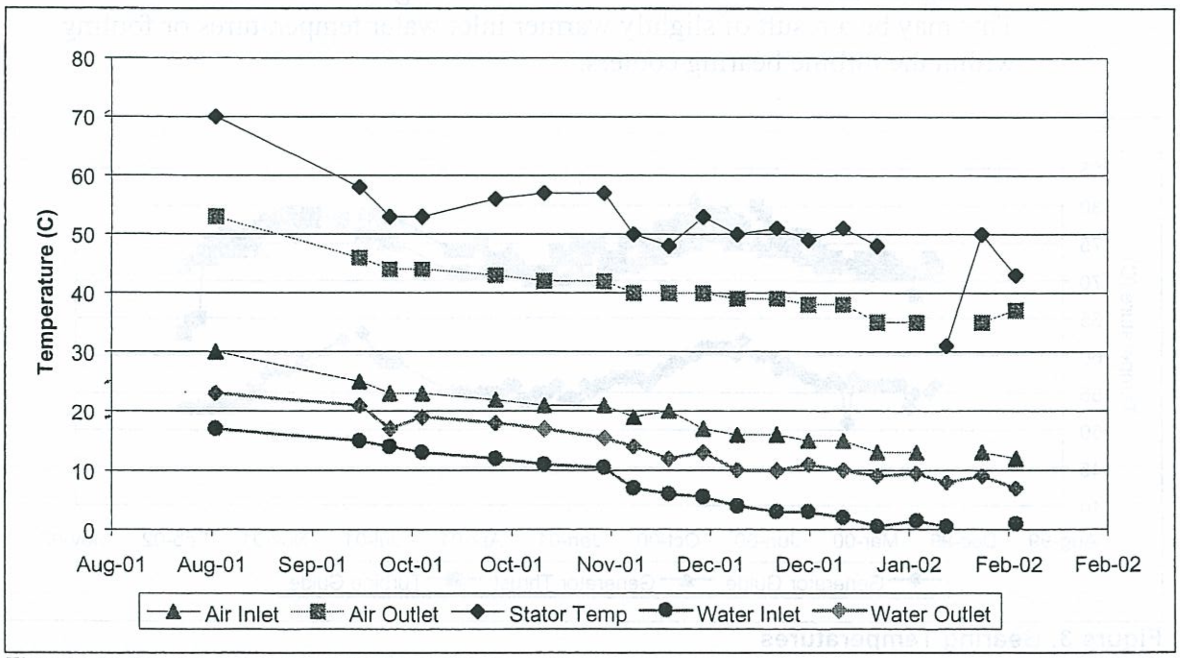


Figure 4: Stator Temperature Trending

Cooler Flow Rate

The cooler flow rates are trended in this section to determine operating conditions and to highlight problems with fouling within the coolers and piping. The table below displays the flow rate alarm set points and operating ranges for the flow meters used in the system.

	Flow Range	Alarm
Surface Air Coolers	0 - 7600 LPM	2200 LPM
Generator Bearing Coolers	0 - 500 LPM	160 LPM
Turbine Bearing Coolers	0 - 160 LPM	65 LPM

Table 14: Flow Alarm Set Points for Coolers

For each of the three flow meters there are inconsistencies with the readings. These are highlighted on each of the trend graphs. Although the errors appear to be caused when the new flow meter transducers and displays were installed it was suggested that the errors in the readings were present before. The past errors were masked by the fact that the old analog displays could be adjusted to produce the desired readings.

The other main highlight from these graphs is lack of fluctuation in flow rate from summer to winter. This is due to the flow control device, that is, the flow is controlled manual by a globe valve in the discharge of each line as opposed to the temperature control valves that are used on Units 1-6.

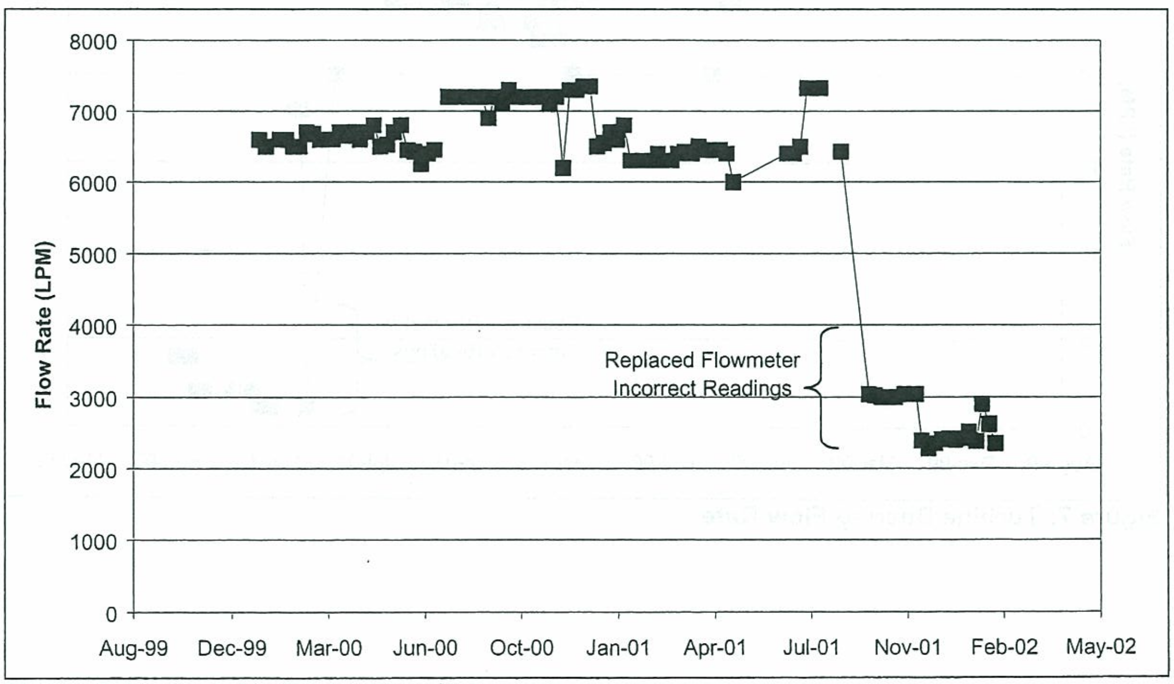


Figure 5: Surface Air Cooler Flow Rate

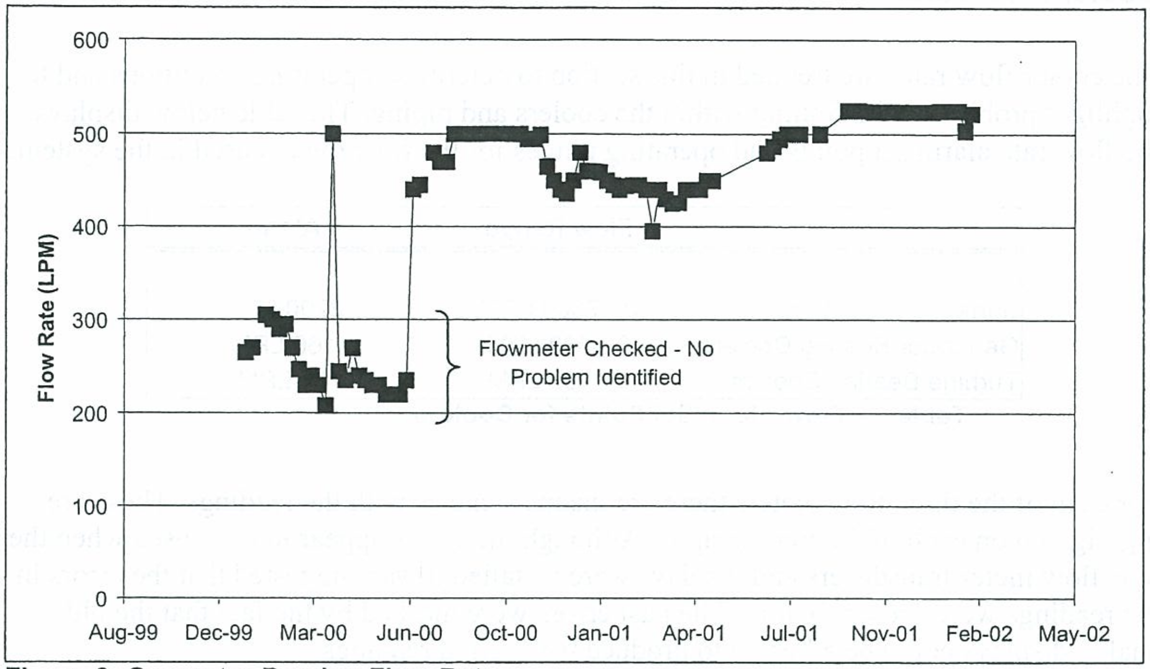


Figure 6: Generator Bearing Flow Rate

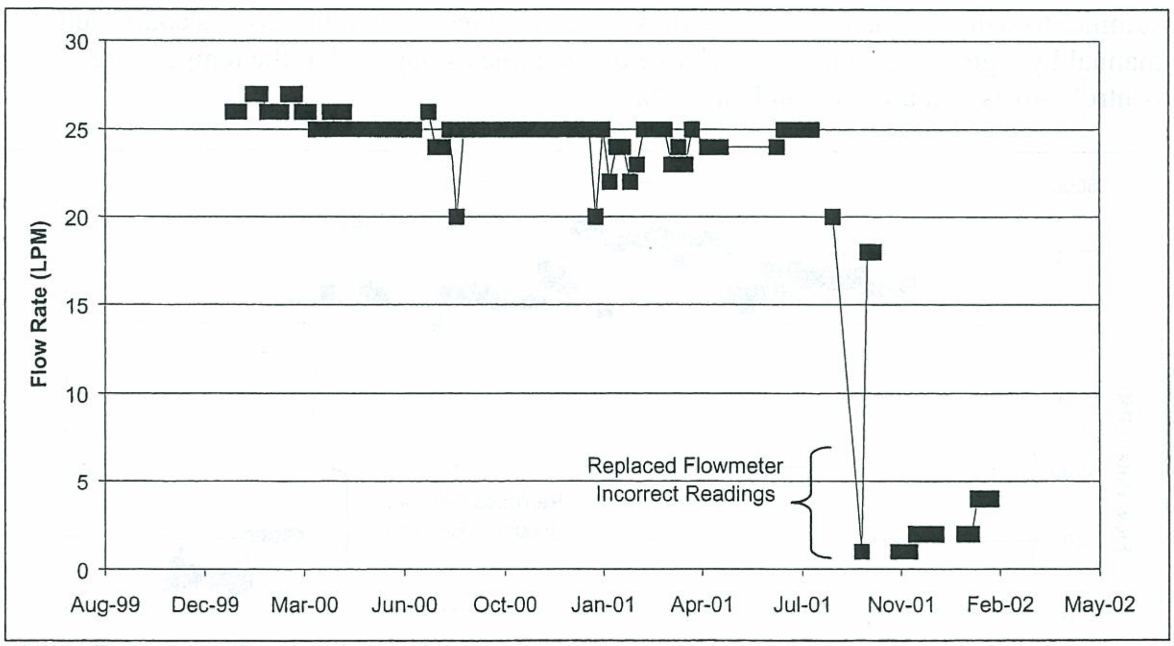


Figure 7: Turbine Bearing Flow Rate

Tube Velocity

Another important aspect of the cooling water system is the water velocity in the coolers. When the tube velocity is too low the particles in the water can settle out. 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 7. 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 Original	Surface Air Coolers Modified	Generator Bearing Coolers	Turbine Bearing Coolers
Cooler Specifications				
Number of Tubes:	156	156	36	6
Number of Passes:	2	4	6	2
Tube Area (m2):	0.00022	0.00022	0.00031	0.00014
Flow Area (m2):	0.01680	0.00840	0.00184	0.00042
Design Condition				
Flow Rate / Cooler (LPS):	15.15	15.15	2.08	1.33
Velocity (m/s):	0.90	1.80	1.14	3.14
Velocity (fps):	2.96	5.92	3.72	10.30
Actual Maximum				
Flow Rate / Cooler (LPS):	15.63	15.63	2.19	0.23
Velocity (m/s):	0.93	1.86	1.19	0.55
Velocity (fps):	3.05	6.10	3.91	1.81
Actual Minimum				
Flow Rate / Cooler (LPS):	12.50	12.50	0.83	0.17
Velocity (m/s):	0.74	1.49	0.45	0.39
Velocity (fps):	2.44	4.88	1.49	1.30

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 and for installations of new systems.

The original design velocity for Bay D'Espoir Unit 7 surface air coolers was 2.96 ft/sec. Since this is below the recommended velocity of 4.5 ft/sec it was recommended by the report to modify the design of the cooler to increase the tube velocity. A spare cooler has been purchased that is modified from a 2-pass configuration to a 4-pass configuration. This modification effectively doubles the tube velocity; the modified cooler has a tube velocity of 5.92 ft/sec. There is a program currently underway to removed each cooler, one at a time, and modified them in the same manner.

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 22 ft in diameter to allow for 2100 GPM. 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 considered for unit #7 only.

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 D.

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 E.

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 (8 Coolers) = 64 hrs
- Surface Air Cooler Piping: 4 days = 32 hrs
- Generator Coolers: (16 hrs / Cooler) x (4 Coolers) = 64 hrs
- Generator Cooler Piping: 4 days = 32 hrs

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

Equipment	Time	Rate	Total Cost
Surface Air Coolers	64 hrs	$118.30	**$ 7571.28**
Surface Air Cooler Piping	32 hrs	$118.30	**$ 3785.64**
Generator Coolers	64 hrs	$118.30	**$ 7571.28**
Generator Cooler Piping	32 hrs	$118.30	**$ 3785.64**

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.
- 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 stainless steel piping that was originally installed does not require replacement, only the carbon steel piping is considered. The total estimated piping costs are $56,505.

Piping Section	Materials	Labor	Total
Supply Header	$ 8,709	$ 17,388	**$ 26,097**
Discharge Header	$ 1,894	$ 5,090	**$ 6,984**
Surface Air Cooler Piping	$ 7,991	$ 6,387	**$ 14,378**
Turbine Bearing Piping	$ 777	$ 898	**$ 1,675**
Contingency 15%	$ 2,906	$ 4,465	**$ 7,370**
Total	**$ 22,277**	**$ 34,229**	**$ 56,505**

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 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	**$ 7571.28**
Surface Air Cooler Piping	10 years	**$ 3785.64**
Generator Coolers	5 years	**$ 7571.28**
Generator Cooler Piping	10 years	**$ 3785.64**

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 $114,757.

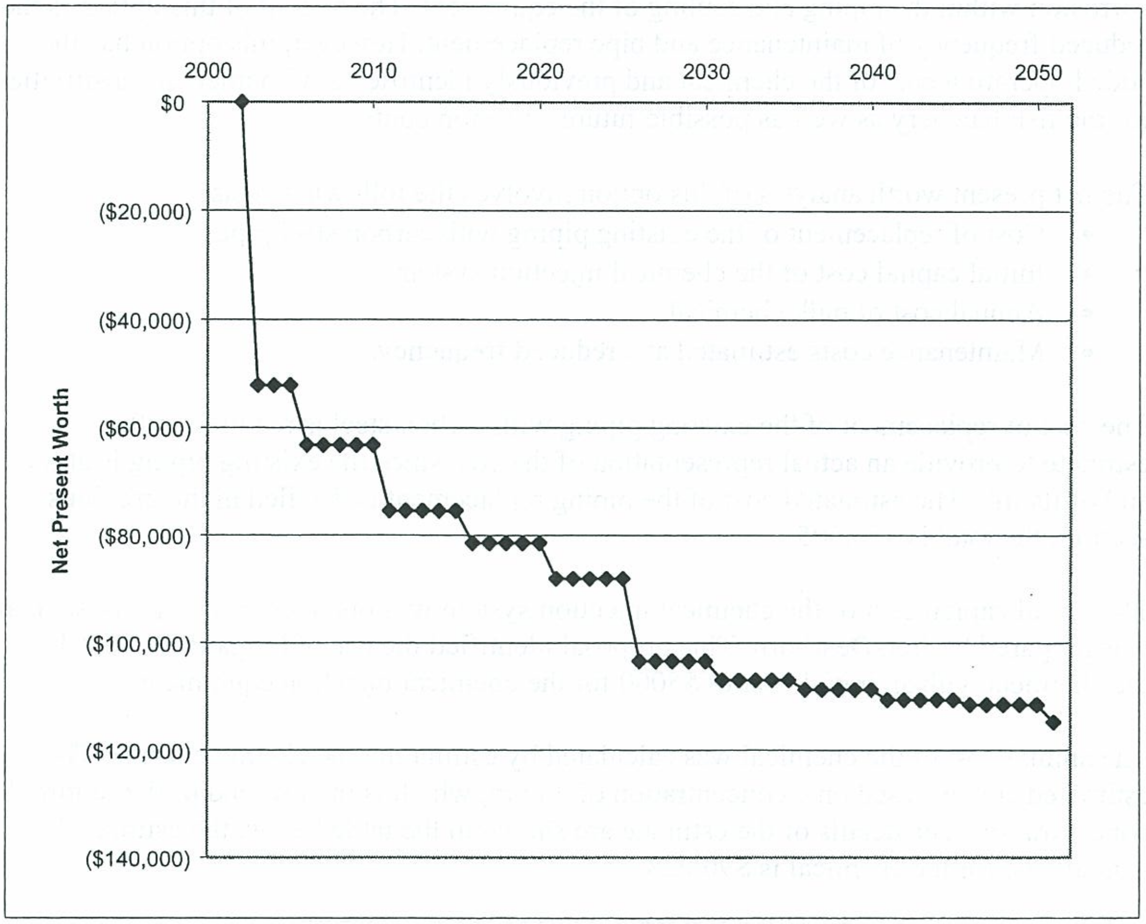


Figure 8: NPW – Option 1

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.
- 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 $56,505.

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 required concentration. The details of the estimate are shown in the table below, the estimated annual cost for the chemical is $90,028.

Water Usage:	
Volume Flow Rate	7956 L/min
Yearly Usage	4181.6736 L x 10^6
Chemical Usage:	
Desired Concentration	4 ppm
Volume Consumption	16727 L/yr
Density of Chemical	1398 kg/m^3
Mass Consumption	23384 kg/yr
Chemical Cost:	
Bulk Cost	$ 3.85 /kg
Total Cost	$ 90,028.09 /yr

Table 22: Chemical Cost Estimate

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	**$ 7571.28**
Surface Air Cooler Piping	50 years	**$ 3785.64**
Generator Coolers	25 years	**$ 7571.28**
Generator Cooler Piping	50 years	**$.3785.64**

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 $1,382,906.

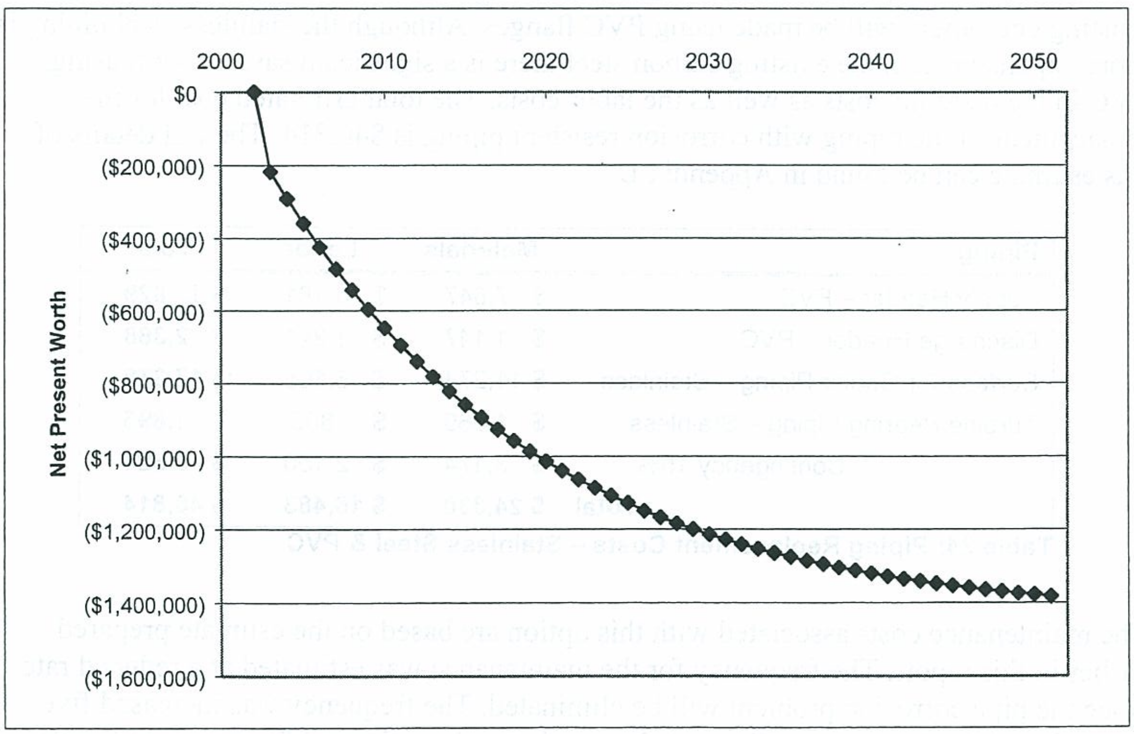


Figure 9: NPW – Option 2

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.
- Maintenance costs estimated at a reduced frequency.

The following table details the material and labor cost associated with replacement of the piping with corrosion resistant piping. Inside the generator housing the piping 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 total estimated cost for the replacement of the piping with corrosion resistant piping is $40,814. The full details of this estimate can be found in Appendix D.

Piping	Materials	Labor	Total
Supply Header – PVC	$ 7,647	$ 6,181	**$ 13,829**
Discharge Header – PVC	$ 1,147	$ 1,241	**$ 2,388**
Surface Air Cooler Piping – Stainless	$ 11,274	$ 6,105	**$ 17,378**
Turbine Bearing Piping – Stainless	$ 1,089	$ 805	**$ 1,895**
Contingency 15%	$ 3,174	$ 2,150	**$ 5,324**
Total	**$ 24,330**	**$ 16,483**	**$ 40,814**

Table 24: Piping Replacement Costs – Stainless Steel & PVC

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	**$ 7571.28**
Surface Air Cooler Piping	50 years	**$ 3785.64**
Generator Coolers	25 years	**$ 7571.28**
Generator Cooler Piping	50 years	**$ 3785.64**

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 $41,883.

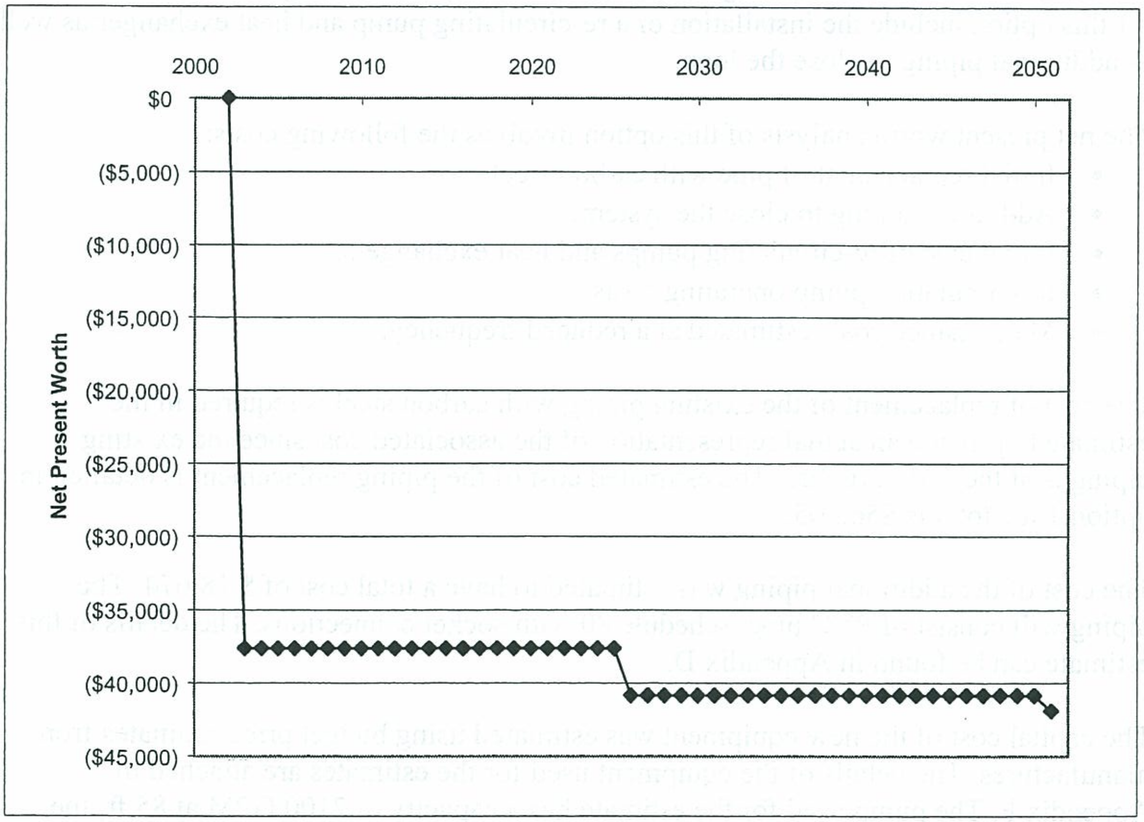


Figure 10: NPW – Option 3

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 F that describes the layout of the system. The surface air coolers, generator bearing coolers and turbine bearing coolers would be included in the loop. The shaft seal water that is lost from the system would be supplied to the loop through a ¾" make-up line from the penstock supply. The existing supply source 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.
- 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 $56,505.

The cost of the additional piping was estimated to have a total cost of $ 18,674. The piping will consist of PVC pipe, schedule 80 with socket connections. The details of this estimate can be found in Appendix D.

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 F. The pump used for the estimate has a capacity of 2100 GPM at 85 ft; the budget estimate is $20,000. 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 re-circulating pump operating costs were determined by the formula below. The pump power requirement is estimated at 60 HP. The equation below produces an approximate annual operating cost of $19,597.

$$\text{Cost} = (60\ \text{HP} \times 0.7457 \frac{\text{kW}}{\text{HP}}) \times (0.05 \frac{\$}{\text{kW} \cdot \text{hr}} \times 8760 \frac{\text{hr}}{\text{yr}}) = \$19{,}597/\text{yr}$$

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	$ 7571.28
Surface Air Cooler Piping	50 years	$ 3785.64
Generator Coolers	25 years	$ 7571.28
Generator Cooler Piping	50 years	$ 3785.64

Table 26: Option 4 - 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 $417,473.

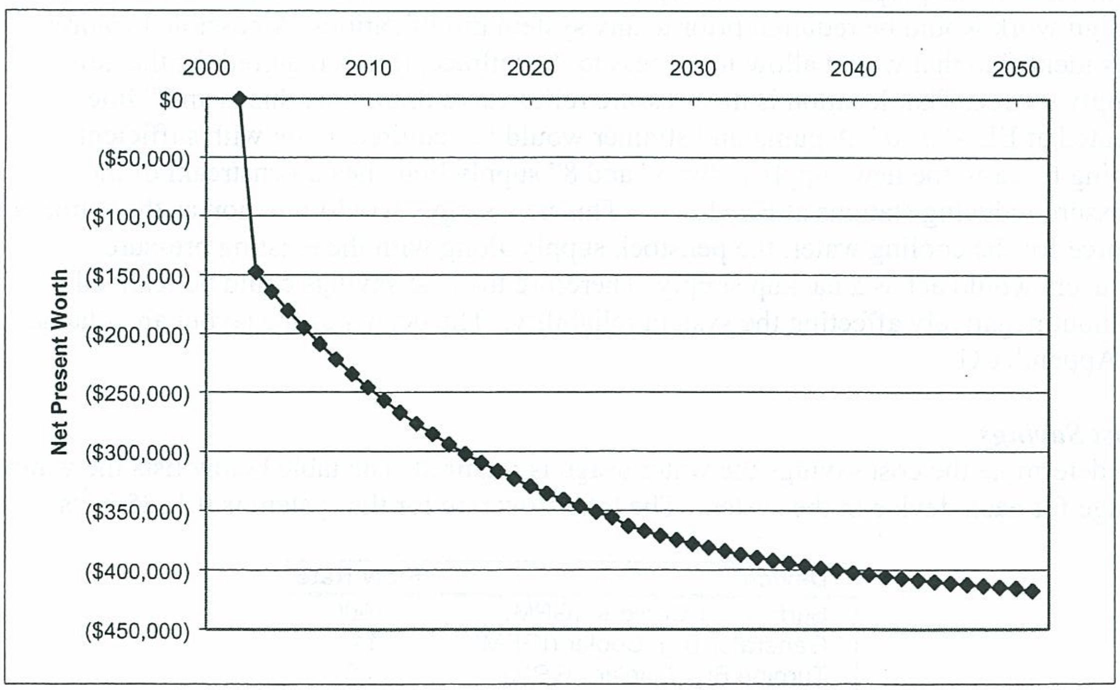


Figure 11: NPW - Option 4

Cooling Water Source

Introduction

As described in *"The Guide to Hydropower Mechanical Design"*, usually an upstream source is used for the cooling water for plants with heads of 90 meters (300 ft) or more. Plants with lower heads usually pump cooling water from the draft tube or tailrace. The head for unit # 7 is 176 meters (577 ft) and the cooling water source currently is the penstock. The main advantage to utilizing an upstream source is the increased reliability of the cooling water supply. However when an upstream source is used it results in a decrease in the amount of water used for generation. Economics is usually the deciding factor for determining the cooling water source. In this section of the study the economics of the cooling water source is evaluated. This involves comparing the cost savings due to increased generation resulting from supplying the system from the tailrace. Also the capital and operating costs associated with converting the water source is evaluated.

Economic Review

System Layout

The system layout and design was developed to a level necessary to perform cost estimates for the purpose of evaluating the feasibility of the modification. Additional design work would be required prior to any system modifications. A possible location was identified that would allow for access to the tailrace, this is required for the new supply source. That location is the pressure relief valve drain line, this is an 8" line located at EL –10'-0". A pump and strainer would be required along with sufficient piping to tie-in the new supply at the 3" and 8" supply branches downstream of the pressure reducing stations at EL+12'-0". This new supply would function as the primary source for the cooling water, the penstock supply along with the existing pressure reducers would act as a backup supply. Therefore the cost savings could be realized without negatively affecting the system reliability. The details of the layout are attached in Appendix G

Cost Savings

To determine the cost savings the water usage is required. The table below lists the water usage for each device in the system. The total flow rate for the system is 0.1325 m^3/s.

Device	Flow Rate
Surface Air Coolers (IGPM):	1600
Generator Brg. Cooler (IGPM):	110
Turbine Brg. Cooler (IGPM):	35
Shaft Seal (IGPM):	4
Total (IGPM):	1749
Total (m^3/s):	**0.1325**

Table 27: Cooling Water Usage

The cost savings for converting the source to the tailrace are realized by increased generation from the water that was previously used in the cooling system. The power is quantified by the following formula. The description of the variables and the values used in the formula are contained in the table below.

$$P = \rho \cdot g \cdot Q \cdot H \cdot \eta_t \cdot \eta_g$$

Variable	Value
ρ = Density of Water (kg/m^3)	1000
g = Gravity (m/s^2)	9.81
Q = Water Flow (m^3/s)	0.133
H = Head (m)	172.0
η_t= Turbine Peak Efficiency	0.94
η_g= Generator Peak Efficiency	0.97
P = Power (Watts)	203,880

Table 28: Power Generation by Cooling Water

The additional power that is generated from the cooling water results in reducing the generation requirements at the Holyrood Generating Station. Therefore the cost savings is calculated by multiplying the power generation by the marginal cost of generation at Holyrood based on oil at CDN$25/bbl. Also the system usage is factored into this equation since the system is not in operation constantly throughout the year. The usage factor (0.89) was determined by evaluating the running hours for 2001. The following table shows the results of the calculation; the annual cost savings is $71,529 / year.

$$\text{Annual Cost Saving} = (203.88\,\text{kW}) \times (0.041\frac{\$}{\text{kW} \cdot \text{hr}} \times 8760\frac{\text{hr}}{\text{yr}} \times 0.89) = \$71{,}529/\text{yr}$$

Capital Cost

The capital cost associated with converting the source to the tailrace is described in the table below. For the estimate it was assumed that schedule 80 PVC pipe would be used for the new system supply. The pipe material costs were obtained from EMCO supply and the labor costs were estimated using RSMeans Mechanical Cost Data 2002. The pump cost is based on a Model 3196 Goulds Pump, 85 ft Head at 2100 GPM. The strainer cost is based on an 8" – 2100 GPM self-cleaning rotary filter from Spirax Sarco. The total capital cost is estimated at $53,516.

