PDBBD076

EVALUATION REPORT

OFFICIAL PROJECT DOCUMENT

# AN INVESTIGATION of CURRENT PROBLEMS at CAPE VERDE DESALINATION and POWER PROJECT (SAL)

655-0005

Prepared For

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# I. SUMMARY

## A. BACKGROUND INFORMATION

The desalination plant at Sal has been plagued with problems virtually since its start. The plant began operation in March 1983. By June the product water was no longer meeting design requirements. By August, the plant was no longer capable of making the design capacity of product water. The records indicate that the plant has never operated properly with all of the equipment installed.

Burns and Roe Industrial Services Corporation (BRISC), and Polymetrics, Inc. (Polymetrics) both reported (see "IV.B DOCUMENTS CONSIDERED") on the plant and recommended corrective action. There are some differences in their recommendations. There is a sharp difference of opinion regarding who is responsible for replacement of 26 permeators (the heart of the plant, and the principal reason for the high salinity and low production of the water):

1. BRISC took the position, that 26 of the 33 permeators originally installed, were irreversibly damaged by the iron which came from the corrosion of the carbon steel pulsation dampeners (supplied by Polymetrics), after their linings failed (See IV.B.3.A).

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

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

   Due to fouling, low productivity, low product water quality and permeator damage, a total of twenty-six (26) permeators shall be replaced immediately."

   However, BRISC conditioned their Final Report (See IV.B.3.C):

   "Excessive ΔP's may have been caused by the iron from the accumulator or by suspended material in the seawater feed or a combination of the first two factors ....it is impossible to determine which of these two factors is to blame..."

2. Polymetrics, on the other hand (though they admitted that the pulsation dampeners had, in fact, corroded, and replaced them with stainless steel ones, which they should have supplied, originally), took the position that the iron in the system did not damage the permeators. Instead, they claim that the permeators were damaged by misoperation of the plant, specifically:

"Irreversible damage has been done to the permeators by not maintaining the feed/brine pressure drop in accordance with the O&M manual. In view of this, and in accordance with Paragraph 7 of the Warranty, the claim is denied." (See IV.B.4).

B. OBJECTIVES

The Author was called upon to achieve the following objectives:

1. Make an independent survey to determine:

   a. What needs to be done to make production of design quality and quantity of water and power a reality at the Sal Island Desalination Plant.

   b. Who should be responsible for replacing defective equipment.

2. Report on these findings:

   a. At a debriefing meeting with the USAID Mission Representative at Cape Verde.

   b. At another debriefing at USAID in Washington, DC.

   c. In a Final Report to USAID in Washington, DC.

depending on the source, but generally less than 500 ppm is regarded as desirable, and less than 1000 ppm is mandatory). One can easily taste the salt in the product water.

3. POWER

At the time of the Author's visit, no power was being produced, although, apparently it soon will be. One of the generators had been shutdown for scheduled maintenance, when the other one failed. The cylinder liners had corroded through. The product water, which is used as a coolant for the generators, is very slightly acidic (pH 6.7). This is believed to be the cause of this corrosion problem. It was also the cause of the product water in the storage tank turning brown - so-called "brown water". Since January of 1985, Electra has been adding lime and soda ash to the product water, in order to make it alkaline (pH 8.5). This has already made the "brown water" problem disappear. It should also prevent recurrence of the rapid corrosion of the cylinder liners.

4. OPERATION AND MAINTENANCE

Since its inception, the plant has been operated and maintained under the direction of Engineer A. Rabalo. The Author engaged in discussions about the operation and maintenance of the plant with Engineer Rabalo every day for over a week. Engineer Rabalo appears qualified to operate and maintain the plant and appears dedicated to making the plant a success. The Author also reviewed countless documents (operation, laboratory, and maintenance records (See IV.B.7), and spent a portion of each day, and one full day, observing plant operation and maintenance. He also engaged in discussions with members of the operation and maintenance staff, and the laboratory staff. They all clearly understood what they were doing, and also appear dedicated to their work.

5. CONDITION OF THE PLANT

Considering that 26 out of 33 permeators originally supplied were severely damaged (the other 7 were, no doubt, at least slightly damaged), and that flexible hoses that don't leak at the welds have never been supplied, and numerous other problems, relating to incorrect materials used, and lack of spare parts, it is remarkable that the plant is doing as well as it is. This must be regarded as a tribute to the great skill and dedication of the Electra staff. Fortunately, the rate of deterioration of the plant has dropped drastically, now that the carbon steel parts have been replaced by stainless steel.

But the plant, in its present condition, requires significant upgrading in order to make it a credit to the United States and American technology. Detailed recommendations are presented in Section III, but, in general, the plant needs to have at least enough permeators replaced to lower the salinity to an acceptable level, and produce enough water to meet the demand. Ideally, all 26 permeators should be replaced so that the plant will do what USAID offered to the Government of Cape Verde. The other thing, that is sorely needed, is an adequate supply of spare parts, particularly those which come from the U.S.

E. HOW THE PROBLEMS CAME TO BE

Section "V.B. POLYMETRICS' PERFORMANCE" states that, "The principal problems with Polymetrics' performance stemmed from their poor selection of materials and equipment." Unfortunately, simply replacing the defective parts did not completely solve the problem in all instances. The high pressure flexible hoses that leaked at the welds were replaced with other high pressure flexible hoses that leak at the welds. This is a serious problem, but the corrosion of the carbon steel pulsation dampener bodies was far more serious. These have now been replaced with stainless steel. Hence, these parts were no longer a source for iron in the system. As a result, deterioration of the system has nearly drawn to a standstill, but the damage had already been done.

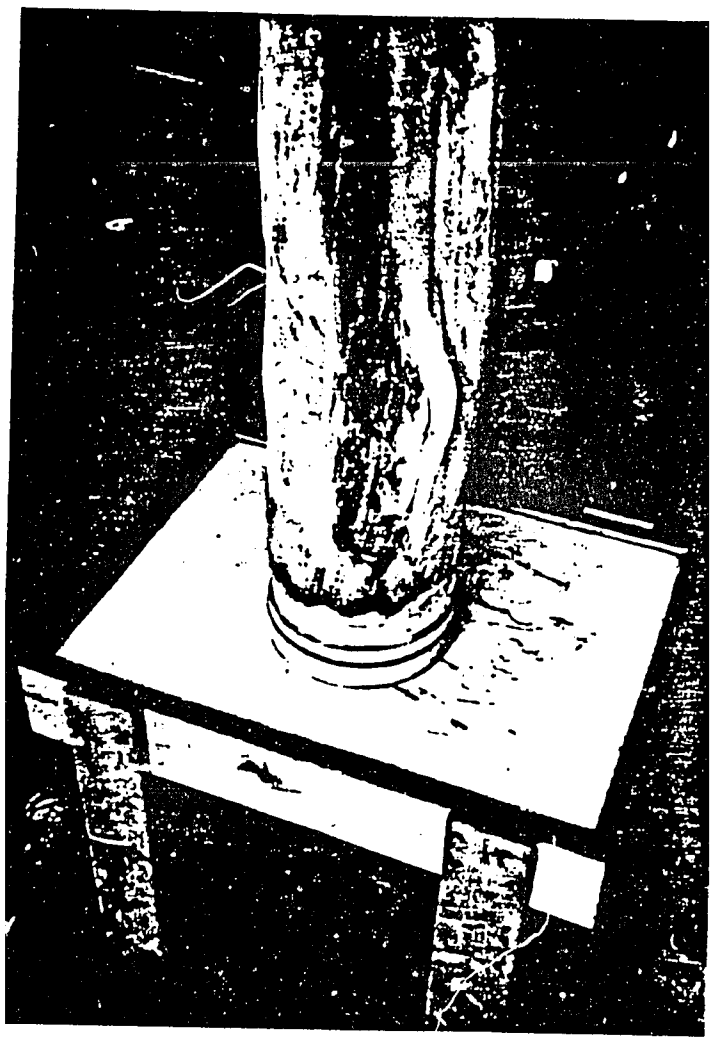
1. THE FOULING OF THE PERMEATORS

A total of 26 out of the original 33 permeators had been sufficiently (and irreversibly) damaged, that they could no longer meet design water quality or quantity or both. Polymetrics knew that the corrosion was occurring, however, "Polymetrics allowed operation to continue as the corrosion rate at a pH of 8.2 is low..." They deny that the iron was there in significant amounts, but they are unconvincing. They state (IV.B.4 - III.1 - page 2):

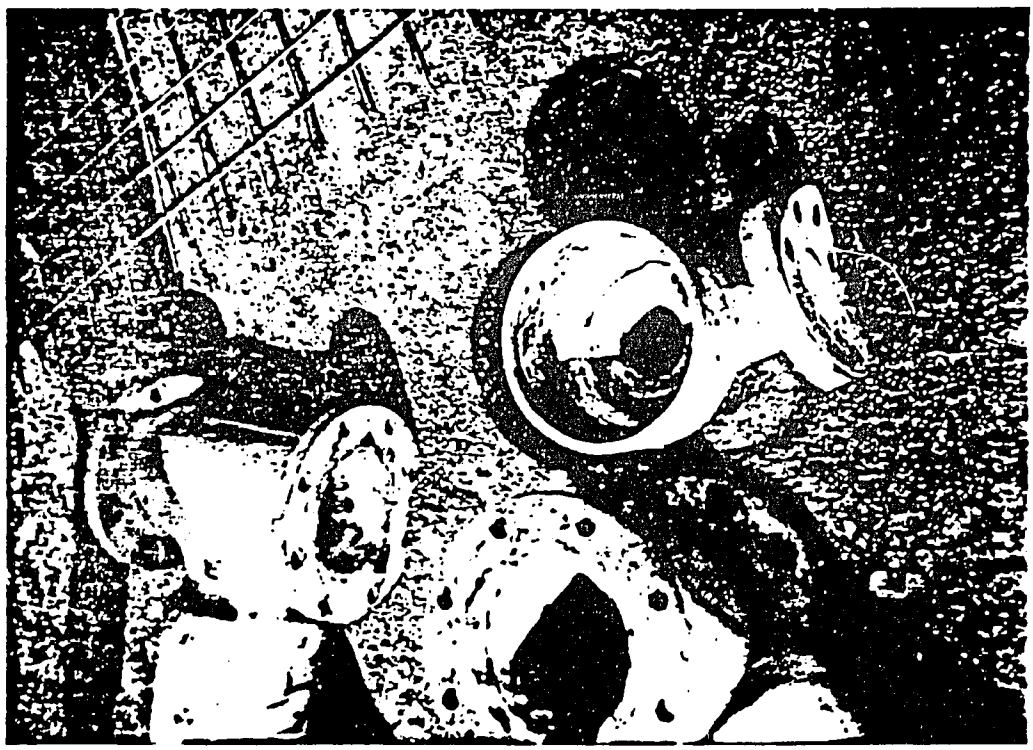
"Further, the permeators were cleaned with Citric Acid and Sodium Hydrosulphite solutions to remove any iron. The solutions had a low iron level after recirculation which indicated that the permeators were not iron fouled. Therefore, it was concluded that the steel pulsation dampeners had not damaged the permeators."

According to Engineer Rabalo, they did run a colorimetric analysis of a sample, but they did not report their results, other than to say "...had a low iron level." At the same time, Electra took samples and ran a chemical analysis. The analysis was designed to look for very low levels of iron. There was so much iron there, that it overran the previously prepared reagents (prepared on the assumption that less iron would be present). New reagents were prepared and another analysis was made. This analysis showed 27.8 milligrams/liter (IV.5), more than 500 times the maximum level for safe operation recommended by DuPont (Ref. A), the manufacturer of the permeators. DuPont also warns (Ibid.) that high iron concentrations can damage the permeators in less than 24 hours.

