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Newfoundland & Labrador Hydro

HYDRO

Hydro Plant Corrosion / Fouling Study 2002

Cat Arm Generating Station

SERVICE WATER SYSTEM

Newfoundland & Labrador Hydro

Cat Arm Generating Station

SERVICE WATER SYSTEM

Piping
Strainer
Supply Pumps
Control Valves
Heat Exchangers

Prepared for:	Newfoundland & Labrador Hydro Hydro Generation
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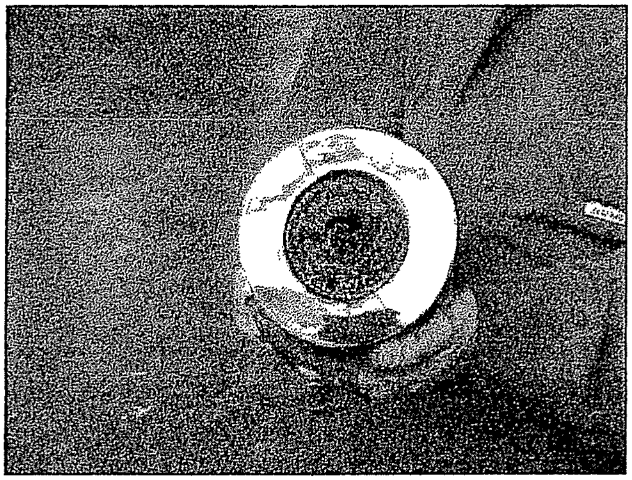
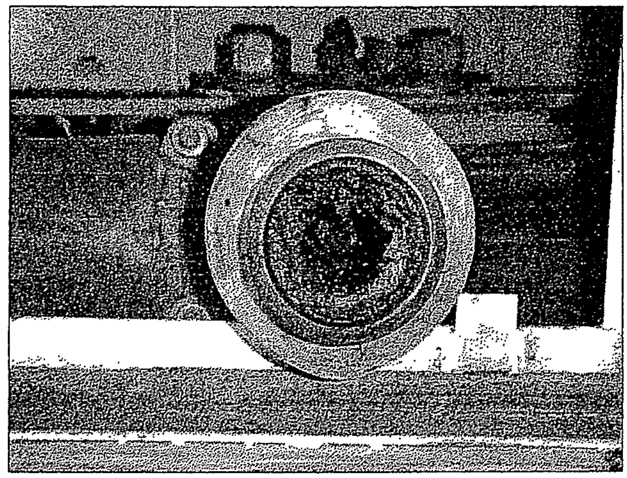
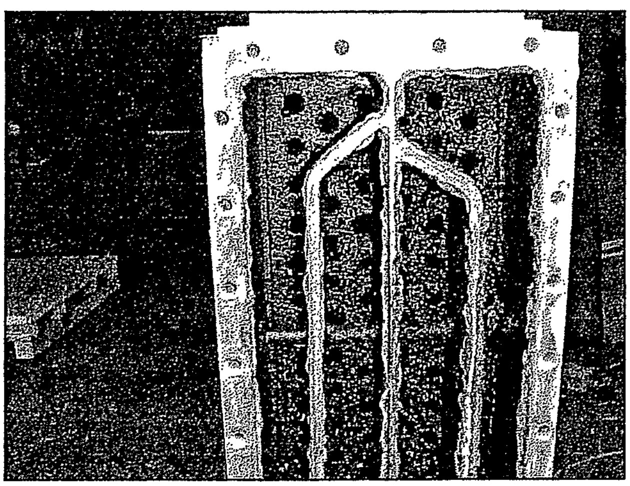
Date:	November 23, 2001

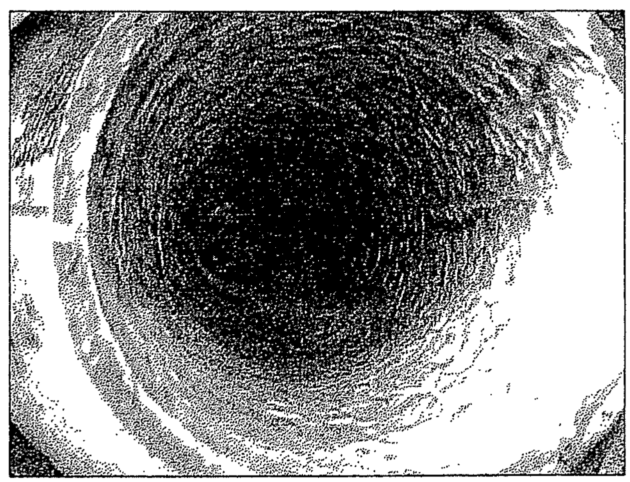
Newfoundland & Labrador Hydro

Cat Arm Generating Station









SERVICE WATER SYSTEM

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SUMMARY

It was determined that a hydro plant cooling water study was needed to determine the most effective solution to the cooling water fouling that is plaguing our hydro plants. The methodology for this study was planned out to include the following: prioritize plants and systems for review, review drawings, inspect coolers for extent of fouling, calculate actual flow rates, and determine the best solution for each hydro plant.

It was determined that Upper Salmon, Cat Arm, and Hinds Lake had the most problems with regards to cooling water.

In order to first determine which plant had the worse problems an in-depth analysis of each plants cooling water system had to be undertaken. Next a complete review of the plants work history had to be done. This was accomplished by reviewing all work orders related to the plants cooling water system in the J.D.Edwards. From this it can be determined which plant had the worse problems.

What was needed next was a review of how the plant's cooling water system has been operating. This was accomplished by using the Trend Monitoring Program that I designed. From the trend graphs one could see just how efficiently the plant has been operating and how the work on the cooling water system affects it. This gives us a time frame for cleaning components of the system so that we could set up a maintenance program for the cooling water system.

A cost analysis was done to determine the amount of money being spent on the current cooling water system in each plant. Also a cost analysis for replacing the piping was done using RSMeans Mechanical Cost Data for each plant.

Several solutions were presented to combat the fouling problem and they are; chemical cleaning of the system, replace the piping with corrosion resistant pipe, add a corrosion inhibitor to the water, use organic filters, or convert to a closed cooling water system.

From these solutions four were chosen for further investigation and they are; replace piping with corrosion resistant pipe, add a corrosion inhibitor to the water, convert the system to a closed system, and continue to operate as we have. Each solution was researched and a Net Present Worth calculation was done to determine the most economical solution. It was determine that replacing the piping with corrosion resistant pipe is the best solution, considering that the pipe has to be replaced in the next few years the other solutions did not seem economical.

The NPW of this solution for Cat Arm is $420,252 for both units over the pipe life of 20 years. The NPW of continuing to operate as we have is $434,640 for both units and this does not include replacing the existing piping which labour alone is $42,000. The closed loop solution has a NPW of $293,131 but again the existing piping has to be replaced. The closed loop solution can always be added on after the piping is replaced.

SERVICE WATER SYSTEM

The service water system in Cat Arm has had fouling problems since it's opening in 1985. At first this was though to be caused by the unsettled organic materials within the water reservoir and should be 'washed' through the system in three to four years. Every two or three years since the early 90's a scheduled outage is preformed on the units to clean the service water system. This maintenance is required to prevent the units from over heating during the summer months. The coolers are clogged with organic 'slim' and the piping is corroded with hardened organics attached to the walls.

The purpose of this report is to provide the reader with a complete review of the service water system along with an analysis of how the system has been operated. In conclusion to this information recommendations are provided that will help to improve the reliability and service of the cooling water system.

General Information

The service water systems primary supply of water is from the fresh water sump. A secondary supply is a direct feed from the penstock.

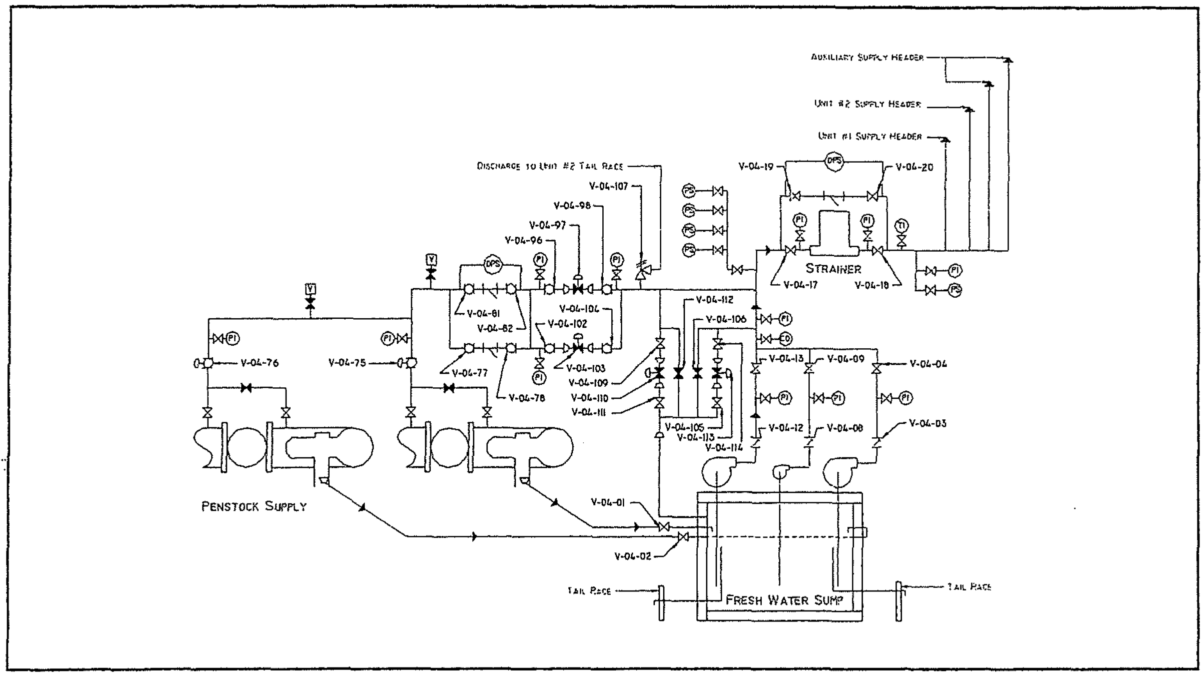
The freshwater sumps primary water supply is from a trough that is attached to the turbine pit's liner. The discharge water from the turbine is collected for the fresh water sump via these troughs.

The primary service water system consists of two main vertical turbine pumps taking water from the freshwater sump. A smaller capacity service water auxiliary pump is also incorporated into the system. When the main pumps are off, this smaller auxiliary pump operates providing service water for the fire protection system, compressed air water-cooled after-coolers and the air conditioning units water-cooled condensers.

The capacity and arrangement of each of the three service water pumps is as follows:

- The capacity of one main service water pump at or near peak pump operating efficiency is equal to the mean anticipated service water flow rate with both units operating.
- The capacity of one main service water pump together with the smaller service water auxiliary pump is equal to or greater than the maximum design service water flow with both units operating.
- The capacity of the smaller service water auxiliary pump is equal to or greater than the powerhouse miscellaneous service water requirements.

A separate supply line is provided, from the spherical valve bypass high pressure penstock water supply connections for each unit, as a secondary means of service water supply. This system is installed as a backup to the primary system and operates whenever there is a low freshwater sump level, a malfunction in the pump service water system or whenever both units are placed in the synchronous condenser mode of operation. The following is a flow diagram of both supply systems.



Drawing 1

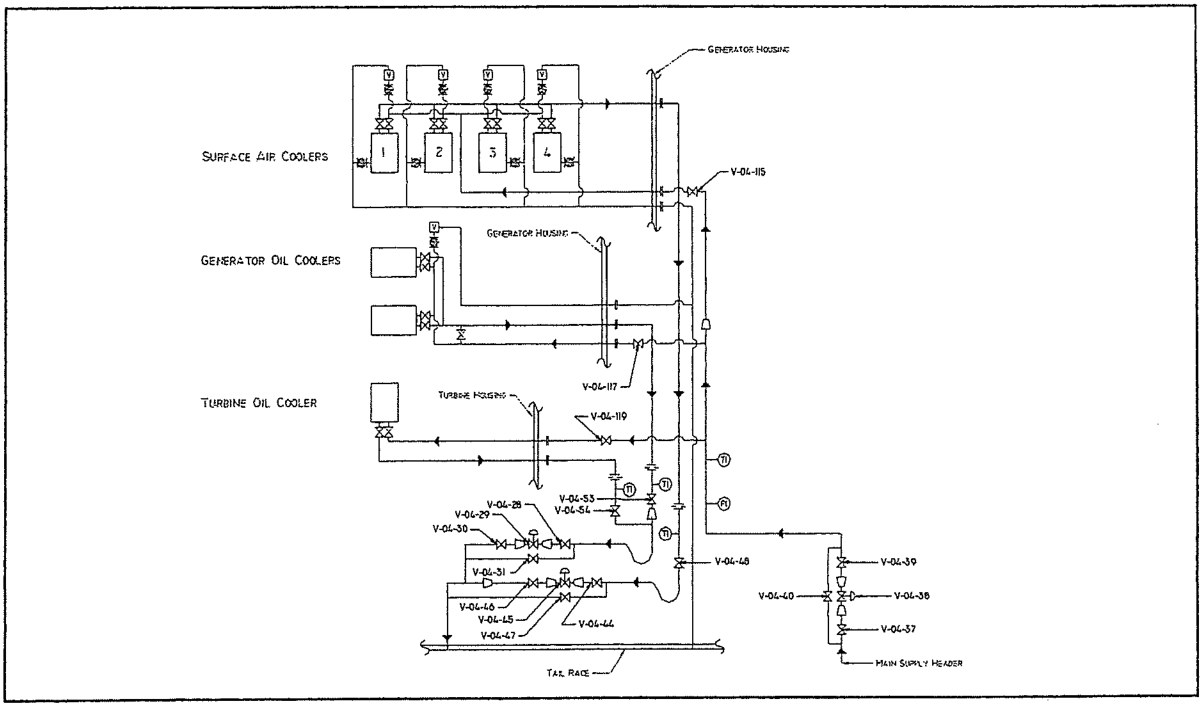
All flow diagrams can be found in Appendix A.

The following is the operating controls used to maintain the service water distribution header pressure together with set points and device.

Function	Set Point	Device
Operate service water auxiliary pump to augment main service water pump.	445 KPa ↓	PS-04-01
Operate lag main service water pump	385 KPa ↓	PS-04-02
Operate a main service water pump as standby when auxiliary pump is out of service.	400 KPa ↓	PS-04-03
Open high-pressure penstock lead PRV (V-04-97).	379 KPa ↓	V-04-97
Open high-pressure penstock lag PRV (V-04-103).	345 KPa ↓	V-04-103
Service water high-pressure alarm.	670 KPa ↑	PS-04-06
Service water low-pressure alarm.	310 KPa ↓	PS-04-07
Safety relief valve	690 KPa ↑	V-04-107

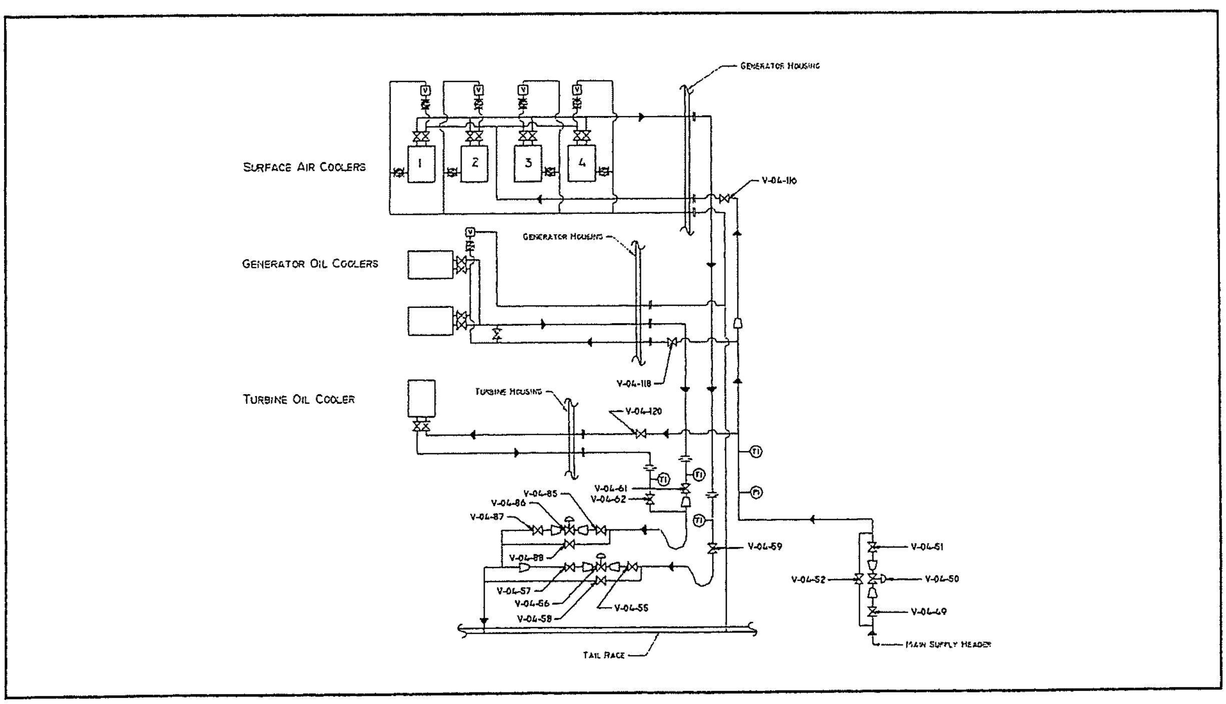
Table 1

The following drawing is the flow diagram for unit #1.



Drawing 2

The following drawing is the flow diagram for unit #2.



Drawing 3

Main Equipment

Primary Supply Pumps

There are two main vertical turbine supply pumps. Fairbanks Morse, model series 7000-12L-2 stage, manufactures both pumps. The following table lists the pump's technical specifications.

Lubrication	Water
Column Size	200mm
Discharge Connection	125mm
Type	Vertical Hollow Shaft
KW	37.3
Voltage	575V / 3Ph / 60Hz
RPM	1800
Capacity	57.4 L/s @ 441 KPa

Table 2

Auxiliary Supply Pump

There is only one auxiliary vertical turbine supply pump. Fairbanks Morse, model series 7000-6M-10 stage, manufactures the pump. The following table lists the pump's technical specifications.

Lubrication	Water
Column Size	100mm
Discharge Connection	100mm
Type	Vertical Hollow Shaft
KW	3.73
Voltage	575V / 3Ph / 60Hz
RPM	1800
Capacity	5.16 L/s @ 441 KPa

Table 3

Flow Meter Orifices

There are three flow meters located in the discharge lines of the coolers.

Discharge Line	Line size (sch 40)	Orifice size
SAC	4 inches	3.0295 inches
Generator	2 inches	1.1963 inches
Turbine	1 ¼ inches	0.7111 inches

Table 4

Self-Cleaning Strainer

Before the service water is supplied to the cooling water distribution header for each unit it is first passed through a self-cleaning strainer. This strainer's back wash system is set in automatic mode and a timer is used to control the backwash system. The timer is set for a 60 second back wash every hour. An inspection glass allows one to see the dirty side of the meshes and determine if they are in need of replacement. A conventional 200 mm Y strainer designed to handle the maximum anticipated water demand is also provided as a backup to the self-cleaning strainer. The following table lists the strainer's technical specifications.

Service	Water
Serial number	8319V
Design Pressure	150 psig @ 200 °F
Working Pressure	100 psig
Filter Media	60x60 s.s mesh with 10x10 s.s mesh
Motor	¾ HP
Voltage	120V / 1Ph / 60 Hz
RPM	1800

Table 5

Surface Air Coolers

There are four surface air coolers within the generator housing. These are aluminum-finned air to water heat exchangers with stainless steel tubes and carbon steel head covers. The following table lists the cooler's technical specifications.

MAWP	100 psig @ 200 °F
Water Pressure Drop Across Cooler	5.62 psi
Water Flow Rate per cooler	5.68 L/s
Number Tubes	186
Number Rows	6
Number Passes	6
Tube O.D	0.625 inches
Tube Wall Thickness	0.049 inches

Table 6

Design Velocity Calculations:

Flow Rate per tube $Q_t = 0.183$ L/s
Area per tube $A_t = 0.218$ in^2

Velocity per tube $V_t = Qt/At = 4.27$ ft/s

Generator Bearing Oil Coolers

There are two generator thrust and guide bearing oil coolers within the generator housing. These are aluminum-finned oil to water heat exchangers with stainless steel tubes and carbon steel head covers. The following table lists the cooler's technical specifications.

MAWP	150 psig @ 200 °F
Water Pressure Drop Across Cooler	1.5 psi
Water Flow Rate per cooler	1.52 L/s
Number Tubes	24
Number Rows	6
Number Passes	6
Tube O.D	0.625 inches
Tube Wall Thickness	0.049 inches

Table 7

Design Velocity Calculations:

Flow Rate per tube Q_t = 0.380 L/s
Area per tube A_t = 0.218 in^2
Velocity per tube $V_t = {Qt}/{At}$ = 8.86 ft/s

Turbine Bearing Oil Cooler

There is one turbine bearing oil cooler made from 1 inch, sch 40, seamless, 304 stainless steel pipe. The piping is joined together to form two semicircles and is laid into the turbine oil pot. The following table lists the cooler's technical specifications.

MAWP	3521 psig @ 200 °F
Water Flow Rate	1.1 L/s
Tube O.D	1.315 inches
Tube Wall Thickness	0.133 inches

Table 8

Design Velocity Calculations:

Flow Rate per tube Q_t = 1.1 L/s
Area per tube A_t = 0.864 in^2
Velocity per tube $V_t = {Qt}/{At}$ = 6.475 ft/s

Main Control Valves

Inlet Header Pressure Reducing Valve

The inlet header pressure reducing valve V-04-38 unit #1 and V-04-50 unit #2 are a four inch Masoneilan Camflex II control valve model # 35-35102. The following table lists the valve's technical specifications.

Specifications	Minimum	Normal	Maximum
Inlet Pressure	346 KPa		540 KPa
Outlet Pressure		309 KPa	
Flow Rate	7.3 L/s	15.6 L/s	29.7 L/s
CF		0.85	
Required CV	203.4		81.35
Rated CV		230	
Diff. Pressure Size	37 KPa		231 KPa
Diff. Pressure shut off			620 KPa

Table 9

SAC Temperature Control Valve

The SAC temperature control valve V-04-45 unit #1 and V-04-56 unit #2 are a three inch Masoneilan control valve model # 47-21125. The following table lists the valve's technical specifications.

Specifications	Minimum	Normal	Maximum
Inlet Pressure	144 KPa		299 KPa
Outlet Pressure	0 KPa		7 KPa
Flow Rate	5.3 L/s		25.3 L/s
CF		0.9	
Required CV	12.8		88.6
Rated CV		110	
Diff. Pressure Size	137 KPa		292 KPa
Diff. Pressure shut off			1450 KPa

Table 10

Generator/Turbine Automatic Shut Off Valve

The generator/turbine automatic shut off valve V-04-29 unit #1 and V-04-86 unit #2 are two inch valves with Canadian Worcester Controls (model # 20-405). The valves them selves are wrapped in insulation making their identification not possible.

Penstock Emergency Automatic Shut Off Valve

The penstock automatic shut off valves V-04-75 and V-04-76 are six inch valves with Marks Controls (model #896). The valves themselves are wrapped in insulation making their identification not possible.

Penstock Pressure Reducing Valve

The penstock pressure reducing valves V-04-97 and V-04-103 are two inch Masoneilan control valves (model # 48-21734). The following table lists the valve's technical specifications.

Specifications	Minimum	Normal	Maximum
Inlet Pressure		3772 KPa	
Outlet Pressure		434 KPa	
Flow Rate	7.3 L/s	14.6 L/s	31.0 L/s
CF		0.95	
Required CV	5.26		22.3
Rated CV		30	
Diff. Pressure Size		3338 KPa	
Diff. Pressure shut off		6800 KPa	

Table 11

Supply Pump Excess Pressure Release Valve

The excess pressure release valve V-04-113 is a one & half inch Masoneilan control valve model # 48-21135. The following table lists the valve's technical specifications.

Specifications	Minimum	Normal	Maximum
Inlet Pressure		540 KPa	
Outlet Pressure		7 KPa	
Flow Rate		600 L/s	
CF		0.9	
Required CV		26.80	
Rated CV		35	
Diff. Pressure shut off			1450 KPa

Table 12

Sump Level Control Valve

The sump level control valve V-04-110 is a two-inch Masoneilan control valve model # 48-21135. The following table lists the valve's technical specifications.

Specifications	Minimum	Normal	Maximum
Inlet Pressure		427 KPa	
Outlet Pressure		0 KPa	
Flow Rate		18.5 L/s	
CF		0.93	
Required CV		37.4	
Rated CV		46	
Diff. Pressure Size		427 KPa	
Diff. Pressure shut off		434 KPa	1450 KPa

Table 13

Unit #1 in Operation

The service water pressure can fluctuate between 345 KPa (50 psi) and 550 KPa (80 psi), therefore a pressure-regulating valve V-04-38 has been installed to maintain pressure at 220 KPa (32 psi). A bypass valve V-04-40 is provided so that the pressure-regulating valve can be isolated for repairs. The pressure-regulating valve is located after the self-cleaning strainer at the start of unit #1 service water distribution header. All inlet header valves, V-04-115 SAC, V-04-117 generator, V-04-119 turbine, are in the full open position.

Approximately twelve (12) seconds after initiation of unit #1, the following occurs:

1. Pneumatically operated temperature control valve V-04-45 opens and water flow is established through the surface air coolers. A bypass valve V-04-47 is provided so that the control valve can be isolated for repairs.
2. Pneumatically operated automatic shut-off valve V-04-29 opens and water flow is established through the turbine guide bearing cooler and the generator thrust/guide bearing coolers. A bypass valve V-04-31 is provided so that the control valve can be isolated for repairs.

After the water flows have been established, the flow indicator switches Fi/s-04-01, Fi/s-04-02, Fi/s-04-03 pick up and start measuring flows through the surface air coolers, turbine guide bearing cooler, and the generator thrust/guide bearing coolers.

Water flow through the turbine guide bearing cooler is manually controlled by ball valve V-04-54. This ball valve is throttled to provide 1.20 L/s of water through the cooler at maximum flow and is located after the cooler. Temperature indicator Ti-04-02 together with the flow meter provided on the flow meter panel have been provided to help set the required maximum flow through the cooler. The turbine guide bearing cooler water flow should never be set less than 0.25 L/s.

Water flow through two generator thrust/guide bearing coolers is manually controlled by ball valve V-04-53. This ball valve is throttled to provide 3.50 L/s of water through the coolers at maximum flow and is located after the cooler. Temperature indicator Ti-04-03 together with the flow meter provided on the flow meter panel have been provided to help set the required maximum flow through the coolers. The generator thrust/guide bearing coolers water flow should never be set less than 0.7 L/s.

Water flow through four surface air coolers is controlled automatically by temperature control valve V-04-45. The integral controller for this valve remotely senses the temperature of the common cooling water leaving the surface air coolers. This valve is set to maintain a leaving water temperature of 35 C, which corresponds to a surface air cooler discharge air temperature of 40 C. The temperature control valve is equipped with a pneumatic minimum position relay to ensure that whenever the unit is operating, water flow is never allowed to fall below 4.0 L/s. The temperature control valve is also equipped with an electric solenoid to fully close the valve whenever the unit is shutdown.

Temperature indicator Ti-04-04 has been provided to facilitate the checking of the operation of the temperature control valve. Balancing valve V-04-48 on the surface air cooler return line should be set to provide a surface air cooler flow of 26.0 L/s when the temperature control valve is fully open.

Flow meter panel settings:

Flow Rates	Scale Range	Set Point
Turbine guide bearing cooler flow	0-1.20 L/s	0.20 L/s
Generator thrust/guide bearing coolers flow	0-3.50 L/s	0.60 L/s
Surface Air Coolers flow	0-26.0 L/s	3.50 L/s

Table 14

Unit #2 in Operation

The service water distribution header pressure can fluctuate between 345 KPa (50 psi) and 550 KPa (80 psi), therefore a pressure-regulating valve V-04-50 has been installed to maintain pressure at 220 KPa (32 psi). A bypass valve V-04-52 is provided so that the pressure-regulating valve can be isolated for repairs. The pressure-regulating valve is located after the self-cleaning strainer. All inlet header valves, V-04-116 SAC, V-04-118 generator, V-04-120 turbine, are in the full open position.

Approximately twelve (12) seconds after initiation of unit #1, the following occurs:

3. Pneumatically operated temperature control valve V-04-56 opens and water flow is established through the surface air coolers. A bypass valve V-04-58 is provided so that the control valve can be isolated for repairs.
4. Pneumatically operated automatic shut-off valve V-04-86 opens and water flow is established through the turbine guide bearing cooler and the generator thrust/guide bearing coolers. A bypass valve V-04-88 is provided so that the control valve can be isolated for repairs.

After the water flows have been established, the flow indicator switches Fi/s-04-04, Fi/s-04-05, Fi/s-04-06 pick up and start measuring flows through the surface air coolers, turbine guide bearing cooler, and the generator thrust/guide bearing coolers.

Water flow through the turbine guide bearing cooler is manually controlled by ball valve V-04-62. This ball valve is throttled to provide 1.20 L/s of water through the cooler at maximum flow and is located after the cooler. Temperature indicator Ti-04-07 together with the flow meter provided on the flow meter panel have been provided to help set the required maximum flow through the cooler. The turbine guide bearing cooler water flow should never be set less than 0.25 L/s.

Water flow through two generator thrust/guide bearing coolers is manually controlled by ball valve V-04-61. This ball valve is throttled to provide 3.50 L/s of water through the coolers at maximum flow and is located after the cooler. Temperature indicator Ti-04-06 together with the flow meter provided on the flow meter panel have been provided to help set the required maximum flow through the coolers. The generator thrust/guide bearing coolers water flow should never be set less than 0.7 L/s.

Water flow through four surface air coolers is controlled automatically by temperature control valve V-04-56. The integral controller for this valve remotely senses the temperature of the common cooling water leaving the surface air coolers. This valve is set to maintain a leaving water temperature of 35 C, which corresponds to a surface air cooler discharge air temperature of 40 C. The temperature control valve is equipped with a pneumatic minimum position relay to ensure that whenever the unit is operating, water flow is never allowed to fall below 4.0 L/s. The temperature control valve is also equipped with an electric solenoid to fully close the valve whenever the unit is shutdown.

Temperature indicator Ti-04-05 has been provided to facilitate the checking of the operation of the temperature control valve. Balancing valve V-04-59 on the surface air cooler return line should be set to provide a surface air cooler flow of 26.0 L/s when the temperature control valve is fully open.

Flow meter panel settings:

Flow Rates	Scale Range	Set Point
Turbine guide bearing cooler flow	0-1.20 L/s	0.20 L/s
Generator thrust/guide bearing coolers flow	0-3.50 L/s	0.60 L/s
Surface Air Coolers flow	0-26.0 L/s	3.50 L/s

Table 15

HISTORY OF SERVICE WATER SYSTEM

General Information

All work orders that are in the J.D.Edwards system since the fall of 1994 pertaining to the service water pumps, strainers, and heat exchangers have been reviewed to piece together an overview of the major work done on the service water system. All of the major work done on this system is listed below in the following table. It can be seen from table 16 that the SAC's are cleaned every second year since 1995. It can also be seen that the SAC piping has been cleaned every three years since 1997.

CAT ARM Work Order History				
	May	June	July	Oct
1995		Unit #1 Cleaned all SAC Unit #2 Cleaned all SAC		
1997				All four SAC were cleaned. 2.5" piping I.D = 2.0" - 2.3" scraped clean one section I.D = 2.467"
1998			Unit #1 Chemical Cleaning (TRAC 100) of generator coolers and turbine cooler. Unit #2 Chemial Cleaning (TRAC 100) of generator coolers and turbine cooler. Unit #2 leaked during flushing of coolers.	
1999			Unit #1 Flushed SAC and measured flows, 1: 7 l/s, 2: 13 l/s, 3: 10 l/s, 4: 4.5 l/s. Cleaned SAC 1, 3, & 4. Unit #2 Flushed SAC and measured flows, 1: 5 l/s, 2: 1 l/s, 3: 9.5 l/s, 4: 7 l/s Cleaned SAC 1,3, & 4, replaced 2.	
2000	Installed new rotary strainer.	Unit #1 Replaced SAC #4 with spare. Unit #2 Replaced SAC #1 with spare. Lag pump #3 cutting in during rotary strainer backwash.	Unit #1 Removed and cleaned all 2.5" and 3" pipe for SAC inside of generator housing. Unit #2 Removed and cleaned all 2.5" and 3" pipe for SAC inside of generator housing.	Unit #1 Removed and cleaned all 4" pipe for SAC inside of generator housing. Unit #2 Removed and cleaned all 4" pipe for SAC inside of generator housing.

Table 16

Table 17 gives the dates when each unit was off line for maintenance since 1999.

CAT ARM UNIT OUTAGES						
Month	Unit #1			Unit #2		
	1999	2000	2001	1999	2000	2001
January		8,26	1,12,17	4	1,2,3,8,12,26	
February	13	8		9	8,18	
March	12			9	10	
April	13			9	11	
May	10			7,8,17		
June	14	14,19,23		12	23	13
July	2,7,8,9,14			6,14,16,20,21		
August	3,8	24		3,8	24	
September		18,25			18,20,26	
October		10				
November		25			30	
December	6,13-17,21	5,6,29		7,15-18,20,31		

Table 17

Review of Trend Monitoring Readings

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.

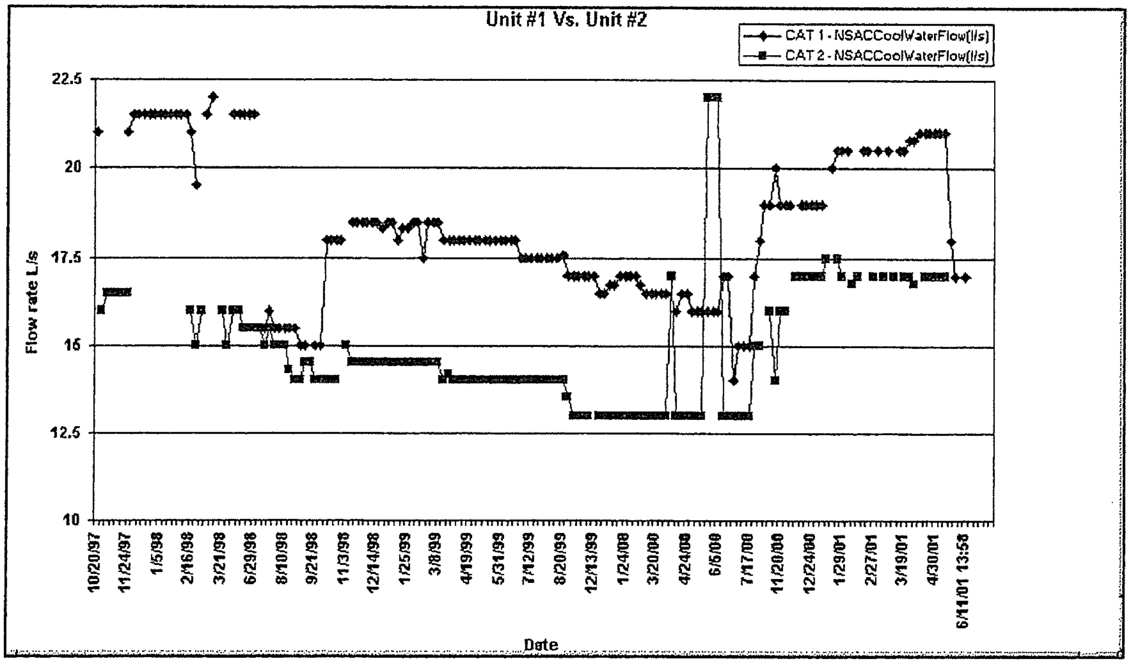
The Trend monitoring readings are now being stored into a database using Microsoft Access. A hard copy of the weekly readings is being kept on site for backup. The Microsoft Access Trend Monitoring program now allows quick graphing of operating parameters to help us determine the efficiency of the unit.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

Table 18 shows the missing trend monitoring readings for Cat Arm.

	UNIT #1		UNIT #2	
DATES			1997/11/24 to 1998/02/16	Early Winter 1998
	1998/03/09 to 1998/06/01	Spring 1998	1998/03/23 to 1998/06/01	Spring 1998
	1999/08/20 to 1999/11/08	Fall 1999	1999/08/20 to 1999/11/08	Fall 1999
	2000/07/31 to 2000/10/30	Late Summer 2000	2000/07/31 to 2000/10/30	Late Summer 2000

Table 18

Graph 1 - SAC Flow Rates



Graph 1 shows the flow rates for the SAC's since October 1997. The recommended flow rates are 23 L/s during the summer months and 5 L/s during the winter months. One can see the increase in flow rate around July 2000 when the SAC piping was cleaned. Cleaning the SAC's in July 1999 did nothing to increase the flow rate because the problem was clogged piping. Cleaning the SAC's in October 1997 did maintain high flow rates up until the fall 1998 when both units SAC's started a steady decline until the piping was cleaned in July 2000. It is interesting to note that the flow rate through unit #2 has always been lower than unit #1, this warrants further investigation.

The SAC flow rate has also increased in the fall and decreased in the spring. This is believed to be caused by the spring run off carrying suspended particulates of organic matter. After these particulates flow through the SAC the heat causes them to solidify and fall out of the solution. Theses solid globes of matter then become caught along the inside of the pipe, especially if the pipe is corroded.

To combat this problem for the summer it was suggested that the 3-inch by-pass line also be fully opened. So both units by-pass lines where fully open along with their main 4-inch discharge lines. Unit #1 increased its flow from 18 L/s to 20 L/s and unit #2 increased its flow from 15.5 L/s to 17L/s. The by-pass lines will remain open until the end of the warm season some time in September 2001.

Actual Velocity Calculations:

Unit #1

Flow Rate per tube $Q_t = 0.161$ L/s

Area per tube $A_t = 0.218$ in^2

Velocity per tube $V_t = Qt/At$ = 3.76 ft/s

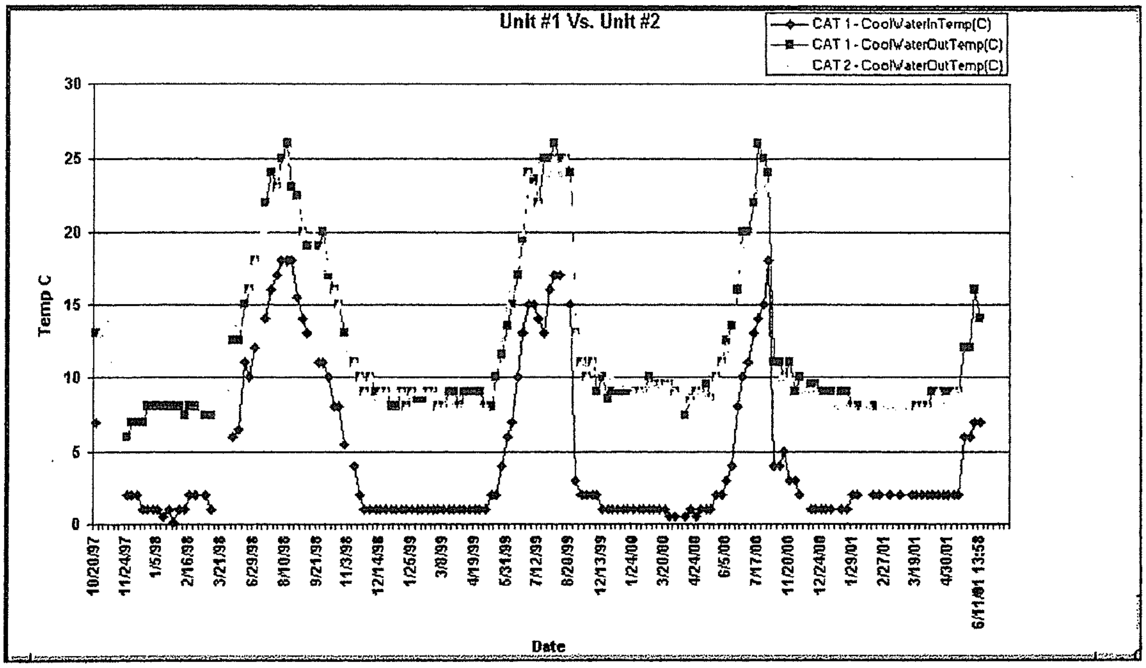
Unit #2

Flow Rate per tube $Q_t = 0.137$ L/s

Area per tube $A_t = 0.218$ in^2

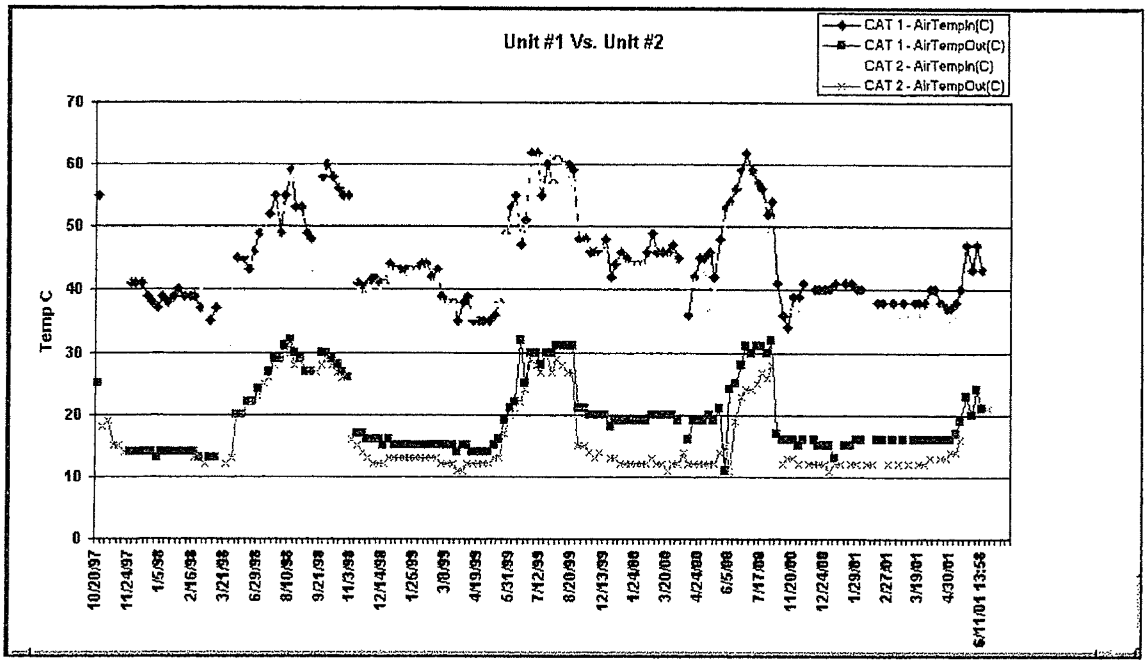
Velocity per tube $V_t = Qt/At$ = 3.20 ft/s

Graph 2 - SAC Water Temperature



Graph 2 shows the water temperature differential for the SAC's on both units since October 1997. This clearly shows how the water temperature fluctuates through out the year, with increased temperatures during the summer months and decreased temperatures during the winter months. Even though the temperature fluctuates the differential temperature between inlet and discharge remains constant around an average of 5 °C.