Item	Estimate
Piping Materials	$ 8,759
Piping Labor	$ 9,054
Pump Cost	$ 20,000
Strainer Cost	$ 5,000
25% Contingency:	$ 10.703
Total Capital Cost:	**$ 53,516**

Table 29: Estimated Capital Cost

Operating Cost
The operating costs that are created by the installation of the new equipment have to be considered in the economic evaluation. The pump operating cost is determined by the calculation below. The pump power requirement is estimated at 60 HP, the details for the pump sizing are attached. The same usage factor that was used to determine the cost savings is used in this calculation. The equation below produces an approximate annual operating cost of $14,302.

$$\text{Cost} = (60\ \text{HP} \times 0.7457\frac{\text{kW}}{\text{HP}}) \times (0.041\frac{\$}{\text{kW}\cdot\text{hr}} \times 8760\frac{\text{hr}}{\text{yr}} \times 0.89) = \$14{,}302/\text{yr}$$

Other additional operating costs associated with converting the cooling water source include the maintenance cost for the pump and strainer. To estimate these costs it was assumed that a maintenance crew was required for two days per year for both the pump and the strainer. The table below summarizes all the annual operating costs used in the economic analysis. The total annual operating cost was estimated at $16,963.

Item	Estimate
Pump Power Costs ($/yr)	$ 14,302
Pump Maintenance Costs ($/yr)	$ 1,331
Strainer Maintenance Costs ($/yr)	$ 1,331
Total Operating Cost ($/yr):	**$ 16,963**

Table 30: Operating Cost for Cooling Water Source

Results
A net present worth analysis was performed to compare the savings and costs over the life of the plant. The evaluation period used for the analysis was 50 years. The escalation rate used was 2.0% and the discount rate was 8.5%.

A summary of the results of this analysis is shown in the figure below. The pay back period for the conversion of the source is less than 2 years. The total net present worth for converting the cooling water supply to the tailrace is approximately $750,000 saving over 50 years.

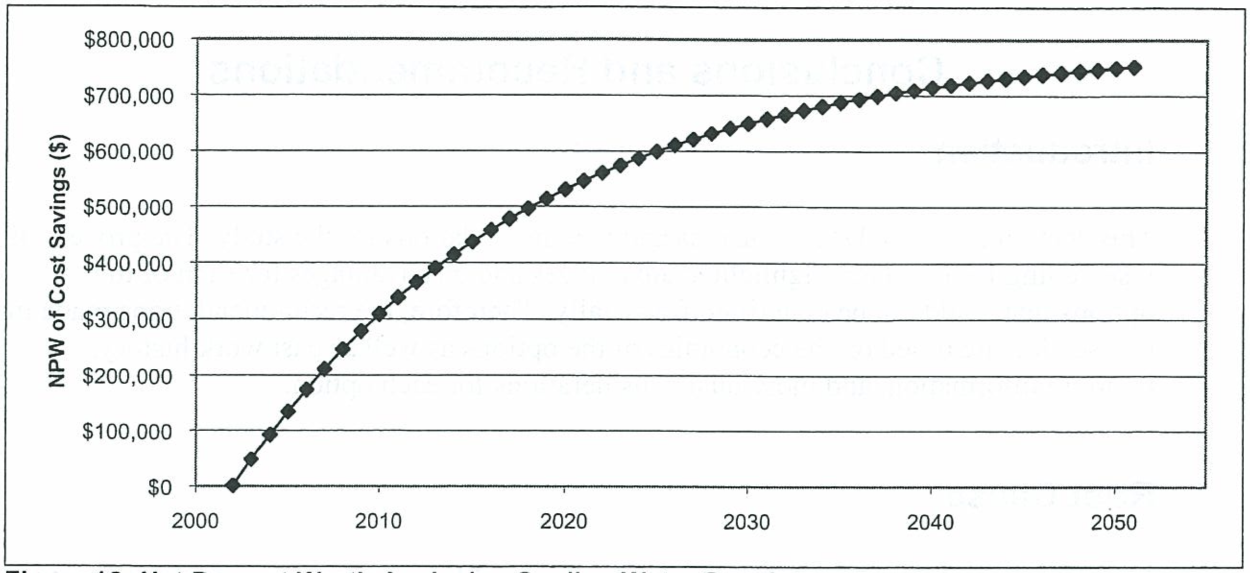


Figure 12: Net Present Worth Analysis - Cooling Water Supply

Alternative Solution

There is an alternative approach to realizing cost savings by modifying the cooling water source. This is to utilize a turbine generator set at the location of the existing reducing valves. With this modification the cooling water would flow from the penstock through the turbine and then supply the cooling water system through the existing piping. The cost savings would be realized through the additional generation and would be offset by operating costs and initial capital costs.

The analysis for this option was compared to that of the modification of pumping cooling water from the tailrace to determine its feasibility:

- The increased generation would be lower in this case since the head is reduced due to the necessary outlet pressure required to supply the cooling system.
- The operating costs would be reduced since there would be no pumping costs as in the tailrace supply option.
- The reduced savings due to generation would be offset by the reduced operating costs to produce an equal net annual savings for both options.
- The cost for the turbine and generator would be comparable to the pump and motor.
- The cost for the switchgear is comparable to the pump starter.
- However there would be increased cost due to the installation of the protection equipment associated with the generator.

The increased capital costs and reduced reliability of the system compared to providing an additional source results in a less feasible option. Therefore the economics for this possible modification were not fully developed since it is known to have increased costs over the previous scenario.

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 powerhouse #1 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	$ 114,757
2. Chemical Treatment	$ 1,382,906
3. Corrosion Resistant Piping	$ 41,833
4. Closed System	$ 417,473

Table 31: 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.

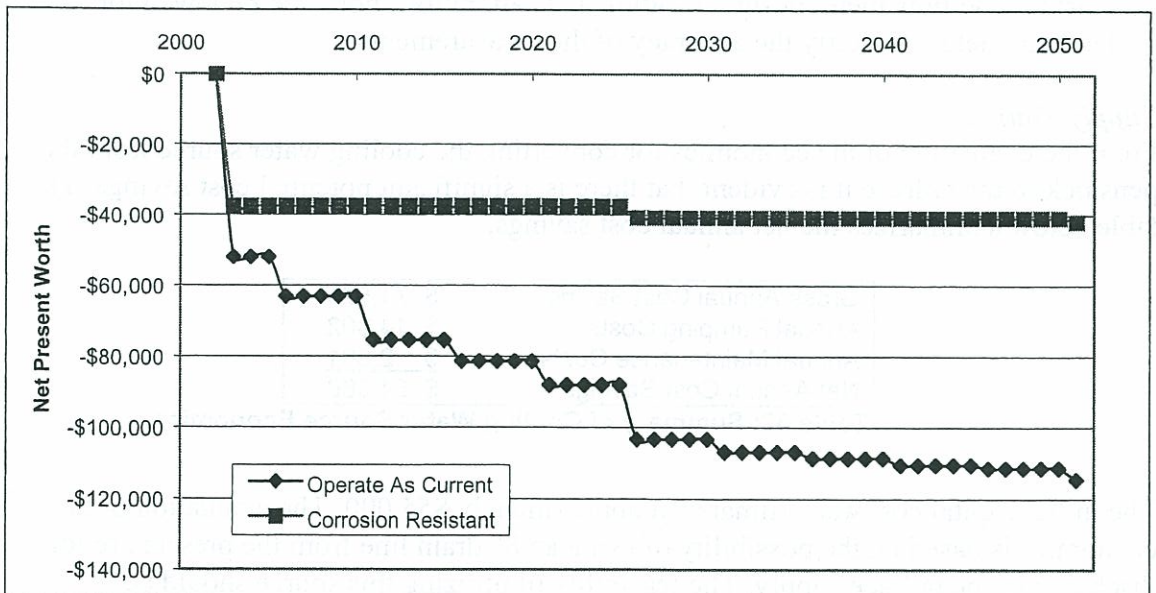


Figure 13: NPW Comparison of Options

Recommendations

Coolers

A program is in place for the re-tubing and modification of the surface air coolers. The coolers are being modified to increase the number of passes to increase the tube velocity. A spare surface air cooler has been purchased and each of coolers will be removed and modified on a sequential basis.

The generator bearing coolers have been the cause of downtime during the past year. A failure of these coolers causes forced outages for the unit as this results in water in the bearing oil. From reviewing the past work history it was determined that these coolers have a high frequency of replacement. The coolers were originally installed in 1977, leaked and repaired in 1990, replaced in 1991, leaked and repaired in 2001 and are planned for replacement. Therefore the life of these coolers can be estimated at approximately 10-12 years. The design configuration and materials of these coolers should be reviewed with a view to improving their expected life.

Due to recent failures of the turbine bearing coolers for units 1-6, money was budgeted for replacement of the unit 7 turbine bearing coolers. However, this cooler is stainless steel and has no past history of leaking. It is planned is to purchase a spare cooler to have on hand for replacement and assess the condition of the existing coolers with a hydrostatic test.

Flow meters

The readings from the three flow meters throughout the system are known to be inaccurate. The flow meter design, location and calibration should be reviewed for each of the three meters to verify the accuracy of the measurements.

Supply Source

From the evaluation of the economics for converting the cooling water source from the penstock to the tailrace it is evident that there is a significant potential cost savings. The table below summarizes the net annual cost savings.

Gross Annual Cost Saving	$ 71,529
Annual Pumping Costs	$ 14,302
Annual Maintenance Costs	$ 2,661
Net Annual Cost Savings	$ 54,566

Table 32: Summary of Cooling Water Source Economics

The initial capital cost was estimated at approximately $55,000. The evaluation of the economics is based on the possibility of using an 8" drain line from the pressure relief discharge as the tailrace supply. The feasibility of utilizing this source should be confirmed and a detailed design should be prepared to facilitate the conversion of the cooling water supply to the tailrace.

Pipe Fouling and Corrosion

The following table summarizes the advantages and disadvantages of each of the viable options developed in the study to deal with the pipe fouling and corrosion problem. From this study it is apparent that the option of replacing the piping with corrosion resistant material is the recommended option.

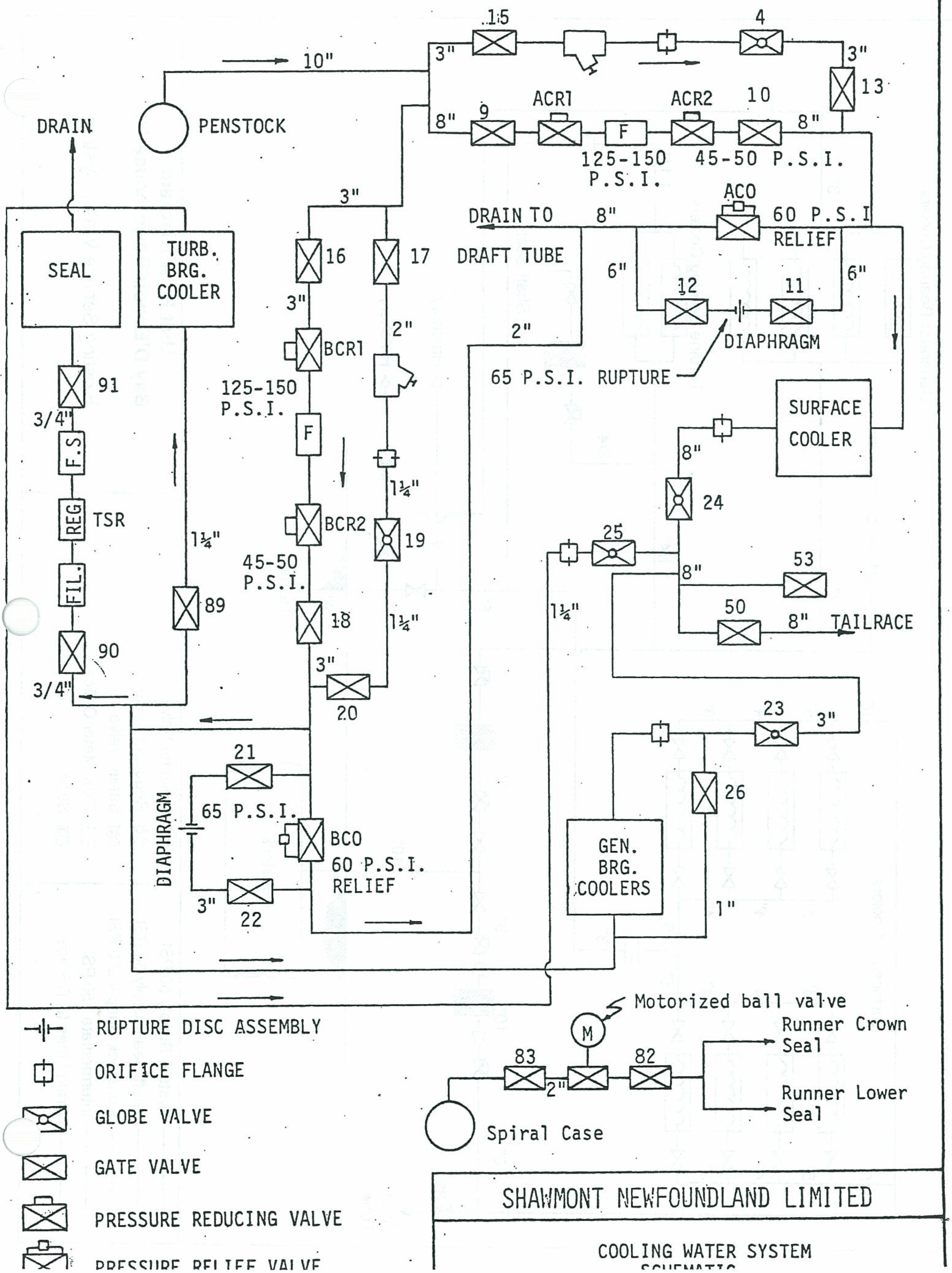
Option	Advantages	Disadvantages
Operate as Current	• Existing design unchanged	• Reduced system reliability • Downtime for maintenance • Future piping replacements
Chemical Treatment	• Reduces corrosion	• Highest cost solution • High chemical costs • Environmental risk
Corrosion Resistant	• Eliminates corrosion • Original pipe was stainless • Lowest cost solution - NPW • Increases system reliability • Existing design unchanged	
Closed Loop System	• High temperature control • Reduces corrosion	• Added equipment mntc. • Loss water to shaft seal of treated water.

Table 33: Option Summary

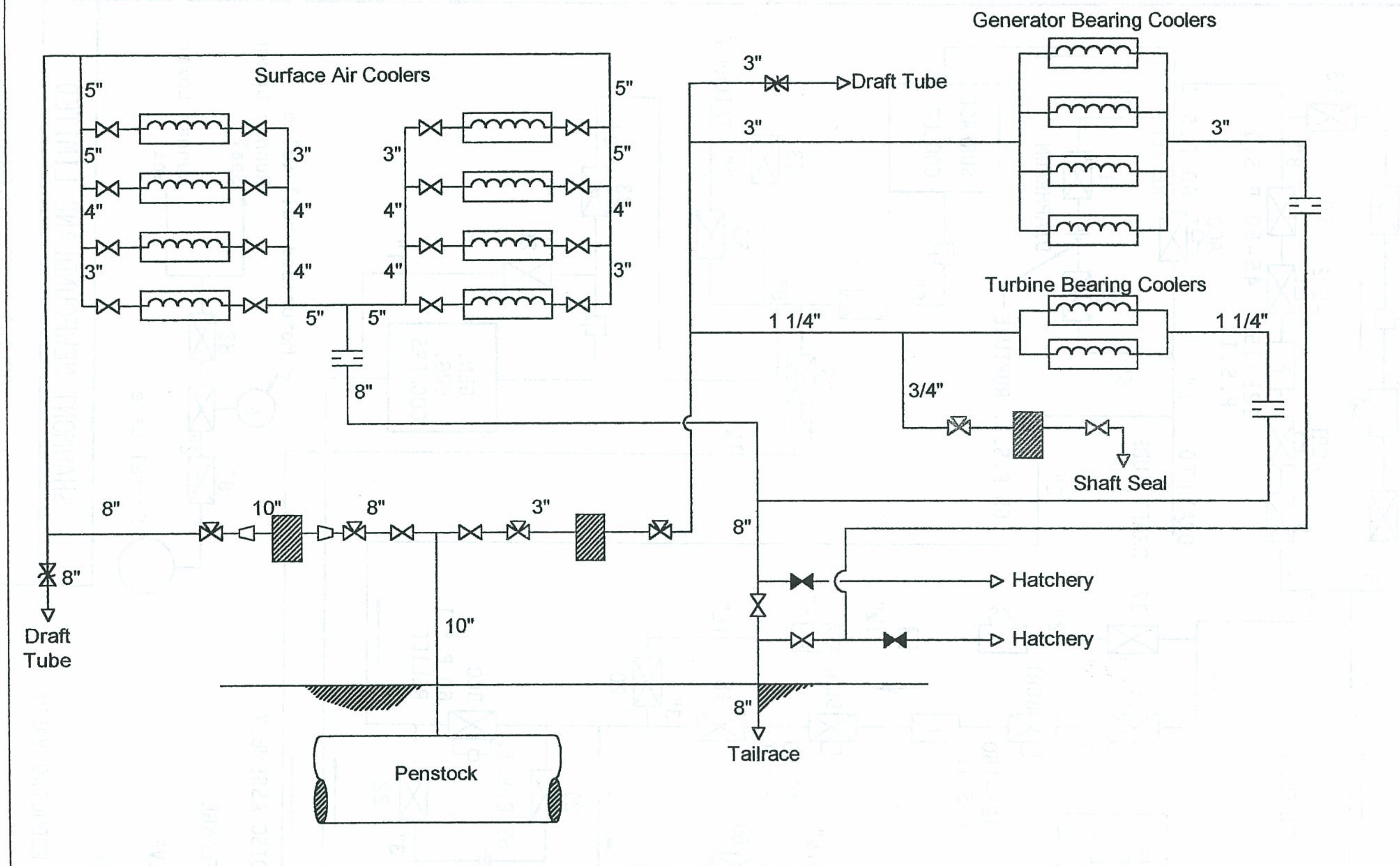
To implement the "Corrosion resistant" option it is recommended to convert each section of piping to corrosion resistant material as outlined below. This should be performed when the existing system requires replacement due to pipe failures or plugging.

- Turbine Bearing Supply and Shaft Seal Piping. This piping should be replaced with stainless steel as it was when originally installed. The material and labor costs were estimated at $1,900. The materials identified for use are stainless steel schedule 10 with victaulic fittings.
- Surface Air Cooler Supply and Discharge Piping. The material and labor costs were estimated at $17,300 for this replacement. The materials identified for use are stainless steel schedule 10 with victaulic fittings.
- Supply and Discharge Header. The material and labor costs were estimated at $16,200 for this replacement. The materials identified for use are PVC schedule 80 pipe and socket fittings, with flanged connections to existing equipment.

Appendix A:
Flow Diagrams and Sketches



DRAIN
PENSTOCK
10"
15
4
3"
13
9
ACR1
F
ACR2
10
8"
125-150 P.S.I.
45-50 P.S.I.
ACO
60 P.S.I RELIEF
DRAIN TO DRAFT TUBE
6"
12
11
DIAPHRAGM
65 P.S.I. RUPTURE
2"
SEAL
TURB. BRG. COOLER
16
17
BCR1
91
3/4"
F.S
REG
TSR
FIL.
90
89
1¼"
BCR2
19
18
20
SURFACE COOLER
24
25
53
50
TAILRACE
23
26
21
22
65 P.S.I.
BCO
60 P.S.I. RELIEF
GEN. BRG. COOLERS
1"
RUPTURE DISC ASSEMBLY
ORIFICE FLANGE
GLOBE VALVE
GATE VALVE
PRESSURE REDUCING VALVE
PRESSURE RELIEF VALVE
Motorized ball valve
M
83
82
Runner Crown Seal
Runner Lower Seal
Spiral Case
SHAWMONT NEWFOUNDLAND LIMITED
COOLING WATER SYSTEM SCHEMATIC



System Supply 50 PSI
Shaft Seal Supply 30 PSI
Penstock Supply 250 PSI
Intermediate 150 PSI
Drain Lines to Tailrace

Isolation Valve
Reducing Valve
Safety Valve
Flow Meter Orifice
Strainer

Unit Flow Diagram
Bay D'Espoir Powerhouse #2

Existing Service Water System

CANADIAN GENERAL ELECTRIC COMPANY LIMITED

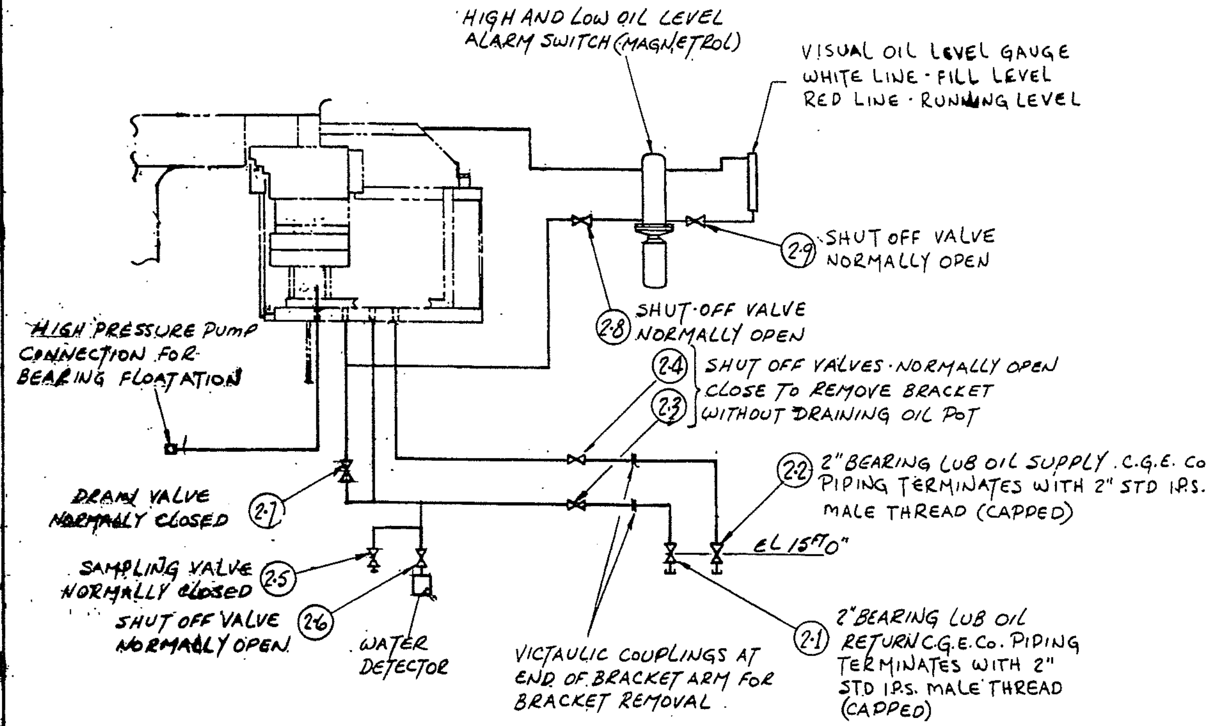
292D660HM CONT ON - SHT 2

NFLD. & LAB. HYDRO BAY D'ESPOIR #7

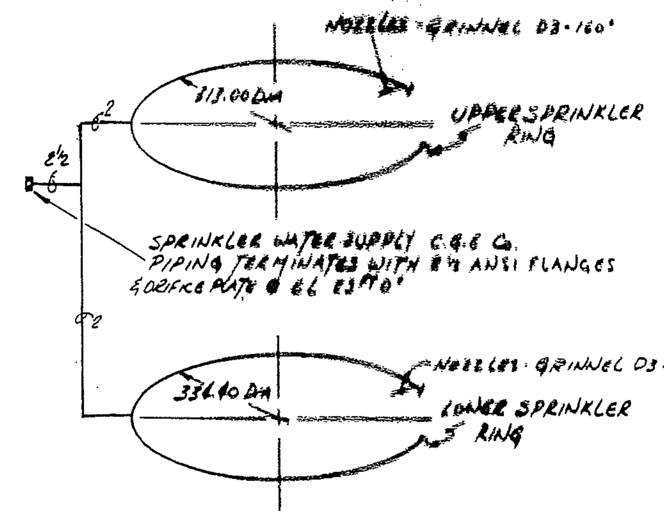
TITLE PIPING PLAN AIR, OIL, WATER AND FIRE PROTECTION

FIRST MADE FOR PL 525L675 COMP 1766

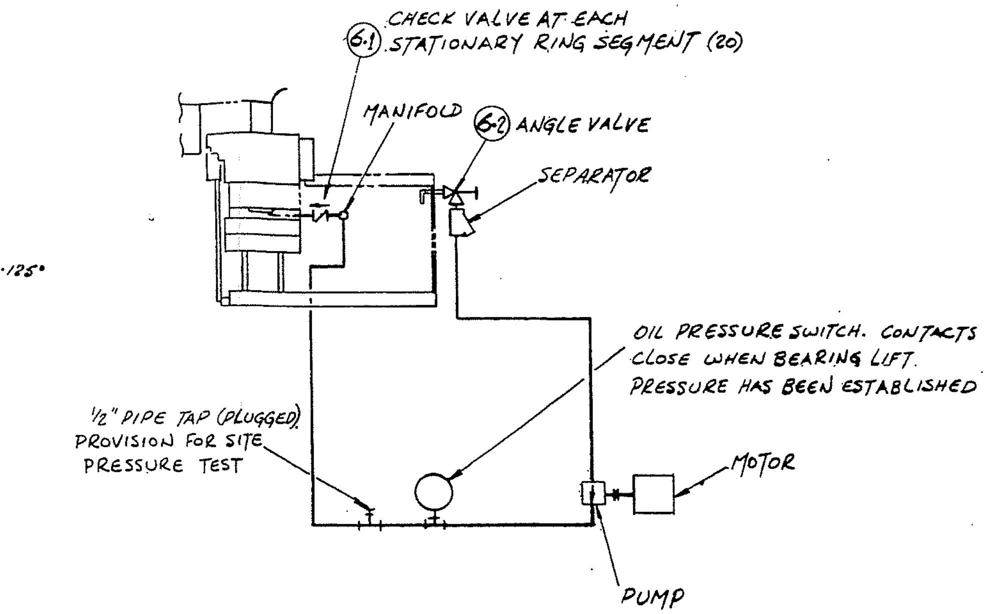
FOR PURCHASER'S NOTES SEE 215A9926EB



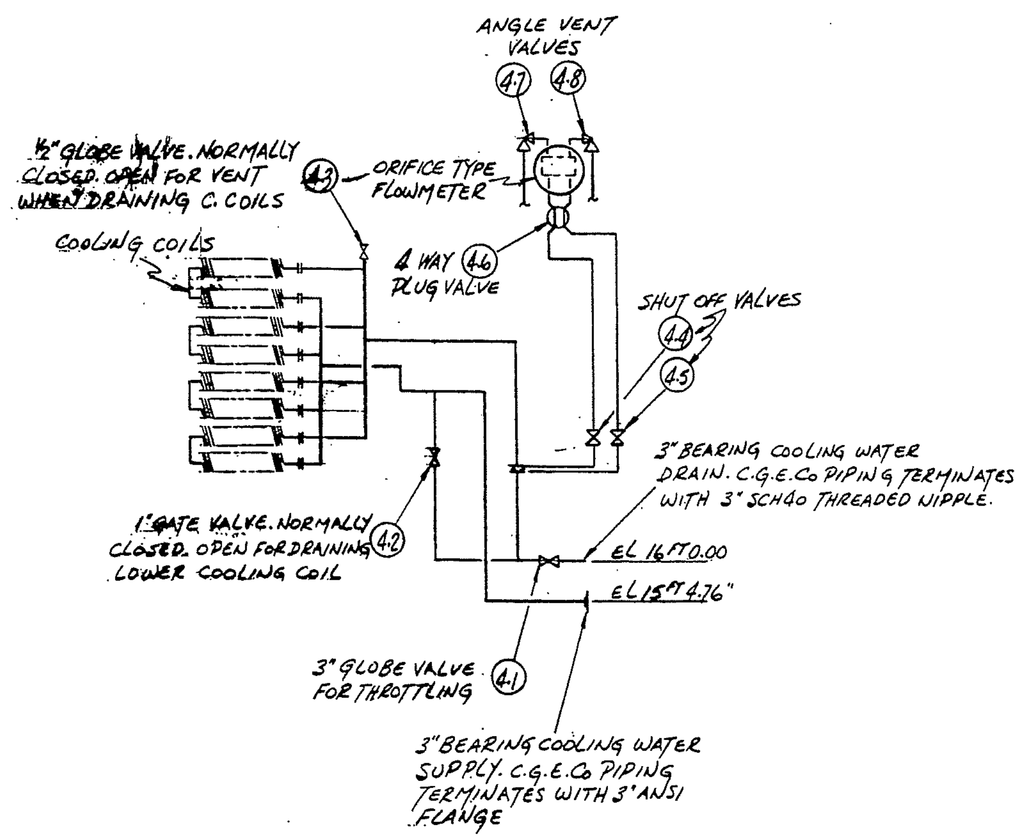
SCHEMATIC DIAGRAM OF BEARING LUB OIL SYSTEM



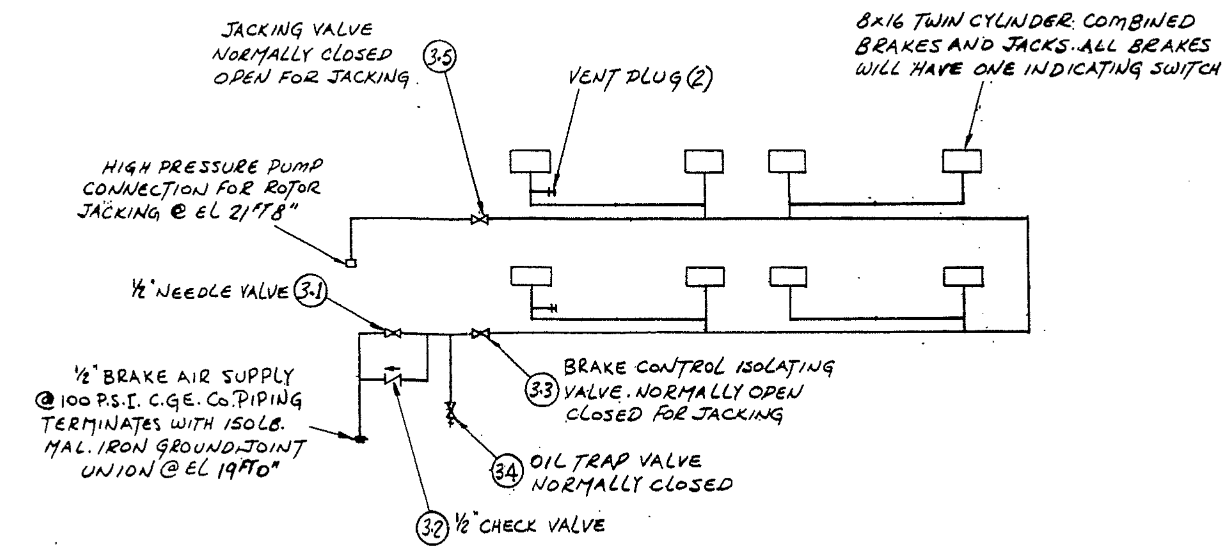
SCHEMATIC DIAGRAM OF SPRINKLER PIPING



SCHEMATIC DIAGRAM OF BEARING HIGH PRESSURE START



SCHEMATIC DIAGRAM OF BEARING COOLING WATER SYSTEM



SCHEMATIC DIAGRAM OF BRAKING AND JACKING SYSTEM

VALVE IDENTIFICATION	
LOCATION	SERIES
BRG LUB OIL SYSTEM	2.0
BRAKE AND JACK SYSTEM	3.0
BRG COOL. WATER SYSTEM	4.0
FIRE PROTECTION SYSTEM	5.0
HIGH PRESSURE PUMP SYSTEM	6.0

