PD-AAY-557

PROJECT COMPLETION REPORT

CAPE VERDE SAL DESALINATION AND POWER PROJECT 655-0005

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INTRODUCTION

This project completion report is prepared by Winfield Collins, REDSO/WCA's General Development Officer with the active participation and assistance of USAID/Praia's PSC Engineer, Jose Trindade and USAID editing. ELECTRA provided invaluable information and commentary in its preparation.

The report, written in accordance with the requirements of AID Handbook No. 3, Appendix 14A, will try to give an overall picture of project background, accomplishments, problems encountered and lessons learned, as well as conclusions and recommendations for similar projects that AID may undertake elsewhere in the future.

BACKGROUND

The Cape Verde archipelago is composed of a total of ten islands and several islets between 14 and 18 degrees north latitude and between 21 and 26 degrees west longitude. The archipelago is about 2,000 kilometers south of the Canary Islands and some 800 kilometers west of Dakar, Senegal.The islands, in general, are volcanic, very mountainous and within the arid Sahel belt which also affects a great portion of North and West Africa. Total land area is under 4,000 square kilometers and the latest population estimate as of 1987 is 360,000.

The project is located on the island of Sal which is in the windward group of islands. Sal is one of the smaller but more important islands. Although its land area is only about 450 square kilometers and its population only 6,700, Sal is the site of Cape Verde's only international airport. In addition, there are important fishing, canning and tourism operations that represent an important source of foreign exchange for Cape Verde (GOCV).

Sal is relatively flat, but like several of her sister islands, characterized by sandy, rocky terrain, little or no vegetation, hot and windy climate, and little or no rainfall. According to existing meteorological data, Sal has had virtually no rainfall for about nineteen years. At the time of project conception in 1977/78, Sal had experienced virtually no rainfall for about eight years and groundwater aquifers were nearly depleted; saltwater intrusion rendered the little water that was drawn practically undrinkable with saltwater content of betweenn 2,000 to 5,000 parts per million (ppm) or about five times the maximum level internationally acceptable for potable water.

Similarly, natural energy resources are virtually non-existent in Sal which is lacking in coal, oil, timber or hydro-power potential. Also, the state of the art of commercial applications of solar and wind energy at that time was such that it did not merit serious consideration as a viable source of energy for public consumption. There were several small inefficient generators, a larger one at the airport but the demand was far in excess of the supply which was costly and limited primarily to the airport and a few hotels.

With a view to removing the water and power constraints, and furthering the economic growth on Sal island in particular, and in the Cape Verde islands in general, the GOCV requested the assistance in May 1977 of the U.S. Agency for International Development to investigate the available options and to assist in the design and implementation of a suitable project.

After investigating various alternatives including rainfall catchments, solar stills, barging of water from other islands or from the African mainland, and desalination, it was concluded that desalination was the most economical means of providing water to the inhabitants of Sal Island and that a joint diesel fuel power plant and reverse osmosis water production plant would be the most cost-effective solution to the overall water/electric power deficiency problems.

After reviewing the various options, the AID Assistant Administrator for Africa authorized on March 24, 1978 a $6.29 million Grant to the GOCV to undertake design, construction and supervision of construction of a joint desalination and power plant to remedy the water and power deficiency problems on Sal. A contract was signed between Burns and Roe Industrial Services Corporation (BRISC) and AID, on behalf of the US Government, in July 1979, to prepare design plans, construction plans specifications, and cost estimates; also to assist with the selection of a construction firm and supervise the construction/installation of the various project components which included: (a) a desalination/power plant; (b) a fresh water delivery/distribution system; (c) a high tension power delivery/distribution system; and (d) a sewage collection/wastewater treatment system. In addition, BRISC was charged under the contract with developing a training plan for key GOCV operational personnel associated with the desalination/power plant,

its delivery/distribution systems and the wastewater/treatment system; design of a system for metering individual user consumption of water and power, billing payment, and general administration; and preparation of a detailed operation and maintenance plan.

However, AID and the GOCV soon realized, that given the galloping inflation prevalent in the late 1970's, the project cost was in fact vastly underestimated. In January 1980, BRISC revised estimates of project costs at $15,128,000 instead of the $6.29 million authorized. Joint AID/GOCV decisions were made to eliminate: services to the two communities farthest from the plant, viz; Pedra Lume and Santa Maria; all workers' housing (with the GOCV picking up the costs of rehabilitating existing facilities); utilities to sparsely populated areas around the two remaining communities being served (Espargos/Preguica, and Palmeira); and sanitation facilities. It was also decided to reduce dimensions of water pipes, storage tanks, generators, line pole spacing, plant building, plant lighting and cables. This reduced total project costs to $7,910,800.