Graph 3 - SAC Air Temperatures



Graph 3 shows the air temperature differential for the SAC's on both units since October 1997. The air temperature into the SAC's is measured inside the stator frame and the air temperature out of the SAC's is measured inside the generator housing. Only one SAC air temperatures are measured, which is SAC #2 for unit #1 and SAC #3 for Unit #2. This graph clearly shows how the air temperature fluctuates through out the year, with increased temperatures during the summer months and decreased temperatures during the winter months. Even though the temperature fluctuates the differential temperature between inlet and outlet remains constantly around an average of 20 °C.

SAC Air Temperature Set Points:

Unit #1	Cold Air	Warm Air
Alarm	45 °C	70 °C
Trip Unit Off Line	52 °C	

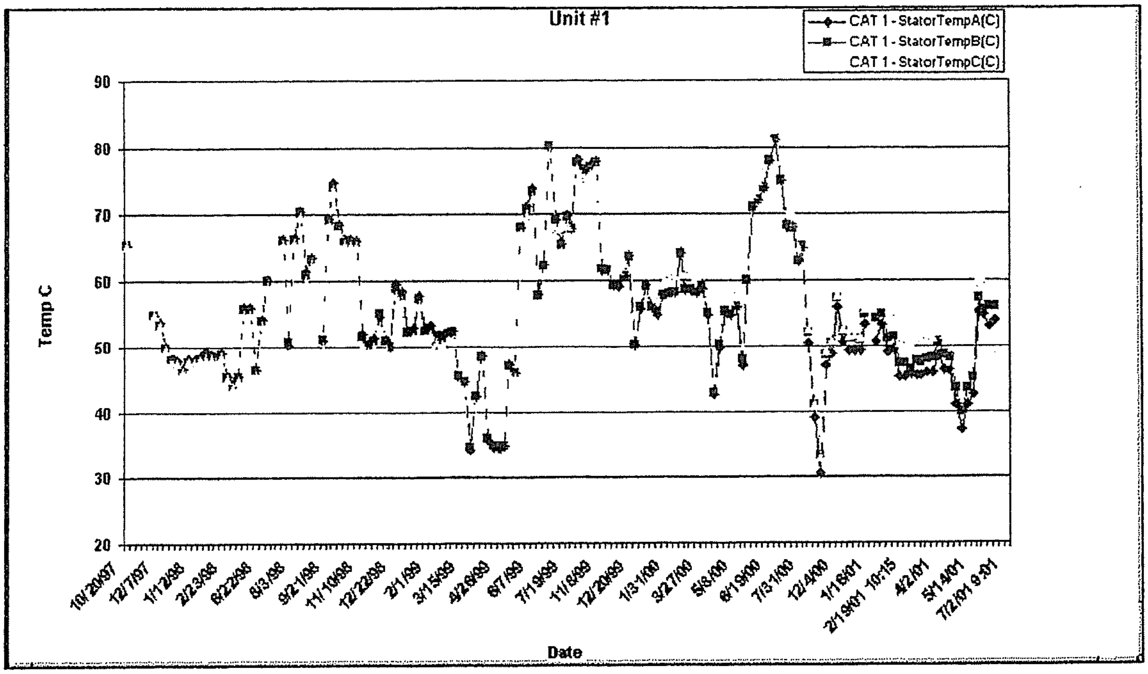
Table 19

Unit #2	Cold Air	Warm Air
Alarm	45 °C	68 °C
Trip Unit Off Line	50 °C	

Table 20

The air temperature out of the SAC's have never reached the alarm set point of 45 °C at least since October 1997.

Graph 4 - Unit #1 Stator Temperatures



Graph 4 shows the Stator temperatures for unit #1 since October 1997. This graph clearly shows how the stator temperature fluctuates through out the year, with increased temperatures during the summer months and decreased temperatures during the winter months.

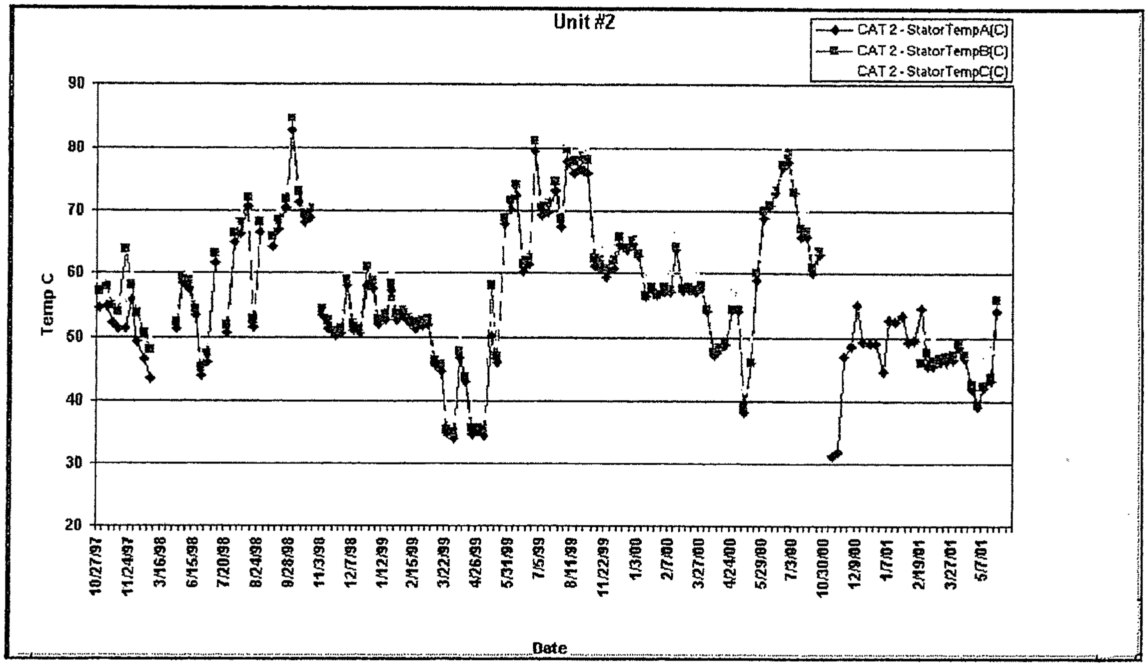
Stator Temperature Set Points:

Core Alarm	105 °C
Iron Alarm	90 °C

Table 21

The stator temperatures have never reached the iron alarm set point of 90 °C at least since October 1997.

Graph 5 – Unit #2 Stator Temperatures



Graph 5 shows the Stator temperatures for unit #2 since October 1997. This graph clearly shows how the stator temperature fluctuates through out the year, with increased temperatures during the summer months and decreased temperatures during the winter months.

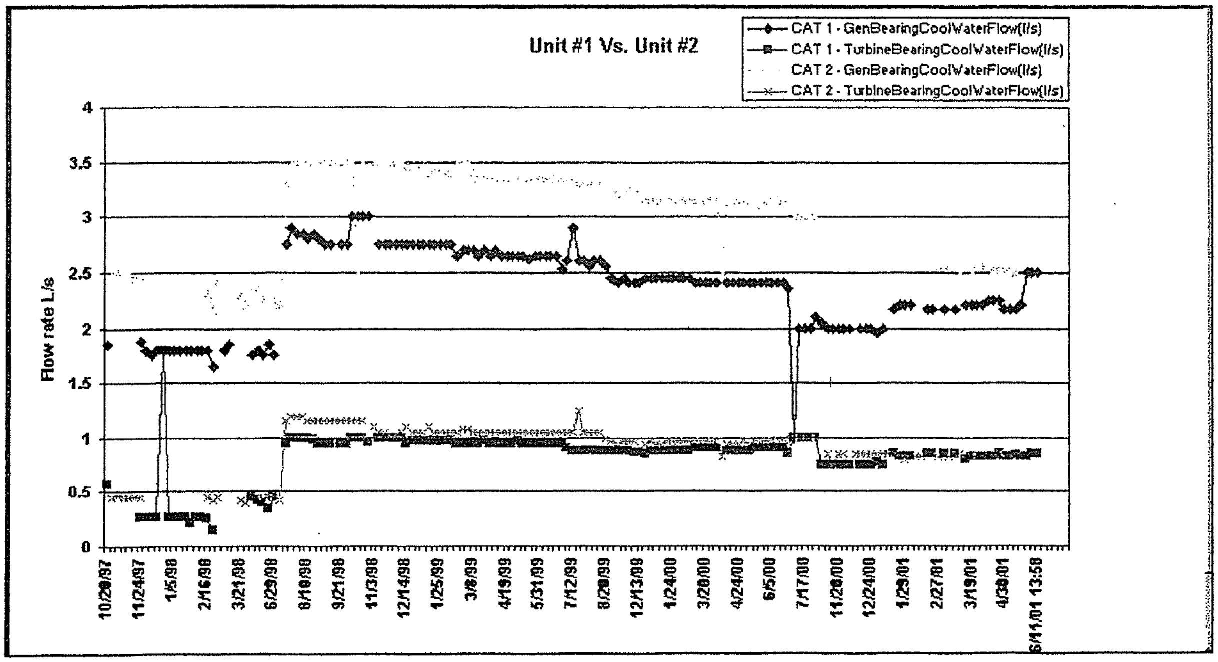
Stator Temperature Set Points:

Core Alarm	105 °C
Iron Alarm	90 °C

Table 22

During the summer of 1998 unit #2 stator temperatures climbed to 86 °C almost reaching the iron alarm temperature of 90 °C.

Graph 6 - Generator/Turbine Flow Rates



Graph 6 shows the flow rates for the generator and turbine coolers since October 1997. The recommended flow rates are 3.5 L/s for the generator coolers and 1.20 L/s for the turbine cooler. One can see how much the flow rate increased through the coolers in July 1998 after they where chemically cleaned with Trac 100.

To combat the problem of summer fouling it was also suggested that the 2-inch by-pass line also be fully opened. Only unit #1 by-pass line was fully open, unit #2 by-pass line was not opened due to the by-pass valve being seized closed. The flow rate through the generator and turbine coolers did not change. This seized by-pass valve will be fixed during the fall 2001 outage under work order # 230448.

Actual Velocity Calculations:

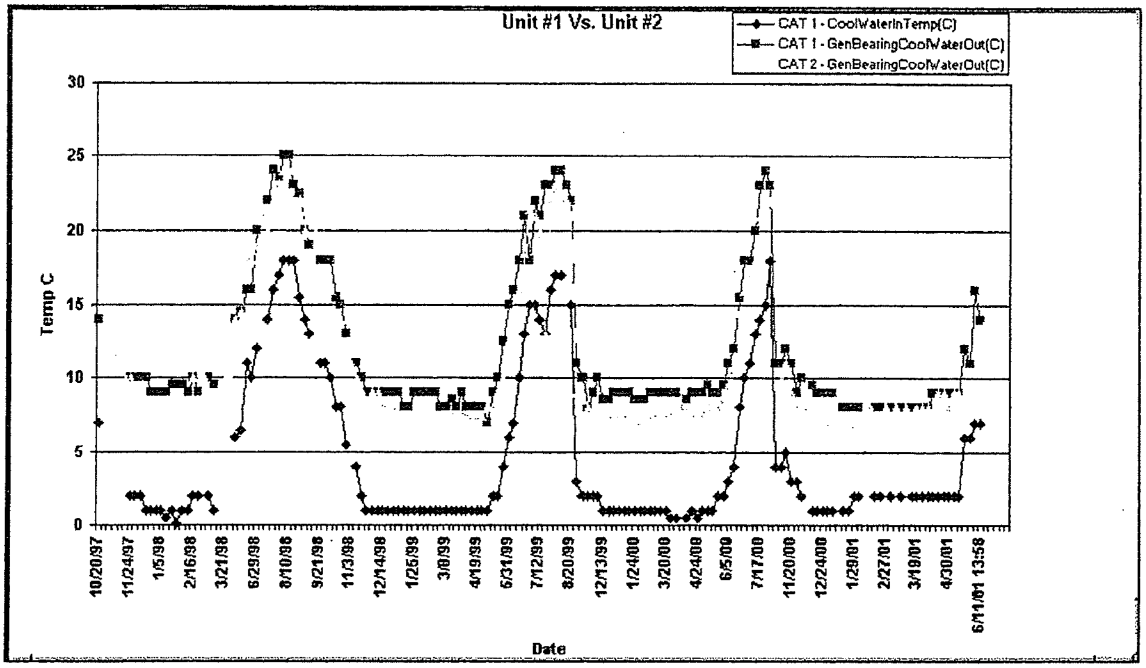
Generator Coolers:

Flow Rate per tube $Q_t = 0.312$ L/s
Area per tube $A_t = 0.218$ in^2
Velocity per tube $V_t = Qt/At = 7.29$ ft/s

Turbine Cooler:

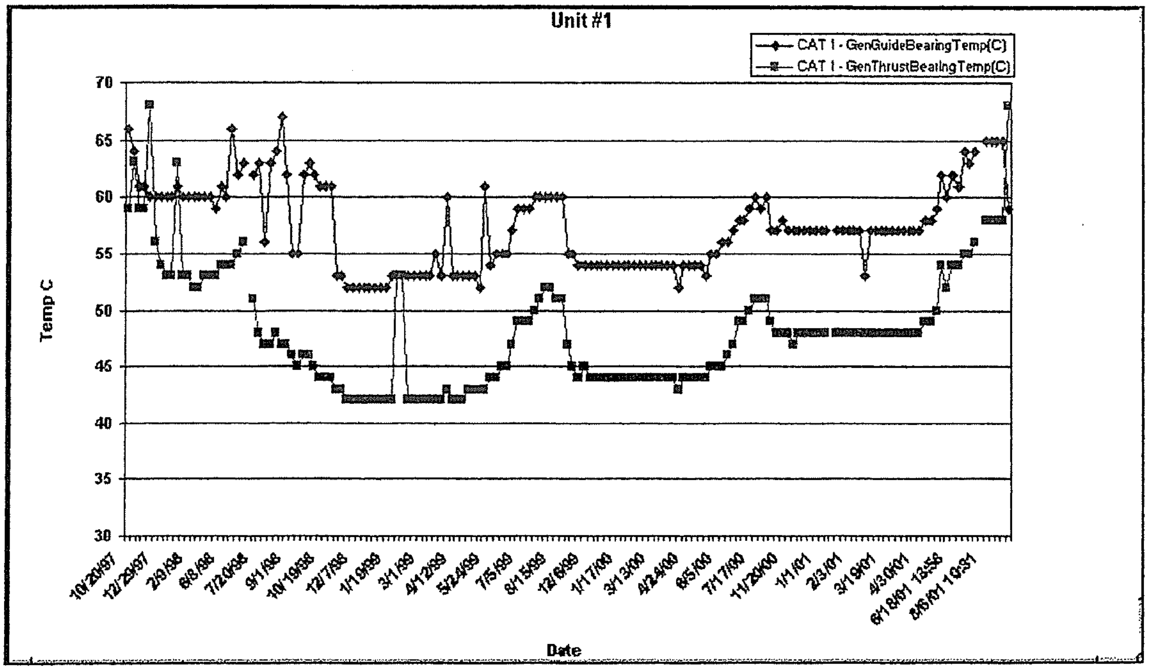
Flow Rate per tube $Q_t = 0.80$ L/s
Area per tube $A_t = 0.864$ in^2
Velocity per tube $V_t = Qt/At = 4.71$ ft/s

Graph 7 - Generator Water Temperatures



Graph 7 shows the water temperature differential for the generator coolers on both units since October 1997. This graph clearly shows how the water temperature fluctuates through out the year, with increased temperatures during the summer months and decreased temperatures during the winter months.

Graph 8 – Unit #1 Gen Bearing Temperatures



Graph 8 shows unit #1 generator's guide and thrust bearing temperatures since October 1997. One can see the temperature dropped in July 1998 after the coolers were chemically cleaned with Trac 100. Since then one can also see how the temperatures have continually increased from year to year when you compare the consistent winter temperatures from year to year. This continuous increase in temperature from year to year is resulting from the gradual build up of particulates inside the cooler tubes and pipes.

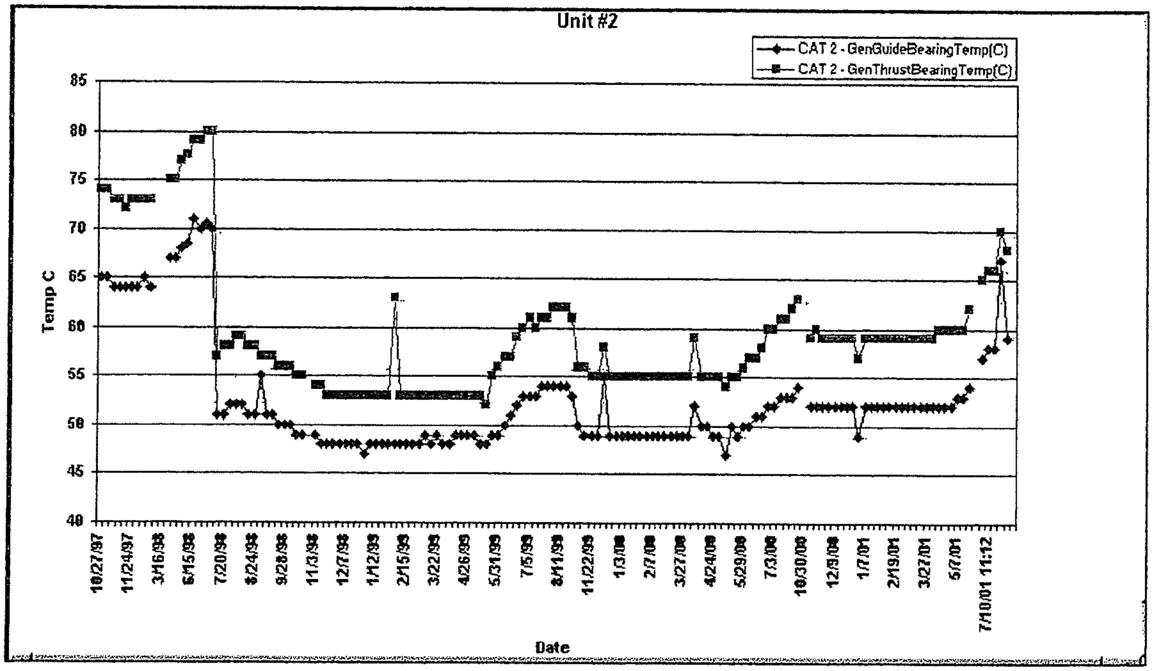
Generator Bearing Temperature Set Points:

Unit #1	Guide Bearing	Thrust Bearing
Alarm	72.5 °C	80 °C
Trip to Synchronous Condense Mode	75 °C	85 °C
Trip Unit Off Line	90 °C	95 °C

Table 23

Before the coolers were cleaned in the summer of 1998 the guide bearing temperature climbed to 67 °C, almost reaching the guide bearing alarm set point of 72.5 °C. The guide bearing temperatures are again on the rise since they're cleaning with Trac 100 in the summer of 1998. The recorded high temperatures this summer for the guide bearing were 65 °C.

Graph 9 – Unit #2 Gen Bearing Temperatures



Graph 9 shows unit #2 generator's guide and thrust bearing temperatures since October 1997. One can see the dramatic temperature dropped in July 1998 after the coolers were chemically cleaned with Trac 100. This graph also shows how the temperatures have been continually increasing from one year to the next. Comparing the winter temperature of 2001 with that of 1999 there has been an increase of at less 5 °C. This continuous increase in temperature from year to year is resulting from the gradual build up of particulates inside the cooler tubes which directly affects the heat transfer rate.

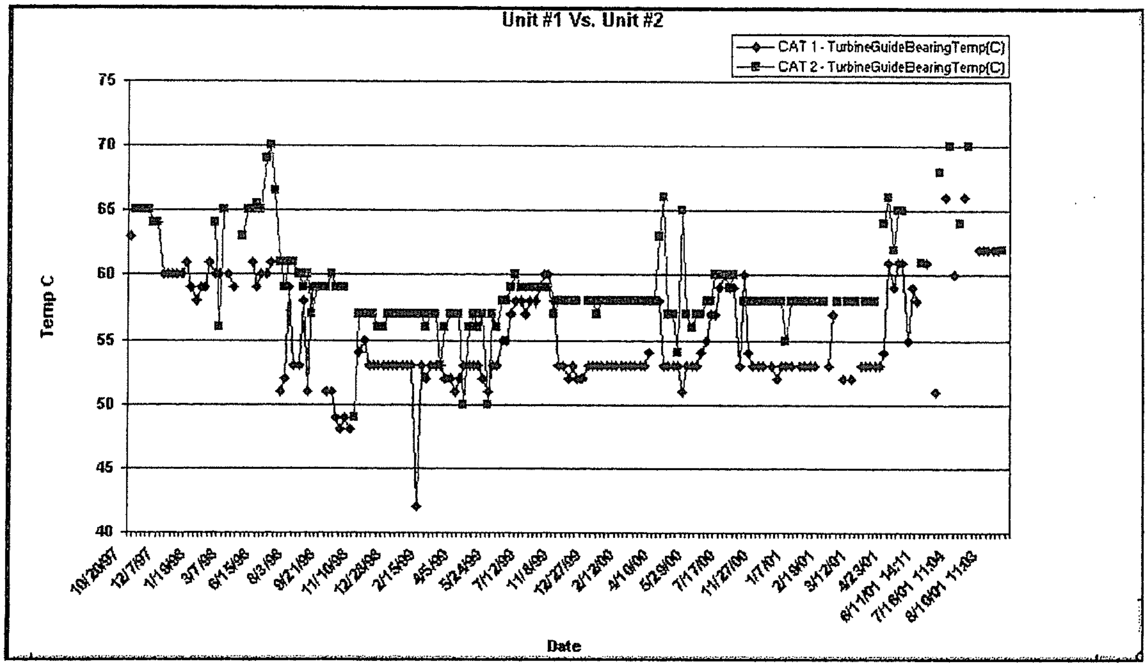
Generator Bearing Temperature Set Points:

Unit #2	Guide Bearing	Thrust Bearing
Alarm	71 °C	80 °C
Trip to Synchronous Condense Mode	76 °C	85 °C
Trip Unit Off Line	90 °C	95 °C

Table 24

The trust and guide bearing alarm set points were reached in the summer of 1998 before the coolers were cleaned with Trac 100.

Graph 10 – Turbine Bearing Temperature



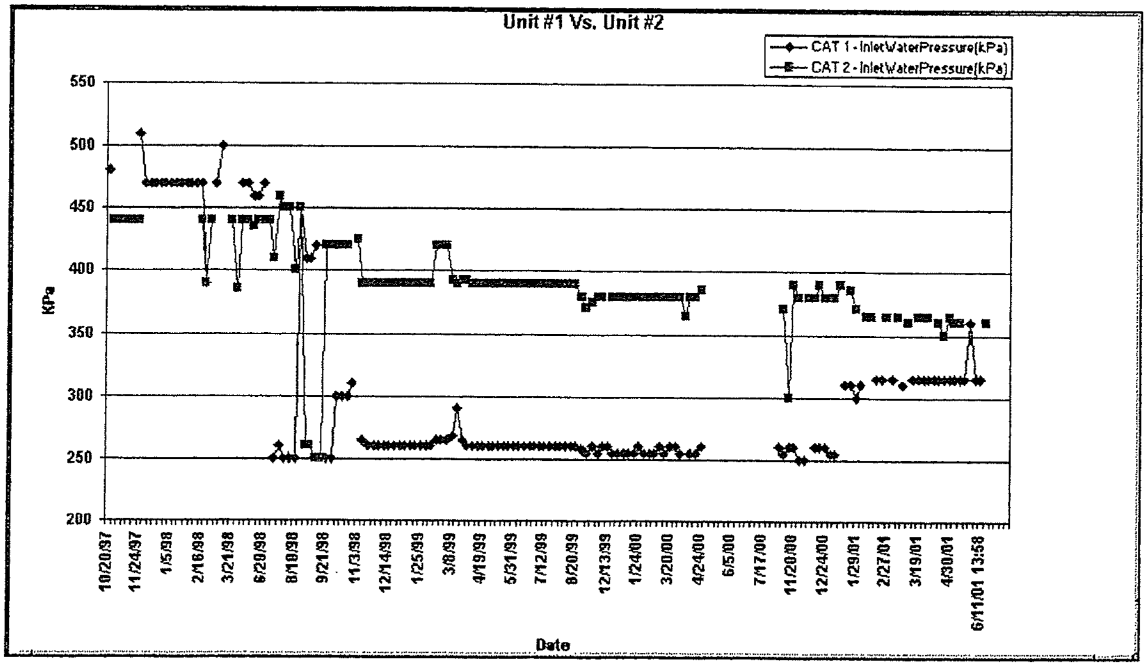
Graph 10 shows the Turbine guide bearing temperatures since October 1997. It can be seen from this graph the temperature drop in July 1998, which was due to chemically cleaning the cooler with Trac 100. The bearing is again starting to run hot due to the continuous build up of particulates over the last three years within the system.

Turbine Bearing Temperature Set Points for unit #1 and unit #2:

Alarm	75 °C
Trip to Synchronous Condense Mode	80 °C
Trip Unit Off Line	85 °C

Table 25

Graph 11 - Water Pressure



Graph 11 shows the water inlet pressure on the six-inch supply header that feeds each unit with cooling water. This pressure reading is taken down stream from the pressure reducing valve on each header. A Technician from New Valve adjusted the pressure reducing valve on unit #1 in July 1998, which caused the sudden drop in pressure. Reducing the pressure in the supply header directly affects the volume of cooling water being supplied.

To increase the water flow through unit #2 the pressure-reducing valve V-04-50 located in the inlet header was open from 70% to 100%. This caused an increase in pressure from 390 KPa to 410 KPa. The main supply pump is operating around 490 KPa. This pressure difference will be investigated during the fall 2001 outage under work order # 228335. It is thought that the valve may be malfunctioning, the by-pass valve V-04-52 was open fully, and the pressure remained at 410 KPa. It is now thought that the main supply header has considerable build up and the by-pass line is clogged. The pressure gauge was also changed, and the pressure still remained the same.

Test Samples

In August 2000 water and hard barnacle pipe deposits from the Cat Arm plant were sent to BetzDearborn for analysis. The water sample is directly from the penstock supply and the barnacle deposits are from the SAC cooling water piping. Table 26 shows the composition of the water sample.

Composition	Sample #1	Sample #2
PH	5.0	5.1
Specific Conductance @ 25C, umhos	91	77
Alkalinity "P" as $CaCO_3$, ppm	0	0
Alkalinity "M" as $CaCO_3$, ppm	< 2	< 2
Sulfur Total as SO_4, ppm	< 5	< 5
Chloride as CL, ppm	3.1	3.7
Hardness Total as $CaCO_3$, ppm	6.5	5.3
Calcium Hardness Total as $CaCO_3$, ppm	2.3	1.6
Magnesium Hardness Total as $CaCO_3$, ppm	4.2	3.6
Copper Total as Cu, ppm	< 0.05	< 0.05
Iron Total as Fe, ppm	0.79	0.87
Sodium as Na, ppm	2.2	2.1
Phosphate Total Inorganic as Po_4, ppm	< 0.2	< 0.2
Phosphate Ortho- as Po_4, ppm	< 0.2	< 0.2
Silica Total as SiO_2, ppm	1.5	1.5

Table 26

As one can see the pH level of 5.0 tells us that the water is acidic in nature. This type of water is very aggressive and will corrode piping and equipment.

Table 27 shows the composition of the SAC piping barnacle deposit.

Composition	**Sample #1**	**Sample #2**
Iron $Fe_2O_3 + Fe_3O_4$	72 %	66%
Loss on Ignition LOI	21%	18%
Manganese MnO_2	6%	15%
Aluminum Al_2O_3	1%	1%

Table 27

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 of ignition LOI refers to the organics within the sample.

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

Cost Analysis

Maintenance Cost for Cleaning

In order to clean the service water coolers and piping in Cat Arm, a maintenance crew has to be assembled in Bay D'Espoir and drive to Cat Arm. Travel time to Cat Arm from Bay D'Espoir is normally eight hours.

Travel Arrangements (normal workweek)

Monday: Leave Bay D'Espoir in the morning and drive to the West coast. Work 4.0 hours upon arriving on site.
Tuesday to Thursday: Regular workweek 8.0 hours per day.
Friday: Work 4.0 hours and then drive back to Bay D'Espoir for the weekend.

Hours of actually work performed on site for one workweek is 32.0 hours.

Perdiem Expenses ($9 Breakfast, $11 Dinner, $18 Supper, $6 Incidentals (over night))

Monday: $34 (no breakfast)
Tuesday to Thursday: $43 per day
Friday: $20 (no supper or incidentals)

Total Perdiem charge per person per week: $183

Having a work crew of more than 4 workers will require the services of a cook and perdiem will not be paid while the services of a cook is provided on site.

For the purpose of this study all workers will receive perdiem.

Minimum Work Crew and Wages

3 Workers at $21.56 hr (2 workers on floor, 1 worker operating the crane)
1 Supervisor at $23.72 hr (10% more than the worker)

Total over head costs = salary x 1.63

Travel to site will be by fleet vehicles, 2 required, one supervisor vehicle and one work crew truck. Tools and cleaning equipment will be transported to the site with these vehicles.

The supervisor is usually over seeing two or three jobs while on site. For this cost analysis 1/3 of the supervisors wage will be allocated to the job.

Required gas for travel is $80 to site and $80 return from site for one work truck.

Total Cost to Clean SAC per Unit

Time required to clean four SAC's for one work crew is four days (32.0 hrs), one cooler per day (8.0 hrs); this includes removal, cleaning, and reinstallation of cooler.

Labour: 3 (workers) x 40.0 hrs (32.0 cleaning, 8.0 driving) x $21.56 = $2,587.20
1 (supervisor) x 13.3 hrs (1/3 x 40.0 hrs) x $23.72 = $315.48

Total Over Head Costs: $2,902.68 x 1.63 = $4,731.37

Perdiem: 4 (work crew) x $183 = $732
(Monday $34, Tuesday to Thursday $129, Friday $20)

Gas: 4 (2 vehicles) x $80 = $320

Total cost: $5,783.37

Total Cost to Clean SAC Piping per Unit

Time required to clean SAC piping inside of generator housing for one work crew is three days (24.0 hrs); this includes removal, cleaning, and reinstallation of piping.

Labour: 3 (workers) x 32.0 hrs (24.0 cleaning, 8.0 driving) x $21.56 = $2,069.76
1 (supervisor) x 10.7 hrs (1/3 x 32.0 hrs) x $23.72 = $253.80

Total Over Head Costs: $2,323.56 x 1.63 = $3,787.40

Perdiem: 4 (work crew) x $140 = $560
(Monday $34, Tuesday to Wednesday $86, Thursday $20)

Gas: 4 (2 vehicles) x $80 = $320

Total cost: $4,667.409

Total Cost to Clean Generator Coolers per Unit

Time required to clean two generator coolers for one work crew is four days (32.0hrs), two days (16.0 hrs) per cooler; this includes removal, cleaning, and reinstallation of cooler.

Labour: 3 (workers) x 40.0 hrs (32.0 cleaning, 8.0 driving) x $21.56 = $2,587.20
1 (supervisor) x 13.3 hrs (1/3 x 40.0 hrs) x $23.72 = $315.48

Total Over Head Costs: $2,902.68 x 1.63 = $4,731.37

Perdiem: 4 (work crew) x $183 = $732
(Monday $34, Tuesday to Thursday $129, Friday $20)

Gas: 4 (2 vehicles) x $80 = $320

Total cost: $5,783.37

Total Cost to Clean Generator Cooler Piping per Unit

Time required to clean generator piping inside of generator housing for one work crew is three days (24 hrs); this includes removal, cleaning, and reinstallation of piping.

Labour: 3 (workers) x 32.0 hrs (24.0 cleaning, 8.0 driving) x $21.56 = $2,069.76
1 (supervisor) x 10.7 hrs (1/3 x 32.0 hrs) x $23.72 = $253.80

Total Over Head Costs: $2,323.56 x 1.63 = $3,787.40

Perdiem: 4 (work crew) x $140 = $560
(Monday $34, Tuesday to Wednesday $86, Thursday $20)

Gas: 4 (2 vehicles) x $80 = $320

Total cost: $4,667.40

Maintenance Costs Over Piping Life (20 years) per Unit

SAC cleaning every 2 yrs = $57, 833.70
SAC pipe cleaning every 10 yrs = $9,334.80
Gen coolers cleaning every 5 yrs = $23,133.48
Gen pipe cleaning every 10 yrs = $9,334.80

ALTERNATIVE SOLUTIONS

General Information

The fouling problem with regard to the cooling water system is being caused by two problems. The first problem is corrosion of the piping system and the second problem is organic build up. The acidic water supply is causing the piping system to corrode and the organics are then attaching themselves to the corroded pipe. Over time the organics build up and are able to clog the pipe. The heat transferred into the cooling water from the heat exchangers cause the suspended organics in the water to participate out. This then causes the discharge piping to become clogged with organics and choke off the flow rate. 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 solutions that can be used to combat this problem.

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.

A brief description of each proposed solution is discussed below.

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 happen.

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

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.

Chemical Treatment of the Water

The water can be chemically treated to reduce the acidity of the water by raising the ph level and also help keep all organic materials in a suspended state. The existing service water system is a once through operation and will require large amounts of chemical. BetzDearborn purposed a chemical treatment solution, which can be found in appendix C. It is estimated to cost $5,000 to set up this system and $45,000 per year for chemical usage.

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.

If a flushing program was implemented it would reduce the amount of lose 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. A flushing procedure for Cat Arm can be found in Appendix D.

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 Cat Arm would be around 14 ft in diameter to allow for 900 gpm. Space would then become a problem with this solution.

Closed System Operation

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 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 because you are reusing the existing water that is in the cooling pond. The water in the cooling pond can be chemically treated to ensure that it remains neutral and does not become acidic. Again space would be a restriction with this type of solution.

VIABLE SOLUTIONS

In order to compare the viable solutions the Net Present Worth (NPW) method will be used to determine which solution is most feasibly from a financial point of view. The NPW method will only take into account the investment dollars needed to bring the solution to life. Other benefits to each solution is not taken into account using the NPW method because of the many variables involved in placing a dollar sign on there worth.

In the conclusions and recommendations section each solution will be discussed including all of the advantages and disadvantages associated with that solution.

Continue to Maintain Current Operation

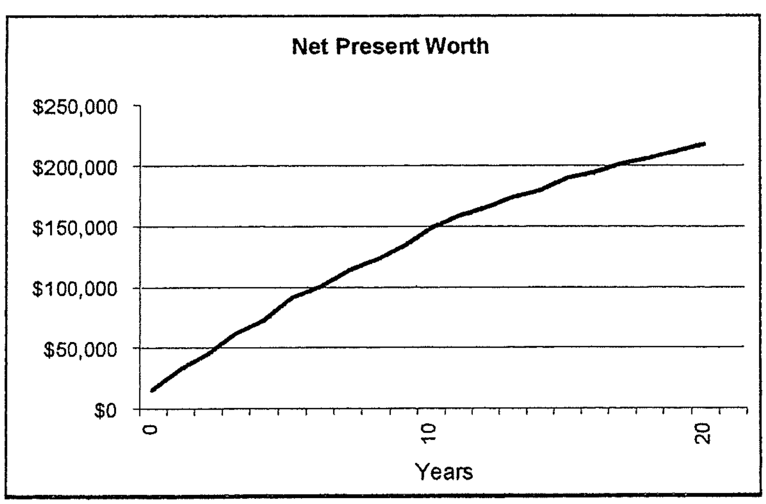
The "do nothing" approach is to continue operating the plant as we have in the past. This means mechanically cleaning the SAC's every second year, generator bearing coolers every five years, SAC piping every ten years, and generator bearing cooler piping every ten years. This solution will require high maintenance and unit outages so that the work can be performed.

The NPW cost associated with this solution is for only one unit in Cat Arm and in order to compare this solution to the others the NPW cost should be doubled.

NPW Analysis

Below is the NPW analysis of the "do nothing" solution. There is no capital expenditures related to this solution only yearly operating costs.

Graph 1 is the NPW analyse of "do nothing" solution:



Graph 1

Table 28 shows the costs associated with this solution:

Capital Cost	
Total	0

Operating Cost	
Pump consumption (49 weeks)	$15,353
Clean SAC (2 yr)	$5,783
Clean SAC Piping (10 yr)	$4,667
Clean Gen Brg Coolers (5 yr)	$5,783
Clean Gen Brg Cooler Piping (10	$4,667

Table 28

The NPW is calculated over the life span of the piping, which is 20 years. The inflation rate used is 2%, the power rate used for the pump is $0.05 kWh, and the rate of return for Hydro is 8.5%.

The total NPW of this solution is $217,320 per unit.

The spreadsheet for the NPW graph showing each year's increase can be found in Appendix E.

Replace Piping Inside of Generator Housing

Stainless Steel is recommended as the ideal piping material to be used inside of the generator housing due to its corrosion resistance and mechanical properties. The generator cooler piping is carbon steel and should be replaced with stainless steel. The turbine cooler piping is already stainless steel. The surface air cooler piping is being replaced with stainless steel in the Fall 2001.

Generator Bearing Cooler Water Piping per Unit

The generator cooler water piping is currently carbon steel with victaulic couplings for all the connections. It is recommended to replace the carbon steel with stainless steel sch 10 inside the generator housing. The stainless steel system will reuse the existing carbon steel victaulic couplings with all new gaskets. Galvanic corrosion between the existing couplings and stainless steel pipe is not of any concern due to such a small contact surface area between the coupling and pipe. The following table is a list of parts needed to replace the piping with stainless steel. The price quote is from EMCO Distribution Ltd.

Parts Table:

Item #	Part Description	Quantity	Price	Total
1	2" Pipe s.s sch 10	105	$7.51	$788.55
2	2" Elbow s.s vic 90 degrees	8	$70.15	$561.20
3	2" Elbow s.s vic 45 degrees	8	$70.15	$561.20
4	2" Coupling c.s vic style 77 E gasket	10	$11.50	$115.00
5	2" E Gasket style 77	46	$5.01	$230.46
6	1/2" x 2 1/2" Bolts c/w nuts	40	$2.00	$80.00
7	2" Tee s.s vic	2	$154.92	$309.84
8	2" Vic-Flange adapter style 741	2	$36.30	$72.60

The total cost for parts is $2,679.90 per unit.

Cost Analysis to Replace Generator Bearing Cooler Water Piping per Unit

The labour time required for a crew to replace the piping was calculated using RS Means Mechanical Cost Data 2000. An additional 25% labour time was added to the RS Means calculation for pipe location and restrictions. An additional 15% labour time was added to the RS Means calculation for removal of old piping system. One additional worker will be placed on this job, shortening the labour time by 25%. RS Means calculation can be found in Appendix F. The costs break down associated with travel, perdiem, and minimum work crew can be found under the Cost Analysis section on page 29.

Total labour required for work crew of three: 20.9 hrs
Added labour due to pipe location and space restrictions: 20.9 x 25% = 5.2 hrs
Labour time for work crew to remove old piping: 26.1 x 15% = 3.9 hrs
Total labour time required to complete job: 30.0 hrs

In order to complete this job within the one week scheduled outage all work has to be done in 32.0 hours, leaving 8.0 hours for travel. The supervisor is usually over seeing two or three jobs while on site; therefore only 1/3 of the supervisors wage will be allocated to this particular job.

Labour: 3 (workers) x 38.0 hrs (30.0 installation + 8.0 driving) x \$21.56 = \$2,457.84
1 (supervisor) x 12.7 hrs (1/3 x 38.0 hrs) x \$23.72 (\$21.56 x 10%) = \$301.24

Total Over Head Costs: \$2,759.08 x 1.63 = \$4,497.30

Perdiem: 4 (work crew) x \$183 = \$732
(Monday \$34, Tuesday to Thursday \$129, Friday \$20)

Gas: 4 trips (2 vehicles) x \$80 = \$320

Total Cost per Unit: \$5,549.30

Replace Piping Outside of Generator Housing

Polyvinyl chloride (PVC) is recommended as the ideal piping material to be used outside of the generator housing due to its corrosion resistance, mechanical properties, thermal properties, and cost. The inlet header and discharge piping is carbon steel and should be replaced with PVC.

Inlet Header Piping per Unit

The inlet header piping for each unit branches off from the main supply header and uses a pipe rack to ascend from the floor to the ceiling where it then runs along the ceiling into the generator housing. Damage caused by accidental impact should not be of any concern due to this piping arrangement. The inlet header piping for each unit will be replaced starting from the discharge side of the pressure-reducing valve for each unit and continue to the entrance of the generator housing where it will meet the start of the stainless steel pipe. The following table is the list of parts needed to replace the inlet piping per unit with PVC. The price quote is from EMCO Distribution Ltd.