REGISTERED PROFESSIONAL ENGINEER A. BERNSTEIN PROVINCE OF ONTARIO

REVISIONS
1 BRG COOL. DRAIN EL WAS 16'3.00 & ... AIR SUPPLY EL WAS 21'0" ...
2 3 NOV 77 ADDED PIPE SIZES FOR SPRINKLER RINGS P.R.P

DRAWN BY | CHECKED BY 2 APR 76 P. PEARSON | LARGE GENERATOR PETERBORO | 292D660HM

CANADIAN GENERAL ELECTRIC
COMPANY LIMITED

292D660GT

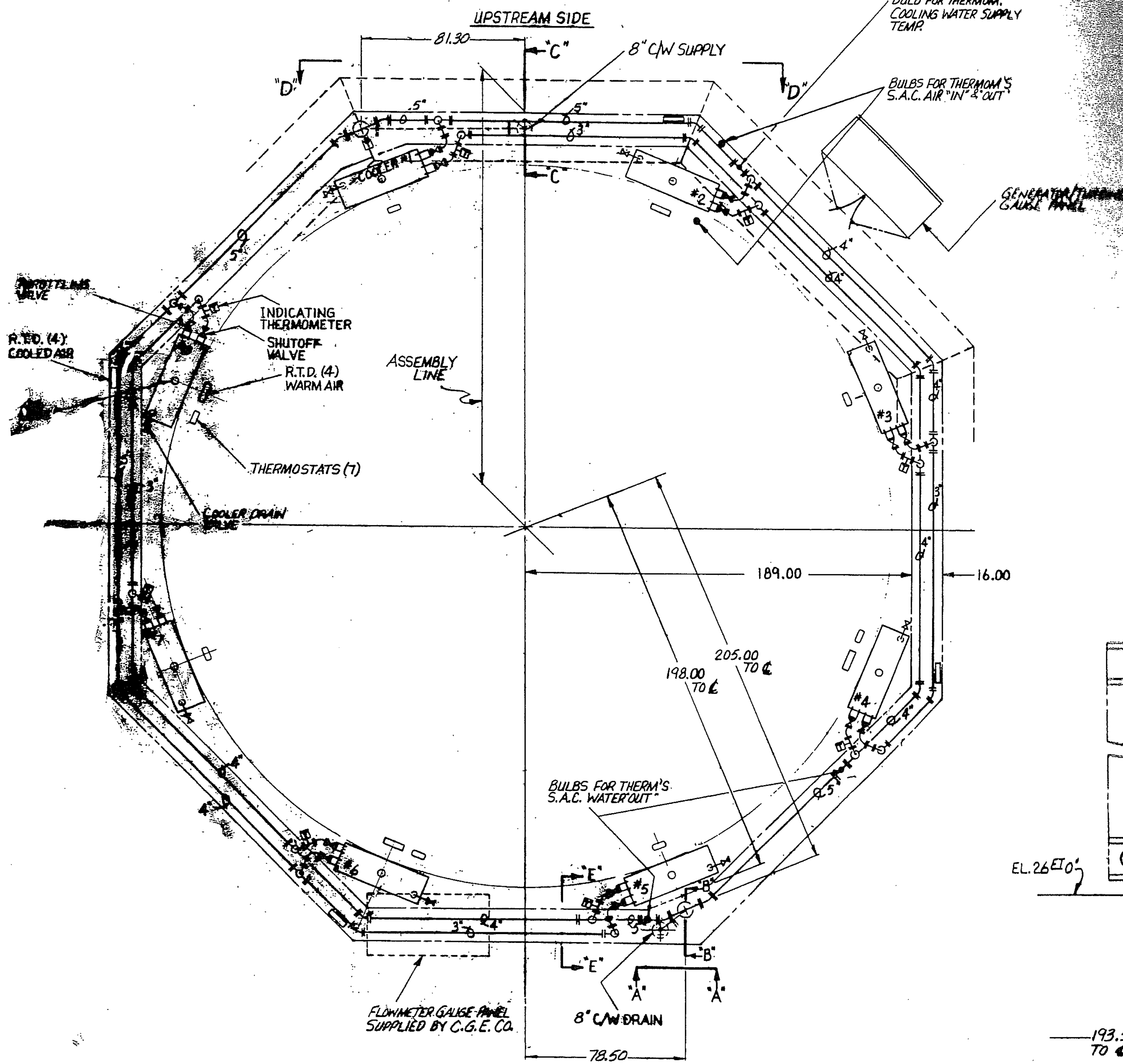
NEWFOUNDLAND AND LABRADOR HYDRO BAY D'ESPOIR #7

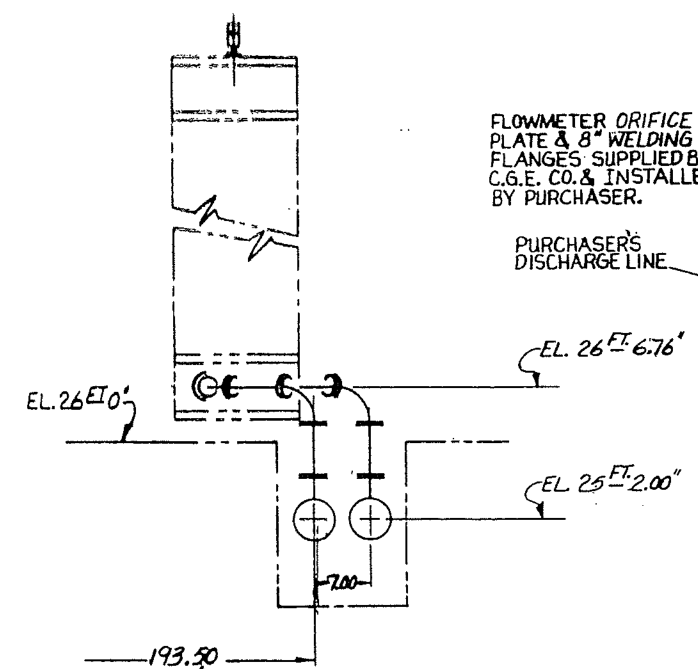
TITLE PIPING PLAN
SURFACE AIR COOLER

FIRST MADE FOR ATI-W-32-225 13.8 17200 K.V.A.

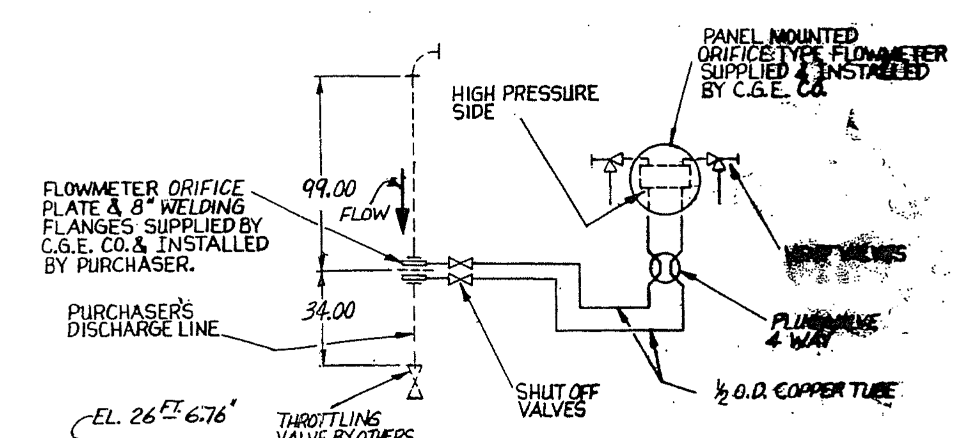
PL-525

FOR NOTES TO PURCHASER SEE – 215A9926 DF





SEC. "E-E"



SCHEMATIC DIAGRAM OF FLOWMETER PIPING SHOWING MINIMUM STRAIGHT PIPE LENGTHS

A. BERNSTEIN — ELECTRICAL — REGISTERED PROFESSIONAL ENGINEER — PROVINCE OF ONTARIO

DRAWN BY VAUGHN R. DAFOE

CHECKED BY

292D660GT

292D660G1

CANADIAN GENERAL ELECTRIC COMPANY LIMITED

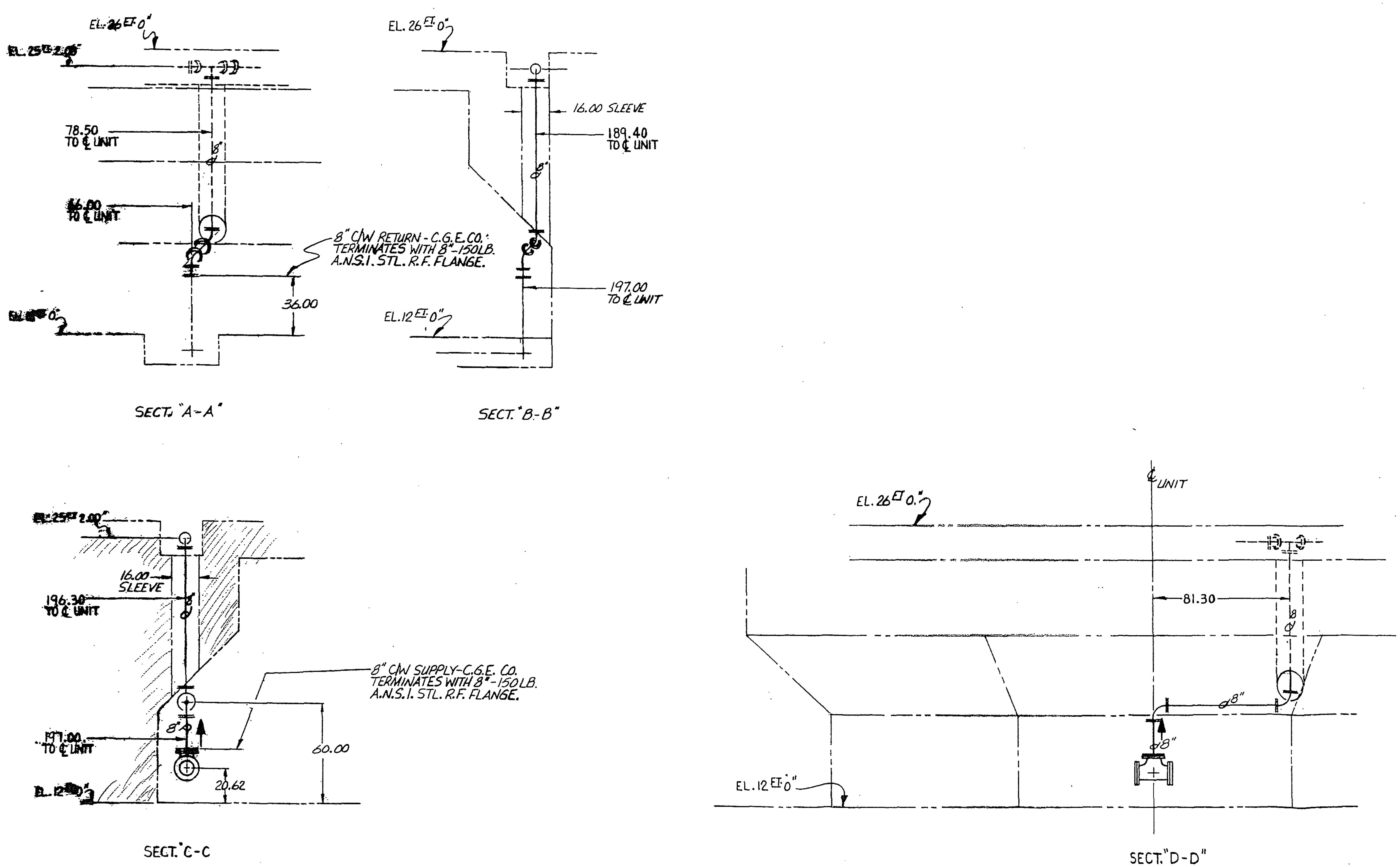
292D660G | CONT'D SHT. — SH.

NEWFOUNDLAND AND LABRADOR HYDRO BAY D'ESPOIR #7

TITLE PIPING PLAN SURFACE AIR COOLER

PL-525L4.T COMP.-1517

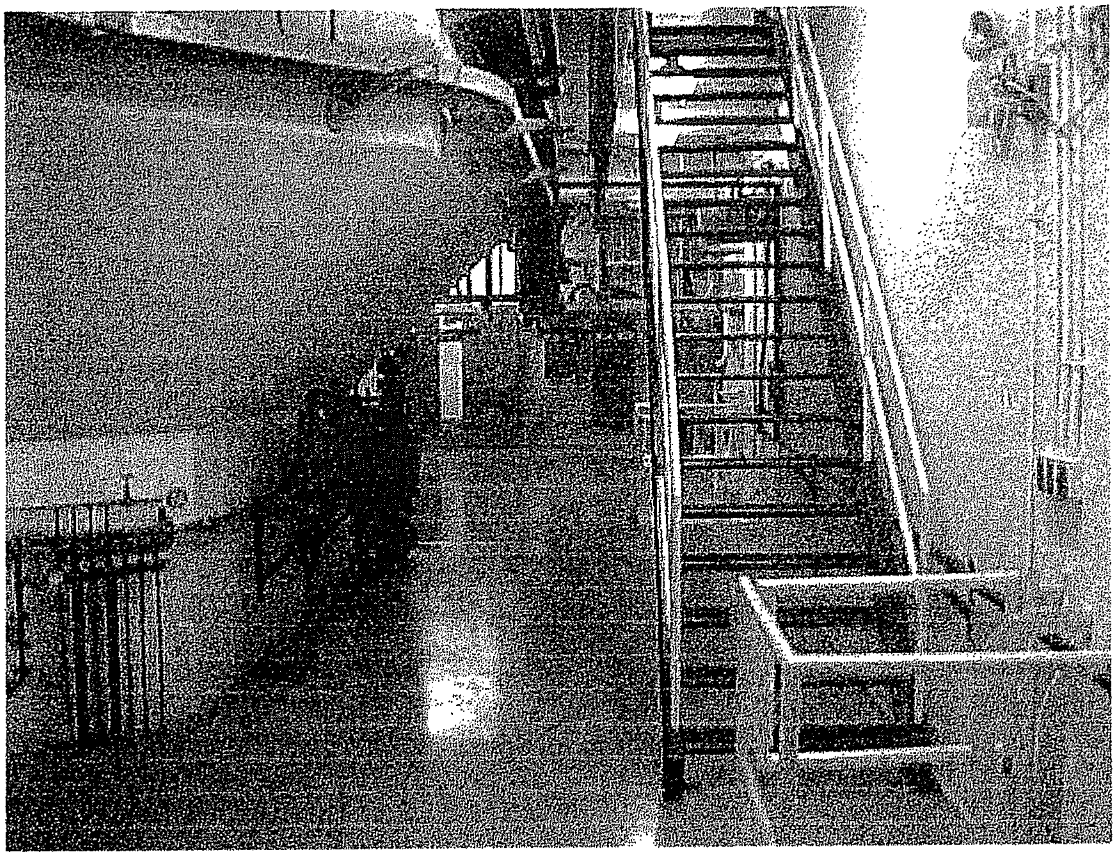
FIRST MADE FOR ATI-W-32-225 13.8-17200 KVA.

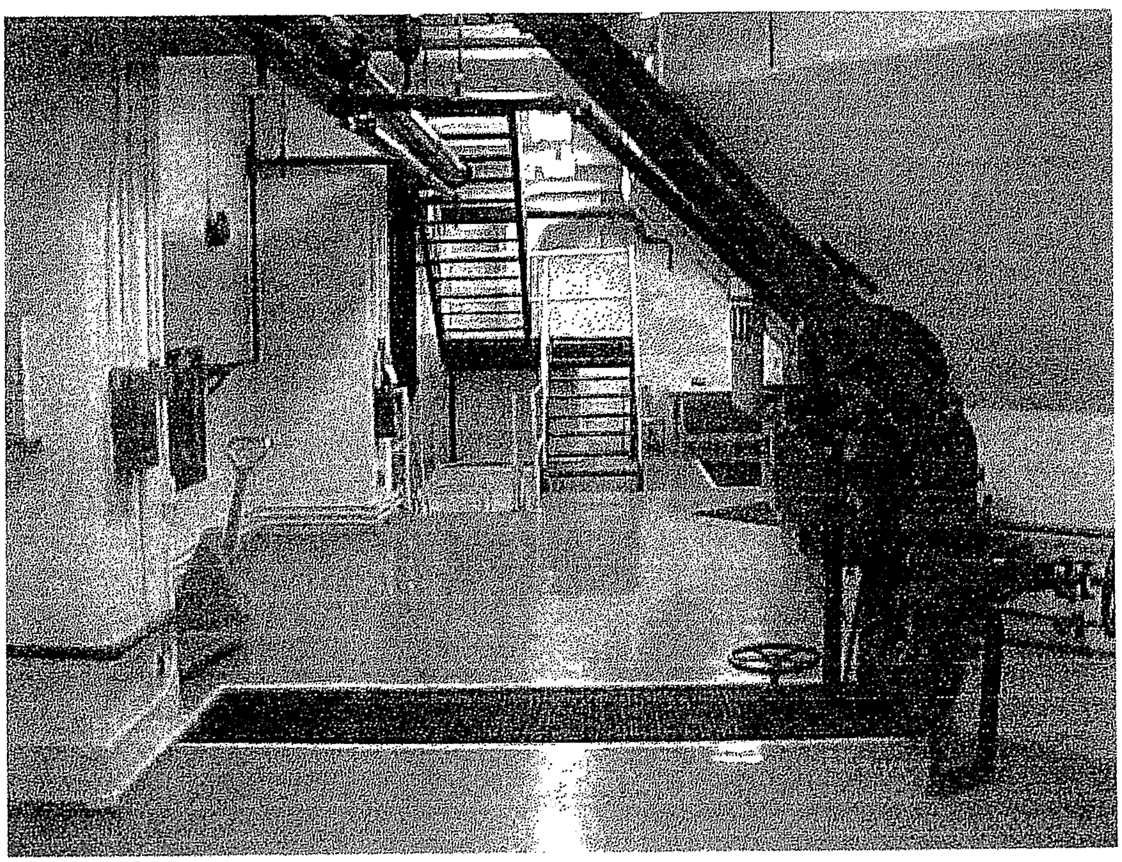


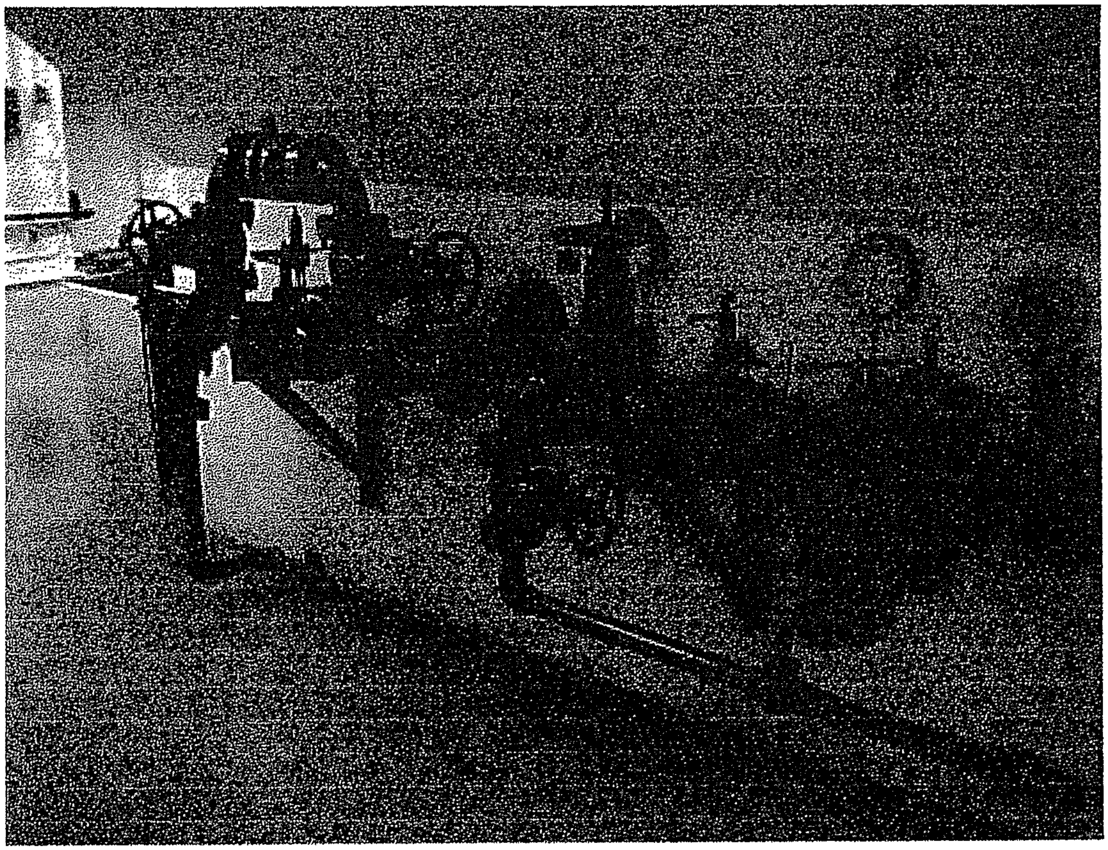
REVISIONS | 741

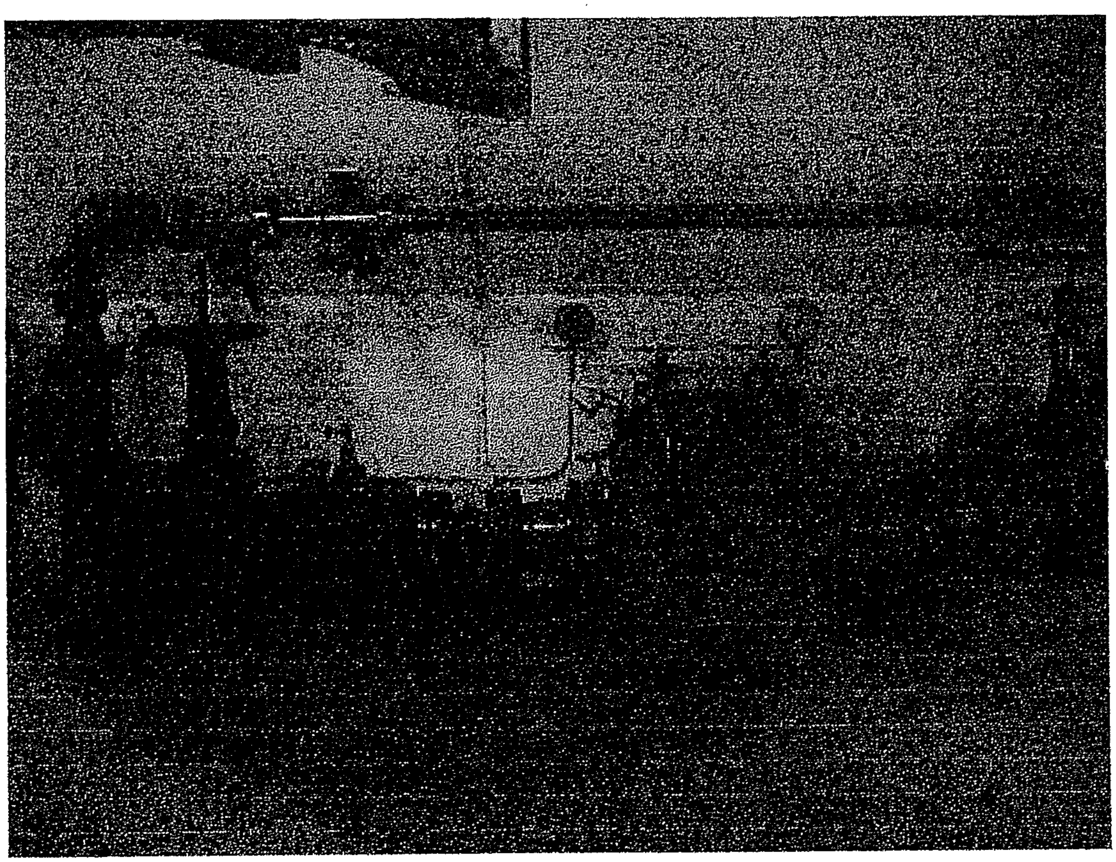
DRAWN BY VAUGHN R. DAFOE | CHECKED BY | NOV 20 75 | LARGE GENERATOR PETERBOROUGH PLANT | 292D660G | CONT'D SHT. — SH.