This estimated cost was revised once more in April 1980 to $8,943,000 of which $1,372,000 would be the cost of sewage installation and $7,571,000 the cost of other capital investments.

After carefully re-evaluating the advantages and disadvantages of the various options viz: (a) proceeding with the original project; (b) undertaking the reduced scope project ($7,571,000); or (c) abandoning the project altogether,AID decided to proceed with the reduced-scope project in June 1980.

In view of the limited AID funding available, the GOCV concurred in AID's decision to do a reduced project but regarded it as Phase I of the total project in the hope that additional donor funding would be available in the future to complete the project as originally conceived. In any event BRISC had already completed all plans up to the design development phase for the entire project as originally conceived.

Contract bid documents were then prepared for the reduced project only, even though provision had been made in the BRISC contract to prepare bid documents for the entire project as originally conceived, if necessary.

The total estimated cost of the BRISC contract (cost plus fixed fee) was $1,573,955, which included estimated cost of $1,452,843 and a fixed fee of $121,112. It should be noted that the budget attached to the Project Agreement of March 30, 1978 did not allow for the cost of engineering. This was rectified by the addition of an engineering budget item in Amendment No. 1 of Dec 1980 which added $900,000 additionally and a second addition of $600,000 in January 1982 (Amendment No. 4 to the Project Agreement).

A memorandum dated June 16, 1980 from the Director AFR/DR to the AA/AFR, subject: Cape Verde-Sal Desalination and Power (655-0005); Supplemental Information to Action Memorandum, indicates that BRISC had proposed the reverse osmosis technology and the GOCV had concurred. It is generally accepted that the Reverse Osmosis Process is more energy efficient, requiring less energy than other desalination systems to produce a unit volume of desalinated water.

BRISC completed the construction documents in the first quarter of 1982. Construction was undertaken shortly thereafter by Ruhlin/Wallace, a joint venture of Ruhlin Company of Columbus, Ohio and Carl P. Wallace of Dallas Texas. Power generation equipment was shipped by Maison International of Norwood, New Jersey; and desalination equipment by Polymetrics, Inc. of San Jose, California. Cummings Engine Company was the manufacturer/supplier of the diesel engines. The construction was completed in March 1983. Polymetrics Inc. procured and installed all desalination equipment.

PROJECT DESCRIPTION AND PURPOSE

The ultimate goal of the project was to establish a basis for continuing economic growth on Sal island in the Republic of Cape Verde. It aimed to improve substantially the existing standards of living, public health and, in general, the quality of life. These goals were to be attained by increasing the availability of potable water and electric energy to the population and to distribute those two products to all households on the island and at the same time providing an appropriate sewage removal system. However, as mentioned above, because of skyrocketing costs and limited AID funding the project had to be reduced in scope, and the sewage removal system and other elements were eliminated. The project as modified consists of providing technical assistance, commodities and services required to carry out the purchase and installation of a water desalination/power generating plant; water/power delivery systems to two of the four communities in Sal, viz; Espargos/Preguica and Palmeira; water and power distribution systems to eleven hundred (1100) households in each of these two communities plus business and government consumers.

An immediate accomplishment expected to result from the project was an increase in the level of per capita water consumption from 10 liters per day to 50 liters per day (12.5% of the average 400 liters per day in developed countries). Existing households were also expected to have a higher access to electric energy for household use from 20 percent to near full access. Two important benefits that were expected to result from successful implementation of the project were:
(a) Improved public health i.e. less water and food-storage related diseases, given home access to pure water and refrigeration; (b) increased growth in the industrial sector, given an assured expandable supply of pure water and electric energy at reduced costs.

The project was authorized on March 24, 1978 for $6.29 million of Grant funds to the GOCV of which $525,000 were allocated from FAA Section 104 funds and $5,765,000 from FAA Section 106 funds. The initial authorized project period was four years from the date of the Project Agreement. However, as discussed above, the project had to be reduced considerably from a subsequently estimated cost of $15.1 million to remain within AID's funding

capability. In addition, several implementation problems were encountered necessitating costly adjustments or corrections and requiring several Project Authorization and Project Agreement amendments. As it turned out, the project authorization was amended four times. The PACD was extended three times, first on January 22, 1982 to December 31, 1984; next on August, 1986 to September 30, 1987; the third time on September 22, 1987 to March 30, 1988. The Project Agreement was amended a total of six times and the LOP amount finally increased to $8,377,000 by the addition of $587,000 in August 1986 for the purchase of equipment and parts to rehabilitate the desalination plant which had been operating well below design quality and production level. The GOCV contribution, matching the $8,377,000 from A.I.D. was about $2,000,000 during construction which included seafreight, local materials, labor, housing and board for the general contractor, (Ruhlin & Wallis), and BRISC site engineers. In addition, ELECTRA purchased 12 permeators during the 1985 emergency and has subsequently made a number of other emergency spare parts purchases. This does not include the cost attribution for land and ELECTRA staff time, etc.