Item #	Part Description	Quantity	Price	Total
1	4" Pipe PVC Sch 80	20	$4.17	$83.40
2	4" Elbows 90 PVC Socket Sch 80	2	$9.47	$18.94
3	4" Flange PVC Socket Sch 80	1	$13.09	$13.09
4	6"x4" Reducer PVC Socket Sch 80	1	$48.49	$48.49
5	6"x6"x3" Tee PVC Socket Sch 80	2	$36.30	$72.60
6	2" Pipe PVC Sch 80	20	$1.32	$26.40
7	2" Elbows 90 PVC Socket Sch 80	3	$2.54	$7.62
8	2" Butterfly Valve PVC Flanged	1	$184.85	$184.85
9	2" Flange PVC Socket Sch 80	3	$6.07	$18.21
10	3"x2" Reducer PVC Socket Sch 80	2	$10.00	$20.00
11	1 1/4" Pipe PVC Sch 80	20	$0.85	$17.00
12	1 1/4" Elbows 90 PVC Socket Sch 80	1	$1.82	$1.82
13	1 1/4" Elbows 45 PVC Socket Sch 80	1	$3.65	$3.65
14	1 1/4" Butterfly Valve PVC Flanged	1	$31.35	$31.35
15	1 1/4" Flange PVC Socket Sch 80	3	$4.80	$14.40
16	6" Pipe PVC Sch 80	40	$7.80	$312.00
17	6" Elbows 90 PVC Socket Sch 80	6	$29.96	$179.76
18	6" Flange PVC Socket Sch 80	3	$48.10	$144.30
19	2"x1 1/4" Reducer PVC Socket Sch 80	1	$3.64	$3.64
20	6" Elbows 45 PVC Socket Sch 80	1	$34.84	$34.84

The total cost for parts is $1, 236.36 for unit #1.
The total cost for parts is $1,080.36 for unit #2. (Unit #2 needs 20 feet of 6 inch Pipe)

Cost Analysis to Replace Inlet Header Piping per Unit

The labour time required for a crew to replace the piping was calculated using RS Means Mechanical Cost Data 2000. An additional 25% labour time was added to the RS Means calculation for pipe location and restrictions. Also an additional 15% labour time was added to the RS Means calculation for removal of old piping system. RS Means calculations can be found in Appendix F. The costs break down associated with travel, perdiem, and minimum work crew can be found under the Cost Analysis section on page 29.

Total labour time for work crew of two: 35.1 hrs
Added labour due to pipe location and space restrictions: 35.1 x 25% = 8.8 hrs
Labour time for work crew to remove old piping: 43.9 x 15% = 6.6 hrs
Total labour time for work crew to complete job: 50.5 hrs

In order to complete this job within a two-week scheduled outage all work has to be done in 64.0 hours, leaving 16.0 hours for travel. The supervisor is usually over seeing two – three jobs while on site; therefore only 1/3 of the supervisors wage will be allocated to this particular job.

Labour: 2 (workers) x 66.5 hrs (50.5 installation + 16.0 driving) x $21.56 = $2,867.48
1 (supervisor) x 22.2 hrs (1/3 x 66.5 hrs) x $23.72 ($21.56 x 10%) = $526.58

Total Over Head Costs: $3,394.06 x 1.63 = $5,532.32

Perdiem: 3 (work crew) x $183 = $549
(Monday $34, Tuesday to Thursday $129, Friday $20)
3 (work crew) x $140 = $420
(Monday $34, Tuesday to Wednesday $86, Thursday $20)

Gas: 4 trips (2 vehicles) x 2 weeks x $80 = $640

Total Cost per Unit: $7,141.32

Discharge Header Piping per Unit

The discharge piping for each unit comes out of the ceiling and descends down the outside of the scroll case wall to the floor. Damage caused by accidental impact should not be of any concern due to the location of the piping on the concrete wall. The discharge piping for each unit will be replaced from where the stainless steel exits the generator housing and will continue until it meets the piping embedded in the floor. The following table is the list of parts needed to replace the piping with PVC. The price quote is from EMCO Distribution Ltd.

Item #	Part Description	Quantity	Price	Total
1	1 1/4" Pipe PVC Sch 80	20	$0.85	$17.00
2	2" Pipe PVC Sch 80	20	$1.32	$26.40
3	2.5" Pipe PVC Sch 80	40	$2.12	$84.80
4	3" Pipe PVC Sch 80	20	$2.86	$57.20
5	4" Pipe PVC Sch 80	40	$4.17	$166.80
6	6" Pipe PVC Sch 80	10	$7.80	$78.00
7	1 1/4" Elbows 90 PVC Socket Sch 80	4	$1.82	$7.28
8	2" Elbows 90 PVC Socket Sch 80	1	$2.54	$2.54
9	2.5" Elbows 90 PVC Socket Sch 80	4	$5.96	$23.84
10	4" Elbows 90 PVC Socket Sch 80	6	$9.47	$56.82
11	2.5" Elbows 45 PVC Socket Sch 80	1	$12.62	$12.62
12	4" Elbows 45 PVC Socket Sch 80	1	$27.66	$27.66
13	4"x4"x4" Tee PVC Socket Sch 80	2	$14.27	$28.54
14	2.5"x2.5"x2.5" Tee PVC Socket Sch 80	3	$9.86	$29.58
15	2.5"x 1 1/4" Reducer PVC Socket Sch 80	1	$6.30	$6.30
16	2.5"x2" Reducer PVC Socket Sch 80	3	$6.30	$18.90
17	4"x3" Reducer PVC Socket Sch 80	2	$25.56	$51.12
18	6"x4" Reducer PVC Socket Sch 80	1	$52.14	$52.14
19	1 1/4" Flange PVC Socket Sch 80	3	$4.80	$14.40
20	2" Flange PVC Socket Sch 80	5	$6.07	$30.35
21	2.5" Flange PVC Socket Sch 80	6	$10.06	$60.36
22	3" Flange PVC Socket Sch 80	2	$11.12	$22.24
23	4" Flange PVC Socket Sch 80	7	$14.07	$98.49
24	1 1/4" Pressure Tap Orifice Flanges s.s Socket Sch 80	1	$387.69	$387.69
25	2" Pressure Tap Orifice Flanges s.s Socket Sch 80	1	$479.75	$479.75
26	4" Pressure Tap Orifice Flanges s.s Socket Sch 80	1	$689.74	$689.74
27	1 1/4" Butterfly Valve PVC Flanged	1	$31.35	$31.35
28	2" Butterfly Valve PVC Flanged	1	$184.85	$184.85
29	2.5" Butterfly Valve PVC Flanged	1	$216.19	$216.19
30	3" Butterfly Valve PVC Flanged	1	$204.33	$204.33
31	4" Butterfly Valve PVC Flanged	1	$239.91	$239.91

The total cost for parts is $3,406.20 per unit.

Total cost with reusing existing pressure tap orifice flanges is $1,849.02 per unit.

Cost Analysis to Replace Discharge Header Piping per Unit

The labour time required for a crew to replace the piping was calculated using RS Means Mechanical Cost Data 2000. An additional 25% labour time was added to the RS Means calculation for pipe location and restrictions. Also an additional 15% labour time was added to the RS Means calculation for removal of old piping system. RS Means calculations can be found in Appendix F. The costs break down associated with travel, perdiem, and minimum work crew can be found under the Cost Analysis section on page 29.

Total labour time for work crew of two: 41.4 hrs
Added labour due to pipe location and space restrictions: 41.4 x 25% = 10.4 hrs
Labour time for work crew to remove old piping: 51.8 x 15% = 7.8 hrs
Total labour time for work crew to complete job: 59.6 hrs

In order to complete this job within a two-week scheduled outage all work has to be done in 64.0 hours, leaving 16.0 hours for travel. The supervisor is usually over seeing two or three jobs while on site; therefore only 1/3 of the supervisors wage will be allocated to this particular job.

Labour: 2 (workers) x 75.6 hrs (59.6 installation + 16.0 driving) x $21.56 = $3,259.87
1 (supervisor) x 25.2 hrs (1/3 x 75.6 hrs) x $23.72 ($21.56 x 10%) = $597.74

Total Over Head Costs: $3,857.61 x 1.63 = $6,287.90

Perdiem: 3 (work crew) x $183 = $549
(Monday $34, Tuesday to Thursday $129, Friday $20)
3 (work crew) x $140 = $420
(Monday $34, Tuesday to Wednesday $86, Thursday $20)

Gas: 4 trips (2 vehicles) x 2 weeks x $80 = $640

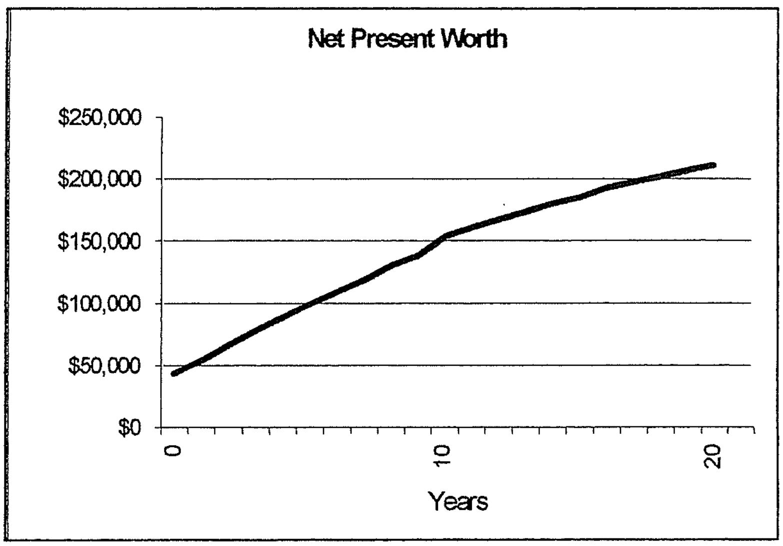
Total Cost per Unit: $7,896.90

NPW Analysis

Below is the NPW analysis of the replace piping solution. There are capital expenditures with this solution along with operating expenditures. The capital is for replacing the existing SAC, generator bearing cooler piping inside the generator housing with stainless steel and replace the inlet and discharge header piping outside of the generator housing with PVC. The SAC piping inside the generator housing has been replaced already with stainless steel this year and will not be factored into the NPW calculations.

The NPW cost associated with this solution is for only one unit in Cat Arm and in order to compare this solution to the others the NPW cost should be doubled.

Graph 2 is the NPW analyse of replacing the piping solution:



Graph 2

Table 29 shows the costs associated with this solution:

Capital Cost	
Gen Brg Piping (Parts & Installation)	$8,229
Inlet Piping (Parts & Installation)	$8,378
Discharge Piping (Parts & Installation)	$11,303
Total	$27,910

Operating Cost	
Pump consumption (49 weeks)	$15,353
Clean SAC (8 yr)	$5,783
Clean SAC Piping (10 yr)	$4,667
Clean Gen Brg Coolers (10 yr)	$5,783
Clean Gen Brg Cooler Piping (10 yr)	$4,667

Table 29

The NPW is calculated over the life span of the piping, which is 20 years. The inflation rate used is 2%, the power rate used for the pump is $0.05 kWh, and the rate of return for Hydro is 8.5%.

The total NPW of this solution is $210,126 per unit.

The spreadsheet for the NPW graph showing each year's increase can be found in Appendix E.

Closed System Operation

Heat Exchanger Selection

The style of heat exchanger that needed to be selected would have to meet the following criteria:

1. Compact design
2. Easy to maintain and clean
3. Will not clog
4. Capacity of 900 Usgpm

It was determined that a plate and frame heat exchanger would meet all of these requirements. Due to it's construction the exchanger can be expanded to meet future cooling requirements by adding more plates and this design also allows for easy access for cleaning.

Tom Furlong of Maynard Reece was contacted for a price estimate on this type of heat exchanger. A quoted price of $17, 500 per unit was established for this cost feasibility study.

Pump Selection

In order to select a pump for this system the pressure drop across the entire cooling water system including the new heat exchanger would have to be known. Using Design Flow Solutions one can enter the entire cooling water system into the program and determine the pressure drop at the desired flow rate.

It was determined that the pressure drop for Cat Arm at 900 Usgpm was 22 psia. A print out of the calculation can be found in Appendix G.

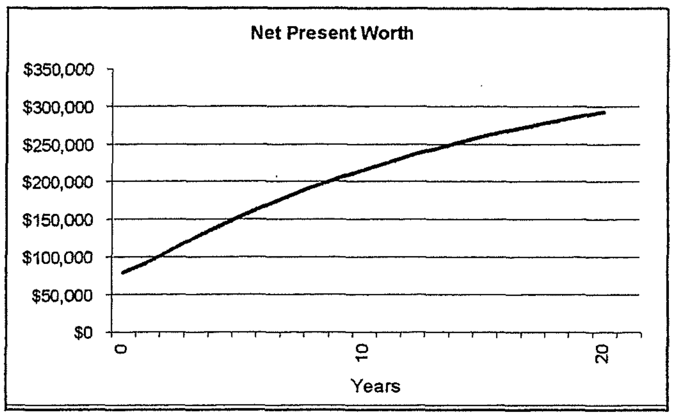
The pump selected for this application is a Goulds centrifugal pump 3196 (4 x 6 - 10H, 9" impeller). This pump is capable of 900 Usgpm @ 60 ft head using water as the medium. The pumps specification sheet can be found in Appendix H.

NPW Analysis

The closed loop solution has capital and operating expenditures associated with it. The capital expenditure is for purchasing the heat exchanger, recirculation pump, and associated piping and hardware for the installation. This solution will require 100% capacity back up so two heat exchangers and recirculation pumps will have to be purchased.

The closed loop solution will treat both units in Cat Arm so the NPW cost does not have to be doubled for this solution.

Graph 3 is the NPW analyse for the closed loop solution:



Graph 3

Table 30 shows the costs associated with this solution:

Capital Cost	
Pump	$14,404
Heat Exchanger	$35,000
Installation Piping & Hardware	$8,000
Total	$57,404

Operating Cost	
Pump consumption (49 weeks)	$15,353
Recir Pump Consumption (49 weeks)	$6,133

Table 30

The NPW is calculated over the life span of the piping, which is 20 years. The inflation rate used is 2%, the power rate used for the pump is $0.05 kWh, and the rate of return for Hydro is 8.5%.

The total NPW of this solution is $293,131 for both units.

The spreadsheet for the NPW graph showing each year's increase can be found in Appendix E.

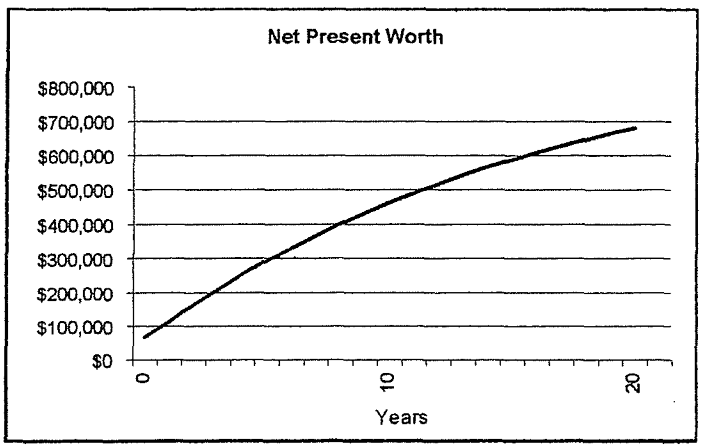
Chemical Injection

The chemical injection solution is based on injecting a chemical known as FLOGARD POT6101 into the cooling water system. This chemical has both cathodic and anodic inhibitors that react with the water to prevent corrosion of the piping and organic build up within the piping. The concentrations are very low 4 ppm and the impact on the environment would be very low considering the chemical is being discharged into the tailrace with the rest of the discharged water.

NPW Analysis

This solution has both capital and operating expenditures. The operating expenditures are very high due to the continuous replacement of the FLOGARD POT6101 chemical.

Graph 4 is the NPW analyse of the chemical injection solution:



Graph 4

BetzDearborn's proposal for chemical injection can be found in Appendix C.

Table 31 shows the costs associated with this solution:

Capital Cost	
Injection System	$5,000
Test Coupon Rack	$515
Total	$5,515

Operating Cost	
Pump consumption (49 weeks)	$15,353
Chemical (49 weeks)	$45,000

Table 31

The NPW is calculated over the life span of the piping, which is 20 years. The inflation rate used is 2%, the power rate used for the pump is $0.05 kWh, and the rate of return for Hydro is 8.5%.

The total NPW of this solution is $679,865 for both units.

The spreadsheet for the NPW graph showing each year's increase can be found in Appendix E.

CONCULSIONS AND RECOMMENDATIONS

From the material presented there were four different solutions that could be taken to resolve the problem. To recap the four alternative solutions were to continue to operate as we have "do nothing approach", replace the piping with corrosion resistant material, inject chemical into the service water for treatment, or install a closed loop system with treated water to cool the units. Each solution has it's benefits and draw backs.

The NPW analysis calculated the following dollar figures for each solution;

Do Nothing	$217,320 x 2 units = $434,640
Replace the Piping with s.s & PVC	$210,126 x 2 units = $420,252
Closed Loop System	$293,131
Chemical Injection	$679,865

Table 30

The "continue to operate as we have" will mean scheduled outages for cooler and pipe cleaning. There is an uncertainty with this solution when it comes to forced outages due to cooling problems during the summer months. If a maintenance program for cleaning and maintaining the cooling water system is not implemented forced outages due to cooling problems during the summer months in the height of the maintenance season will occur. In order to prevent this a fouling monitoring program for the cooling water system has to be put in place.

In addition the cooling water system that is currently in place in Cat Arm has a redundant control valve. There is a pressure-reducing valve located in the inlet header and there are temperature control valves located in the discharge header. The service water pumps maximum pressure is still to low to damage any of the components in the service water system. It seems that the pressure control valve in the inlet header is back up pressure-reducing valve for the secondary water supply that comes off the penstock, yet the penstock lines have there own pressure-reducing valves. This warrants further investigation.

Also the temperature control valves located in the discharge lines regulate flow through the coolers based on the temperature of the water exiting the coolers and not on the temperature of the bearing oil, which they are cooling. This also warrants further investigation.

The other alternative of replacing the piping with corrosion resistant pipe solution has an initial capital investment with a low operating cost associated with it. The Cat Arm plant has been in operation since 1985 and most of the cooling water pipe's expected life is coming to an end. The labour cost of replacing this pipe is going to be the same regardless of what type of pipe you use to replace it. Already the SAC piping inside of the generator housing has been replaced with stainless steel sch 10 pipe.

One of the benefits of having the corrosion resistant pipe like stainless steel and PVC is lower maintenance. Unit outages for cleaning service water piping will be less frequent, hence will free up more manpower for other tasks during the maintenance season.

Another benefit to corrosion resistant piping is the reduced likely hood of the pipe becoming clogged with debris. Since the pipe is resistant to corrosion from the service water it is not likely that enough organic material will be able to adhere to the pipe wall to impend flow to the point of stagnation. It is believed that only a small layer of organics will adhere to the inner pipe wall and once that layer is in place the rest of the organics will be washed through the system. Cleaning of the coolers and piping will still have to be done to optimize the efficiency of the system but the frequency of cleanings will be drastically reduced from the current operation.

Another benefit to the replace piping with corrosion resistant pipe solution is that no new equipment or design changes have to be made to the existing system, just replace the existing pipe.

As can be seen from the NPW analysis replacing the piping with corrosion resistant pipe has a NPW of $420,252 and the other solution of continuing to operate like we have in the past has a NPW of $434,640. In order to continue to operate as we have the existing piping has to be replaced and the labour alone is $42,000. This labour figure does not include the SAC piping that was replaced in the Fall 2001 outage.

The closed loop system has a NPW of $293,131which makes this solution better than the other solution presented from a financial point of view. The problem with this solution is that it is add on to the existing cooling water system. Seeing that the service water piping is almost at its life expectancy the cost of replacing that piping has to also be considered.

With the closed loop solution the piping inside of the generator housing can be mild steel sch 40 pipe and the piping outside of the generator housing can be PVC to help reduce costs. This solution will use treated water for recirculating through the unit and use the existing service water to cool the heat exchangers.

The closed loop solution will have more components with the extra two recirculating pumps and heat exchangers. This increases the chances of more problems within the system.

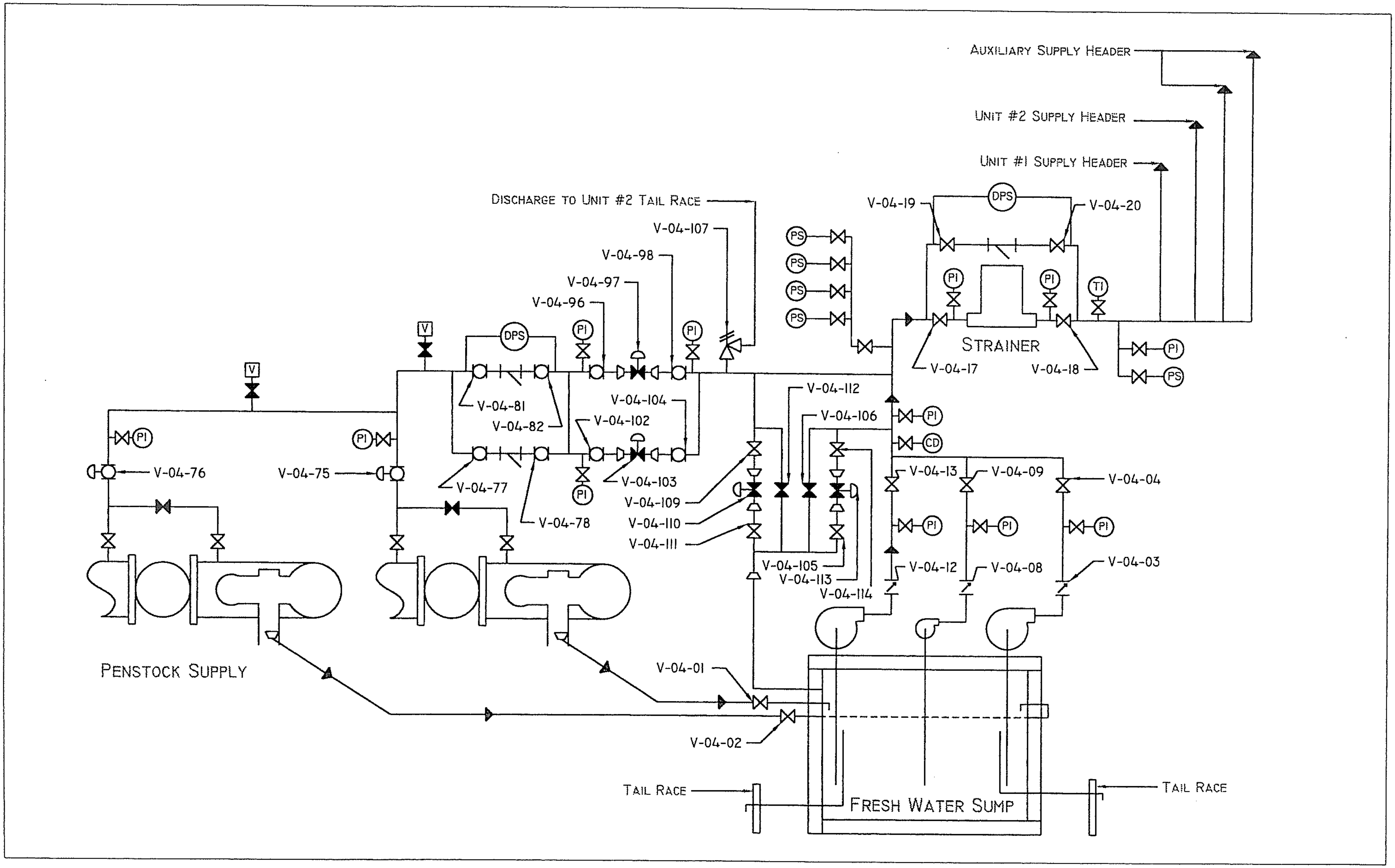
The maintenance of the unit's coolers and piping will be non-existent but the outside heat exchanger will have to be cleaned. The frequency of this clean will have to be determined from operating the system. These outside heat exchangers should be positioned for easy cleaning.

The chemical injection solution has a NPW of $679,865, which makes this solution not feasible compared to the other alternative solutions. Also any solution that doesn't impact the environment is always a better alternative.

It is recommended that we go with the solution of "replacing the piping with corrosion resistant pipe" for Cat Arm. The pipe's life expectancy within the service water system is coming to an end and will need to be replaced in the near future. With this alternative we still have the ability of replacing sections of the existing system year by year until it is all changed over, reducing the over all capital expenditure for that year. Also this solution will result in lower maintenance costs for the system. Another benefit is that no new design work has to be done in order for this solution to be implemented.

It is also recommended that the current design of the cooling water system be re-evaluated to determine if it is indeed operating in the most efficient way. It seems that there is a complexity build into the design that doesn't need to be there, i.e. too many control valves.

APPENDIX A



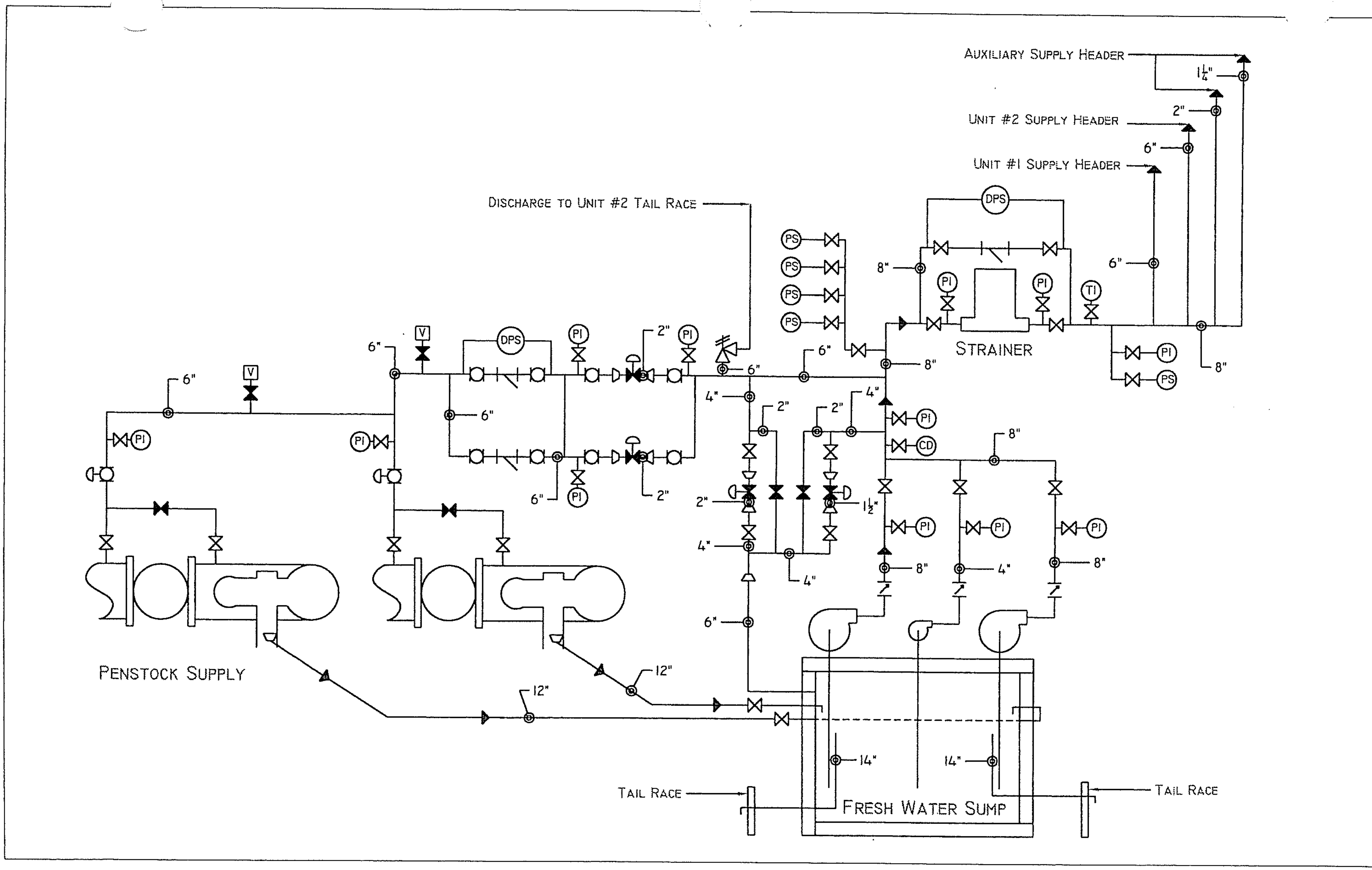
HYDRO

NEWFOUNDLAND AND LABRADOR HYDRO

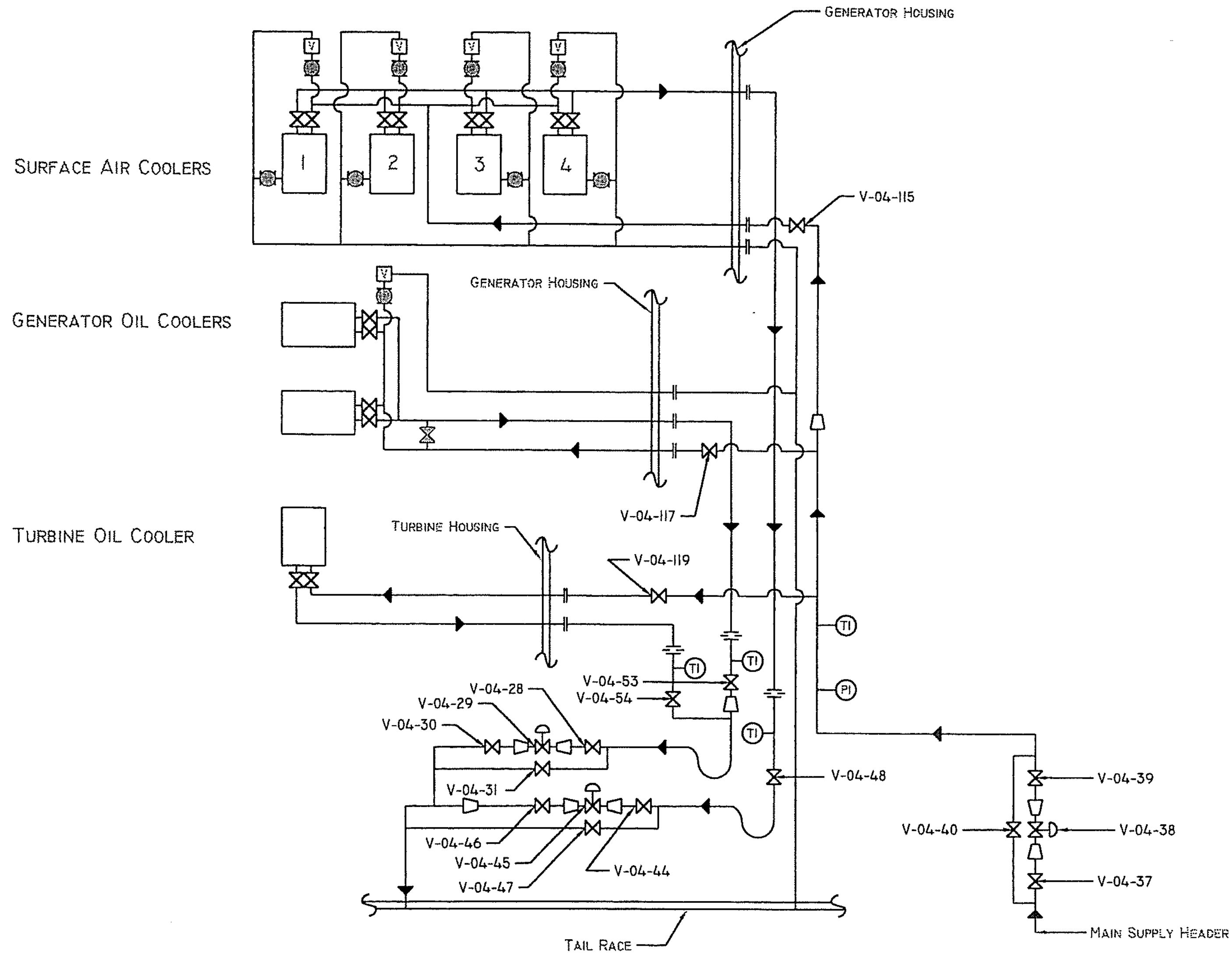
SCALE: N/A
DRAWN: S.WHITE
CHECKED:
APPROVED:

CAT ARM
SERVICE WATER SYSTEM
FLOW DIAGRAM

DATE: AUGUST 28, 2001
W.O# N/A
DWG# 1
REV. 0



HYDRO	NEWFOUNDLAND AND LABRADOR HYDRO	
SCALE: N/A DRAWN: S.WHITE CHECKED: APPROVED:	CAT ARM SERVICE WATER SYSTEM FLOW DIAGRAM	DATE: AUGUST 28, 2001 W.O# N/A DWG# 1 REV. 0



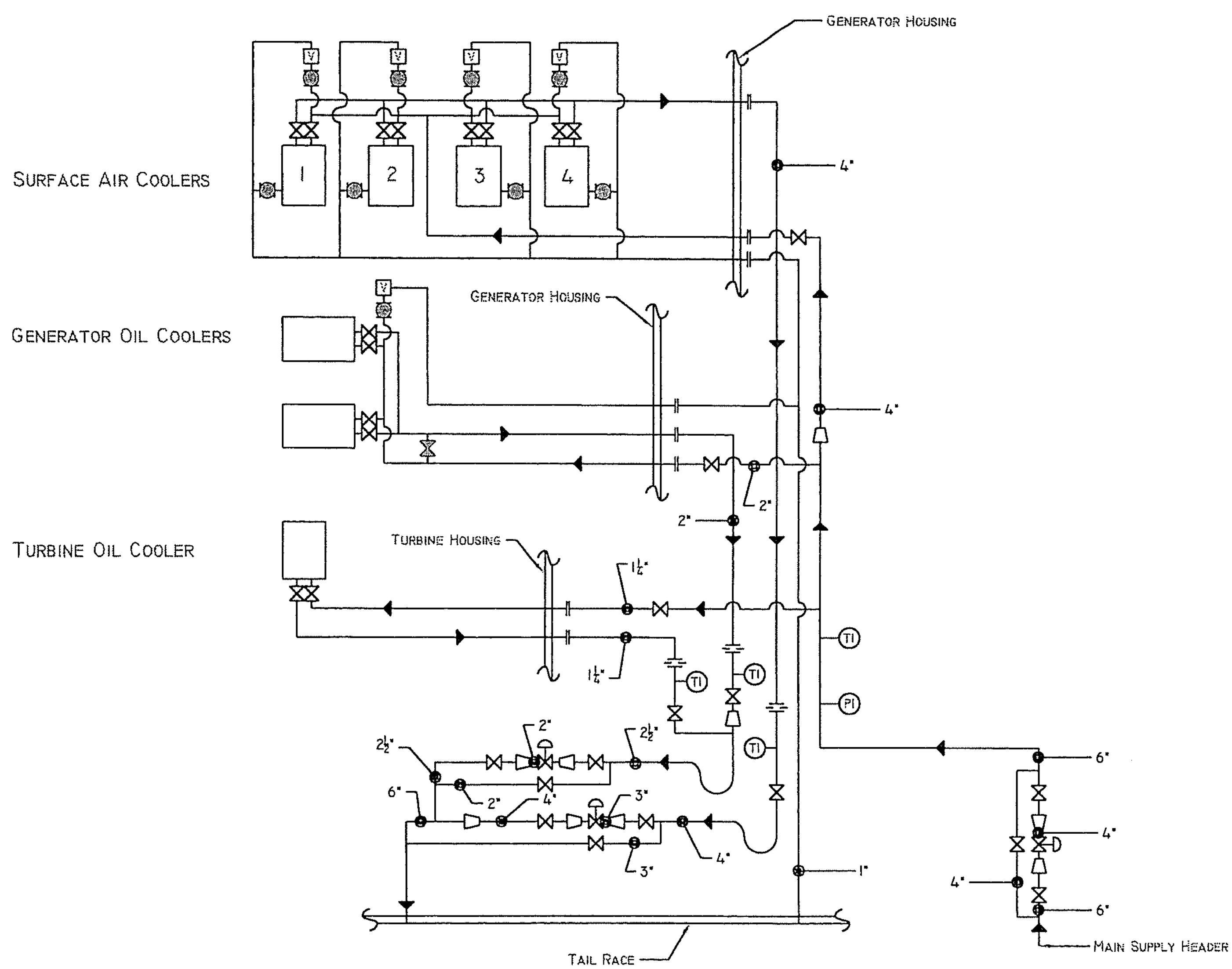
HYDRO

NEWFOUNDLAND AND LABRADOR HYDRO

SCALE: N/A
DRAWN: S.WHITE
CHECKED:
APPROVED:

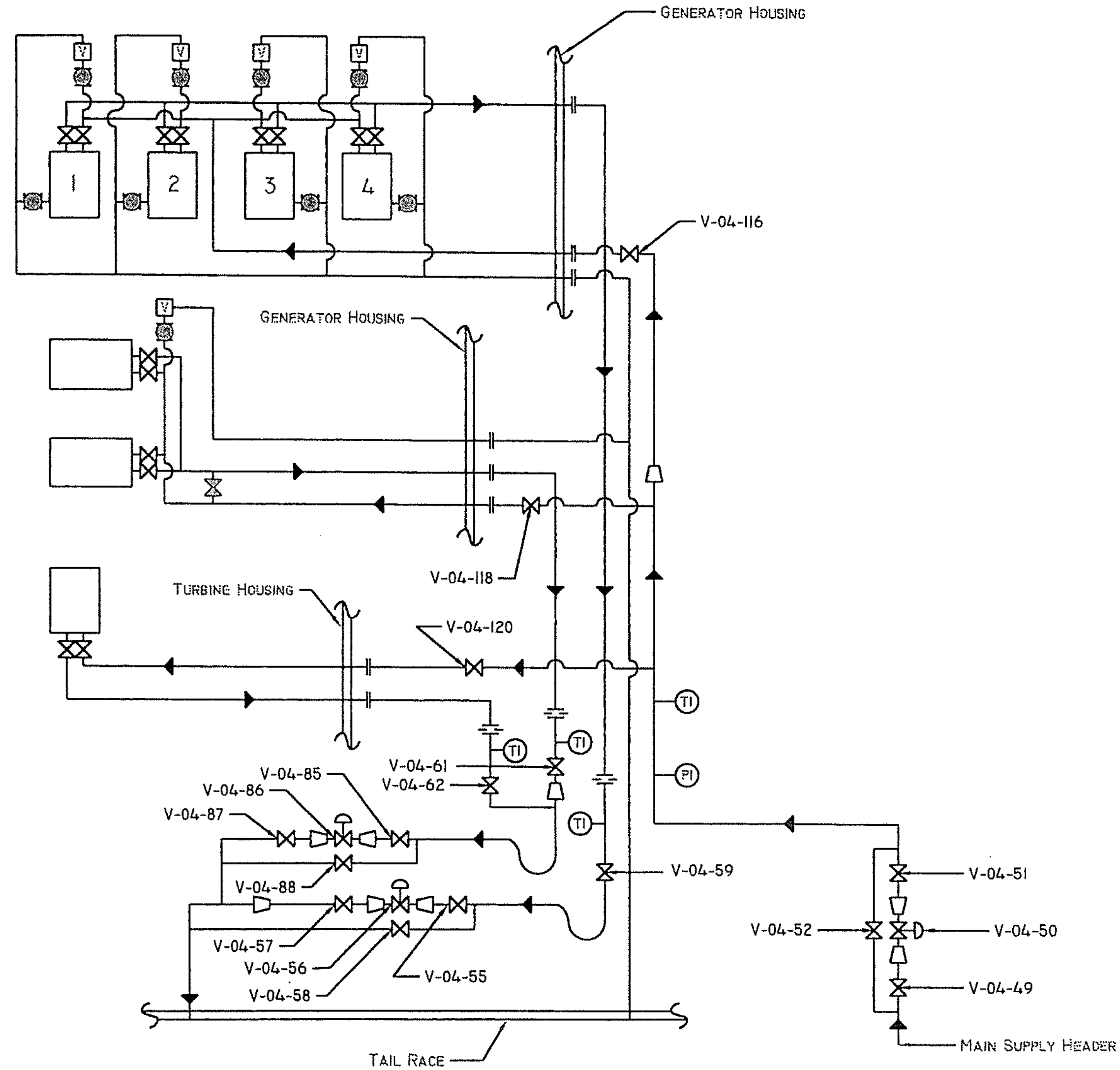
CAT ARM
SERVICE WATER SYSTEM
UNIT #1 FLOW DIAGRAM

DATE: AUGUST 27, 2001
W.O# N/A
DWG# 1
REV. 0

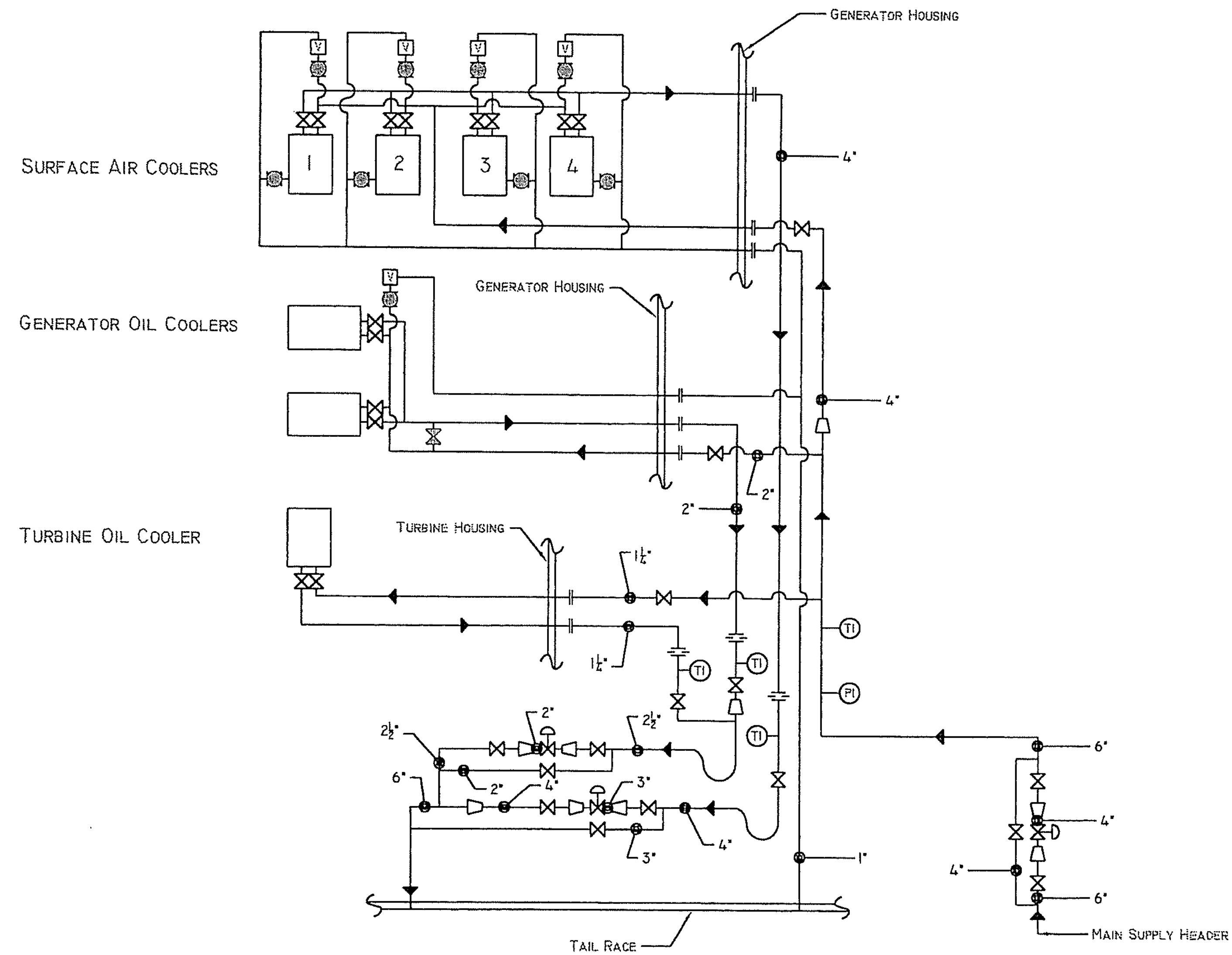


NEWFOUNDLAND AND LABRADOR HYDRO

SCALE: N/A	CAT ARM SERVICE WATER SYSTEM UNIT #1 FLOW DIAGRAM	DATE: AUGUST 27, 2001
DRAWN: S.WHITE		W.O# N/A
CHECKED:		DWG# 1 — REV. 0
APPROVED:		