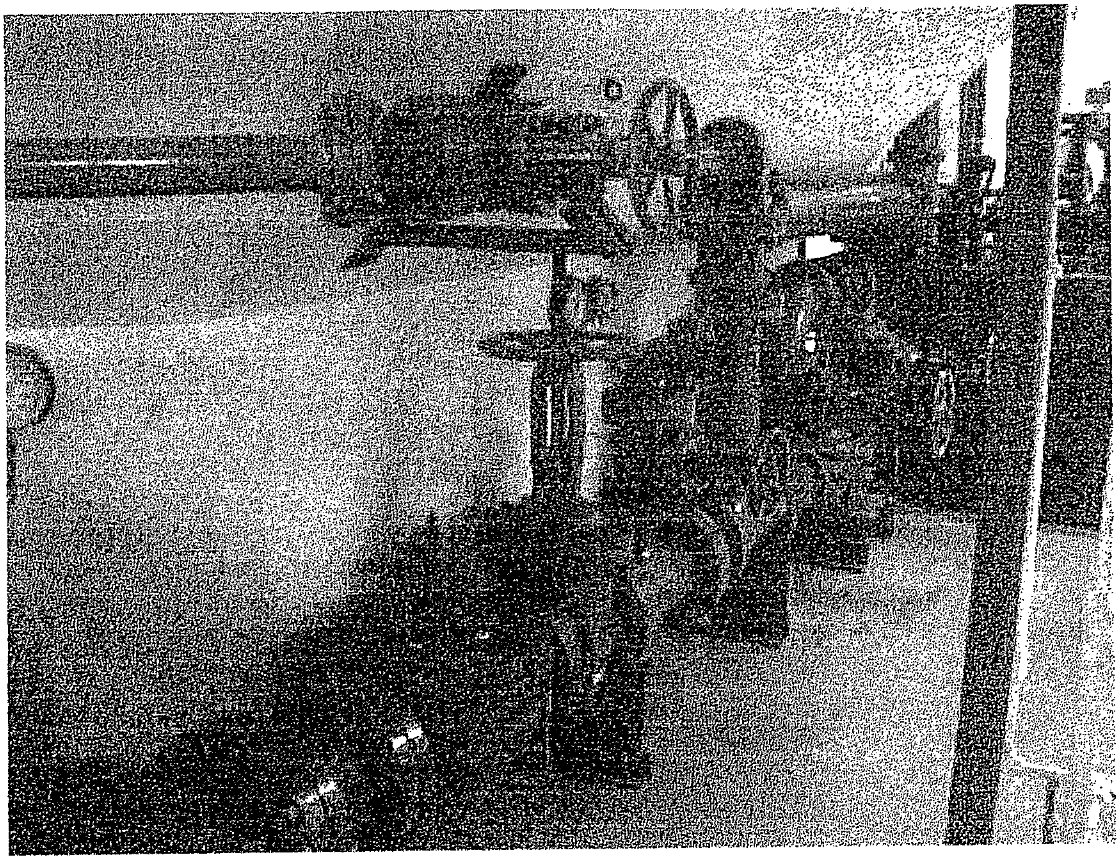
Appendix B:
Equipment Pictures

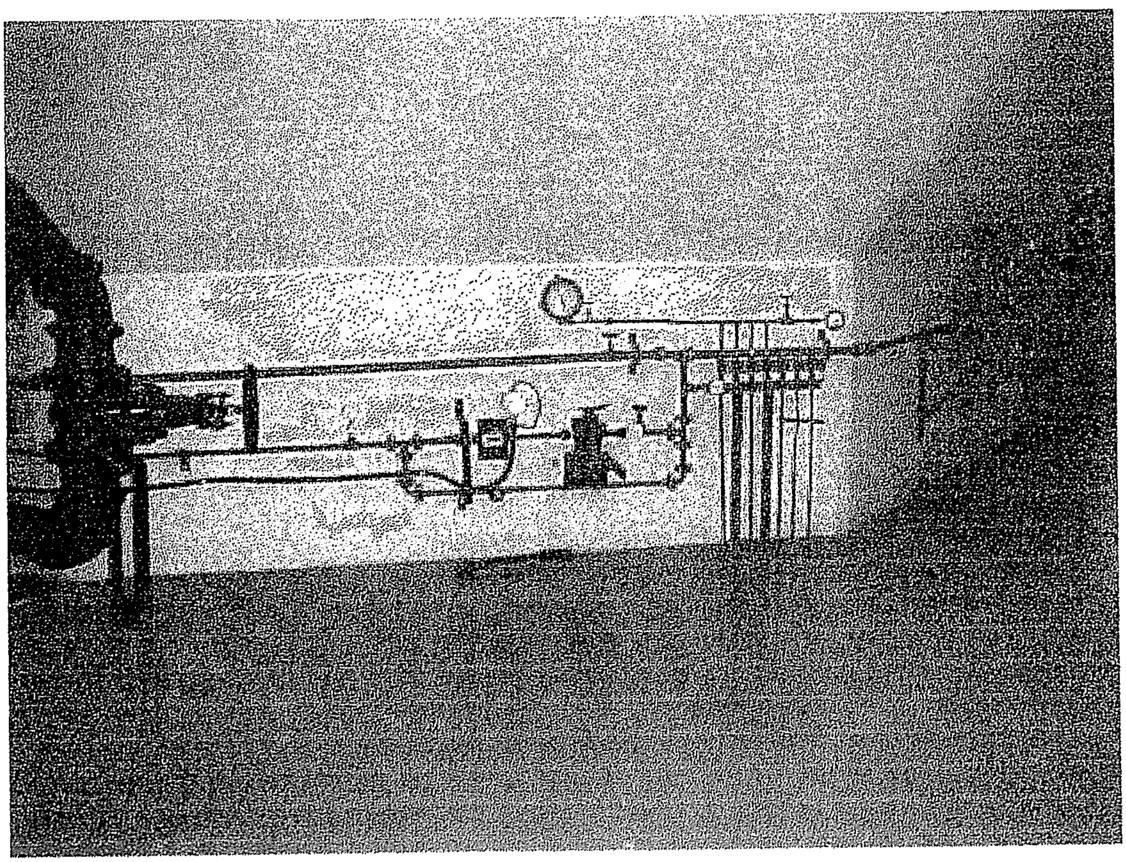


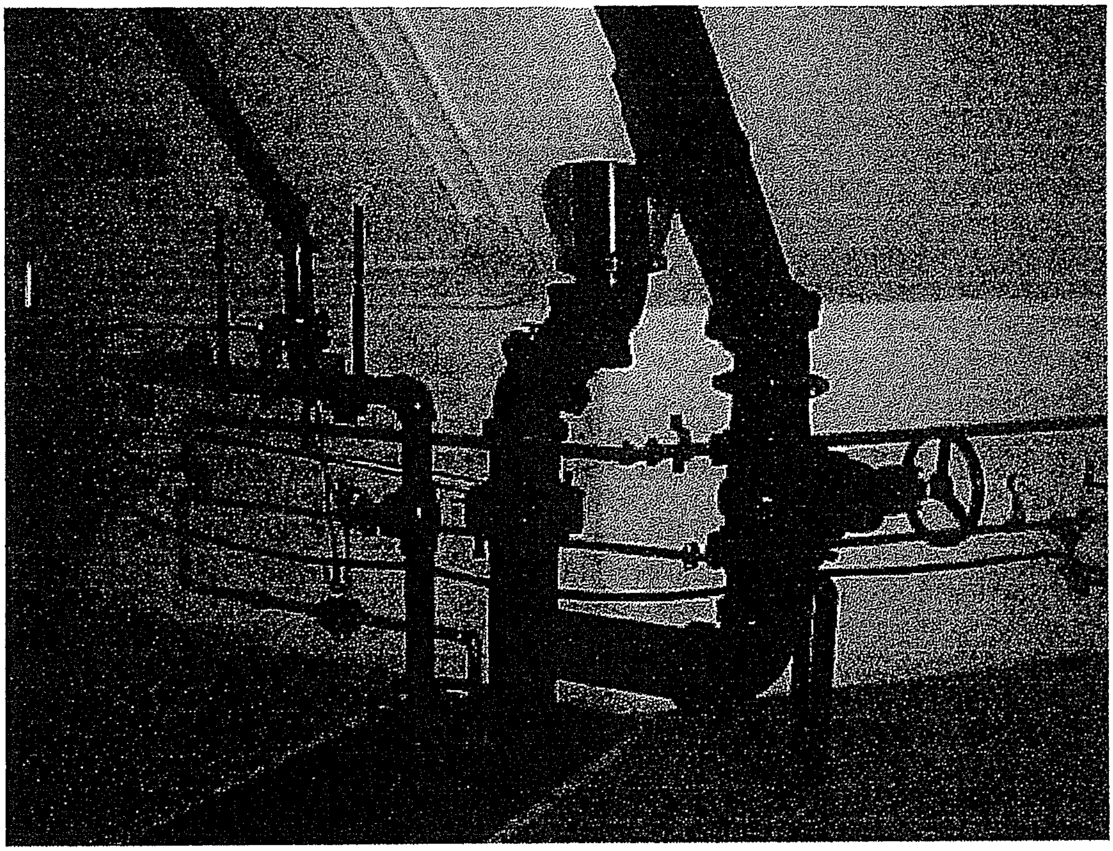


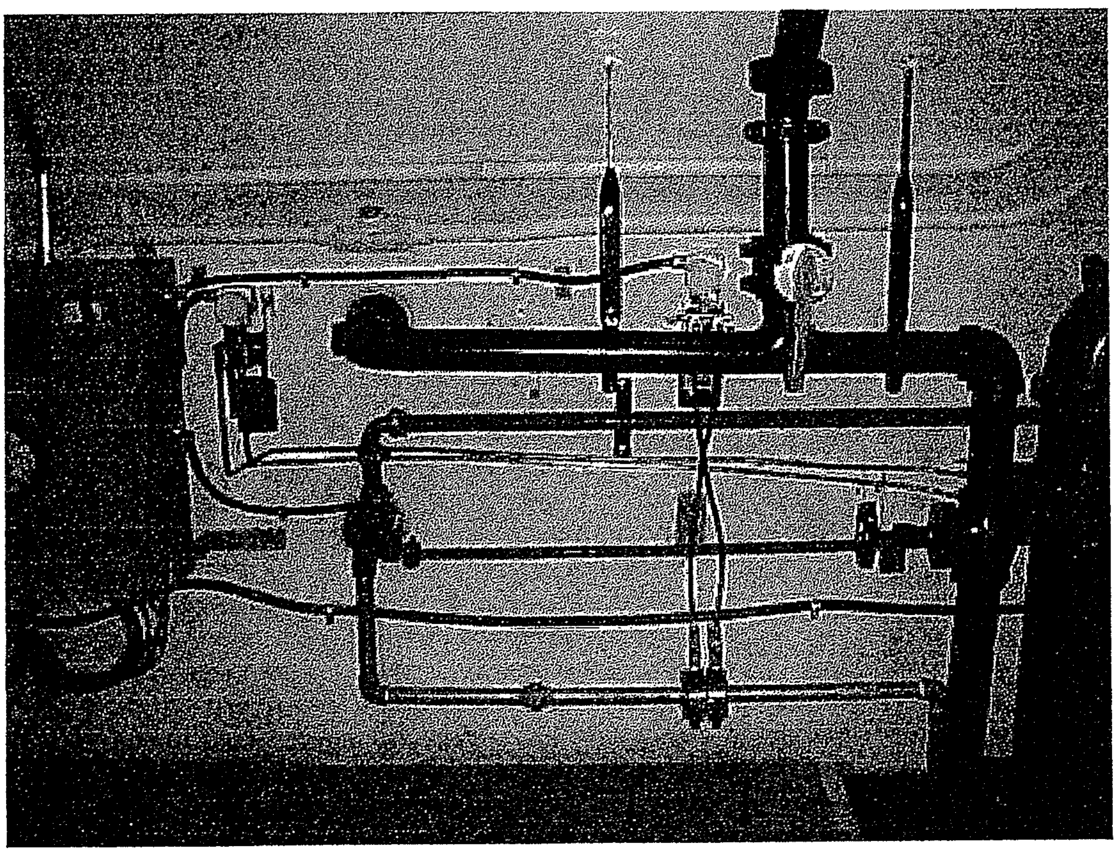


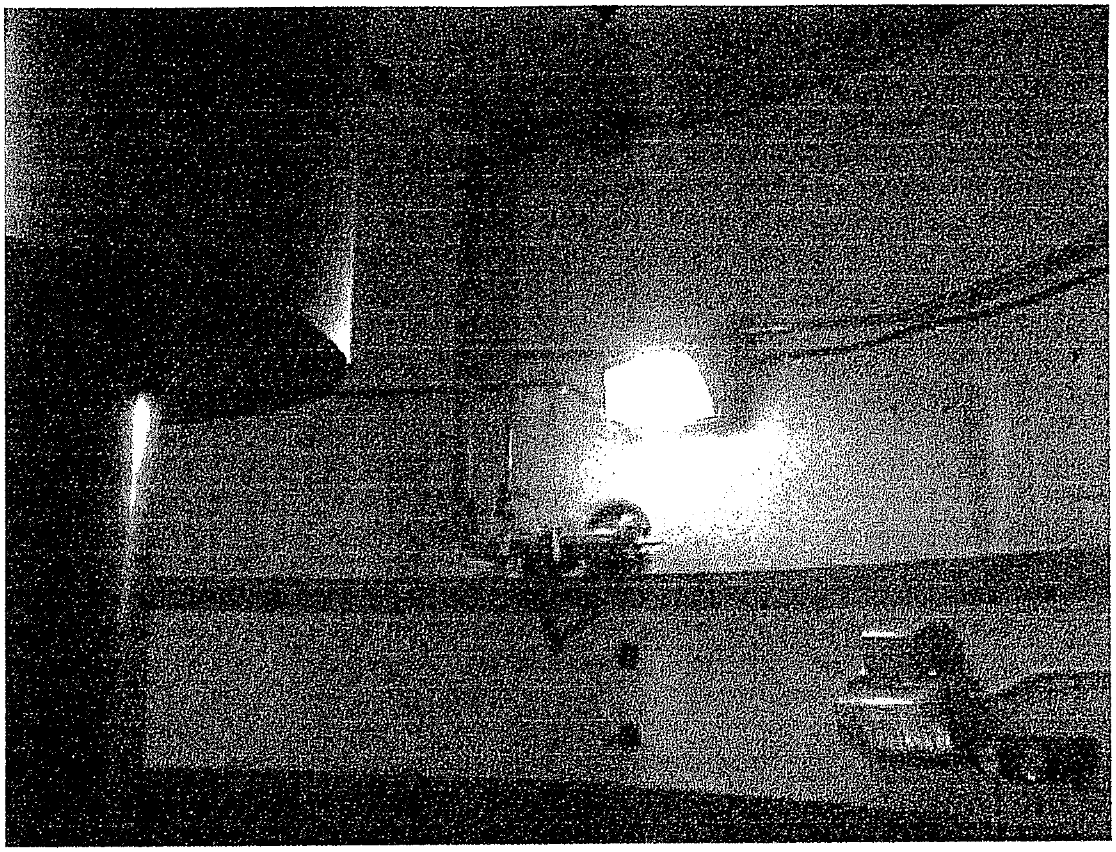


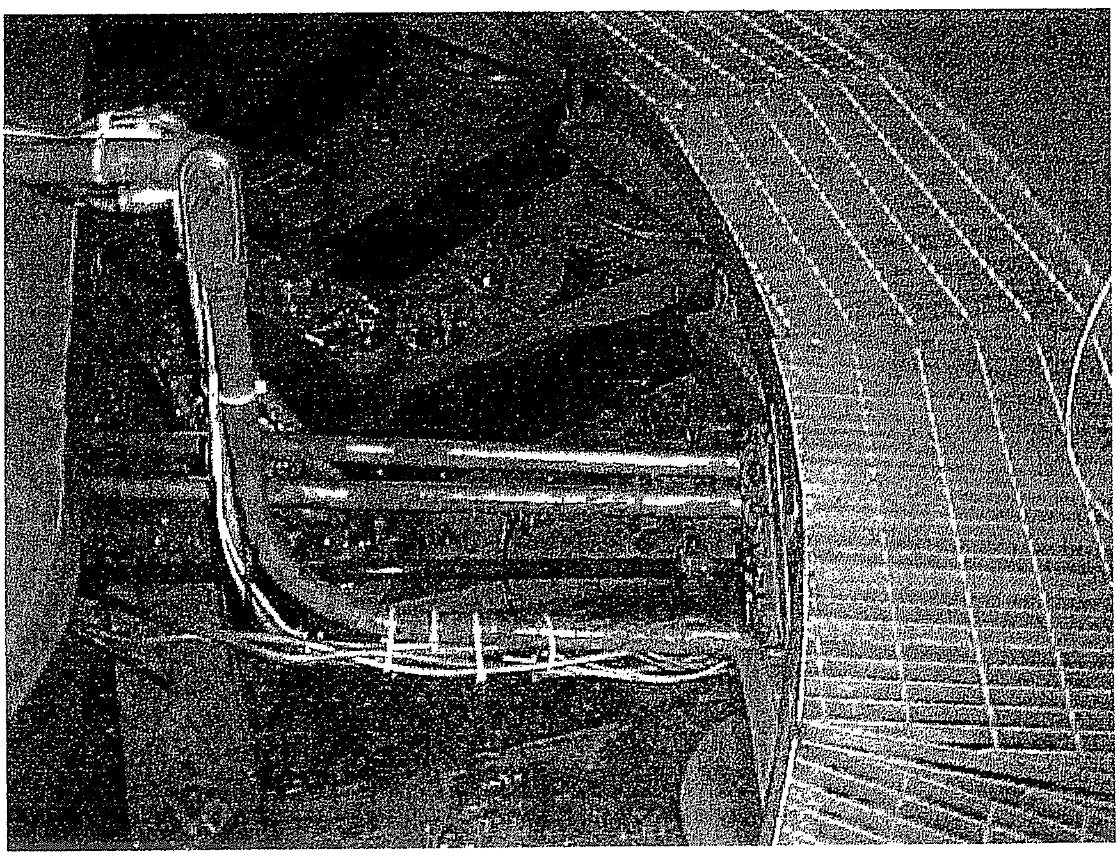


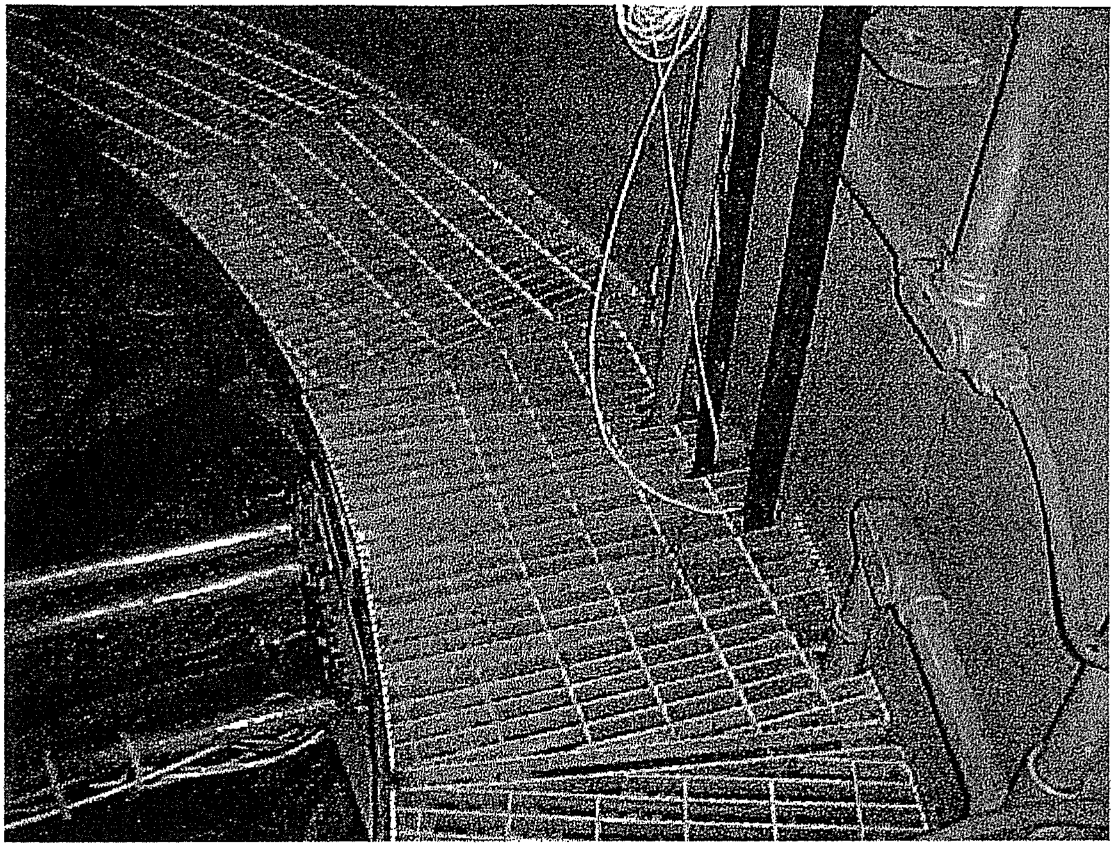


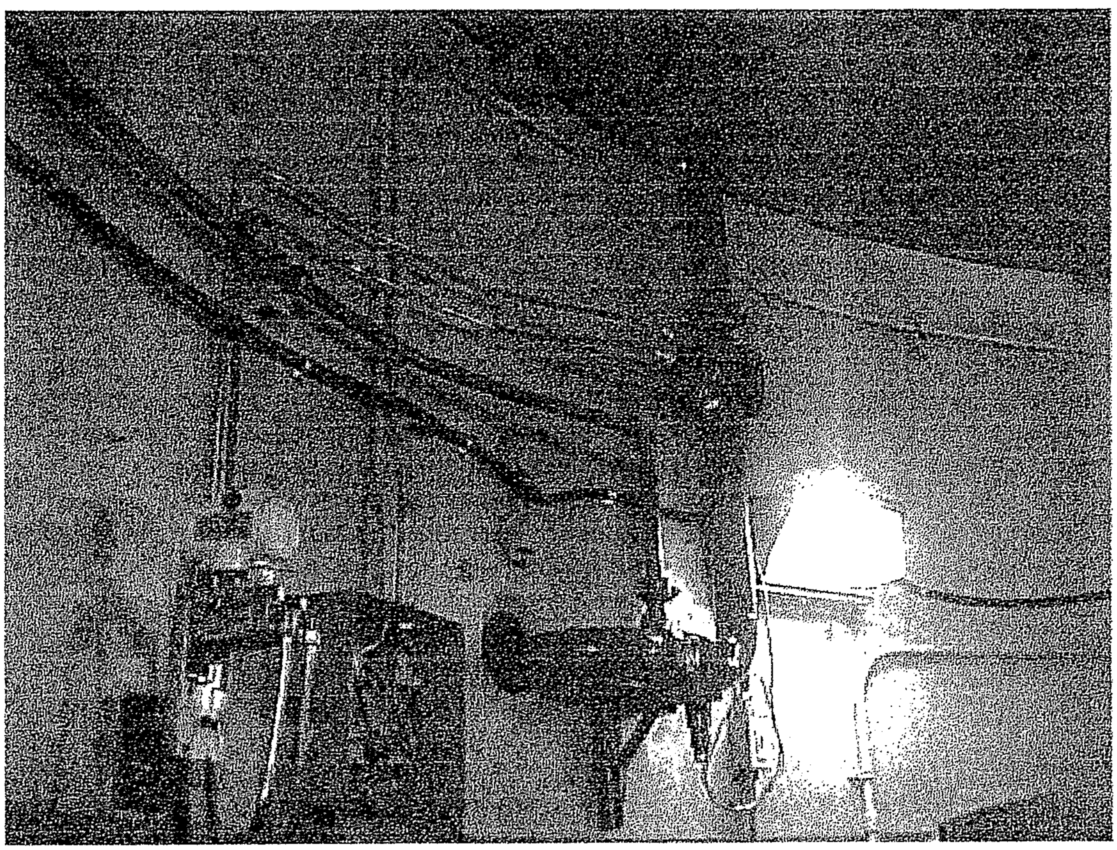












Appendix C:
BetzDearborn Water Analysis

ɔort of deposit analysis. Deposit removed from 10 inch diam cooling water header at Bay Ɛspoir

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 D:
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	64	**$ 7,571.28**
Surface Air Cooler Pipe	32	**$ 3,785.64**
Generator Coolers	64	**$ 7,571.28**
Generator Cooler Pipe	32	**$ 3,785.64**

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 ($)
Supply Header									
3" Carbon Steel Pipe Schd 40	20	3.78	75.60	Q15	43	0.47	946.41	440.19	515.79
2" Carbon Steel Pipe Schd 40	40	1.88	75.20	Q15	61	0.66	946.41	620.60	695.80
8" Gate Valve - 150 - Flanged	2	1134.00	2268.00	Q2	2.5	0.80	946.41	757.13	3025.13
6" Gate Valve - 150 - Flanged	2	640.80	1281.60	Q2	3	0.67	946.41	630.94	1912.54
3" Gate Valve - 150 - Flanged	6	346.80	2080.80	Q1	4.5	1.33	665.27	887.02	2967.82
3" Globe Valve - 150 - Flanged	1	488.40	488.40	Q1	4.5	0.22	665.27	147.84	636.24
2" Gate Valve - 150 - Threaded	2	99.54	199.08	1 PLUM	11	0.18	384.12	69.84	268.92
1-1/4" Globe Valve - 150 - Threaded	1	132.24	132.24	1 PLUM	13	0.08	384.12	29.55	161.79
10" Slip on Welded Flanges	5	42.00	210.00	Q16	4	1.25	1227.55	1534.44	1744.44
8" Slip on Welded Flanges	10	25.95	259.50	Q16	5	2.00	1227.55	2455.10	2714.60
6" Slip on Welded Flanges	12	16.68	200.16	Q16	6	2.00	1227.55	2455.10	2655.26
3" Slip on Welded Flanges	35	9.27	324.45	Q15	9	3.89	946.41	3680.48	4004.93
8" x 10" Reducer - Flanged	2	27.49	54.98	Q16	4	0.50	1227.55	613.78	668.76
3" x 6" Reducer - Schd 40 - Butt Welded	2	14.21	28.42	Q2	10	0.20	946.41	189.28	217.70
3" x 2" Reducer - Schd 40 - Butt Welded	1	5.44	5.44	Q1	12	0.08	665.27	55.44	60.88
10" Elbow 45 - Schd 40 - Butt Welded	1	78.99	78.99	Q2	7	0.14	946.41	135.20	214.19
6" Elbow 90 - Schd 40 - Butt Welded	2	22.24	44.48	Q2	9	0.22	946.41	210.31	254.79
3" Elbow 45 - Schd 40 - Butt Welded	2	5.50	11.00	Q1	11	0.18	665.27	120.96	131.96
3" Elbow 90 - Schd 40 - Butt Welded	6	7.28	43.68	Q1	11	0.55	665.27	362.87	406.55
2" Elbows 90 - Schd 40 - Threaded	3	1.41	4.23	Q1	13	0.23	665.27	153.52	157.75
2" Elbows 45 - Schd 40 - Threaded	2	1.59	3.18	Q1	13	0.15	665.27	102.35	105.53
10" x 8" x 8" Tee Schd 40 - Butt Welded	1	254.66	254.66	Q2	4	0.25	946.41	236.60	491.26
8" x 6" x 6" Tee Schd 40 - Butt Welded	3	104.35	313.05	Q2	5	0.60	946.41	567.85	880.90
8" Tee Schd 40 - Butt Welded	1	104.35	104.35	Q2	5	0.20	946.41	189.28	293.63
6" x 6" x 3" Tee Schd 40 - Butt Welded	1	54.51	54.51	Q2	6	0.17	946.41	157.73	212.24
3" x 3" x 2" Tee - Schd 40 - Butt Welded	2	23.48	46.96	Q1	7	0.29	665.27	190.08	237.04
3" Tee Schd 40 - Butt Welded	3	18.62	55.86	Q1	7	0.43	665.27	285.11	340.97
1-1/4" Union - Schd 40 - Threaded	1	2.38	2.38	Q1	21	0.05	665.27	31.68	34.06
2" Union - Schd 40 - Threaded	2	3.95	7.90	Q1	17	0.12	665.27	78.27	86.17
Supply Header Total:			8709.10			17.90		17388.55	26097.65

Item	Quantity (ea. ft.)	Unit Cost ($/ea.)	Material Cost ($)	Crew Type	Crew Capacity (/day)	Install Time (days)	Crew Cost ($/day)	Labor Cost ($)	Total Cost ($)
Discharge Header (Carbon Steel)									
8" Carbon Steel Pipe Schd 40	20	12.48	249.60	Q16	19	1.05	1227.55	1292.16	1541.76
8" Elbow 90 - Schd 40 - Butt Welded	2	44.48	88.96	Q2	8	0.25	946.41	236.60	325.56
8" Elbow 45 - Schd 40 - Butt Welded	2	55.00	110.00	Q2	8	0.25	946.41	236.60	346.60
8" Slip-on Welded Flanges	12	25.95	311.40	Q16	5	2.40	1227.55	2946.12	3257.52
8" Gate Valve - 150 - Flanged	1	1134.00	1134.00	Q2	2.5	0.40	946.41	378.56	1512.56
Discharge Header Total:			1893.96			4.35		5090.05	6984.01
Surface Air Coolers Supply and Discharge Piping (Carbon Steel)									
8" Carbon Steel Pipe Schd 40	20	12.48	249.60	Q2	37	0.54	946.41	511.57	761.17
5" Carbon Steel Pipe Schd 40	60	7.26	435.60	Q1	37	1.62	665.27	1078.81	1514.41
4" Carbon Steel Pipe Schd 40	120	4.75	570.00	Q1	45	2.67	665.27	1774.05	2344.05
4" Butterfly Valves - 150 - Victaulic	16	204.01	3264.16	Q1	38	0.42	665.27	280.11	3544.27
8" Elbow 90 - Victaulic	2	101.27	202.54	Q2	21	0.10	946.41	90.13	292.67
5" Elbow 45 - Victaulic	4	45.43	181.72	Q1	20	0.20	665.27	133.05	314.77
4" Elbow 90 - Victaulic	24	19.27	462.48	Q1	25	0.96	665.27	638.66	1101.14
4" Elbow 45 - Victaulic	20	23.84	476.80	Q1	25	0.80	665.27	532.21	1009.01
5" x 4" Reducer - Victaulic	8	27.62	220.96	Q1	42	0.19	665.27	126.72	347.68
8" Tee - Victaulic	2	168.26	336.52	Q2	14	0.14	946.41	135.20	471.72
5" Tee - Victaulic	4	72.56	290.24	Q1	13	0.31	665.27	204.70	494.94
4" Tee - Victaulic	16	37.56	600.96	Q1	17	0.94	665.27	626.13	1227.09
3/4" Automatic Air Vent	8	87.47	699.76	1 PLUM	12	0.67	384.12	256.08	955.84
Surface Air Cooler Piping Total:			7991.34			9.55		6387.43	14378.77

Item	Quantity (ea. ft.)	Unit Cost ($/ea.)	Material Cost ($)	Crew Type	Crew Capacity (/day)	Install Time (days)	Crew Cost ($/day)	Labor Cost ($)	Total Cost ($)
Turbine Bearing and Shaft Seal Supply(Carbon Steel)									
1-1/4" Carbon Steel Pipe Schd 40	40	1.31	52.40	1 PLUM	43	0.93	384.12	357.33	409.73
3/4" Carbon Steel Pipe Schd 40	40	0.74	29.60	1 PLUM	71	0.56	384.12	216.41	246.01
1-1/4" Globe Valve - Threaded	1	132.24	132.24	1 PLUM	15	0.07	384.12	25.61	157.85
3/4" Globe Valve - Threaded	2	40.92	81.84	1 PLUM	20	0.10	384.12	38.41	120.25
1-1/4" Elbows 90 - Victaulic	8	12.22	97.76	1 PLUM	40	0.20	384.12	76.82	174.58
1-1/4" Elbows 45 - Victaulic	2	12.22	24.44	1 PLUM	40	0.05	384.12	19.21	43.65
3/4" Elbows 90 - Victaulic	6	12.22	73.32	1 PLUM	50	0.12	384.12	46.09	119.41
3/4" Elbows 45 - Victaulic	1	12.22	12.22	1 PLUM	50	0.02	384.12	7.68	19.90
3" Tee - Schd 40 - Victaulic	1	28.35	28.35	Q1	22	0.05	665.27	30.24	58.59
1-1/4" x 3" Reducer - Victaulic	1	68.46	68.46	Q1	34	0.03	665.27	19.57	88.03
1-1/4" Tee - Schd 40 - Victaulic	1	23.22	23.22	1 PLUM	27	0.04	384.12	14.23	37.45
3/4" x 1-1/4" Reducer - Victaulic	1	60.00	60.00	1 PLUM	65	0.02	384.12	5.91	65.91
3/4" Tee - Victaulic	4	23.22	92.88	1 PLUM	38	0.11	384.12	40.43	133.31
Turbine Bearing Cooler Supply Total:			776.73			2.28		897.94	1674.67
Subtotal:			19371			34		29764	49135
15% Contingency:			2906			5		4465	7370
Piping Cost (Carbon Steel):			**22277**			**39**		**34229**	**56505**

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 ($)
Supply Header (PVC)									
8" PVC Pipe Schd 80	20	12.06	241.20	Q2	47	0.43	946.41	402.73	643.93
3" PVC Pipe Schd 80	20	2.86	57.20	Q1	50	0.40	665.27	266.11	323.31
2" PVC Pipe Schd 80	40	1.32	52.80	Q1	55	0.73	665.27	483.83	536.63
8" Butterfly Valve - Steel/Rubber Lined	2	390.04	780.08	Q2	2.5	0.80	946.41	757.13	1537.21
6" Butterfly Valve - PVC - Flanged	2	362.01	724.02	Q2	3	0.67	946.41	630.94	1354.96
3" Butterfly Valve - PVC - Flanged	6	204.33	1225.98	1 PLUM	27.6	0.22	384.12	83.51	1309.49
3" Globe Valve - PVC - Flanged	1	496.42	496.42	1 PLUM	27.6	0.04	384.12	13.92	510.34
2" Butterfly Valve - PVC - Flanged	2	184.85	369.70	1 PLUM	19.55	0.10	384.12	39.30	409.00
1-1/4" Globe Valve - PVC - Socket	1	100.51	100.51	1 PLUM	21	0.05	384.12	18.29	118.80
10" Flanged Adapters - PVC - Socket	3	328.79	986.37	Q2	14	0.21	946.41	202.80	1189.17
8" Flanged Adapters - PVC - Socket	8	40.91	327.28	Q2	17.1	0.47	946.41	442.76	770.04
6" Flanged Adapters - PVC - Socket	3	22.87	68.61	Q1	18.5	0.16	665.27	107.88	176.49
3" Flanged Adapters - PVC - Socket	14	11.12	155.68	Q1	30.3	0.46	665.27	307.38	463.06
2" Flanged Adapters - PVC - Socket	4	6.07	24.28	Q1	60.6	0.07	665.27	43.91	68.19
8" x 10" Reducer - PVC - Socket - Schd 80	2	139.40	278.80	Q2	10.1	0.20	946.41	187.41	466.21
3" x 6" Reducer - PVC - Socket - Schd 80	2	18.30	36.60	Q1	11.1	0.18	665.27	119.87	156.47
3" x 2" Reducer - PVC - Socket - Schd 80	1	12.88	12.88	Q1	36.4	0.03	665.27	18.28	31.16
8" x 6" Reducer - PVC - Socket - Schd 80	3	44.51	133.53	Q2	10.2	0.29	946.41	278.36	411.89
10" Elbow 45 - PVC - Socket - Schd 80	1	246.42	246.42	Q2	9.3	0.11	946.41	101.76	348.18
6" Elbow 90 - PVC - Socket - Schd 80	2	27.53	55.06	Q1	10.1	0.20	665.27	131.74	186.80
3" Elbow 45 - PVC - Socket - Schd 80	2	6.38	12.76	Q1	20.8	0.10	665.27	63.97	76.73
3" Elbow 90 - PVC - Socket - Schd 80	6	6.38	38.28	Q1	20.8	0.29	665.27	191.90	230.18
2" Elbows 90 - PVC - Socket - Schd 80	3	2.54	7.62	Q1	33.1	0.09	665.27	60.30	67.92
2" Elbows 45 - PVC - Socket - Schd 80	2	3.00	6.00	Q1	33.1	0.06	665.27	40.20	46.20
10" x 8" x 8" Tee - PVC - Socket - Schd 80	1	554.57	554.57	Q2	5.7	0.18	946.41	166.04	720.61
8" x 8" x 6" Tee - PVC - Socket - Schd 80	3	116.81	350.43	Q2	6.2	0.48	946.41	457.94	808.37
8" Tee - PVC - Socket - Schd 80	1	116.81	116.81	Q2	6.2	0.16	946.41	152.65	269.46
6" x 6" x 3" Tee - PVC - Socket - Schd 80	1	48.74	48.74	Q1	6.7	0.15	665.27	99.29	148.03
3" x 3" x 2" Tee - PVC - Socket - Schd 80	2	36.30	72.60	Q1	13.9	0.14	665.27	95.72	168.32
3" Tee - PVC - Socket - Schd 80	3	11.71	35.13	Q1	13.9	0.22	665.27	143.58	178.71
1-1/4" Union - PVC - Socket - Schd 80	1	7.62	7.62	1 PLUM	15.5	0.06	384.12	24.78	32.40
2" Union - PVC - Socket - Schd 80	2	11.68	23.36	Q1	28.1	0.07	665.27	47.35	70.71
Supply Header Total:			7647.34			7.80		6181.62	13828.96

Item	Quantity (ea. ft.)	Unit Cost ($/ea.)	Material Cost ($)	Crew Type	Crew Capacity (/day)	Install Time (days)	Crew Cost ($/day)	Labor Cost ($)	Total Cost ($)
Discharge Header (PVC)									
8" PVC Pipe Schd 80	20	12.06	241.20	Q2	47	0.43	946.41	402.73	643.93
8" Elbow 90 - PVC - Socket - Schd 80	2	75.90	151.80	Q2	9.3	0.22	946.41	203.53	355.33
8" Elbow 45- PVC - Socket - Schd 80	2	100.00	200.00	Q2	9.3	0.22	946.41	203.53	403.53
8" Flanged Adapters - PVC - Socket	4	40.91	163.64	Q2	17.1	0.23	946.41	221.38	385.02
8" Butterfly Valve - Steel/Rubber Lined	1	390.04	390.04	Q2	4.5	0.22	946.41	210.31	600.35
Discharge Header Total:			1146.68			1.31		1241.48	2388.16
Surface Air Coolers Supply and Discharge Piping (Stainless Steel)									
8" Stainless Steel Pipe Schd 10	20	43.23	864.60	Q2	41	0.49	946.41	461.66	1326.26
5" Stainless Steel Pipe Schd 10	60	38.35	2301.00	Q1	40	1.50	665.27	997.90	3298.90
4" Stainless Steel Pipe Schd 10	120	16.11	1933.20	Q1	49	2.45	665.27	1629.23	3562.43
4" Butterfly Valves - Rubber Lined - Victauli	16	202.25	3236.00	Q1	39	0.41	665.27	272.93	3508.93
8" Elbow 90 - Victaulic	2	101.27	202.54	Q2	21	0.10	946.41	90.13	292.67
5" Elbow 45 - Victaulic	4	45.43	181.72	Q1	20	0.20	665.27	133.05	314.77
4" Elbow 90 - Victaulic	24	19.27	462.48	Q1	25	0.96	665.27	638.66	1101.14
4" Elbow 45 - Victaulic	20	23.84	476.80	Q1	25	0.80	665.27	532.21	1009.01
5" x 4" Reducer - Victaulic	8	27.62	220.96	Q1	42	0.19	665.27	126.72	347.68
8" Tee - Victaulic	2	168.26	336.52	Q2	14	0.14	946.41	135.20	471.72
5" Tee - Victaulic	4	72.56	290.24	Q1	13	0.31	665.27	204.70	494.94
4" Tee - Victaulic	16	37.56	600.96	Q1	17	0.94	665.27	626.13	1227.09
3/4" Automatic Air Vent - PVC	8	20.85	166.80	1 PLUM	12	0.67	384.12	256.08	422.88
Surface Air Cooler Piping Total:			11273.82			9.15		6104.61	17378.43

