PD-ABA-187
60471

CAPE VERDE DESALINATION AND POWER (SAL) PROJECT

CONTRACT NO. AID/afr-C-1531

Report No. 34

SITE INSPECTION TRIP REPORT

for

AGENCY FOR INTERNATIONAL DEVELOPMENT

June 15, 1984

W.O. 4850

Submitted by:

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I. INTRODUCTION

The inspection trip to Sal Island Desalination Plant was conducted in accordance with the instructions from Agency for International Development, AID. Refer to Appendix A which provides the background of the plant problems which necessitated this evaluation trip.

The reverse osmosis (RO) seawater desalination plant equipment was supplied by Polymetrics, Inc. of Sunnyvale, California and was installed at Palmeira on the Island of Sal, Republic of Cape Verde. ELECTRA (Electricidade e Agua do Cabo Verde) is the owner of the plant.

Objectives:

The objectives of the trip was to inspect and evaluate all failed and underperforming parts within the warranty period as well as to evaluate the plant performance at the end of one-year operation and to determine the action necessary by the manufacturer to meet the guarantee and warranty clauses. The parameters for which the plant is guaranteed by Polymetrics are as follows:

1. Each permeator (and other components) to be free of defects in materials and workmanship.

2. Each permeator to meet guaranteed performance such as permeate flow rate and salt passage specifications at the end of one-year of operation.

3. Product Water Capacity of 660 cubic meters per day.

4. Product water quality at 600 mg/l total dissolved solids (TDS) or less (specified).

5. Product water recovery of 25 percent at feedwater design temperature of 25°C.

6. Every consumption per unit product output at 5.6 Kwh/cu.m with energy recovery turbine.

II. INSPECTION

Plant inspection was conducted by BRISC Engineer during the period of May 22 thru 25, 1984. The results of inspection and tests are described below:

A. Mechanical

1. Pulsation Dampeners associated with the high pressure Reverse Osmosis Feed Pumps.

   There are three (3) pulsation dampeners for each high pressure pump and a total of nine (9) pulsation dampeners for the-plant. Figure 1 shows the locations of the tees and accumulator body of the pulsation dampeners at the high pressure pumps suction and discharge. Visual inspection and test with a magnet showed that the pulsation dampeners were painted carbon steel whereas the specification calls for SS316L stainless steel. The tees and housings of the pulsation dampeners were heavily corroded and pitted due to chloride, galvanic and crevice attack. Figures 2, 3, and 4 show the corrosion of the dampeners and the magnetic pin sticking at the dampeners. Carryover of the corrosion products of these dampeners, affected the permeator performance and contributed to the product recovery drop from design recovery of 25 percent to actual between 18 and 20 percent.

2. High Pressure Flexible Pipes

   The brine reject original flexible pipe in Train A was leaking from the inside caused by failure due to chloride attack and pitting. Figure 5 shows the brine reject pitted flexible pipe in Train A.

   All the replacement flexible pipes with rewelding done in South Africa are working well. All the original feedwater

H'

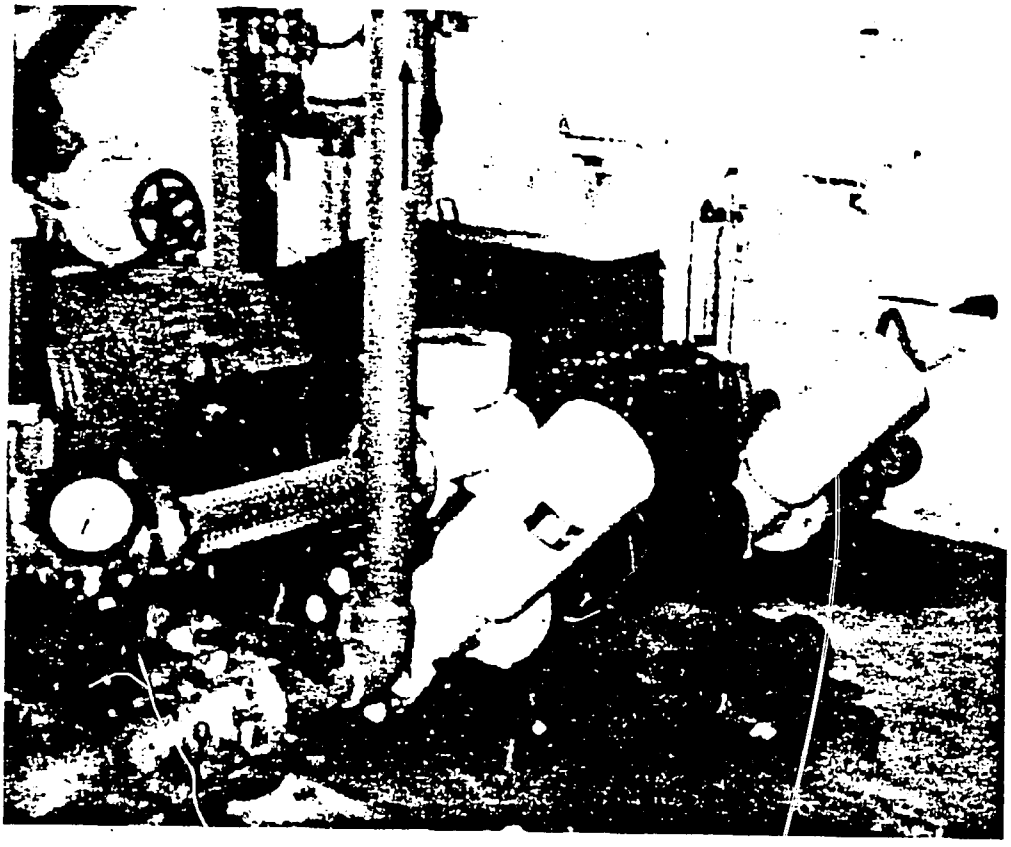


Figure 1 Location of the Pulsation Dampeners
at the High Pressure RO Feedwater Pump