HYDRO	NEWFOUNDLAND AND LABRADOR HYDRO		
SCALE: N/A DRAWN: S.WHITE CHECKED: APPROVED:	CAT ARM SERVICE WATER SYSTEM UNIT #2 FLOW DIAGRAM	DATE: AUGUST 27, 2001 W.O# N/A DWG# 1	REV. 0



NEWFOUNDLAND AND LABRADOR HYDRO

SCALE: N/A
DRAWN: S.WHITE
CHECKED:
APPROVED:

CAT ARM
SERVICE WATER SYSTEM
UNIT #2 FLOW DIAGRAM

DATE: AUGUST 27, 2001
W.O# N/A
DWG# 1
REV. 0

APPENDIX B

BetzDearborn

WATER ANALYSIS REPORT

BC562412
NEWFOUNDLAND & LABRADOR HYDRO
HOLYROOD GENERATING STATION
Holyrood, NF A0A2R0

Sampled: 04-AUG-2000
Reported: 14-AUG-2000
Field Rep: Finn,Ed
BB59M

	JM 01	JM 02
	K0809046	K0809047
pH	5.0	5.1
Specific Conductance, at 25°C, µmhos	91	77
Alkalinity, "P" as $CaCO_3$, ppm	0	0
Alkalinity, "M" as $CaCO_3$, ppm	< 2	< 2
Sulfur, Total, as SO_4, ppm	< 5	< 5
Chloride, as Cl, ppm	3.1	3.7
Hardness, Total, as $CaCO_3$, ppm	6.5	5.3
Calcium Hardness, Total, as $CaCO_3$, ppm	2.3	1.6
Magnesium Hardness, Total, as $CaCO_3$, ppm	4.2	3.6
Copper, Total, as Cu, ppm	< 0.05	< 0.05
Iron, Total, as Fe, ppm	0.79	0.87
Sodium, as Na, ppm	2.2	2.1
Phosphate, Total Inorganic, as PO_4, ppm	< 0.2	< 0.2
Phosphate, Ortho-, as PO_4, ppm	< 0.2	< 0.2
Silica, Total, as SiO_2, ppm	1.5	1.5

BetzDearborn

INORGANIC ANALYSIS REPORT

BC562412
NEWFOUNDLAND & LABRADOR HYDRO
HOLYROOD GENERATING STATION
Holyrood, NF A0A2R0

Laboratory ID: 61729.1

Sampled: 21-JUL-2000
Reported: 10-AUG-2000
Field Rep: Finn,Ed
BB59M

Sample Description:
SAC #3 JM03

PRIMARY COMPOSITION (%)

Iron, Fe_2O_3 + Fe_3O_4	72
Loss on Ignition LOI	21
Manganese, MnO_2	6
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

Appendix 1 - Water Chemistry in Cat Arm Watershed

Parameter	Location of Sample: South Inlet	Seepage	Outlet
Alkalinity mg/l	1.0	--	0.6
Hardness mg/l	--	--	4.2
pH	5.42	4.28	5.03
Conductance u mhos/cm	16.76	34.78	19.37
Acidity mg/l	--	15	--
Chloride mg/l	3.9	--	--
Sulphate	3.0	--	--
Total Kjeldahl N mg/l	0.231	0.394	0.394
% Soluble Kjeldahl N	40	57	63
% Particulate Kjeldahl N	60	43	37
Nitrate mg/l	0.01	0.01	0.012
Chemical Oxygen Demand (as carbon) mg/l	35.5	92.5	41.8
% Soluble COD	53	77	77
% Particulate COD	47	23	23
Phosphorous mg/l	0.056	0.073	0.040
% Soluble P	38	75	63
% Particulate P	62	25	37
Silicate mg/l	0.073	0.436	0.143
Total Calcium mg/l	0.535	1.270	0.745
% Soluble Calcium	100	92	94
% Particulates Calcium	0	8	6
Total Magnesium mg/l	0.261	0.682	0.408
% Soluble Magnesium	61	97	67
% Particulate Magnesium	39	3	33
Total Manganese mg/l	0.017	0.033	0.017
% Soluble Manganese	59	85	58
% Particulate Manganese	41	15	42
Total Iron mg/l	0.386	1.018	0.498
% Soluble Iron	30	88	48
% Particulate Iron	70	12	52
Total Zinc mg/l	0.01	0.01	0.01
Total Molybdenum	0.001	0.003	0.001
Total Cobalt mg/l	0.01	0.01	0.01
Total Sodium mg/l	1.303	2.352	1.725
Total Potassium mg/l	0.230	0.230	0.200
Floride mg/l	--	--	0.1
Copper mg/l	--	--	0.004
Zinc mg/l	--	--	0.01
Cadium mg/l	--	--	0.01

APPENDIX C

Corrosion Inhibitor Program
FLOGARD POT6101

Newfoundland Hydro
St. John's, Newfoundland

October 10, 2001

Edward Finn
District Representative

BetzDearborn Canada Inc.
P.O. Box 1048
Carbonear, Newfoundland
A1Y 1C5
Tel: 709-596-3100
Fax: 709-596-1332

October 18, 2001

Newfoundland Hydro
P.O. Box 12400
St. Johns, NF
A1B 4K7

Attention: **John Mallam**

SUBJECT : **Cooling Water Inhibitor Proposal**

John,

Please find below our proposal to treat the once-thru cooling water systems in your Hydroelectric Station with our corrosion inhibitor – **Flogard POT6101**.

In short, we propose that you install a chemical injection and monitoring system to dose the system with 4 ppm of Flogard POT6101.

The annual cost of the chemical treatment, based on continuous operation, would be $30,000.

We suggest, you monitor the effectiveness of the program by using corrosion coupons that simulate the corrosion in the system and are analyzed in our lab.

THEORY:

The recent set of water samples, taken by yourselves, were tested by our analytical lab in the USA. A short table comparing the important parameters in these tests is below. These have been communicated to you previously, but we show them here for completeness.

As well, we have calculated the Langelier index, which is calculated by a nomagraph and is used in the water treatment industry as an overall indication of the scaling or corrosion tendency of any particular water.

Your waters all had a Langelier's index below –5.0, so these waters would be described as "Very Corrosive". Therefore, the problems you have been experiencing with rust and corrosion are predictable and understandable. Fortunately, they are also preventable with proper chemical treatment.

TABLE 1

	HINDS LAKE	CAT ARM	UPPER SALMON	BAIE D'ESPOIR
Date	08/21/2001	08/04/2000	08/2001	08/2001
pH	5.9	5.1	5.1	6.2
Conductivity (mmhos)	25	91	24	13.7
'M' alkalinity (ppm)	0.7	< 2	< 2	2.1
Total Hardness (ppm)	6.5	6.5	3.4	3.8
Copper (ppm)	0.05	0.05	0.06	< 0.05
Iron (ppm)	4.3	0.79	0.17	0.08
TOC (ppm)	2.4	--	5.1	4.7
Langelier Index	- 5.1	- 5	- 5.3	- 5.5

The deposits that we analysed were also reported to you by e-mail. These deposits proved to be high in iron and manganese. The iron is from the rusted piping, while the manganese is chemically associated with the organic matter in the surface water supply. This manganese is noteworthy because it is found in deposits where the surface water is high in organics like these. Manganese does foul piping by depositing on the pipe wall rather than corrode. Fortunately, it is a problem that can be treated chemcially.

In its simplest terms, corrosion is a reaction like the reactions that occur in a conventional lead - acid battery.

The Cathodic reaction is:

$$2H^+ + 2e^- \rightarrow H_2$$

This reaction occurs in a low pH – acidic environment because of the relative abundance of H^+.

The Anodic reaction is:

$$Fe \rightarrow Fe^{2+} + 2e^-$$

This reaction results in the loss of metal from the piping.

If you can stop these reactions from occurring, by stopping the flow of electrons, then the corrosion is stopped .

Chemical corrosion inhibitors basically fall into two broad classes: Anodic and Cathodic, depending on how they act. The product we propose, Flogard POT6101, contains both a Cathodic and an Anodic inhibitor. The phosphate in the product acts as a weak anodic inhibitor, by forming a loosely adhered film of iron phosphate - $FePO_4$. The Cathodic inhibitor is zinc - Zn. As well, the zinc will sequester the manganese, which is currently causing fouling problems, so the problems with the manganese deposition will be significantly reduced.

PRODUCT:

Please see the Product Bulletin attached for the Inhibitor, which describes the inhibitor in detail. The product is available in both drums and 1136 kg semi - bulk tanks. I suggest, you obtain the product in these semi-bulk tanks. We have also attached product facts and its MSDS for your review.

PRICING:

The dosage is 4 ppm, based on the flow of the water. At an estimated flow rate of 600 imperial gallons per minute for 24 hrs per day, 365 days per year, the consumption of the Flogard POT6101 is 7970 kgs per year.

The price of the Flogard POT6101 in these semi-bulk tanks is $3.85/ kg FOB Pointe Claire, QC. Freight and taxes extra. Therefore, the annual cost of the chemical would be $30,685. If the facility is run less than 100% of the time, then the consumption will be less - directly proportional to operating hours.

REFERENCES:

BetzDearborn currently treats many similar applications to yours in Atlantic Canada. References include:

Contacts:

Mr. Bob Cass
Manager of Water and Wastewater
City of Port Hawkesbury
Phone: 902-435-1494

Mr. Herve Richard
Chief Engineer
Noranda Inc.
Brunswick Mines
Phone: 506-546-6671

Mr. Pat Bellemare
Senior Operator
City of Dartmouth
Phone: 902-435-8300

WORK PLAN / SERVICE:

You should have on-site help from your chemical supplier to implement and monitor this chemical program, particularly since the references above needed to have the chemical introduced at a low concentration, which was gradually increased over several months.

As part of this proposal, we are offering as part of our service, 2-3 days of on-site service during start-up, followed by monthly visits for the first six months of the program and then twice yearly visits thereafter. This service is important. If the program is to succeed, operators need to be familiarized with testing procedures, corrosion coupon installation / changeout, the associated piping racks, chemical dosing pumps and chemical injection procedures and drawdowns. Site visits will be followed up by a written service report by BetzDearborn.

CHEMICAL FEED EQUIPMENT:

We have identified a chemical injection system, with a remote start / stop that would be suitable for this application (see the diagram attached). Prominant Fluid Controls can supply a dual metering pump skid, which can be automized to operate according to our needs. Options include:

- Duty and standby injection pumps.
- Flow switch to provide alarm if there is loss of chemical injection.
- Automatic switch over to stand-by pump in the event of duty pump failure.

The attached literature describes the Prominent options and provides a discussion matrix to select the chemical injection system to meet your application needs. We would be pleased to assist in selecting this system with Prominent. Budgetary cost for such a system would be $5000.

CHEMICAL TESTING:

We suggest, you obtain a simple chemical test so that the operators can check the chemcial concentration of PO_4 injected into the water. These chemical tests are straight forward and easy to use. Hach sells a simple PO_4 test (catalogue No. 2248-00), they are available from Atlantic Purification systems at 902-469-2806 and cost $141.33 for a kit with 100 tests.

We will provide any instructions necessary for the operators to run this test. By using this test, we will unsure that the correct concentration of inhibitor is injected into the water.

CORROSION COUPONS:

As you are probably aware, corrosion coupons offer a method to quantitatively measure any reduction in the rate of corrosion over time. Coupons consist of a small strip of metal (either copper or mild steel) that measures approximately 50 x 10 x 5 mm and is inserted directly into the cooling water and left there for some time - typically 100 days. The coupons are then replaced and sent to the lab, where surface corrosion is noted. The weights before and after the in-service period are used to calculate a rate of corrosion in mil/year or g/ft^2 removed per year. Thus, the effectiveness of any corrosion reduction program can be evaluated quantitatively.

To ensure the results are reliable, the coupons must be installed properly and exposed to the correct flow rate. We recommend installation of a 1" diameter, iron corrision rack, with flow control valve, Part No. 2029978. The cost of this unit is $515.

Do not hesitate to contact me at 709-596-3100, if you would like to discuss our proposal.

Yours truly,
BetzDearborn

Edward Finn

Edward Finn
District Representative

Cc: Shane White
Phil Millard
Yves Lefebvre

Enc.

Product Facts

FLOGARD™ POT6101
Potable Water Treatment

- NSF Approved for potable water
- Single-product liquid treatment
- Highly effective inhibitor

DESCRIPTION AND USE

FLOGARD™ POT6101 is a liquid blend of phosphate and zinc designed to inhibit corrosion of mild steel in mill supply water systems and once-through cooling systems. Corrosion control is accomplished by two mechanisms. At typical use levels, the major protection is due to the formation of a zinc-phosphate barrier film at the cathodic site of the corrosion cell. Phosphate also provides some additional corrosion protection by promoting the formation of a protective film at the anodic sites.

TREATMENT AND FEEDING REQUIREMENTS

The optimum dosage of FLOGARD POT6101 is a function of the corrosivity of the water to be treated and other conditions particular to a given installation. For best performance, this product should be fed continuously. While the typical feedrate is 4 - 20 ppm, this product is to be used in accordance with control procedures BetzDearborn establishes for a specific application and local potable water guidelines.

FLOGARD POT6101 may be fed directly from the shipping container or diluted to any convenient strength.

Tanks, pumps, piping and valves may be made of 316 stainless steel or most common plastics. Avoid the use of mild steel and copper alloys.

GENERAL PROPERTIES

Physical properties of FLOGARD POT6101 are shown on the Material Safety Data Sheet, a copy of which is available upon request.

PACKAGING INFORMATION

FLOGARD POT6101 is a liquid blend available in a variety of containers and delivery methods. Contact your BetzDearborn representative for details.

STORAGE

Protect from freezing. If this product is frozen during shipment or storage, slight mixing may be required to ensure homogeneity.

SAFETY PRECAUTIONS

A Material Safety Data Sheet containing detailed information about this product is available upon request.

BetzDearborn
Shaping the Future of Water & Process Treatment

www.betzdearborn.com

BetzDearborn

ISSUE DATE: 16-JAN-2001

MATERIAL SAFETY DATA SHEET

BetzDearborn Canada, Inc.*
3451 Erindale Station Road
Mississauga, ON L5C 2S9
Business telephone: (905) 279-2222

EMERGENCY TELEPHONE (HEALTH/ACCIDENT)
(800) 963-5222 (Canada)

HMIS RATINGS
(See Section 16 for additional information)

HEALTH:	3
FLAMMABILITY:	0
REACTIVITY:	0

*Hercules Canada, Inc. and BetzDearborn Canada, Inc. carrying on business as Hercules Canada

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1 PRODUCT IDENTIFICATION

PRODUCT NAME:

FLOGARD POT6101

PRODUCT APPLICATION AREA:

CORROSION INHIBITOR.

2 COMPOSITION / INFORMATION ON INGREDIENTS

Information for specific product ingredients as required by the WHMIS Regulations is listed. Refer to additional sections of this MSDS for our assessment of the potential hazards of this formulation.

HAZARDOUS INGREDIENTS:

Cas#	Chemical Name	Range (w/w%)
7664-38-2	PHOSPHORIC ACID Corrosive ORAL LD50-RAT: 1,530 MG/KG DERMAL LD50-RABBIT: 2,740 MG/KG INHL. LC50: NO DATA.	15-40
7733-02-0	ZINC SULFATE Severe irritant; potential reproductive toxin ORAL LD50-RAT: 2,949 MG/KG DERMAL LD50: NO DATA. INHL. LC50: NO DATA.	15-40

No component is considered to be a carcinogen by the U.S. National Toxicology Program (NTP), the International Agency for Research on Cancer (IARC) or under WHMIS.

3 HAZARDS IDENTIFICATION

****

EMERGENCY OVERVIEW

Severe irritant to the skin. Corrosive to the eyes. Mists/aerosols cause irritation to the upper respiratory tract.

Odor: None; Appearance: Colorless, Liquid

Fire fighters should wear positive pressure self-contained breathing apparatus(full face-piece type). Proper fire-extinguishing media: dry chemical, carbon dioxide, foam or water

****

POTENTIAL HEALTH EFFECTS

ACUTE SKIN EFFECTS:
Primary route of exposure; Severe irritant to the skin.

ACUTE EYE EFFECTS:
Corrosive to the eyes.

ACUTE RESPIRATORY EFFECTS:
Primary route of exposure;Mists/aerosols cause irritation to the upper respiratory tract.

INGESTION EFFECTS:
May cause severe gastrointestinal irritation.

TARGET ORGANS:
Prolonged or repeated exposures may cause tissue necrosis. Product or product component may cause reproductive toxicity at maternal toxic levels (based on animal testing).

MEDICAL CONDITIONS AGGRAVATED:
Not known.

SYMPTOMS OF EXPOSURE:
Inhalation of vapors/mists/aerosols may cause eye, nose, throat and lung irritation. Skin contact may cause severe irritation or burns.

4 FIRST AID MEASURES

SKIN CONTACT:
Wash thoroughly with soap and water. Remove contaminated clothing. Thoroughly wash clothing before reuse. Get medical attention if irritation develops or persists.

EYE CONTACT:
URGENT! Immediately flush eyes with plenty of low-pressure water for at least 20 minutes while removing contact lenses. Hold eyelids apart. Get immediate medical attention.

INHALATION:
Remove to fresh air. If breathing is difficult, give oxygen. If breathing has stopped, give artificial respiration. Get immediate

medical attention.

INGESTION:

Do not feed anything by mouth to an unconscious or convulsive victim. Do not induce vomiting. Immediately contact physician. Dilute contents of stomach using 3-4 glasses milk or water.

NOTES TO PHYSICIANS:

No special instructions

5 FIRE FIGHTING MEASURES

FIRE FIGHTING INSTRUCTIONS:

Fire fighters should wear positive pressure self-contained breathing apparatus (full face-piece type).

EXTINGUISHING MEDIA:

dry chemical, carbon dioxide, foam or water

HAZARDOUS DECOMPOSITION PRODUCTS:

Thermal decomposition (destructive fires) yields elemental oxides.

FLASH POINT:

> 200F   > 93C P-M(CC)

6 ACCIDENTAL RELEASE MEASURES

PROTECTION AND SPILL CONTAINMENT:

Ventilate area. Use specified protective equipment. Contain and absorb on absorbent material. Place in waste disposal container. Flush area with water. Wet area may be slippery. Spread sand/grit.

DISPOSAL INSTRUCTIONS:

The waste characteristics of the absorbed material, or any contaminated soil, should be determined in accordance with provincial regulations. Water contaminated with this product may be sent to a sanitary sewer treatment facility, in accordance with any local agreement or discharged under provincial regulations.
Incinerate or land dispose in an approved landfill.

7 HANDLING & STORAGE

HANDLING:

Acidic. Corrosive(Metal). Do not mix with alkaline material.

STORAGE:

Keep containers closed when not in use. Use approved containers only. Store in cool, well-vented area. Contact with metals may release flammable hydrogen gas.

8 EXPOSURE CONTROLS / PERSONAL PROTECTION

EXPOSURE LIMITS

Consult local authorities for acceptable provincial values.

CHEMICAL NAME

PHOSPHORIC ACID
PEL (OSHA): 1 MG/M3
TLV (ACGIH): 1 MG/M3

ZINC SULFATE
PEL (OSHA): NOT DETERMINED
TLV (ACGIH): NOT DETERMINED

ENGINEERING CONTROLS:
Adequate ventilation to maintain air contaminants below exposure limits.
RESPIRATORY PROTECTION:
If air-purifying respirator use is appropriate, use a respirator with dust/mist filters.
SKIN PROTECTION:
rubber gloves-- Wash off after each use. Replace as necessary.
EYE PROTECTION:
splash proof chemical goggles

9 PHYSICAL & CHEMICAL PROPERTIES

Specific Grav.(70F,21C)	1.398	Vapor Pressure (mmHG)	~ 18.0
Freeze Point (F)	-13	Vapor Density (air=1)	< 1.00
Freeze Point (C)	-25		
Viscosity(cps 70F,21C)	10	% Solubility (water)	100.0

Odor		None
Appearance		Colorless
Physical State		Liquid
Flash Point	P-M(CC)	> 200F > 93C
pH As Is (approx.)		1.4
Evaporation Rate (Ether=1)		< 1.00

NA = not applicable ND = not determined

10 STABILITY & REACTIVITY

STABILITY:
Stable under normal storage conditions.
HAZARDOUS POLYMERIZATION:
Will not occur.
INCOMPATIBILITIES:
May react with strong oxidizers.
DECOMPOSITION PRODUCTS:
Thermal decomposition (destructive fires) yields elemental oxides.
BETZDEARBORN INTERNAL PUMPOUT/CLEANOUT CATEGORIES:
"B"

11 TOXICOLOGICAL INFORMATION

Oral LD50 RAT:	>2,000 mg/kg
NOTE - Estimated value	
Dermal LD50 RABBIT:	>2,000 mg/kg
NOTE - Estimated value	

12 ECOLOGICAL INFORMATION

AQUATIC TOXICOLOGY

Rainbow Trout 96 Hour Static Acute Bioassay

LC50: 21.3 mg/L

No Effect Level: 15.5 mg/L

Daphnia magna 48 Hour Static Acute Bioassay phytoplankton

LC50: 3.8 mg/L
No Effect Level: 3.2 mg/L

Fathead Minnow 96 Hour Acute Toxicity
Product toxicity determined from bioassays conducted on individual components.

LC50: 16 mg/L
No Effect Level: 6.3 mg/L

BIODEGRADATION
No Data Available.

13 DISPOSAL CONSIDERATIONS

Incinerate or bury in approved landfill. Please be advised that there may be additional local or provincial requirements relating to the disposal of waste. Consult provincial and local regulations regarding the proper disposal of this material.

14 TRANSPORT INFORMATION

Transportation of Dangerous Goods:
Proper Shipping Name: Corrosive Liquids, n.o.s. (Phosphoric Acid)
PIN: UN1760; Classification: 8(9.2); Packing Group: III

15 REGULATORY INFORMATION

This product has been classified in accordance with the hazard criteria of the CPR and the MSDS contains all the information required by the CPR.

CEPA:
All components of this product comply with substance notification requirements under CEPA.

WHMIS CLASSIFICATION:
D2A D2B E

FOOD AND DRUG ADMINISTRATION:
The ingredients in this product are Generally Recognized As Safe by FDA for direct addition to human food.

16 OTHER INFORMATION

NFPA/HMIS		CODE TRANSLATION
Health	3	Serious Hazard
Fire	0	Minimal Hazard
Reactivity	0	Minimal Hazard
Special	CORR	DOT corrosive
(1) Protective Equipment	B	Goggles,Gloves

(1) refer to section 8 of MSDS for additional protective equipment recommendations.

CHANGE LOG

	EFFECTIVE DATE	REVISIONS TO SECTION:	SUPERCEDES
MSDS status:	22-MAY-1998		** NEW **
	09-DEC-1998	15	22-MAY-1998
	23-MAR-2000	15	09-DEC-1998
	07-APR-2000	4	23-MAR-2000
	14-JUL-2000	15	07-APR-2000
	16-JAN-2001	14	14-JUL-2000

Prepared by the Regulatory Affairs Group, BetzDearborn Canada, Inc.
Telephone: 1(905)279-2222   Date of preparation: 16-JAN-2001

BetzDearborn
Shaping the Future of Water & Process Treatment

Corrosion Test Coupon Racks

BetzDearborn Corrosion Test Coupon Racks provide a convenient means of monitoring the progress of corrosion in systems such as boilers, condensate lines, open recirculating cooling water, closed circulating hot or chilled water systems, etc. The corrosion test rack creates a side stream off the main system in which corrosion test coupons can be exposed to system water under controlled and reproducible conditions.

The corrosion coupons can be periodically removed and either visually examined or returned to the laboratory for determination of weight loss, corrosion rate, and pitting severity.

BLACK IRON CORROSION RACK

The Black Iron Corrosion Rack is recommended for corrosion monitoring in high temperature and/or high-pressure installations such as steam condensate, high temperature water, hydronic heating, recirculating process systems, etc. The Black Iron Rack is constructed of 1" threaded black iron pipe. It is supplied with four 1" MNPT steel mounting plugs, and one 10 gpm Dole™ flow control valve. Caution: Maximum pressure & temperature are limited by the Dole flow control valve.

Maximum Pressure: 200 psig (13.8 bar)

Maximum Temperature: 160° F (71° C)

PVC CORROSION RACK

The PVC Corrosion Rack is recommended for corrosion monitoring in low temperature systems such as open recirculating cooling water systems, chilled water, process water systems, etc. The PVC Rack is constructed of 1" threaded Sched. 80 PVC pipe. It is supplied with four 1" PVC mounting plugs and an 8 gpm Dole™ flow control valve. Two designs are available. One is constructed of all gray, opaque PVC. The other features transparent pipe sections for viewing the test coupons in place. See Figures 1 & 2. To discourage algae growth in the transparent sections, opaque snap-on pipe covering is supplied with this corrosion rack.

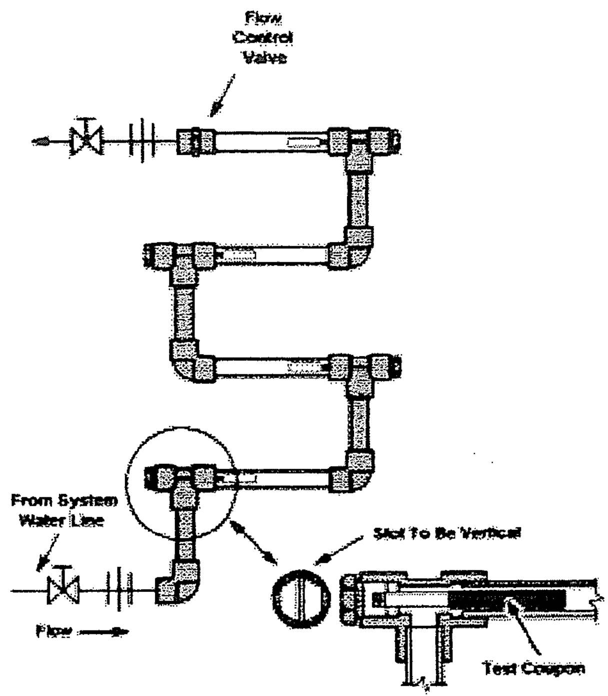


Figure 1

FLOW RATE	VELOCITY	
	1" PVC Rack	1" Black Iron Rack
5 gpm	2.2 ft/sec (0.67 m/sec)	1.9 ft/sec (0.58 m/sec)
8 gpm	**3.6 ft/sec (1.1 m/sec)**	**3.0 ft/sec (0.91 m/sec)**
10 gpm	4.5 ft/sec (1.4 m/sec)	3.7 ft/sec (1.3 m/sec)
12 gpm	5.4 ft/sec (1.6 m/sec)	4.4 ft/sec (1.4 m/sec)

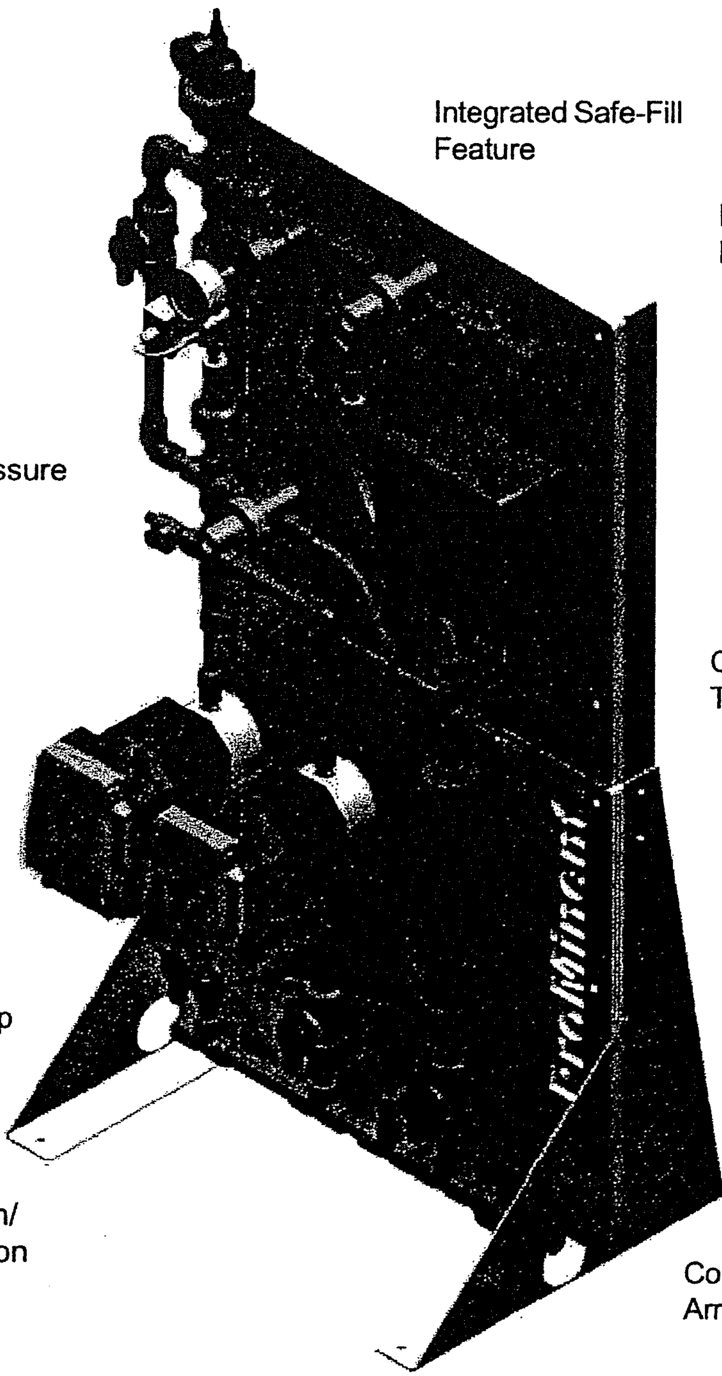
Equipment Facts

  www.betzdearborn.com Printed in the U.S.A.

MODULAR DOSING SYSTEM... Function by Design

ProMinent

Offering industry a new standard in convenience, safety, and reliability. ProMinent's new modular design concept allows custom-tailored arrangements to suit your immediate needs. Matched with our exceptional line of chemical metering pumps - the functionality, flexibility, and performance you demand is yours today - all this at an industry-valued price.



ProMinent Fluid Controls Ltd. 490 Southgate Drive, Guelph, Ontario, N1G 4P5 phone: 519-836-5692 fax: 519-836-5226
ProMinent Fluid Controls, Inc. 136 Industry Drive, Pittsburgh, PA, 15275-1014 phone: 412-787-2484 fax: 412-787-0704

MODULAR SELECTION... As Easy as 1-2-3

STEP ONE: Select Pump

Using Prominent's comprehensive catalog determine the pump capacity and pressure you require. Up to 2 pumps may be incorporated into a single package - dual pumps offer redundent function and convenience for continous dosing. You may choose any of ProMinent's line of compact Solenoid-driven metering pumps - Concept, Beta, Gamma, Gala in most sizes and materials.

STEP TWO: Select Modules

Two modules are currently available. The Suction Module includes provision for up to 2 pumps - 1 primary, the other a backup. A calibration column for setting the pump for optimum performance, and all manual control valves required to isolate and service the system easily. The Discharge Module comes standard with integrated safety relief valve, our "Safe-Fill" feature, dual function Priming/Bleed valve and all necessary isolation valves. Just add any or all of the options below for added functionality and performance...

STEP THREE Select Options and Accessories

Select from a handful of safety and performance enhancements like...

- Pressure Gauge/Seal to accurately tune your system for the best results.
- Pulsation Dampener to improve flow characteristics and repeatability.
- Back Pressure Valve for better pump performance under variable conditions.
- Flow Monitor for flow confirmation.
- Convenient junction box for all system wiring.
- Mounting arrangement - wall-mount is standard, or you may choose floor stands or tote mount hanging brackets.

MOD A B C - D E F - G H I - J K L - M

A

	I/O Connection Size / Type
1	1/2" FNPT

B

	Material Of Construction
1	Schedule 80 PVC

C

	Elastomer
1	EPDM
2	FPM (Viton)

D

	Suction Module
1	Wall-mount Module with Back Panel includes Pump Shelf (1), Calibration Column (1), Ball Valves (3), and Pipe & Fittings

E

	Calibration Column
1	100 mL
2	500 mL
Multiply Pump Strokes per Minute by Pump mL per Second for 60 sec. drawdown	

F

	Backup Pump Mount Kit
0	Not Applicable
1	Kit includes Pump Shelf (1), Ball Valve (1), and Pipe & Fittings

Circle each number that applies to your configuration and enter above each letter location.

G

	Discharge Module
0	Not Applicable
1	Wall-mount Module with Back Panel and "Safe-Fill" feature includes PRV (1), Ball Valves (3), and Pipe & Fittings

H

	Pressure Gauge & Seal Kit
0	Not Applicable
1	Kit includes Pressure Gauge with integral Seal (1), and Pipe & Fittings

I

	Pulsation Dampener Kit
0	Not Applicable
1	Kit includes Pulsation Dampener (1), and Pipe & Fittings

J

	Back Pressure Valve Kit
0	Not Applicable
1	Kit includes BPV (1), and Pipe & Fittings

K

	Flow Monitor Option
0	Not Applicable
1	Type 1 or 2 Flow Monitor (1), and Pipe & Fittings
2	Type 3 Flow Monitor (1) with Bypass includes Ball Valve (1) and Pipe & Fittings

L

	Back Panel Mount Option
0	Not Applicable
1	Corrosion-resistant, Plastic Floor Mount
2	Corrosion-resistant, Stainless Steel Tote Mount

M

	Junction Box Option
0	Not Applicable
1	Option includes Prewired JB (1) for Single Pump
2	Option includes Prewired JB (1) for Dual Pump

Viton® is a registered trademark of Dupont Dow Elastomers

Maximum Pressure:	200 psi at 70° F (13.8 bar at 21° C)
	120 psi at 120° F (6.9 bar at 49° C)
	70 psi at 140° F (4.8 bar at 60° C)

FLOW VS VELOCITY CHART

Velocities in **BOLD** indicate standard flow controller supplied with that rack. For other available Dole flow control valves, see Equipment Fact Sheet EF15-07.

OPTIONS

A Corrater™ probe may be installed in the corrosion rack to provide instantaneous corrosion readings to supplement the data provided by the weight loss corrosion coupons.

CORROSION TEST RACK INSTALLATION

1. The Corrosion Test Rack may be assembled for vertical mounting as shown in Figure 1, or a horizontal position, Figure 2. Items shown in single line schematic are not furnished.
2. Attach the corrosion rack to a wall or column. **DO NOT** suspend it from the supply and return piping alone.
3. To avoid air binding, pipe the corrosion rack so that water will flow upward through it, and in such a way that it will remain full of water at all times and not backdrain when the main recirculating system shuts own.
4. Install gate or ball-type isolation valves of both sides of the rack.
5. **DO NOT** use this bypass loop for any other purpose such as chemical injection, or mounting of conductivity or pH sensors.
6. For measurement of corrosion at points of highest temperature in the circulating system, the water supply to the corrosion rack should be from the exit of the heat exchanger(s). Average corrosion rate measurements may be obtained by supplying the corrosion rack with water from the main cooling tower riser, etc.
7. Return water may be piped to the recirculating pump suction header, cooling tower basin, or other suitable point with sufficiently low pressure to insure flow through the rack.
8. Flow velocities should not be variable. Avoid extremely high or low velocity conditions. A Dole™ or other suitable flow control valve is recommended to insure constant velocity.
9. For PVC Test Racks with transparent viewing sections, install the slotted polyfoam pipe insulation over the transparent sections to discourage algae growth.

CORROSION TEST COUPON INSTALLATION

1. Keep the metal test coupon in the special treated envelope **BEFORE AND AFTER** exposure.
2. **DO NOT** leave fingerprints on the coupon. They will cause false corrosion readings.
3. Attach the coupon to the mounting stud using the special nut and bolt provided.

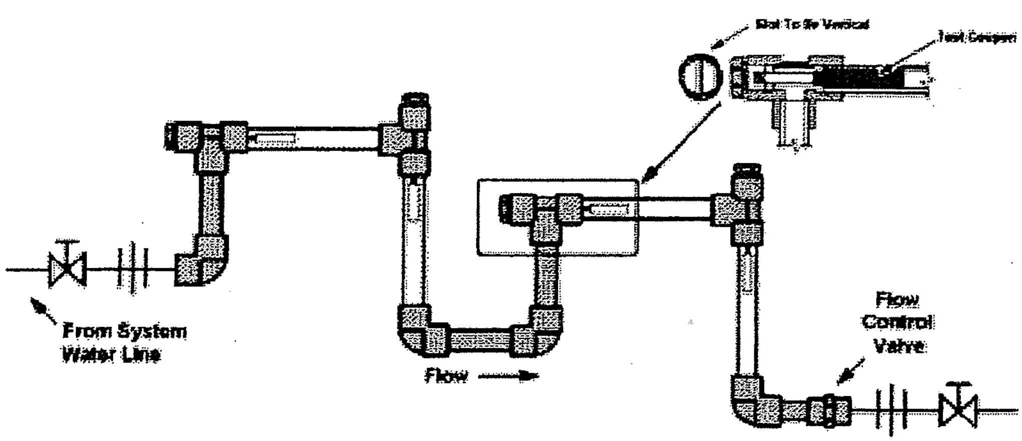


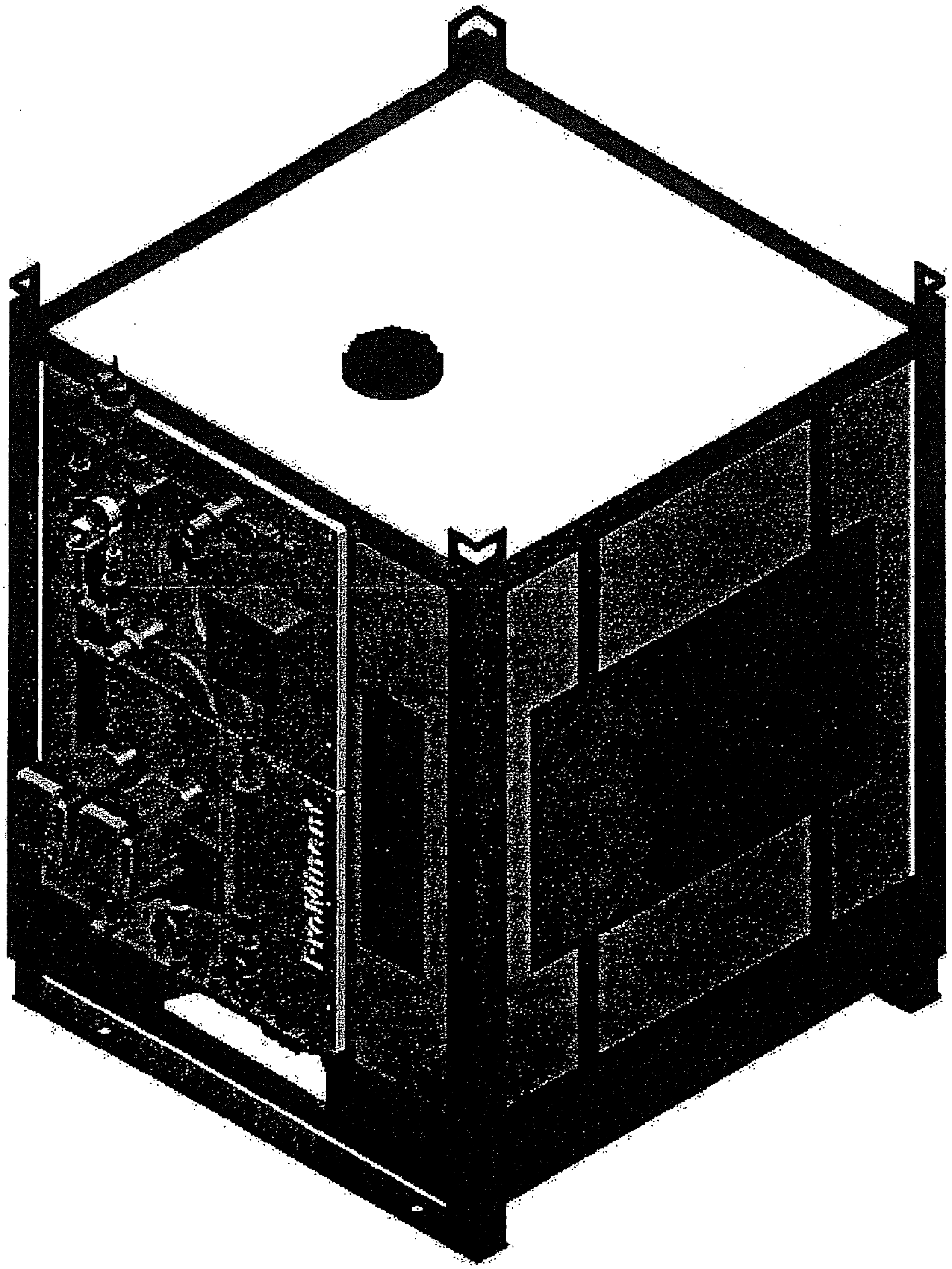
Figure 2

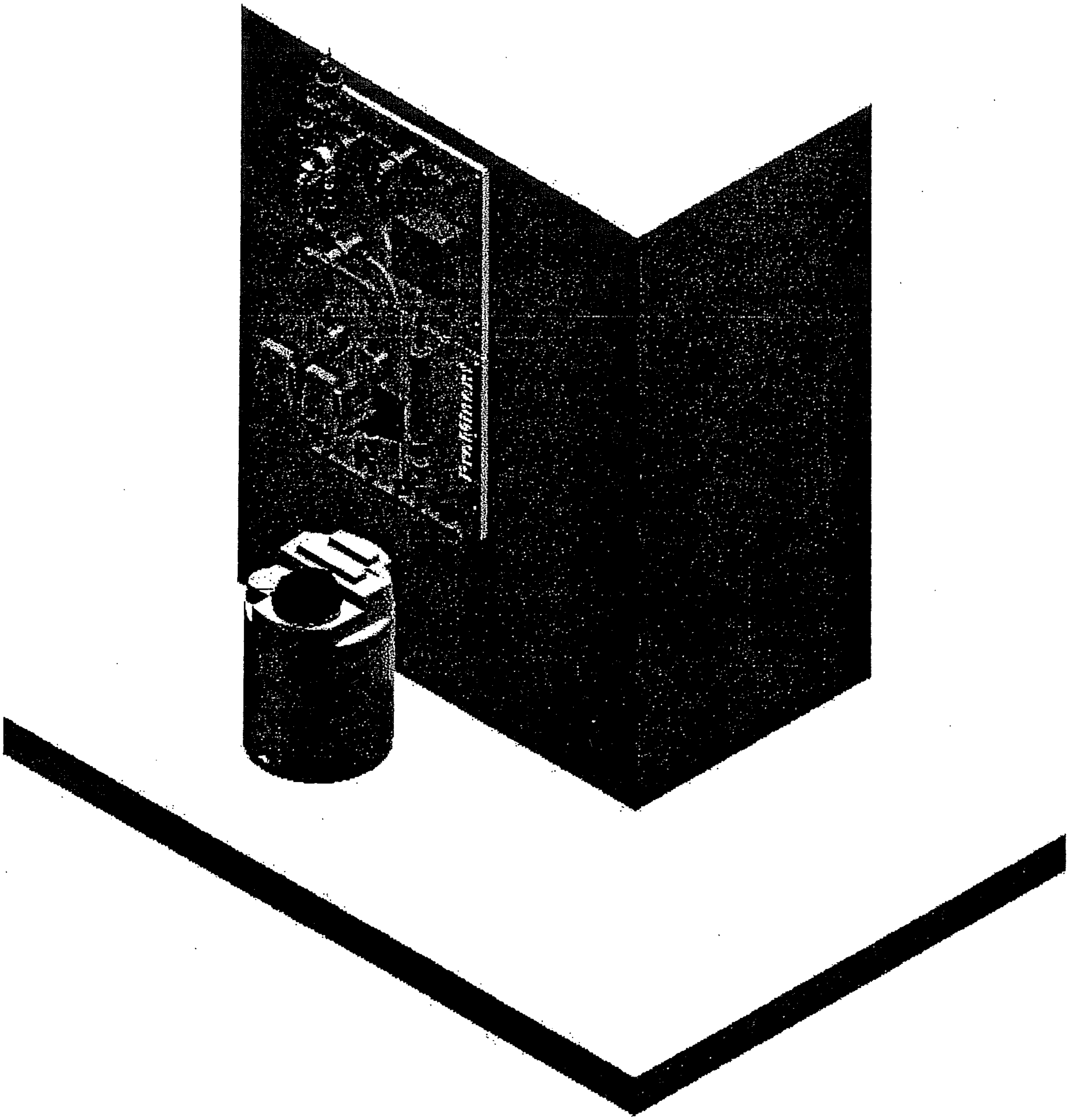
4. Corrosion coupons should always be installed so the water flow first over the plastic mounting rod and then over the coupon. Water flowing directly onto the coupon may cause erosion-corrosion and lead to false weight loss measurements.
5. Use **ONLY** Teflon™ thread sealing tape on mounting plug threads. **DO NOT** use pipe dope.
6. The witness slot on the coupon mounting plug should be parallel with the flat surface of the corrosion test coupon. Install the mounting plug in the tee and align the witness slot (and coupon) in the **VERTICAL** position as shown in Figure 1.
7. Note the date of installation on back of the white Tyvek™ Coupon Return Envelope (ENG 322) and retain both the Coupon Return Envelope and the treated brown envelope.
8. When removing, each test coupon should be carefully dismounted from the holder and immediately dried with a blast of hot air or blotted with a paper towel or clean rag. DO NOT CLEAN. Reinsert the coupon in the treated brown envelope in which it was received.
9. Complete the back of the white Coupon Return Envelope, insert the treated brown envelopes with coupons inside, and return the envelope with the coupons to the Woodlands laboratory.