Also, Polymetrics never proposed an alternate place where the iron from the corroded pulsation dampener might have gone. At least one piece, 3x1x1 cubic centimeters, of iron from a pulsation dampener was found inside one of the permeators (IV.5). No other observer agreed with Polymetrics' position (See V.A.).



PICTURE 1 - AN IRREVERSIBLY DAMAGED PERMEATOR



PICTURE 2 - ORIGINAL CORRODED PULSATION DAMPENERS AND TEE

Polymetrics states that fouling was caused by mis-operation of the plant (See A.2 above for the direct quote), but their attempt to show this was weak, and internally inconsistent. First they state that (IV.4 - III.5.b- page 5):

"The first recorded differential pressures (Delta-P) across the bundles (26 July 1983) indicated that the membranes were in need of cleaning. (New bundle delta-P's are around 0.4 - 0.6 kg/cm²). The delta-P's at this time were 1.0 - 1.95 kg/cm². All batteries were cleaned around 19 - 24 August 1983 with Delta P's being 0.5 - 0.7 kg/cm²) or as new. Thus, as of August 1983, the damage was yet to occur."

In other words, operation at high delta-P did <u>not</u> damage the membranes. But, on the very next page:

"Irreversible damage has been done to the permeators by not maintaining the feed/brine pressure drop in accordance with the O&M manual. In view of this, and in accordance with Paragraph 7 of the Warranty, the claim is denied."

Here they have shifted from no damage to irreversible damage. The only way in which that could be true, would be if the alleged misoperation occurred <u>after</u> August 1983. The records clearly show that this is not the case. According to BRISC (IV.3.A - 11.C.1):

"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 [as] before it was cleaned.... The frequent increase of pressure differential (about one week after cleaning) indicated the iron had already deposited inside the fibersheet of the permeator."

But, it is quite clear that the permeators were damaged before June 1983. For the reader's convenience, Tables 2, 3, and 6 from IV.3A have been reproduced here. Design product water quality TDS is less than 600 ppm (equivalent to 1350 µmhos/cm. It can be seen in each table that this value was exceeded by June, and has steadily worsened.

| 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

| 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

| 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

This was confirmed by the fact that product water recovery fell below the design value of 25 percent by August, and has steadily deteriorated.

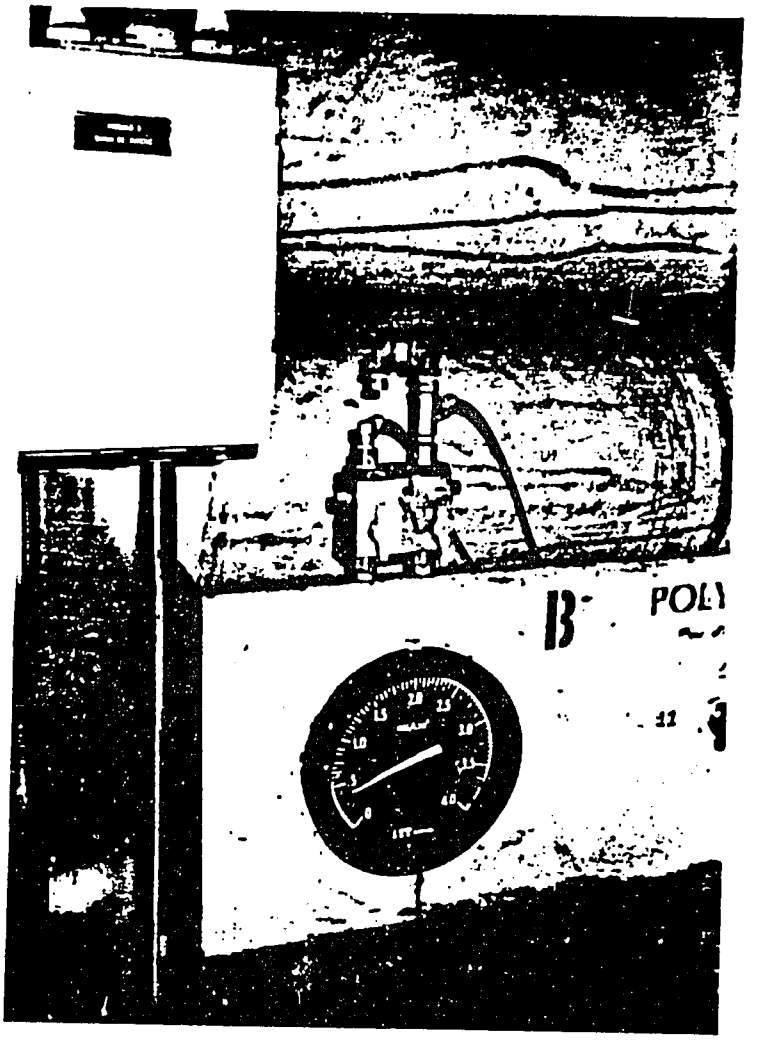
2. THE EARLY WARNING SYSTEM

It was, of course, very unfortunate that the linings in the pulsation dampeners failed, thereby creating an iron source inside the system. This situation was made much worse by the fact that an important early warning system was inoperative during these critical months. This system consists of instruments to measure the differential pressure (delta-P) across the permeators. This delta-P is regarded as one of the most sensitive indicators of the need for permeator cleaning. If these delta-P instruments had been operative, the fouling of the membranes could have been spotted early and taken care of before irreversible damage occurred. However, they were inoperative during this critical period because Polymetrics had provided low pressure tubing and fittings (for this high pressure system), which, according to Engineer Robalo, ruptured during the first attempt to activate them. If Polymetrics regarded continued operation with these delta-P instruments inoperative, as a violation of the Warranty, and, perhaps more importantly, as putting the permeators in grave jeopardy, then a warning to Electra to shutdown the plant until Polymetrics could supply the correct tubing and fittings would have been appropriate. They did not do so. Of course, at this time, they were unaware of the failure of the linings in the pulsation dampeners, which would lead to the demise of the permeators. Without this unfortunate coincidental occurrence, it is highly likely that the permeators would not have required cleaning until after these delta-P instruments were made operative.

It is important to note that as soon as Polymetrics provided the means of measuring these delta-P's (July 1983), Electra put them into immediate use in accordance with the Operation and Maintenance Manual.

3. THE LEAKING FLEXIBLE HOSES

The next most serious and still recurring problem, in this area, is the high pressure stainless steel hoses which Polymetrics supplied. The original ones leaked at the welds. They were repaired, but unsuccessfully.



PICTURE 3 - A DELTA-P INSTRUMENT - PART OF
"THE EARLY WARNING SYSTEM"

Polymetrics supplied new ones. They now leak at the welds.

4. OTHER PROBLEMS

There are other less important problems, which can be seen in Section "I.G.1 Equipment Recommendations Status". Further discussion of this subject may be found in Sections V.A. and V.B.

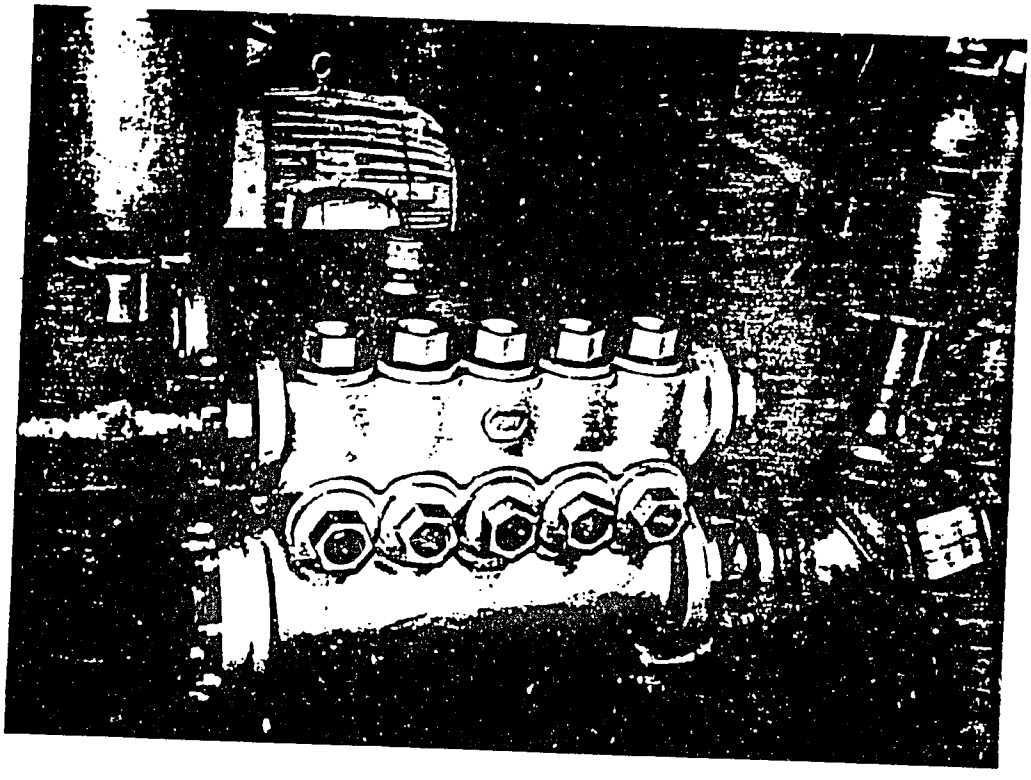
F. WAS THE PLANT MISOPERATED?

1. POLYMETRICS' CLAIM

As stated above, Polymetrics' has taken the position that the fouling of the permeators was not caused by iron from the carbon steel parts which they furnished, but instead was caused by misoperation of the plant, specifically, "...not maintaining the feed/brine pressure drop in accordance with the O&M manual." Initially, it was not possible to read these pressure drops, because of improper equipment provided by Polymetrics. The record clearly shows that Electra did follow the O&M manual as soon as Polymetrics supplied the necessary equipment. In fact, they were cleaning the permeators about four times as often as normal in an apparently fruitless attempt to keep the performance of these (already irreversibly damaged) permeators within specifications. Out of countless pieces of data available, and their extended opportunity to observe operations at the plant, they only challenged one piece of data. All of this is discussed in detail and documented in Section V.C.

2. BRISC'S POSITION

BRISC's position on whether or not Electra ever misoperated the plant in such a way as to cause fouling of the membranes is unclear. They point out that they were in charge of operation of the plant, until October 1983 (by which time, in the Author's best judgement, the permeators had already been irreversibly damaged), and the training and skill of the operating staff. Then, they make some undocumented references to misoperation and recommend procedures, already in force, that could imply misoperation of the plant. But, when they get to specific details, they are very positive about Electra's performance.



PICTURE 4 - NEW PULSATION DAMPENERS
AND (LEAKING) TEE

This entire subject is discussed in detail and documented in Section V.C.

3. THE AUTHOR'S OBSERVATIONS

The Author's effort to ascertain whether misoperation of the plant was a factor in the fouling of the membranes is summarized in Section IV.C, and his conclusions are presented in Section II.

G. RECOMMENDATIONS STATUS

1. EQUIPMENT RECOMMENDATION STATUS

The following summarizes recommendations from various sources, and their status on October 29, 1985.

a. BRISC Report No. 34 (IV.3A)

(1) All corroded tees and accumulators of pulsation dampeners shall be replaced with 316L.

Done: Replaced by Polymetrics in March 1985, but corrosion and leakage is occurring at the welds on replacements.