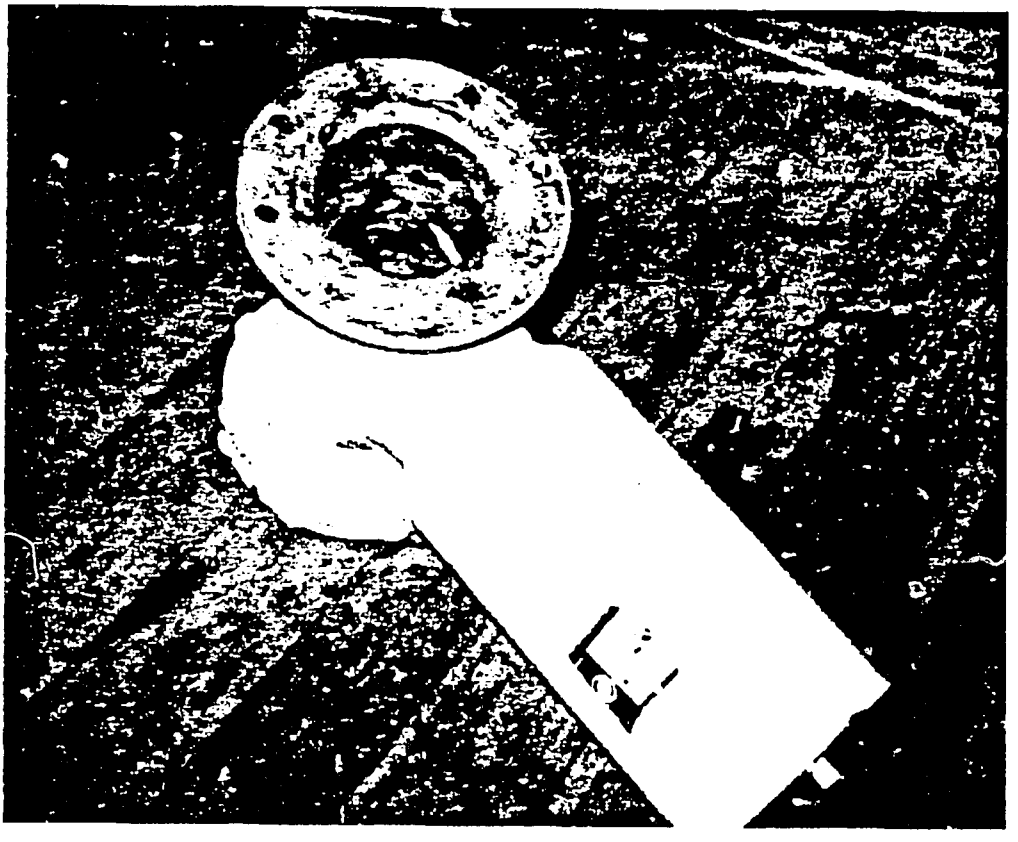


Figure 2 Corrosion of Pulsation Dampener

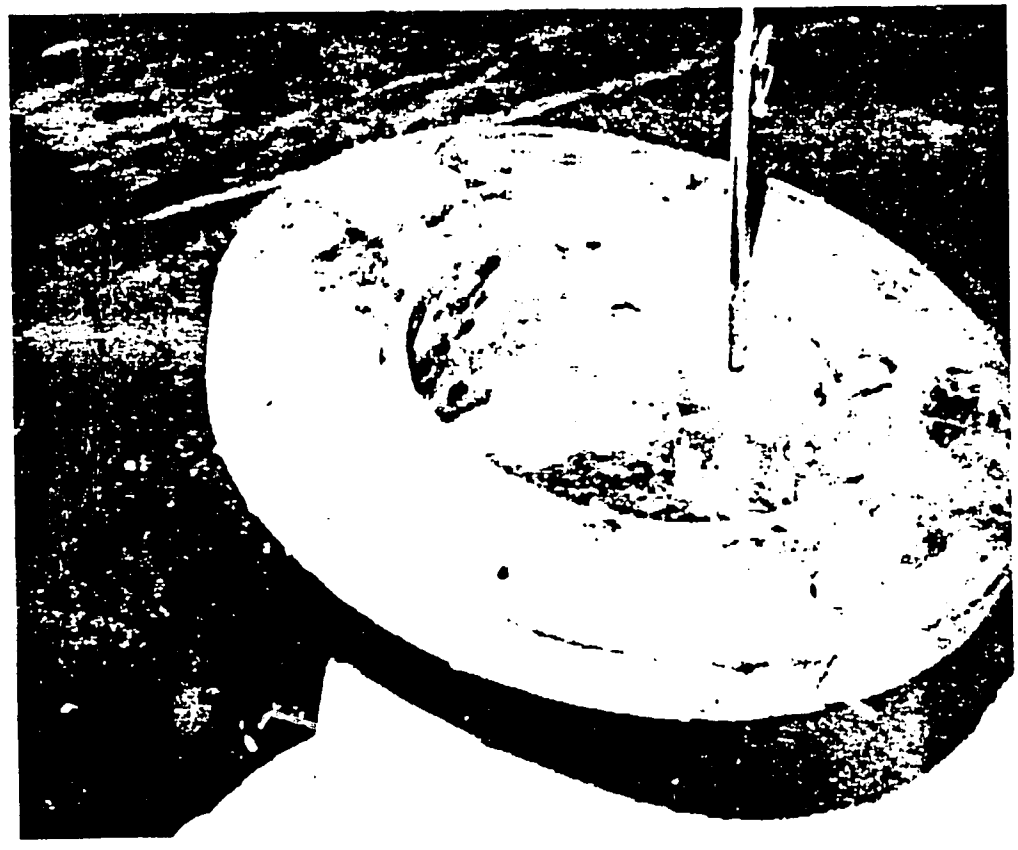
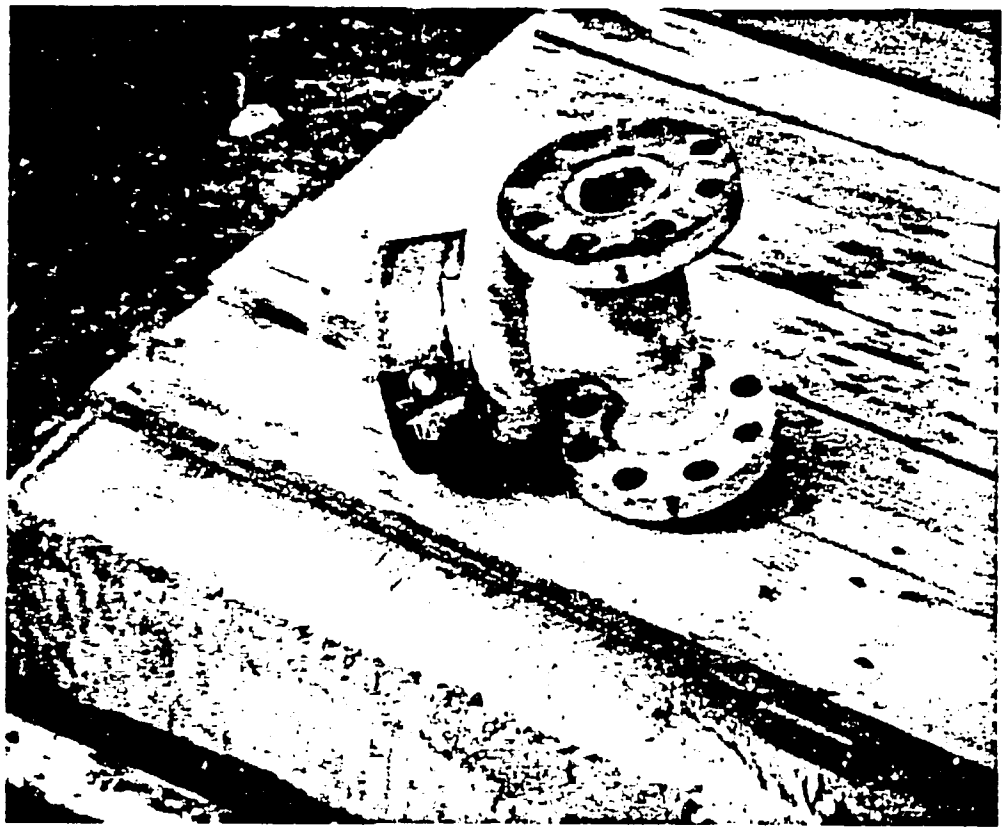