Part Numbers

2013971	Corrosion Rack, PVC, 1" NPT, w/ 4 coupon holders & 8 gpm flow control valve.
2042205	Corrosion Rack, PVC, 1" NPT w/ 4 coupon holders, 8 gpm valve and 4 TRANSPARENT viewing sections.
2029978	Corrosion Rack, Black Iron, 1" NPT, w/ 4 coupon holders & 10 gpm flow control valve.
2032806	Corrosion Rack, 304 SS, 1" NPT, w/ 4 coupon holders.
2015850	Replacement Coupon Holder, 1" PVC w/ 6" stem.
2041977	Replacement Coupon Holder, 1" Black Iron w/ 6" Teflon™ Stem and Teflon nut & Screw

Corrosion test coupons and mounting screws are not supplied with the corrosion rack and must be ordered separately from the BetzDearborn Woodlands, TX laboratory.


ProMinent



APPENDIX D

CAT ARM

Flushing Service Water Heat Exchangers Online

General

Flush each unit individually at a 50 MW load. Use the data chart on the following page to record the necessary readings (marked with an asterisk) before, during, and after flushing the service water heat exchangers. During flushing the stator temperatures will be monitored at all times to prevent over heating. If stator temperatures rise to alarm conditions during flushing reroute service water through SAC to cool the unit.

Procedure

All heat exchangers will be flushed on each unit, starting with the turbine guide cooler and generator guide/thrust bearing coolers being flushed together, and then the Surface Air Coolers (SAC) being flushed individually. Record all necessary readings before flushing. Fully open the Pressure Reducing Valve (Unit #1 V-04-38, Unit #2 V-04-50) on the inlet header to the unit to begin the flushing procedure.

1) Flushing turbine and generator bearing coolers

Place the temperature control valve in the full open position (Unit #1 V-04-29, Unit #2 V-04-86) and also open the isolation valve for the by-pass discharge line (Unit #1 V-04-31, Unit #2 V-04-88). Make sure turbine isolation discharge valve (Unit #1 V-04-54, Unit #2 V-04-62) and generator isolation discharge valve (Unit #1 V-04-53, Unit #2 V-04-61) are in the full open position. Manually throttle SAC inlet header isolation valve to 30% normal flow (7.8 l/s) (Unit #1 V-04-115, Unit #2 V-04-116), this valves normal operating position is full open. Flush turbine and generator bearing coolers for 10 minutes and record readings half way through these coolers during flushing as per the data chart. After flushing return SAC inlet header isolation valve to full open, then close the isolation valve for the by-pass discharge line, then return service water temperature control valve to normal operating position, and finally record readings through these coolers as per the data chart.

2) Flushing Surface Air Coolers

Place the temperature control valve in the full open position (Unit #1 V-04-45, Unit #2 V-04-56) and also open the isolation valve for the by-pass discharge line (Unit #1 V-04-47, Unit #2 V-04-58). Flush SAC by isolating three coolers and allowing all service water to flow through the remaining cooler. Flush the SAC in the following order starting with cooler #2, #3, #1, and #4. Record readings through these coolers during flushing as per the data chart. Flush each cooler for 10 minutes. After flushing all SAC open all cooler isolation valves, then close the isolation valve for the by-pass discharge line, then return service water temperature control valve to normal operating position, and finally record readings through the coolers as per the data chart.

Flushing F ure data

Cat Arm Readings Unit #1	Before Flushing	During Flushing Gen & Turb	After Flushing Gen & Turb	During Flushing Surface Air Coolers				After Flushing SAC
				#1	#2	#3	#4	
Inlet water pressure	*	*	*	*	*	*	*	*
SAC Air inlet temp	*					*		*
SAC Air outlet temp	*					*		*
Stator A temp	*	*	*	*	*	*	*	*
Stator B temp	*	*	*	*	*	*	*	*
Stator C temp	*	*	*	*	*	*	*	*
Water inlet temp	*	*	*	*	*	*	*	*
SAC water outlet temp	*	*	*	*	*	*	*	*
Gen brg water outlet temp	*	*	*					
Turb brg water outlet temp	*	*	*					
Gen brg oil temp	*	*	*					
Turb brg oil temp	*	*	*					
SAC flow rate	*	*	*	*	*	*	*	*
Gen brg flow rate	*	*	*	*	*	*	*	*
Turb brg flow rate	*	*	*	*	*	*	*	*

Flushing Procedure data

Cat Arm Readings Unit #2	Before Flushing	During Flushing Gen & Turb	After Flushing Gen & Turb	During Flushing Surface Air Coolers #1	#2	#3	#4	After Flushing SAC
Inlet water pressure	*	*	*	*		*		*
SAC Air inlet temp	*					*		*
SAC Air outlet temp	*					*		*
Stator A temp	*	*	*	*	*	*	*	*
Stator B temp	*	*	*	*	*	*	*	*
Stator C temp	*	*	*	*	*	*	*	*
Water inlet temp	*	*	*	*	*	*	*	*
SAC water outlet temp	*	*	*	*	*	*	*	*
Gen brg water outlet temp	*	*	*					
Turb brg water outlet temp	*	*	*					
Gen brg oil temp	*	*	*					
Turb brg oil temp	*	*	*					
SAC flow rate	*	*	*	*	*	*	*	*
Gen brg flow rate	*	*	*	*	*	*	*	*
Turb brg flow rate	*	*	*	*	*	*	*	*

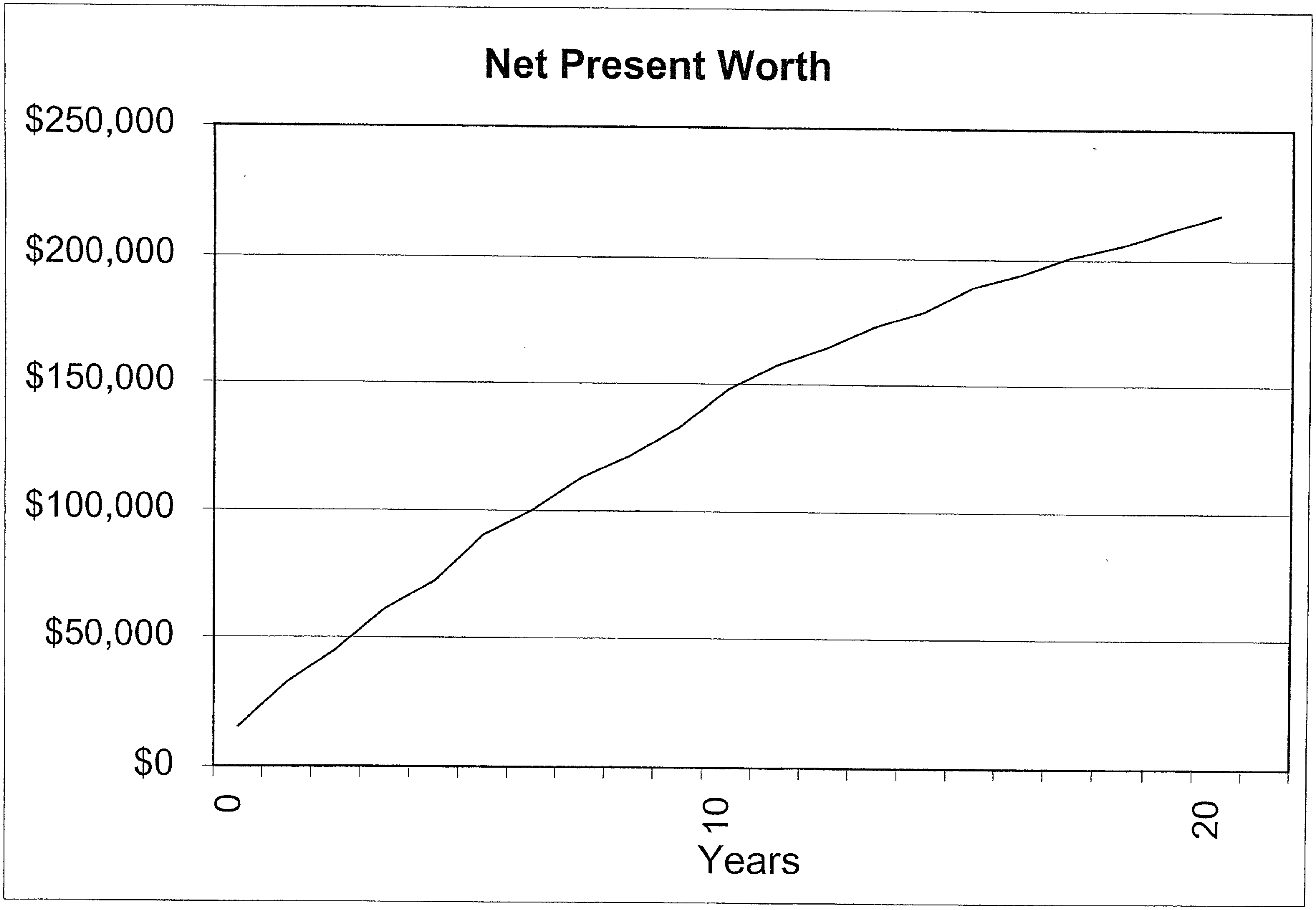
APPENDIX E

DO NOTHING (Per Unit)

Capital Cost	
Total	0

Operating Cost	
Pump consumption (49 weeks)	15,353
Clean SAC (2 yr)	5,783
Clean SAC Piping (10 yr)	4,667
Clean Gen Brg Coolers (5 yr)	5,783
Clean Gen Brg Cooler Piping (10 yr)	4,667

	Year	Cash Flow	NPW
0	2002	$15,353	$15,353
1	2003	$21,559	$32,463
2	2004	$15,973	$44,969
3	2005	$22,430	$61,154
4	2006	$16,619	$72,206
5	2007	$29,721	$90,423
6	2008	$17,290	$100,191
7	2009	$24,279	$112,832
8	2010	$17,988	$121,464
9	2011	$25,259	$132,636
10	2012	$37,143	$147,777
11	2013	$26,280	$157,650
12	2014	$19,471	$164,392
13	2015	$27,342	$173,118
14	2016	$20,258	$179,077
15	2017	$36,229	$188,899
16	2018	$21,076	$194,165
17	2019	$29,596	$200,980
18	2020	$21,928	$205,634
19	2021	$30,791	$211,657
20	2022	$31,407	$217,320

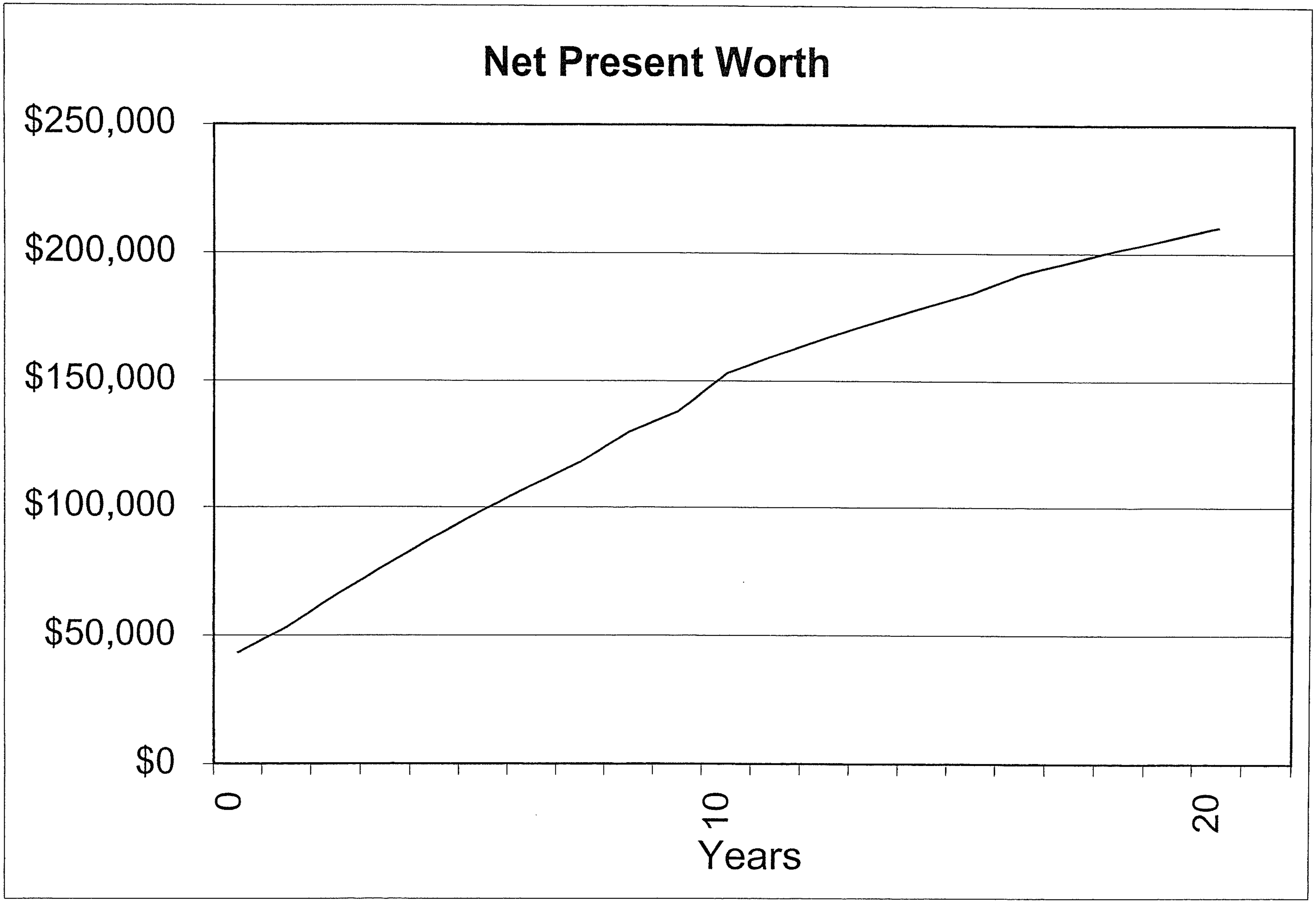

Net Present Worth
$250,000
$200,000
$150,000
$100,000
$50,000
$0
0
10
20
Years

REPLACE PIPING (per Unit)

Capital Cost	
Gen Brg Piping (Parts & Installation)	8,229
Inlet Piping (Parts & Installation)	8,378
Discharge Piping (Parts & Installation)	11,303
Total	27,910

Operating Cost	
Pump consumption (49 weeks)	15,353
Clean SAC (8 yr)	5,783
Clean SAC Piping (10 yr)	4,667
Clean Gen Brg Coolers (10 yr)	5,783
Clean Gen Brg Cooler Piping (10 yr)	4,667

	Year	Cash Flow	NPW
0	2002	$43,263	$43,263
1	2003	$15,660	$53,176
2	2004	$15,973	$65,682
3	2005	$16,293	$77,438
4	2006	$16,619	$88,490
5	2007	$16,951	$98,880
6	2008	$17,290	$108,648
7	2009	$17,636	$117,830
8	2010	$24,764	$129,714
9	2011	$18,348	$137,829
10	2012	$37,143	$152,970
11	2013	$19,090	$160,142
12	2014	$19,471	$166,884
13	2015	$19,861	$173,223
14	2016	$20,258	$179,181
15	2017	$20,663	$184,783
16	2018	$29,015	$192,033
17	2019	$21,498	$196,983
18	2020	$21,928	$201,637
19	2021	$22,366	$206,013
20	2022	$22,814	$210,126

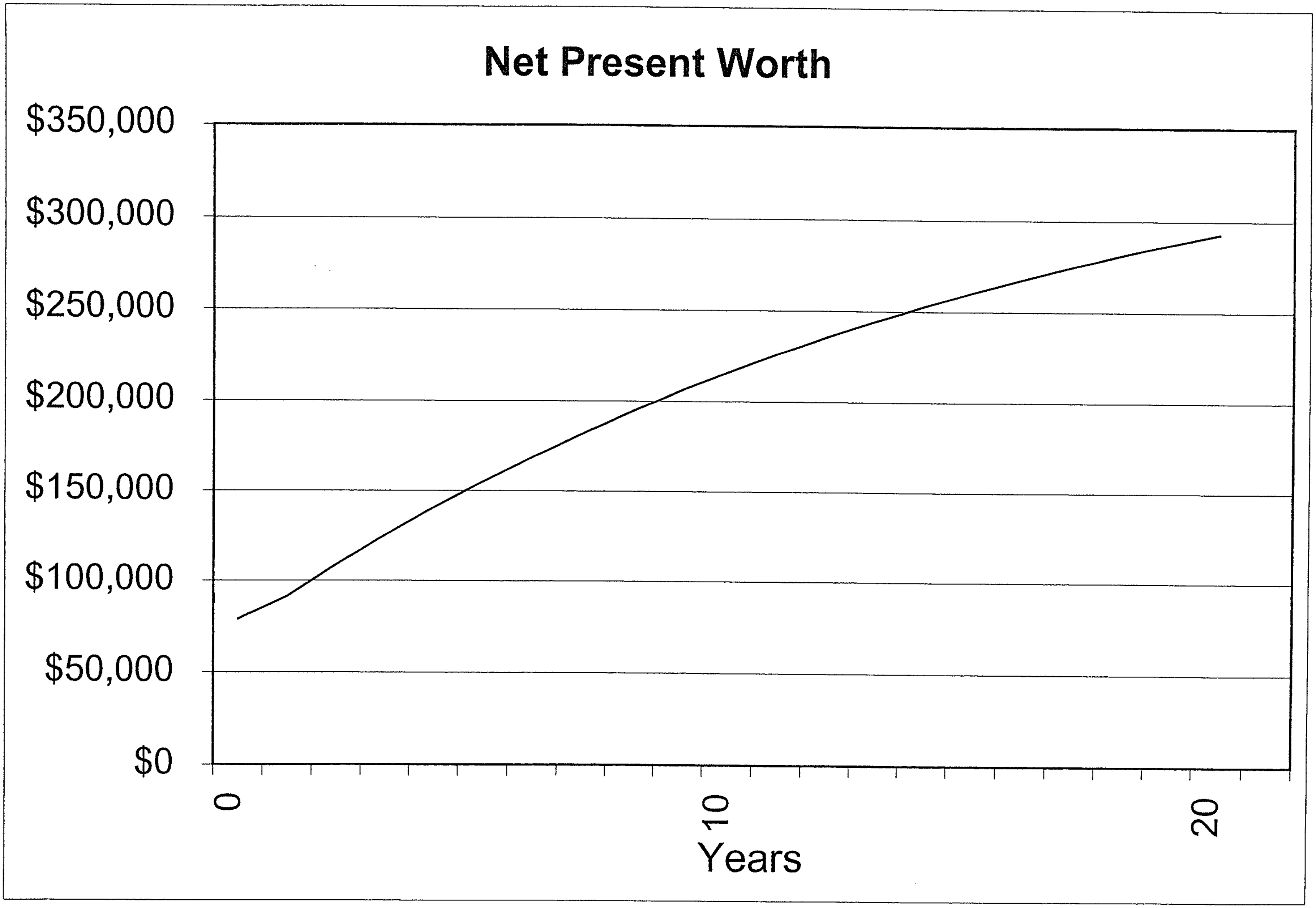

Net Present Worth
$250,000
$200,000
$150,000
$100,000
$50,000
$0
0
10
20
Years

CLOSED LOOP SYSTEM (Two Units)

Capital Cost	
Pump	$14,404
Heat Exchanger	$35,000
Installation Piping & Hardware	$8,000
Total	$57,404

Operating Cost	
Pump consumption (49 weeks)	$15,353
Recir Pump Consumption (49 weeks)	$6,133

	Year	Cash Flow	NPW
0	2002	$78,890	$78,890
1	2003	$21,916	$91,326
2	2004	$22,354	$108,827
3	2005	$22,801	$125,279
4	2006	$23,257	$140,746
5	2007	$23,722	$155,287
6	2008	$24,197	$168,956
7	2009	$24,680	$181,806
8	2010	$25,174	$193,887
9	2011	$25,678	$205,244
10	2012	$26,191	$215,920
11	2013	$26,715	$225,957
12	2014	$27,249	$235,393
13	2015	$27,794	$244,263
14	2016	$28,350	$252,602
15	2017	$28,917	$260,441
16	2018	$29,495	$267,811
17	2019	$30,085	$274,739
18	2020	$30,687	$281,252
19	2021	$31,301	$287,375
20	2022	$31,927	$293,131



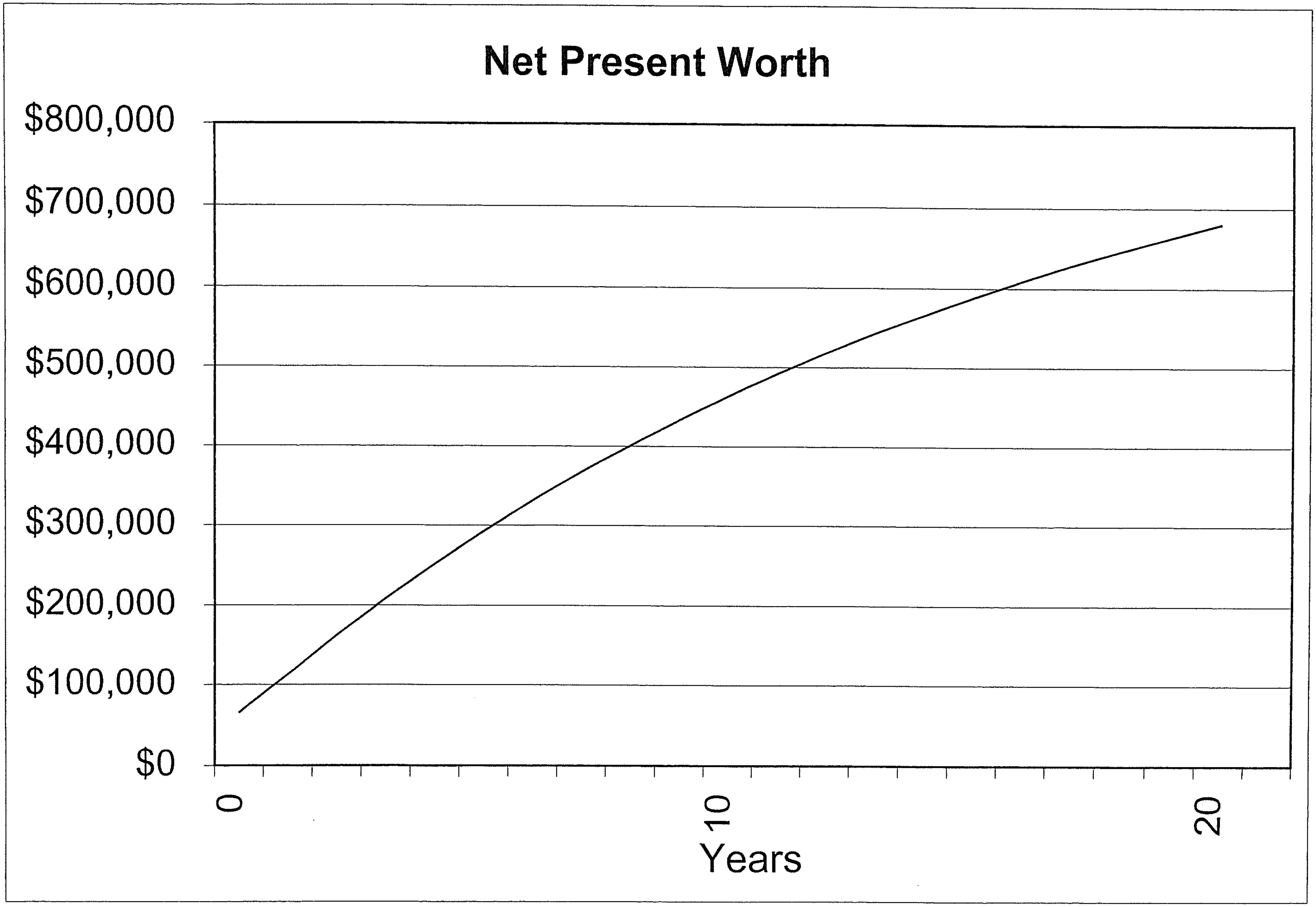
Net Present Worth
$350,000
$300,000
$250,000
$200,000
$150,000
$100,000
$50,000
$0
0
10
20
Years

CHEMICAL INJECTION (Two Units)

Capital Cost	
Injection System	5,000
Test Coupon Rack	515
Total	5,515

Operating Cost	
Pump consumption (49 weeks)	15,353
Chemical (49 weeks)	45,000

	Year	Cash Flow	NPW
0	2002	$65,868	$65,868
1	2003	$61,560	$113,000
2	2004	$62,791	$162,160
3	2005	$64,047	$208,375
4	2006	$65,328	$251,821
5	2007	$66,635	$292,664
6	2008	$67,967	$331,061
7	2009	$69,327	$367,157
8	2010	$70,713	$401,091
9	2011	$72,127	$432,992
10	2012	$73,570	$462,982
11	2013	$75,041	$491,175
12	2014	$76,542	$517,679
13	2015	$78,073	$542,595
14	2016	$79,635	$566,019
15	2017	$81,227	$588,039
16	2018	$82,852	$608,741
17	2019	$84,509	$628,202
18	2020	$86,199	$646,497
19	2021	$87,923	$663,696
20	2022	$89,681	$679,865


Net Present Worth
$800,000
$700,000
$600,000
$500,000
$400,000
$300,000
$200,000
$100,000
$0
0
10
20
Years

APPENDIX F

Labour Costs, Cat Arm

Gen. Bldg. Piping (2")

Estimate			Actual	
Description	Crew	day	Quantity	day
Sch 10, black, 2"	1PLUM	43'	105'	2.44
90°+45° Elbows, 2"	1PLUM	25	16	0.64
Tee, 2"	1PLUM	17	2	0.12
Coupling, 2"	1PLUM	50	46	0.92
Roll Groving, 2"	1Q	116	46	0.40

1Q crew = 1PLUM + 1 Apprentice

Time required for 1PLUM.
= 2.44 + 0.64 + 0.12 + 0.92 = 4.12 days

* Add additional work reduces time by 25%.
= 4.12 x 0.75 = 3.09 days

Total Time required for 1Q crew.
= 3.09 + 0.40 = 3.49 days (27.9 hrs)

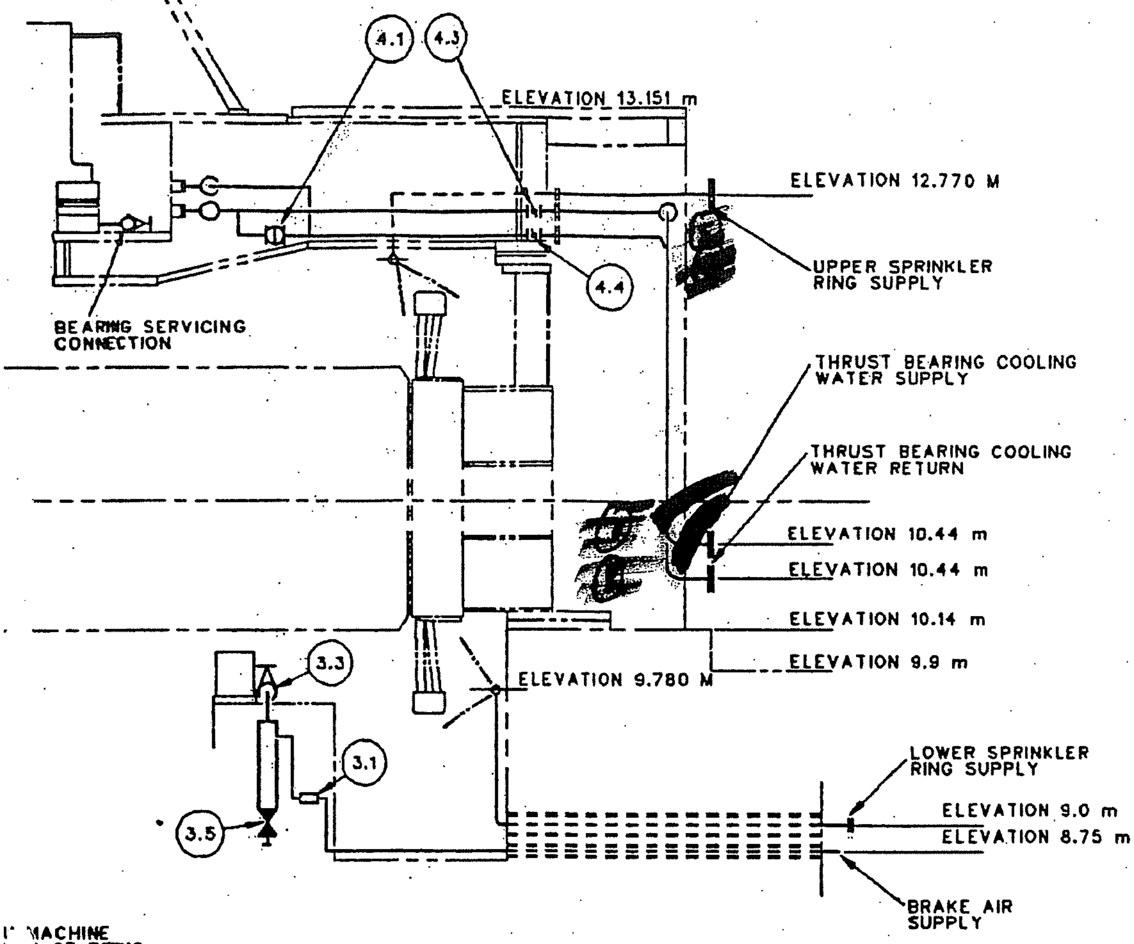
5 | 6 | 7 | 8 | 9

NEWFOUNDLAND AND LABRADOR HYDRO CAT ARM DEVELOPMENT	PIPING PLAN AIR, OIL, WATER AN[D] ... UNIT
C.A.C. DWG. No. M-1602-170-45	

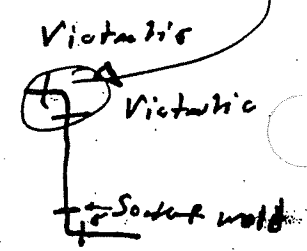
Canadian General Elect[ric]

FOR PURCHASER'S NO[TE]

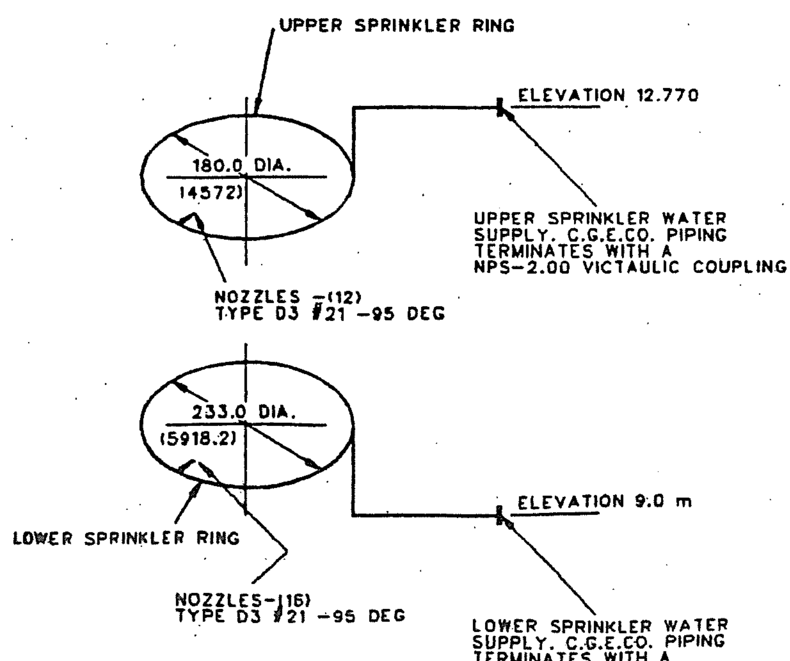
VALVE ID
LOCATION
BEARING LUB OIL SY[STEM]
BRAKING AND JACKIN[G]
BEARING COOLING W[ATER]
FIRE PROTECTION SY[STEM]
HIGH PRESSURE INJE[CTION]
LOUVER AIR



Start to replace C.S pipe with S.S pipe at this 90° Elbow Victaulic.