Permanent repair must be made, or more suitable parts must be found.

(2) All corroded brine reject flexible pipes shall be replaced with new ones.

Status is the same as "(1)" above.

(3) Feedwater temperature control shall be replaced with 50 Hertz rating.

Supplied by Polymetrics: will be installed October 31, 1985.

(4) High pressure pump pressure transmitters shall be replaced with correct range.

Supplied (repaired) by Polymetrics: Will be installed in a few days (need fittings).

(5) Twenty-six (26) permeators shall be replaced.

None were replaced by Polymetrics.

Three have been added (to the original 30) and one replaced (of the 10 bad ones still installed, but inoperative).

Twelve, of a higher capacity model, have been procured by Electra, and are soon to be installed by Electra.

(6) Cleaning pump impeller shall be replaced with right size (and larger motor, if required).

It appears that this claim was never made to Polymetrics (BRISC letter of June 20, 1984, Attachment A).

b. <u>BRISC Report No. 35 (IV.3B)</u>

(1) Repair coating to product water tank.

Planned, but not done: Matec (local contractor) is scheduled for the near future.

(2) Replace intake pump shafts.

Done by Electra: Satisfactory.

(3) Deepen intake pump suction.

Done by Electra: Satisfactory.

c. <u>BRISC Report No. 37 (IV.3C)</u>

(1) Install full capacity submersible pump.

Supplied by Electra: Will be installed in the near future.

(2) Repair damage to pipe and cable.

Done by Electra: Satisfactory.

d. Discussions with Engineer Rabalo

In addition to the recommendations listed above, Engineer Rabalo added the following:

(1) Install one additional generator of 1000 KW (this would double the present installed capacity).

(2) Increase the present inventory of supplies and spare parts. A list of estimated requirements for two years was supplied, by Engineer Rabalo (See Appendix B).

e. Based on the Author's observations of plant operation, the following additional recommendations are made:

(1) A sample point should be installed in the inlet header to each battery. These should be sampled daily, at first, and analyzed for iron. If no iron appears during the first three months, the frequency could be reduced to weekly, and then, in another three months, to monthly.

Note: If this had been done when the plant was built, the permeators could have been saved.

(2) Install high point vents at each end, and at the center support, of the suction header to the high pressure pumps. These would be used to vent the air that enters during maintenance operations prior to starting the high pressure pumps.

(3) A copying machine should be provided. It now takes two days to get copies made. Such a machine would have been immensely helpful during the trip reported on here. Many things had to be copied by hand since two days weren't available. Other visitors must have had similar experiences. The machine would eventually pay for itself in routine plant operations, such as reproducing forms.

2. OTHER RECOMMENDATIONS STATUS

a. BRISC Report No. 34 (IV.3A)

(1) Check reason for low ("11.6 percent lower than design") feed pump flow (550 liters/min vs. 611 design): plunger strokes, RPM, and pulley size.

Electra will check RPM of pump itself (eliminates pulley size as problem, if RPM OK). Plunger is not adjustable.

b. BRISC Report No. 37 (IV.3C)

An attempt should also be made for possible guarantee claim for replacement of permeators per GOCV contract with the supplier.

However, in the letter of transmittal for this referenced report, BRISC warns:

"We feel that any guarantee claim by GOCV may be challenged by the vendor due to operational anomalies (against limits set by the Operating Manuals) such as high delta-P across the membrane and the reuse of disposable cartridges in filters. This could lead to a long drawn argument and loss of time and effort."

c. Polymetrics' Letter of May 28, 1985 (IV.4)

(1) Paint or shield FRP piping.

Scheduled for the near future.

(2) Determine cause of feedwater pressure relief valve malfunction, and correct.

Correct set pressure to be verified.

The other Polymetrics' recommendations are considered in Section V.C.2.

i. Staffing

The present staff (See Appendix C) appears to be adequate, and will be even better when increases currently planned are implemented. But, it is

important to maintain present levels of capability. There must be adequately educated (including specific off and on-the-job training) and experienced replacements for:

Engineer Rabalo (when he leaves)
Chemist (who has already left)
Other technical personnel (who may leave)

H. WARRANTY STATUS

Except for repeated claims on parts that have been replaced under warranty and have failed again (like the high pressure flexible hoses), all warranties have expired except the "Long-Term Performance Guarantee". For a detailed discussion of warranty status, see Section V.D.

I. CONTRACTORS' PERFORMANCE

Polymetrics' performance is discussed in Section V.B. BRISC's and Ruhlin/Wallace's performance are discussed in Section V.E.

## II. CONCLUSIONS

### A. THE AUTHOR'S VIEWPOINT

The Author spent four days reviewing pertinent documents, over seven days at Sal observing operation and maintenance of the plant, engaging in discussions with the staff, and examining records. Since that time, he has spent several days sifting through the information that he has gathered, and has drawn the conclusions that follow. Some (perhaps, the most important ones) will probably not be contested by any observer. Others will most likely be hotly contested, particularly by those who could be adversely affected, if the Author's views prevailed.

The Author recognizes that he has not had the advantage of being on the scene when the most important events were occurring, as other observers have. He also knows that observation of how the plant is operated and maintained today does not prove how the plant may have been operated and maintained during certain critical periods in the past, but he believes that it is certainly a strong indicator of past performance, particularly in view of the fact that the plant has been under the same Plant Manager, Engineer A. Rabalo, from the beginning. The Author has done his best to put himself back into this critical period by careful examination of records, and the reports made by others who were there.

What follows is the Author's best judgment of what can be concluded from his work. Others exposed to exactly the same set of facts may draw different conclusions.

### B. MOST LIKELY UNCONTESTED CONCLUSIONS

1. The plant in its present condition (only capable of less than half of design capacity, and producing water that would be regarded as unhealthful by any standard of which the Author is aware), is not a credit to the United States or to American technology.

2. Only deliberate speed in solving current problems can prevent virtually complete failure of the project.

3. An adequate supply of spare parts is sorely needed.

4. The present organization is satisfactory and the staff (particularly when currently planned increases are implemented) is adequate to operate and maintain the plant, stock and maintain proper control over supplies and spare parts, PROVIDED that they have adequate funds to do so.

5. The economics of the plant would be significantly improved by operating it at design capacity.

6. The economics would be even better if the once planned 50 percent expansion of water and power capacity could be realized (assuming that there is an adequate market for the water and power).

7. Twenty-six (of the original 33) permeators were irreversibly damaged by fouling.

C. MOST LIKELY HOTLY CONTESTED CONCLUSIONS

1. The permeators were fouled by iron from the corroding pulsation dampeners.

2. Significant damage to the permeators had already occurred by June of 1983, about two months after the initial performance test, and one month before the correct tubing and fittings required to activate the all important delta-P instruments for the permeators arrived. Both Polymetrics and BRISC say that the damage occurred MUCH later. This is a VERY IMPORTANT difference in opinion. Yet, the Author recognizes that, while the technical evidence he offers is conclusive, it is not coercive.

3. If it had been possible to activate the delta-P instruments at the time of the plant start-up (and keep them operative), the rise in delta-P could have been spotted early enough to take corrective action (cleaning the permeators), thereby saving the permeators.

4. By the time the delta-P instruments were activated (July 1983), no amount of cleaning could save the permeators. They were already irreversibly damaged. That is why "...one week after cleaning, the pressure differential increased back to the same value [as] before it was cleaned..." This, of course, led to cleaning the permeators "...every three to four weeks

instead of the normal cleaning frequency of three to four months." But it was to no avail, at least in terms of preventing damage to the permeators.

5. Polymetrics' claim that the permeators were damaged by misoperation of the plant (failure to comply with the O&M manual) is invalid:

   a. This would be very difficult to prove.

   b. This would be particularly difficult to prove without a reaffirmation by BRISC that the permeators were fouled by iron.

## III. RECOMMENDATIONS

### A. GOALS

1. The principal goal should be to take whatever steps are necessary to make the plant one that the United States can turn over to the GOCV with pride, and one which will be a future showplace for American technology.

2. The secondary goal should be to prevail upon responsible parties to acknowledge and satisfy their obligations.

### B. PREPARING THE PLANT FOR TURNOVER

This section presents what the Author regards as the minimum which USAID can do in order to honorably extricate themselves from their present position, and achieve Goal No. 1:

1. Replace 14 of the 26 damaged permeators (12 have very recently - during the Author's visit to Cape Verde - arrived, but were not installed).

2. Select and install suitable (ones that won't leak at the welds) tees for the pulsation dampeners, and high pressure flexible hoses.

3. Replace the cleaning pump impeller with one of the proper size. This may, in turn, require replacement of the motor with a larger one.

4. A sample point should be installed in the inlet header to each battery. These should be sampled daily, at first, and analyzed for iron. If no iron appears during the first three months, the frequency could be reduced to weekly, and then, in another three months, to monthly.

   Note: If this had been done when the plant was built, the permeators could have been saved.

5. Install high point vents at each end, and at the center support of the suction header to the high pressure pumps. These would be used to vent the air that enters during maintenance operations prior to starting the high pressure pumps.

6. Replace any other parts that may have failed between the time of the Author's visit and the time of the Final Performance Test, recommended below, so that for the first time in the history of the plant all of the equipment will be installed and operating properly.

7. Witness a Final Performance Test (run by Electra) that demonstrates the plant's ability to substantially comply with the original specifications for water quality, water capacity, and electrical generating capacity.

8. Furnish two years estimated requirements of supplies and spare parts (based on Engr. Robalo's recommended lists).

These activities will be complemented by Electra's ongoing program to correct deficiencies in the plant. The purchase of 12 permeators (mentioned above) is indicative of Electra's interest in making the plant a success. For a summary of their other activities in this area see Section I.G.

## 2. WARRANTY ACTION

Since Polymetrics did replace leaking tees and high pressure flexible hoses previously (under their Materials and Workmanship Warranty), and since the replacements have also proved to be defective, a new claim should be placed.

But, the most important open warranty action is the claim for replacement of 26 permeators, under Polymetrics' "Long-Term Performance Guarantee". Polymetrics has rejected this claim. They claim that the permeators were not damaged by iron, but by misoperation of the plant. The Author strongly disagrees, but this does not mean that the Author's view would prevail if the GOCV decided to press their claim, particularly if they were unsupported by BRISC, who was USAID's engineer on this project during the entire period in which these events (the damage to the permeators) occurred.

The decision as to whether or not to press the claim, and how hard, is a legal matter, and hence is outside the field of expertise of the Author. If a decision is made to press this claim, then the Author would recommend the following:

BRISC should be asked to reaffirm that it was the iron that caused the fouling of the permeators (not misoperation of the plant). They should be asked further when they believe the damage was done to the permeators, and how they determined that.

If BRISC now insists that misoperation was the sole, or at least a partial cause of the fouling, they should be asked to provide specifics as to when and how the plant was misoperated, and the permeators damaged.

## D. PHASE II RECOMMENDATIONS

The recommendations made above, concerned themselves with minimum satisfactory completion of what the original Phase I project was supposed to accomplish. With regard to the future, there are other recommendations worthy of consideration by USAID/GOVC:

1. Provision should be made for training suitable replacements for key technical and managerial personnel so that the present level of competence will not be diminished

2. Addition of the third generator

3. The water distribution line to Santa Maria

4. Construction of permanent workshops and stores

5. A copying machine should be provided. It now takes two days to get copies made. Such a machine would have been immensely helpful during the trip reported on here. Many things had to be copied by hand since two days weren't available. Other visitors must have had similar experiences. The machine would eventually pay for itself in routine plant operations, such as reproducing forms.