Figure 3 Corrosion of Pulsation Dampener



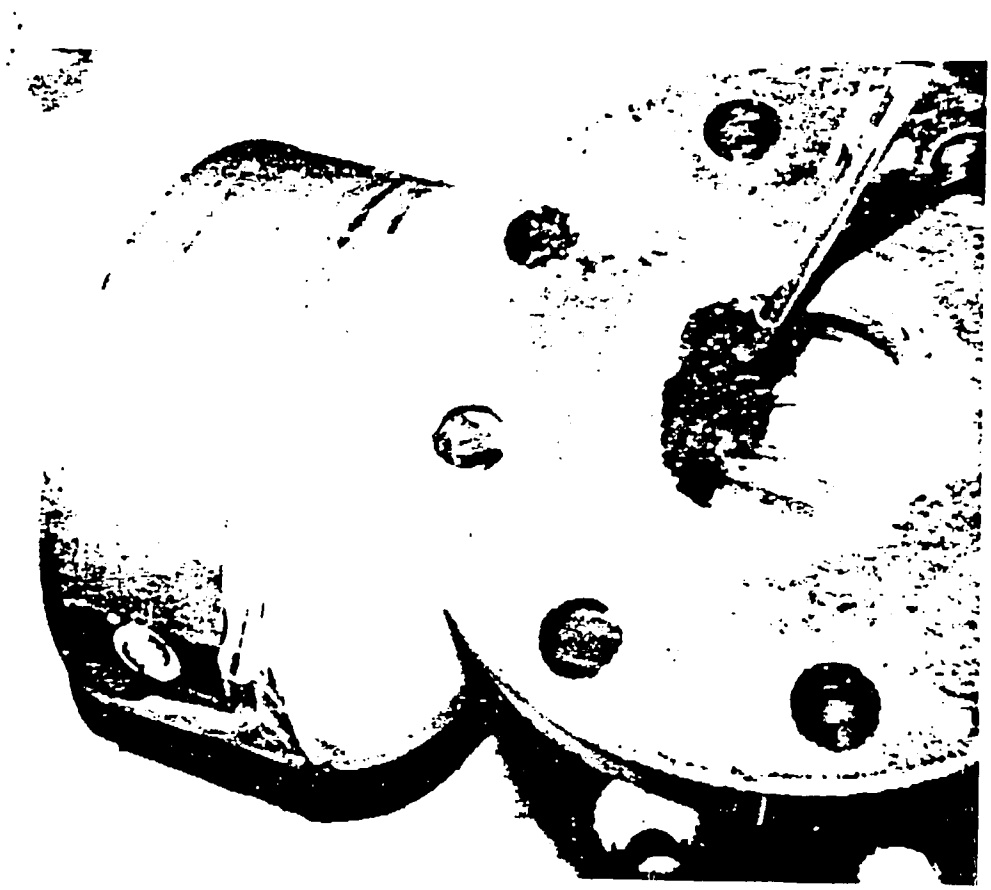
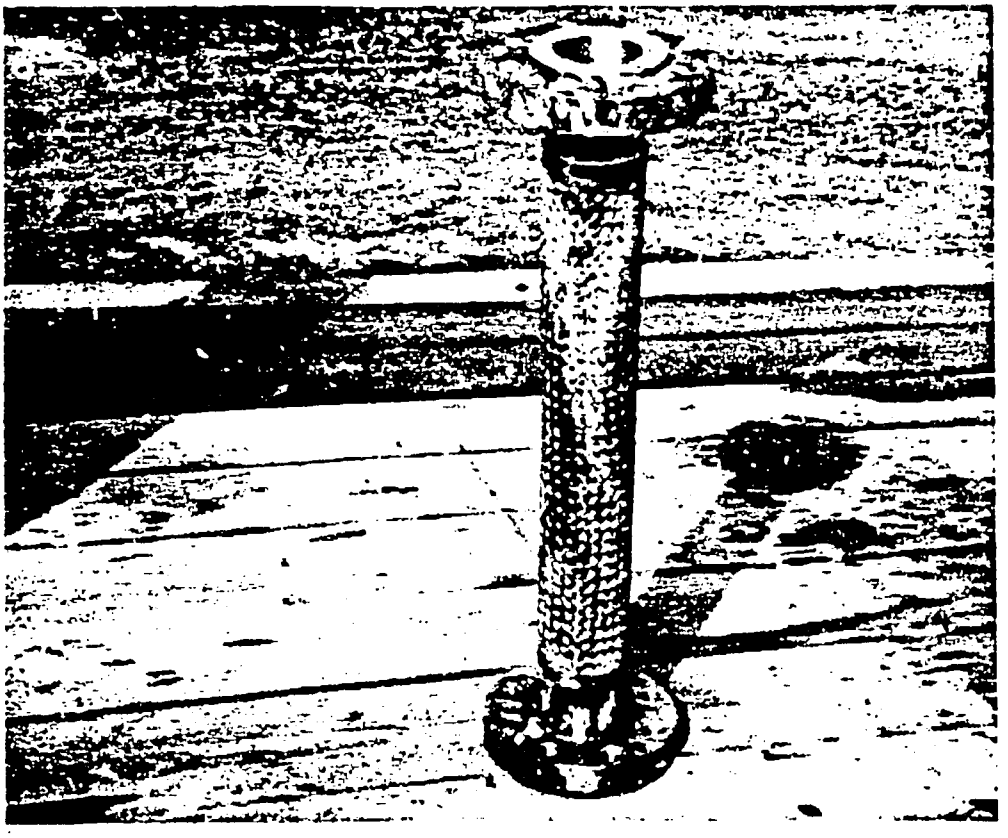


Figure 4 Corrosion of Pulsation Dampener



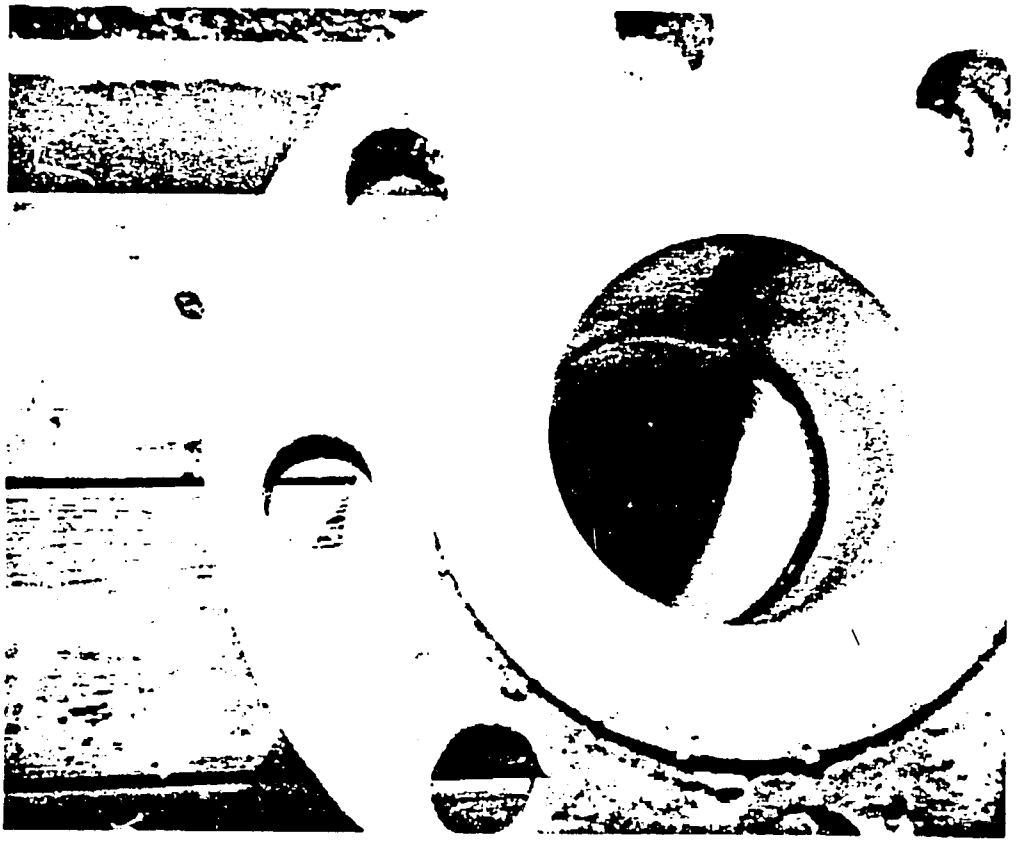


Figure 5 Train A Brine Reject Flexible Pipe Corrosion

flexible pipes were ruptured and leaking due to poor welding quality. Train B and C feedwater pipes were misaligned by about 1-inch. Subsequently, the misalignment was corrected and the old flexible pipes were replaced with the new ones.

3. High Pressure RO Feedwater Pumps

Oil was leaking from the pump in Train A and seawater was leaking in Train C.

4. RO Cleaning Pump

The cleaning pump impeller diameter was measured at 5-7/16 inch. This impeller diameter is not the right size. During startup polymetrics had to remove the strainer from the cleaning tank in order to provide enough cleaning solution capacity.

B. Instrumentation and Control

1. Feedwater Temperature Controller - The high/low feedwater temperature controller to decrease/increase hot water flow to raw water storage tank was 60 Hertz instead of 50 Hertz.

2. Pressure Transmitter - All the pressure transmitter signals at 31.5 mA (for excessive pressure in high pressure manifold) to shutdown high pressure pumps was too high. The signal should be 10-12 mA. The three pressure transmitters plus one spare are out-of-service.

C. Permeators

Figure 6 shows the permeator assemblies with their serial number and rack number in each of the RO skid or train. Divalent and monovalent analyses were conducted for the product in each permeator. Figure 7 shows the results analysis for total dissolved

CAPE VERDE DESALINATION PLANT 660 CUM/DAY

POLYMETRIC/REVERSE OSMOSIS

DATE _____

Column / Row	BLOCK A				BLOCK B				BLOCK C			
	1		2		1		2		1		2	
	2 8200076	1 8200298			2 8109558	1 8109205			2 8108982	1 8108781		
	4 8200088	3 8201136			4 8108992	3 8108262			4 8200056	3 8109431		
	6 8201206	5 8110313			6 8109173	5 8108501			6 8110953	5		
	8 8110383	7 8201196			8	7 8200520			8 8109608	7 8110385		
	10 8201295	9			10 8110389	9 8109718			10 8109530	9 8201269		
	12 8201653	11 8201183			12 8201141	11 8200082			12 8200083	11 8201238		

Note: Numbering is left to right, top to bottom, facing the product end.