Item	Quantity (ea. ft.)	Unit Cost ($/ea.)	Material Cost ($)	Crew Type	Crew Capacity (/day)	Install Time (days)	Crew Cost ($/day)	Labor Cost ($)	Total Cost ($)
Turbine Bearing Supply (Stainless Steel)									
1-1/4" Stainless Steel Pipe Schd 10	40	6.25	250.00	1 PLUM	58	0.69	384.12	264.91	514.91
3/4" Stainless Steel Pipe Schd 10	40	3.08	123.20	1 PLUM	71	0.56	384.12	216.41	339.61
1-1/4" Globe Valve - Threaded	1	140.50	140.50	1 PLUM	15	0.07	384.12	25.61	166.11
3/4" Globe Valve - Threaded	2	47.36	94.72	1 PLUM	20	0.10	384.12	38.41	133.13
1-1/4" Elbows 90 - Victaulic	8	12.22	97.76	1 PLUM	40	0.20	384.12	76.82	174.58
1-1/4" Elbows 45 - Victaulic	2	12.22	24.44	1 PLUM	40	0.05	384.12	19.21	43.65
3/4" Elbows 90 - Victaulic	6	12.22	73.32	1 PLUM	50	0.12	384.12	46.09	119.41
3/4" Elbows 45 - Victaulic	1	12.22	12.22	1 PLUM	50	0.02	384.12	7.68	19.90
3" Tee - Schd 40 - Victaulic	1	28.35	28.35	Q1	22	0.05	665.27	30.24	58.59
1-1/4" x 3" Reducer - Victaulic	1	68.46	68.46	Q1	34	0.03	665.27	19.57	88.03
1-1/4" Tee - Schd 40 - Victaulic	1	23.22	23.22	1 PLUM	27	0.04	384.12	14.23	37.45
3/4" x 1-1/4" Reducer - Victaulic	1	60.00	60.00	1 PLUM	65	0.02	384.12	5.91	65.91
3/4" Tee - Victaulic	4	23.22	92.88	1 PLUM	38	0.11	384.12	40.43	133.31
Turbine Bearing Cooler Supply Total:			1089.07			2.04		805.53	1894.60
Subtotal:			21157			20		14333	35490
15% Contingency:			3174			3		2150	5324
Piping Cost (Corrosion Resistant):			**24330**			**23**		**16483**	**40814**

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 ($)
Closed Loop Piping (PVC)									
8" PVC Pipe Schd 80	120	12.06	1447.20	Q2	47	2.55	946.41	2416.37	3863.57
3" PVC Pipe Schd 80	20	2.86	57.20	Q1	50	0.40	665.27	266.11	323.31
8" Butterfly Valve - Steel/Rubber Lined	10	390.04	3900.40	Q2	4.5	2.22	946.41	2103.13	6003.53
8" Check Valve - PVC - Wafer - Chemline	1	1174.87	1174.87	Q2	2.5	0.40	946.41	378.56	1553.43
3" Butterfly Valve - PVC - Flanged	1	204.33	204.33	Q1	27.6	0.04	665.27	24.10	228.43
8" Elbow - 90 - PVC - Socket - Schd 80	14	75.90	1062.60	Q2	9.3	1.51	946.41	1424.70	2487.30
8" Elbow - 45 - PVC - Socket - Schd 80	9	100.00	900.00	Q2	9.3	0.97	946.41	915.88	1815.88
3" Elbow - 90 - PVC - Socket - Schd 80	3	6.38	19.14	Q1	20.8	0.14	665.27	95.95	115.09
8" x 8" x 6" Tee - PVC - Socket - Schd 80	1	116.81	116.81	Q2	6.2	0.16	946.41	152.65	269.46
10" x 8" Reducer - PVC - Socket - Schd 80	3	139.40	418.20	Q2	10.1	0.30	946.41	281.11	699.31
6" x 3" Reducer - PVC - Socket - Schd 80	1	18.30	18.30	Q1	11.1	0.09	665.27	59.93	78.23
10" Flanged Adapters - Socket - Schd 80	3	328.79	986.37	Q2	14	0.21	946.41	202.80	1189.17
8" Flanged Adapters - Socket - Schd 80	18	40.91	736.38	Q2	17.1	1.05	946.41	996.22	1732.60
3" Flanged Adapters - Socket - Schd 80	2	11.12	22.24	Q1	30.3	0.07	665.27	43.91	66.15
Subtotal:			9560			7		6679	16239
15% Contingency:			1434			1		1002	2436
Total Estimated Piping Cost:			**10994**			**8**		**7681**	**18674**

Appendix E:
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:	$	(56,505.38)

Piping Replacement:

Replacement Freq. (yr):		25
Replacement Cost:	$	(56,505.38)

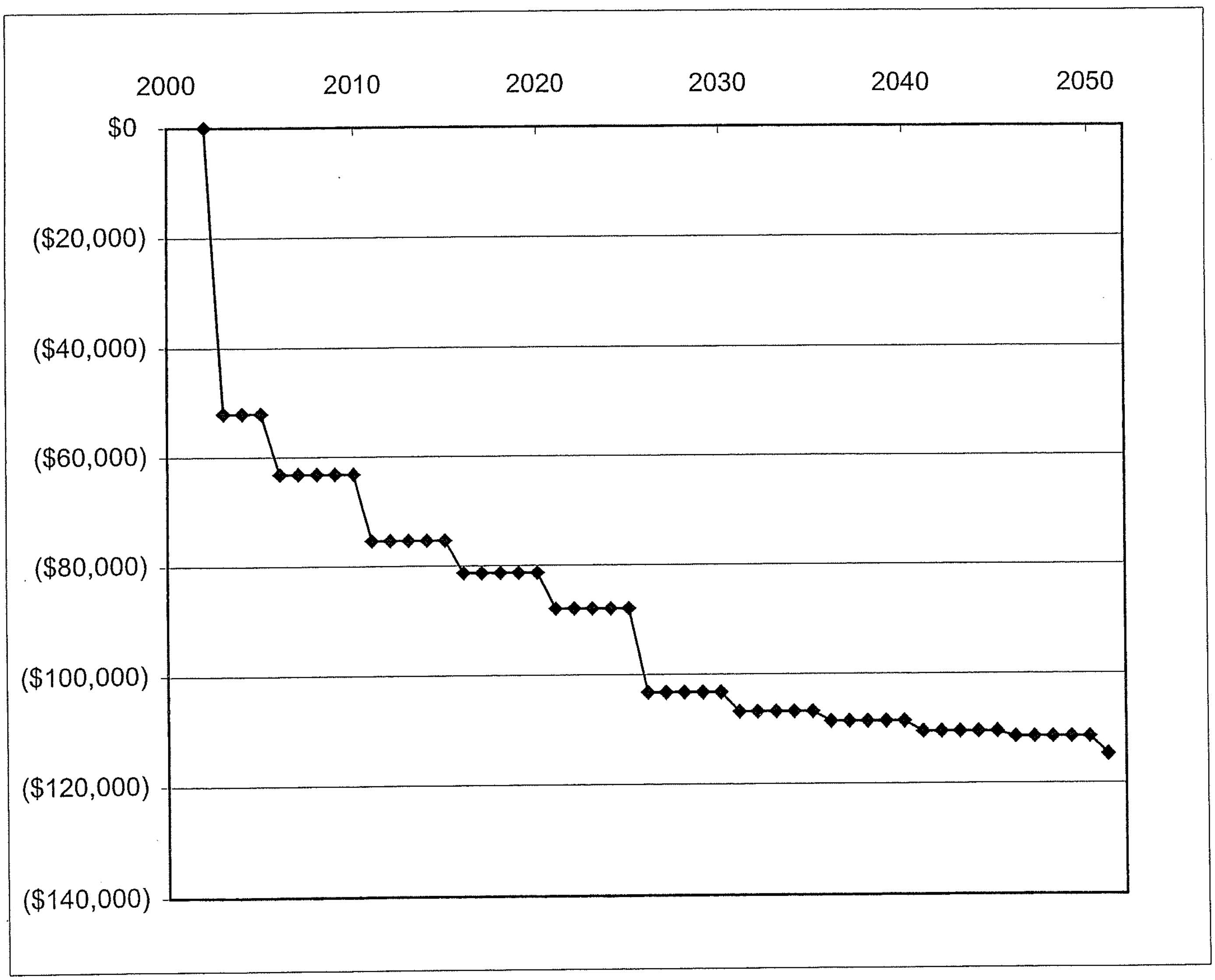
Operating Costs:

System Maintenance Costs:

SAC Frequency (yr):		5
SAC Cost:	$	(7,571.28)
SAC Pipe Freq. (yr):		10
SAC Pipe Cost:	$	(3,785.64)
Gen. Brg Freq. (yr)		5
Gen. Brg. Cost:	$	(7,571.28)
Gen. Brg. Pipe Freq.:		10
Gen. Brg. Pipe Cost:	$	(3,785.64)

Additional Annual Operating Costs:

None:	$	-



Net Present Worth: **($114,757)**

NPW Data Table for the Option: Operate As Current

No.	Year	SAC	SAC Pipe	Gen Brg.	Gen Pipe	Additional	Capital	Cash Flow	NPW
1	2002	0	0	0	0	0	-56505	-56505	0
2	2003	0	0	0	0	0	0	0	-52079
3	2004	0	0	0	0	0	0	0	-52079
4	2005	0	0	0	0	0	0	0	-52079
5	2006	-8359	0	-8359	0	0	0	-16719	-63197
6	2007	0	0	0	0	0	0	0	-63197
7	2008	0	0	0	0	0	0	0	-63197
8	2009	0	0	0	0	0	0	0	-63197
9	2010	0	0	0	0	0	0	0	-63197
10	2011	-9229	-4615	-9229	-4615	0	0	-27688	-75443
11	2012	0	0	0	0	0	0	0	-75443
12	2013	0	0	0	0	0	0	0	-75443
13	2014	0	0	0	0	0	0	0	-75443
14	2015	0	0	0	0	0	0	0	-75443
15	2016	-10190	0	-10190	0	0	0	-20380	-81438
16	2017	0	0	0	0	0	0	0	-81438
17	2018	0	0	0	0	0	0	0	-81438
18	2019	0	0	0	0	0	0	0	-81438
19	2020	0	0	0	0	0	0	0	-81438
20	2021	-11251	-5625	-11251	-5625	0	0	-33752	-88040
21	2022	0	0	0	0	0	0	0	-88040
22	2023	0	0	0	0	0	0	0	-88040
23	2024	0	0	0	0	0	0	0	-88040
24	2025	0	0	0	0	0	0	0	-88040
25	2026	-12421	0	-12421	0	0	-92703	-117546	-103332
26	2027	0	0	0	0	0	0	0	-103332
27	2028	0	0	0	0	0	0	0	-103332
28	2029	0	0	0	0	0	0	0	-103332
29	2030	0	0	0	0	0	0	0	-103332
30	2031	-13714	-6857	-13714	-6857	0	0	-41143	-106892
31	2032	0	0	0	0	0	0	0	-106892
32	2033	0	0	0	0	0	0	0	-106892
33	2034	0	0	0	0	0	0	0	-106892
34	2035	0	0	0	0	0	0	0	-106892
35	2036	-15142	0	-15142	0	0	0	-30283	-108634
36	2037	0	0	0	0	0	0	0	-108634
37	2038	0	0	0	0	0	0	0	-108634
38	2039	0	0	0	0	0	0	0	-108634
39	2040	0	0	0	0	0	0	0	-108634
40	2041	-16718	-8359	-16718	-8359	0	0	-50153	-110553
41	2042	0	0	0	0	0	0	0	-110553
42	2043	0	0	0	0	0	0	0	-110553
43	2044	0	0	0	0	0	0	0	-110553
44	2045	0	0	0	0	0	0	0	-110553
45	2046	-18458	0	-18458	0	0	0	-36915	-111493
46	2047	0	0	0	0	0	0	0	-111493
47	2048	0	0	0	0	0	0	0	-111493
48	2049	0	0	0	0	0	0	0	-111493
49	2050	0	0	0	0	0	0	0	-111493
50	2051	-20379	0	-20379	0	0	-152089	-192847	-114757

Net Present Worth Analysis

Case Details

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

Capital Costs:

Piping - Carbon Steel	$	(56,505.38)
Injection Facility	$	(5,000.00)
Total:	$	(61,505.38)

Piping Replacement:

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

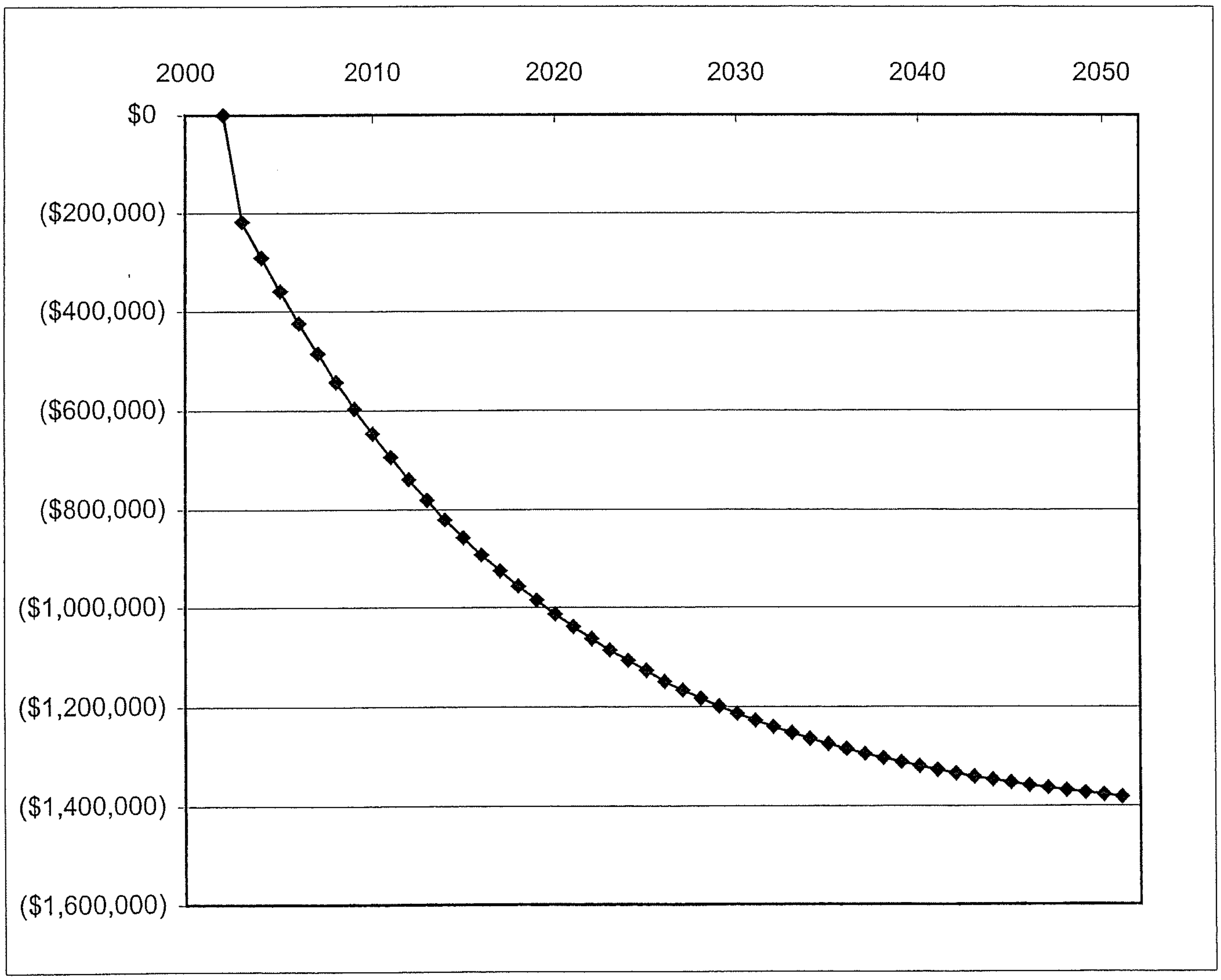
Operating Costs:

System Maintenance Costs:

SAC Frequency (yr):		25
SAC Cost:	$	(7,571.28)
SAC Pipe Freq. (yr):		50
SAC Pipe Cost:	$	(3,785.64)
Gen. Brg Freq. (yr)		25
Gen. Brg. Cost:	$	(7,571.28)
Gen. Brg. Pipe Freq.:		50
Gen. Brg. Pipe Cost:	$	(3,785.64)

Additional Annual Operating Costs:

Chemical Costs:	$	(90,028.00)



Net Present Worth: ($1,382,906)

NPW Data Table for the Option: Chemical Injection

No.	Year	SAC	SAC Pipe	Gen Brg.	Gen Pipe	Additional	Capital	Cash Flow	NPW
1	2002	0	0	0	0	-90028	-61505	-151533	0
2	2003	0	0	0	0	-91829	0	-91829	-217666
3	2004	0	0	0	0	-93665	0	-93665	-290998
4	2005	0	0	0	0	-95538	0	-95538	-359936
5	2006	0	0	0	0	-97449	0	-97449	-424744
6	2007	0	0	0	0	-99398	0	-99398	-485669
7	2008	0	0	0	0	-101386	0	-101386	-542945
8	2009	0	0	0	0	-103414	0	-103414	-596790
9	2010	0	0	0	0	-105482	0	-105482	-647408
10	2011	0	0	0	0	-107592	0	-107592	-694995
11	2012	0	0	0	0	-109744	0	-109744	-739730
12	2013	0	0	0	0	-111939	0	-111939	-781786
13	2014	0	0	0	0	-114177	0	-114177	-821322
14	2015	0	0	0	0	-116461	0	-116461	-858489
15	2016	0	0	0	0	-118790	0	-118790	-893430
16	2017	0	0	0	0	-121166	0	-121166	-926278
17	2018	0	0	0	0	-123589	0	-123589	-957157
18	2019	0	0	0	0	-126061	0	-126061	-986187
19	2020	0	0	0	0	-128582	0	-128582	-1013478
20	2021	0	0	0	0	-131154	0	-131154	-1039134
21	2022	0	0	0	0	-133777	0	-133777	-1063253
22	2023	0	0	0	0	-136452	0	-136452	-1085927
23	2024	0	0	0	0	-139181	0	-139181	-1107242
24	2025	0	0	0	0	-141965	0	-141965	-1127281
25	2026	-12421	0	-12421	0	-144804	0	-169647	-1149351
26	2027	0	0	0	0	-147700	0	-147700	-1167061
27	2028	0	0	0	0	-150654	0	-150654	-1183709
28	2029	0	0	0	0	-153668	0	-153668	-1199361
29	2030	0	0	0	0	-156741	0	-156741	-1214074
30	2031	0	0	0	0	-159876	0	-159876	-1227906
31	2032	0	0	0	0	-163073	0	-163073	-1240910
32	2033	0	0	0	0	-166335	0	-166335	-1253134
33	2034	0	0	0	0	-169661	0	-169661	-1264627
34	2035	0	0	0	0	-173055	0	-173055	-1275430
35	2036	0	0	0	0	-176516	0	-176516	-1285587
36	2037	0	0	0	0	-180046	0	-180046	-1295135
37	2038	0	0	0	0	-183647	0	-183647	-1304111
38	2039	0	0	0	0	-187320	0	-187320	-1312549
39	2040	0	0	0	0	-191066	0	-191066	-1320482
40	2041	0	0	0	0	-194888	0	-194888	-1327939
41	2042	0	0	0	0	-198785	0	-198785	-1334950
42	2043	0	0	0	0	-202761	0	-202761	-1341541
43	2044	0	0	0	0	-206816	0	-206816	-1347737
44	2045	0	0	0	0	-210953	0	-210953	-1353561
45	2046	0	0	0	0	-215172	0	-215172	-1359037
46	2047	0	0	0	0	-219475	0	-219475	-1364185
47	2048	0	0	0	0	-223865	0	-223865	-1369024
48	2049	0	0	0	0	-228342	0	-228342	-1373574
49	2050	0	0	0	0	-232909	0	-232909	-1377851
50	2051	-20379	-10189	-20379	-10189	-237567	0	-298703	-1382906

Net Present Worth Analysis

Case Details

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

Capital Costs:

Piping - Non Corrosive:	$	(40,813.67)

Piping Replacement:

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

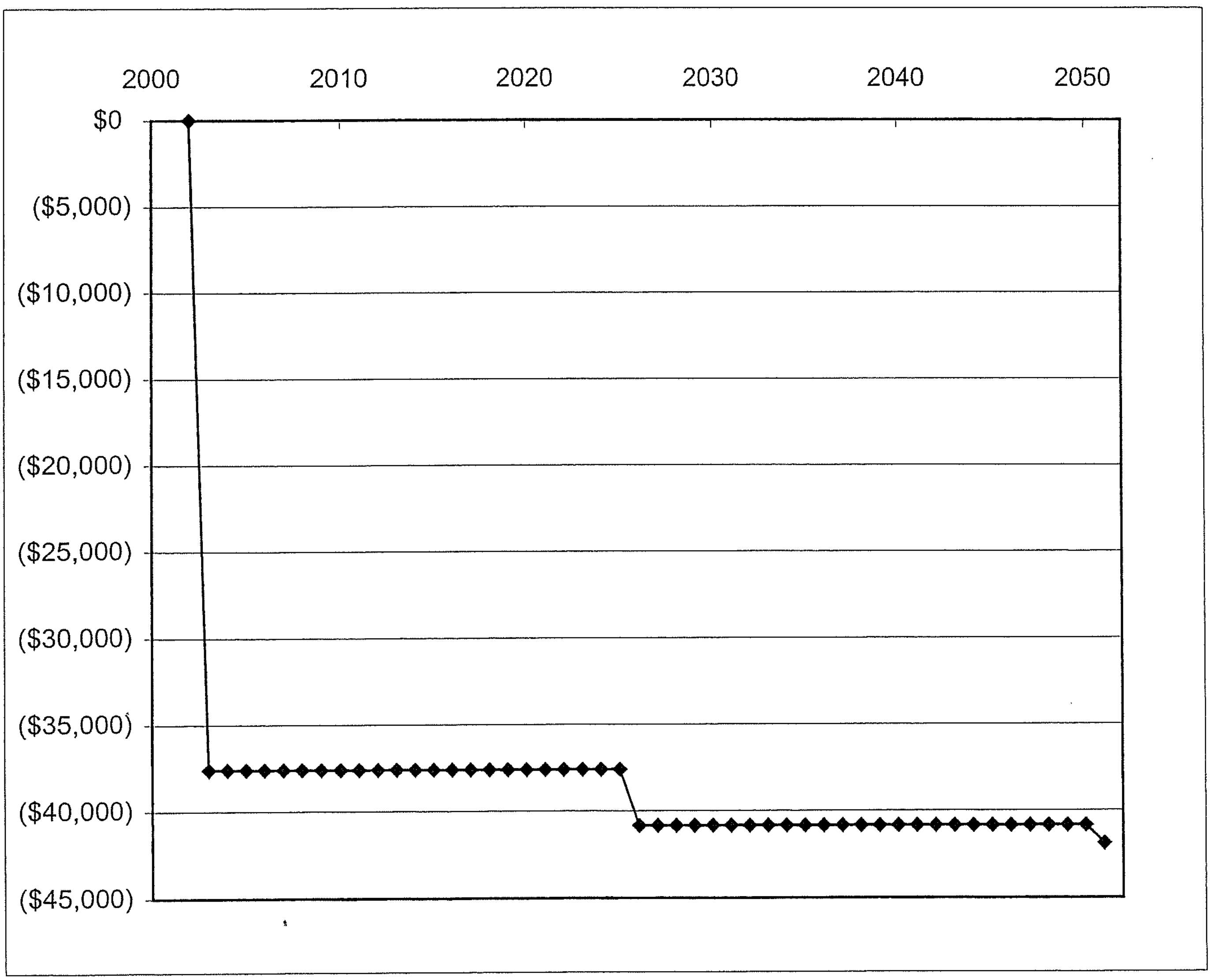
Operating Costs:

System Maintenance Costs:

SAC Frequency (yr):		25
SAC Cost:	$	(7,571.28)
SAC Pipe Freq. (yr):		50
SAC Pipe Cost:	$	(3,785.64)
Gen. Brg Freq. (yr)		25
Gen. Brg. Cost:	$	(7,571.28)
Gen. Brg. Pipe Freq.:		50
Gen. Brg. Pipe Cost:	$	(3,785.64)

Additional Annual Operating Costs:

None:	$	-



Net Present Worth: ($41,883)

NPW Data Table for the Option: Corrosion Resistant

No.	Year	SAC	SAC Pipe	Gen Brg.	Gen Pipe	Additional	Capital	Cash Flow	NPW
1	2002	0	0	0	0	0	-40814	-40814	0
2	2003	0	0	0	0	0	0	0	-37616
3	2004	0	0	0	0	0	0	0	-37616
4	2005	0	0	0	0	0	0	0	-37616
5	2006	0	0	0	0	0	0	0	-37616
6	2007	0	0	0	0	0	0	0	-37616
7	2008	0	0	0	0	0	0	0	-37616
8	2009	0	0	0	0	0	0	0	-37616
9	2010	0	0	0	0	0	0	0	-37616
10	2011	0	0	0	0	0	0	0	-37616
11	2012	0	0	0	0	0	0	0	-37616
12	2013	0	0	0	0	0	0	0	-37616
13	2014	0	0	0	0	0	0	0	-37616
14	2015	0	0	0	0	0	0	0	-37616
15	2016	0	0	0	0	0	0	0	-37616
16	2017	0	0	0	0	0	0	0	-37616
17	2018	0	0	0	0	0	0	0	-37616
18	2019	0	0	0	0	0	0	0	-37616
19	2020	0	0	0	0	0	0	0	-37616
20	2021	0	0	0	0	0	0	0	-37616
21	2022	0	0	0	0	0	0	0	-37616
22	2023	0	0	0	0	0	0	0	-37616
23	2024	0	0	0	0	0	0	0	-37616
24	2025	0	0	0	0	0	0	0	-37616
25	2026	-12421	0	-12421	0	0	0	-24843	-40848
26	2027	0	0	0	0	0	0	0	-40848
27	2028	0	0	0	0	0	0	0	-40848
28	2029	0	0	0	0	0	0	0	-40848
29	2030	0	0	0	0	0	0	0	-40848
30	2031	0	0	0	0	0	0	0	-40848
31	2032	0	0	0	0	0	0	0	-40848
32	2033	0	0	0	0	0	0	0	-40848
33	2034	0	0	0	0	0	0	0	-40848
34	2035	0	0	0	0	0	0	0	-40848
35	2036	0	0	0	0	0	0	0	-40848
36	2037	0	0	0	0	0	0	0	-40848
37	2038	0	0	0	0	0	0	0	-40848
38	2039	0	0	0	0	0	0	0	-40848
39	2040	0	0	0	0	0	0	0	-40848
40	2041	0	0	0	0	0	0	0	-40848
41	2042	0	0	0	0	0	0	0	-40848
42	2043	0	0	0	0	0	0	0	-40848
43	2044	0	0	0	0	0	0	0	-40848
44	2045	0	0	0	0	0	0	0	-40848
45	2046	0	0	0	0	0	0	0	-40848
46	2047	0	0	0	0	0	0	0	-40848
47	2048	0	0	0	0	0	0	0	-40848
48	2049	0	0	0	0	0	0	0	-40848
49	2050	0	0	0	0	0	0	0	-40848
50	2051	-20379	-10189	-20379	-10189	0	0	-61136	-41883

Net Present Worth Analysis

Case Details

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

Capital Costs:

Piping - Carbon Steel	$	(56,505.38)
Additional Piping Loop	$	(18,674.39)
Pump & Heat Exchanger	$	(45,000.00)
Total:	$	(120,179.77)

Piping Replacement:

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

Operating Costs:

Re-circulating Pump:

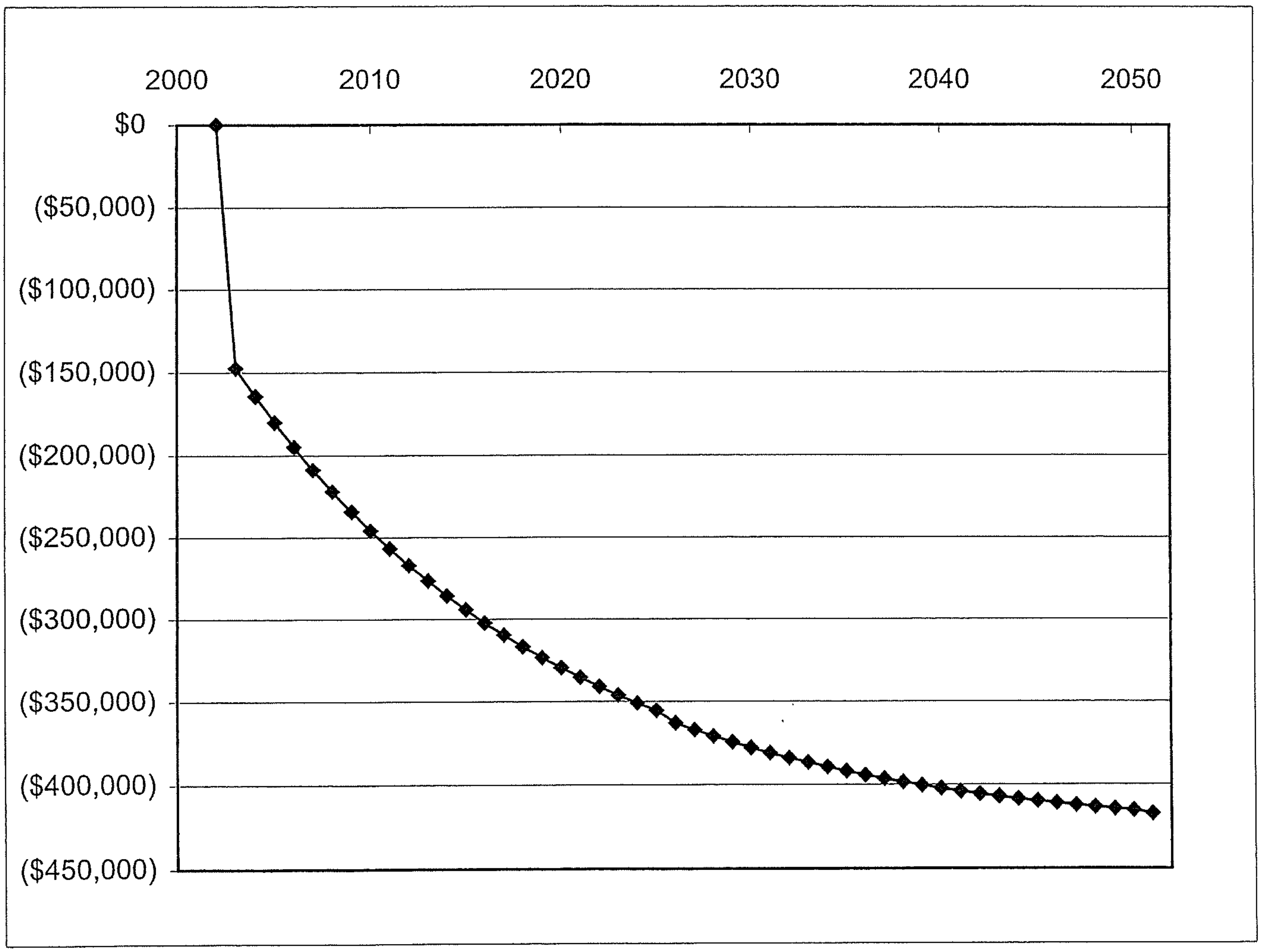
Pump Rating (hp):		60
Pump Rating (kW):		44.74
Electrical Cost ($/kWh):		0.05
Yearly Pump Cost:	$	(19,596.99)