## IV. HOW THE PROJECT WAS DONE

### A. FOCUS OF THE STUDY

There are two principal objectives of this effort:

1. Determine what needs to be done to make production of design quality and quantity of water and power a reality at the Sal Island Desalination Plant.

2. Determine whose responsibility it should be to replace defective equipment.

Most of what needs to be done to meet the first objective had already been found by others (BRISC, Electra, and Polymetrics). Corrective action has already been taken or is underway on most of these (See "I.G.1 Equipment Recommendations Status", and I.G.2 Other Recommendations Status"). Virtually all active warranty claims are against Polymetrics. While they have been very slow in doing so, Polymetrics has generally honored their various warranties (See "V.D. Warranty Status") except the MOST IMPORTANT WARRANTY OF ALL - their "Long-Term System Performance Guarantee". BRISC's claim to replace 26 permeators was denied by Polymetrics on the basis that the plant was misoperated (See "V.A. HOW THE MEMBRANES CAME TO BE FOULED"). As a result, much attention was focused on this subject during document review, plant surveillance, and discussions with plant personnel.

### B. DOCUMENTS CONSIDERED

The documents germane to this study, would make a stack nearly two feet high. Obviously, selection of which documents to study in more detail required keeping the mission in mind. While bits and pieces of information came from numerous sources, the principal documents studied in some detail were:

Washington D.C. Document Review
October 23 - 25, 1985

1. "Technical Specification - Agency for International Development - Cape Verde Desalination and Power (SAL) Project - Specification No.: 4850-M-101 - Desalination Equipment - Revision 3"; BRISC, March 5, 1981.

2. "Proposal for a Reverse Osmosis Water Purification System - Proposal No.: P2437 (Base Bid)", Polymetrics, Inc. (To AID), May 4, 1981.

3. "Cape Verde Desalination and Power (SAL) Project - Contract No. AID/afr-C-1531;

   A. Report No. 34 - Site Inspection and Trip Report - June 15, 1984,

   B. Report No. 35 - Project Status Report - August 21, 1984,

   C. Report No. 37 - Final Report - March 29, 1985", BRISC (all for AID).

4. Polymetrics/Michael F. Lamendola - Letter to AID, May 28, 1985.

Visit to Desalination Plant at Sal
<u>October 27 - November 1, 1985</u>

5. "Operating Problems Report on Sal Island Desalination Plant Equipment supplied by Polymetrics, Inc.", Electra/A. Rabalo, (to Delegation do Sal) September 30, 1985.

6. "Operation and Maintenance Manual:

   A. Volume I - System and Equipment Operations

   B. Volume II - System and Equipment Maintenance

   Power and Desalination Plant - Sal Island, Cape Verde", BRISC.

7. Data Sheets:

   A. "Laboratories - Controle do Processo."

   B. "Diario das Baterias de Permadores."

   C. "Folha de Registo do Painel de Controle."

   D. "Folha de Registo de Funcionamento das de Baterias Osmose Inversa."

   E. "Folha de Registo Semanal de TDS e P dos Permeadores."

F. "Folha de Registo de Funcionamento - Servico Comuns."

G. "Relatorio de (Special) Analises De Amostras de Agua."

8. A. Electra Organization Chart.

B. Shift Schedule - June 1985.

9. Electricidade E. Agua do Sal, E.P./Martino C. Ramos - Letter of April 14, 1983 to Polymetrics.

10. Polymetrics/Peter K. Smith - Letter of September 30, 1983 to BRISC.

11. BRISC/Amit Chattopadhyay - Letter of June 20, 1984 to Polymetrics.

Throughout the text, references to these documents will be made by numbers, such as "D.C. 1", D.C. 2", et cetera.

General "References" (as distinguished from "Documents considered" - which were prepared specifically in connection with this project) are listed in Appendix A, and are referred to as "Ref. A", et cetera.

## C. INSPECTION AND EVALUATION OF THE DESALINATION FACILITY

1. The purpose of this phase of the work was to:

a. Identify current technical problems such as:

(1) Equipment that needs to be replaced, now, and,

(2) Operation and maintenance procedures changes (if any) which need to be instituted, now,

In order to make the plant meet all of its design performance requirements, and

b. Determine past and present compliance with the Operation and Maintenance Manual, with particular emphasis on the period from initial plant start-up to the time (August 1983) when it

was patently obvious that the permeators had been irreversibly damaged.

2. This was accomplished by:

   a. Inspection of operation and maintenance records

   b. Observation of day-to-day operation and maintenance of the plant

   c. Discussions with operating and maintenance personnel

3. The Author visited the plant from October 27 - November 1, 1985, and again on November 8, 1985. A portion of each day, and one entire day, was spent in the plant observing both operation and maintenance, and engaging in conversation with the staff, about their work. (The balance of the time was spent in examining records.) During this period the Author had an opportunity to observe (among other things):

   a. Washing of the filters

   b. Taking samples of raw water, water before the cartridge filters, water after the cartridge filters, brine, and product

   c. The Silt Density Index (SDI) procedure being run (correctly) and the calculations being made (correctly)

   d. Routine daily and weekly analysis of the various samples being run in the plant or the laboratory as required by the Operation and Maintenance Manual

   e. Removal and replacement of (damaged) permeators (so that the Author could inspect them)

   f. Scheduled (15 day) cleanout of algae from the suction header for the high pressure pumps

   g. Restart of the plant following the above cleanout (This was achieved in about one hour and ten minutes from the time bolt-up began until product water began to flow.)

## V. DISCUSSION

### A. HOW THE MEMBRANES CAME TO BE FOULED

1. All observers agree that the membranes were fouled, and that fouling caused irreversible damage to the permeators. (This problem by itself is so serious, that it dwarfs all others combined, by comparison.)

2. There are two possible causes of fouling:

   a. Iron - believed by all observers but Polymetrics to be the culprit (although BRISC vacillated seriously in their Final Report (D.C. 3.C - Section 4.3.1.G - page 4-14).

      (1) BRISC Report No. 34 (D.C. 3A)

      "Carryover of corrosion products of these dampeners, affected the permeator performance and contributed to product recovery drop from design recovery of 25 percent to actual between 18 and 20 percent." (II.A.1)

      "The decline in product water recovery and high pressure differential of the permeators is an indication of fouling. The fouling is due to the corrosion product from the painted carbon steel tee and accumulator body of the pulsation dampeners located at the suction and discharge of the 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." (II.C.1)

"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 [contributed] to the fouling of the permeators." (II.C.2)

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

"Due to iron fouling, the product water recovery decreased from design 25 percent to 19 percent in Train A, 16 percent in Train B and 19 percent in Train C based on actual feed and product flows. (III.3 and 4)

"Iron in the corrosion product has been causing fouling in the membranes, requiring frequent cleaning." (Appendix A.a)

(2) <u>BRISC Report No. 37 (D.C. 3C)</u>

"The equipment is not performing well due to degradation of R.O. membranes in all three trains. The problem started with the iron fouling due the corrosion products from the accumulators at the H.P. pump." (4.2.1)

"Accumulator corrosion problem was obvious and was severely affecting membrane performance." (Appendix B)

Note: All of the above statements unequivocally say that the permeators were fouled with iron, to the point that the following statement seems almost contradictory:

"Excessive $\Delta$ P's may have been caused by the iron from the accumulator or by suspended material in the seawater feed or a

combination of the first two factors... it is impossible to establish which of the above factors is to blame..." (4.3.1.G)

No explanation was offered for this abrupt and very important change in position.

b. Other suspended material - Polymetrics is the only observer to assert that this was the cause (In their letter of May 28, 1985, (D.C. 4) rejecting the claims on the permeators):

"Further, the permeators were cleaned with Citric Acid and Sodium Hydrosulphite solution to remove any iron. The solutions had a low iron level after recirculation which indicated that the permeators were not iron fouled. Therefore, it was concluded that the steel pulsation dampeners had not damaged the permeators." (III.1)

"Irreversible damage has been done to the permeators by not maintaining the feed/brine pressure drop in accordance with the O&M manual. In view of this, and in accordance with paragraph 7 of the Warranty, the claim is denied." (III.5.b)

But, the <u>only</u> evidence that they offer is that their representative and the Electra operator disagreed on <u>one</u> SDI reading (out of countless readings made):

"Check that the operators are correctly trained to measure and calculate SDI. In one case, Polymetrics and operator obtained readings of 3.2 and 1.6, respectively, on the same sample" (IV.1)

It is possible to make two different calculations on the data from the same sample - one correct and one erroneous for example. But, it is unlikely that significantly different readings would be taken on the same sample, since taking the sample and taking the readings (with a stopwatch) are done simultaneously. However, according to Engineer Rabalo, it was not that way. Polymetrics did not take their reading from the

same sample. They did not even use the plant sampling equipment. They used their own apparatus which operated at a different pressure (40 psi vs. 30).

Aside from the above, Polymetrics gives no specific examples of misoperation of the plant. They do provide a list of suggestions for improvement of operation, but these things, for the most part, had been done from the beginning, or were not related to the fouling of the permeators, or both. This subject is discussed in more detail in Section C.3, below.

Did BRISC support the position that other suspended material was the cause of the fouling? A review of this quotes under Section a, above will reveal that they appeared absolutely confident that the fouling was caused by iron, and then suddenly decided that "suspended material" may have been the cause. They say:

"There have been some instances of relaxing operational limits set by manufacturers." (D.C. 3C - 4.5), and

"We feel that any guarantee claim by GOCV may be challenged by the vendor due to operational anomalies (against limits set by Operating Manuals) such as high delta-P across the membrane and reuse of disposal cartridges in filter." (Ibid., Letter of Transmittal),

thus, echoing Polymetrics. Like Polymetrics, BRISC offers no specific examples. And, again, like Polymetrics, they recommend procedures that are already in place which could imply misoperation of the plant. This is discussed in more detail under Section C.4., below.

B. <u>POLYMETRICS' PERFORMANCE</u>

1. The principal problems with Polymetrics' performance stemmed from their poor selection of materials and equipment:

   a. Their selection of carbon steel bodies for the pulsation dampeners led to the demise of the permeators. It is true that the bodies were

lined with hypalon, and that if the lining had not failed, all would be well. But, linings are always a risky choice. It is not only that they often fail, but they can cause consequential damage when they fail, as they did in this case. It is a well known fact that the penalty for accumulation of iron in a membrane system like this one is death to the permeators. In fact, DuPont, who is the manufacturer of the permeators and the licensor of Polymetrics, says in their "Engineering Design Manual" (Ref. A), that iron fouling, with its attendant (up to two-fold) increase in salt passage and permeator delta-P, and a 20-50 percent loss of product water recovery, can occur within 24 hours. A much more conservative choice (the stainless steel that they finally supplied, after the damage was done) was called for here.

b. One of the most important indications of membrane fouling (from iron, or any other source) is an increase in differential pressure (delta-P) across the permeators. In fact, a rise in this delta-P is called out in the "Operation and Maintenance Manual" (D.C. 6) as an indicator of when to clean the permeators. Polymetrics clearly realizes the importance of this now. They state failure to maintain delta-P's within proscribed limits as the reason for denial of a claim under the system performance guarantee:

"Irreversible damage has been done to the permeators by not maintaining the feed/brine pressure drop in accordance with the O&M manual. In view of this, and in accordance with paragraph 7 of the warranty, the claim is denied." (D.C. 4 - Section III.5.b) - page 6).

The question is: "Did Polymetrics regard these delta-P's as important at the time that the first attempt was made to operate the delta-P instruments. These instruments were equipped by Polymetrics with low (versus high) pressure tubing and fittings that ruptured the first time (according to Engineer Rabalo) that an attempt was made to use the instruments. Of course, Polymetrics needed these delta-P readings to

pass their initial performance test - a very important (financial/contractural) objective for them.