Comments:

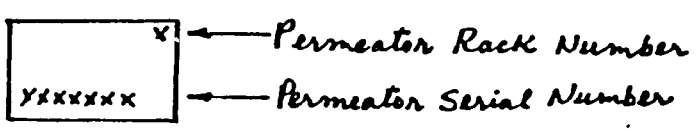


Figure 6. Permeator Assemblies

solids, calcium, chloride and bicarbonate in the product of each permeator. There were eleven (11) permeators operating for each train with a feed flow between 530 and 550 liters/min. The RO feedwater analysis for calcium, chloride, Bicarbonate and total dissolved solids were performed and the results are as follows:

RO Feedwater Analysis:

Ca - 352 PPM as Ca
Cl - 20,900 PPM as Cl
HCO_3^- - 120 PPM as $CaCO_3$
TDS - 55,000 µmhos

Although the conductivity meter was calibrated for TDS Analysis, all TDS and chlorides data in Figure 7 are plotted to confirm the accuracy of TDS Analysis for each permeator. Figure 8 shows that there is a good correlation between TDS is µmhos and chlorides in PPM as chlorides. At 364 PPM of chloride or 600 PPM of sodium chloride, the corresponding TDS was about 1180 µmhos. The correlation between TDS and chloride in Figure 7 was further confirmed by Figure 9. (Reference OSW Distillation Plant Data Book) which shows the correlation at 77°F (25°C) between 600 PPM sodium chloride and 1200 µmhos specific conductance. In Figure 8, it shows there is a deviation of about 10% from the correlation between TDS and chloride. Hence, it is a fair judgement that TDS at approximately 1350 µmhos is equivalent to 600 PPM.

CAPE VERDE DESALINATION PLANT 660 CUM/DAY

POLYMETRIC/REVERSE OSMOSIS

DATE _____

Row \ Column	BLOCK A 1		BLOCK A 2		BLOCK 1		BLOCK 2		BLOCK C 1		BLOCK C 2	
	1780 1.2 534 5	2	8300 43.6 2940 20	1	2100 4.0 790 5	2	3350 11.6 990 12.5	1	1100 0.8 314 5	2	1500 0.8 450 5	1
	1900 2.0 572 5	4	3100 6.0 910 5	3	2000 3.2 660 7.5	4	3850 12.0 1170 5	3	1320 1.2 378 5	4	1400 1.2 416 5	3
	1750 0.8 524 5	6	2150 2.4 646 5	5	2100 4.4 690 5	6	510 0.4 200 5	5 *	1500 2.0 438 5	6	X	5
	2000 2.8 760 7.5	8	4150 13.6 1680 10	7	X	8	3250 5.2 980 5	7	4400 20.4 1332 5	8	1320 1.6 394 5	7
	1750 2.8 640 7.5	10	X	9	690 0.4 240 5	10 *	2000 8.0 880 5	9	1300 1.6 370 5	10	1400 1.2 404 5	9
	1300 1.2 470 5	12	5100 19.2 2000 17.5	11	4300 12.8 1290 7.5	12	2000 3.2 660 10	11	1600 2.8 430 5	12	1180 1.6 410 5	11

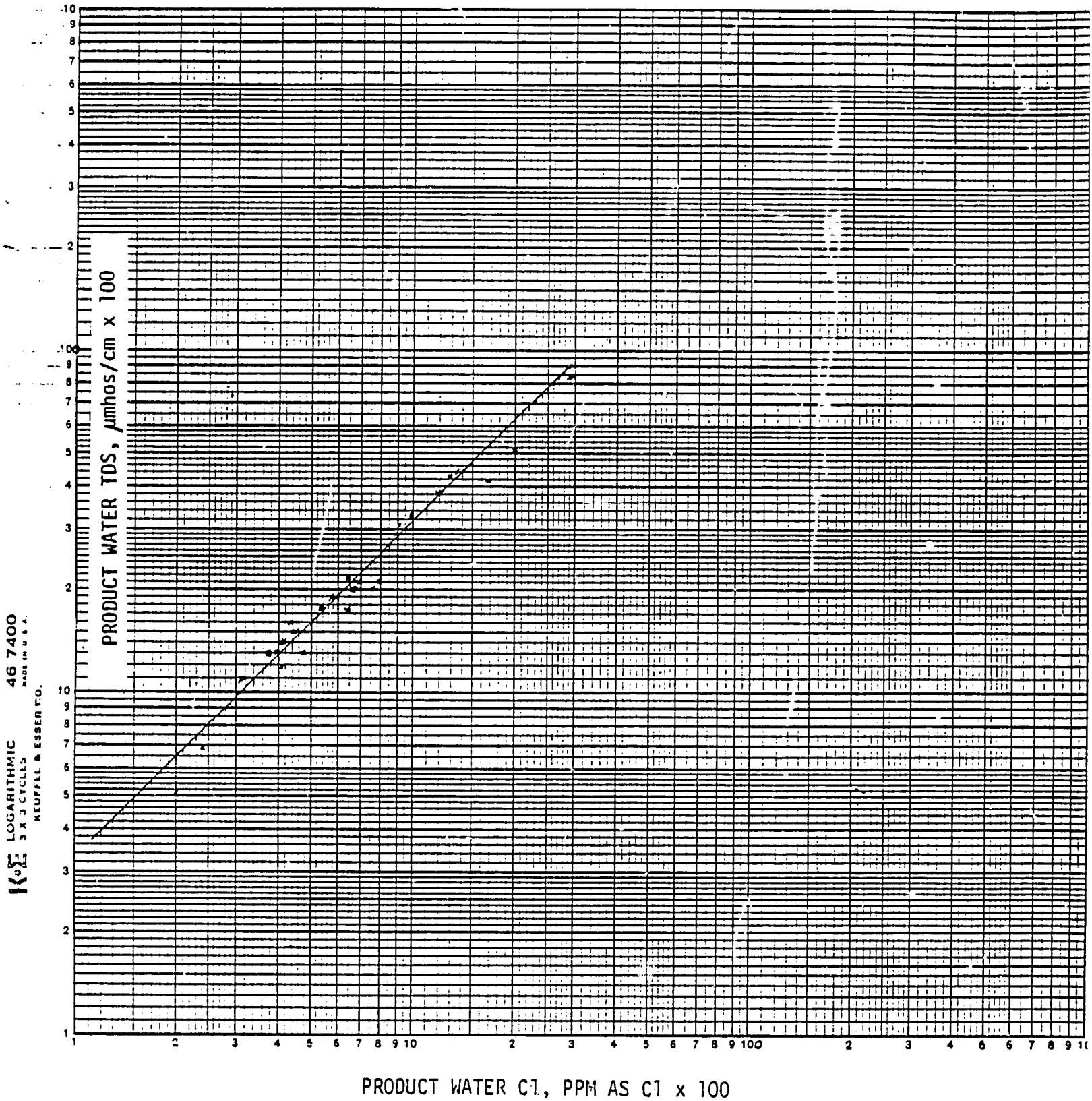
Note: Numbering is left to right, top to bottom, facing the product end.
* Newly installed permeator (from stock).

Comments:

TDS umhos	X ← Permeator Rack Number
Ca PPM as Ca	
Cl PPM as Cl	
HCO_3 PPM as $CaCO_3$	