PROJECT ACCOMPLISHMENTS

General: The project involved the construction and installation of a desalination and power generation plant in Palmeira, Sal island, to produce 660 m3 per day of potable water with provision for future expansion to 880 m3 per day. The potable water is stored in a 2,000 m3 steel tank at the Palmeira site. Installed power generation consists of two 2,500 Kw generators with provision for doubling the generating capacity in the future to meet the demand up to the year 2000. With the exception of the sewage system and the employee service and support, all of the major project components as envisioned in the reduced scope project were accomplished with varying degrees of success. The power plant, the water delivery and distribution system, the power delivery and distribution system, as well as the plant buildings were all installed and operational by April 1983. The desalination plant, however, was plagued with problems from the very beginning. This will be discussed in greater detail in the section below entitled "Problems Encountered".

Desalination

During the conceptual stage, a process selection study was conducted. The study indicated a clear economic advantage of the Reverse Osmosis (R.O.) System over the vapor systems for seawater desalination on Sal. Consequently, an R.O. system together with energy recovery from the high pressure reject concentrate, was adopted for design and later installed. The drive power for the high pressure pumps is obtained from the diesel-electric plant.
The desalination plant as installed has a design capacity of 660 m3/day, as conceived in the P.P., and consists of a full pretreatment system followed by three parallel trains of Reverse Osmosis systems of 220 m3/day capacity each. Provision is made for adding another 220 m3/day train as demand requires in the future.
As mentioned above, the plant has experienced operational problems and has never produced near capacity but has been able to provide Sal residents with more than twice the amount of water available prior to project construction. Consumption is now estimated at about 23 litres per capita per day (p/c/d) vs 5-6 litres p/c/d prior to construction.

Potable Water Distribution

The communities of Palmeira and Espargos/Preguica are directly served with water as envisioned in the reduced project agreement. In addition, a main line has been installed with other, non-project financing since project construction completion to the community of Santa Maria. Water is also supplied by truck to other small communities with a total population of approximately 600 inhabitants (Hortela and Pedra do Lume). A main steel storage tank of 2,000 m3 capacity was constructed as planned at the Palmeira site. This provides over 72 hours of full rated production or somewhat more than a 5-day water availability at the present rate of 220 m3/day. (Water demand is at about 400 m3/day.) However, it is evident that proper anti-corrosion measures have not been taken with respect to all storage tanks which have experienced severe corrosion on the inside as well as on the exterior of the tanks after only three years of operation. Its use has been and will be interrupted for anti-corrosion cleaning and protective work, creating great strain on the desalination plant which is already operating at a less than desirable production level. Both (Palmeira and Morro Curral) tank roofs have been replaced.

The main storage tank is connected by a 6 inch main to a 980 m3 Morro Curral storage tank and also to the airport. Pumping capacity is more than adequate at 75 m3/hour. It is estimated that the water distribution system is capable of providing water to the communities it serves beyond the year 2000.

In Palmeira, Espargos/Preguica and the airport area, a network of underground 4-inch mains, 2-inch submains, 3/4 inch laterals and curbs stops for house connections has been provided. At the airport an overhead storage tank of 100 m3 capacity has been installed.

An office building for administrative staff, a plant building housing the desalination and power equipment, and an intake pumphouse were constructed under the project.

The demand for water on the island is steadily increasing. Prior to construction of this project the total drinking water available was 48 m3/d from the desalination plant in Santa Maria which was producing a little more than half of its capacity of 90 m3/day.

Brackish water, unsuitable for drinking, was available from wells in Espargos and Pedra de Lume. Consumption was estimated to be 60 m3/day. The average demand has now grown to over 300 m3/d. This is lower than the projections made in 1979. The following table provides the comparison:

TABLE 1

Year of Operation	Water Demand Originally projected m3/d	Annual Production (m3/d)
1983	396	127
1984	435	222
1985	468	224
1986	501	176
1987	534	261

I is obvious that the water plant sizing has been adequate. The timing of any future addition should be adjusted to reflect actual growth pattern. Electra is providing house connections on demand basis. A total of 655 connections have been provided so far, of which 573 are to private homes, 43 to government facilities and 39 to industry and commerce. This represents about 60 percent of all possible connections.