According to Engineer Rabalo, they hooked-up their own instruments to measure these delta-P's, and took these instruments with them when they left. At that time (before the permeators were damaged), did they regard these delta-P's as essential to protecting the permeators from "Irreversible damage..."? If so, why didn't Polymetrics warn Electra not to operate the plant until after these critical instruments were operational, and advise them that they would be putting their warranty, as well as their permeators, in jeopardy? Perhaps, it was because it had not yet occurred to Polymetrics that the linings in the pulsation dampeners might fail, thus leading to the ruination of the permeators, and that this would be undetected by the delta-P instruments, which were inoperable because of the low pressure tubing and parts that were supplied by them.

c. The next most serious and still recurring problem, in this area, is the high pressure stainless steel hoses which they supplied. The original ones leaked at the welds. They were repaired, but unsuccessfully. Polymetrics supplied new ones. They now leak at the welds. It must be possible to supply ones that don't leak at the welds.

d. There are other less important problems:

The impeller for the Cleaning Pump is too small. When Polymetrics needed to use this pump, they removed the strainer in order to get enough flow. The pump still needs a larger impeller (and, perhaps, a larger motor).

The shafts in the intake pumps had to be replaced. They were of the wrong material.

Additional minor problems in this area can be seen in Section "I.G.1. Equipment Recommendations Status".

2. The problems cited above were seriously aggravated by Polymetrics' generally very slow and incomplete response to them (See Section V.D. WARRANTY STATUS).

C. POLYMETRICS' CLAIM THAT THE PLANT WAS MISOPERATED

Note: As used here, "misoperation" means failure to operate and maintain the plant in accordance with the Operation and Maintenance Manual.

1. Polymetrics appears to have taken the position that, if the failure of the plant could possibly have been caused by misoperation (which could, but not necessarily must, occur in any plant), then it was. However, they provided, at best, extremely little and very dubious evidence of this.

2. The plant is very well operated now, under the direction of the same Plant Manager (Engineer A. Rabalo).

3. Before they dismiss their responsibilities under their warranty, Polymetrics must be asked to provide MUCH better evidence of misoperation of the plant, particularly during the period prior to August 1983, by which time it was patently obvious that the permeators were fouled (D.C.3. - Tables 2,3,&6). Their most important assertion (IV.B.1.b. above) is that Electra was "...not maintaining the feed/brine pressure drop in accordance with the O&M manual." It must be asked, "During which period?" For the purposes of this discussion, the plant operation can be divided into two periods: (1) before July 1983 (specifically before July 5, when the delta-P instruments became operative for the first time, and (2) after July 1983.

Although it is the Author's firm belief that the permeators had been damaged very early in the first period, Polymetrics says not so (D.C.4 - III.5.b - page 5):

"The first recorded differential pressures (delta-P) across the bundles (26 July 1983) indicated that the membranes were in need of cleaning. New bundle delta-P's are around 0.4 - 0.6 kg/cm²). The delta-P's at this time were 1.0 - 1.95 kg/cm². All batteries were cleaned around 19 - 24 August 1983 with delta-P's being 0.5 - 0.7 kg/cm²) or as new. Thus, as of

August 1983, the damage was yet to occur." But, if they had admitted that the damage had, in fact, already occurred, they would also have admitted their role in causing that damage, namely, their failure to provide the proper tubing and fittings that were necessary to be able to operate the instruments that read those all-important delta-P's. Hence, Electra was deprived of the means to observe these values during this critical period.

Regardless, it is quite clear that the permeators were damaged before June 1983. For the reader's convenience, Tables 2,3,&6 from D.C. 3A have been reproduced here. Design product water quality TDS is less than 600 ppm (equivalent to 1350 µmhos/cm. It can be seen in each table that this value was exceeded by June, and has steadily worsened. This evidence of the membrane fouling was confirmed by the fact that product water recovery fell below the design value of 25 percent, by August 1983, and has steadily deteriorated.

Since Polymetrics themselves rejected the first period as the one in which the plant was thus misoperated, the second period must be examined. But, the cleaning records for the plant show that this alleged misoperation of the plant did not occur then, either. This is reaffirmed by BRISC (D.C.3.A - II.C.1):

"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 [as] before it was cleaned.... The frequent increase of pressure differential, (about one week after cleaning) indicated the iron has already deposited inside the fibersheet of the permeator."

Aside from the unsustained assertion that is discussed above, Polymetrics only alludes to misoperation by the type of recommendations that they make (D.C.4 - IV.1 - Other Observations) that would lead any uninformed reader to believe that the recommendations regarding operation were not already being done (if needed), or that the ones regarding equipment weren't

| 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

| 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

| 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 | 22 - 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

5/7

needed to correct Polymetrics' deficiencies. Let Polymetrics show more than:

a. Disagreement on one Silt Density Index (SDI), when Polymetrics witnessed countless others, by the same staff, which they did not challenge, before it is concluded that the operators are not "...correctly trained to measure and calculate SDI".

b. Any real evidence that the permeators were operated with SDI's in the permeator feed above 3.0.

c. Similar evidence that:

(1) Chlorine residuals "...of 0.2 - 0.3 mg/l at the outlet of the secondary media filters." were above that range.

(2) "...washing and re-installation of filter elements." was ever practiced (Actually, only wash out of the filter's housing to get rid of the algae, was done).

(3) During this critical period, the cartridge filters used were not the ones supplied by Polymetrics.

(4) Polystabilizer was not used, during this critical period, and that sodium hexametaphosphate (used worldwide - AND, recommended by DuPont, Ref. A.) was used during this critical period, or prior to obtaining written permission (D.C. 9) from Polymetrics.

(5) Running cartridge filters in parallel could contribute to the failure of the permeators.

(6) The calibration and alarm function of the ORP were not checked with sufficient frequency, and explain how this influenced the failure of the permeators.

(7) The extent to which the lack of painting or shielding FRP piping to reduce direct exposure to sunlight contributed to the failure of the permeators.

(8) The lack of cleaning of filter rotameters contributed directly to the failure of the permeators.

(9) OMO was used, during this critical period, and that it was not introduced into the system for the first time by the Polymetrics' representative, and that it is not on DuPont's list of "Alternate Detergents" (Ref. A).

4. Did BRISC believe that misoperation of the plant caused the fouling of the permeators? One simply cannot be sure from reading their reports. They say:

"Since the start up and initial operation in end-March 1983 BRISC field supervisor continued to provide O&M supervision, training and guidance for a period of approximately seven (7) months." (D.C. 3.A - 4.5)

(Surely, they did <u>not</u> mean that the plant was misoperated during <u>this</u> period, when they were in charge. Yet, in the Author's best judgment, it was during this period that the permeators were irreversibly damaged).

"Since October 1983, and upon completing BRISC site activities, Electra personnel has been operating the plant. The plant was originally staffed with qualified and trained personnel who also participated in the project during the construction phase.... The quality of Electra's O&M activity has been generally good." (Ibid.)

But, then they say:

"There have been some instances of relaxing operational limits set by manufacturers." (Ibid.), and

"We feel that any guarantee claim by GOCV may be challenged by the vendor due to operational anomalies (against limits set by Operating Manuals) such as

# VI. APPENDIX

## APPENDIX A

## REFERENCES

A. "Engineering Design Manual - Permasep Permeator" DuPont.

# APPENDIX B

# RECOMMENDED SPARE PARTS

COMPRESSORS PARTS

MODEL Nº ST 2NL D5

SERIAL NUMBER 30T 307 659

| REF NBR | Part Number | DESCRIPTION | CCN NUMBER | Qty |
|---|---|---|---|---|
| 1-2 | W75261T1 | TUBE ASM, BREATHER W/NUTS | 137003761 | 4 |
| 1-3 | 71A1087 | CONNECTOR - TUBE | 95082475 | 8 |
| 1-4 | W75261T2 | TUBE ASM, DISCHARGE TO PILOT VALVE | 3206 3779 ~~95082475~~ | 4 |
| 1-5 | 71A1087 | CONNECTOR - TUBE | 95031852 | 4 |
| 1-6 | 75A1038 | ELBOW - TUBE | 95031852 | 4 |
| 1-9 | W11316 | GASKET - AIR HEAD | 302 803358 | 8 |
| 1-13 | W75299T805 | SPACER COMPLETE | 302 18770 | 4 |
| 1-14 | W11317 | GASKET SPACER | 302 80366 | 4 |
| 1-15 | W6874 | VALVE - FINGER | 302 21170 | 12 |
| 1-16 | 87A2C145P | SCREW - FILLISTER HEAD 1/4 x 5/8 | 952 27823 | 12 |
| 1-17 | 14A5C55P | WASHER - LOCK 1/4 | 95081766 | 12 |
| 1-18 | 16A4C1P | NUT - HEX 1/4 | 95366803 | 12 |
| 1-19 | 87A2C142P | SCREW - FILLISTER HEAD 1/4 x 3/8 | 95600915 | 12 |
| 1-20 | X101ET124C | WASHER - STEEL 1/4 | 30326573 | 12 |
| 1-21 | W75295T121 | PISTON COMPLETE | 302 87825 | 4 |
| 1-22 | W11860 | PIN PISTON | 302 97022 | 4 |
| 1-23 | W11862 | RING - LOCK | 302 87751 | 6 |
| 1-24 | X145T19A | SET PISTON RING | 304 23628 | 4 |
| 1-26 | W75332 | GASKET FLANGE | 302 94201 | 4 |
| 1-30 | W6870 | GASKET - AIR HEAD | 302 80507 | 6 |
| 1-33 | W90937 | GASKET SPACER | 370 07481 | 4 |
| 1-34 | W6874 | VALVE - FINGER | 302 21170 | 8 |
| 1-35 | 87A2C145P | SCREW - FILLISTER HEAD 1/4 x 5/8 | 952 27823 | 12 |
| 1-36 | 14A5C55P | WASHER - LOCK 1/4 | 95081766 | 12 |
| 1-37 | 16A4C1P | NUT - HEX 1/4 | 95366803 | 12 |
| 1-38 | W75295T100 | PISTON COMPLETE | 302 15253 | 4 |
| 1-39 | W11861 | PIN - PISTON | 302 97063 | 4 |
| 1-40 | W11862 | RING LOCK | 302 87751 | 6 |
| 1-41 | X145T14A | SET PISTON RING | 304 23532 | [illegible] |

| REF NBR | PART NUMBER | DESCRIPTION | CCN NUMBER | QT |
|---|---|---|---|---|
| 1-43 | W75332 | GASKET - FLANGE | 30274201 | 4 |
| 1-54 | X1434T58 | TUBE ASM - FINNED W/NUTS | 30335533 | 6 |
| 1-55 | X1434T42 | TUBE ASM - FINNED W/NUTS | 30335418 | 6 |
| 1-59 | 18A786 | NIPPLE - PIPE CLOSE | 95034765 | 6 |
| 2-3 | R40622 | GASKET - FRAME END COVER | 30439327 | 4 |
| 2-8 | 20A11CM212 | O-RING | 95018149 | 4 |
| 2-14 | W99622T4 | SEAL - OIL | 37007630 | 4 |
| 2-15 | W11319 | GASKET - SHAFT END COVER | 30280531 | 4 |
| 2-19 | 23A9C705 | KEY - WOODRUFF | 95433173 | 4 |
| 2-20 | W75328 | BUSHING - CRANKPIN | 30210165 | 4 |
| 2-21 | R40641 | ROD - CONNECTING | 91141306 | 8 |
| 3-37 | X1091PP311 | SPING | 32010447 | 4 |
| 3-14 | 20A11CM006 | O-RING | 95210225 | 4 |
| 4-9 | X1396T28-200 | VALVE - RECEIVER SAFETY | 31383633 | 4 |
| 4-10 | X1396T28-260 | VALVE DISCHARGE LINE SAFETY | 37106184 | 4 |
| 4-11 | 17363993T20 | VALVE DISCHARGE CHECK | 32001955 | 4 |
| 4-12 | W75410T10 | VALVE ANGLE BIB DRAIN | 37140360 | 4 |