Figure 7. Permeator Product Water Chemical Test Analysis

FIGURE 8. TOTAL DISSOLVED SOLIDS (TDS) VS. CHLORIDE (Cl) IN PRODUCT WATER



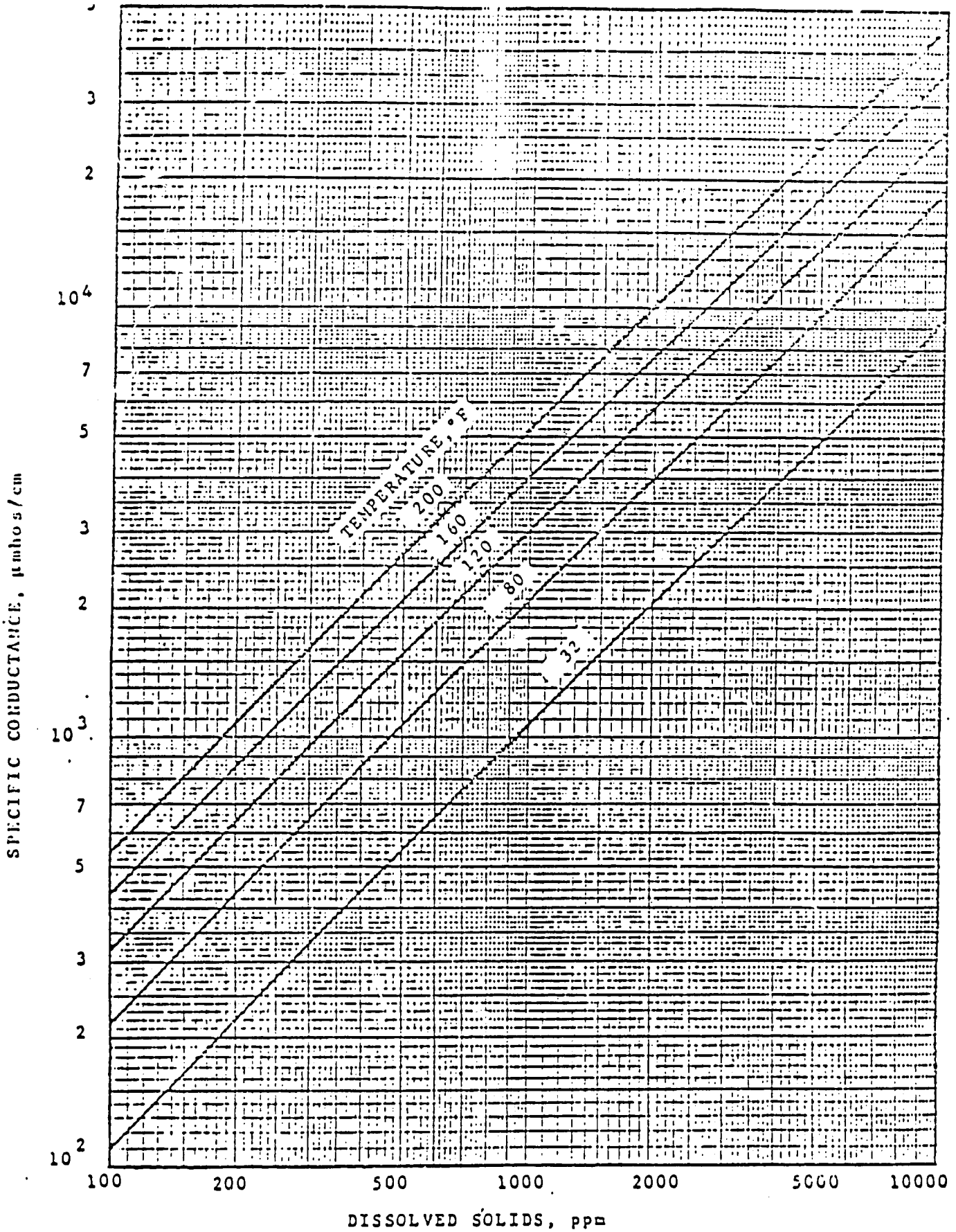


Figure 9. Specific conductance for water based on sodium chloride.

Reference: OSW Distillation Plant Data Book

The salt passage and salt rejection for DuPont B-10 permeators at standard test conditions are as follows:

Constituent	Salt Passage %	Salt Rejection %
Sodium, Na	1.5	98.5
Potassium, K	1.5	98.5
Calcium, Ca	0.6	99.4
Magnesium, Mg	0.6	99.4
Barium, Ba	0.6	99.4
Iron, Fe	0.6	99.4
Strontium, Sr	0.6	99.4
Nitrate, NO_3	2.3	97.7
Chloride, Cl	1.5	98.5
Sulfate, SO_4	0.6	99.4
Carbonate, CO_3	0.6	99.4
Phosphate, PO_4	0.3	99.7
Silica, SiO_2	2.3	97.7
Carbon Dioxide, CO_2	100	0
Hydrogen Sulfide, H_2S	100	0
TDS	1.5	98.5

Reference: DuPont/Permasep Engineering Manual

1. Train A

Table 1 shows the results of product water analysis and percent of salt rejection for total dissolve solids, calcium, chloride and bicarbonate. Except for permeator No. 12 or Serial No. 8201653, the test for TDS showed that all the other ten (10) permeators produced water quality above 1350 µmhos or 600 ppm and the salt rejection of lower than 98.5 percent. There were three (3) permeators (Nos. 1, 7 and 11) were above 4000 µmhos, three (3) permeator Nos. 3, 5 and 8) above 2000 µmhos and four (4) permeators (Nos. 2, 4, 6 and 10) above 1750 µmhos in product water TDS. Calcium analysis showed

only four (4) permeators that show a decline in calcium rejection while all the permeators show the decline of chloride rejection. The chloride to calcium (Cl/Ca) ratio of 67.4 in permeator No. 1 at 8300 µmhos is very close to the RO feedwater Cl/Ca ratio of 59.4. This is an indication of permeator deterioration. Permeator No. 11 is at 5100 µmhos also approaching to deterioration as in permeator No. 1.

The overall decline in salt rejection for TDS, calcium and chloride is an indication of any or a combination of mechanical leaks, fibersheet failure, membrane degradation and fouling. Reviewing the daily operating data, the RO feedwater always had zero chloride residue and SDI of less than 3.0.

When Train A was first started in April 1983, the product water recovery was between 26% and 28% and product water quality was 600 µmhos to 1000 µmhos. At year end of operation, the product water recovery and quality was average about 19% and 2300 µmhos. Table 2 shows the average decline of product water recovery and quality and average increase of pressure differential for permeators Nos. 1, 2, 11 and 12 in Train A. The feedwater flow to the RO was always approximately 540 liters/min. At this feedwater flowrates and product recovery between 25% and 19%, the product capacity was between 135 liters/min. and 102.6 liters/min. The design feedwater flow and product water capacity were 611 liters/min and 152.8 liters/min, respectively. With fouling in Train A, the product water capacity was reduced 33% from design. The temperature of RO feedwater was 25°C for the month of May which is the same as design feedwater temperature and no temperature correction factor is required to apply for product water capacity.

The decline in product water recovery and high pressure differential of the permeators is an indication of fouling. The

Permeators		TDS		Ca		Cl		HCO3		Cl/Ca
Rack No.	Serial No.	μmhos	%SR	PPM as Ca	%SR	PPM as Cl	%SR	PPM as CaCO3	%SR	Ratio
1	8200298	8300	84.9	43.6	87.6	2940	85.9	20	83.3	67.4
2	8200076	1780	96.8	1.2	99.6	534	97.4	5	95.8	445
3	8201136	3100	94.6	6.0	98.3	910	95.6	5	95.8	151.7
4	8200088	1900	96.5	2.0	99.4	572	97.2	5	95.8	286
5	8110313	2150	96.1	2.4	99.3	646	96.9	5	95.8	269
6	8201206	1750	96.8	0.8	99.8	524	97.5	5	95.8	655
7	8201196	4150	92.4	13.6	96.1	1680	91.9	10	91.6	123.5
8	8110383	2000	96.4	2.8	99.2	760	96.3	7.5	93.8	271.4
9	-	-	-	-	-	-	-	-	-	-
10	8201295	1750	96.8	2.8	99.2	640	96.9	7.5	93.8	228.6
11	8201183	5100	90.7	19.2	94.5	2000	90.4	17.5	85.4	104.6
12	8201653	1300	97.6	1.2	99.6	470	97.7	5	95.8	391.7

Table 1 Train A Product Water Analysis

Date Month/Year	Product Recovery %	Product Quality µmhos	Permeator Differential Pressure, Kg/Cm^2 Permeator Rack Nos. 1	2	11	12
4/83 @ 24°C	26 - 28	600-1000	-	-	-	-
5/83 @ 25°C	25 - 28	900-1200	-	-	-	-
6/83 @ 25°C	27 - 30	1800-1950	-	-	-	-
7/83 @ 24.5-25°C	26 - 30	1800-1900	1.8	1.5 - 1.9	1.9 - 2.1	1.9
8/83 @ 26-27°C	21 - 24	1350-2100	0.6 - 1.75	0.6 - 1.5	0.6 - 1.9	0.7 - 1.75
9/83 @ 27°C	24 - 26	1700-2000	0.75	0.6 - 0.7	0.75	0.8
10/83 @ 27°C	23 - 26	1250-2200	0.75	0.7 - 0.8	0.77 - 1.0	0.8 - 1.1
11/83 @ 27°C	22 - 24	1800-2200	0.9 - 1.0	0.75 - 0.9	0.95 - 1.15	1.0 - 1.25
12/83 @ 25-26°C	20 - 21	1900-2000	0.9 - 1.3	0.8 - 1.0	1.0 - 1.5	1.3 - 1.95
1/84 @ 23-24.5°C	18 - 20	1900-2000	1.5 - 1.8	1.1 - 1.5	1.9 - 2.5	2.1 - 2.6
2/84 @ 22-23°C	18 - 20	1500-1600	1.6 - 1.85	1.1 - 1.3	1.95 - 2.3	1.9 - 2.2
3/84 @ 23°C	18 - 20	1400-1550	0.95 - 2.2	0.7 - 1.5	0.96 - 2.8	1.0 - 2.65
4/84 @ 24°C	18 - 20	1700-2300	2.3 - 2.5	1.5 - 1.8	2.65 - 2.95	2.53-2.95
5/84 @ 25°C	18.3-18.7	2000-2700	2.2 - 2.3	1.5 - 1.65	2.85 - 2.95	2.58-2.85

Table 2 Train A System Profile

fouling is due to carry over of the corrosion product from the painted carbon steel tee and accumulator body of the pulsation dampeners located at the suction and discharge of the feed pump.