Power Generation/Distribution

Two of the three 500 KW diesel generators specified in the contract documents have been installed. Provisions have been made to permit the installation of a third 650 KW diesel generator in the future in response to demands for additional power. This installed capacity was determined on the basis of a peak demand projection of 884 KW.

The main transmission line from the substation at Palmeira plan site is 15 KV 3/c #1 aluminum cable suitable for carrying up to 2,000 KW of load to the communities of Palmeira and Espargos/Preguica.

Demand for electricity is also steadily increasing. The two (2) 500 KW diesel generators must both run from 18:30 hours through 23:00 hours to meet the peak demand. Moreover, the existing 3 generators of 400 KW at the airport plant also operate as needed. It must be noted that at this time the electric power demand in Pedra de Lume is met by a local generator which is not a part of this project. Forecasted demand and actual power production data are provided below for the five years since the project has been completed:

TABLE 2

Year of Operation	Power Demand Originally projected Year total/Peak MWh/KW	Actual Power Production Year total/Peak MWh/kW
1983	3765/800	1958/440
1984	3938/852	2934/480
1985	4112/869	1946/490
1986	4285/906	2434/540
1987	4459/945	2838/710

The generating capacity as installed is inadequate to meet present demand. In order to meet current high peak demand and to alleviate the burden on the airport generators, a third 650 KW (spare) diesel generator is planned to be installed in 1988/89 through IDA financing.

TRAINING PLAN

From all accounts, the training given under the project to operational and administrative staff of the desalination/power plant was excellent. The professional and senior administrative staff participated in technical and administrative training courses of varying lengths (3-5 weeks) in the United States. On-the-job training was also given by the BRISC director for a period of seven months following completion of construction. The efficacy of the training was demonstrated by the high quality of operation and maintenance carried out by the plant personnel during the early years of the plant's operation, as testified to in consultant Paul Schroeder's report of November 1985.

Unfortunately, after the early years, performance at the plant appears to have declined and several parts are wearing out prematurely because of irregular and inadequate maintenance. It is ELECTRA's view that one of the main causes of maintenance problems beginning in 1986 was an inadequate procurement system instituted then wherein the insertion of an approved procurement services agent required by A.I.D. complicated and delayed procurement rather than enhanced it. ELECTRA would have preferred to deal directly with EMCO, the supplier they were about to select. This problem is, without doubt, compounded by inadequate budgeting on the part of ELECTRA. This does not permit timely ordering and stocking of needed parts and equipment.

DESIGN/CONSTRUCTION/INSTALLATION DEFICIENCIES

General: Based on the reports of ELECTRA, Paul Schroeder and other consultants who have examined the desalination plant there are several deficiencies in design and installation which resulted in numerous interruptions of water supply and inconvenience to the public.

Water Intake
The desalination plant itself has been plagued with problems virtually from the start. The plant was completed and operations commenced in March 1983. By June 1983 the product water was no longer meeting design requirements, and by August 1983 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.

A start-up and performance test was carried out over a four-day period and completed on April 14, 1983. However, this test was done before all parts and supplies were installed and ELECTRA, the Cape Verde Public Water and Power Company that has responsibility for water and power plants in Cape Verde, gave only a conditional acceptance of the test subject to the submittal of a list of some twenty assorted equipment parts as well as instructions for assembly and start up of energy turbine drive, verification of origin size and float size for train fed water flow meters and the supply of parts to allow proper calibration. The major problem which has affected the quality and level of production of potable water produced by the desalination plant is the irreversible damage to the permeators caused by iron deposits released by corrosive action of the product water.

The desalination plant has experienced repeated problems resulting in low quality performance during its five years of operation. These problems have occurred in each major area of the plant. that is, in the intake area, the pre-treatment area and the reverse osmosis area comprised of the high pressure pumps, the permeators and the energy recovery turbines. The problem of low performance of the plant with respect to quantity and quality of water (reverse osmosis area of the plant) mentioned above, intensified in August/September 1983 and frequent shutdowns were required because of alarms by pressure transmitters. Based on several successive investigations by BRISC in May 1984, Polymetrics in February 1985 and a Consultant Paul Schroeder in Oct/Nov 1985, it is obvious that the problem was caused by corrosion of the carbon steel dampeners.