REMARKS

REFERENCE ALSO

INGERSOLL - RAND

SMAL COMPRESSOR OPERATIONS

MODEL ST 2M LDS

SERIAL NUMBER 30T 507659

EMPRESA PÚBLICA DE ELECTRICIDADE E ÁGUA DE CABO VERDE

ELECTRA - DELEGAÇÃO DO SAL

LIST OF SPARE PARTS FOR SAL ISLAND DESAL/POWER PLANT

| Q ty req. | Part nomenclature | Specification/Description | Ref Design |
|---|---|---|---|
| 25 | Orifice flange | Per Poly Dwg. D81725 - 4" Size | |
| 6 | Orifice flange insert | Per Poly Dwg. D81725 - 6" Size | |
| 15 | Pressure gauges | 0-6 kg/cm2 Per Poly Data Sheet (003)002 | |
| 6 | Ball Valves | Per Poly Dwg II 003 K 008 | 118 A,B, |
| 3 Sets | Reinforced seats and seals for above | TFE Per Poly data sheet II 003K008 | |
| 10 | Rupture disc | Per Poly Data sheet 003K045 FOR PRESSURE 1200 PSIG | |
| 3 | Pressure indicator | 003 J003 (0-100 kg/cm 2 | |
| 2 | Pressure switch | 003J004 | |
| 4 | Pressure transmitters | 00JC05 | PT 105 |
| 2 | Floats HAST.C | For flowmeters Poly D.Sheet 003J008 | |
| 4 | Liquid level | Per Poly Inst. D. Sheet 003 J025, Rev o | |
| 4 | Press.diff.gauge | Per Poly Data sheet 003 J006 | PDI 225 |
| 6 | Check valve | Per Poly spec. 003 K 043 | |
| 1 | Gear for Gollock valve | Per Poly Spec 003K016 | |
| 18 | Perm-feed tubing | Per Poly Dwg 00M106 | |
| 20 | Gaskets | Garlock Style 555 type, 3" Size (347 SStil | |
| 16 | Tube fitting | Gyrolock II 6 CM8-316 sstil | |
| 10 | Red cplg | 3/4" x1/2" 150 Lb., 316 sstil Thrd wrolght mat'e | |
| 10 | NIPPLE | 3/4"x8" lg.Sch.40 316 sst'l | |
| 20 | Tube fitting | Gyrolock II 2 CM2 - 316 SST'L | |
| 20 | Tube fitting | II 6 CM 4 - | |
| 20 | " | II12 CF 12 | |
| 20 | " | II 12 CM 12 | |
| 16 | Permeator concen- | | |

53

ELECTRA - DELEGAÇÃO DO SAL

| Q-ty req. | Part nom. | Specification/Description | Ref. design |
|---|---|---|---|
| 3 | Diff.Pressure indicator | Per Poly SHT. 003 J007 | PDI 107 |
| 20 | Male barb | F & T Nº P4 MCB - 4 Per Poly 003M200 | |
| 10 | Sample Valves | Per Poly SHT 003K034 | 143 A |
| 60 m | Tubing | "Parker Parflex II N13-4-062 | |
| 10 | Tube fittings | Gyrolock II 4 CM 4 - 316 | |
| 12 | | II 4 CF 6 - 316 | |
| 6 | | II 4 CM 2 - 316 | |
| 3 | Red. bushing | 150 II 1/4" MPT x 1/8" FPT 316 SS | |
| 3 | FIKE RUPTURE DISC [illegible] | Per Poly SHT 003K045 | |
| 4 | Pressure indicators | 0 - 15 kg/CM2 | |
| ~~8~~ | ~~RUPTURE DISC~~ | ~~PER POLY SHT 003K045~~ ~~FOR SET PRESSURE : 12040 PSIG~~ | |
| 3 | ACTION PACK ALARM SWITCH | MODEL AP 1001<br>POWER INPUT : 220 VAC, 50 HZ<br>AMBIENT Tº : 0 - 60°C | |
| 4 | ROSEMOUNT PRESSURE TRANSMITTERS | OUTPUT : 4-20 MA DC<br>MAX INPUT VOLT - 35 V DC<br>INT. VOLT. DROP 12 V<br>CONDUIT CONN. 1/2" FNPT<br>ELEMENT TYPE : DIAPHRAGM<br>RANGE : 0-120 kg/cm²<br>MODEL : 1144G 20000 A 33 | ROSEMOUNT INC<br>P.O. BOX 35129<br>MINNEAPOLIS,<br>MINESOTA 5543<br>TLX. 29-0183 |

SPARE PARTS REQUIRED FOR

WHEATLEY PUMPS HP _ 125 L S/N 2 126

QUINTUPLEX PLUNGER PUMP

| PART Nº | QTY RQD | PART NAME |
|---|---|---|
| | | FLUID END |
| 008- 013023 - 310 | 3 | BODY (ALUMINUM BRONZE) |
| 002 - 012800 - 310 | 20 | CYLINDER HEAD PLUG (BRONZE STD) |
| 204 - 000104 - 206 | 50 | GASKET |
| 180 - 165000 - 220 | 15 | LUBRIFICATING FITTING |
| 001 - 010887 - 200 | 15 | BAFFLE DISC |
| 001 - 003497 - 301 | 20 | STUFFING BOX NUT (BRONZE) |
| 214 - 212206 - 370 | 40 | PACKING, STYLE 838 |
| 002 - 010551 - 999 | 10 | CERAMIC PLUNGER 2½ |
| 001 - 007783 - 302 | 15 | 2½ THROAT BUSHING |
| 001 - 012844 - 302 | 15 | 2½ LANTERN RING |
| 001 - 007783 - 302 | 15 | 2½ FOLLOWER |
| 998 - 016330 - 012 | 30 | COMPLETE VALVE ASSEMBLY |
| 001 - 010975 - 320 | 60 | DISC |
| 001 - 008734 - 362 | 20 | SPRING |
| 150 - 012013 - 306 | 60 | NUT |
| | - POWER FRAME - | |
| 001 - 011251 - 204 | 6 | GASKET |
| 001 - 010803 - 999 | 4 | OIL GAUGE |
| 002 - 001292 - 999 | 30 | BEARING |
| 001 - 007959 - 999 | 30 | SHIM |
| 100 - 012234 - 273 | 10 | CAP SCREW |
| 154 - 012087 - 220 | 10 | WA SHER |
| 002 - 007955 - 350 | 3 | CONNECTING ROD |

| PART Nº | QUY RQD | PART NAME |
|---|---|---|
| 110 - 000238 - 201 | 20 | O - RING |
| 001 - 007963 - 237 | 15 | WIPER BOX |
| 145 - 158238 - 999 | 60 | SEAL |
| 120 - 256053 - 999 | 6 | BEARING |
| 145 - 212312 - 999 | 10 | OIL SEAL |
| 998 - 016300 - 037 | 6 | SHIM GASKET KIT |
| 002 - 016950 - 220 | 3 | OIL FILTER |
| 001 - 011096 - 999 | 3 | SWITCH |

MOTOR 100 HP, 1 500 RPM
NEMA DESIGN B, CLASS F
COUPLED TO HP - 125 L
WHEATLEY PUMP

| QTY RQD4 | PART NAME |
|---|---|
| 3 SETS | BEARINGS |
| 4 | SPACE HEATERS |

ORDER TO
SUNAIR CO.
P.O.BOX
ABINGTON, PA 1 9001
(215) 885 - 6 460

SPARE PARTS FOR

ENERGY RECOVERY TURBINE

S/N 830601, 02, 03 DRAWING 01 - 100 - 625

| PART NAME | MATERIAL | DRAW. ITEM | QTY | REF. ASSEMBLY |
|---|---|---|---|---|
| ANTI - FRICTION BALL BEARING - IN BOARD END | STELL | 4 305 | 6 | 31482 |
| SK 5 309 (DOUBLE ROW) | | | | |
| ANTI - FRICTION BALL BEARING - OUT BOARD END | STEEL | 43 06 | 6 | 31482 |
| SK 6309 (SINGLE ROW) | | | | |
| POWER GRIP HTD BELT | | | 4 | |
| GATES SYNCHRO - POWER HTD | 2 800 | 14 M 115 | | |
| BELT WIDTH 115 mm 200 TEETH | | | | |
| BELT PITCH 14 MM | | | | |
| V BELT | | | | |
| SUPER HC 5 V X 1250 V 80 191 B 118 | | | 32 | |

ORDER TO: HAYWARD TYLER PUMP CO
1 500 NORTH KINGS HIGHWAY
CHERRY HILL, NJ 08034
REP.BILL DEVOE
PHONE: (609)428 - 8680
TLX: 83 - 4767

ELECTROLYTIC SODIUM HYPOCHLORITE GENERATOR

MANUFACT: ENGELHARD INDUSTRIES DIVISION
ENGELHARD MINERALS AND CHEMICAL CORP
2 655 U.S. ROUTE 22 UNION
NEW JERSEY 07083 U.S.A
SPARE PARTS LIST
REFERENCE DRAWING A - 5 4413
POWER SUPPLY SCHEMATIC

| Q -TY | PART | PART Nº |
|---|---|---|
| 16 | VITON "O" - RING | 50632 - 2 |
| 4 | END PLATE GASKET | 36882 |
| 8 | CELL END CONE | 50667 |
| 4 | CELL SPACER | 50639 - 32 |
| 2 | CELL TAPPED SPACER | 50639 - 33 |
| 4 | SPIDER SPACER (TI) | 50634 |
| 2 | PRESSURE SWITCH | 53558 - 5 |
| 1 | GENERATING CELL (COMP) | 50669 - 2 |
| 3 | INPUT CIRCUIT BREAKER (CBI) | 37936 - 2 |
| 5 | OUT PUT CIRCUIT BREAKER (CB2 AND 3) | 50250 |
| 9 | POWER RECTIFIERS (CRI - CR 6) | 37955 |
| 6 | HIgH - LOW SWITCH DIODES (CRIO-11) | 36579 |
| | AUX. TRANSFORMER AND SATURABLE | |
| 6 | REACTOR DIODES (CR7 - CR9) | 50726 |
| 2 | RED PILOT LIGHT (DSI) | 50940 - 1 |
| 2 | AMBER PILOT LAMP (DSI) | 50940 - 2 |
| 2 | AMMETER (MI) | 50379 - 5 |
| 2 | VOLTMETER (M2) | 51029 - 1 |
| 1 | MAGNETIC CONTACTOR (KI) | 50941 - 2 |
| 2 | TOGGLE SWITCH | 35502 |

| Q - TY | PART | PART Nº |
|---|---|---|
| 2 | CONTROLER | 50508 - 2 |
| 2 | CONTROL TRANSØISTOR | 37868 |
| 4 | PAIRED OUT PUT TRANSISTOR | 37869 |
| 3 | PITOT TUBE FLOW METER FOR 1" SCH 40 PVC PIPE, 5 - 30 GPM RANGEØ, NIOBIUM FLOAT | |

SPARE PARTS REQUIRED FOR

GOULDS PUMPS

MODEL 3196 "MT"

S/N: E 134 CO 78 - 1 - 2

ORDER TO

GOULDS PUMPS, INC

SENECA FALLS

N. YORK 13148

SPARE PARTS LIST

| ITEM | QTY | PART NAME | MAT. L |
|---|---|---|---|
| | 6 | LANTERN RING II R 76293 | |
| | 6 | BALL BEARING - OUT BOARD II 8049 - 30900 | |
| | 4 | SHAFT SLEEVE II 737 05 x 2229 | |
| | 4 | BEARING LOCKNUT II 8601 - 0009 | |
| | 6 | BALL BEARING - IN BOARD II 8050 - 30960 | |
| | 4 | GASKET BEARING FR - ADAPTOR II 73 078 - 5130 - 0001 | |

SEA WATER PUMP

MODEL 3755 M DRAW. SA 7 550 L

S/N 734 CO 77. 1

GOULDS PUMPS, INC.