System Maintenance Costs:

SAC Frequency (yr):		25
SAC Cost:	$	(7,571.28)
SAC Pipe Freq. (yr):		50
SAC Pipe Cost:	$	(3,785.64)
Gen. Brg Freq. (yr)		25
Gen. Brg. Cost:	$	(7,571.28)
Gen. Brg. Pipe Freq.:		50
Gen. Brg. Pipe Cost:	$	(3,785.64)

Additional Annual Operating Costs:

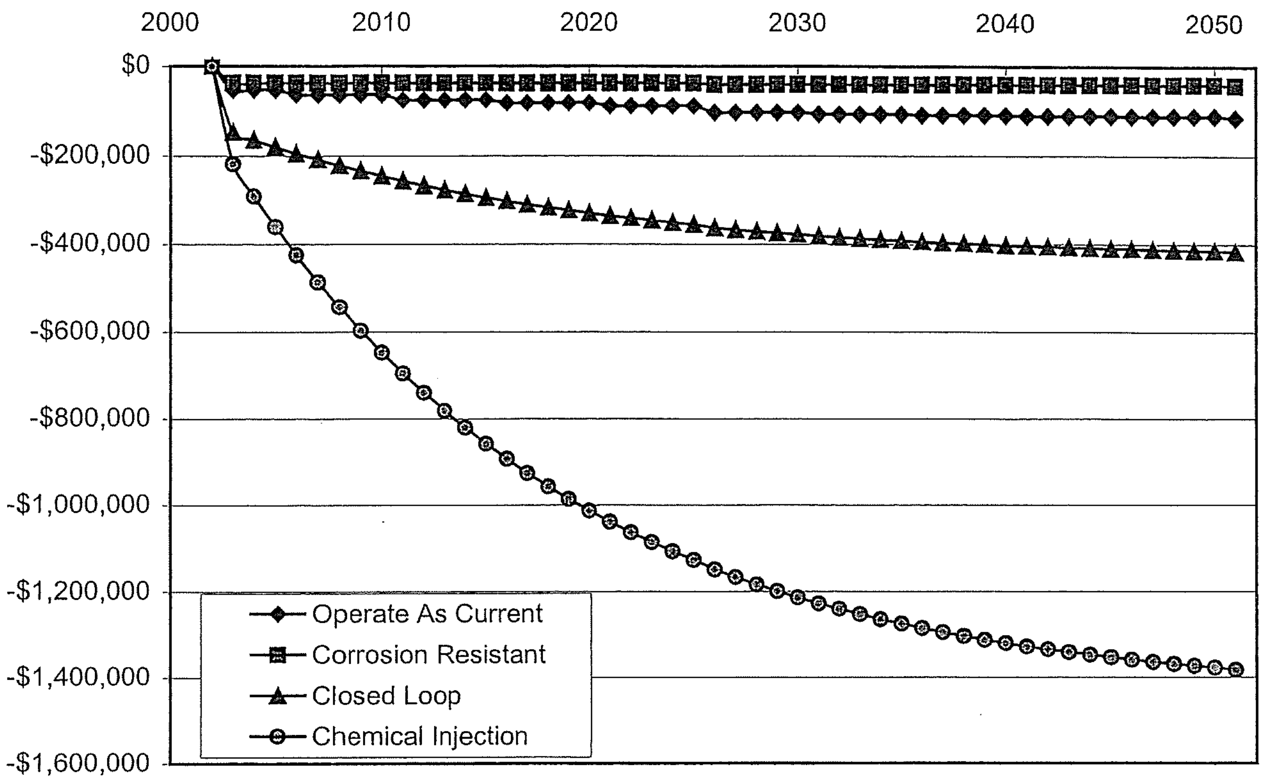
Heat Exchanger Maintenance	$	(1,000.00)



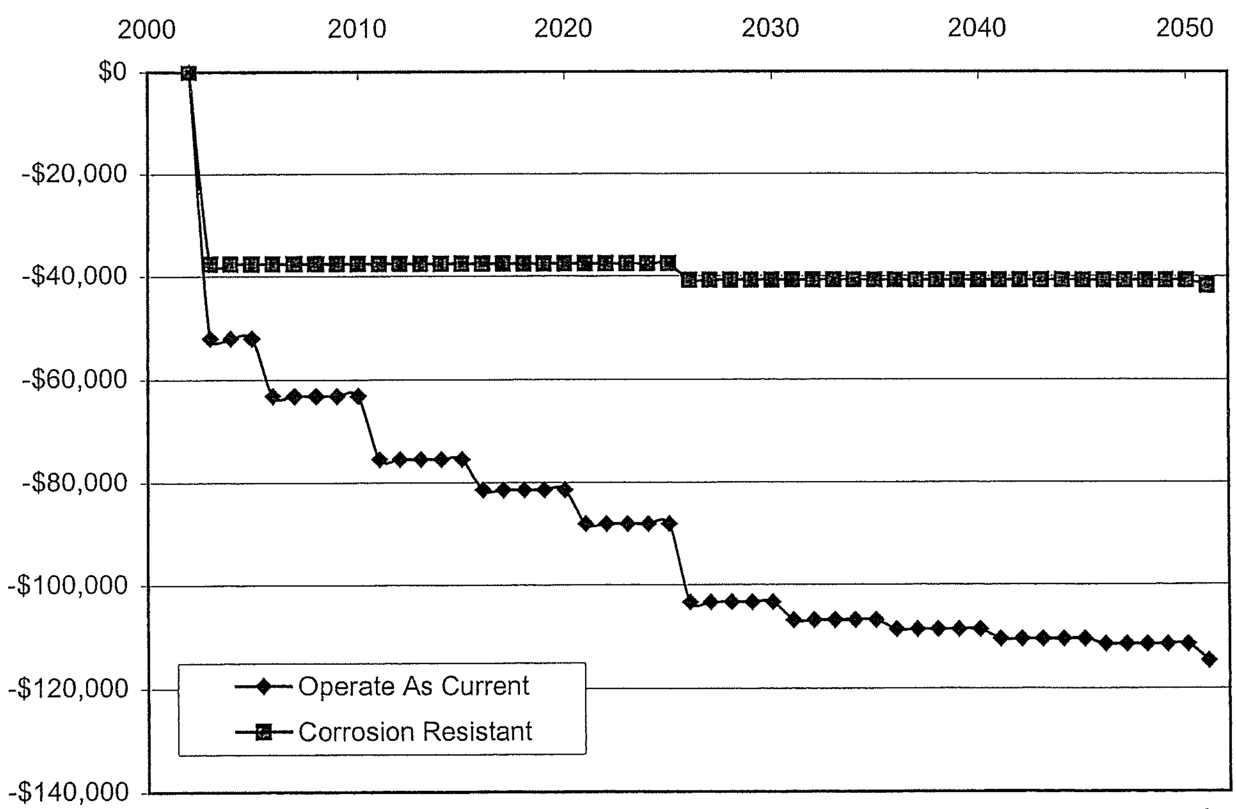
Net Present Worth: **($417,473)**

NPW Data Table for the Option: Closed Loop

No.	Year	Pump	SAC	SAC Pipe	Gen Brg.	Gen Pipe	Additional	Capital	Cash Flow	NPW
1	2002	-19597	0	0	0	0	-1000	-120180	-140777	0
2	2003	-19989	0	0	0	0	-1020	0	-21009	-147594
3	2004	-20389	0	0	0	0	-1040	0	-21429	-164371
4	2005	-20796	0	0	0	0	-1061	0	-21858	-180143
5	2006	-21212	0	0	0	0	-1082	0	-22295	-194970
6	2007	-21637	0	0	0	0	-1104	0	-22741	-208909
7	2008	-22069	0	0	0	0	-1126	0	-23196	-222013
8	2009	-22511	0	0	0	0	-1149	0	-23659	-234332
9	2010	-22961	0	0	0	0	-1172	0	-24133	-245913
10	2011	-23420	0	0	0	0	-1195	0	-24615	-256800
11	2012	-23889	0	0	0	0	-1219	0	-25108	-267034
12	2013	-24366	0	0	0	0	-1243	0	-25610	-276656
13	2014	-24854	0	0	0	0	-1268	0	-26122	-285701
14	2015	-25351	0	0	0	0	-1294	0	-26644	-294205
15	2016	-25858	0	0	0	0	-1319	0	-27177	-302198
16	2017	-26375	0	0	0	0	-1346	0	-27721	-309713
17	2018	-26902	0	0	0	0	-1373	0	-28275	-316778
18	2019	-27441	0	0	0	0	-1400	0	-28841	-323420
19	2020	-27989	0	0	0	0	-1428	0	-29418	-329664
20	2021	-28549	0	0	0	0	-1457	0	-30006	-335533
21	2022	-29120	0	0	0	0	-1486	0	-30606	-341051
22	2023	-29703	0	0	0	0	-1516	0	-31218	-346239
23	2024	-30297	0	0	0	0	-1546	0	-31843	-351115
24	2025	-30902	0	0	0	0	-1577	0	-32479	-355700
25	2026	-31521	-12421	0	-12421	0	-1608	0	-57972	-363242
26	2027	-32151	0	0	0	0	-1641	0	-33792	-367293
27	2028	-32794	0	0	0	0	-1673	0	-34467	-371102
28	2029	-33450	0	0	0	0	-1707	0	-35157	-374683
29	2030	-34119	0	0	0	0	-1741	0	-35860	-378049
30	2031	-34801	0	0	0	0	-1776	0	-36577	-381214
31	2032	-35497	0	0	0	0	-1811	0	-37309	-384189
32	2033	-36207	0	0	0	0	-1848	0	-38055	-386986
33	2034	-36931	0	0	0	0	-1885	0	-38816	-389615
34	2035	-37670	0	0	0	0	-1922	0	-39592	-392087
35	2036	-38423	0	0	0	0	-1961	0	-40384	-394410
36	2037	-39192	0	0	0	0	-2000	0	-41192	-396595
37	2038	-39976	0	0	0	0	-2040	0	-42016	-398648
38	2039	-40775	0	0	0	0	-2081	0	-42856	-400579
39	2040	-41591	0	0	0	0	-2122	0	-43713	-402394
40	2041	-42422	0	0	0	0	-2165	0	-44587	-404100
41	2042	-43271	0	0	0	0	-2208	0	-45479	-405704
42	2043	-44136	0	0	0	0	-2252	0	-46389	-407212
43	2044	-45019	0	0	0	0	-2297	0	-47316	-408629
44	2045	-45919	0	0	0	0	-2343	0	-48263	-409962
45	2046	-46838	0	0	0	0	-2390	0	-49228	-411215
46	2047	-47775	0	0	0	0	-2438	0	-50212	-412392
47	2048	-48730	0	0	0	0	-2487	0	-51217	-413499
48	2049	-49705	0	0	0	0	-2536	0	-52241	-414540
49	2050	-50699	0	0	0	0	-2587	0	-53286	-415519
50	2051	-51713	-20379	-10189	-20379	-10189	-2639	0	-115488	-417473

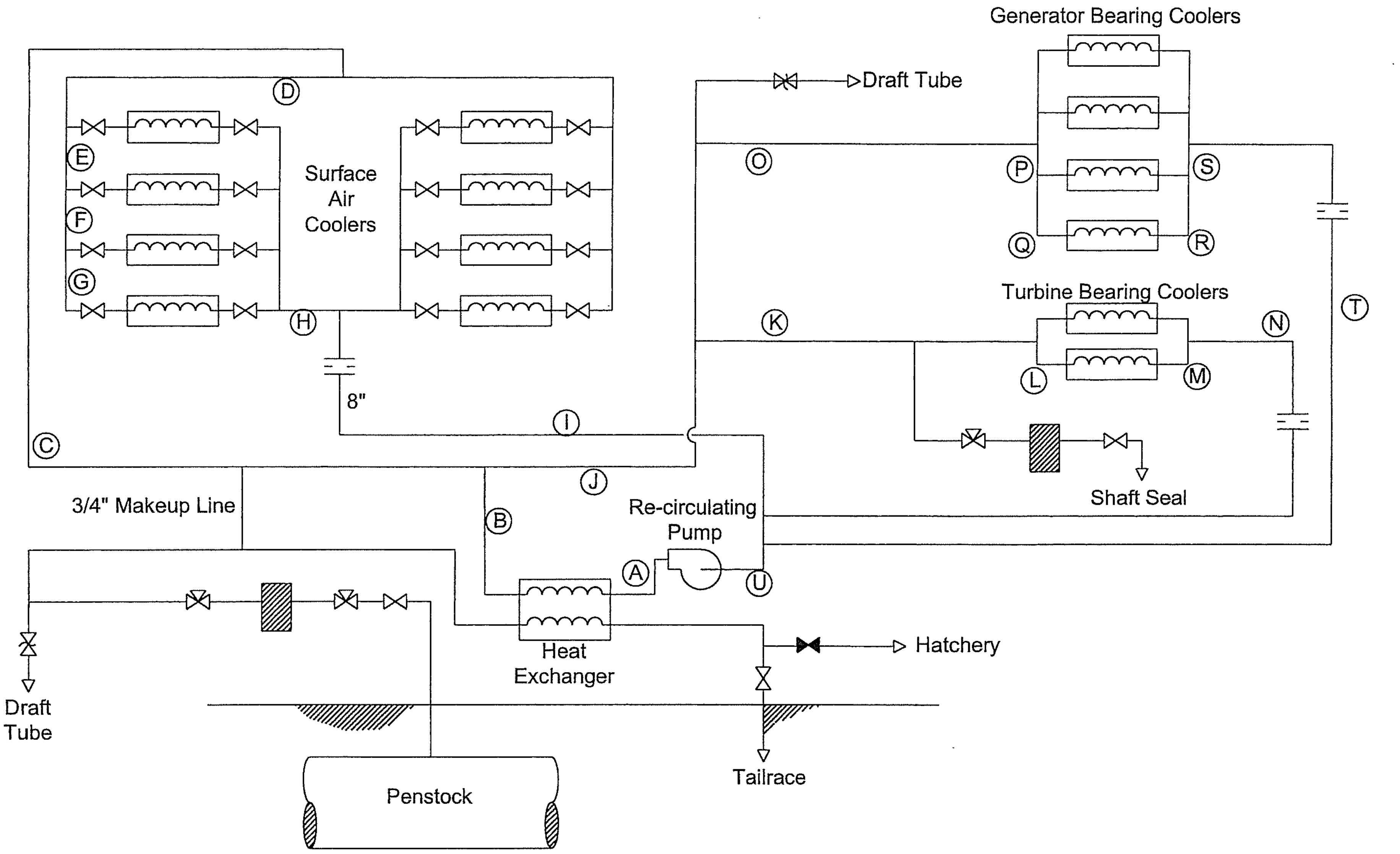


2000
2010
2020
2030
2040
2050
$0
-$200,000
-$400,000
-$600,000
-$800,000
-$1,000,000
-$1,200,000
-$1,400,000
-$1,600,000
Operate As Current
Corrosion Resistant
Closed Loop
Chemical Injection



2000
2010
2020
2030
2040
2050
$0
-$20,000
-$40,000
-$60,000
-$80,000
-$100,000
-$120,000
-$140,000
Operate As Current
Corrosion Resistant

Appendix F:
Closed Loop Piping and Equipment Details



Isolation Valve
Reducing Valve
Safety Valve
Flow Meter Orifice
Strainer

Unit Flow Diagram
Bay D'Espoir Powerhouse #2

Closed Loop Service Water System
Pipe Section Identification

Frictional Pressure Loss for each Section of Piping

Section	Flow Rate	Pipe Size		Length	Fittings Equivalent Length (ft)												Total Length	Pressure Loss	Pressure Loss
					Elbows		Tee St.		Tee Br.		Reducer		Valves		Other				
	(GPM)	*Nom*	*ID*	*(ft)*	*Qt.*	*(ft)*	*Qt.*	*(ft)*	*Qt.*	*(ft)*	*Qt.*	*(ft)*	*Qt.*	*(ft)*	*Qt.*	*(ft)*	*(ft)*	*(PSI/100ft)*	*(PSI)*
A	2100	8	7.97	10	1	20							1	4.5	1	4.5	39	3.27	1.277
B	2100	8	7.97	10	1	20			1	42			1	4.5			76.5	3.27	2.505
C	1920	8	7.97	15	3	20	1	20									95	2.77	2.633
D	960	5	5.044	10	2	13	1	13									49	7.52	3.685
E	720	5	5.044	15	1	13	1	13									41	4.40	1.806
F	480	4	4.026	15	1	11	1	11									37	6.40	2.366
G	240	4	4.026	15	3	11	1	11					1	2.2			61.2	1.76	1.078
H	960	5	5.044	10	2	13	1	13					1	2.8			51.8	7.52	3.896
I	1920	8	7.97	10	2	20											50	2.77	1.386
J	174	3	3.068	8	2	8			1	18							42	3.77	1.583
K	42	1 1/4	1.38	10	4	3.5							1	0.8			24.8	14.55	3.610
L	21	3/4	0.824	1	1	2											3	52.83	1.585
M	21	3/4	0.824	1	1	2											3	52.83	1.585
N	42	1 1/4	1.38	10	2	3.5							1	0.8			17.8	14.55	2.591
O	132	3	3.068	20	3	8	1	8	1	18			1				70	2.25	1.578
P	66	2	2.072	10	2	5	1	5									25	4.42	1.105
Q	33	1 1/4	1.38	10	2	3.5	1	3.5									20.5	9.29	1.905
R	33	1 1/4	1.38	10	2	3.5	1	3.5									20.5	9.29	1.905
S	66	2	2.072	10	2	5	1	5									25	4.42	1.105
T	132	3	3.068	20	3	8	1	8	1	18							70	2.25	1.578
U	2100	8	7.97	20	2	20							1	4.5			64.5	3.27	2.112
SAC																			5.000
GBC																			5.000
TBC																			5.000

Determine Frictional Pressure Drop for Pump

Notes:

- Static Head Neglected since system is a Closed Loop
- Typical Pressure Loss for Plate Heat Exchangers: 5 PSI
- Pressure Loss in Coolers Estimated as piping branches.

Path with the Highest Frictional Pressure Drop

Path 1		Path 2		Path 2	
Section A	1.277	Section A	1.277	Section A	1.277
Heat Exch	5	Heat Exch	5	Heat Exch	5
Section B	2.505	Section B	2.505	Section B	2.505
Section C	2.633	Section J	1.583	Section J	1.583
Section D	3.685	Section K	3.61	Section O	1.578
Section E	1.806	Section L	1.585	Section P	1.105
Section F	2.366	TBC	5	Section Q	1.905
Section G	1.078	Section M	1.585	GBC	5
SAC	5	Section N	2.591	Section R	1.905
Section H	3.896	Section U	2.112	Section S	1.105
Section I	1.386	**Total**	**26.85**	Section T	1.578
Section U	2.112			Section U	2.112
Total	**32.75**			**Total**	**26.66**

Maximum Frictional Pressure Drop 33 PSI

Pump Requirements

Flow Rate: 2100 GPM
Head + 15%: 87 ft

Model:3196	Size:6X8-17	Group:	60 Hz	RPM:1180	Stages:1

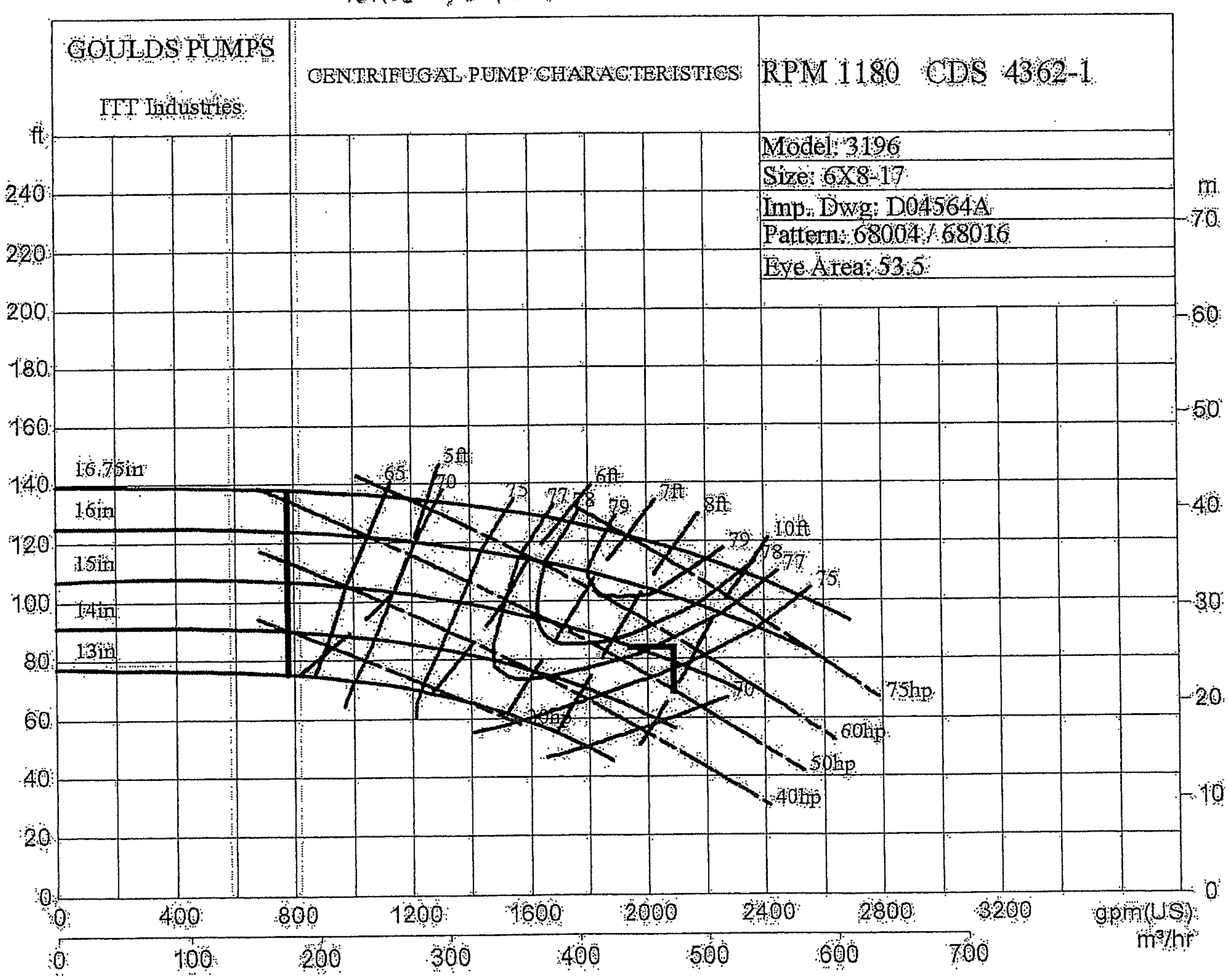
Purchaser:
User:
Item/Equip.No:
Service:

Date: 3/13/02
Certified By: ____________

Operating Conditions		Pump Performance			
Liquid:	Water	Rated Efficiency:	76.5 %	Suction Specific Speed:	11340 (gpm(US) , ft)
Temp.:	70 °F	Rated Pump Power:	59.8 hp	Min. Cont. Stable Flow:	778 gpm(US)
Sp. Heat:		Mech/Dyn Seal Loss:	0 hp	Min. Cont. Thermal Flow:	
S.G./Visc.:	1	Other Power Loss:	0 hp		
Flow:	2100 gpm(US)	Rated Total Power:	59.8 hp	Non-Overloading Power:	63.5 hp
TDH:	85 ft	Impeller Dia. 1st stage:	15.375 in	Addt'l stages:	
NPSHa:		NPSHr:	9.3 ft		
		Shut off Head:	113.5 ft	Mag. Drive Circuit Flow:	
Max Dia. Solids:				Max Drive Power:	
% Solids:				Max Drive Temp:	
Vapor Press:				Max Motor Size:	

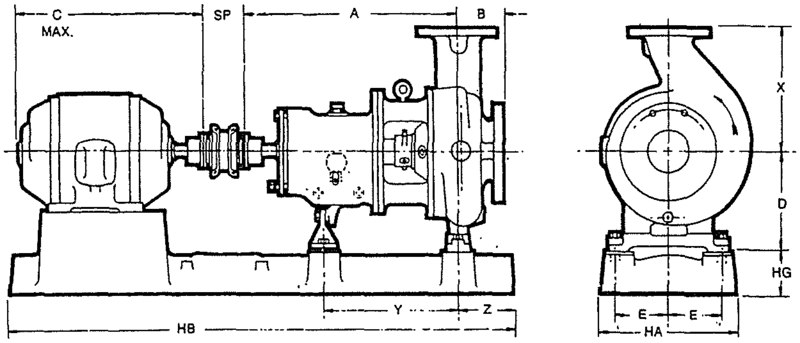
Notes: 1. Mechanical seal increased drag effect on power and efficiency is not included. 2. Magnetic drive eddy current and viscous effect on power and efficiency is not included. 3. Elevated temperature effects on performance are not included.

PUMP $15,000
MOTOR $5,000
TOTAL $20,000



Dimensions Model 3196

All dimensions in inches and (mm) Not to be used for construction.



DIMENSIONS DETERMINED BY PUMP

Model	Pump Size	ANSI Designation	Discharge Size	Suction Size	X	A	B	D	Y	Z	E	SP	Shaft Diameter at Cplg.	Key-Way	Pump Weight lbs. (kg.)
3196 ST	1 x 1½-6	AA	1	1½	6½ (165)	13½ (343)	4 (102)	5¼ (133)	7¼ (184)	4½ (114)	3 (76.2)	3¾ (95.3)	⅞ (22.2)	3/16 x 3/32 (4.8 x 2.4)	84 (38)
	1½ x 3-6	AB	1½	3											92 (42)
	2 x 3-6		2	3											95 (43)
	1 x 1½-8	AA	1	1½											100 (45)
	1½ x 3-8	AB	1½	3											108 (49)
3196 MT**	2 x 3-6	A10	2	3	8¼ (210)	19½ (495)	4 (102)	8¼ (210)	12½ (318)	4½ (114)	4⅞ (124)	3¾ (95.3)	1⅛ (28.6)	¼ x ⅛ (6.4 x 3.2)	180 (82)
	3 x 4-7	A70	3	4	11 (280)										220 (100)
	2 x 3-8	A60	2	3	9½ (242)										200 (91)
	3 x 4-8	A70	3	4	11 (280)										220 (100)
	3 x 4-8G	A70	3	4	11 (280)										220 (100)
	1 x 2-10	A05	1	2	8½ (216)										200 (91)
	1½ x 3-10	A50	1½	3	8½ (216)										220 (100)
	2 x 3-10	A60	2	3	9½ (242)										230 (104)
	3 x 4-10	A70	3	4	11 (280)										265 (120)
	3 x 4-10H	A40	3	4	12½ (318)	19½ (495)	4 (102)	10 (254)							275 (125)
	4 x 6-10	A80	4	6	13½ (343)										305 (138)
	1½ x 3-13	A20	1½	3	10½ (267)										245 (111)
	2 x 3-13	A30	2	3	11½ (292)										275 (125)
	3 x 4-13	A40	3	4	12½ (318)										330 (150)
	4 x 6-13	A80	4	6	13½ (343)										405 (184)
3196 XLT	6 x 8-13	A90	6	8	16 (406)	27⅞ (708)	6 (152)	14½ (368)	18¾ (476)	6½ (165)	8 (203)	5¼ (133)	2⅜ (60.3)	⅝ x 5/16 (15.9 x 7.9)	560 (254)
	8 x 10-13	A100	8	10	18 (457)										670 (304)
	6 x 8-15	A110	6	8	18 (457)										610 (277)
	8 x 10-15	A120	8	10	19 (483)										740 (336)
	8 x 10-15G	A120	8	10	12 (483)										710 (322)

**On LTC frame, shaft diameter at coupling is 1⅞. (47.6) keyway is ½" x ¼". (12.7) x (6.4) ps.

DIMENSIONS DETERMINED BY MOTOR

Model	Bed-plate	MOTOR: Motor Frame Sizes Applicable	MOTOR: C Max.	BEDPLATE: HA	BEDPLATE: HB	BEDPLATE: HG + ⅜ (9.5) − ⅛ (3.2)	BEDPLATE: Approx. Bedplate Weight Lbs. (kg.)
3196 ST	1	56-145	13½ (343)	10 (254)	35 (889)	3 (76.2)	75 (34)
	2	182-215	19½ (495)	12 (305)	39 (991)	3¼ (82.6)	80 (36)
	3	254-286	27 (686)	15 (381)	46 (1168)	4⅛ (105)	120 (54)
3196 MT	1	143-215	19½ (495)	12 (305)	45 (1143)	[1] 3¾ (95.3) / [2] 3¾ (95.3)	105 (48)
	2	254-286	27 (686)	15 (381)	52 (1321)	4⅛ (105) / 4⅛ (105)	155 (70)
	3	324-326	30 (762)	18 (457)	58 (1473)	4¾ (121) / 4¾ (121)	205 (93)
		364-365	34 (864)	18 (457)	58 (1473)	5¾ (146) / 4¾ (121)	
	4	404-405	35½ (902)	18 (457)	60 (1524)	6¾ (171) / 5 (127)	240 (109)
		440 SER	46½ (1181)	18 (457)	60 (1524)	7¾ (197) / 6 (152)	
3196 XLT	1	213-256	24 (610)	26 (660)	62 (1575)	4 (102)	375 (170)
	2	284-365	34 (864)	22 (559)	68 (1730)	4¾ (121)	
	3	404-445	46½ (1181)	22 (559)	80 (2032)	4¾ (121)	460 (209)
	4	447	46½ (181)	26 (660)	74 (1880)	4 (102)	435 (198)

[1] Applies to pumps where D = 8¼"
[2] Applies to pumps where D = 10"

TAPPED OPENINGS
Color Indicates Items furnished standard

PURPOSE	No. of Taps	TAP SIZE 3196 ST	TAP SIZE 3196 MT	TAP SIZE 3196 XLT
Lantern Ring Connection or Seal Flush	1	¼	⅜	⅜
Frame Adapter Drain	1	SLOT	1	1
Casing Drain (with asbestos gasket)	1	⅜"	⅜"	⅜"
Alternate Casing Drain	1	½"	½"	½"
Bearing Frame Cooling	4□	½	½"	½"
Discharge Gage Connection	1	¼"	⅜"	⅜"
Suction Gage Connection	1	¼"	⅜" ■	⅜"
Bypass Connection	1	¼"	½"	½"
Quench Gland Connection (packing gland)	2	¼	¼	¼

□ 2 Taps on Model 3196 XLT.

■ 4x6-10 and 4x6-13 have no tap. 3x4-8 and 3x4-13 have ¼" (6.4) tap.

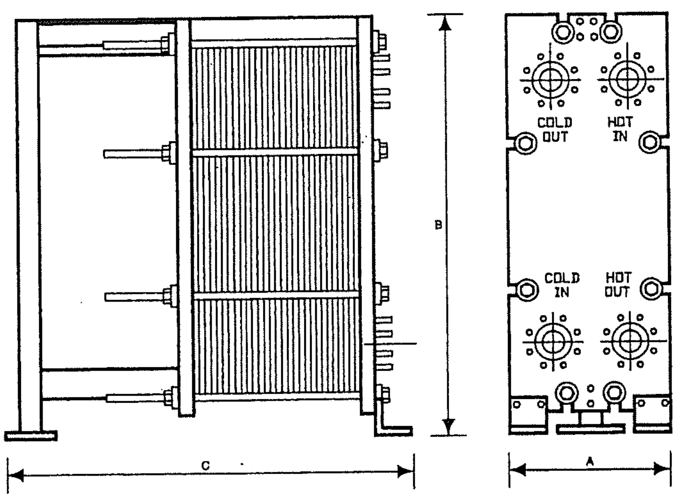
Model 3196 MT illustrated. Dimensions apply to 3196 ST, 3196 MT and 3196 XLT. Dimensions apply to both 150 and 300 pound flanges. Flanges are drilled to ANSI dimensions.