The problem at the seawater intake has had negative effects on the performance of the generators. During winter storms when the surge action at the intake well increases considerably, and the centrifugal intake pumps become airbound and lose their prime, the diesel generators have occasionally had to shut down due to lack of feedwater. They cannot be restarted until the pumps have reprimed, thus there is occasional interruption of power supply during the winter months. This situation will not be corrected definitively until a permanent solution is found for the intake problem. Specific deficiencies are cited below:

(a) An on-shore intake pit or well should have been designed and constructed to avoid the problem of water surge during the winter storms in February and March. Admittedly, this would have been more expensive because of the rocky nature of the terrain at the shoreline. However, in the long run it would have been more cost-effective and provided a permanent solution to the intake question which is a very critical area of the plant. As it is now, much time and money has already been spent and yet the intake pump suffered primary problems as recently as March 1988, when surge caused a loss of suction to the pump, the fiberglass piping broke and the rubber piping for the submersible pump was thrown out of the concrete ditch. ELECTRA is redesigning an intake system that will represent some improvement over the existing system though not a permanent solution to the problem. ELECTRA agrees that only an intake well or pit offshore from the surf zone would provide a permanent solution to the problem. Nevertheless, ELECTRA does not presently have the funding capability to execute such a measure.

(b) The horizontal centrifugal pumps at the intake should have had stainless steel impellers to more effectively resist corrosion. Bronze impellers were used instead resulting in early replacement. Fortunately these pumps have been replaced by larger pumps with stainless steel impellers. Larger more appropriate (15HP) motors have also been re-installed. This was accomplished as part of A.I.D.'s rehabilitation effort in 1987.

(c) The piping should have been heavy duty rubber able to withstand the huge wave energy during winter storms instead of the flimsy fiberglass piping used, which was quickly destroyed by wave action. ELECTRA is designing an intake system that would hopefully improve this situation.

Pre-Treatment

. The raw water tank should have been designed and constructed with a roof. ELECTRA had to install a wooden roof to protect the raw water from dust accumulation.

. Filters, pumps, etc. should have been installed in an enclosed space or inside the building to protect them from the elements.

. The fiberglass piping used was not suitable for exposure to the elements. ELECTRA has done the corrective work by painting the tubing with appropriate paint to eliminate translucency and avoid obstructive algae growth.

High Pressure Pumps

. Stainless steel flexible connections at HP pump discharge should have been designed as rigid spools made of 316 SSL (stainless steel) material instead of flexible connections which are prone to leaking.

. The 4-inch suction pipe to the HP pump is inadequate, resulting in a fluid velocity of 1.3 m/sec. The firm, Wheatley Pumps, recommends a maximum velocity of 0.4 m/sec which would mean replacing it with a 6-inch pipe.

. Suction pulsation dampeners should be in-line type right at pump inlet with 6-inch flanges on both sides.

. When there is risk of severe cavitation, as is the case with the HP pump, the use of bronze valves is not recommended. It should be made of stainless steel instead of cast iron to avoid corrosion.

. HP pumps should be provided with a star-triangle starter to avoid peak power demand at start-up.

Permeators

Delta-P instruments should be installed outside the permeator skids to prevent damages caused by excessive vibrations.

2000 m^3 Storage Reservoir at Palmeira

. A concrete tank such as the raw water tank would have been more appropriate instead of the bolted steel tank actually installed. This would have eliminated the corrosion problems experienced which proved very costly to remedy. ELECTRA, has in fact spent 4 million Cape Verde escudos or about $57,000 U.S. for sandblasting and repainting the interior and exterior of the tank. Furthermore, the design and construction of two 1000 m^3 storage tanks would have been a more effective alternative since one tank could have been kept in operation while the other was being worked on, eliminating the need for a total shutdown of the plant.

. A small truck feeding pump should have been designed and installed to permit expeditious filling of the trucks needed to transport water to those areas in Santa Maria and Pedra do Lume that are not serviced by water distribution lines.

The tank should have been provided with automatic level controls that would permit automatic pump starts at a specified low water level and automatic cut-off at a given high water level.

The 75 HP transfer pumps should have been provided with a star-triangle starter that would have permitted the use of much less energy during peak power demands. They should also have been provided with a device for monitoring water levels in the reservoir to permit automatic start up and cut-off.

Sewage Discharge Piping

The 22-inch PVC piping from the plant to the seashore should have had manholes installed at pipe bends and at critical angle joints to prevent clogging. Also, an appropriate outlet valve should have been provided to prevent the discharge end from being clogged up with gravel and other wave-washed debris.

Water Transmission Main

. Exhaust pipes of the generators should have been firmly installed to avoid serious vibrations.

. The fuel storage tank as well as the fuel tanks for each generator should have been provided with a metering device at the outlet.

. The generators should have been provided with cooling radiators as a backup situation for the case where the intake needed to be shutdown for emergency or maintenance repairs. This would have enabled continuing operation of the turbines when there was insufficient water for cooling of the turbines.

. The transformer on the 6.3 KW power line to the airport is equipped with inadequate primary and secondary coils; thus no power can be delivered on this line on those occasions when there is a need for supplemental power.

. Fixtures for the Palmeira street lighting have defective balasters.