SENECA FALLS

N. YORK 13148 SPARE PARTS LIST

| ITEM | QTY | PART NAME | MATERIAL |
|---|---|---|---|
| 101 | 3 | IMPELLER | 316 SS |
| 103 | 6 | WEAR RING CASE | 316 SS |
| 112 A | 6 | BALL BEARING - OUT BOARD 8050 - 30961 | STEEL |
| 122 | 3 | SHAFT | 316 SS |
| 123 | 3 | DEFLECTOR | BRONZE |
| 126 | 3 | SHAFT SLEEVE 71240 - 2226 | 303 SSS |
| 168 A | 6 | BALL BEARING - INB 8050 - 20961 | STEEL |
| 199 | 6 | IMPELLER WASHER | 303 SS |
| 251 | 3 | SIGHT OILER | STL/GL |
| 304 | 6 | IMPELLER NUT | 304 SS |
| 332 A | 6 | OIL SEAL - CPLG 8690 -62043 | BUNA/RBR |
| 333 A | 6 | OIL SEAL - INBD 8690-53 | BUNA/RBR |
| 361 | 6 | RETAIN. RING SHAFT 84008 - 177 | STEEL C1075 |
| 361 A | 6 | R TNG RING - BRG HSG 58101 - 393 | STEEL C 1075 |
| 496 | 12 | O - RING - BRG HSG 70721 - 33 | BUNA/RBR |
| 248 | 6 | OIL THROWER | STEEL |
| 211 | 12 | GASKET - SHAFT SLEEVE | |
| 103 | 12 | DISCHARGE RING 103 | 316 SS |
| 165 | 12 | SUCTION RING 165 | 316 SST |
| 351 | 12 | GASKET SUCTION COVER | ASB/BUNA |
| 102 | | IMPELLER KEY 249568 -102 -2226 | |

SIZE 3 x 2 x 8

SERIAL NUMBER

IMPELLER D/AMETER: 7.4"

SPARE PARTS LIST

| ITEM | NAME PART | QTY |
|---|---|---|
| 2 | IMPELLER | 1 |
| 7 | RING, CASSING | 6 |
| 14 | SLEEVE SHAFT | 3 |
| 24 - A | LOCK WASHER, IMPELLER | 6 |
| 26 | SCREW, IMPELLER | 6 |
| 27 | RING, ADAPTER AND COVER | 3 |
| 28 | GASKET, IMPELLER SCREW | 6 |
| 30 | GASKET, IMP. LOCKWASHER | 6 |
| 32 | KEY, IMPELLER | 3 |
| 38 | GASKET SLEEVE (OUTER) | 6 |
| 38 A | RING "O", SHAFT SLEEVE | 6 |
| 65 | SEAT (MECHANICAL SEAL) | 12 |
| 73 | GASKET, CASING | 6 |
| 80 | ROTOR, MECH. SEAL | 12 |
| 211 | RING RETAINING (MECH. SEAL ROFOR) | 12 |

MILTON ROY PUMPS

MODEL AR

SERIAL - 153427 - 2

CAPACITY

ORDER TO: PARTS DEPARTMENT
MILTON ROY COMPANY
201 IVYLAND ROAD
IVYLAND, PA. 18974

| Q.TY | PART NAME | ITEM Nº |
|---|---|---|
| 8 | DIAPHRAGM | 298 - B |
| 8 | SUCTION CARTRIDGE ASS. | 221 - B |
| 8 | DISCHARGE CARTRIDGE ASS. | 221 - C |
| 20 | CHECK VALVE CARTR "O" RING | 408 - B |
| 12 | CONTROL SPOOL "O" RING SEALS | 408 - A |
| 16 | SPIRALBACK - UP RINGS | 408 - E |
| 4 | SPRING RELIEF VALVE | 280 - A |
| 2 | DISCHARGE CARTRIDGE SPRING | 280 - B |
| 8 | BEARING CONE (COMPLETE) | 409 - B + 409 - C |
| 8 | KNOB GRADUATION PLATE | 253 - B |
| 8 | CONTROL KNOB | 255 |
| 8 | CONTROL PLUNGER | 212-A |
| 8 | PLUNGER | 212 - B |
| 3 | CONNECTING ROD | 214 - A |
| 3 | LINKAGE ARM | 214 - B |

WORTHINGTON PUMP

MODEL D - 1022

SIZE 6 x 4 x 8

SERIAL NUMBER

IMPELLER DIAMETER 6.8"

| ITEM Nº | NAME OF PART | QTY |
|---|---|---|
| 7 | RING, CASING | 6 |
| 14 | SLEEVE, SHAFT | 3 |
| 24 A | LOCK WASHER, IMPALLER | 6 |
| 26 | SCREW, IMPELLER | 6 |
| 27 | RING ADAPTER AND COVER | 3 |
| 28 | GASKET IMPELLER SCREW | 6 |
| 30 | GASKET IMP. LOCKWASHER | 6 |
| 32 | KEY, IMPELLER | 3 |
| 38 | GASKET SLEEVE (OUTER) | 6 |
| 38 A | RING "O" SHAFT SLEEVE | 6 |
| 65 | SEAT (MECHANICAL SEAL) | 12 |
| 73 | GASKET CASING | 6 |
| 80 | ROTOR N/ECH. SEAL | 12 |
| 211 | RING, RETAINING (MECH.SEAL ROTOR) | 12 |

PRESSURE DIFF. GAUGES

MOUNTING: SURFACE

DIAL DIA: 6"

LENS MTL: GLASS

CONNECTION SIZE: 1/4" ANPT

SERVICE: SBAWATER

SWITCH: TYPE: 8NAP - ACTING

FORM: SPDT

RATING: 5AO 230 VAC

COND.CON.: 1/2" FNPT

M F G: ITT BARTON

| Q T Y | MAX. PRESS HI SIDE | NOM PRESS HISIDE | NOM PRESS LOW SIDE | MIN. PRESS. LOW SIDE | RANGE | BODY PRESS RATING | MODEL |
|---|---|---|---|---|---|---|---|
| 4 | 5.62 | 4.92 | 4.22 | 3.52 | 0-2 Kgcm2 | 35 Kg/cm2 | SWITCH 288 A ACTUATOR 224 |
| 6 | 96.32 | 6328 | 62.57 | 49.22 | 0-4 Kg/cm2 | 200 kg/2 | INDICATOR 227 ACTUATOR 224 |

A L L PRESSURES IN KG/CM2

WORTINGTON PUMP

MODEL D. 1022

SIZE 2 x 2 x 6

SERIAL NUMBER

IMPELLER DIAMETER 6.65"

| ITEM Nº | NAME OF PART | QTY |
|---|---|---|
| 7 | RING CASING | 2 |
| 11 A | COVER MECHANICAL SEAL | 2 |
| 14 | SLEEVE SHAFT | 2 |
| 24 A | LOCKWASHER, IMPELLER | 2 |
| 26 | SCREW IMPELLER | 2 |
| 27 | RING ADAPTER AND COVER | 2 |
| 28 | GASKET, IMPELLER SCREW | 4 |
| 30 | GASKET IMPELLER LOCK WASHER | 4 |
| 32 | KEY IMPELLER | 2 |
| 38 | GASKET SLEEVE (OUTER) | 4 |
| 38 A | RING "O" SHAFT SLEEVE | 4 |
| 65 SEAT | MECHANICAL SEAL | 4 |
| 73 | GASKET CASING | 4 |
| 80 | ROTOR MECH - SEAL | 4 |
| 211 | RING RETAINING (MECH. SEAL ROTOR) | 4 |

11

SOBRESSALENTES PARA MOTORES DIESEL CUMMINS KTA - 200 G - SÉRIE 3310558/9

| Quant. | Part name | Part. Number |
|---|---|---|
| | Piston Cooling Valve | |
| 4 | Gasket, piston cooling housing | 3011649 |
| 4 | Gasket, oil jumper | 3011651 |
| | Crancase breather | |
| 8 | Gasket | 3175032 |
| | CRAMSHAFT | |
| 3 | Set of crankshaft bearings standard, Cousisting of: | AR 12250 |
| 15 | Bearings, main (N.2,3,4,5 and 6 up) | 206580 |
| 15 | Bearings, main (N 2,3,4,5, and 6 10w) | 206590 |
| 6 | Bearings, main (N 1 and 7 upper | 206600 |
| 6 | Bearing, main (N. 1 and 7 lower) | 206610 |
| 6 | Bearing, thrust ring | 3000139 |
| | Connecting rod | |
| 48 | Bearing, connecting rod (STD) | 206 160 |
| | Cranshaft idler gear | |
| 8 | Bearing, thrust | 130083 |
| | Front gear housing cover | |
| 2 | Bushing, trunion | 205683 |
| 4 | Bushing, acessory drive | 132770 |
| 4 | Gasket, cover | 206407 |
| | Cilinder head | |
| 80 | Plug expansion | |
| 48 | Plug expansion | |
| 96 | Grommet, cylinder head water | 207448 |
| 24 | Grommet, cylinder head oil | 205852 |
| 96 | Grommet, cylinder head push-rod | 205855 |
| 20 | Capscrew, cylinder head | 3007238 |
| 24 | Rocker lever housing | |
| 24 | Dawel ring | 205129 |
| 24 | Gasket rocker lever | 3005956 |
| 20 | Nut | 5 - 212 |
| 16 | Screw, adjusting | 168 306 |

| Quant. | Part name | Part Number |
|---|---|---|
| | **Cam Follower and housing** | |
| 24 | Pin, cam follower injector | 205068 |
| 24 | Roller, cam follower injector | 3007120 |
| 48 | Pin cam follower intake and exaust | 205071 |
| 48 | Gasket, cam follower cover | 3008404 |
| | **Fuel System** | |
| 4 | O-ring, Shaft | 190876 |
| 4 | O-ring, coil to housing | 129888 |
| 4 | Shield, fuel | 129839 |
| 2 | Spring | 129768 |
| 4 | O-ring | 154087 |
| 2 | Diaphragm, damper | 202897 |
| 4 | O-ring | 100099 |
| 4 | O-ring | 139988 |
| 4 | Washer, nylon | 160514 |
| 4 | Capscrew | 153346 |
| 2 | Lockwasher | 181466 |
| 2 | ring, sealing | 151900 |
| 4 | Washer peain | 70 704 |
| 24 | Injector, less link | 3016676 |
| 24 | Clip, filter screen | 174299 |
| 24 | Filter Screen | 3008706 |
| 24 | Gasket, orifize plug | 173086 |
| 24 | O - Ring | 144967 |
| 24 | O - Ring | 193736 |
| 24 | O - Ring | 205216 |
| 24 | Spring | 205464 |
| | **Fuel Manifold** | |
| 96 | O - ring | 3001340 |
| 32 | O - ring | 131026 |
| 32 | Ferrule, rubber | 3175727 |
| 16 | Ferrule, rubber | 3002150 |
| 8 | O - ring | 70861 |
| 8 | O - ring | 145507 |
| 8 | O - ring | 43696-A |
| | **Lubrificating oil pump** | |
| 4 | Bushing, Lub pump | 205548 |
| 4 | Bushing, cover | 205548 |
| 4 | Gasket, pressure relief | |