The permeators are now being cleaned with citric acid every three to four weeks instead of the normal cleaning frequency of three to four months. But one week after cleaning, the pressure differential increased back to the same value before it was cleaned. In early May of 1984, the iron content in the flushwater after cleaning was 0.5 ppm. On May 25, 1984, While Train A was being cleaned, the iron in the cleaning flushwater was 0.05 ppm. The frequent increase of pressure differential (about one week after cleaning) indicated the iron had already deposited inside the fibersheet of the permeator.

2. Train B

In early March of 1984, permeator Serial No. 8103749 was taken out from Train B to replace O-ring due to high salt passage. When the plant was started in April 1983, this permeator was producing water at 1650 µhmos. All other new permeators were producing between 400 - 800 µhmos. Inspection of this permeator revealed that the fiber bundle was shrunk caused by longitudinal compression. It also showed the split of fiber sheet and broken fiber. Figure 10 and 11 show the deformation and damage of this permeator.

The pressure differential in permeator Nos. 1, 2, 11 and 12 were much lower when compared with Train A and C. Table 3 shows the profile of Train B between April 1983 and May 1984. Train B was started up on May 25, 1984 with a new permeator (Serial No. 8108501) in Rack No. 5 so that samples can be taken for analysis. After 15 minutes, the reject brine pressure increased from 56 Kg/cm^2 to 60 Kg/cm^2. The feed