' MACHINE
N OF PIPING
IEW
O



SCHEMATIC DIAGRAM OF SPRINKLER PIPING

LING
TERMINATES
OUPLING AT

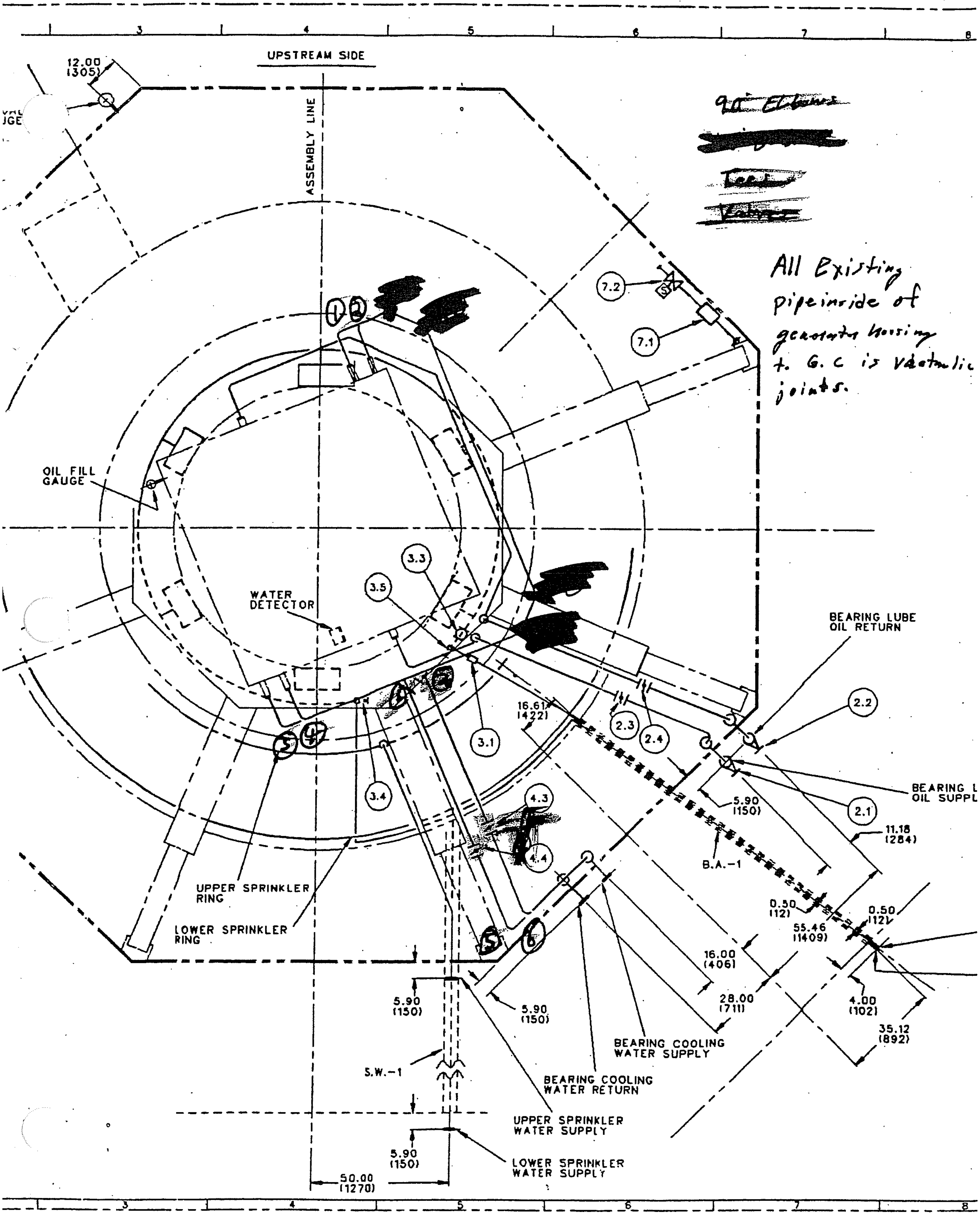
• ELEVATION TO BE SUPPLIED BY PURCHASER

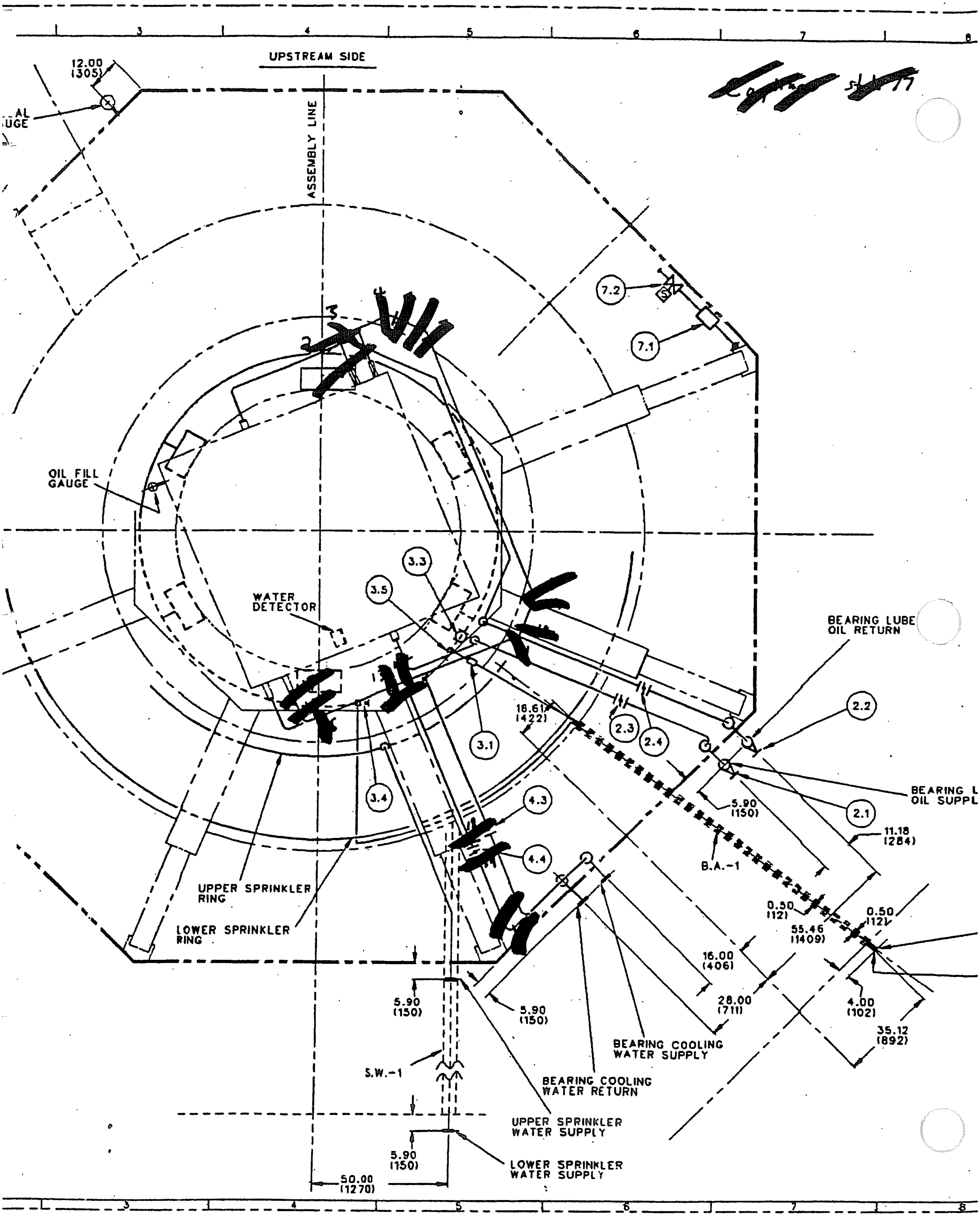
LING VALVE
D-MOUNTED
ELEVATION •

F VALVE
D MOUNTED
T ELEVATION •

VAUGHN R DAFOE	13JULY82 V. R. DAFOE	LARGE GE[NERATOR] PETERBOR[OUGH]

5 | 6 | 7 | 8 | 9 | 10


UPSTREAM SIDE
ASSEMBLY LINE
12.00 (305)
All Existing pipe inside of generator housing to G.C is Victaulic joints.
7.2
7.1
OIL FILL GAUGE
WATER DETECTOR
3.3
3.5
3.1
3.4
2.2
2.3
2.4
2.1
4.3
4.4
BEARING LUBE OIL RETURN
16.61 (422)
5.90 (150)
B.A.-1
11.18 (284)
0.50 (12)
0.50 (12)
55.46 (1409)
16.00 (406)
28.00 (711)
4.00 (102)
35.12 (892)
UPPER SPRINKLER RING
LOWER SPRINKLER RING
5.90 (150)
5.90 (150)
S.W.-1
BEARING COOLING WATER SUPPLY
BEARING COOLING WATER RETURN
UPPER SPRINKLER WATER SUPPLY
5.90 (150)
LOWER SPRINKLER WATER SUPPLY
50.00 (1270)
3
4
5
6
7
8


3
4
5
6
7
8
UPSTREAM SIDE
12.00
(305)
ASSEMBLY LINE
[redacted]
[redacted]
7.2
7.1
OIL FILL
GAUGE
WATER
DETECTOR
3.3
3.5
3.1
3.4
BEARING LUBE
OIL RETURN
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2.3
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18.61
(422)
5.90
(150)
BEARING L
OIL SUPPL
11.18
(284)
B.A.-1
4.3
4.4
UPPER SPRINKLER
RING
LOWER SPRINKLER
RING
0.50
(12)
55.46
(1409)
0.50
(12)
16.00
(406)
28.00
(711)
4.00
(102)
35.12
(892)
5.90
(150)
5.90
(150)
BEARING COOLING
WATER SUPPLY
S.W.-1
BEARING COOLING
WATER RETURN
UPPER SPRINKLER
WATER SUPPLY
5.90
(150)
LOWER SPRINKLER
WATER SUPPLY
50.00
(1270)

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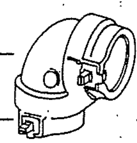
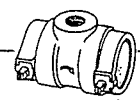
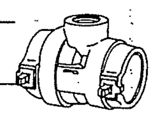
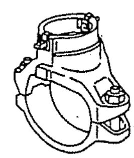
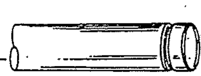
			CREW	DAILY OUTPUT	LABOR-HOURS	UNIT	2000 BARE COSTS MAT.	LABOR	EQUIP.	TOTAL	TOTAL INCL O&P	
660	9342	4" to 8" pipe, 6" stem	1 Plum	14	.571	Ea.	38.50	19		57.50	71	660
	9343	8" pipe and larger, 6" stem	"	13	.615	"	38.50	20.50		59	73.50	
	9400	Mechanical joint ends for plain end pipe										
	9410	Malleable iron, black										
	9420	90° Elbows, 1-1/4"	Q-1	29	.552	Ea.	9.30	16.50		25.80	35.50	
	9430	1-1/2"		27	.593		10.20	17.75		27.95	38	
	9440	2"		24	.667		12.05	19.95		32	43.50	
	9490	Tee, reducing outlet										
	9510	1-1/4" x 1/2"	Q-1	18	.889	Ea.	7.45	26.50		33.95	48.50	
	9520	1-1/4" x 3/4"		18	.889		7.45	26.50		33.95	48.50	
	9530	1-1/4" x 1"		18	.889		7.45	26.50		33.95	48.50	
	9540	1-1/2" x 1/2"		17	.941		7.90	28		35.90	51	
	9550	1-1/2" x 3/4"		17	.941		7.90	28		35.90	51	
	9560	1-1/2" x 1"		17	.941		7.90	28		35.90	51	
	9570	2" x 1/2"		15	1.067		9.65	32		41.65	59	
	9580	2" x 3/4"		15	1.067		9.65	32		41.65	59	
	9590	2" x 1"		15	1.067		9.65	32		41.65	59	
	9640	Tee, reducing run and outlet										
	9660	1-1/4" x 1" x 1/2"	Q-1	18	.889	Ea.	7.95	26.50		34.45	49.50	
	9670	1-1/4" x 1" x 3/4"		18	.889		7.95	26.50		34.45	49.50	
	9680	1-1/4" x 1" x 1"		18	.889		7.95	26.50		34.45	49.50	
	9690	1-1/2" x 1-1/4" x 1/2"		17	.941		8.45	28		36.45	52	
	9700	1-1/2" x 1-1/4" x 3/4"		17	.941		8.45	28		36.45	52	
	9710	1-1/2" x 1-1/4" x 1"		17	.941		8.45	28		36.45	52	
	9720	2" x 1-1/2" x 1/2"		15	1.067		10.25	32		42.25	60	
	9730	2" x 1-1/2" x 3/4"		15	1.067		10.25	32		42.25	60	
	9740	2" x 1-1/2" x 1"		15	1.067		10.25	32		42.25	60	
	9790	Tee, outlet										
	9810	3" x 1-1/4"	Q-1	29	.552	Ea.	18.05	16.50		34.55	45	
	9820	3" x 1-1/2"		28	.571		18.05	17.10		35.15	46	
	9830	3" x 2"		26	.615		20	18.40		38.40	50	
	9840	4" x 1-1/4"		28	.571		22.50	17.10		39.60	50.50	
	9850	4" x 1-1/2"		26	.615		23.50	18.40		41.90	54	
	9860	4" x 2"		24	.667		23.50	19.95		43.45	56	
	9940	For galvanized fittings for plain end pipe, add					20%					
690	0010	PIPE, GROOVED-JOINT STEEL FITTINGS & VALVES										690
	0020	Pipe includes coupling & clevis type hanger 10' O.C.										
	0500	Schedule 10, black										
	0550	2" diameter	1 Plum	43	.186	L.F.	3.02	6.20		9.22	12.65	
	0560	2-1/2" diameter	Q-1	61	.262		3.65	7.85		11.50	15.90	
	0570	3" diameter		55	.291		4.18	8.70		12.88	17.75	
	0580	3-1/2" diameter		53	.302		5.35	9.05		14.40	19.55	
	0590	4" diameter		49	.327		5.65	9.75		15.40	21	
	0600	5" diameter		40	.400		8.95	11.95		20.90	28	
	0610	6" diameter	Q-2	46	.522		9.60	16.20		25.80	35	
	0620	8" diameter	"	41	.585		18.45	18.15		36.60	48	
	0700	To delete couplings & hangers, subtract										
	0710	2" diam. to 5" diam.					25%	20%				
	0720	6" diam. to 8" diam.					27%	15%				
	1000	Schedule 40, black										
	1040	3/4" diameter	1 Plum	71	.113	L.F.	2.04	3.75		5.79	7.90	
	1050	1" diameter		63	.127		2.17	4.22		6.39	8.80	
	1060	1-1/4" diameter		58	.138		2.64	4.59		7.23	9.85	
	1070	1-1/2" diameter		51	.157		2.97	5.20		8.17	11.15	
	1080	2" diameter		40	.200		3.46	6.65		10.11	13.85	











15 MECHANICAL

15107 | Metal Pipe & Fittings

		CREW	DAILY OUTPUT	LABOR-HOURS	UNIT	2000 BARE COSTS MAT.	LABOR	EQUIP.	TOTAL	TOTAL INCL O&P
1090	2-1/2" diameter	Q-1	57	.281	L.F.	4.68	8.40		13.08	17.85 690
1100	3" diameter		50	.320		5.70	9.60		15.30	21
1110	4" diameter		45	.356		8.05	10.65		18.70	25
1120	5" diameter		37	.432		12.40	12.95		25.35	33
1130	6" diameter	Q-2	42	.571		15.90	17.75		33.65	44.50
1140	8" diameter		37	.649		23.50	20		43.50	56.50
1150	10" diameter		31	.774		36	24		60	76
1160	12" diameter		27	.889		47.50	27.50		75	93.50
1170	14" diameter		20	1.200		56	37		93	118
1180	16" diameter		17	1.412		79.50	44		123.50	154
1190	18" diameter		14	1.714		142	53		195	237
1200	20" diameter		12	2		108	62		170	213
1210	24" diameter		10	2.400		128	74.50		202.50	254
1740	To delete coupling & hanger, subtract									
1750	3/4" diam. to 2" diam.					35%	27%			
1760	2-1/2" diam. to 5" diam.					18%	18%			
1770	6" diam. to 12" diam.					14%	13%			
1800	Galvanized									
1840	3/4" diameter	1 Plum	71	.113	L.F.	2.27	3.75		6.02	8.15
1850	1" diameter		63	.127		2.34	4.22		6.56	9
1860	1-1/4" diameter		58	.138		2.85	4.59		7.44	10.10
1870	1-1/2" diameter		51	.157		3.23	5.20		8.43	11.45
1880	2" diameter		40	.200		3.81	6.65		10.46	14.25
1890	2-1/2" diameter	Q-1	57	.281		5.25	8.40		13.65	18.45
1900	3" diameter		50	.320		6.40	9.60		16	21.50
1910	4" diameter		45	.356		9.10	10.65		19.75	26
1920	5" diameter		37	.432		15.25	12.95		28.20	36.50
1930	6" diameter	Q-2	42	.571		19.80	17.75		37.55	49
1940	8" diameter		37	.649		29.50	20		49.50	63
1950	10" diameter		31	.774		44	24		68	85
1960	12" diameter		27	.889		58	27.50		85.50	106
2540	To delete coupling & hanger, subtract									
2550	3/4" diam. to 2" diam.					36%	27%			
2560	2-1/2" diam. to 5" diam.					19%	18%			
2570	6" diam. to 12" diam.					14%	13%			
2600	Schedule 80, black									
2610	3/4" diameter	1 Plum	65	.123	L.F.	2.31	4.09		6.40	8.75
2650	1" diameter		61	.131		2.50	4.36		6.86	9.35
2660	1-1/4" diameter		55	.145		3.12	4.84		7.96	10.75
2670	1-1/2" diameter		49	.163		3.57	5.45		9.02	12.15
2680	2" diameter		38	.211		4.35	7		11.35	15.40
2690	2-1/2" diameter	Q-1	54	.296		5.95	8.85		14.80	19.90
2700	3" diameter		48	.333		7.45	10		17.45	23.50
2710	4" diameter		44	.364		10.75	10.90		21.65	28.50
2720	5" diameter		35	.457		12.55	13.70		26.25	34.50
2730	6" diameter	Q-2	40	.600		20.50	18.60		39.10	50.50
2740	8" diameter		35	.686		47.50	21.50		69	84.50
2750	10" diameter		29	.828		75.50	25.50		101	122
2760	12" diameter		24	1		83.50	31		114.50	139
3240	To delete coupling & hanger, subtract									
3250	3/4" diam. to 2" diam.					30%	25%			
3260	2-1/2" diam. to 5" diam.					14%	17%			
3270	6" diam. to 12" diam.					12%	12%			
3300	Galvanized									
3310	3/4" diameter	1 Plum	65	.123	L.F.	2.01	4.09		6.10	8.40
3350	1" diameter		61	.131		2.06	4.36		6.42	8.85

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690		CREW	DAILY OUTPUT	LABOR-HOURS	UNIT	2000 BARE COSTS MAT.	LABOR	EQUIP.	TOTAL	TOTAL INCL O&P
3360	1-1/4" diameter	1 Plum	55	.145	L.F.	2.51	4.84		7.35	10.05
370	1-1/2" diameter		46	.174		2.83	5.80		8.63	11.85
3380	2" diameter		38	.211		3.26	7		10.26	14.20
3390	2-1/2" diameter	Q-1	54	.296		4.25	8.85		13.10	18.05
3400	3" diameter		48	.333		5.25	10		15.25	21
3410	4" diameter		44	.364		7.55	10.90		18.45	25
3420	5" diameter		35	.457		15.45	13.70		29.15	37.50
3430	6" diameter	Q-2	40	.600		26.50	18.60		45.10	57.50
3440	8" diameter		35	.686		46	21.50		67.50	82.50
3450	10" diameter		29	.828		73	25.50		98.50	120
3460	12" diameter		24	1		81	31		112	136
3920	To delete coupling & hanger, subtract									
3930	3/4" diam. to 2" diam.					30%	25%			
3940	2-1/2" diam. to 5" diam.					15%	17%			
3950	6" diam. to 12" diam.					11%	12%			
3990	Fittings: cplg. & labor required at joints not incl. in fitting									
3994	price. Add 1 per joint for installed price.									
4000	Elbow, 90° or 45°, painted									
4030	3/4" diameter	1 Plum	50	.160	Ea.	12.10	5.30		17.40	21.50
4040	1" diameter		50	.160		12.10	5.30		17.40	21.50
4050	1-1/4" diameter		40	.200		12.10	6.65		18.75	23.50
4060	1-1/2" diameter		33	.242		12.10	8.05		20.15	25.50
4070	2" diameter		25	.320		12.10	10.65		22.75	29.50
4080	2-1/2" diameter	Q-1	40	.400		12.10	11.95		24.05	31.50
4090	3" diameter		33	.485		21.50	14.50		36	45.50
4100	4" diameter		25	.640		23.50	19.15		42.65	55
10	5" diameter		20	.800		56.50	24		80.50	98.50
0	6" diameter	Q-2	25	.960		66.50	30		96.50	118
4130	8" diameter		21	1.143		139	35.50		174.50	207
4140	10" diameter		18	1.333		254	41.50		295.50	340
4150	12" diameter		15	1.600		405	49.50		454.50	520
4170	14" diameter		12	2		725	62		787	895
4180	16" diameter		11	2.182		945	67.50		1,012.50	1,150
4190	18" diameter	Q-3	15	2.133		1,200	67.50		1,267.50	1,425
4200	20" diameter		13	2.462		1,575	78		1,653	1,875
4210	24" diameter		11	2.909		2,300	92.50		2,392.50	2,675
4250	For galvanized elbows, add					26%				
4690	Tee, painted									
4700	3/4" diameter	1 Plum	38	.211	Ea.	18.65	7		25.65	31
4740	1" diameter		33	.242		18.65	8.05		26.70	32.50
4750	1-1/4" diameter		27	.296		18.65	9.85		28.50	35.50
4760	1-1/2" diameter		22	.364		18.65	12.10		30.75	39
4770	2" diameter		17	.471		18.65	15.65		34.30	44
4780	2-1/2" diameter	Q-1	27	.593		18.65	17.75		36.40	47.50
4790	3" diameter		22	.727		26	22		48	62
4800	4" diameter		17	.941		40	28		68	86.50
4810	5" diameter		13	1.231		93.50	37		130.50	159
4820	6" diameter	Q-2	17	1.412		108	44		152	186
4830	8" diameter		14	1.714		238	53		291	345
4840	10" diameter		12	2		495	62		557	640
4850	12" diameter		10	2.400		690	74.50		764.50	875
4851	14" diameter		9	2.667		730	83		813	930
[illegible]	16" diameter		8	3		825	93		918	1,050
3	18" diameter	Q-3	11	2.909		1,025	92.50		1,117.50	1,275
4854	20" diameter		10	3.200		1,475	101		1,576	1,775
4855	24" diameter		8	4		2,250	127		2,377	2,675

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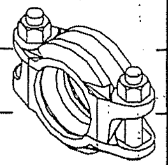

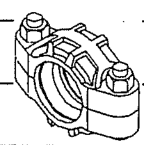

		CREW	DAILY OUTPUT	LABOR-HOURS	UNIT	2000 BARE COSTS MAT.	LABOR	EQUIP.	TOTAL	TOTAL INCL O&P
4900	For galvanized tees, add				Ea.	24%				
4906	Couplings, rigid style, painted									
4908	1" diameter	1 Plum	100	.080	Ea.	8.80	2.66		11.46	13.65
4909	1-1/4" diameter		100	.080		8.80	2.66		11.46	13.65
4910	1-1/2" diameter		67	.119		8.80	3.97		12.77	15.65
4912	2" diameter		50	.160		9	5.30		14.30	17.95
4914	2-1/2" diameter	Q-1	80	.200		10.40	6		16.40	20.50
4916	3" diameter		67	.239		12.15	7.15		19.30	24
4918	4" diameter		50	.320		17.20	9.60		26.80	33.50
4920	5" diameter		40	.400		22.50	11.95		34.45	42.50
4922	6" diameter	Q-2	50	.480		30	14.90		44.90	55.50
4924	8" diameter		42	.571		47	17.75		64.75	78.50
4926	10" diameter		35	.686		84	21.50		105.50	125
4928	12" diameter		32	.750		94.50	23.50		118	139
4930	14" diameter		24	1		123	31		154	182
4931	16" diameter		20	1.200		161	37		198	234
4932	18" diameter		18	1.333		186	41.50		227.50	267
4933	20" diameter		16	1.500		221	46.50		267.50	315
4934	24" diameter	Q-9	13	1.231		325	36		361	415
4940	Flexible, standard, painted									
4950	3/4" diameter	1 Plum	100	.080	Ea.	6.30	2.66		8.96	10.95
4960	1" diameter		100	.080		6.30	2.66		8.96	10.95
4970	1-1/4" diameter		80	.100		8.40	3.33		11.73	14.30
4980	1-1/2" diameter		67	.119		9.20	3.97		13.17	16.10
4990	2" diameter		50	.160		9.70	5.30		15	18.70
5000	2-1/2" diameter	Q-1	80	.200		11.60	6		17.60	22
5010	3" diameter		67	.239		12.80	7.15		19.95	25
5020	3-1/2" diameter		57	.281		18.70	8.40		27.10	33
5030	4" diameter		50	.320		18.70	9.60		28.30	35
5040	5" diameter		40	.400		28.50	11.95		40.45	49.50
5050	6" diameter	Q-2	50	.480		34	14.90		48.90	60
5070	8" diameter		42	.571		55.50	17.75		73.25	88
5090	10" diameter		35	.686		92	21.50		113.50	133
5110	12" diameter		32	.750		105	23.50		128.50	150
5120	14" diameter		24	1		127	31		158	187
5130	16" diameter		20	1.200		167	37		204	240
5140	18" diameter		18	1.333		195	41.50		236.50	278
5150	20" diameter		16	1.500		305	46.50		351.50	410
5160	24" diameter		13	1.846		335	57.50		392.50	455
5176	Lightweight style, painted									
5178	1-1/2" diameter	1 Plum	67	.119	Ea.	8	3.97		11.97	14.80
5180	2" diameter	"	50	.160		8.20	5.30		13.50	17.05
5182	2-1/2" diameter	Q-1	80	.200		9.50	6		15.50	19.50
5184	3" diameter		67	.239		11.05	7.15		18.20	23
5186	3-1/2" diameter		57	.281		15.65	8.40		24.05	30
5188	4" diameter		50	.320		15.65	9.60		25.25	31.50
5190	5" diameter		40	.400		22.50	11.95		34.45	43
5192	6" diameter	Q-2	50	.480		27	14.90		41.90	52.50
5194	8" diameter		42	.571		42.50	17.75		60.25	74
5196	10" diameter		35	.686		115	21.50		136.50	158
5198	12" diameter		32	.750		128	23.50		151.50	176
5200	For galvanized couplings, add					33%				
5220	Tee, reducing, painted									
5225	2" x 1-1/2" diameter	Q-1	38	.421	Ea.	40.50	12.60		53.10	63.50
5226	2-1/2" x 2" diameter		28	.571		40.50	17.10		57.60	70.50
5227	3" x 2-1/2" diameter		23	.696		35.50	21		56.50	70.50

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			CREW	DAILY OUTPUT	LABOR-HOURS	UNIT	2000 BARE COSTS MAT.	LABOR	EQUIP.	TOTAL	TOTAL INCL O&P	
690	5228	4" x 3" diameter	Q-1	18	.889	Ea.	48	26.50		74.50	93.50	690
	5229	5" x 4" diameter	↓	15	1.067		103	32		135	163	
	5230	6" x 4" diameter	Q-2	18	1.333		114	41.50		155.50	188	
	5231	8" x 6" diameter		15	1.600		238	49.50		287.50	335	
	5232	10" x 8" diameter		13	1.846		310	57.50		367.50	430	
	5233	12" x 10" diameter		11	2.182		475	67.50		542.50	625	
	5234	14" x 12" diameter		10	2.400		530	74.50		604.50	700	
	5235	16" x 12" diameter	↓	9	2.667		660	83		743	850	
	5236	18" x 12" diameter	Q-3	12	2.667		790	84.50		874.50	1,000	
	5237	18" x 16" diameter		11	2.909		1,000	92.50		1,092.50	1,250	
	5238	20" x 16" diameter		10	3.200		1,300	101		1,401	1,575	
	5239	24" x 20" diameter	↓	9	3.556	↓	2,050	113		2,163	2,450	
	5240	Reducer, concentric, painted										
	5241	2-1/2" x 2" diameter	Q-1	43	.372	Ea.	14.10	11.15		25.25	32.50	
	5242	3" x 2-1/2" diameter		35	.457		17.05	13.70		30.75	39.50	
	5243	4" x 3" diameter		29	.552		20.50	16.50		37	47.50	
	5244	5" x 4" diameter	↓	22	.727		29	22		51	64.50	
	5245	6" x 4" diameter	Q-2	26	.923		33.50	28.50		62	80	
	5246	8" x 6" diameter		23	1.043		87.50	32.50		120	145	
	5247	10" x 8" diameter		20	1.200		178	37		215	253	
	5248	12" x 10" diameter	↓	16	1.500	↓	320	46.50		366.50	420	
	5255	Eccentric, painted										
	5256	2-1/2" x 2" diameter	Q-1	42	.381	Ea.	30	11.40		41.40	50.50	
	5257	3" x 2-1/2" diameter		34	.471		34	14.10		48.10	59	
	5258	4" x 3" diameter		28	.571		42	17.10		59.10	72	
	5259	5" x 4" diameter	↓	21	.762		57	23		80	97	
	5260	6" x 4" diameter	Q-2	25	.960		66.50	30		96.50	118	
	5261	8" x 6" diameter		22	1.091		135	34		169	199	
	5262	10" x 8" diameter		19	1.263		370	39		409	470	
	5263	12" x 10" diameter	↓	15	1.600	↓	510	49.50		559.50	635	
	5270	Coupling, reducing, painted										
	5272	2" x 1-1/2" diameter	1 Plum	52	.154	Ea.	14.20	5.10		19.30	23.50	
	5274	2-1/2" x 2" diameter	Q-1	82	.195		18.55	5.85		24.40	29.50	
	5276	3" x 2" diameter		69	.232		21	6.95		27.95	34	
	5278	4" x 2" diameter		52	.308		34	9.20		43.20	51.50	
	5280	5" x 4" diameter	↓	42	.381		38.50	11.40		49.90	59.50	
	5282	6" x 4" diameter	Q-2	52	.462		58	14.30		72.30	85.50	
	5284	8" x 6" diameter	"	44	.545	↓	87	16.95		103.95	122	
	5290	Outlet coupling, painted										
	5294	1-1/2" x 1" pipe size	1 Plum	65	.123	Ea.	17.70	4.09		21.79	25.50	
	5296	2" x 1" pipe size	"	48	.167		18.20	5.55		23.75	28.50	
	5298	2-1/2" x 1" pipe size	Q-1	78	.205		28	6.15		34.15	40.50	
	5300	2-1/2" x 1" pipe size	1 Plum	70	.114		32	3.80		35.80	41	
	5302	3" x 1" pipe size	Q-1	65	.246		27	7.35		34.35	41	
	5304	4" x 3/4" pipe size		48	.333		40	10		50	59	
	5306	4" x 1-1/2" pipe size	↓	46	.348		57	10.40		67.40	79	
	5308	6" x 1-1/2" pipe size	Q-2	44	.545	↓	81	16.95		97.95	115	
	5750	Flange, w/groove gasket, black steel (see 15107-660-0620, bolt sets)										
	5760	ANSI class 125 and 150, painted										
	5780	2" pipe size	1 Plum	23	.348	Ea.	41.50	11.55		53.05	63	
	5790	2-1/2" pipe size	Q-1	37	.432		50	12.95		62.95	74.50	
	5800	3" pipe size		31	.516		54	15.45		69.45	83	
	5820	4" pipe size		23	.696		72.50	21		93.50	111	
	5830	5" pipe size	↓	19	.842		84	25		109	131	
	5840	6" pipe size	Q-2	23	1.043		92	32.50		124.50	150	
	5850	8" pipe size	↓	17	1.412	↓	104	44		148	181	

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Important: See the Reference Section for critical supporting data - Reference Nos., Crews, & City Cost Indexes

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		CREW	DAILY OUTPUT	LABOR-HOURS	UNIT	2000 BARE COSTS MAT.	LABOR	EQUIP.	TOTAL	TOTAL INCL O&P	
5860	10" pipe size	Q-2	14	1.714	Ea.	164	53		217	262	690
5870	12" pipe size		12	2		215	62		277	330	
5880	14" pipe size		10	2.400		495	74.50		569.50	660	
5890	16" pipe size		9	2.667		575	83		658	755	
5900	18" pipe size		6	4		705	124		829	965	
5910	20" pipe size		5	4.800		850	149		999	1,150	
5920	24" pipe size		4.50	5.333		1,075	165		1,240	1,450	
5940	ANSI class 350, painted										
5946	2" pipe size	1 Plum	23	.348	Ea.	50.50	11.55		62.05	73	
5948	2-1/2" pipe size	Q-1	37	.432		58.50	12.95		71.45	84	
5950	3" pipe size		31	.516		80	15.45		95.45	112	
5952	4" pipe size		23	.696		107	21		128	150	
5954	5" pipe size		19	.842		121	25		146	172	
5956	6" pipe size	Q-2	23	1.043		141	32.50		173.50	205	
5958	8" pipe size		17	1.412		162	44		206	246	
5960	10" pipe size		14	1.714		259	53		312	365	
5962	12" pipe size	1 Plum	12	.667		276	22		298	340	
6100	Coupling, for PVC plastic pipe										
6110	2" diameter	1 Plum	50	.160	Ea.	10.80	5.30		16.10	19.95	
6112	2-1/2" diameter	Q-1	80	.200		15.20	6		21.20	26	
6114	3" diameter		67	.239		18.45	7.15		25.60	31.50	
6116	4" diameter		50	.320		24	9.60		33.60	41	
6118	6" diameter	Q-2	50	.480		40	14.90		54.90	66.50	
6120	8" diameter		42	.571		65.50	17.75		83.25	99	
6122	10" diameter		35	.686		108	21.50		129.50	150	
6124	12" diameter		32	.750		136	23.50		159.50	185	
7400	Suction diffuser										
7402	Grooved end inlet x flanged outlet										
7410	3" x 3"	Q-1	50	.320	Ea.	425	9.60		434.60	485	
7412	4" x 4"		38	.421		620	12.60		632.60	705	
7414	5" x 5"		30	.533		675	15.95		690.95	765	
7416	6" x 6"	Q-2	38	.632		850	19.60		869.60	965	
7418	8" x 8"		27	.889		1,575	27.50		1,602.50	1,800	
7420	10" x 10"		20	1.200		2,150	37		2,187	2,425	
7422	12" x 12"		16	1.500		3,550	46.50		3,596.50	3,975	
7424	14" x 14"		15	1.600		4,475	49.50		4,524.50	5,000	
7426	16" x 14"		14	1.714		4,600	53		4,653	5,150	
7500	Strainer, tee type, painted										
7506	2" pipe size	1 Plum	38	.211	Ea.	265	7		272	300	
7508	2-1/2" pipe size	Q-1	62	.258		278	7.70		285.70	315	
7510	3" pipe size		50	.320		315	9.60		324.60	360	
7512	4" pipe size		38	.421		355	12.60		367.60	410	
7514	5" pipe size		30	.533		515	15.95		530.95	590	
7516	6" pipe size	Q-2	38	.632		555	19.60		574.60	640	
7518	8" pipe size		27	.889		855	27.50		882.50	980	
7520	10" pipe size		20	1.200		1,250	37		1,287	1,425	
7522	12" pipe size		16	1.500		1,625	46.50		1,671.50	1,850	
7524	14" pipe size		15	1.600		5,750	49.50		5,799.50	6,400	
7526	16" pipe size		14	1.714		7,150	53		7,203	7,925	
7570	Expansion joint, max. 3" travel										
7572	2" diameter	1 Plum	38	.211	Ea.	218	7		225	250	
7574	3" diameter	Q-1	50	.320		255	9.60		264.60	296	
7576	4" diameter	"	38	.421		320	12.60		332.60	370	
7578	6" diameter	Q-2	38	.632		555	19.60		574.60	645	
7800	Ball valve w/handle, carbon steel trim										
7810	1-1/2" pipe size	1 Plum	50	.160	Ea.	64.50	5.30		69.80	79	

15107 | Metal Pipe & Fittings

		CREW	DAILY OUTPUT	LABOR-HOURS	UNIT	2000 BARE COSTS MAT.	LABOR	EQUIP.	TOTAL	TOTAL INCL O&P
690 7812	2″ pipe size	1 Plum	38	.211	Ea.	89	7		96	109
7814	2-1/2″ pipe size	Q-1	62	.258		184	7.70		191.70	214
7816	3″ pipe size		50	.320		290	9.60		299.60	335
7818	4″ pipe size		38	.421		445	12.60		457.60	510
7820	6″ pipe size	Q-2	30	.800		1,300	25		1,325	1,500
7830	With gear operator									
7834	2-1/2″ pipe size	Q-1	62	.258	Ea.	325	7.70		332.70	365
7836	3″ pipe size		50	.320		430	9.60		439.60	485
7838	4″ pipe size		38	.421		575	12.60		587.60	655
7840	6″ pipe size	Q-2	30	.800		1,475	25		1,500	1,675
7870	Check valve									
7874	2-1/2″ pipe size	Q-1	62	.258	Ea.	116	7.70		123.70	140
7876	3″ pipe size		50	.320		137	9.60		146.60	166
7878	4″ pipe size		38	.421		145	12.60		157.60	178
7880	5″ pipe size		30	.533		241	15.95		256.95	289
7882	6″ pipe size	Q-2	38	.632		286	19.60		305.60	345
7884	8″ pipe size		27	.889		390	27.50		417.50	470
7886	10″ pipe size		20	1.200		1,125	37		1,162	1,300
7888	12″ pipe size		16	1.500		1,350	46.50		1,396.50	1,550
7900	Plug valve, balancing, w/lever operator									
7906	3″ pipe size	Q-1	50	.320	Ea.	238	9.60		247.60	277
7908	4″ pipe size	″	38	.421		262	12.60		274.60	305
7909	6″ pipe size	Q-2	30	.800		470	25		495	555
7916	With gear operator									
7920	3″ pipe size	Q-1	50	.320	Ea.	430	9.60		439.60	490
7922	4″ pipe size	″	38	.421		455	12.60		467.60	520
7924	6″ pipe size	Q-2	38	.632		660	19.60		679.60	760
7926	8″ pipe size		27	.889		885	27.50		912.50	1,025
7928	10″ pipe size		20	1.200		1,400	37		1,437	1,575
7930	12″ pipe size		16	1.500		2,025	46.50		2,071.50	2,300
8000	Butterfly valve, 2 position handle, with standard trim									
8010	1-1/2″ pipe size	1 Plum	50	.160	Ea.	103	5.30		108.30	121
8020	2″ pipe size	″	38	.211		103	7		110	124
8030	3″ pipe size	Q-1	50	.320		147	9.60		156.60	177
8050	4″ pipe size	″	38	.421		162	12.60		174.60	197
8070	6″ pipe size	Q-2	38	.632		355	19.60		374.60	420
8080	8″ pipe size		27	.889		540	27.50		567.50	635
8090	10″ pipe size		20	1.200		775	37		812	910
8200	With stainless steel trim									
8240	1-1/2″ pipe size	1 Plum	50	.160	Ea.	130	5.30		135.30	151
8250	2″ pipe size	″	38	.211		130	7		137	154
8270	3″ pipe size	Q-1	50	.320		175	9.60		184.60	207
8280	4″ pipe size	″	38	.421		190	12.60		202.60	228
8300	6″ pipe size	Q-2	38	.632		355	19.60		374.60	420
8310	8″ pipe size		27	.889		605	27.50		632.50	705
8320	10″ pipe size		20	1.200		960	37		997	1,100
8322	12″ pipe size		16	1.500		1,225	46.50		1,271.50	1,425
8324	14″ pipe size		15	1.600		1,600	49.50		1,649.50	1,850
8326	16″ pipe size		14	1.714		2,200	53		2,253	2,500
8328	18″ pipe size	Q-3	12	2.667		2,700	84.50		2,784.50	3,100
8330	20″ pipe size		11	2.909		3,675	92.50		3,767.50	4,175
8332	24″ pipe size		10	3.200		4,675	101		4,776	5,275
[illegible]5	Note: sizes 12″ up w/manual gear operator									
[illegible]0	Cut one groove, labor									
9010	3/4″ pipe size	Q-1	152	.105	Ea.		3.15		3.15	4.77
9020	1″ pipe size		140	.114			3.42		3.42	5.15

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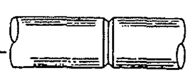
			CREW	DAILY OUTPUT	LABOR-HOURS	UNIT	2000 BARE COSTS MAT.	LABOR	EQUIP.	TOTAL	TOTAL INCL O&P	
690	9030	1-1/4" pipe size	Q-1	124	.129	Ea.		3.86		3.86	5.85	690
	9040	1-1/2" pipe size		114	.140			4.20		4.20	6.35	
	9050	2" pipe size		104	.154			4.60		4.60	6.95	
	9060	2-1/2" pipe size		96	.167			4.99		4.99	7.55	
	9070	3" pipe size		88	.182			5.45		5.45	8.25	
	9080	3-1/2" pipe size		83	.193			5.75		5.75	8.75	
	9090	4" pipe size		78	.205			6.15		6.15	9.30	
	9100	5" pipe size		72	.222			6.65		6.65	10.05	
	9110	6" pipe size		70	.229			6.85		6.85	10.35	
	9120	8" pipe size		54	.296			8.85		8.85	13.40	
	9130	10" pipe size		38	.421			12.60		12.60	19.05	
	9140	12" pipe size		30	.533			15.95		15.95	24	
	9150	14" pipe size		20	.800			24		24	36	
	9160	16" pipe size		19	.842			25		25	38	
	9170	18" pipe size		18	.889			26.50		26.50	40.50	
	9180	20" pipe size		17	.941			28		28	42.50	
	9190	24" pipe size	↓	15	1.067	↓		32		32	48.50	
	9210	Roll one groove										
	9220	3/4" pipe size	Q-1	266	.060	Ea.		1.80		1.80	2.72	
	9230	1" pipe size		228	.070			2.10		2.10	3.18	
	9240	1-1/4" pipe size		200	.080			2.39		2.39	3.62	
	9250	1-1/2" pipe size		178	.090			2.69		2.69	4.07	
	9260	2" pipe size		116	.138			4.13		4.13	6.25	
	9270	2-1/2" pipe size		110	.145			4.35		4.35	6.60	
	9280	3" pipe size		100	.160			4.79		4.79	7.25	
	9290	3-1/2" pipe size		94	.170			5.10		5.10	7.70	
	9300	4" pipe size		86	.186			5.55		5.55	8.40	
	9310	5" pipe size		84	.190			5.70		5.70	8.60	
	9320	6" pipe size		80	.200			6		6	9.05	
	9330	8" pipe size		66	.242			7.25		7.25	11	
	9340	10" pipe size		58	.276			8.25		8.25	12.50	
	9350	12" pipe size		46	.348			10.40		10.40	15.75	
	9360	14" pipe size		30	.533			15.95		15.95	24	
	9370	16" pipe size		28	.571			17.10		17.10	26	
	9380	18" pipe size		27	.593			17.75		17.75	27	
	9390	20" pipe size		25	.640			19.15		19.15	29	
	9400	24" pipe size	↓	23	.696	↓		21		21	31.50	
920	0010	PIPE, STAINLESS STEEL										920
	0020	Welded, with clevis type hangers 10' O.C.										
	0500	Schedule 5, type 304										
	0540	1/2" diameter	Q-15	128	.125	L.F.	3.91	3.74	.38	8.03	10.35	
	0550	3/4" diameter		116	.138		4.46	4.13	.42	9.01	11.60	
	0560	1" diameter		103	.155		5.35	4.65	.47	10.47	13.40	
	0570	1-1/4" diameter		93	.172		6.05	5.15	.52	11.72	15.10	
	0580	1-1/2" diameter		85	.188		6.95	5.65	.57	13.17	16.80	
	0590	2" diameter		69	.232		8.30	6.95	.71	15.96	20.50	
	0600	2-1/2" diameter		53	.302		11.40	9.05	.92	21.37	27	
	0610	3" diameter		48	.333		13.70	10	1.02	24.72	31.50	
	0620	4" diameter		44	.364		17.45	10.90	1.11	29.46	37	
	0630	5" diameter	↓	36	.444		35	13.30	1.36	49.66	60	
	0640	6" diameter	Q-16	42	.571		32	17.75	1.16	50.91	64	
	0650	8" diameter		34	.706		49	22	1.43	72.43	88.50	
	0660	10" diameter		26	.923		69	28.50	1.87	99.37	122	
	0670	12" diameter	↓	21	1.143	↓	90.50	35.50	2.32	128.32	156	
	0700	To delete hangers, subtract										



MECHANICAL 15

Labour Costs, Cat Arm

Inlet Piping per Unit are the same (unit #2 has only 20' of 6" O.D pipe)

Estimate	crew	per day	Quantity	Actual days	
6" O.D PVC sch80	Q1	38'	40'	1.05	1.85
4" O.D PVC sch80	Q1	46'	20'	0.44	
2" O.D PVC sch80	Q1	55'	20'	0.36	
1¼" O.D PVC sch80	1 Plum	39'	20'	0.51	
6" 90° Elbow Epoxy ($45)	Q1	8	6+1	~~0.75~~ 0.875	1.245
4" 90° Elbow Epoxy	Q1	13	2	0.15	
2" 90° Elbow Epoxy	Q1	23	3	0.13	
1" 90° Elbow Epoxy (45)	Q1	23	1+1	~~0.05~~ 0.09	
1" Tee Epoxy	Q1	5	2	0.4	
" Flange Epoxy	Q1	16	3	0.1875	0.3475
4" Flange Epoxy	Q1	26	1	0.04	
" Flange Epoxy	Q1	46	3	0.06	
1¼" Flange Epoxy	Q1	46	3	0.06	
1"x4" Reducer bushing	Q1	17	1	0.05	0.09
x2" Reducer bushing	Q1	22	1	0.04	
4" Valve	1 Plum	21	1	0.048	
" Valve	1 Plum	17	1	0.06	

Labour Costs, Cat Arm

Inlet Piping per unit

Time required for 1Plum.

= 0.048 + 0.06 + 0.51 = 0.618 days

Add an additional worker reduces time by 25%.

= 0.618 x 0.75 = 0.46 days

Time required for 1Q crew.

1.85 + 1.245 + 0.3475 + 0.09 + 0.4 = 3.93 days

Total time for 1Q crew.

= 3.93 + 0.46 = 4.39 days (35.12 hrs)

Labor Costs, Cat Arm

Discharge Piping for Both Units are the same.