Integrity.

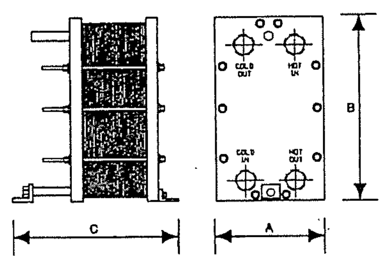
Easily incorporated.

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

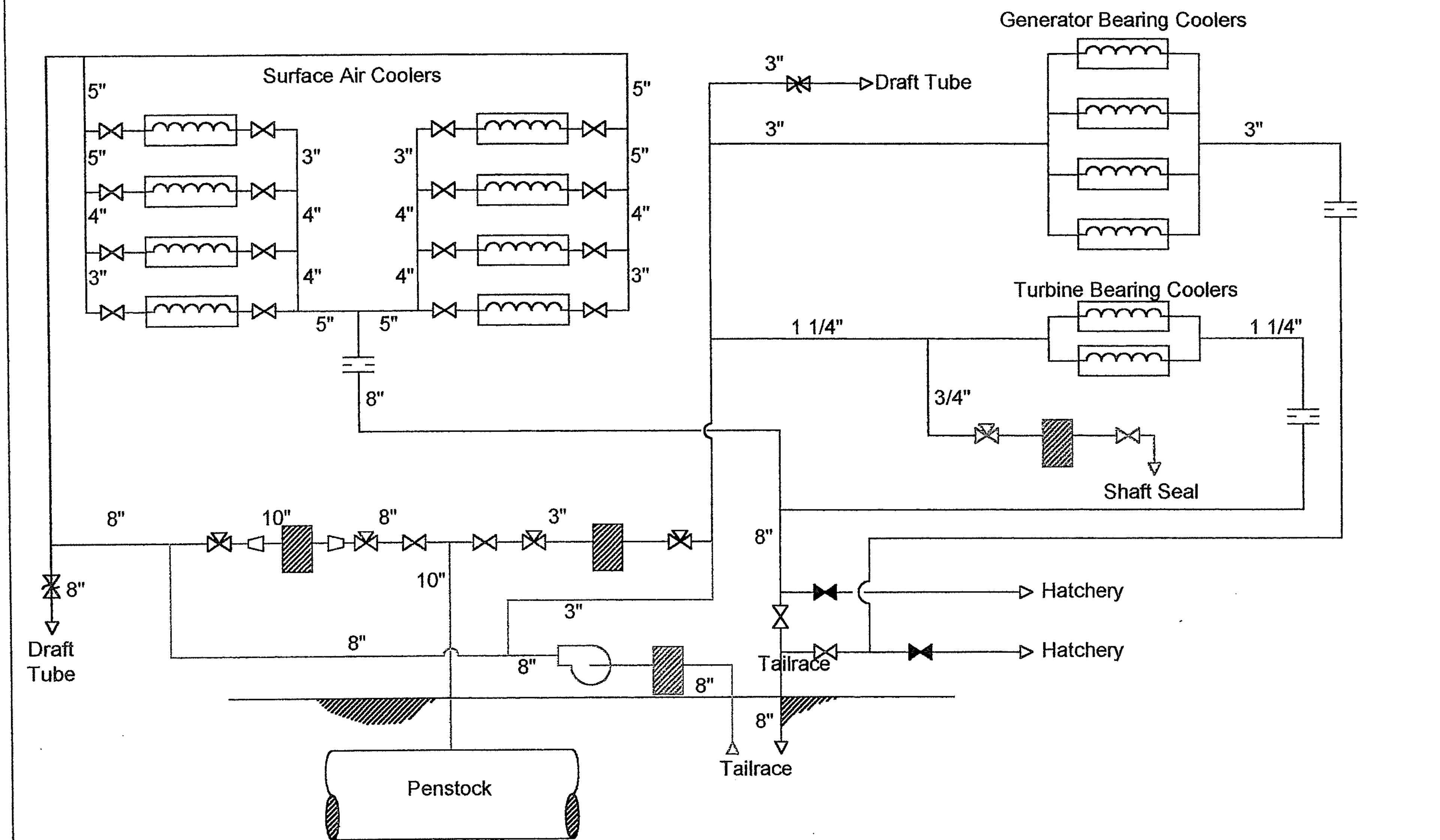


$ 25,000

Dimensions and Details

[illegible]	[illegible]						
Construction: Plate Materials	304 and 316 stainless steel, [illegible] SMO [illegible] Incoloy, palladium [illegible]						
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

Appendix G:
Cooling Water Source Details

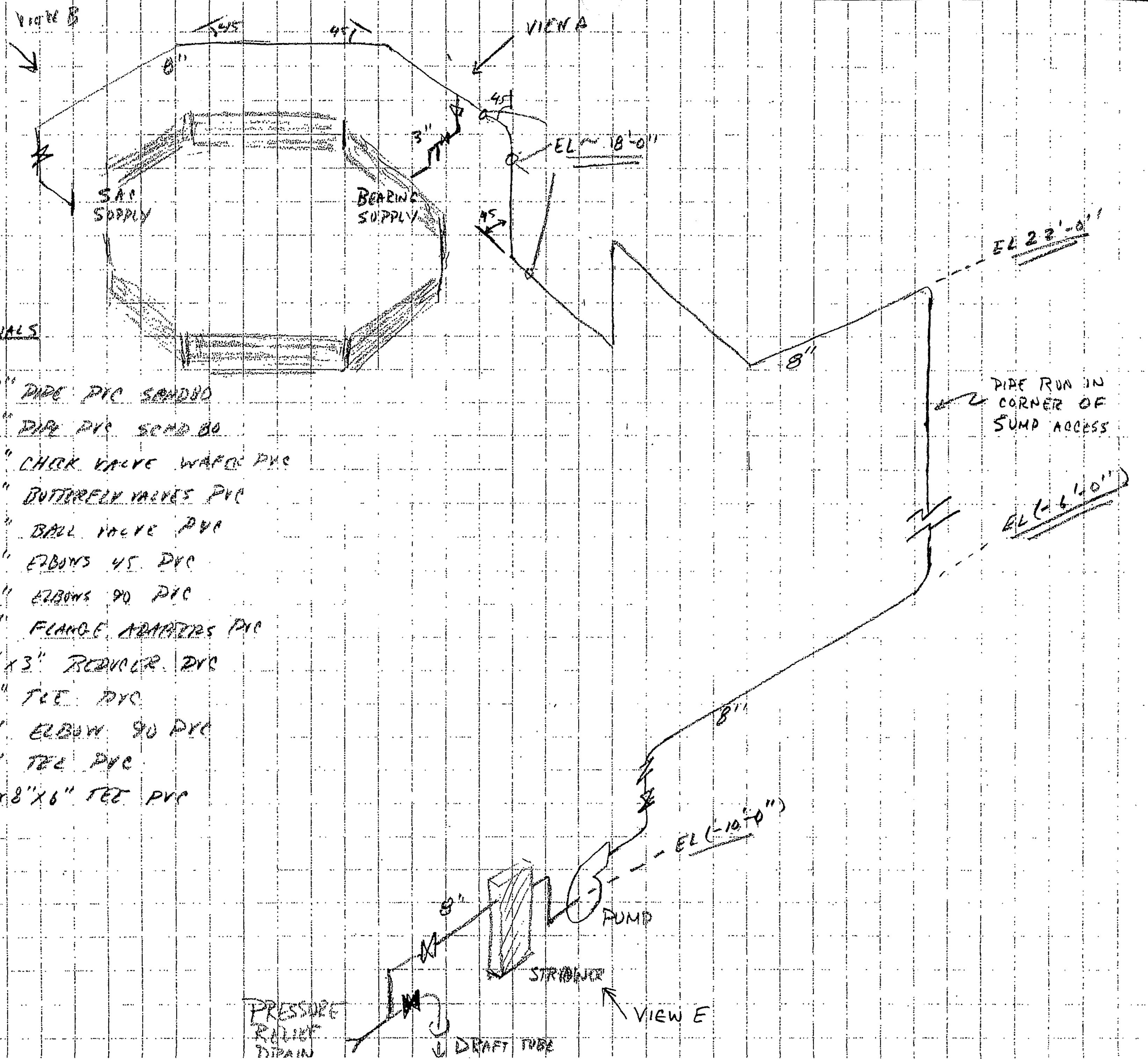


System Supply 50 PSI	Isolation Valve
Shaft Seal Supply 30 PSI	Reducing Valve
Penstock Supply 250 PSI	Safety Valve
Intermediate 150 PSI	Flow Meter Orifice
Drain Lines to Tailrace	Strainer
Tailrace Supply 55 PSI	

Unit Flow Diagram
Bay D'Espoir Powerhouse #2

Modification for Supply from Tailrace

TAILRACE COOLING WATER SO



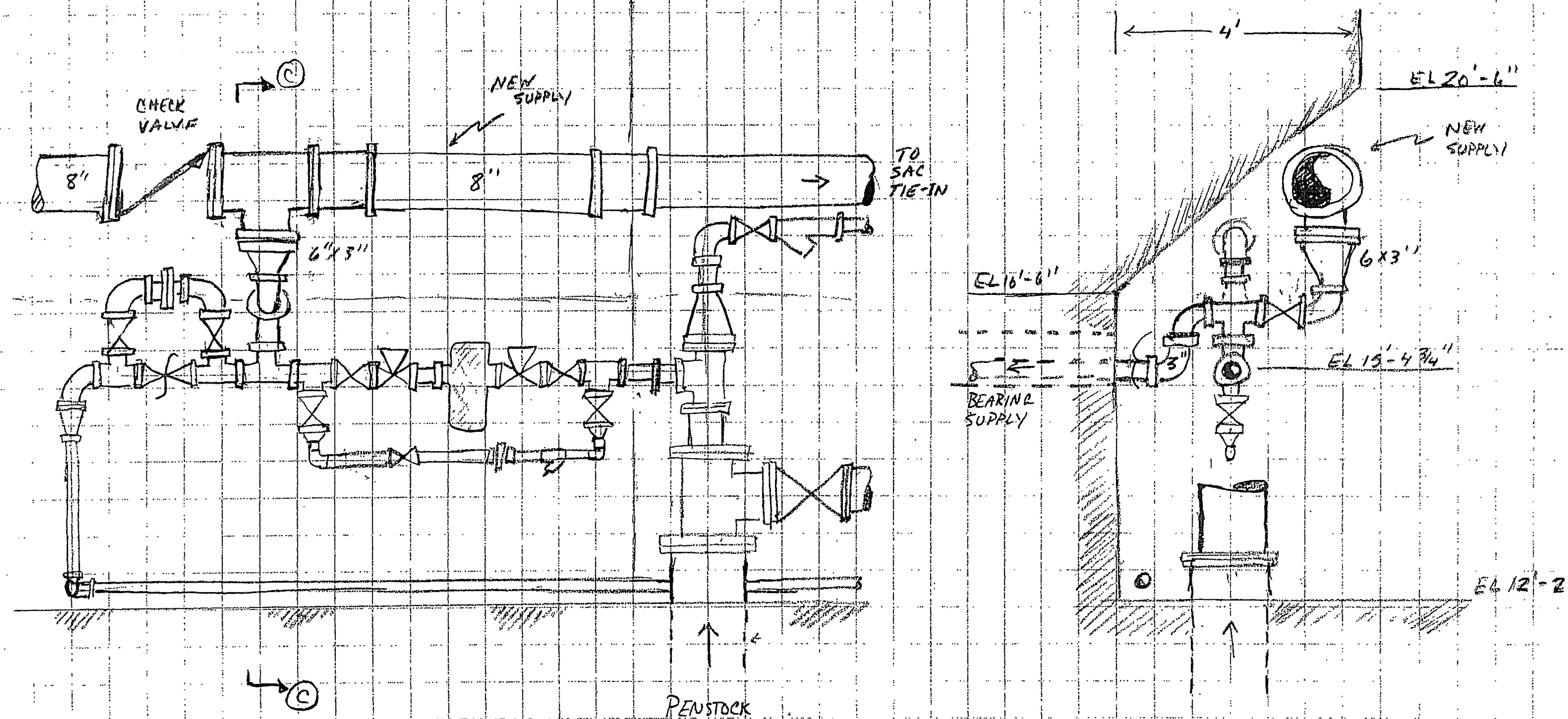
MATERIALS

150' - 8" PIPE PVC SCHD 80
10' - 3" PIPE PVC SCHD 80
1 - 8" CHECK VALVE WAFER PVC
4 - 8" BUTTERFLY VALVES PVC
1 - 3" BALL VALVE PVC
4 - 8" ELBOWS 45 PVC
12 - 8" ELBOWS 90 PVC
10 - 8" FLANGE ADAPTERS PVC
1 - 6" x 3" REDUCER PVC
2 - 8" TEE PVC
3 - 3" ELBOW 90 PVC
1 - 3" TEE PVC
1 - 8" x 8" x 6" TEE PVC

TAILRACE COOLING WATER SUPPLY

TIE-IN FOR 3" BEARING COOLING WATER SUPPLY

REFERENCE ORIGINAL 222F31747



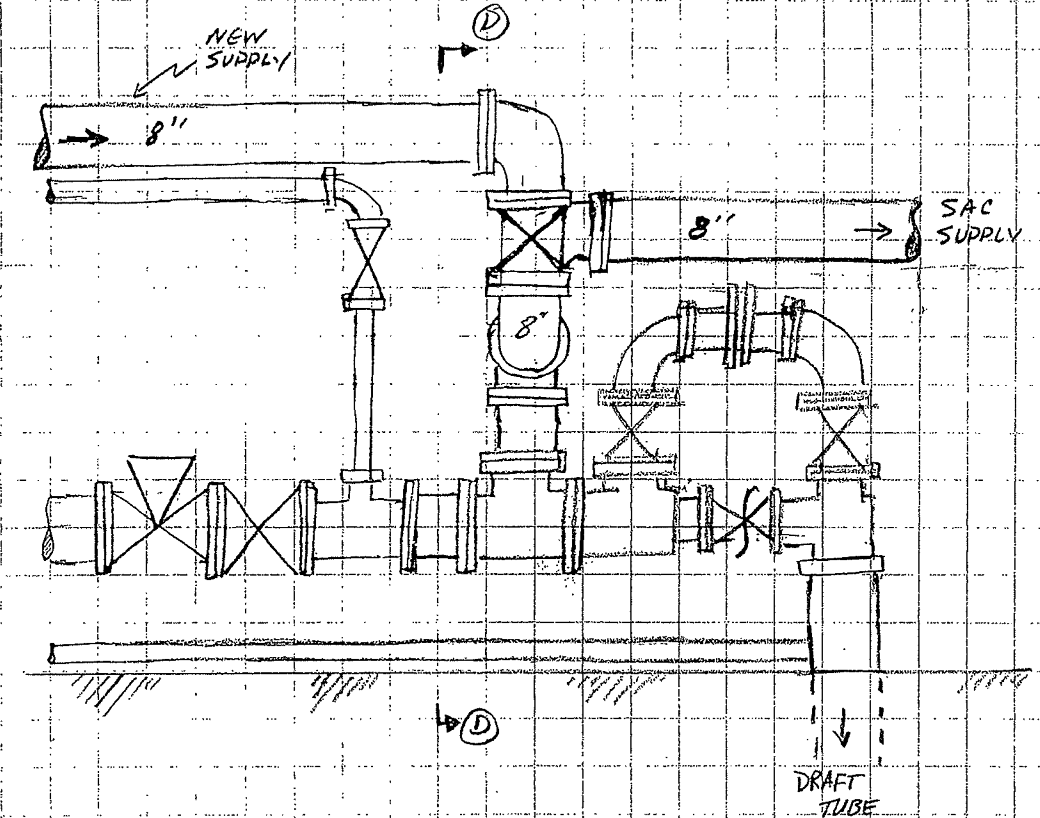
VIEW A

SECTION CC

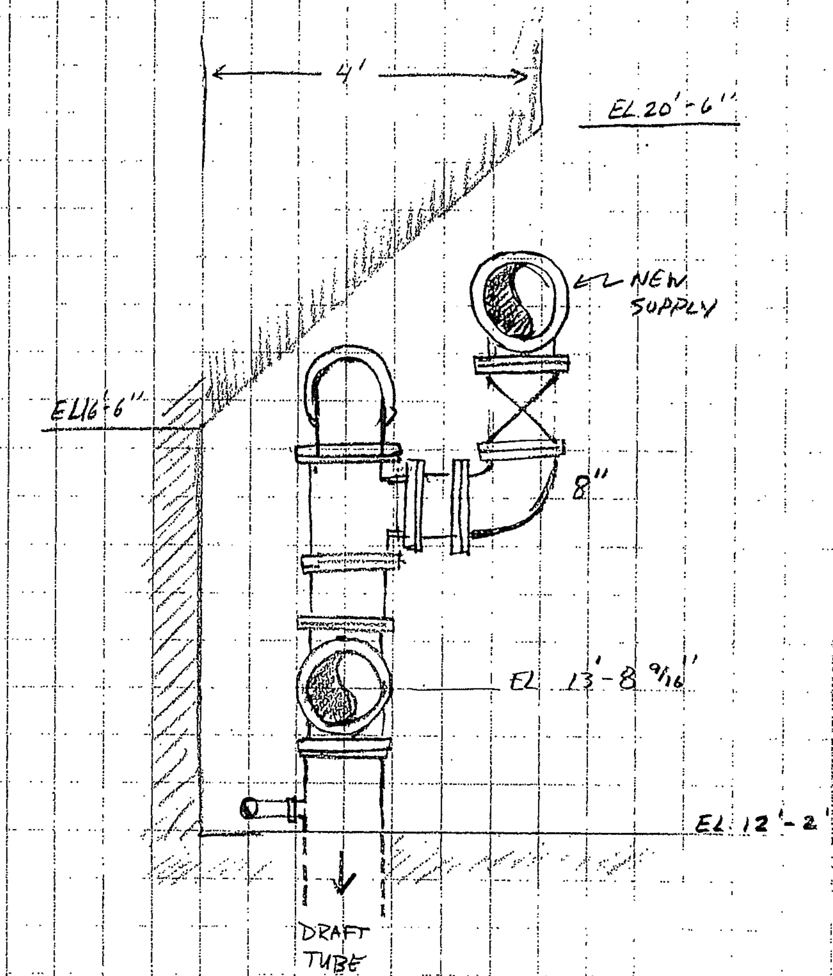
TAILRACE COOLING WATER SUPPLY

TIE-IN FOR 8" SURFACE AIR COOLER SUPPLY

REFERENCE ORIGINAL 222F31747



VIEW B

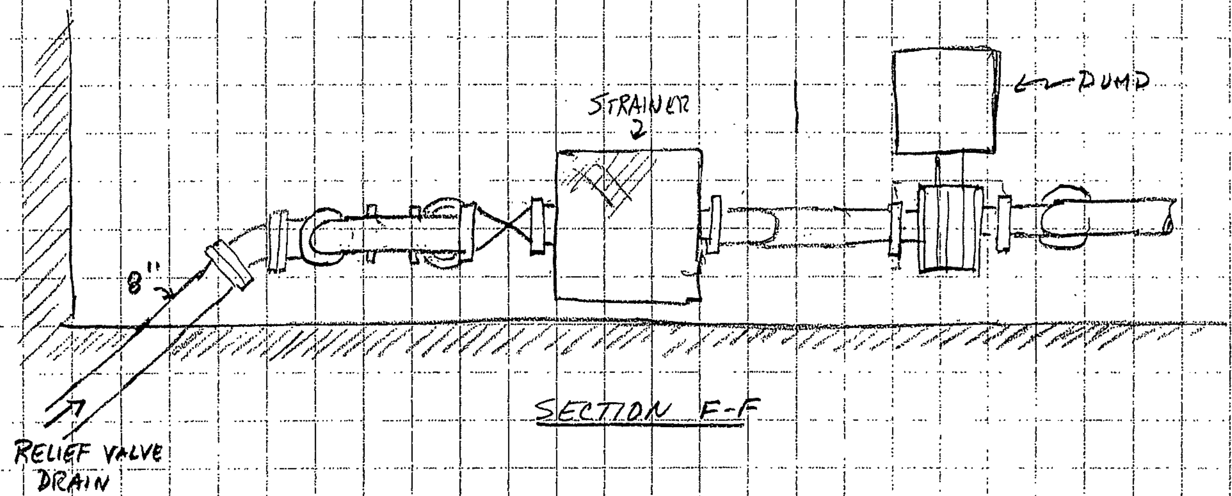


SECTION D D

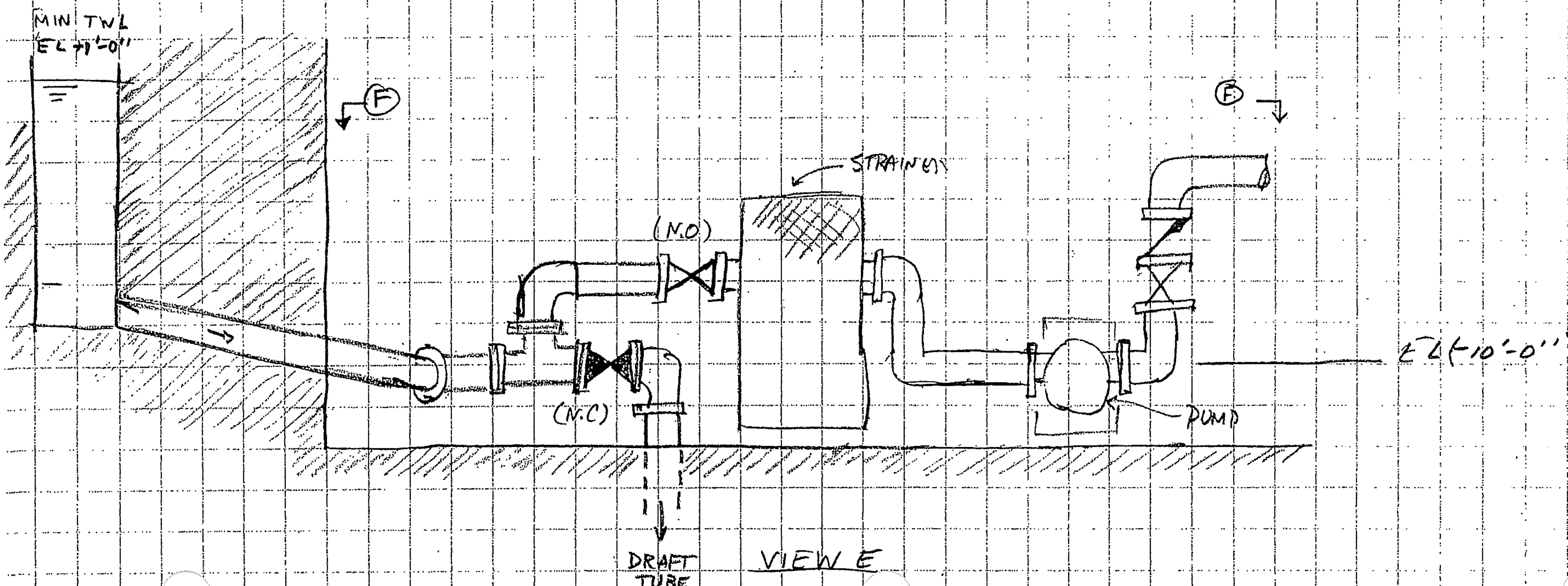
TAILRACE COOLING WATER SUPPLY/

TIE-IN FOR PUMP SUPPLY TO RELIEF VALVE DRAIN

REFERENCE ORIGINAL F-3107-M-103



SECTION F-F



VIEW E

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

Labor Crews for Maintenance Cost Estimates:

	Cleaning Crew	
	Quantity	Cost
Mechanical Main "A"	2	$ 43.12
Supervisor	0.333	$ 7.90
Overhead (63%)		$ 32.14
Crew Rate per Hour		**$ 83.16**

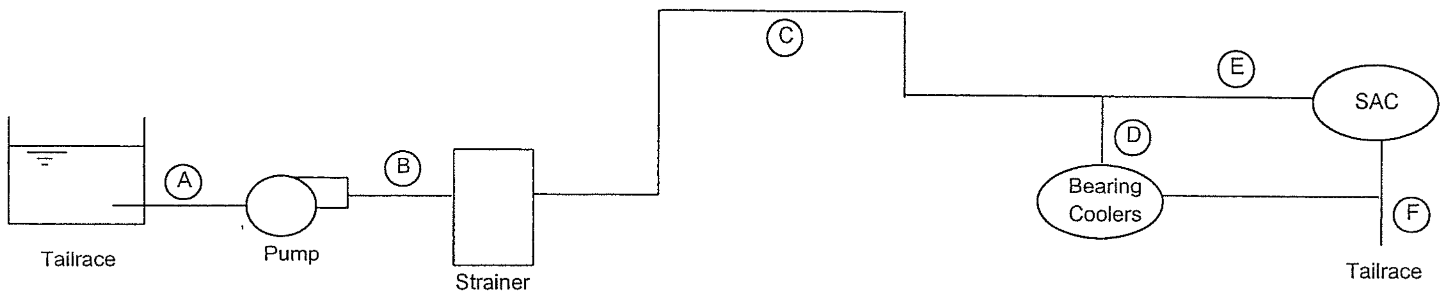
Maintenance Requirements for Additional Equipment:

Equipment	Hours	Frequency (/Year)	Cost
Pump Overhaul	16	1	**$ 1,331**
Strainer Cleaning	8	2	**$ 1,331**

Piping Cost Estimate

Item	Quantity (ea. ft.)	Unit Cost ($/ea.)	Material Cost ($)	Crew Type	Crew Capacity (/day)	Install Time (days)	Crew Cost ($/day)	Labor Cost ($)	Total Cost ($)
8" Pipe - PVC - Schd 80	150	12.06	1809.00	Q2	47	3.19	946.41	3020.46	4829.46
3" Pipe - PVC - Schd 80	10	3.54	35.40	Q1	50	0.20	665.27	133.05	168.45
8" Check Valve - Wafer - Chemline	1	1174.87	1174.87	Q2	2.5	0.40	946.41	378.56	1553.43
8" Butterfly Valve - Steel/Rubber Lined	4	390.04	1560.16	Q2	4.5	0.89	946.41	841.25	2401.41
3" Ball Valve - Socket - Chemline	1	300.00	300.00	Q1	25	0.04	665.27	26.61	326.61
8" Flanged Adapter - PVC - Socket	10	40.91	409.10	Q2	17.1	0.58	946.41	553.46	962.56
6" x 3" Reducer - PVC - Socket	1	18.30	18.30	Q1	11.1	0.09	665.27	59.93	78.23
8" - 45 Elbow - PVC - Socket	4	100.00	400.00	Q2	9.3	0.43	946.41	407.06	807.06
8" - 90 Elbow - PVC - Socket	12	75.90	910.80	Q2	9.3	1.29	946.41	1221.17	2131.97
8" Tee - PVC - Socket	2	116.81	233.62	Q2	6.2	0.32	946.41	305.29	538.91
8" x 8" x 6" Tee - PVC Socket	1	116.81	116.81	Q2	6.2	0.16	946.41	152.65	269.46
3" - 90 Elbow - PVC - Socket	3	7.73	23.19	Q1	20.8	0.14	665.27	95.95	119.14
3" Tee - PVC - Socket	1	15.64	15.64	Q1	13.9	0.07	665.27	47.86	63.50
Subtotal:			7007			8		7243	14250
25% Contingency:			1752			2		1811	3563
Total Estimated Piping Cost:			**8759**			**10**		**9054**	**17813**

Pressure Requirement for New Supply Pump - BDE 7



Friction Loss:

Section	Flow Rate (GPM)	Pipe Size (in)	Length (ft)	Fittings Equivalent Length (ft)												Total Length (ft)	Pressure Loss (PSI/100ft)	Pressure Loss	
				Elbows		Tee St.		Tee Br.		Reducer		Valves		Other					
				Qt.	(ft)	Qt.	(ft)	Qt.	(ft)	Qt.	(ft)	Qt.	(ft)	Qt.	(ft)			(PSI)	(FT)
A	2100	8	20	2	20			1	45			1	4.5			109.5	3	3.285	7.6
B	2100	8	10	2	20											50	3	1.500	3.5
C	2100	8	100	9	20							1	4.5	1	4.5	289	3	8.670	20.0
D	178	3	10	3	8	1	8	1	17	2	8	1	1.8			76.75	4	3.070	7.1
E	1922	8	20	2	20	1	20	1	45	1	20	1	4.5			149.5	2.6	3.887	9.0
F	2100	8	40	5	20	1	20					2	4.5			169	3	5.070	11.7

Total Dynamic Pressure Loss (FT):

Path 1

Section A	7.6
Section B	3.5
Strainer 4 PSI	9.2
Section C	20.0
Section D	7.1
Cooler Friction Loss	10.0
Section F	11.7
Total	**69.1**

Path 2

Section A	7.6
Section B	3.5
Strainer 4 PSI	9.2
Section C	20.0
Section E	9.0
Cooler Friction Loss	10.0
Section F	11.7
Total	**71.0**

Pump Requirements

Flow Rate:	2100	GPM
Max Head + 20%:	85	ft

Model:3196	Size:6X8-17	Group:	60 Hz	RPM:1180	Stages:1

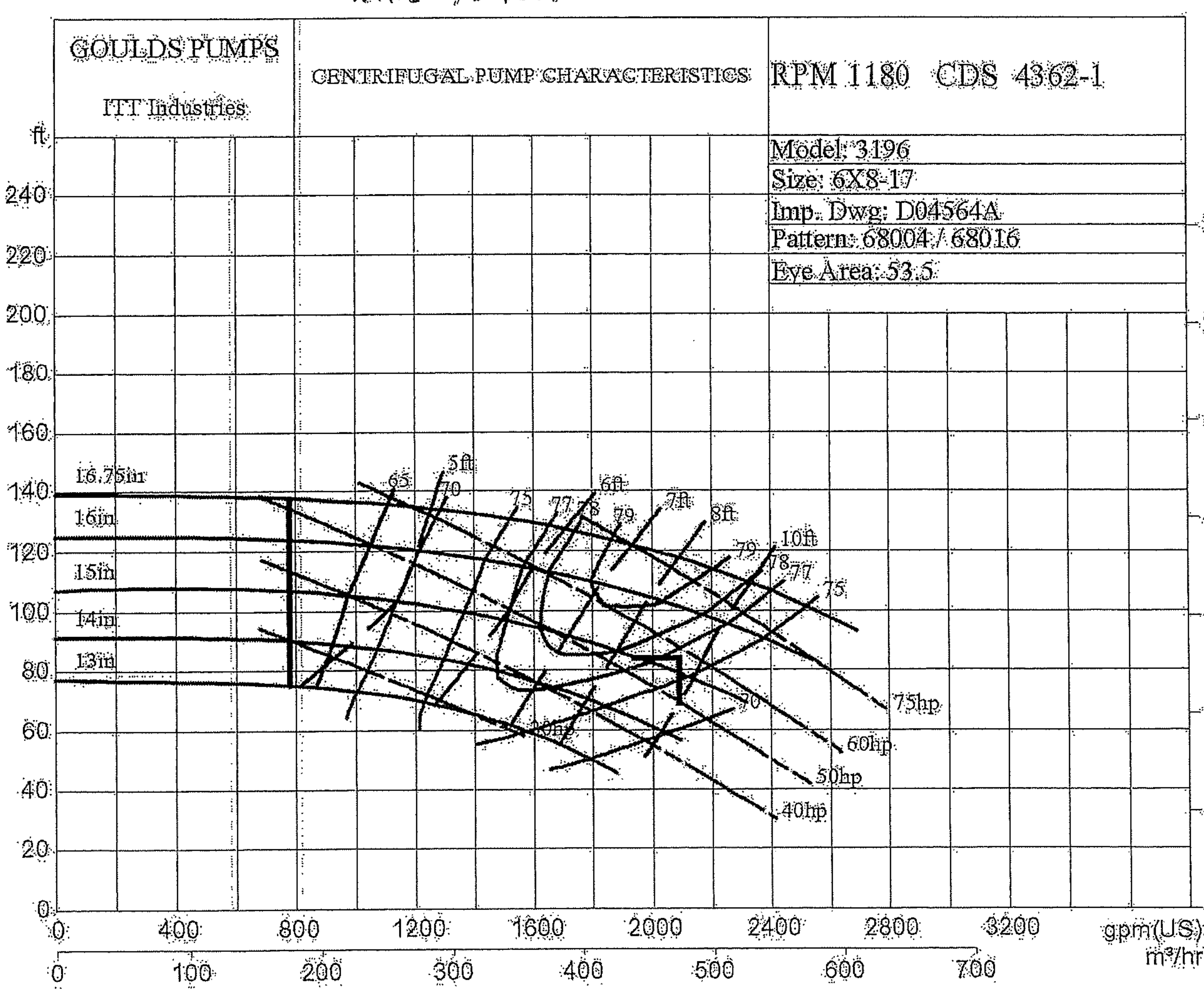
Purchaser:
User:
Item/Equip.No: Date: 3/13/02
Service: Certified By: ____________

Operating Conditions | **Pump Performance**

Liquid:	Water	Rated Efficiency:	76.5 %	Suction Specific Speed:	11340 (gpm(US) , ft)
Temp.:	70 °F	Rated Pump Power:	59.8 hp	Min. Cont. Stable Flow:	778 gpm(US)
Sp. Heat:		Mech/Dyn Seal Loss:	0 hp	Min. Cont. Thermal Flow:	
S.G./Visc.:	1	Other Power Loss:	0 hp		
Flow:	2100 gpm(US)	Rated Total Power:	59.8 hp	Non-Overloading Power:	63.5 hp
TDH:	85 ft	Impeller Dia. 1st stage:	15.375 in	Addt'l stages:	
NPSHa:		NPSHr:	9.3 ft		
		Shut off Head:	113.5 ft	Mag. Drive Circuit Flow:	
Max Dia. Solids:				Max Drive Power:	
% Solids:				Max Drive Temp:	
Vapor Press:				Max Motor Size:	

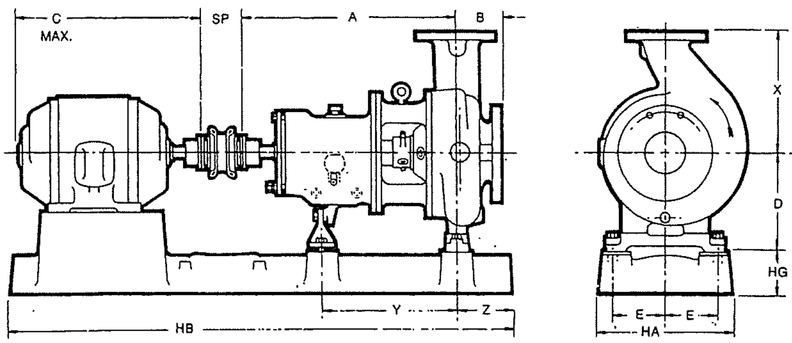
Notes: 1. Mechanical seal increased drag effect on power and efficiency is not included. 2. Magnetic drive eddy current and viscous effect on power and efficiency is not included. 3. Elevated temperature effects on performance are not included.