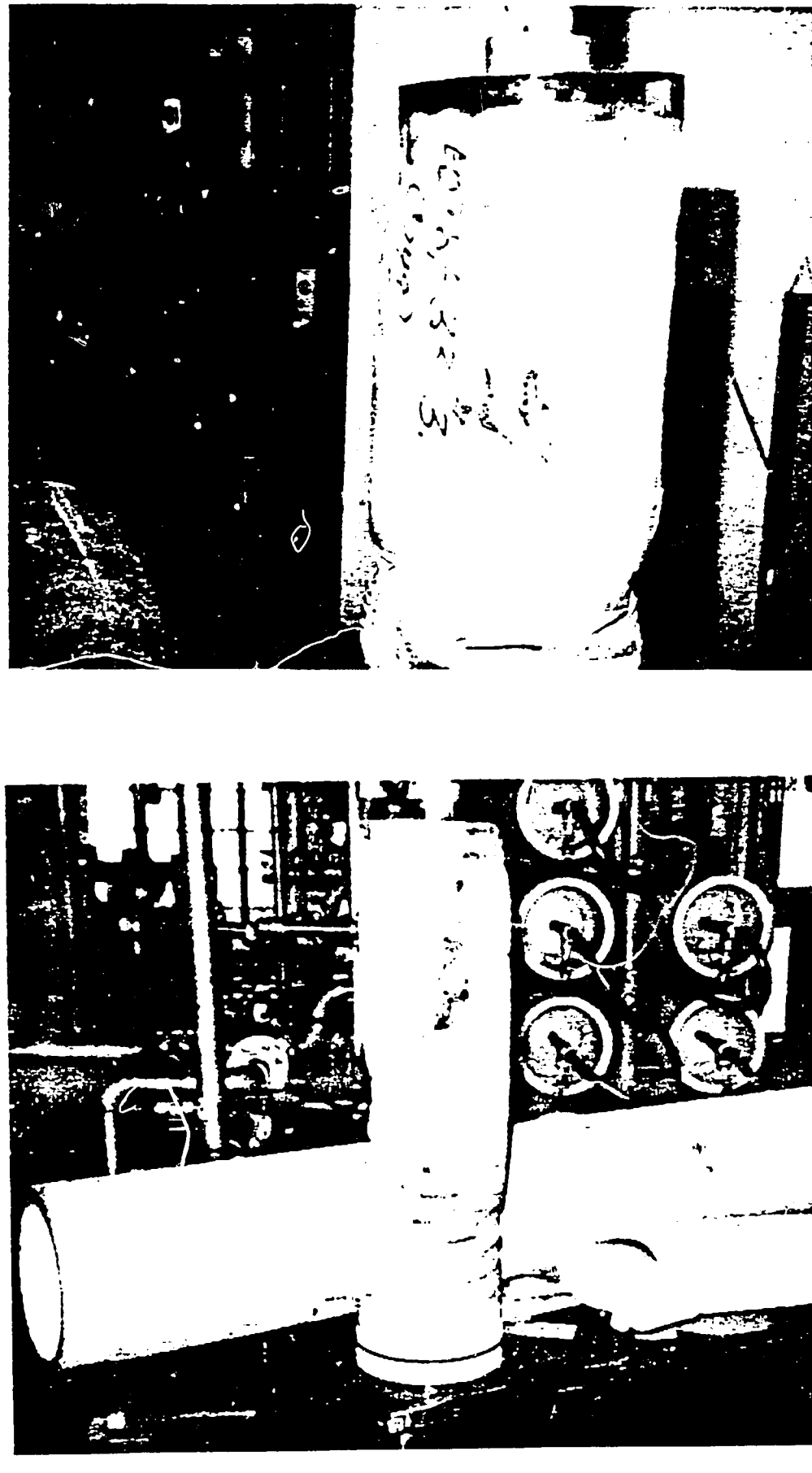


Figure 10 Train B Permeator Serial No. 8103749

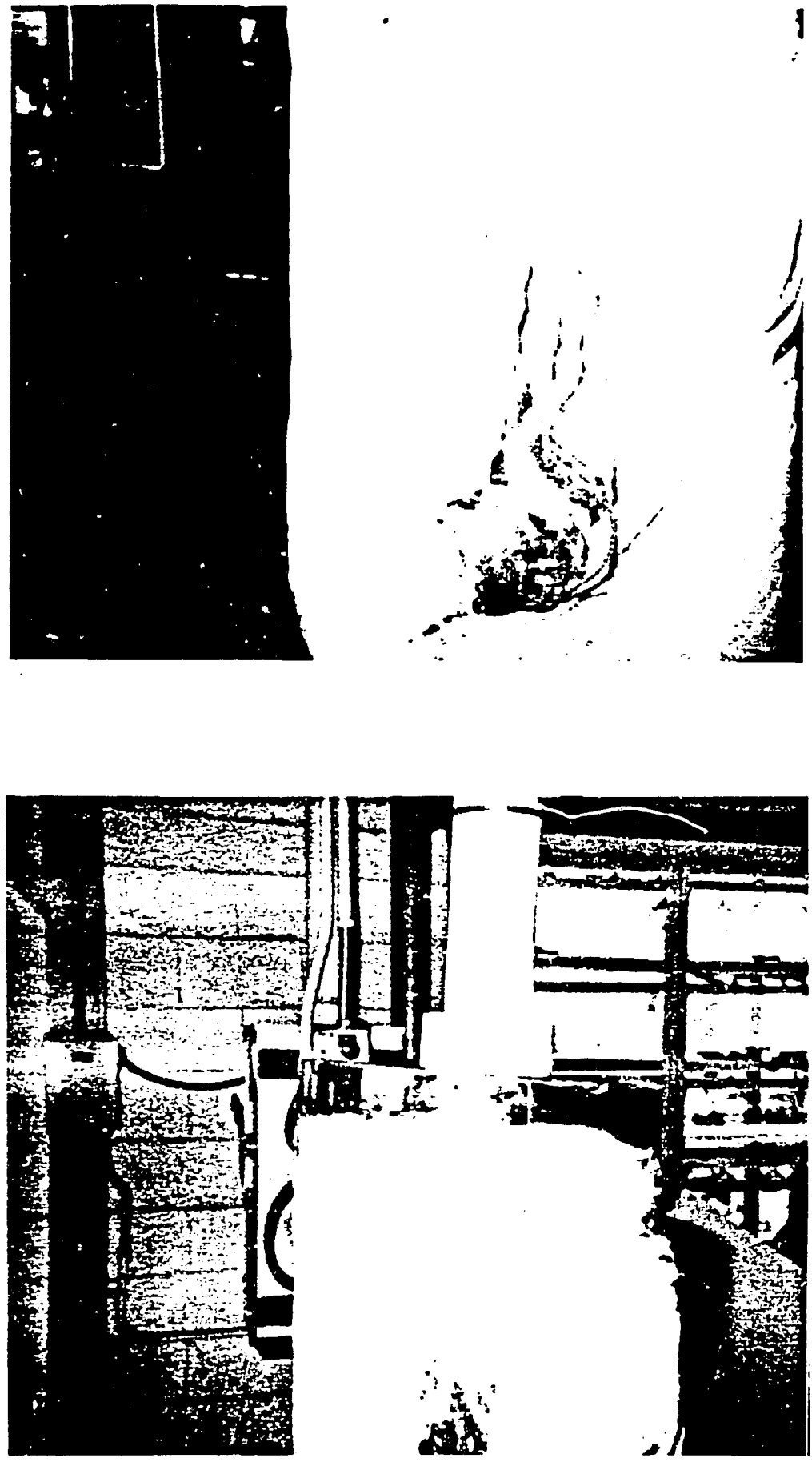


Figure 11 Train B Permeator Serial No. 8103749

pressure in all the trains were 60 Kg/cm^2. Normally, the pressure differential between the feed and reject was about 6 to 8 Kg/cm^2. Due to low pressure differential between the feed and reject, Train B was secured. The low pressure differential is an indication that feedwater is bypassing the permeators. The bypassing of feedwater may be due to ruptured feed tube or ripped fibersheet.

The product recovery was between 26% and 28% when it was just started up in April 1983 and gradually declined to between 16% and 18.7%. The increase of product water recovery between March and May of 1984 is due to the installation of 2 new permeators. The feedwater flow rate to the RO was about 540 liters/min. At this feedwater flow and product water recovery between 25% and 16%, the product capacity was between 136 liters/min and 86.4 liters/min. The design feedwater flow and product capacity were 611 liters/min and 152.8 liters/min, respectively. With fouling and bypass in Train B, the product water capacity was reduced 43.4% from design.

The low pressure product recovery was due to permeator fouling and/or fibersheet leakage. The corrosion of painted carbon steel tee and accumulator body of pulsation dampeners at the feedwater pump attributed to the fouling of the permeators. The high fouling of the permeator may contribute to the ripping of fibersheet.

Table 4 shows the results of product water analysis and percent of salt rejection for total dissolved solids, calcium, chloride and bicarbonate. Except in permeators Nos. 5 and 11, all other permeators produced water quality above 1350 µhmos or 600 PPM and salt rejection of lower than 98.5 percent. There were four (4) permeators (Nos. 1, 3, 7 and 12) were above 3000 µhmos and five (5) permeators (Nos. 2, 4, 6, 9, and 11) above 2000 µhmos in product water TDS. The overall salt rejections for calcium and chloride were also

Date Month/Year	Product Recovery %	Product Quality µmhos	Permeator Differential Pressure, Kg/Cm^2 Permeator Rack Nos. 1	2	11	12
4/83 @ 24°C	26 - 28	700-1000	-	-	-	-
5/83 @ 25°C	25 - 28	850-1400	-	-	-	-
6/83 @ 25°C	27 - 30	1550-1800	-	-	-	-
7/83 @ 24.5-25°C	26 - 30	1500-1800	0.95 - 1.3	1.2 - 1.5	1.1 - 1.3	1.4 - 1.3
8/83 @ 26-27°C	21 - 24	1350-2100	0.8 - 1.4	0.7 - 1.6	0.7 - 1.5	1.2 - 2.1
9/83 @ 27°C	24 - 26	1400-2000	1 - 1.25	0.9 - 1	1.1 - 1.25	1.4 - 1.7
10/83 @ 27°C	21.8-24	1700-2000	0.8 - 1.15	0.7 - 0.95	1.25 - 1.35	1.25-1.35
11/83 @ 27°C	19.6-24	1500-2400	0.75 - 0.95	0.75 - 0.95	1.25 - 1.35	1.0 - 1.25
12/83 @ 25-26°C	19.2-20.3	2350-2450	0.8	0.75	0.95	0.95
1/84 @ 23-24.5°C	17.5-20	2300	0.75	0.75	0.8	0.8
2/84 @ 22-23°C	~16 - 18.7	1700-2100	0.6 - 0.7	0.7 - 0.8	0.7 - 0.8	0.65 - 0.8
3/84 @ 23°C	21 - 22	1600-2000	0.4	0.6	0.5	0.5
4/84 @ 24°C	-	-	-	-	-	-
5/84 @ 25°C	23	-	0.35	0.5	0.5	0.4

Table 3 Train B System Profile

Permeators		TDS		Ca		Cl		HCO3		Cl/Ca
Rack No.	Serial No.	µmhos	%SR	PPM as Ca	%SR	PPM as Cl	%SR	PPM as CaCO3	%SR	Ratio
1	8109205	3350	93.9	11.6	96.7	990	95.2	12.5	89.6	85.3
2	8109558	2100	96.2	4.0	98.8	790	96.2	5	95.8	197.5
3	8108262	3850	93.0	12.0	96.6	1170	94.4	5	95.8	97.5
4	8108992	2000	96.3	3.2	99.1	660	96.8	7.5	93.7	206.3
5	8108501	510	99.0	0.4	99.8	200	99.0	5	95.8	500
6	8109173	2100	96.2	4.4	98.7	690	96.7	5	95.8	156.8
7	8200520	3250	94.1	5.2	98.5	980	95.3	5	95.8	188.5
8	-	-	-	-	-	-	-	-	-	-
9	8109718	2900	94.7	8.0	97.7	880	95.8	5	95.8	110
10	8110389	690	98.7	0.4	99.8	240	98.8	5	95.8	600
11	8200082	2000	96.3	3.2	99.1	660	96.8	10	91.7	206
12	8201191	4300	92.2	12.8	96.3	1290	93.8	7.5	93.7	100.8

Note: Permeator Nos. 5 and 10 - Newly installed permeator (from stock)

Table 4 Train B Product Water Analysis

declined. The chloride and calcium ratio (Cl/Ca) were low between 85 and 200 when compared to the new permeator (No. 5) at 500. The overall decline in salt rejection for TDS, calcuim, chloride and Cl/Ca ratio in an indication of any or a combination of mechanical leaks, fibersheet failure, membrane degradation and fouling. Reviewing the daily operating data, the RO feedwater always had zero chloride residue and SDI of less than 3.0.

3. Train C

Table 5 shows the results of product water analysis and percent of salt rejection for total dissolved solids, calcium, chloride and bicarbonate. There were five (5) permeators (Nos. 1, 3, 6, 9 and 12) with above 1350 µhmos or 600 ppm and one (1) permeator (No. 8) above 4000 µhmos in product water TDS. Permeator (No. 8) Serial No. 810 9608 shows low salt rejection for TDS, calcium and chloride and the ratio for chloride and calcium at 65.3 was approaching the same as in the feedwater of 59.4 is an indication of membrane degradation and/or fibersheet failure. Permeators (Nos. 1, 6 and 12) also shows sign of initial permeator failure but it is not as critical as the other permeator in Train A & B. Overall, the analysis results in percent of salt rejection for TDS, calcium and chloride in Train C permeators performed much better than the other two (2) trains. Daily operating data sheets showed that the RO feedwater always had zero chloride residue and SDI of less than 3.0.