Estimate	Crew	Per day	Actual Quantity	days	
6" O.D PVC Sch 80	Q1	38'	10'	0.26	2.26
4" O.D PVC Sch 80	Q1	46'	40'	0.87	
2.5" O.D PVC Sch 80	Q1	52'	40'	0.77	
2" O.D PVC Sch 80	Q1	55'	20'	0.36	
1¼" O.D PVC Sch 80	1 Plum	39'	20'	0.51	
4" 90° & 45° Elbows Epoxy	Q1	13	7	0.54	1.01
3" 90° & 45° Elbows Epoxy	Q1	19	5	0.26	
[illegible] 90° & 45° Elbows Epoxy	Q1	23	1	0.04	
" 90° & 45° Elbows Epoxy	Q1	23	4	0.17	
4" Tee Epoxy	Q1	8	2	0.25	0.48
" Tee Epoxy	Q1	13	3	0.23	
" Flange Epoxy	Q1	26	7	0.27	0.655
3" Flange Epoxy	Q1	32	2	0.06	
" Flange Epoxy	Q1	39	6	0.15	
" Flange Epoxy	Q1	46	5	0.11	
Flange Epoxy	Q1	46	3	0.065	
x 4" Reducer bushing	Q1	17	1	0.06	0.31
x 3" Reducer bushing	Q1	19	2	0.10	
3" [illegible] Reducer bushing	Q1	25	3	0.12	
x 1¼" Reducer bushing	Q1	30	1	0.03	

abour Costs, Cat Arm

ischarge Piping per unit — 1Q crew = 1 PLUM + 1 Apprentice

Estimate: Description	crew	day	Actual: Quantity	day	
Valve, 4"	1 Q	20	1	0.05	0.13
Valve, 3"	1 Q	24	1	0.04	
Valve, 2½"	1 Q	26	1	0.04	
Valve, 2"	1 PLUM	17	1	0.06	0.11
Valve, 1¼"	1 PLUM	21	1	0.05	

Time required for 1 PLUM.
= 0.51 + 0.11 = 0.62 day

Add an addition worker reduce time by 25%.
= 0.62 x 0.75 = 0.46 day

Time required for 1Q crew.
= 2.26 + 1.01 + 0.48 + 0.655 + 0.31 = 4.72 days

Total Time for 1Q crew.
= 4.72 + 0.46 = 5.18 days (41.44 hrs)

107 | Metal Pipe & Fittings

		CREW	DAILY OUTPUT	LABOR-HOURS	UNIT	2000 BARE COSTS MAT.	LABOR	EQUIP.	TOTAL	TOTAL INCL O&P	
5	2"	Q-1	9	1.778	Ea.	133	53		186	227	960
70	For couplings and unions use 3000 lb., type 316										
	3000 lb., type 304										
1	Coupling										
20	1/8"	1 Plum	19	.421	Ea.	2.41	14		16.41	23.50	
	1/4"		19	.421		2.53	14		16.53	24	
4	3/8"		19	.421		3.04	14		17.04	24.50	
50	1/2"		19	.421		4.84	14		18.84	26.50	
60	3/4"		18	.444		7.30	14.80		22.10	30.50	
7	1"		15	.533		12.40	17.75		30.15	40.50	
8	1-1/4"	Q-1	26	.615		28	18.40		46.40	58.50	
90	1-1/2"		24	.667		32	19.95		51.95	65.50	
	2"		21	.762		46	23		69	85.50	
2	Union										
30	1/8"	1 Plum	12	.667	Ea.	25.50	22		47.50	61.50	
	1/4"		12	.667		25.50	22		47.50	61.50	
	3/8"		12	.667		27.50	22		49.50	63.50	
	1/2"		11	.727		27.50	24		51.50	66.50	
70	3/4"		10	.800		33.50	26.50		60	77	
	1"		9	.889		56	29.50		85.50	106	
	1-1/4"	Q-1	16	1		78.50	30		108.50	132	
	1-1/2"		15	1.067		88	32		120	146	
	2"		13	1.231		123	37		160	192	
	3000 lb., type 316										
	Coupling										
	1/8"	1 Plum	19	.421	Ea.	2.95	14		16.95	24.50	
	1/4"		19	.421		3.25	14		17.25	24.50	
	3/8"		19	.421		3.46	14		17.46	25	
	1/2"		19	.421		5.60	14		19.60	27	
	3/4"		18	.444		8.25	14.80		23.05	31.50	
	1"		15	.533		13.95	17.75		31.70	42.50	
	1-1/4"	Q-1	26	.615		32	18.40		50.40	63.50	
	1-1/2"		24	.667		36.50	19.95		56.45	70	
	2"		21	.762		53	23		76	93	
	Union										
	1/8"	1 Plum	12	.667	Ea.	26	22		48	62.50	
	1/4"		12	.667		26	22		48	62.50	
	3/8"		12	.667		32	22		54	69	
	1/2"		11	.727		32	24		56	72	
	3/4"		10	.800		36.50	26.50		63	80	
	1"		9	.889		63	29.50		92.50	114	
	1-1/4"	Q-1	16	1		94	30		124	149	
	1-1/2"		15	1.067		118	32		150	178	
	2"		13	1.231		154	37		191	225	

108 | Plastic Pipe & Fittings

		CREW	DAILY OUTPUT	LABOR-HOURS	UNIT	MAT.	LABOR	EQUIP.	TOTAL	TOTAL INCL O&P	
	PE, PLASTIC										520
	Fiberglass reinforced, couplings 10' O.C., hangers 3 per 10'										
	General service										
	2" diameter	Q-1	59	.271	L.F.	9.65	8.10		17.75	23	
	3" diameter		52	.308		13	9.20		22.20	28.50	
	4" diameter		48	.333		15.85	10		25.85	32.50	
	6" diameter		39	.410		23	12.30		35.30	43.50	
	8" diameter	Q-2	49	.490		36.50	15.20		51.70	63	
	10" diameter		41	.585		53.50	18.15		71.65	86.50	
	12" diameter		36	.667		65.50	20.50		86	104	

15108 | Plastic Pipe & Fittings		Crew	Daily Output	Labor-Hours	Unit	2000 Bare Costs Mat.	Labor	Equip.	Total	Total Incl O&P
520 0200	High strength									
0240	2" diameter	Q-1	58	.276	L.F.	10.75	8.25		19	[illegible]
0260	3" diameter		51	.314		14.65	9.40		24.05	[illegible]
0280	4" diameter		47	.340		17.65	10.20		27.85	35[illegible]
0300	6" diameter	↓	38	.421		26	12.60		38.60	47.50
0320	8" diameter	Q-2	48	.500		41	15.50		56.50	68.50
0340	10" diameter		40	.600		60	18.60		78.60	94
0360	12" diameter	↓	36	.667	↓	73.50	20.50		94	113
0550	To delete coupling & hangers, subtract									
0560	2" diam. to 6" diam.					33%	56%			
0570	8" diam. to 12" diam.					31%	52%			
0600	PVC, high impact/pressure, cplgs. 10' O.C., hangers 3 per 10'									
1020	Schedule 80									
1040	1/4" diameter	1 Plum	58	.138	L.F.	2.17	4.59		6.76	9.35
1060	3/8" diameter		55	.145		2.26	4.84		7.10	9.80
1070	1/2" diameter		50	.160		2	5.30		7.30	10.25
1080	3/4" diameter		47	.170		2.20	5.65		7.85	10.95
1090	1" diameter		43	.186		2.68	6.20		8.88	12.30
1100	1-1/4" diameter		39	.205		2.80	6.80		9.60	13.40
1110	1-1/2" diameter	↓	34	.235		3.01	7.80		10.81	15.15
1120	2" diameter	Q-1	55	.291		3.19	8.70		11.89	16.65
1130	2-1/2" diameter		52	.308		3.30	9.20		12.50	17.55
1140	3" diameter		50	.320		4.56	9.60		14.16	19.50
1150	4" diameter		46	.348		6.05	10.40		16.45	22.50
1160	5" diameter		42	.381		10.35	11.40		21.75	28.50
1170	6" diameter	↓	38	.421		9.30	12.60		21.90	29.50
1180	8" diameter	Q-2	47	.511		14.95	15.85		30.80	[illegible]
1190	10" diameter		42	.571		23.50	17.75		41.25	[illegible]
1200	12" diameter	↓	38	.632	↓	30	19.60		49.60	62.50
1730	To delete coupling & hangers, subtract									
1740	1/4" diam. to 1/2" diam.					62%	80%			
1750	3/4" diam. to 1-1/4" diam.					58%	73%			
1760	1-1/2" diam. to 6" diam.					40%	57%			
1770	8" diam. to 12" diam.					34%	50%			
1800	PVC, couplings 10' O.C., hangers 3 per 10'									
1820	Schedule 40									
1860	1/2" diameter	1 Plum	54	.148	L.F.	1.90	4.93		6.83	9.55
1870	3/4" diameter		51	.157		2.06	5.20		7.26	10.15
1880	1" diameter		46	.174		2.57	5.80		8.37	11.60
1890	1-1/4" diameter		42	.190		2.61	6.35		8.96	12.45
1900	1-1/2" diameter	↓	36	.222		2.81	7.40		10.21	14.30
1910	2" diameter	Q-1	59	.271		2.83	8.10		10.93	15.40
1920	2-1/2" diameter		56	.286		3.52	8.55		12.07	16.80
1930	3" diameter		53	.302		4.05	9.05		13.10	18.10
1940	4" diameter		48	.333		5.50	10		15.50	21
1950	5" diameter		43	.372		7.50	11.15		18.65	25
1960	6" diameter	↓	39	.410		8.30	12.30		20.60	27.50
1970	8" diameter	Q-2	48	.500		13.15	15.50		28.65	38
1980	10" diameter		43	.558		27.50	17.30		44.80	56.50
1990	12" diameter		42	.571		35	17.75		52.75	65.50
2000	14" diameter		31	.774		108	24		132	156
2010	16" diameter	↓	23	1.043	↓	136	32.50		168.50	198
2340	To delete coupling & hangers, subtract									
2360	1/2" diam. to 1-1/4" diam.					65%	74%			
2370	1-1/2" diam. to 6" diam.					44%	57%			
2380	8" diam. to 12" diam.					41%	53%			

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	Plastic Pipe & Fittings	CREW	DAILY OUTPUT	LABOR-HOURS	UNIT	2000 BARE COSTS MAT.	LABOR	EQUIP.	TOTAL	TOTAL INCL O&P
390	14" diam. to 16" diam.					48%	45%			
420	Schedule 80									
	1/4" diameter	1 Plum	58	.138	L.F.	1.91	4.59		6.50	9.05
	3/8" diameter		55	.145		1.91	4.84		6.75	9.40
460	1/2" diameter		50	.160		2.08	5.30		7.38	10.35
	3/4" diameter		47	.170		2.31	5.65		7.96	11.10
	1" diameter		43	.186		2.84	6.20		9.04	12.50
490	1-1/4" diameter		39	.205		3.02	6.80		9.82	13.60
	1-1/2" diameter		34	.235		3.27	7.80		11.07	15.45
	2" diameter	Q-1	55	.291		3.57	8.70		12.27	17.10
	2-1/2" diameter		52	.308		3.86	9.20		13.06	18.20
530	3" diameter		50	.320		5.30	9.60		14.90	20.50
	4" diameter		46	.348		7.15	10.40		17.55	23.50
	5" diameter		42	.381		9.75	11.40		21.15	28
560	6" diameter		38	.421		11.35	12.60		23.95	31.50
	8" diameter	Q-2	47	.511		18.10	15.85		33.95	44
	10" diameter		42	.571		28	17.75		45.75	57.50
590	12" diameter		38	.632		36	19.60		55.60	69
	To delete coupling & hangers, subtract									
	1/4" diam. to 1/2" diam.					66%	80%			
	3/4" diam. to 1-1/4" diam.					61%	73%			
660	1-1/2" diam. to 6" diam.					41%	57%			
	8" diam. to 12" diam.					31%	50%			
	Schedule 120									
710	1/2" diameter	1 Plum	50	.160	L.F.	2.63	5.30		7.93	10.95
	3/4" diameter		47	.170		3.03	5.65		8.68	11.90
	1" diameter		43	.186		3.89	6.20		10.09	13.65
	1-1/4" diameter		39	.205		4.50	6.80		11.30	15.25
780	1-1/2" diameter		33	.242		5.05	8.05		13.10	17.75
	2" diameter	Q-1	54	.296		6.10	8.85		14.95	20
	2-1/2" diameter		52	.308		8.30	9.20		17.50	23
810	3" diameter		49	.327		10.45	9.75		20.20	26.50
	4" diameter		45	.356		15.70	10.65		26.35	33.50
	6" diameter		37	.432		27.50	12.95		40.45	50
	To delete coupling & hangers, subtract									
850	1/2" diam. to 1-1/4" diam.					52%	74%			
	1-1/2" diam. to 4" diam.					30%	57%			
	6" diam.					17%	50%			
00	PVC, pressure, couplings 10' O.C., hangers 3 per 10'									
	SDR 26, 160 psi									
	1-1/4" diameter	1 Plum	42	.190	L.F.	2.44	6.35		8.79	12.30
	1-1/2" diameter	"	36	.222		2.62	7.40		10.02	14.10
	2" diameter	Q-1	59	.271		2.80	8.10		10.90	15.40
	2-1/2" diameter		56	.286		3.15	8.55		11.70	16.40
	3" diameter		53	.302		3.65	9.05		12.70	17.65
00	4" diameter		48	.333		5.10	10		15.10	20.50
	6" diameter		39	.410		8.05	12.30		20.35	27.50
	8" diameter	Q-2	48	.500		13.15	15.50		28.65	38
60	To delete coupling & hangers, subtract									
	1-1/4" diam.					63%	68%			
	1-1/2" diam. to 4" diam.					48%	57%			
	6" diam. to 8" diam.					60%	54%			
	SDR 21, 200 psi, 1/2" diameter	1 Plum	54	.148	L.F.	2.01	4.93		6.94	9.65
	3/4" diameter		51	.157		2.18	5.20		7.38	10.30
	1" diameter		46	.174		2.63	5.80		8.43	11.65
60	1-1/4" diameter		42	.190		2.75	6.35		9.10	12.60

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		CREW	DAILY OUTPUT	LABOR-HOURS	UNIT	2000 BARE COSTS MAT.	LABOR	EQUIP.	TOTAL	TOTAL INCL [illegible]
520 3770	1-1/2" diameter	1 Plum	36	.222	L.F.	2.96	7.40		10.36	[illegible]
3780	2" diameter	Q-1	59	.271		3.17	8.10		11.27	[illegible]
3790	2-1/2" diameter		56	.286		4.15	8.55		12.70	[illegible]
3800	3" diameter		53	.302		4.58	9.05		13.63	[illegible]
3810	4" diameter		48	.333		6.25	10		16.25	[illegible]
3830	6" diameter		39	.410		10.05	12.30		22.35	[illegible]
3840	8" diameter	Q-2	48	.500		16.70	15.50		32.20	[illegible]
4000	To delete coupling & hangers, subtract									
4010	1/2" diam. to 3/4" diam.					71%	77%			
4020	1" diam. to 1-1/4" diam.					63%	70%			
4030	1-1/2" diam. to 6" diam.					44%	57%			
4040	8" diam.					46%	54%			
4100	DWV type, schedule 40, couplings 10' O.C., hangers 3 per 10'									
4120	ABS									
4140	1-1/4" diameter	1 Plum	42	.190	L.F.	2.58	6.35		8.93	[illegible]
4150	1-1/2" diameter	"	36	.222		2.56	7.40		9.96	[illegible]
4160	2" diameter	Q-1	59	.271		2.66	8.10		10.76	[illegible]
4170	3" diameter		53	.302		3.28	9.05		12.33	[illegible]
4180	4" diameter		48	.333		4.44	10		14.44	[illegible]
4190	6" diameter		39	.410		7.10	12.30		19.40	[illegible]
4360	To delete coupling & hangers, subtract									
4370	1-1/4" diam.					64%	68%			
4380	1-1/2" diam. to 6" diam.					54%	57%			
4400	PVC									
4410	1-1/4" diameter	1 Plum	42	.190	L.F.	2.66	6.35		9.01	[illegible]
4420	1-1/2" diameter	"	36	.222		2.73	7.40		10.13	[illegible]
4460	2" diameter	Q-1	59	.271		2.91	8.10		11.01	[illegible]
4470	3" diameter		53	.302		3.79	9.05		12.84	[illegible]
4480	4" diameter		48	.333		5.10	10		15.10	[illegible]
4490	6" diameter		39	.410		7.40	12.30		19.70	[illegible]
4500	8" diameter	Q-2	48	.500		16.35	15.50		31.85	[illegible]
4750	To delete coupling & hangers, subtract									
4760	1-1/4" diam. to 1-1/2" diam.					71%	64%			
4770	2" diam. to 8" diam.					60%	57%			
4800	PVC, clear pipe, cplgs. 10' O.C., hangers 3 per 10', Sched. 40									
4840	1/4" diameter	1 Plum	59	.136	L.F.	2.32	4.51		6.83	[illegible]
4850	3/8" diameter		56	.143		2.51	4.75		7.26	[illegible]
4860	1/2" diameter		54	.148		2.87	4.93		7.80	[illegible]
4870	3/4" diameter		51	.157		3.36	5.20		8.56	[illegible]
4880	1" diameter		46	.174		4.51	5.80		10.31	[illegible]
4890	1-1/4" diameter		42	.190		5.25	6.35		11.60	[illegible]
4900	1-1/2" diameter		36	.222		5.95	7.40		13.35	[illegible]
4910	2" diameter	Q-1	59	.271		7.25	8.10		15.35	[illegible]
4920	2-1/2" diameter		56	.286		10.20	8.55		18.75	[illegible]
4930	3" diameter		53	.302		12.75	9.05		21.80	[illegible]
4940	3-1/2" diameter		50	.320		15.65	9.60		25.25	[illegible]
4950	4" diameter		48	.333		16.40	10		26.40	[illegible]
5250	To delete coupling & hangers, subtract									
5260	1/4" diam. to 3/8" diam.					60%	81%			
5270	1/2" diam. to 3/4" diam.					41%	77%			
5280	1" diam. to 1-1/2" diam.					26%	67%			
5290	2" diam. to 4" diam.					16%	58%			
5360	CPVC, couplings 10' O.C., hangers 3 per 10'									
5380	Schedule 40									
5460	1/2" diameter	1 Plum	54	.148	L.F.	2.63	4.93		7.56	[illegible]
5470	3/4" diameter		51	.157		3.04	5.20		8.24	[illegible]

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Line	Plastic Pipe & Fittings	Crew	Daily Output	Labor-Hours	Unit	2000 Bare Costs Mat.	Labor	Equip.	Total	Total Incl O&P	
80	1" diameter	1 Plum	46	.174	L.F.	3.98	5.80		9.78	13.15	520
90	1-1/4" diameter		42	.190		4.57	6.35		10.92	14.65	
	1-1/2" diameter		36	.222		5.20	7.40		12.60	16.90	
	2" diameter	Q-1	59	.271		6.05	8.10		14.15	19	
20	2-1/2" diameter		56	.286		8.85	8.55		17.40	22.50	
	3" diameter		53	.302		10.55	9.05		19.60	25.50	
	4" diameter		48	.333		14.50	10		24.50	31	
50	6" diameter		43	.372		26	11.15		37.15	45.50	
	To delete coupling & hangers, subtract										
	1/2" diam. to 3/4" diam.					37%	77%				
50	1" diam. to 1-1/4" diam.					27%	70%				
60	1-1/2" diam. to 3" diam.					21%	57%				
	4" diam. to 6" diam.					16%	57%				
	Schedule 80										
360	1/2" diameter	1 Plum	50	.160	L.F.	2.74	5.30		8.04	11.05	
	3/4" diameter		47	.170		3.22	5.65		8.87	12.10	
	1" diameter		43	.186		4.24	6.20		10.44	14	
390	1-1/4" diameter		39	.205		4.96	6.80		11.76	15.75	
	1-1/2" diameter		34	.235		5.70	7.80		13.50	18.15	
	2" diameter	Q-1	55	.291		6.85	8.70		15.55	20.50	
	2-1/2" diameter		52	.308		9.90	9.20		19.10	25	
930	3" diameter		50	.320		12.10	9.60		21.70	28	
	4" diameter		46	.348		17	10.40		27.40	34.50	
	6" diameter		38	.421		31.50	12.60		44.10	53.50	
960	8" diameter	Q-2	47	.511		68.50	15.85		84.35	99.50	
	To delete couplings & hangers, subtract										
	1/2" diam. to 3/4" diam.					44%	77%				
	1" diam. to 1-1/4" diam.					32%	71%				
090	1-1/2" diam. to 4" diam.					25%	58%				
	6" diam. to 8" diam.					20%	53%				
	CTS, 1/2" diameter	1 Plum	54	.148	L.F.	2.08	4.93		7.01	9.75	
250	3/4" diameter		51	.157		2.80	5.20		8	11	
	1" diameter		46	.174		3.58	5.80		9.38	12.70	
	1 1/4"		42	.190		4.22	6.35		10.57	14.25	
280	1 1/2" diameter		36	.222		5.05	7.40		12.45	16.75	
290	2" diameter	Q-1	59	.271		7.10	8.10		15.20	20	
	To delete coupling & hangers, subtract										
	1/2" diam.					51%	79%				
390	3/4" diam.					40%	76%				
	1" thru 2" diam.					72%	68%				
	Polyethylene, flexible, no couplings or hangers										
282	Note: For labor costs add 25% to the couplings and fittings labor total.										
	SDR 15, 100 psi										
	3/4" diameter				L.F.	.17			.17	.19	
	1" diameter					.22			.22	.24	
360	1-1/4" diameter					.40			.40	.44	
	1-1/2" diameter					.50			.50	.55	
	2" diameter					.80			.80	.88	
700	SIDR 9, 160 psi										
	1/2" diameter				L.F.	.23			.23	.25	
	3/4" diameter					.23			.23	.25	
	1" diameter					.36			.36	.40	
	1-1/4" diameter					.60			.60	.66	
	1-1/2" diameter					.84			.84	.92	
	2" diameter					1.38			1.38	1.52	
120	SDR 9, 200 psi										

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		15108 Plastic Pipe & Fittings	Crew	Daily Output	Labor-Hours	Unit	2000 Bare Costs Mat.	Labor	Equip.	Total	Total Incl O&P
520	8150	3/4" diameter				L.F.	.20			.20	.22
	8160	1" diameter					.33			.33	[illegible]
	8170	1-1/4" diameter					.49			.49	[illegible]
	8420	SDR 7, 250 psi									
	8440	3/4" diameter				L.F.	.29			.29	.32
	8450	1" diameter					.46			.46	.51
	8460	1-1/4" diameter					.79			.79	.87
	8800	PVC, type PSP, drain & sewer, belled end gasket jnt., no hngr.									
	8840	3" diameter				L.F.	.32			.32	.35
	8850	4" diameter					.40			.40	.44
	8860	6" diameter					.89			.89	.98
	9000	Perforated									
	9040	4" diameter				L.F.	.42			.42	.46
560	0010	**PIPE, PLASTIC, FITTINGS**									
	0030	Epoxy resin, fiberglass reinforced, general service									
	0090	Elbow, 90°, 2"	Q-1	23	.696	Ea.	45.50	21		66.50	81.50
	0100	3" 2.5" 19		16	1		64.50	30		94.50	116
	0110	4"		13	1.231		104	37		141	170
	0120	6"		8	2		156	60		216	263
	0130	8"	Q-2	9	2.667		260	83		343	410
	0140	10"		7	3.429		360	106		466	555
	0150	12"		5	4.800		500	149		649	775
	0160	45° Elbow, same as 90°									
	0170	Elbow, 90°, flanged									
	0172	2"	Q-1	23	.696	Ea.	91	21		112	132
	0173	3"		16	1		105	30		135	16[illegible]
	0174	4"		13	1.231		138	37		175	[illegible]
	0176	6"		8	2		249	60		309	[illegible]
	0177	8"	Q-2	9	2.667		450	83		533	615
	0178	10"		7	3.429		615	106		721	835
	0179	12"		5	4.800		835	149		984	1,150
	0186	Elbow, 45°, flanged									
	0188	2"	Q-1	23	.696	Ea.	91.50	21		112.50	133
	0189	3"		16	1		105	30		135	162
	0190	4"		13	1.231		137	37		174	207
	0192	6"		8	2		251	60		311	365
	0193	8"	Q-2	9	2.667		450	83		533	620
	0194	10"		7	3.429		615	106		721	835
	0195	12"		5	4.800		835	149		984	1,150
	0290	Tee, 2" 2.5" 13	Q-1	17	.941		61	28		89	110
	0300	3"		10	1.600		71.50	48		119.50	151
	0310	4"		8	2		85	60		145	184
	0320	6"		5	3.200		228	96		324	395
	0330	8"	Q-2	6	4		263	124		387	475
	0340	10"		5	4.800		420	149		569	685
	0350	12"		4	6		510	186		696	840
	0352	Tee, flanged									
	0354	2"	Q-1	17	.941	Ea.	124	28		152	179
	0355	3"		10	1.600		166	48		214	256
	0356	4"		8	2		185	60		245	294
	0358	6"		5	3.200		365	96		461	545
	0359	8"	Q-2	6	4		625	124		749	875
	0360	10"		5	4.800		905	149		1,054	1,2[illegible]
	0361	12"		4	6		1,150	186		1,336	1,55[illegible]
	0365	Wye, flanged									

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Line	Plastic Pipe & Fittings	CREW	DAILY OUTPUT	LABOR-HOURS	UNIT	2000 BARE COSTS MAT.	LABOR	EQUIP.	TOTAL	TOTAL INCL O&P
	2"	Q-1	17	.941	Ea.	320	28		348	395
0368	3"		10	1.600		355	48		403	465
	4"		8	2		440	60		500	575
	6"		5	3.200		530	96		626	725
0372	8"	Q-2	6	4		690	124		814	945
	10"		5	4.800		1,175	149		1,324	1,500
	12"		4	6		1,425	186		1,611	1,825
0380	Couplings									
	2"	Q-1	28	.571	Ea.	10.90	17.10		28	38
	3"		20	.800		18.85	24		42.85	56.50
	4"		17	.941		20	28		48	64.50
0440	6"		12	1.333		38	40		78	103
	8"	Q-2	15	1.600		58	49.50		107.50	139
	10"		11	2.182		87.50	67.50		155	198
	12"		10	2.400		117	74.50		191.50	242
	High corrosion resistant couplings, add					30%				
	Reducer, concentric, flanged									
	2" x 1-1/2"	Q-1	30	.533	Ea.	132	15.95		147.95	169
	3" x 2"		24	.667		150	19.95		169.95	195
	4" x 3"		19	.842		158	25		183	212
	6" x 4"		15	1.067		206	32		238	276
	8" x 6"	Q-2	16	1.500		289	46.50		335.50	390
	10" x 8"		13	1.846		385	57.50		442.50	510
	12" x 10"		11	2.182		555	67.50		622.50	710
	Adapter, bell x male or female									
	2"	Q-1	28	.571	Ea.	19.65	17.10		36.75	47.50
	3"		20	.800		25	24		49	63.50
	4"		17	.941		34.50	28		62.50	80.50
	6"		12	1.333		68.50	40		108.50	136
	8"	Q-2	15	1.600		95.50	49.50		145	180
	10"	"	11	2.182		168	67.50		235.50	287
	Flange									
	2" 2.5" 39	Q-1	46	.348	Ea.	17.40	10.40		27.80	35
	3"		32	.500		21	14.95		35.95	46
	4"		26	.615		29.50	18.40		47.90	60.50
	6"		16	1		50	30		80	101
	8"	Q-2	18	1.333		82	41.50		123.50	153
	10"		14	1.714		114	53		167	207
	12"		10	2.400		161	74.50		235.50	290
	PVC schedule 80									
	90° elbow, 1/2"	1 Plum	18	.444	Ea.	.89	14.80		15.69	23.50
	3/4"		17	.471		1.14	15.65		16.79	25
	1"		15	.533		1.83	17.75		19.58	29
	1-1/4"		14	.571		2.44	19		21.44	31
	1-1/2"		13	.615		2.62	20.50		23.12	34
	2"	Q-1	22	.727		3.16	22		25.16	36.50
	3"		14	1.143		8.30	34		42.30	61
	4"		12	1.333		12.65	40		52.65	74.50
	6"		7	2.286		42.50	68.50		111	151
	8"	Q-2	8	3		117	93		210	270
	45° elbow, 1/2"	1 Plum	18	.444		1.68	14.80		16.48	24.50
	3/4"		17	.471		2.54	15.65		18.19	26.50
	1"		15	.533		3.84	17.75		21.59	31
	1-1/4"		14	.571		4.87	19		23.87	34
	1-1/2"		13	.615		5.75	20.50		26.25	37.50
	2"	Q-1	22	.727		7.45	22		29.45	41

560

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		CREW	DAILY OUTPUT	LABOR-HOURS	UNIT	2000 BARE COSTS MAT.	LABOR	EQUIP.	TOTAL	TOTAL INCL O&P
560 2320	3"	Q-1	14	1.143	Ea.	19.05	34		53.05	73
2330	4"		12	1.333		34.50	40		74.50	98
2340	6"		7	2.286		43	68.50		111.50	152
2350	8"	Q-2	8	3		83	93		176	232
2400	Tee, 1/2"	1 Plum	12	.667		2.50	22		24.50	36.50
2420	3/4"		11	.727		2.62	24		26.62	39.50
2430	1"		10	.800		3.27	26.50		29.77	43.50
2440	1-1/4"		9	.889		9	29.50		38.50	54.50
2450	1-1/2"		8	1		9	33.50		42.50	60.50
2460	2"	Q-1	14	1.143		11.25	34		45.25	64.50
2470	3"		9	1.778		15.30	53		68.30	97.50
2480	4"		8	2		17.70	60		77.70	110
2490	6"		5	3.200		60.50	96		156.50	212
2500	8"	Q-2	6	4		85.50	124		209.50	282
2510	Flange, socket, 150 lb., 1/2"	1 Plum	34	.235		4.84	7.80		12.64	17.15
2514	3/4"		32	.250		5.20	8.30		13.50	18.25
2518	1"		28	.286		5.80	9.50		15.30	20.50
2522	1-1/2"		24	.333		6.10	11.10		17.20	23.50
2526	2"	Q-1	42	.381		8.10	11.40		19.50	26
2530	4"		30	.533		17.45	15.95		33.40	43
2534	6"		22	.727		27.50	22		49.50	63
2538	8"	Q-2	26	.923		50	28.50		78.50	98.50
2550	Coupling, 1/2"	1 Plum	18	.444		1.61	14.80		16.41	24.50
2570	3/4"		17	.471		2.17	15.65		17.82	26
2580	1"		15	.533		2.23	17.75		19.98	29.50
2590	1-1/4"		14	.571		3.39	19		22.39	32
2600	1-1/2"		13	.615		3.66	20.50		24.16	35
2610	2"	Q-1	22	.727		3.92	22		25.92	37.50
2620	3"		19	.842		11.10	25		36.10	50
2630	4"		16	1		13.90	30		43.90	61
2640	6"		12	1.333		30	40		70	93.50
2650	8"	Q-2	14	1.714		54	53		107	140
2660	10"		13	1.846		84	57.50		141.50	179
2670	12"		12	2		112	62		174	217
2700	PVC (white), schedule 40, socket joints									
2760	90° elbow, 1/2"	1 Plum	22	.364	Ea.	.23	12.10		12.33	18.55
2770	3/4"		21	.381		.25	12.65		12.90	19.45
2780	1"		18	.444		.45	14.80		15.25	23
2790	1-1/4"		17	.471		.80	15.65		16.45	24.50
2800	1-1/2"		16	.500		.85	16.65		17.50	26
2810	2"	Q-1	28	.571		1.34	17.10		18.44	27.50
2820	2-1/2"		22	.727		4.06	22		26.06	37.50
2830	3"		17	.941		4.86	28		32.86	48
2840	4"		14	1.143		8.70	34		42.70	61.50
2850	5"		12	1.333		22.50	40		62.50	85
2860	6"		8	2		27.50	60		87.50	121
2870	8"	Q-2	10	2.400		77	74.50		151.50	198
2980	45° elbow, 1/2"	1 Plum	22	.364		.37	12.10		12.47	18.70
2990	3/4"		21	.381		.57	12.65		13.22	19.80
3000	1"		18	.444		.68	14.80		15.48	23.50
3010	1-1/4"		17	.471		.96	15.65		16.61	24.50
3020	1-1/2"		16	.500		1.20	16.65		17.85	26.50
3030	2"	Q-1	28	.571		1.57	17.10		18.67	27.50
3040	2-1/2"		22	.727		4.07	22		26.07	37.50
3050	3"		17	.941		6.30	28		34.30	49.50
3060	4"		14	1.143		11.35	34		45.35	64.50

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		CREW	DAILY OUTPUT	LABOR-HOURS	UNIT	2000 BARE COSTS MAT.	LABOR	EQUIP.	TOTAL	TOTAL INCL O&P	
	5"	Q-1	12	1.333	Ea.	22.50	40		62.50	85	560
80	6"	↓	8	2		28	60		88	122	
	8"	Q-2	10	2.400		93	74.50		167.50	215	
	Tee, 1/2"	1 Plum	14	.571		.28	19		19.28	29	
90	3/4"		13	.615		.32	20.50		20.82	31.50	
	1"		12	.667		.59	22		22.59	34	
	1-1/4"		11	.727		.94	24		24.94	37.50	
20	1-1/2"	↓	10	.800		1.13	26.50		27.63	41	
30	2"	Q-1	17	.941		1.65	28		29.65	44.50	
	2-1/2"		14	1.143		5.45	34		39.45	58	
	3"		11	1.455		7.15	43.50		50.65	74	
60	4"		9	1.778		12.90	53		65.90	94.50	
	5"		8	2		31	60		91	125	
	6"	↓	5	3.200		43.50	96		139.50	193	
90	8"	Q-2	6	4		53	124		177	246	
	Coupling, 1/2"	1 Plum	22	.364		.18	12.10		12.28	18.50	
	3/4"		21	.381		.24	12.65		12.89	19.40	
	1"		18	.444		.41	14.80		15.21	23	
10	1-1/4"		17	.471		.57	15.65		16.22	24	
	1-1/2"	↓	16	.500		.61	16.65		17.26	25.50	
	2"	Q-1	28	.571		.95	17.10		18.05	27	
10	2-1/2"		20	.800		2.08	24		26.08	38.50	
	3"		19	.842		3.27	25		28.27	41.50	
	4"		16	1		4.72	30		34.72	50.50	
	5"		14	1.143		8.65	34		42.65	61.50	
	6"	↓	12	1.333		14.90	40		54.90	77	
	8"	Q-2	14	1.714	↓	28	53		81	111	
	Reducing insert, schedule 40, socket weld										
2	3/4"	1 Plum	20	.400	Ea.	.70	13.30		14	21	
	1"		18	.444		1.19	14.80		15.99	24	
	1-1/2"	↓	16	.500		1.25	16.65		17.90	26.50	
6	2"	Q-1	31	.516		1.59	15.45		17.04	25.50	
7	4"		22	.727		7.05	22		29.05	41	
	6"	↓	14	1.143		17.45	34		51.45	71	
	8"	Q-2	18	1.333	↓	61	41.50		102.50	130	
0	Reducing insert, socket weld x female/male thread										
	1/2"	1 Plum	24	.333	Ea.	1.41	11.10		12.51	18.30	
	3/4"		23	.348		.87	11.55		12.42	18.45	
	1"		20	.400		1.22	13.30		14.52	21.50	
	1-1/2"	↓	16	.500		2.20	16.65		18.85	27.50	
	2"	Q-1	26	.615		1.17	18.40		19.57	29.50	
	4"	"	14	1.143	↓	4.61	34		38.61	57	
2	Male adapter, socket weld x male thread										
	1/2"	1 Plum	24	.333	Ea.	.27	11.10		11.37	17.05	
	3/4"		23	.348		.30	11.55		11.85	17.85	
	1"		20	.400		.53	13.30		13.83	20.50	
	1-1/2"	↓	16	.500		.87	16.65		17.52	26	
	2"	Q-1	26	.615		1.14	18.40		19.54	29.50	
	4"	"	14	1.143	↓	6.30	34		40.30	59	
	Female adapter, socket weld x female thread										
	1/2"	1 Plum	24	.333	Ea.	.33	11.10		11.43	17.10	
	3/4"		23	.348		.42	11.55		11.97	17.95	
	1"		20	.400		.49	13.30		13.79	20.50	
	1-1/2"	↓	16	.500		.87	16.65		17.52	26	
	2"	Q-1	26	.615		1.17	18.40		19.57	29.50	
	4"	"	14	1.143	↓	6.60	34		40.60	59.50	

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	15108 | Plastic Pipe & Fittings		CREW	DAILY OUTPUT	LABOR-HOURS	UNIT	2000 BARE COSTS MAT.	LABOR	EQUIP.	TOTAL	TOTAL INCL O&P
560	3800	PVC, schedule 80, socket joints									
	3810	Reducing insert									
	3812	3/4″	1 Plum	23	.348	Ea.	.67	11.55		12.22	[illegible]
	3813	1″		20	.400		1.91	13.30		15.21	22
	3815	1-1/2″		16	.500		4.09	16.65		20.74	29.50
	3816	2″	Q-1	28	.571		5.35	17.10		22.45	32
	3817	4″		16	1		22	30		52	70
	3818	6″		12	1.333		31	40		71	94.50
	3819	8″	Q-2	14	1.714		22.50	53		75.50	106
	3830	Reducing insert, socket weld x female/male thread									
	3832	1/2″	1 Plum	24	.333	Ea.	1.78	11.10		12.88	18.70
	3833	3/4″		23	.348		1.11	11.55		12.66	18.70
	3834	1″		20	.400		1.92	13.30		15.22	22
	3836	1-1/2″		16	.500		3.22	16.65		19.87	28.50
	3837	2″	Q-1	28	.571		4.66	17.10		21.76	31
	3838	4″	″	16	1		41	30		71	91
	3844	Adapter, male socket x male thread									
	3846	1/2″	1 Plum	24	.333	Ea.	1.01	11.10		12.11	17.85
	3847	3/4″		23	.348		1.11	11.55		12.66	18.70
	3848	1″		20	.400		1.92	13.30		15.22	22
	3850	1-1/2″		16	.500		3.22	16.65		19.87	28.50
	3851	2″	Q-1	28	.571		4.66	17.10		21.76	31
	3852	4″	″	16	1		10.45	30		40.45	57
	3860	Adapter, female socket x female thread									
	3862	1/2″	1 Plum	24	.333	Ea.	.81	11.10		11.91	17.65
	3863	3/4″		23	.348		2.88	11.55		14.43	20.50
	3864	1″		20	.400		4.25	13.30		17.55	24.50
	3866	1-1/2″		16	.500		8.45	16.65		25.10	[illegible]
	3867	2″	Q-1	28	.571		14.75	17.10		31.85	[illegible]
	3868	4″	″	16	1		45	30		75	95
	3872	Union, socket joints									
	3874	1/2″	1 Plum	19	.421	Ea.	4.25	14		18.25	25.50
	3875	3/4″		18	.444		5.40	14.80		20.20	28.50
	3876	1″		15	.533		6.15	17.75		23.90	34
	3878	1-1/2″		13	.615		13.85	20.50		34.35	46.50
	3879	2″	Q-1	27	.593		18.80	17.75		36.55	47.50
	3888	Cap									
	3890	1/2″	1 Plum	36	.222	Ea.	2.03	7.40		9.43	13.45
	3891	3/4″		34	.235		2.13	7.80		9.93	14.20
	3892	1″		30	.267		3.80	8.85		12.65	17.60
	3894	1-1/2″		26	.308		4.58	10.25		14.83	20.50
	3895	2″	Q-1	44	.364		9.05	10.90		19.95	26.50
	3896	4″		32	.500		36.50	14.95		51.45	62.50
	3897	6″		24	.667		83	19.95		102.95	122
	3898	8″	Q-2	28	.857		107	26.50		133.50	157
	4500	DWV, ABS, non pressure, socket joints									
	4540	1/4 Bend, 1-1/4″	1 Plum	17	.471	Ea.	.99	15.65		16.64	24.50
	4560	1-1/2″	″	16	.500		.53	16.65		17.18	25.50
	4570	2″	Q-1	28	.571		.87	17.10		17.97	27
	4580	3″		17	.941		2.05	28		30.05	45
	4590	4″		14	1.143		3.57	34		37.57	56
	4600	6″		8	2		22.50	60		82.50	116
	4650	1/8 Bend, same as 1/4 Bend									
	4800	Tee, sanitary									
	4820	1-1/4″	1 Plum	11	.727	Ea.	1.25	24		25.25	[illegible]
	4830	1-1/2″	″	10	.800		.77	26.50		27.27	41

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Important: See the Reference Section for critical supporting data - Reference Nos., Crews, & City Cost Index

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	Plastic Pipe & Fittings	CREW	DAILY OUTPUT	LABOR-HOURS	UNIT	2000 BARE COSTS MAT.	LABOR	EQUIP.	TOTAL	TOTAL INCL O&P	
340	2"	Q-1	17	.941	Ea.	1.10	28		29.10	43.50	560
350	3"		11	1.455		2.79	43.50		46.29	69	
	4"		9	1.778		6.90	53		59.90	88	
362	Tee, sanitary, reducing, 2" x 1-1/2"		17	.941		1.63	28		29.63	44.50	
364	3" x 2"		11	1.455		2.36	43.50		45.86	68.50	
	4" x 3"		10	1.600		7.70	48		55.70	81	
	Combination Y and 1/8 bend										
872	1-1/2"	1 Plum.	10	.800	Ea.	2.34	26.50		28.84	42.50	
	2"	Q-1	17	.941		2.84	28		30.84	45.50	
	3"		11	1.455		5	43.50		48.50	71.50	
1878	4"		9	1.778		9.85	53		62.85	91.50	
1880	3" x 1-1/2"		11	1.455		5.85	43.50		49.35	72.50	
	4" x 3"		10	1.600		8.80	48		56.80	82	
	Wye, 1-1/4"	1 Plum	11	.727		1.44	24		25.44	38	
4902	1-1/2"	"	10	.800		1.47	26.50		27.97	41.50	
	2"	Q-1	17	.941		1.51	28		29.51	44	
	3"		11	1.455		3.47	43.50		46.97	70	
4908	4"		9	1.778		8.20	53		61.20	89.50	
4910	6"		5	3.200		31	96		127	180	
8	3" x 1-1/2"		11	1.455		3.43	43.50		46.93	70	
4920	4" x 3"		10	1.600		5.70	48		53.70	79	
4922	6" x 4"		6	2.667		25.50	80		105.50	150	
0	Double Wye, 1-1/2"	1 Plum	8	1		3.12	33.50		36.62	54	
2	2"	Q-1	12	1.333		4.01	40		44.01	65	
4934	3"		8	2		10.35	60		70.35	102	
	4"		6	2.667		21	80		101	144	
40	2" x 1-1/2"		11	1.455		4.01	43.50		47.51	70.50	
4942	3" x 2"		8	2		7.70	60		67.70	99	
4944	4" x 3"		7	2.286		16.65	68.50		85.15	122	
46	6" x 4"		5	3.200		34.50	96		130.50	183	
50	Reducer bushing, 2" x 1-1/2"		30	.533		.51	15.95		16.46	24.50	
4952	3" x 1-1/2" (3" x 2" 22)		24	.667		1.85	19.95		21.80	32	
54	4" x 2"		20	.800		4.27	24		28.27	40.50	
56	6" x 4"		17	.941		11.40	28		39.40	55	
4960	Couplings, 1-1/2"	1 Plum.	16	.500		.56	16.65		17.21	25.50	
4962	2"	Q-1	28	.571		.33	17.10		17.43	26.50	
63	3"		22	.727		1.15	22		23.15	34.50	
64	4"		17	.941		1.77	28		29.77	44.50	
4966	6"		12	1.333		11.85	40		51.85	73.50	
970	2" x 1-1/2"		30	.533		.34	15.95		16.29	24.50	
972	3" x 1-1/2"		24	.667		1.15	19.95		21.10	31.50	
4974	4" x 3"		19	.842		4.53	25		29.53	43	
978	Closet flange, 4"	1 Plum	32	.250		4.69	8.30		12.99	17.70	
980	4" x 3"	"	34	.235		4.02	7.80		11.82	16.25	
000	DWV, PVC, schedule 40, socket joints										
040	1/4 bend, 1-1/4"	1 Plum	17	.471	Ea.	.93	15.65		16.58	24.50	
060	1-1/2"	"	16	.500		.41	16.65		17.06	25.50	
070	2"	Q-1	28	.571		.63	17.10		17.73	26.50	
080	3"		17	.941		1.57	28		29.57	44	
090	4"		14	1.143		2.82	34		36.82	55	
	6"		8	2		17.15	60		77.15	109	
	8"	Q-2	10	2.400		34.50	74.50		109	151	
	10"	"	7	3.429		37.50	106		143.50	202	
110	1/4 bend, long sweep, 1-1/2"	1 Plum	16	.500		1.28	16.65		17.93	26.50	
112	2"	Q-1	28	.571		1.05	17.10		18.15	27	
114	3"		17	.941		2.73	28		30.73	45.50	