| Quant. | Part Name | Part Number |
|---|---|---|
| 4 | Gasket, lub pump | 205532 |
| 4 | Gear, lub pump | 206756 |
| 2 | Shaft, lub pump | 205544 |
| 2 | Shaft, lub pump | 205545 |
| 2 | Plunger, pressure relief | 205664 |
| 2 | Spring, pressure relief | 205607 |
| 2 | Washer, plain | 146177 |
| 4 | Gasket, oil connection | 206179 |
| 8 | O - ring | 3175244 |
| 4 | Gasket, oil suction flange | 206013 |
| | Oil Pan | |
| 8 | Gasket, drain plug | 67946 |
| 4 | Gasket, oil pan | 206098 |
| 2 | Capscrew | 106069 |
| 2 | Capscrew | 108767 |
| 10 | Capscrew | 206029 |
| 10 | Capscrew | 206030 |
| 4 | Gaskel, oil pan adapter | 207546 |
| | Lubrificating oil filter head | |
| 4 | Gasket cover | 205662 |
| 2 | Guide, regulater valve plunger | 206185 |
| 4 | O - ring | 145530 |
| 2 | Plunger, regulator valve | 205186 |
| 2 | Spring, regulator valve | 206187 |
| 4 | C - ring | 70842 |
| 4 | Gasket, filter head | 3011649 |
| 4 | Gasket, filter head | 3011650 |
| 16 | Gasket | 173368 |
| 16 | Gasket | 3300917 |
| | LUBRIFICATING OIL BY - PASS | |
| 8 | O - ring, cover | 164159 |
| 8 | O - ring, Suppert | 116029 |
| 24 | Gasket, oil cooler | 206021 |
| 48 | O - ring, cooler element | 178937 |
| 4 | Gasket, front water head cover | 3009323 |
| | Water pump | |
| 2 | Ring, retaining | 70183 |
| 2 | " " | 205258 |
| 2 | Shaft, water pump | 206194 |
| 4 | O - ring connection | 206457 |

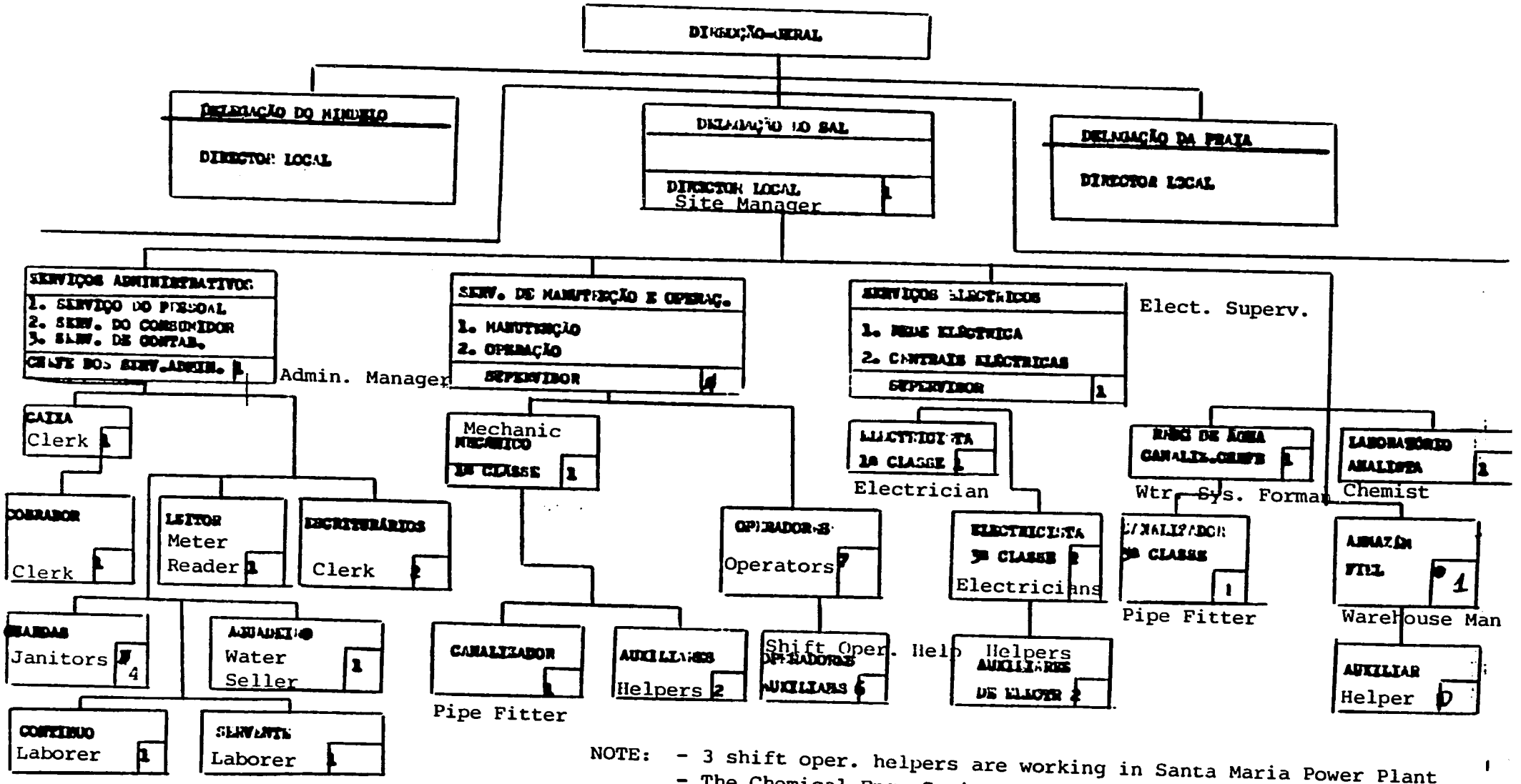
| Quant. | Part. Name | Part Number |
|---|---|---|
| 4 | O - ring, plate | 3007512 |
| 2 | ring, retaining | 205166 |
| 8 | O - ring | 206 449 |
| 16 | O - ring | 70861 |
| 8 | O - ring | 206449 |
| 16 | O - ring | 70861 |
| 16 | Seal, thermostat | 186780 |
| 8 | Gasket, thermostat | 206443 |
| 8 | O - ring | 3008710 |
| 8 | O - ring | 69760 |
| 104 | O - ring | 69760 |
| | <u>Acessory drive suppert</u> | |
| 4 | Bushing, acessory drive | 116391 |
| 4 | Gasket, acessory drive suppert | 205598 |
| 4 | Seal, key way | 181236 |
| | <u>Exhaust manifold</u> | |
| 48 | Gasket, exhaust manifold | 205196 |
| | <u>Air intake manifold</u> | |
| 32 | O - ring, tube | 145617 |
| 8 | Seal, dust | 207543 |
| 32 | O - ring, adapter te cooler element | 3003016 |
| 24 | O - ring | 3175545 |
| 8 | O - ring | 3008710 |
| 16 | Seal, rectangular | 3008710 |
| 8 | "V" Band | 202368 |
| 8 | Bearing, inbeard Haust | 202856 |
| 2 | Impeller | 207428 |
| 24 | O - ring | 202859 |
| 16 | Gasket, turbe te exhaut manifold | 206576 |
| 24 | O - ring | 207236 |
| | <u>Flyweel housing</u> | |
| 4 | Seal, dust | 207551 |
| 8 | Bearing, thrust | 206170 |
| 8 | Bushing, idler gear | 206166 |
| 4 | Gasket, rear gear housing | 206421 |
| 8 | O - ring | 207551 |

ELECTRA - Delegação de Sal, 8 de Novembre de 1985

| QTY REQ'D | PART NOMENCLATURE | SPECIFICATION/DESCRIPTION |
|---|---|---|
| 12 x 3 | HRH. CONC. TUBING | 3/8" O.D x 0.035 WALL x 33 1/2" LG 316 SST'L |
| 12 x 3 | PRIM FEED TUBING | 3/4" O.D x .049 W x 10 1/4" LG 316 SS ASTM A-269 |
| 12 x 3 | TUBE FITTING | GYROLOK # 12CM12 — 316 SST'L |
| 12 x 3 | TUBE FITTING | GYROLOK # 6CM4 - 316 SST'L |
| 12 x 3 | TUBE FITTING | GYROLOK # 6CM8 - 316 SST'L |
| 2 x 3 | RDC. CPLG. | 3/4" x 1/2" 150 lb. 316 SST'L - THR'D. WROUGHT MAT'L |
| 2 x 3 | NIPPLE | 3/4" x 4" LG. SCH 40 316 SST'L |
| 10 | GASKET | GARLOCK STYLE 555 TYPE CR1 (347 SST'L) OR EQUAL - 3" SIZE |
| 10 | GASKET | 1/8" THK. 150 lb RATED NEOPRENE - 2 1/2 SIZE |

# APPENDIX C

# STAFFING




NOTE:
- 3 shift oper. helpers are working in Santa Maria Power Plant
- The Chemical Eng. Sonia Morais used to visit the plant once a mont
- Additional staff already proposed: Plant superintendent 1, driver 1, meter reader 1, mechanic 1, secretary 1, pipe fitter helper 1, instrument and electrical tech. 1. Non permanent personnel: Carpenter 1, workers about 2/month.

EMPRESA PÚBLICA DE ELECTRICIDADE E ÁGUA DE C. VERDE

ELECTRA - DELEGAÇÃO DO SAL

VISTO

O DIRECTOR LOCAL,

INSTALAÇÃO DA PALMEIRA

Mapa de turnos e folga semanais referente ao mês de Junho de 1985.

| PERIODO HRS | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 | 25 | 26 | 27 | 28 | 29 | 30 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 00-08 | C | B | A | A | B | D | D | C | C | B | B | A | A | D | D | C | C | B | B | A | A | D | D | C | C | B | B | A | A | D |
| 08-16 | B | D | C | C | B | B | A | A | D | B | C | C | B | B | A | A | D | D | C | C | B | B | A | A | D | D | C | C | B | B |
| 16-24 | A | A | B | B | C | C | B | B | A | A | D | B | C | C | B | B | A | A | D | D | C | C | B | B | A | A | B | B | C | C |
| Dias da semana | SAB | D | S | T | Q | Q | S | S | D | S | T | Q | Q | S | S | D | S | T | Q | Q | S | S | D | S | T | Q | Q | S | S | D |
| Folgas semanais | | C | | B | | A | | D | | C | | B | | A | | D | | C | | B | | A | | D | | C | | B | | A |

Delegação da ELECTRA no Sal, 10 de Junho de 1985

CONSTITUIÇÃO DOS TURNOS

A - EFREM DO ROSÁRIO
LUÍS DE BRITO
- EMILIANO BRITO
MANUEL DA LUZ

B - JOÃO EVANGELISTA ÉVORA
HERMITÉRIO SOARES

D - MIGUEL ALMEIDA
JOSÉ ALBERTO BRITO

O RESPONSÁVEL DA SECÇÃO,

/ BALTAZAR NASCIMENTO S. RAMOS /