Table 6 shows the gradual decline of product recovery from startup in April 1983 at 28% to May 1984 at 19%. The pressure differential for permeators (Nos. 1, 2, 11 and 12) were also increased gradually during the one year of operation. The decline in product recovery and increase of pressure differential is an indication of fouling. The fouling was due to the corrosion of painted carbon steel tee

Permeators		TDS		Ca		Cl		HCO3		Cl/Ca
Rack No.	Serial No.	µmhos	%SR	PPM as Ca	%SR	PPM as Cl	%SR	PPM as CaCO3	%SR	Ratio
1	8108781	1500	97.3	0.8	99.7	450	97.8	5	95.8	562.5
2	8108982	1100	98.0	0.8	99.7	314	98.5	5	95.8	392.5
3	8109431	1400	97.4	1.2	99.6	416	98.0	5	95.8	346.7
4	8200056	1320	97.6	1.2	99.6	378	98.2	5	95.8	315
5	-	-	-	-	-	-	-	-	-	-
6	8110953	1500	97.2	2.0	99.4	438	97.9	5	95.8	219
7	8110385	1320	97.6	1.6	99.5	394	98.1	5	95.8	246
8	8109608	4400	92.0	20.4	94.2	1332	93.6	5	95.8	65.3
9	8201269	1400	97.4	1.2	99.5	404	98.0	5	95.8	336.7
10	8109530	1300	97.6	1.6	99.5	370	98.2	5	95.8	231
11	8201258	1180	97.8	1.6	99.5	410	98.0	5	95.8	256
12	8200083	1600	97.1	2.8	99.2	430	97.9	5	95.8	153.6

Table 5 Train C Product Water Analysis

Date Month/Year	Product Recovery %	Product Quality µmhos	Permeator Differential Pressure, Kg/Cm^2 Permeator Rack Nos. 1	2	11	12
4/83 @ 24°C	26 - 28	700-1000	-	-	-	-
5/83 @ 25°C	25 - 28	850-1400	-	-	-	-
6/83 @ 25°C	26 - 27	1300-1450	-	-	-	-
7/83 @ 24.5-25°C	24 - 28	1500-1800	1.5 - 1.7	1.4 - 1.85	1.75	1.25 - 1.65
8/83 @ 26-27°C	24 - 25	1100-1800	0.7 - 2.0	0.6 - 1.75	0.6 - 2.1	0.5 -1.6
9/83 @ 27°C	23 - 25	1200-1500	0.8 - 0.9	0.7 - 0.8	0.9	0.6 - 0.7
10/83 @ 27°C	22.6-24.6	1400-1500	0.9	0.7 - 0.8	0.9 - 1.0	0.6 - 0.7
11/83 @ 27°C	22-24.2	1450-1500	0.7 - 0.85	0.7 - 0.75	0.75 - 0.8	0.6 - 0.7
12/83 @ 25-26°C	21 - 24	1500	0.9 - 1.15	0.75	0.8	0.7
1/84 @ 23-24.5°C	18.7-20	1500	1.2	1	1.3	0.9
2/84 @ 22-23°C	-	-	-	-	-	-
3/84 @ 23°C	-	-	-	-	-	-
4/84 @ 24°C	21.8-22.5	1450-1800	0.8 - 1.4	0.75 - 1.35	1.15 - 2.3	0.75 - 1.4
5/84 @ 25°C	19-21.8	1500	1.65 - 1.7	1.7 - 1.8	2.8	1.55 - 1.8

Table 6 Train C System Profile

and accumulator body of pulsation dampeners at the feedwater pump. The feedwater flow in Train C was always about 540 liters/min. At this feedwater rate and product recovery between 25% and 19%, the product capacity was between 135 liters/min and 102 liters/min. The design feedwater flow was 611 liters/min and product capacity was reduced 32.8% from design.

III. CONCLUSION

1. The tees and accumulator body of the pulsation dampeners at the suction and discharge of the high pressure feed pump were heavily corroded.

2. The tees and accumulators body of the pulsation dampeners were painted carbon steel materials.

3. Evidence of fouling occurred in the permeators due to carry over of corrosion products from the tees and accumulators body of the pulsation dampeners.

4. Due to iron fouling, the product water recovery decreased from design 25% to 19% in Train A, 16% in Train B and 19% in Train C based on actual feed and product flows.

5. Low differential pressure in Train B indicated seawater feed bypass in permeator due to feed tube rupture and/or fibersheet ripped.

6. Inspection found that permeator Serial No. 8103749 in Train B was completely and permanently damaged.

7. Ten (10) permeators in Train A produced product water quality at above 600 mg/l.

8. Nine (9) permeators in Train B produced product water quality at above 600 mg/l.

9. Six (6) permeators in Train C produced product water quality above 600 mg/l.

10. The average feedwater flow rate was 540 liters/min instead of 611 liter/min at feedwater pressure 60 Kg/cm^2. With fouling in the permeators, the product water capacity was reduced 33% in Train A; 43% in Train B and 33% in Train C.

11. Due to low productivity, electricity consumption per cubic meter of product water increased 37% taking into account the power recovery by the turbine.

12. High pressure RO feedwater pump discharge flow was always approximately 11.6% lower than design.

IV. RECOMMENDATIONS

1. All the corroded tees and accumulators body of the pulsation dampeners shall be replaced with SS316L or other corrosion resistant materials (such as aluminum-bronze as required for the HP pump liquid end) according to the specification.

2. All corroded brine reject flexible pipes shall be replaced with new ones. (Material and test certification documents are required.)

3. The feedwater temperature controller shall be replaced with 50 Hertz rating.

4. All pressure transmitter to shutdown high pressure pump shall be replaced with signal 10 - 12 mA.

5. Due to fouling, low productivity, low product water quality and permeator damage, a total of twenty-six (26) permeators shall be replaced immediately. The following are serial numbers of the permeators to be replaced in each train.

Train	Permeator Rack Nos.	Permeator Serial Nos.
A	1	8200298
	2	8200076
	3	8201136
	4	8200088
	5	8110313
	6	8201206
	7	8201196
	8	8110383
	10	8201295
	11	8201183

Train	Permeator Rack Nos.	Permeator Serial Nos.
B	1	8109205
	2	8109558
	3	8108262
	4	8108992
	6	8109173
	7	8200520
	9	8109718
	11	8200082
	12	8201191
	-	8103759

Train	Permeator Rack Nos.	Permeator Serial Nos.
C	1	8108781
	3	8109431
	6	8110953
	8	8109608
	9	8201269
	12	8200083

6. Train B should be opened up to check the cause for seawater bypass inside the permeator.

7. The existing cleaning pump impeller shall be replaced with the required size (larger impeller) and the drive rating with the new impeller should be verified.

8. The high pressure RO feed pump should be checked for plunger strokes, RPM and pully size to verify the reason of low flow.

APPENDIX A

Background:

Polymetric's equipment did not perform to meet the guarantee and warranties. Since January 1984, numerous telexes were sent by BRISC and GOCV and many telephone calls were place, but Polymetrics' response was very slow. In the meantime, overall performance of the plant was gradually deteriorating and AID/GOCV were much concerned. In April 1984, Polymetrics was officially notified regarding the breach of warranty and were given a period of sixty (60) days to correct the deficiencies. Polymetrics agreed to comply, but did not want to inspect the site to fully evaluate the problems. In the meantime, corrosion of certain parts was aggravating the situation and both product quality and recovery were deteriorating.

Under the circumstances, in a meeting held in early May 1984, AID/BRISC determinedd that an urgent site inspection was required to fully evaluate the matter. Specifically, the major problems to be evaluated were as follows:

a) Pulsation dampeners housing and tee material - BRISC repeatedly requested that Polymetrics correct the corrosion problem with this hardware. Polymetrics agreed to investigate and recently advised by telephone that they were most likely made of SS316L. The material as supplied, however, is only painted carbon steel and is inappropriate for the service. Iron in the corrosion product has been causing fouling in the membranes, requiring frequent cleaning. Later verification with the manufacturer revealed that the painted carbon steel material was chosen by Polymetrics against the recommendation of the manufacturer, who suggested their stainless steel line of product.

b) Train B permeator performance - overall performance of this train deteriorated, with very low delta-P across membrane, it was taken out of service and stored. One permeator shrunk and collapsed and was rendered unusable. Salt rejection in several permeators in Trains A and B are gradually decreasing, thus causing product water TDS higher than guaranteed values.

c) Possible corrosion inside the HP pumps.

d) Product recovery rate has lowered.

e) Failure of SS flexible connections - poor welding quality and corrosion caused this problem.

f) Pressure transmitters malfunctioned.