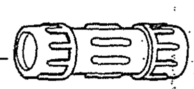
15108 | Plastic Pipe & Fittings		CREW	DAILY OUTPUT	LABOR-HOURS	UNIT	2000 BARE COSTS MAT.	LABOR	EQUIP.	TOTAL	TOTAL INCL O&P
560 5116	4"	Q-1	14	1.143	Ea.	5.40	34		39.40	58
5150	1/8 bend, 1-1/4"	1 Plum	17	.471		.82	15.65		16.47	24.50
5170	1-1/2"	"	16	.500		.46	16.65		17.11	25.50
5180	2"	Q-1	28	.571		.66	17.10		17.76	26.50
5190	3"		17	.941		1.35	28		29.35	44
5200	4"		14	1.143		2.25	34		36.25	54.50
5210	6"		8	2		15.70	60		75.70	108
5215	8"	Q-2	10	2.400		41	74.50		115.50	158
5216	10"		7	3.429		62	106		168	230
5217	12"		6	4		99.50	124		223.50	297
5250	Tee, sanitary 1-1/4"	1 Plum	11	.727		1.45	24		25.45	38
5254	1-1/2"	"	10	.800		.61	26.50		27.11	40.50
5255	2"	Q-1	17	.941		.83	28		28.83	43.50
5256	3"		11	1.455		2.29	43.50		45.79	68.50
5257	4"		9	1.778		4.38	53		57.38	85.50
5259	6"		5	3.200		25.50	96		121.50	173
5261	8"	Q-2	6	4		76	124		200	272
5264	2" x 1-1/2"	Q-1	17	.941		2.05	28		30.05	45
5266	3" x 1-1/2"		12	1.333		1.76	40		41.76	62.50
5268	4" x 3"		12	1.333		8.05	40		48.05	69.50
5271	6" x 4"		8	2		25	60		85	118
5276	Tee, sanitary, reducing									
5281	2" x 1-1/2" x 1-1/2"	Q-1	17	.941	Ea.	.87	28		28.87	43.50
5282	2" x 1-1/2" x 2"		17	.941		1.63	28		29.63	44.50
5283	2" x 2" x 1-1/2"		16	1		1.03	30		31.03	46.50
5284	3" x 3" x 1-1/2"		12	1.333		2.13	40		42.13	63
5285	3" x 3" x 2"		11	1.455		2.36	43.50		45.86	68.50
5286	4" x 4" x 1-1/2"		11	1.455		6.15	43.50		49.65	73
5287	4" x 4" x 2"		10	1.600		5.90	48		53.90	79
5288	4" x 4" x 3"		9	1.778		8.05	53		61.05	89.50
5291	6" x 6" x 4"		6	2.667		24.50	80		104.50	148
5294	Tee, double sanitary									
5295	1-1/2"	1 Plum	8	1	Ea.	1.57	33.50		35.07	52
5296	2"	Q-1	12	1.333		2.66	40		42.66	63.50
5297	3"		8	2		7.45	60		67.45	96.50
5298	4"		6	2.667		12	80		92	134
5303	Wye, reducing									
5304	2" x 1-1/2" x 1-1/2"	Q-1	17	.941	Ea.	2.25	28		30.25	45
5305	2" x 2" x 1-1/2"		15	1.067		2.13	32		34.13	51
5306	3" x 3" x 2"		12	1.333		4.40	40		44.40	65.50
5307	4" x 4" x 2"		11	1.455		4.10	43.50		47.60	70.50
5309	4" x 4" x 3"		10	1.600		4.79	48		52.79	78
5314	Combination Y & 1/8 bend, 1-1/2"	1 Plum	10	.800		1.88	26.50		28.38	42
5315	2"	Q-1	17	.941		2.50	28		30.50	45.50
5317	3"		11	1.455		4.12	43.50		47.62	70.50
5318	4"		9	1.778		8.10	53		61.10	89.50
5319	6"		5	3.200		62.50	96		158.50	214
5320	8"	Q-2	6	4		100	124		224	298
5324	Combination Y & 1/8 bend, reducing									
5325	2" x 2" x 1-1/2"	Q-1	17	.941	Ea.	3.64	28		31.64	46.50
5327	3" x 3" x 1-1/2"		13	1.231		4.80	37		41.80	61
5328	3" x 3" x 2"		12	1.333		3.01	40		43.01	64
5329	4" x 4" x 2"		11	1.455		6.70	43.50		50.20	73.50
5331	Wye, 1-1/4"	1 Plum	11	.727		1.39	24		25.39	38
5332	1-1/2"	"	10	.800		1.21	26.50		27.71	41.50
5333	2"	Q-1	17	.941		1.21	28		29.21	44

15108 | Plastic Pipe & Fittings

Line	15108 Plastic Pipe & Fittings	Crew	Daily Output	Labor-Hours	Unit	2000 Bare Costs Mat.	Labor	Equip.	Total	Total Incl O&P	
	3"	Q-1	11	1.455	Ea.	2.79	43.50		46.29	69	560
5335	4"		9	1.778		5.10	53		58.10	86	
	6"		5	3.200		33	96		129	182	
	8"	Q-2	5	4.800		37.50	149		186.50	267	
5338	10"		4	6		58.50	186		244.50	345	
5339	12"		3	8		86.50	248		334.50	470	
	2" x 1-1/2"	Q-1	17	.941		2.13	28		30.13	45	
	3" x 1-1/2"		12	1.333		2.82	40		42.82	63.50	
5343	4" x 3"		10	1.600		4.79	48		52.79	78	
	6" x 4"		6	2.667		18.80	80		98.80	142	
	8" x 6"	Q-2	8	3		45	93		138	191	
5347	Double wye, 1-1/2"	1 Plum	8	1		2.57	33.50		36.07	53.50	
	2"	Q-1	12	1.333		3.30	40		43.30	64	
	3"		8	2		8.50	60		68.50	100	
	4"		6	2.667		17.25	80		97.25	140	
5354	2" x 1-1/2"		11	1.455		3.02	43.50		46.52	69.50	
	3" x 2"		8	2		6.35	60		66.35	97.50	
	4" x 3"		7	2.286		13.70	68.50		82.20	119	
5357	6" x 4"		5	3.200		28.50	96		124.50	177	
	Coupling, 1-1/4"	1 Plum	17	.471		.78	15.65		16.43	24.50	
	1-1/2"	"	16	.500		.26	16.65		16.91	25.50	
5378	2"	Q-1	28	.571		.27	17.10		17.37	26.50	
5380	3"		22	.727		.78	22		22.78	34	
	4"		17	.941		1.28	28		29.28	44	
	6"		12	1.333		6.85	40		46.85	68	
5402	8"	Q-2	14	1.714		15.45	53		68.45	97.50	
	2" x 1-1/2"	Q-1	30	.533		.68	15.95		16.63	25	
	3" x 1-1/2"		25	.640		2.15	19.15		21.30	31.50	
5408	4" x 3"		18	.889		3.73	26.50		30.23	44.50	
	Reducer bushing, 2" x 1-1/4"		31	.516		.46	15.45		15.91	24	
	2" x 1-1/2"		30	.533		.46	15.95		16.41	24.50	
	3" x 1-1/2"		25	.640		2.01	19.15		21.16	31	
13	3" x 2"		24	.667		.93	19.95		20.88	31	
	4" x 2"		22	.727		3.51	22		25.51	37	
	4" x 3"		20	.800		1.94	24		25.94	38	
16	6" x 4"		14	1.143		10.05	34		44.05	63	
	8" x 6"	Q-2	18	1.333		20	41.50		61.50	84.50	
	Closet flange 4"	Q-1	32	.500		4.73	14.95		19.68	27.50	
	4" x 3"	"	34	.471		3.55	14.10		17.65	25.50	
50	Solvent cement for PVC, industrial grade, per quart				Qt.	10.80			10.80	11.90	
	CPVC, Schedule 80, threaded joints										
	90° Elbow, 1/4"	1 Plum	20	.400	Ea.	5.35	13.30		18.65	26	
	1/2"		18	.444		2.09	14.80		16.89	25	
	3/4"		17	.471		2.67	15.65		18.32	26.50	
	1"		15	.533		4.24	17.75		21.99	31.50	
	1-1/4"		14	.571		9.20	19		28.20	38.50	
	1-1/2"		13	.615		10.25	20.50		30.75	42.50	
	2"	Q-1	22	.727		12.40	22		34.40	46.50	
	2-1/2"		18	.889		28.50	26.50		55	72	
	3"		14	1.143		32	34		66	87.50	
	4"		12	1.333		58	40		98	125	
	6"		7	2.286		117	68.50		185.50	232	
	45° Elbow same as 90° Elbow										
	Tee, 1/4"	1 Plum	14	.571	Ea.	6.55	19		25.55	35.50	
	1/2"		12	.667		6.55	22		28.55	40.50	
	3/4"		11	.727		6.65	24		30.65	44	

15108 | Plastic Pipe & Fittings

			Crew	Daily Output	Labor-Hours	Unit	2000 Bare Costs Mat.	Labor	Equip.	Total	Total Incl O&P
560	5890	1"	1 Plum	10	.800	Ea.	8.15	26.50		34.65	49
	5900	1-1/4"		9	.889		12.90	29.50		42.40	58.[illegible]
	5910	1-1/2"	↓	8	1		14.80	33.50		48.30	67
	5920	2"	Q-1	14	1.143		16.45	34		50.45	70
	5930	2-1/2"		12	1.333		42	40		82	107
	5940	3"		9	1.778		42	53		95	127
	5950	4"		8	2		56	60		116	152
	5960	6"	↓	5	3.200		145	96		241	305
	6000	Coupling, 1/4"	1 Plum	20	.400		5.70	13.30		19	26.[illegible]
	6020	1/2"		18	.444		2.21	14.80		17.01	25
	6030	3/4"		17	.471		3.09	15.65		18.74	27
	6040	1"		15	.533		4.16	17.75		21.91	31.[illegible]
	6050	1-1/4"		14	.571		6.25	19		25.25	35.[illegible]
	6060	1-1/2"	↓	13	.615		7.85	20.50		28.35	39.[illegible]
	6070	2"	Q-1	22	.727		9.15	22		31.15	43
	6080	2-1/2"		20	.800		20.50	24		44.50	58.[illegible]
	6090	3"		19	.842		22	25		47	62.[illegible]
	6100	4"		16	1		29	30		59	77.[illegible]
	6110	6"	↓	12	1.333		68	40		108	136
	6120	8"	Q-2	14	1.714	↓	126	53		179	220
	6200	CTS, 100 psi at 180°F, hot and cold water									
	6230	90° Elbow, 1/2"	1 Plum	20	.400	Ea.	.07	13.30		13.37	20
	6250	3/4"		19	.421		.16	14		14.16	21
	6251	1"		16	.500		.52	16.65		17.17	25.[illegible]
	6252	1-1/4"		15	.533		.89	17.75		18.64	28
	6253	1-1/2"	↓	14	.571		1.43	19		20.43	30
	6254	2"	Q-1	23	.696		3.08	21		24.08	35
	6260	45° Elbow, 1/2"	1 Plum	20	.400		.12	13.30		13.42	20
	6280	3/4"		19	.421		.18	14		14.18	2[illegible]
	6281	1"		16	.500		.48	16.65		17.13	2[illegible]
	6282	1-1/4"		15	.533		.94	17.75		18.69	28
	6283	1-1/2"	↓	14	.571		1.49	19		20.49	30
	6284	2"	Q-1	23	.696		3.14	21		24.14	35
	6290	Tee, 1/2"	1 Plum	13	.615		.10	20.50		20.60	31
	6310	3/4"		12	.667		.23	22		22.23	34
	6311	1"		11	.727		1.18	24		25.18	38
	6312	1-1/4"		10	.800		1.80	26.50		28.30	42
	6313	1-1/2"	↓	10	.800		2.34	26.50		28.84	42.[illegible]
	6314	2"	Q-1	17	.941		3.80	28		31.80	46.[illegible]
	6320	Coupling, 1/2"	1 Plum	22	.364		.09	12.10		12.19	18.[illegible]
	6340	3/4"		21	.381		.10	12.65		12.75	19.[illegible]
	6341	1"		18	.444		.45	14.80		15.25	23
	6342	1-1/4"		17	.471		.56	15.65		16.21	24
	6343	1-1/2"	↓	16	.500		.79	16.65		17.44	26
	6344	2"	Q-1	28	.571	↓	1.58	17.10		18.68	27.[illegible]
	6360	Solvent cement for CPVC, commercial grade, per quart				Qt.	7.30			7.30	8
	7990	Polybutyl/polyethyl pipe, for copper fittings see 15107-460-7000									
	8000	Compression type, PVC, 160 psi cold water									
	8010	Coupling, 3/4" CTS	1 Plum	21	.381	Ea.	1.90	12.65		14.55	21
	8020	1" CTS		18	.444		2.34	14.80		17.14	25
	8030	1-1/4" CTS		17	.471		3.27	15.65		18.92	27
	8040	1-1/2" CTS		16	.500		4.50	16.65		21.15	30
	8050	2" CTS		15	.533		6.30	17.75		24.05	34
	8060	Female adapter, 3/4" FPT x 3/4" CTS		23	.348		3.01	11.55		14.56	21
	8070	3/4" FPT x 1" CTS		21	.381		4.50	12.65		17.15	[illegible]
	8080	1" FPT x 1" CTS	↓	20	.400	↓	4.53	13.30		17.83	2[illegible]

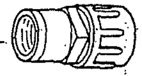
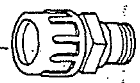
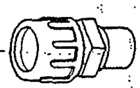
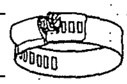
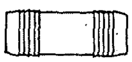
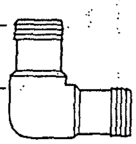


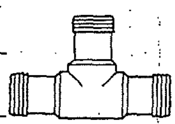
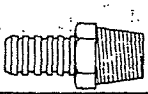
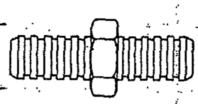
15 MECHANICAL

Important: See the Reference Section for critical supporting data - Reference Nos., Crews, & City Cost Ind[illegible]

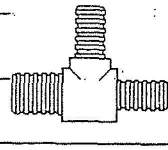
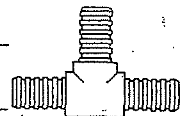
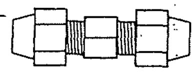
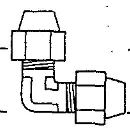
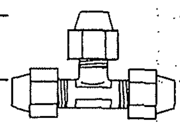
8 | Plastic Pipe & Fittings

	CREW	DAILY OUTPUT	LABOR-HOURS	UNIT	2000 BARE COSTS MAT.	LABOR	EQUIP.	TOTAL	TOTAL INCL O&P	
1-1/4" FPT x 1-1/4" CTS	1 Plum	18	.444	Ea.	5.95	14.80		20.75	29	560
1-1/2" FPT x 1-1/2" CTS		16	.500		6.95	16.65		23.60	32.50	
2" FPT x 2" CTS		13	.615		10.30	20.50		30.80	42.50	
Male adapter, 3/4" MPT x 3/4" CTS		23	.348		2.71	11.55		14.26	20.50	
3/4" MPT x 1" CTS		21	.381		3.34	12.65		15.99	23	
1" MPT x 1" CTS		20	.400		3.42	13.30		16.72	24	
1-1/4" MPT x 1-1/4" CTS		18	.444		5.25	14.80		20.05	28.50	
1-1/2" MPT x 1-1/2" CTS		16	.500		6.05	16.65		22.70	31.50	
2" MPT x 2" CTS		13	.615		9.70	20.50		30.20	41.50	
Spigot adapter, 3/4" IPS x 3/4" CTS		23	.348		2.71	11.55		14.26	20.50	
3/4" IPS x 1" CTS		21	.381		2.71	12.65		15.36	22	
1" IPS x 1" CTS		20	.400		2.94	13.30		16.24	23	
1-1/4" IPS x 1-1/4" CTS		18	.444		5.25	14.80		20.05	28.50	
1-1/2" IPS x 1-1/2" CTS		16	.500		6.05	16.65		22.70	31.50	
2" IPS x 2" CTS	↓	13	.615	↓	9.70	20.50		30.20	41.50	
Price includes insert stiffeners										
250 psi is same price as 160 psi										
Insert type, nylon, 160 & 250 psi, cold water										
Clamp ring stainless steel, 3/4" IPS	1 Plum	115	.070	Ea.	.62	2.31		2.93	4.18	
1" IPS		107	.075		.63	2.49		3.12	4.45	
1-1/4" IPS		101	.079		.63	2.63		3.26	4.67	
1-1/2" IPS		95	.084		.64	2.80		3.44	4.94	
2" IPS		85	.094		.64	3.13		3.77	5.45	
Coupling, 3/4" IPS		22	.364		.56	12.10		12.66	18.90	
1-1/4" IPS		18	.444		1.34	14.80		16.14	24	
1-1/2" IPS		17	.471		1.74	15.65		17.39	25.50	
2" IPS		16	.500		2.09	16.65		18.74	27.50	
Elbow, 90°, 3/4" IPS		22	.364		.82	12.10		12.92	19.20	
1" IPS		19	.421		.90	14		14.90	22	
1-1/4" IPS		18	.444		1.01	14.80		15.81	23.50	
1-1/2" IPS		17	.471		1.19	15.65		16.84	25	
2" IPS		16	.500		1.67	16.65		18.32	27	
Male adapter, 3/4" IPS x 3/4" MPT		25	.320		.57	10.65		11.22	16.75	
1" IPS x 1" MPT		21	.381		.74	12.65		13.39	19.95	
1-1/4" IPS x 1-1/4" MPT		20	.400		1.23	13.30		14.53	21.50	
1-1/2" IPS x 1-1/2" MPT		18	.444		1.63	14.80		16.43	24.50	
2" IPS x 2" MPT		15	.533		2.09	17.75		19.84	29.50	
Tee, 3/4" IPS		14	.571		1.07	19		20.07	29.50	
1" IPS		13	.615		1.75	20.50		22.25	33	
1-1/4" IPS		12	.667		3.14	22		25.14	37	
1-1/2" IPS		11	.727		3.95	24		27.95	41	
2" IPS	↓	10	.800	↓	5.35	26.50		31.85	46	
Insert type, PVC, 100 psi @ 180°F, hot & cold water										
Coupler, male, 3/8" CTS x 3/8" MPT	1 Plum	29	.276	Ea.	.96	9.15		10.11	14.95	
3/8" CTS x 1/2" MPT		28	.286		.96	9.50		10.46	15.40	
1/2" CTS x 1/2" MPT		27	.296		.30	9.85		10.15	15.25	
1/2" CTS x 3/4" MPT		26	.308		.86	10.25		11.11	16.45	
3/4" CTS x 1/2" MPT		25	.320		.86	10.65		11.51	17.05	
3/4" CTS x 3/4" MPT		25	.320		4.11	10.65		14.76	20.50	
Coupling, 3/8" CTS x 1/2" CTS		25	.320		2.15	10.65		12.80	18.45	
1/2" CTS		23	.348		2.50	11.55		14.05	20.50	
1/2" CTS x stub		23	.348		1.96	11.55		13.51	19.65	
3/4" CTS		22	.364		3.96	12.10		16.06	22.50	
Elbow 90°, 3/8" CTS		25	.320		.65	10.65		11.30	16.80	
1/2" CTS		23	.348		.65	11.55		12.20	18.20	
3/4" CTS	↓	22	.364	↓	.82	12.10		12.92	19.20	

15108 | Plastic Pipe & Fittings

	15108 Plastic Pipe & Fittings		Crew	Daily Output	Labor-Hours	Unit	2000 Bare Costs Mat.	Labor	Equip.	Total	Total Incl O&P
560	8800	Rings, crimp, copper, 3/8" CTS	1 Plum	120	.067	Ea.	.11	2.22		2.33	3.47
	8810	1/2" CTS		117	.068		.12	2.27		2.39	[illegible]
	8820	3/4" CTS		115	.070		.15	2.31		2.46	[illegible]
	8850	Reducer tee, 3/8" x 3/8" x 1/2" CTS 		17	.471		1.46	15.65		17.11	25
	8860	1/2" x 3/8" x 1/2" CTS		15	.533		1.25	17.75		19	28.50
	8870	3/4" x 1/2" x 1/2" CTS		14	.571		1.31	19		20.31	30
	8890	3/4" x 3/4" x 1/2" CTS		14	.571		1.24	19		20.24	30
	8900	3/4" x 1/2" x 3/8" CTS		14	.571		1.09	19		20.09	29.50
	8930	Tee, 3/8" CTS 		17	.471		1.05	15.65		16.70	24.50
	8940	1/2" CTS		15	.533		1.19	17.75		18.94	28.50
	8950	3/4" CTS	↓	14	.571	↓	1.29	19		20.29	30
	8960	Copper rings included in fitting price									
	9000	Flare type, assembled, acetal, hot & cold water									
	9010	Coupling, 1/4" & 3/8" CTS 	1 Plum	24	.333	Ea.	2.14	11.10		13.24	19.10
	9020	1/2" CTS		22	.364		2.45	12.10		14.55	21
	9030	3/4" CTS		21	.381		3.61	12.65		16.26	23
	9040	1" CTS		18	.444		4.61	14.80		19.41	27.50
	9050	Elbow 90°, 1/4" CTS 		26	.308		2.38	10.25		12.63	18.10
	9060	3/8" CTS		24	.333		2.55	11.10		13.65	[illegible]
	9070	1/2" CTS		22	.364		3.01	12.10		15.11	21.50
	9080	3/4" CTS		21	.381		4.61	12.65		17.26	24
	9090	1" CTS		18	.444		5.80	14.80		20.60	29
	9110	Tee, 1/4" & 3/8" CTS 		15	.533		2.62	17.75		20.37	30
	9120	1/2" CTS		14	.571		3.44	19		22.44	32.50
	9130	3/4" CTS		13	.615		5.25	20.50		25.75	37
	9140	1" CTS	↓	12	.667	↓	7	22		29	41
	9550	For plastic hangers see 15060-300-8000									
	9560	For copper/brass fittings see 15107-460-7000									
590	0010	**PIPE, HIGH DENSITY POLYETHYLENE PLASTIC (HDPE)**									
	0020	Not incl. hangers, trenching, backfill, hoisting or digging equipment.									
	0030	Standard length is 40', add a weld for each joint.									
	0050	Straight									
	0054	1" diameter DR 11				L.F.	.28			.28	.31
	0058	1-1/2" diameter DR 11					.62			.62	[illegible]
	0062	2" diameter DR 11					.79			.79	[illegible]
	0066	3" diameter DR 11					1.72			1.72	[illegible]
	0070	3" diameter DR 17					1.15			1.15	[illegible]
	0074	4" diameter DR 11					2.84			2.84	[illegible]
	0078	4" diameter DR 17					1.91			1.91	[illegible]
	0082	6" diameter DR 11					6.15			6.15	[illegible]
	0086	6" diameter DR 17					4.13			4.13	[illegible]
	0090	8" diameter DR 11					10.40			10.40	[illegible]
	0094	8" diameter DR 26					4.69			4.69	[illegible]
	0098	10" diameter DR 11					16.20			16.20	[illegible]
	0102	10" diameter DR 26					7.25			7.25	8
	0106	12" diameter DR 11					23			23	25
	0110	12" diameter DR 26					10.25			10.25	[illegible]
	0114	16" diameter DR 11					34			34	37
	0118	16" diameter DR 26					15.20			15.20	[illegible]
	0122	18" diameter DR 11					43			43	47
	0126	18" diameter DR 26					19.20			19.20	21
	0130	20" diameter DR 11					53			53	58
	0134	20" diameter DR 26					23.50			23.50	[illegible]
	0138	22" diameter DR 11					64			64	[illegible]
	0142	22" diameter DR 26					28.50			28.50	[illegible]
	0146	24" diameter DR 11				↓	76			76	84

15 MECHANICAL

Important: See the Reference Section for critical supporting data - Reference Nos., Crews, & City Cost Index

15110 | Valves	CREW	DAILY OUTPUT	LABOR-HOURS	UNIT	2000 BARE COSTS MAT.	LABOR	EQUIP.	TOTAL	TOTAL INCL O&P	
1-1/2″ size	1 Stpi	11	.727	Ea.	274	24.50		298.50	335	400
2″ size	″	8	1		330	33.50		363.50	415	
2-1/2″ size	Q-5	5	3.200		360	96.50		456.50	540	
3″ size	″	4.50	3.556		380	107		487	580	
Flanged										
3″ size	Q-5	4.20	3.810	Ea.	415	115		530	630	
4″ size	″	3	5.333		835	161		996	1,175	
5″ size	Q-6	3.80	6.316		990	197		1,187	1,400	
6″ size		3	8		1,200	250		1,450	1,700	
8″ size		2.50	9.600		1,775	300		2,075	2,400	
10″ size		2.20	10.909		2,525	340		2,865	3,300	
12″ size		2.10	11.429		7,075	355		7,430	8,350	
14″ size		2	12		10,100	375		10,475	11,700	
VALVES, PLASTIC R15100-090										500
Angle, PVC, threaded										
1/4″ size	1 Plum	26	.308	Ea.	47.50	10.25		57.75	67.50	
1/2″ size		26	.308		47.50	10.25		57.75	67.50	
3/4″ size		25	.320		55.50	10.65		66.15	77	
1″ size		23	.348		66.50	11.55		78.05	90.50	
Ball, PVC, socket or threaded, single union										
1/4″ size	1 Plum	26	.308	Ea.	22	10.25		32.25	39.50	
3/8″ size		26	.308		22	10.25		32.25	39.50	
1/2″ size		26	.308		22	10.25		32.25	39.50	
3/4″ size		25	.320		26.50	10.65		37.15	45	
1″ size		23	.348		31	11.55		42.55	51.50	
1-1/4″ size		21	.381		41.50	12.65		54.15	65	
1-1/2″ size		20	.400		52	13.30		65.30	77	
2″ size		17	.471		74.50	15.65		90.15	105	
2-1/2″ size	Q-1	26	.615		185	18.40		203.40	232	
3″ size		24	.667		185	19.95		204.95	234	
4″ size		20	.800		320	24		344	385	
For PVC, flanged, add					100%	15%				
Double union 1/2″ size	1 Plum	26	.308		25	10.25		35.25	43	
3/4″ size		25	.320		28	10.65		38.65	46.50	
1″ size		23	.348		35	11.55		46.55	56	
1-1/4″ size		21	.381		58	12.65		70.65	83	
1-1/2″ size		20	.400		58	13.30		71.30	84	
2″ size		17	.471		79.50	15.65		95.15	111	
CPVC, socket or threaded, single union										
1/2″ size	1 Plum	26	.308	Ea.	36.50	10.25		46.75	55.50	
3/4″ size		25	.320		43.50	10.65		54.15	63.50	
1″ size		23	.348		51	11.55		62.55	73.50	
1-1/4″ size		21	.381		88	12.65		100.65	116	
1-1/2″ size		20	.400		88	13.30		101.30	117	
2″ size		17	.471		118	15.65		133.65	154	
3″ size	Q-1	24	.667		248	19.95		267.95	305	
For CPVC, flanged, add					65%	15%				
For true union, socket or threaded, add					50%	5%				
Polypropylene, threaded										
1/4″ size	1 Plum	26	.308	Ea.	30	10.25		40.25	48.50	
3/8″ size		26	.308		30	10.25		40.25	48.50	
1/2″ size		26	.308		30	10.25		40.25	48.50	
3/4″ size		25	.320		37.50	10.65		48.15	57	
1″ size		23	.348		44.50	11.55		56.05	66.50	
1-1/4″ size		21	.381		64.50	12.65		77.15	90	

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	15110 | Valves		CREW	DAILY OUTPUT	LABOR-HOURS	UNIT	2000 BARE COSTS MAT.	LABOR	EQUIP.	TOTAL	TOTAL INCL O&P
500	2170	1-1/2" size	1 Plum	20	.400	Ea.	74	13.30		87.30	102
	2180	2" size (R15100-090)		17	.471		101	15.65		116.65	13[illegible]
	2190	3" size	Q-1	24	.667		266	19.95		285.95	325
	2200	4" size	"	20	.800		445	24		469	525
	2550	PVC, three way, socket or threaded									
	2600	1/2" size	1 Plum	26	.308	Ea.	56.50	10.25		66.75	77.50
	2640	3/4" size		25	.320		64	10.65		74.65	86.50
	2650	1" size		23	.348		69.50	11.55		81.05	94
	2660	1-1/2" size		20	.400		140	13.30		153.30	174
	2670	2" size		17	.471		188	15.65		203.65	231
	2680	3" size	Q-1	24	.667		455	19.95		474.95	530
	2740	For flanged, add					60%	15%			
	3150	Ball check, PVC, socket or threaded									
	3200	1/4" size	1 Plum	26	.308	Ea.	25	10.25		35.25	43
	3220	3/8" size		26	.308		25	10.25		35.25	43
	3240	1/2" size		26	.308		25	10.25		35.25	43
	3250	3/4" size		25	.320		28	10.65		38.65	46.50
	3260	1" size		23	.348		35	11.55		46.55	56
	3270	1-1/4" size		21	.381		58	12.65		70.65	83
	3280	1-1/2" size		20	.400		58	13.30		71.30	84
	3290	2" size		17	.471		79	15.65		94.65	111
	3310	3" size	Q-1	24	.667		183	19.95		202.95	231
	3320	4" size	"	20	.800		259	24		283	320
	3360	For PVC, flanged, add					50%	15%			
	3750	CPVC, socket or threaded									
	3800	1/2" size	1 Plum	26	.308	Ea.	36.50	10.25		46.75	55.50
	3840	3/4" size		25	.320		43.50	10.65		54.15	6[illegible]
	3850	1" size		23	.348		51	11.55		62.55	7[illegible]
	3860	1-1/2" size		20	.400		88	13.30		101.30	117
	3870	2" size		17	.471		118	15.65		133.65	154
	3880	3" size	Q-1	24	.667		249	19.95		268.95	305
	3920	4" size	"	20	.800		335	24		359	400
	3930	For CPVC, flanged, add					40%	15%			
	4340	Polypropylene, threaded									
	4360	1/2" size	1 Plum	26	.308	Ea.	25	10.25		35.25	43
	4400	3/4" size		25	.320		29	10.65		39.65	48
	4440	1" size		23	.348		37.50	11.55		49.05	58.50
	4450	1-1/2" size		20	.400		72.50	13.30		85.80	100
	4460	2" size		17	.471		91	15.65		106.65	124
	4500	For polypropylene flanged, add					200%	15%			
	4850	Foot valve, PVC, socket or threaded									
	4900	1/2" size	1 Plum	34	.235	Ea.	36.50	7.80		44.30	52
	4930	3/4" size		32	.250		41.50	8.30		49.80	58
	4940	1" size		28	.286		54	9.50		63.50	74
	4950	1-1/4" size		27	.296		104	9.85		113.85	129
	4960	1-1/2" size		26	.308		104	10.25		114.25	130
	4970	2" size		24	.333		120	11.10		131.10	149
	4980	3" size		20	.400		287	13.30		300.30	335
	4990	4" size		18	.444		505	14.80		519.80	580
	5000	For flanged, add					25%	10%			
	5050	CPVC, socket or threaded									
	5060	1/2" size	1 Plum	34	.235	Ea.	64.50	7.80		72.30	83
	5070	3/4" size		32	.250		78	8.30		86.30	98
	5080	1" size		28	.286		92	9.50		101.50	115
	5090	1-1/4" size		27	.296		129	9.85		138.85	157
	5100	1-1/2" size		26	.308		150	10.25		160.25	181

15 MECHANICAL

0 | Valves

Line	Description		Crew	Daily Output	Labor-Hours	Unit	2000 Bare Costs Mat.	Labor	Equip.	Total	Total Incl O&P	
110	2" size	R15100 -090	1 Plum	24	.333	Ea.	193	11.10		204.10	230	500
120	3" size			20	.400		365	13.30		378.30	420	
130	4" size		↓	18	.444		790	14.80		804.80	890	
140	For flanged, add					↓	25%	10%				
280	Needle valve, PVC, threaded											
300	1/4" size		1 Plum	26	.308	Ea.	32	10.25		42.25	50.50	
340	3/8" size			26	.308		37	10.25		47.25	56	
360	1/2" size		↓	26	.308		37	10.25		47.25	56	
380	For polypropylene, add					↓	10%					
800	Y check, PVC, socket or threaded											
	1/2" size		1 Plum	26	.308	Ea.	52.50	10.25		62.75	73	
	3/4" size			25	.320		56.50	10.65		67.15	78	
	1" size			23	.348		62	11.55		73.55	85.50	
	1-1/4" size			21	.381		97	12.65		109.65	126	
	1-1/2" size			20	.400		105	13.30		118.30	136	
	2" size			17	.471		131	15.65		146.65	169	
	2-1/2" size		↓	15	.533		277	17.75		294.75	330	
	3" size		Q-1	24	.667		260	19.95		279.95	315	
	4" size		"	20	.800		455	24		479	535	
	For PVC flanged, add					↓	45%	15%				
	Y sediment strainer, PVC, socket or threaded											
	1/2" size		1 Plum	26	.308	Ea.	29.50	10.25		39.75	48	
	3/4" size			24	.333		32	11.10		43.10	52.50	
	1" size			23	.348		39	11.55		50.55	60.50	
	1-1/4" size			21	.381		64.50	12.65		77.15	90	
	1-1/2" size			20	.400		67.50	13.30		80.80	94.50	
	2" size			17	.471		78.50	15.65		94.15	110	
	2-1/2" size		↓	15	.533		192	17.75		209.75	238	
	3" size		Q-1	24	.667		192	19.95		211.95	241	
	4" size		"	20	.800		320	24		344	385	
	For PVC, flanged, add					↓	55%	15%				
	VALVES, SEMI-STEEL	R15100 -090										600
	Lubricated plug valve, threaded, 200 psi											
	1/2" pipe size		1 Plum	18	.444	Ea.	61.50	14.80		76.30	90	
	3/4" pipe size			16	.500		61.50	16.65		78.15	92.50	
	1" pipe size			14	.571		79	19		98	116	
	1-1/4" pipe size			12	.667		95	22		117	139	
	1-1/2" pipe size			11	.727		102	24		126	149	
	2" pipe size		↓	8	1		120	33.50		153.50	183	
	2-1/2" pipe size		Q-1	5	3.200		186	96		282	350	
	3" pipe size		"	4.50	3.556	↓	228	106		334	410	
	Flanged, 200 psi											
	2" pipe size		1 Plum	8	1	Ea.	145	33.50		178.50	211	
	2-1/2" pipe size		Q-1	5	3.200		218	96		314	385	
	3" pipe size			4.50	3.556		264	106		370	450	
	4" pipe size			3	5.333		335	160		495	610	
	5" pipe size		↓	2.50	6.400		500	192		692	840	
	6" pipe size		Q-2	3	8		655	248		903	1,100	
	8" pipe size			2.50	9.600		1,125	298		1,423	1,700	
	10" pipe size			2.20	10.909		1,725	340		2,065	2,400	
	12" pipe size		↓	1.70	14.118	↓	2,975	440		3,415	3,925	
	VALVES, STEEL	R15100 -090										700
	[illegible]											
	Check valve, swing type, 150 lb., flanged											
	2" size		1 Plum	8	1	Ea.	465	33.50		498.50	565	

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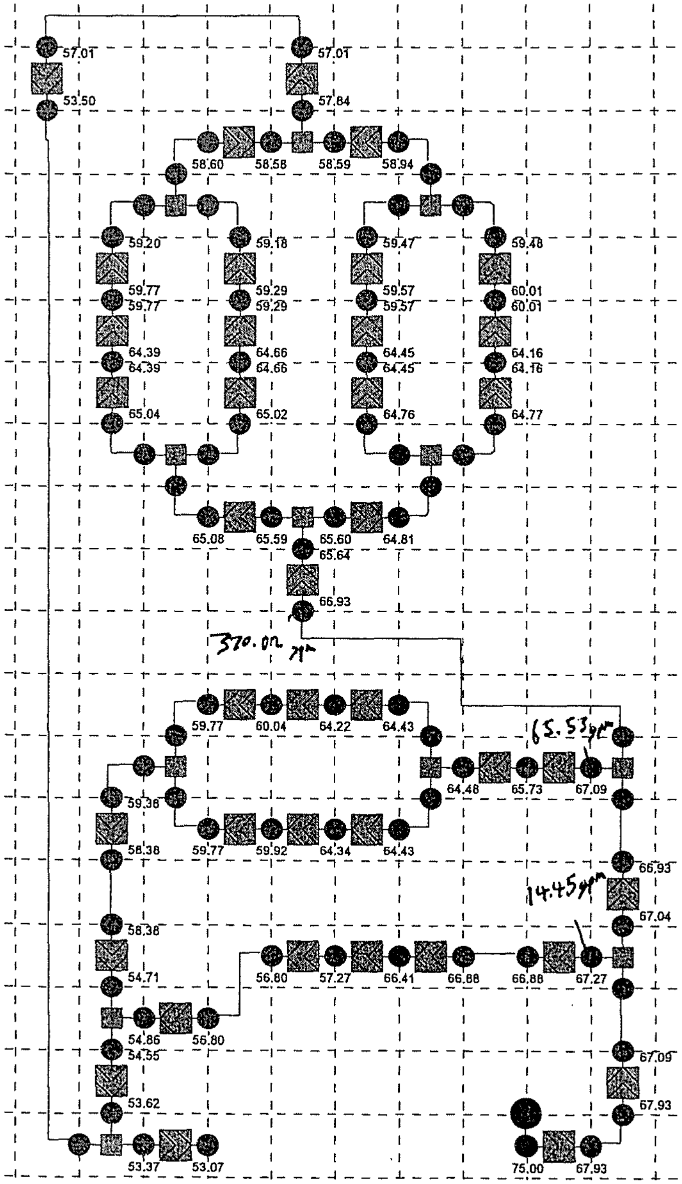
APPENDIX G

Pressure in PSIA



APPENDIX H

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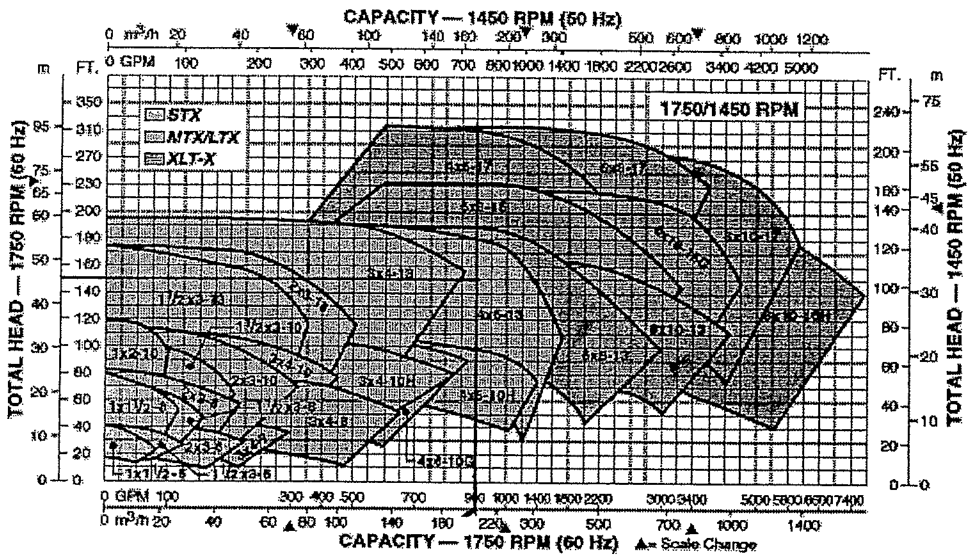

50 Hz 1480 RPM	60 Hz 1780 RPM
1X1.5-6-Alloy	1X1.5-6-Alloy
1x1.5-6-Iron	1X1.5-6-Iron
1.5X3-6	1.5X3-6
2x3-6-Alloy	2x3-6-Alloy
2x3-6-Iron	2x3-6-Iron
1x1.5-8-Alloy	1x1.5-8-Alloy
1x1.5-8-Iron	1X1.5-8-Iron
1.5X3-8-Alloy	1.5X3-8-Alloy
1.5X3-8-Iron	1.5X3-8-Iron
2X3-8-Alloy	2X3-8-Alloy
2X3-8-Iron	2X3-8-Iron
3x4-7	3x4-7
3X4-8	3X4-8
3X4-8G	3X4-8G
1X2-10-Alloy	1X2-10-Alloy
1X2-10-Iron	1X2-10-Iron
1.5X3-10-Alloy	1.5X3-10-Alloy
1.5X3-10-Iron	1.5X3-10-Iron
2X3-10	2X3-10
3x4-10	3X4-10
3X4-10H	3X4-10H
4X6-10	4X6-10
4X6-10H-Alloy	4x6-10H-Alloy
4x6-10H-Iron	4x6-10H-Iron
4X6-10G	4X6-10G
1.5x3-13-Alloy	1.5x3-13-Alloy
1.5x3-13-Iron	1.5x3-13-Iron
2X3-13	2X3-13
3x4-13	3x4-13
4X6-13	4X6-13
6X8-13	6X8-13
8x10-13	8x10-13
6X8-15	6X8-15
8X10-15	8X10-15G
8X10-15G	8x10-16H

Goulds Pumps
ITT Industries

CENTRIFUGAL PUMP CHARACTERISTICS

RPM 1780 CDS 4027-3

Cat Arm

Model:	3196
Size:	4x6-10H
Imp. Dwg.	C02478A
Pattern	63702
Eye Area	27.1 in²