Administration Building

The false ceiling was not strong enough to withstand local windy conditions. Proof of this was given when the conference room ceiling fell and had to be replaced.

. Flushing cisterns could have been supplied with seawater instead of desalinated product water. This would have resulted in increased volume of valuable potable water being available to consumers.

Incorrect Installation/Materials

. Dampeners for the HP pump were supplied with a carbon steel body with hypalon coating rather than stainless steel as specified in the Polymetrics contract. Membrane degradation resulting from iron failing due to corrosion products from the dampener caused irreversible damage to the permeators. Consequently, numerous permeators had to be replaced at great cost.

. Shafts for the three centrifugal type seawater pumps were originally supplied in carbon steel by the contractor. These failed in mid-1984 but subsequently have been replaced by the contractor with 316 SSL material at no charge.

PROJECT IMPACTS/BENEFITS

Despite the fact that the project scope had to be reduced substantially to remain within the limits of available A.I.D. funding, and despite the persistent problems experienced in the desalination plant, numerous benefits have resulted from the realization of this project. Most important of all is the availability of increased quantities of potable water to all the residents of Sal. Whereas the pre-construction availability of potable water was about 5 to 6 litres/person/day (11.25 litres/person/day for all water including brackish water), the residents of Sal are today consuming about 22-23 litres per day of acceptable quality drinking water.

Also important is the fact that the desalination plant can be expanded to meet the growing demands for drinkable water at a relatively low differential cost since the main infrastructure has been installed with provisions for adding additional trains of permeators and power turbines, pumps and other instrumentation as needed. The intake structure, storage facilities, plant building, office building etc. can also serve an expanded system at a substantially reduced unit cost of production. The same convenience, ease of expansion and reduced unit costs of production apply equally well with respect to expansion of power production to meet future needs.

The increased access to water and power in Sal has also established a basis for increased commercial, industrial and tourist activity the results of which are evidenced in increased jobs and an overall higher standard of living and health. There are also many secondary benefits to Sal residents and to the economy of Cape Verde. Sal residents' constant fear of water shortage, rationing and at times periodic interruptions of potable water supply was eliminated with the construction of the desalination/power plant.

The following are examples of commercial or industrial facilities built on Sal based on the improved availability of water and power:

(1) SALMAR (the lobster plant) completed the expansion of its facilities to include freezing, ice-making and fresh food storage (for local consumption). It has installed storage capacities of 640 tons each for fish, lobster and food. It has the capability for making 10 tons of flake ice for selling to fishing boats so that they can preserve the fish brought back to port. The annual power consumption of this plant has reached 10,000 KWH.

(2) Palmeira port construction was completed in late 1986 but is yet to be connected to the ELECTRA power plant. The pier can berth ships up to 300 tons and will afford Sal Island the capacity of exporting frozen fish and lobster by ship directly to Europe, as well as importing needed products directly from Europe.

(3) The airport has expanded and modernized its terminal building and facilities.

(4) Construction of a new 96-room hotel in Santa Maria was completed in late 1986. It is owned by a joint venture company called Hotelmar and was financed by a French investment firm. The same French firm in conjunction with the GOCV and the EEC financed the water and electricity transmission lines from the airport to Santa Maria.

(5) Eighty additional rooms were added to the Morabeza Hotel in a major expansion of its facilities. In addition, a new hotel is expected to be built in Santa Maria by a German investor.

The following table illustrates a comparison of anticipated end-of-project benefits with actual observed benefits. It is obvious that although numerical targets, which in many cases were difficult to estimate due to lack of hard data were not met, the overall impact is positive.

ANTICIPATED BENEFITS	ACTUAL OBSERVED BENEFITS
Access to Water & Power by 1,100 households	Access to water by 573 households,43 govt facilities and 39 industry & commerce units (655 units). Access to power provided to 905 households, 57 govt facilities and 48 industry & commerce units (1,010 units).
Unit price to households for desalinated water reduced from $2.52/m3 to unsubsidized price of $0.45/m3.	Subsidized unit price of water to households varies between $1.25/m3 and $2.90/m3 depending on amount consumed. Unsubsidized production cost of desalinated water is approximately $8.70/m3.