PUMP $ 15,000
MOTOR $ 5,000
TOTAL $20,000



Dimensions Model 3196

All dimensions in inches and(mm) Not to be used for construction.



DIMENSIONS DETERMINED BY PUMP

Model	Pump Size	ANSI Designation	Discharge Size	Suction Size	X	A	B	D	Y	Z	E	SP	Shaft Diameter at Cplg.	Key-Way	Pump Weight lbs. (kg.)
3196 ST	1 x 1½-6	AA	1	1½	6½ (165)	13½ (343)	4 (102)	5¼ (133)	7¼ (184)	4½ (114)	3 (76.2)	3¾ (95.3)	⅞ (22.2)	3/16 x 3/32 (4.8 x 2.4)	84 (38)
	1½ x 3-6	AB	1½	3											92 (42)
	2 x 3-6		2	3											95 (43)
	1 x 1½-8	AA	1	1½											100 (45)
	1½ x 3-8	AB	1½	3											108 (49)
3196 MT**	2 x 3-6	A10	2	3	8¼ (210)	19½ (495)	4 (102)	8¼ (210)	12½ (318)	4½ (114)	4⅞ (124)	3¾ (95.3)	1⅛ (28.6)	¼ x ⅛ (6.4 x 3.2)	180 (82)
	3 x 4-7	A70	3	4	11 (280)										220 (100)
	2 x 3-8	A60	2	3	9½ (242)										200 (91)
	3 x 4-8	A70	3	4	11 (280)										220 (100)
	3 x 4-8G	A70	3	4	11 (280)										220 (100)
	1 x 2-10	A05	1	2	8½ (216)										200 (91)
	1½ x 3-10	A50	1½	3	8½ (216)										220 (100)
	2 x 3-10	A60	2	3	9½ (242)										230 (104)
	3 x 4-10	A70	3	4	11 (280)										265 (120)
	3 x 4-10H	A40	3	4	12½ (318)	19½ (495)	4 (102)	10 (254)							275 (125)
	4 x 6-10	A80	4	6	13½ (343)										305 (138)
	1½ x 3-13	A20	1½	3	10½ (267)										245 (111)
	2 x 3-13	A30	2	3	11½ (292)										275 (125)
	3 x 4-13	A40	3	4	12½ (318)										330 (150)
	4 x 6-13	A80	4	6	13½ (343)										405 (184)
3196 XLT	6 x 8-13	A90	6	8	16 (406)	27⅞ (708)	6 (152)	14½ (368)	18¾ (476)	6½ (165)	8 (203)	5¼ (133)	2⅜ (60.3)	⅝ x 5/16 (15.9 x 7.9)	560 (254)
	8 x 10-13	A100	8	10	18 (457)										670 (304)
	6 x 8-15	A110	6	8	18 (457)										610 (277)
	8 x 10-15	A120	8	10	19 (483)										740 (336)
	8 x 10-15G	A120	8	10	12 (483)										710 (322)

**On LTC frame, shaft diameter at coupling is 1⅞. (47.6) keyway is ½" x ¼". (12.7) x (6.4) ps.

DIMENSIONS DETERMINED BY MOTOR

Model	Bed-plate	MOTOR: Motor Frame Sizes Applicable	MOTOR: C Max.	BEDPLATE: HA	BEDPLATE: HB	BEDPLATE: HG + ⅜ (9.5) − ⅛ (3.2)	BEDPLATE: Approx. Bedplate Weight Lbs. (kg.)
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	2	182-215	19½ (495)	12 (305)	39 (991)	3¼ (82.6)	80 (36)
	3	254-286	27 (686)	15 (381)	46 (1168)	4⅛ (105)	120 (54)
3196 MT	1	143-215	19½ (495)	12 (305)	45 (1143)	[1] 3¾ (95.3) [2] 3¾ (95.3)	105 (48)
	2	254-286	27 (686)	15 (381)	52 (1321)	4⅛ (105) 4⅛ (105)	155 (70)
	3	324-326	30 (762)	18 (457)	58 (1473)	4¾ (121) 4¾ (121)	205 (93)
		364-365	34 (864)	18 (457)	58 (1473)	5¾ (146) 4¾ (121)	
	4	404-405	35½ (902)	18 (457)	60 (1524)	6¾ (171) 5 (127)	240 (109)
		440 SER	46½ (1181)	18 (457)	60 (1524)	7¾ (197) 6 (152)	
3196 XLT	1	213-256	24 (610)	26 (660)	62 (1575)	4 (102)	375 (170)
	2	284-365	34 (864)	22 (559)	68 (1730)	4¾ (121)	
	3	404-445	46½ (1181)	22 (559)	80 (2032)	4¾ (121)	460 (209)
	4	447	46½ (181)	26 (660)	74 (1880)	4 (102)	435 (198)

[1] Applies to pumps where D = 8¼"
[2] Applies to pumps where D = 10"

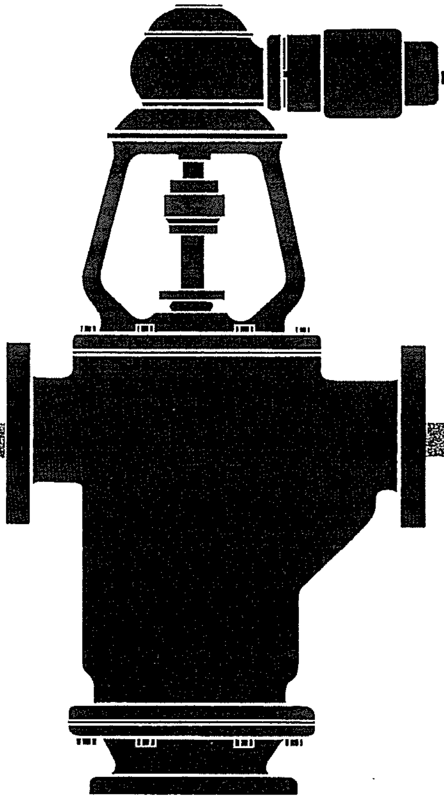
TAPPED OPENINGS
Color Indicates Items furnished standard

PURPOSE	No. of Taps	TAP SIZE: 3196 ST	TAP SIZE: 3196 MT	TAP SIZE: 3196 XLT
Lantern Ring Connection or Seal Flush	1	¼"	⅜"	⅜"
Frame Adapter Drain	1	SLOT	1"	1"
Casing Drain (with asbestos gasket)	1	⅜"	⅜"	⅜"
Alternate Casing Drain	1	½"	½"	½"
Bearing Frame Cooling	4□	½"	½"	½"
Discharge Gage Connection	1	¼"	⅜"	⅜"
Suction Gage Connection	1	¼"	⅜" ■	⅜"
Bypass Connection	1	¼"	½"	½"
Quench Gland Connection (packing gland)	2	¼"	¼"	¼"

□ 2 Taps on Model 3196 XLT.
■ 4x6-10 and 4x6-13 have no tap. 3x4-8 and 3x4-13 have ¼" (6.4) tap.

Model 3196 MT illustrated. Dimensions apply to 3196 ST, 3196 MT and 3196 XLT. Dimensions apply to both 150 and 300 pound flanges. Flanges are drilled to ANSI dimensions.

$ 5,000
8" - 2100 GPM.



Rotary Filters

Type VRS Motor-Operated Rotary Filter
Type VRS Hand-Operated Rotary Filter
Model VRS Control Panel

Available in both hand operated and motor driven models, the Spirax Sarco Rotary Filter supplies the perfect answer to your difficult filtering needs in a cost effective way.

Features and Benefits

- **Self Cleaning Unit**
  Eliminates maintenance and production downtime.
- **Helical Worm Gear Design**
  Removes debris from element while pushing debris down to the blowdown.
- **Use of Finer Mesh Elements**
  Since filter elements are continuously cleaned, pressure drops are kept to a minimum
- **Motor Driven Unit**
  Allows automatic operation.
- **Single Element Design**
  Compact unit will fit where duplex unit will not.
- **Unique Filter Design**
  Allows filtration of most any fluid.

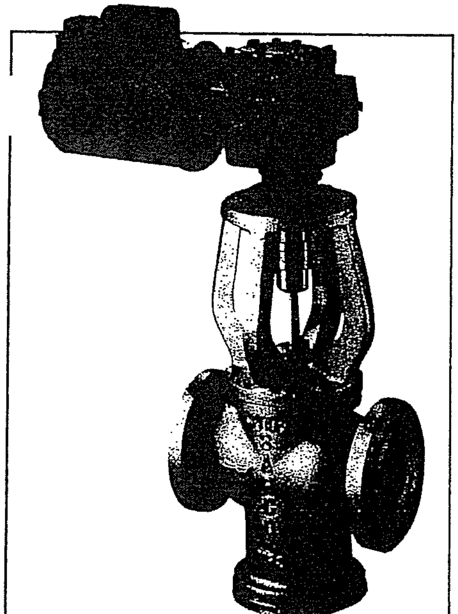
The Spirax Sarco Rotary Filter offers the user the advantage of a cost effective means of filtering foreign matter from virtually any fluid. The unique design provides a way to maintain a clean filter element while pushing dirt and debris to the blowdown. By offering its user continuous product flow with no downtime, production is increased and process becomes more profitable. Since filter elements are always clean finer mesh elements may be used providing a higher quality product with pressure drops kept to a minimum. Downstream equipment is protected and since no manual cleaning is required, labor costs are drastically reduced. With the advantage of no manual cleaning, product contamination is not present and the filtering of toxic and noxious fluids becomes safer. These reasons make the Rotary Filter an important part of your system to assure more profitable operations.

Operation

The rotary filters are constructed with a spiral blade affixed to a rotor which passes through the center of the filter element. Rotation of the worm gear type rotor removes debris from the element while pushing the debris out the blowdown. The rotor may be either hand operated or motor driven for total automatic operation. The rotary filter assures clean element operation and thus eliminates downtime due to element cleanings.

Applications

WATER—River water, cooling water, brine
PROCESS FLUID—Food and beverage, chemicals, pharmaceuticals
PAPER—Coating units, spray nozzles, glue, black liquor, white water
PETROLEUM—Fuel oil, lubricating oils, recycling process, wax
PAINTS & VARNISH—Latex, varnish, lacquer, ink



VRS Rotary Filter

VRS Rotary Filters

The Spirax Sarco Rotary Filter provides a self-cleaning filter for use where continual removal of debris from fluid is required. The self-cleaning design consists of a helical rotor located inside the filter element, which when rotated, scrapes debris from the element into a reservoir until time of disposal.

Sample Specifications

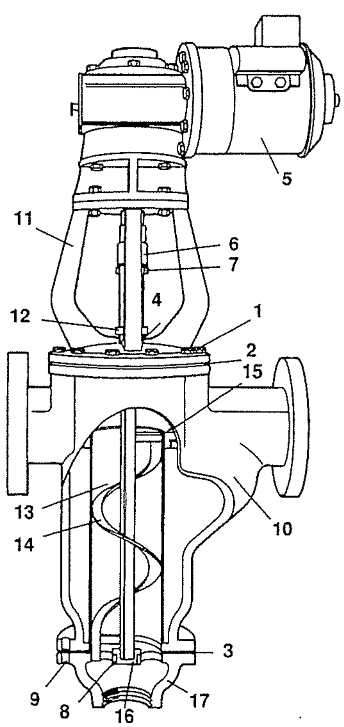
The filter shall be a self cleaning Spirax Sarco Rotary Filter for use on fluid service where continual removal of particulate matter is required. Filter shall use a helical worm gear rotor located inside filter element to remove foreign matter and push debris into blowdown holding leg. Filter shall provide continuous clean element operation and require NO backwash cycle or use of mechanical seals. Unit to be supported by pipework with no legs or special mounting materials required. Available in hand operated or motor drive models as required. For motorized models, motor to be 1/3 HP 1725 RPM TENV gear reduced motor. Available in vertical (VRS) pattern with materials of construction as required by fluids being filtered.

Motor Drive Unit (VRS)

Standard motor 1/3 HP 115/230 Volts, single phase 60 Hz, totally enclosed, non-ventilated construction with gear reduction to 9 rpm. Additional motor features (optional) – Explosion-proof; DC Motors; 230/460 or 575 Volt, 3 phase; XT design for washdown and outdoor use.

Model ⇨	VRS (hand operated)		VRS (Motor operated)			
PMO	200 psig cold water		200 psig cold water		175 psig cold water	Consult factory
Sizes	3/4",1,1-1/2, 2, 2-1/2	3", 4", 6", 8"	2", 2-1/2"	3", 4", 6", 8"	10"	12"
Connections	NPT	ANSI 125 flgd.	NPT	ANSI 125 flgd.		ANSI 150 flgd.
Construction	Cast Iron Body 316 SS or Brass Internals		Cast Iron Body			Fabricated Steel Body
			316SS or Brass Internals		316 SS Internals	
Options	Cast Steel or 316 SS body		Cast Carbon Steel or 316 SS body			Fabricated 316 SS Body
	Bronze Body w/ NPT connections	w/ ANSI 150 flanged connections	w/ NPT connections	w/ ANSI 150 flanged connections		

*** Note:** Consult factory for other available flanges or materials of construction



Construction Materials

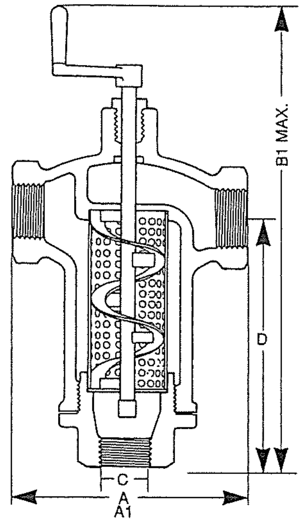
No.	Part	Material
1	Cap Screw	Steel
2	Cap Gasket	Graphite
3	Blowdown Gasket	Graphite
4	Packing	Molded or Braided Graphite
5	Motor Assembly	Cast Iron & Steel
6	Coupling	Steel
7	Shear Pin	Brass
8	Element Gasket	Neoprene
9	Locating Pin	Stainless Steel

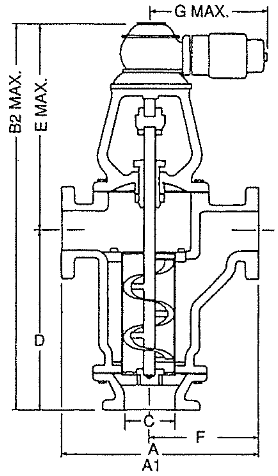
Available Materials

No.	Part	Material
10	Body†	Cast Iron, Bronze, Cast Steel, Stainless Steel
11	Cap†	Cast Iron, Bronze, Cast Steel, Stainless Steel
12	Packing Nut	Stainless Steel, Brass
13	Element Assembly†	Stainless Steel, Brass
14	Rotor Assembly*†	Stainless Steel, Brass
15	Hold Down Screws	Stainless Steel, Brass
16	Shaft Bearing	Stainless Steel, Brass
17	Blowdown Connection†	Cast Iron, Bronze, Cast Steel, Stainless Steel

* Nylon brush or stainless steel brush can be used on rotor material shown. See element selection chart for application.

† Standard materials as shown. Additional materials of construction, i.e., 304 SS, Monel, etc. available upon special request – consult factory.





Dimensions (nominal) in inches

Size	Scr. A	Flgd. A1	B1 Max.	B2 Max.	C	D	E	F	Cast Iron Motor Driven Weight	Cast Iron Hand Operated Weight
3/4"	4.1	–	10.6	–	1/2	4.5	–	–	–	6 lb
1"	5.0	–	11.9	–	3/4	5.5	–	–	–	8 lb
1-1/2"	5.6	–	14.1	–	1	6.4	–	–	–	13 lb
2"	8.0	–	17.5	28.1	1-1/4	8.1	20.0	4.0	85 lb	34 lb
2-1/2"	9.0	–	20.7	31.0	1-1/2	9.0	22.0	4.5	115 lb	46 lb
3"	–	11.25	23.0	33.4	2	9.5	23.9	5.1	125 lb	57 lb
4"	–	17.4	35.5	45.1	3	21.3	23.75	10.1	260 lb	208 lb
6"	–	20.75	40.3	48.4	3	23.1	25.3	12.75	380 lb	321 lb
8"	–	29.0	48.4	55.1	4	28.3	26.8	18.0	710 lb	640 lb
10"	–	34.25	–	63.6	6	34	29.6	21.6	1250 lb	–
12"	–	43.9	–	80	10	47.6	36.3	27.9	1980 lb*	–

C_V Values

Size	3/4"	1"	1-1/4"	1-1/2"	2"	2-1/2"	3"	4"	6"	8"	10	12"
C_V*	11	19	28	38	70	110	165	280	650	1100	1650	2400

* These C_V's are for perf/ opening of 045" or larger. Consult factory for C_V's on smaller perf's, mesh or mesh lined.

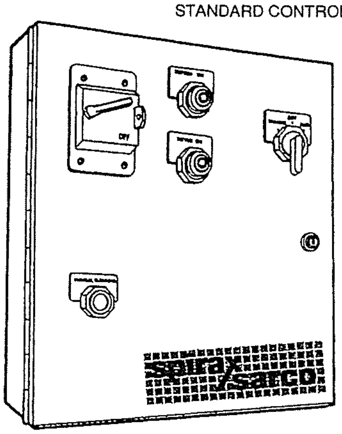
VRS Available Element Selections

Actual Opening inches	Microns	Stainless Steel 316	Brass	Recommended Rotor Assembly
.0055"	140	100 mesh	N/A	nylon brush only
.007"	178	80 mesh	N/A	316 S.S. or nylon brush
.010"	254	60 mesh	N/A	316 S.S. or nylon brush
.020"	508	N/A	1/64" perf	blade
.027"	686	1/64" perf	N/A	blade
.032"	813	1/32" perf	1/32" perf	blade
.046"	1,169	3/64" perf	3/64" perf	blade
.062"	1,575	1/16" perf	1/16" perf	blade
.094"	2,393	3/32" perf	3/32" perf	blade
.109"	2,784	7/64 perf	7/64 perf	blade
.125"	3,175	1/8" perf	1/8" perf	blade
.187"	4,750	3/16" perf	3/16" perf	blade only
.250"	6,350	1/4" perf	1/4" perf	blade only
.375"	9,525	3/8" perf	3/8" perf	blade only
.500"	12,700	1/2" perf	1/2" perf	blade only

Consult factory for other available screen sizes

Mesh-lined screen – use brush rotor only

STANDARD CONTROL PANEL



The Model VRS Control Panel provides a fully-automatic system to operate all functions of the motorized rotary filter product line. Rotor (cleaning function) and purge (blowdown function) is controlled by timer operation. The VRS Control Panel provides a fully-automatic filtration system eliminating manual labor and possible human error.

Optional Extras

Differential pressure switch with isolated alarm contacts.
Electronic resettable cycle counter.
Consult factory if: fluid has a melting point above 50°F, or for corrosive fluids.

Available Types

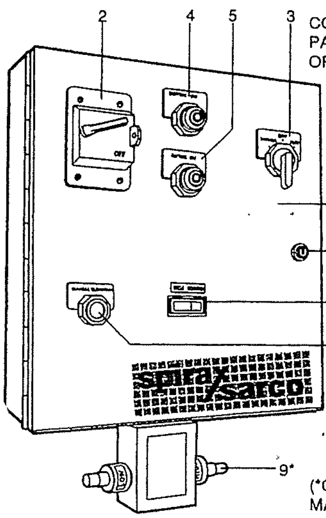
- 115v; Single Phase; 60 Hz; One valve blowdown system (valve not included.)
- 115v; Single Phase; 60 Hz; Two valve blowdown system (valves not included.)

Enclosure: NEMA 4 Key Lockable
Controls: User adjustable interval and duration timers to operate rotor and blowdown valve/valves.
H.O.A. selector switch.
Motor protection and control power fuses.
Manual blowdown push button override.
Indicator pilot lights.
Terminal strip for field connections.
Motor rated output contact and relay.
Lockable, motor rated, external power disconnect.

- 230v/460v; Three Phase; 60 Hz; One valve blowdown system (valve not included.)
- 230v/460v; Three Phase; 60 Hz; Two valve blowdown system (valves not included.)

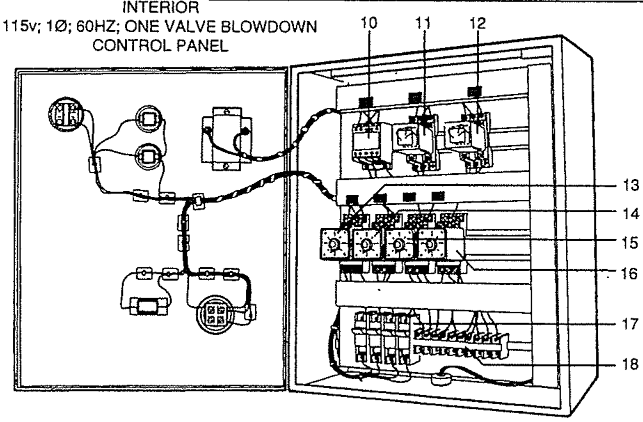
Enclosure: NEMA 4 Key Lockable
Controls: As above, but additional control power transformer secondary and dual primary fusing.
Adjustable overload relay for motor.

CONTROL PANEL WITH OPTIONS



(*OPTIONAL MATERIAL)

INTERIOR
115v; 1Ø; 60HZ; ONE VALVE BLOWDOWN
CONTROL PANEL



Features

Key	Description
1	NEMA 4 Cabinet Enclosure
2	Lockable, Motor Rated, External Power Disconnect
3	Hand-Off-Auto Switch
4	Pilot LIght - System On
5	Pilot LIght - Rotor On
6	Manual Blowdown Override Push Button
7	Kay Lock
*8	Electronic, Resettable Cycle Counter (Optional)
*9	0-25 PSI Differential Pressure Switch 1/4" MNPT (Optional)

Internal Features

Key	Description
10	1CR-Motor Control Relay
11	2CR-Rotor/Blowdown Valve Control Relay
12	3CR-D.P. Override Control Relay
13	1TR-Timer-Blowdown Time Till On
14	2TR-Timer-Rotor Time Till On
15	3TR-Timer-Blowdown Duration On
16	4TR-Timer-Rotor Duration On
17	Main Power Fuse Block
18	Terminal Strip-Field Connections

Sample Specification

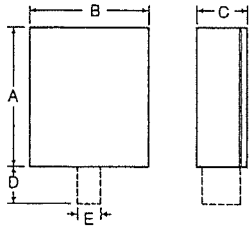
The control panel to operate the self-cleaning rotary filter shall be the Spirax Sarco Model VRS Control Panel. Control panel shall contain user adjustable timers to control interval and duration of both rotor and blowdown valve operations. A differential pressure switch and isolated alarm contact for rotor operation if pressure drop across filter exceeds allowable levels. A manual blowdown override switch, along with H.O.A. selector switch, indicator operation lights, and rotor cycle counter to be provided. Enclosure to be NEMA 4 with cabinet key lock and external lockable power disconnect. Available in voltages of 115v/1Ø/60 Hz and 230-460v/3Ø/60 Hz.

Installation

Control Panel to be installed following standard good electrical practice, and in conformance with local and state codes.

NEMA 4 Enclosure

Type 4 Enclosures are intended for use indoors or outdoors to protect the enclosed equipment against splashing water, seepage of water, falling of hose-directed water, and severe external condensation. They are sleet-resistant but not sleet (ice)-proof. They shall have conduit hubs or equivalent provision for water tight connection at the conduit entrance and mounting means external to the equipment cavity.
Note: Control panel supplied without knockouts, all connections to panel supplied by installer.



Dimensions (nominal inches)

Voltage/Size	A	B	C	D	E
115v;10;60Hz	17	14.5	6.25	4.5	3
230v	24	16	17.5	4.5	3

Cost Savings of Re-routing Cooling Water Supply from Penstock

Annual Statistics:

Annual Escalation Rate	2.0%
Annual Discount Rate:	8.5%
Electrical Rate ($/kWh):	0.041

Water Usage of Cooling Water System:

Surface Air Coolers (IGPM):	1600
Generator Brg. Cooler (IGPM):	110
Turbine Brg. Cooler (IGPM):	35
Shaft Seal (IGPM):	4
Total (IGPM):	1749
Total (m^3/s):	0.1325

Power Generated by Cooling Water:

$$P = \rho \cdot g \cdot Q \cdot H \cdot \eta_t \cdot \eta_g$$

ρ = Density of Water (kg/m^3)	1000
g = Gravity (m/s^2)	9.81
Q = Water Flow (m^3/s)	0.133
H = Head (m)	172.0
η_t= Turbine Peak Efficiency	0.94
η_g= Generator Peak Efficiency	0.97
P = Power (Watts)	203880

Annual Cost Savings:

Power Savings (kW):	203.88
Usage Factor (%/yr):	0.89
Electrical Cost ($/kWh):	0.045
Annual Cost Saving ($/yr):	$ 71,529

Initial Captial Costs:

Piping Materials:	$ 8,759
Piping Labor:	$ 9,054
Pump Cost:	$ 20,000
Strainer Cost:	$ 5,000
25% Contingency	$ 10,703
Total Capital Cost ($):	$ 53,516

Annual Operating Costs:

Pump Rating (hp):	60
Pump Rating (kW):	44.74
Usage Factor (%/yr):	0.89
Electrical Cost ($/kWh):	0.041
Pump Power Costs ($/yr):	$ 14,302
Pump Maintenance Costs ($/yr):	$ 1,331
Strainer Maintenance Costs ($/yr):	$ 1,331
Total Operating Cost ($/yr):	$ 16,963

Year	Date	Operating Cost	Capital Cost	Cost Saving	Net	NPW
1	2002	($16,963)	($53,516)	$71,529	$1,050	$968
2	2003	($17,302)	$0	$72,959	$55,657	$48,246
3	2004	($17,648)	$0	$74,418	$56,770	$92,692
4	2005	($18,001)	$0	$75,907	$57,906	$134,475
5	2006	($18,361)	$0	$77,425	$59,064	$173,755
6	2007	($18,728)	$0	$78,973	$60,245	$210,682
7	2008	($19,103)	$0	$80,553	$61,450	$245,396
8	2009	($19,485)	$0	$82,164	$62,679	$278,031
9	2010	($19,875)	$0	$83,807	$63,932	$308,711
10	2011	($20,272)	$0	$85,483	$65,211	$337,553
11	2012	($20,678)	$0	$87,193	$66,515	$364,667
12	2013	($21,091)	$0	$88,937	$67,846	$390,157
13	2014	($21,513)	$0	$90,716	$69,203	$414,120
14	2015	($21,943)	$0	$92,530	$70,587	$436,647
15	2016	($22,382)	$0	$94,381	$71,998	$457,825
16	2017	($22,830)	$0	$96,268	$73,438	$477,733
17	2018	($23,287)	$0	$98,194	$74,907	$496,450
18	2019	($23,752)	$0	$100,157	$76,405	$514,045
19	2020	($24,227)	$0	$102,161	$77,933	$530,585
20	2021	($24,712)	$0	$104,204	$79,492	$546,135
21	2022	($25,206)	$0	$106,288	$81,082	$560,754
22	2023	($25,710)	$0	$108,414	$82,703	$574,496
23	2024	($26,224)	$0	$110,582	$84,358	$587,416
24	2025	($26,749)	$0	$112,794	$86,045	$599,561
25	2026	($27,284)	$0	$115,049	$87,766	$610,979
26	2027	($27,830)	$0	$117,350	$89,521	$621,713
27	2028	($28,386)	$0	$119,697	$91,311	$631,803
28	2029	($28,954)	$0	$122,091	$93,138	$641,290
29	2030	($29,533)	$0	$124,533	$95,000	$650,207
30	2031	($30,124)	$0	$127,024	$96,900	$658,591
31	2032	($30,726)	$0	$129,564	$98,838	$666,472
32	2033	($31,341)	$0	$132,156	$100,815	$673,882
33	2034	($31,967)	$0	$134,799	$102,831	$680,847
34	2035	($32,607)	$0	$137,495	$104,888	$687,395
35	2036	($33,259)	$0	$140,245	$106,986	$693,551
36	2037	($33,924)	$0	$143,050	$109,126	$699,338
37	2038	($34,603)	$0	$145,911	$111,308	$704,778
38	2039	($35,295)	$0	$148,829	$113,534	$709,893
39	2040	($36,000)	$0	$151,805	$115,805	$714,701
40	2041	($36,720)	$0	$154,841	$118,121	$719,221
41	2042	($37,455)	$0	$157,938	$120,483	$723,470
42	2043	($38,204)	$0	$161,097	$122,893	$727,465
43	2044	($38,968)	$0	$164,319	$125,351	$731,220
44	2045	($39,747)	$0	$167,605	$127,858	$734,750
45	2046	($40,542)	$0	$170,957	$130,415	$738,069
46	2047	($41,353)	$0	$174,377	$133,023	$741,189
47	2048	($42,180)	$0	$177,864	$135,684	$744,122
48	2049	($43,024)	$0	$181,421	$138,398	$746,880
49	2050	($43,884)	$0	$185,050	$141,165	$749,472
50	2051	($44,762)	$0	$188,751	$143,989	$751,909

Bay D'Espoir Unit #7
Economic Analysis of Converting Cooling Water Supply to Tailrace