Creation of 50 new jobs for administrative, technical and support staff at the desalination/power plant.	A total of 46 new jobs were created for needed administrative, technical and support staff.
Average quality of drinking water improved from 1,750 ppm salt content to less than 600 ppm.	Average quality of drinking water improved to about 500 to 900 ppm salt content or below WHO limit of 1,000 ppm.
Average availability of drinking water raised from about 5-6 litres/capita per day to 50 litres/day/person.	Average availability of drinking water raised to 22-23 litres/day/person.
Incidence of impure water-related diseases will be decreased about 50% (WHO figures)	According to Electra's Administrative Head, incidence of high blood pressure and kidney problems is reduced since operation of plant commenced.
Unit price to consumer for electric power reduced from $0.142 - $0.188/KWH to $0.135/KWH.	Unit price to household consumers for electric power is $0.203/KWH. Unit price to Industry averages around $0.29/KWH.
Generate enough revenues to pay back all costs and operate profitably.	75% of all costs including replacement costs are subsidized, with GOCV providing 1/4 of cost and ELECTRA providing 1/2 of cost.

PRESENT STATUS OF DESALINATION PLANT

There are presently two trains (A&B) operating with twelve permeators on train A and eleven on train B. Eleven (11) new permeators have been installed on train C but train C is not yet operating for lack of certain needed parts and fittings e.g. pressure switches, pressure indicators, control valves and feedwater pipe fittings. It is expected that these parts which have been shipped will arrive within two weeks and train C can get operational with a few days thereafter.

Train A is presently producing desalinated water at about 60 percent of design capacity and better than specified desirable water quality. Train B's present production rate is about 40 percent of design capacity and much better than specified desirable water quality. Together trains A & B are producing about 220 m^3/day or 50 percent of their total design capacity. Both trains however show evidence of having some permeators which have suffered irreversible damage and will need to be replaced. Suitable valves to permit the equipping of each permeator with delta-P instrumentation are still not available at the Sal Plant. This is proving to be very costly as the delta-P instrumentation provides the critical early warning signals for timely chemical cleaning of the filters in order to avoid irreversible damage to the permeators.

The operating and maintenance staff is well aware of the importance of the delta-P instruments and could do the necessary monitoring and cleaning of the filters once the delta-P instrumentation is in place and functioning. Hopefully, this problem will be solved soon with the arrival of the appropriate valves. It is very important that the situation be remedied because the huge expense of replacing permeators (the guts of the system) will be entirely the financial responsibility of the GOCV at the expiration of the project on March 30, 1988.

Once train C is put into operation, hopefully within two weeks, assuming no major snags, the plant can reasonably be expected to produce 300 to 350 m^3/day of desalinated water with better than specified desirable quality.

The intake system is presently operating better than it did a year ago but could be expected to lose suction during February and March winter storms unless ELECTRA solves the problem by installing a more permanent solution to the problem of break in suction and resultant loss of pump priming.

The HP pumps have been operating satisfactorily. In the pre-treatment area, one primary filter and one secondary filter are still inoperative as the Garlock butterfly valves and flow indicators have not yet been installed.

The flexible hoses for the energy recovery turbines became inoperative after three or four months of operation. They were replaced by rigid spools which could cause problems because of vibration.

The administrative and operational staff of the Desalination/Power Plant are aware that these deficiencies must be corrected soon in order to prolong plant life, reduce maintenance and rehabilitation costs to ELECTRA and the GOCV, and minimize the interruption of service to the consumers in Sal.

RECURRENT COSTS TO ELECTRA AND GOCV

As can be seen from the operation and maintenance figures provided in Table 3 below, total O&M costs for the desalination plan averaged 37,151,000 Cape Verdean escudos/yr (CVE/yr) equivalent to $530,700/yr (assuming an exchange rate of $ 1US = 70 CVE) for years 1985 - 1987. It can be deduced from Table 4 that annual operation and maintenance costs for the power plant average 23,966,000 CVE or $342,400. The figures in Tables 3 and 4 were obtained partly from the Sal desalinatin/power plant management staff and partly from ELECTRA officials.

ELECTRA's projected figure of 29,218,000 CVE for O&M expenditure for 1988, though twenty percent less than the average annual cost (1985 - 1987) is probably adequate in view of the major rehabilitation performed on the plant in 1986 and 1987 with predominant funding by A.I.D. ELECTRA'S projected figure of 29,310,000 CVE for the power plant compares well with previous expenditures and is in fact eighteen percent higher than the yearly average for years 1985 through 1987.

It should be mentioned here that the O&M costs are higher than normal because of lack of punctual maintenance due to inadequate funding that would permit timely procurement of needed equipment and parts. This issue becomes even more important with the termination of the A.I.D. project because the entire financial burden for operation and maintenance now devolves to the GOCV. Discussions were held with ELECTRA and other GOCV officials and they were advised to consider increases in water and power rates charged to the public, including private, industrial and commercial interests, with a view to reducing GOCV subsidy which is presently as much as one half the cost of production. In this way, the GOCV could perhaps assure the availability of funds for timely acquisition of needed equipment and parts, thereby reducing considerably its overall O&M burden.

TABLE 3

SAL DESALINATION PLANT
ANNUAL O&M COSTS
(Thousands of CVE)

	1983	1984	1985	1986	1987	1988
Operation:						
Power	10,580 1/	12,157	17,853	16,450	7,289 2/	12,597
Labor	4,749 1/	3,436	4,481	4,965	--	3,121
Chemicals, Lubricants and Materials	1,893 1/	1,622	849	3,985	--	1,500
TOTAL	17,222 1/	17,215	23,183	25,400	7,289 2/	17,218
Maintenance:						
ELECTRA	N.A.	N.A.	7,570	2,232	5,780	12,000
A.I.D.	N.A.	N.A.	--	20,000 3/	20,000 3/	--
TOTAL	N.A.	N.A.	7,570	22,232	25,780	12,000
Total O&M	N.A.	N.A.	30,753	47,632	33,069	29,218

1/ Include old plant at S. Maria as of April 1983
2/ As of September 1987
3/ USAID contribution for rehabilitation of plant at Palmeira ($587,000)
N.A. - Not Available

TABLE 4

SAL POWER PLANT
ANNUAL O&M COSTS
(Thousands of CVE)

	1983	1984	1985	1986	1987	1988
Operation						
Diesel	9,380	18,262	14,313	16,690	12,317	17,601
Lubricants and others	448	624	463	3,374	--	1,100
Labor	4,300	6,794	5,877	7,162	2,830	2,791
Supplies and Services	269	630	601	1,386	174	5,228
TOTAL	14,397	26,310	21,254	29,112	15,231	26,720
Maintenance						
ELECTRA	N.A.	N.A.	2,460	1,480	2,360	2,590
A.I.D.	N.A.	N.A.	--	--	--	--
TOTAL	N.A.	N.A.	2,460	1,480	2,360	2,590
TOTAL O&M	N.A.	N.A.	23,714	30,592	17,591	29,310

Even though A.I.D.'s responsibility to this project terminates officially with the PACD of 30 March 1988, USAID/Cape Verde has indicated to the GOCV its willingness to use Sahel Human Resources Development (SHRD III) funds to train ELECTRA personnel in spare parts procurement and in operation and maintenance of the plant. Consultant Schroeder in conjunction with procurement agent, FETCO, had proposed an applicable training program in October 1987. This program needs to be focussed and refined through joint USAID/ELECTRA collaboration so that a detailed program can be costed out and scheduled in USAID/Praia's country Training Plan for review and approval by AFR/TR/EHR.

ISSUES TO BE RESOLVED

POLYMETRICS Performance Bond

The Government of the Republic of Cape Verde agreed in a contract signed 27 July 1981 with Polymetrics Inc, an American company, at 1005 Timothy Drive, San Jose, California, to purchase desalination equipment at a total contract price of $1,112,700 F.A.S., New Bedford, Massachusetts.
On July 31, 1981, Polymetrics Inc, as Principal and the American Home Assurance Company. NY 10005 as Surety, issued a Performance Bond in the amount of $111,270 or 10 percent of the contract amount.
According to the terms of the Bond, "Polymetrics Inc., as Principal, and the American Home Assurance Company as Surety, are held and firmly bound unto the Government of the Republic of Cape Verde, as Obligee in the sum of One Hundred Eleven Thousand, Two Hundred Seventy and no/100ths Dollars ($112,270.00), for the payment of which sum, well and truly to be made, the Principal and Surety bind themselves, their heirs, executors, administrators and assigns, jointly and severally, firmly by these presents."

The desalination equipment was installed and plant completed in March 1983. Performance testing was done between April 10 and April 14, 1983. ELECTRA, the semi-autonomous Cape Verdean company charged with administration of water and power utilities, notified BRISC that tests performed were not satisfactory and issued a conditional acceptance letter, stipulating the additional parts and equipment to be furnished, corrective work to be done, etc. and requiring a deferred performance test when all has been made right with the plant.

On April 23, 1984, ELECTRA asked American International Companies (AIC), a Bond company representing, among others, American Home Assurance Company to extend the validity of the performance bond.

According to a September 1985 ELECTRA report entitled "Operating Problems Report on Sal Island Desalination Plant Equipment Supplied by Polymetrics, Inc.", on May 7, 1984, BRISC notified the AIC Bond company of the decision to extend the period of validity of the performance bond.

There is no record in USAID/Cape Verde's files of the length of extension of the period of validity of the Bond.

On May 15, 1984, Polymetrics Inc. asked ELECTRA for issuance of a letter of acceptance. On August 16, 1984, ELECTRA informed Polymetrics Inc. that it could not issue a letter of acceptance because the problems with pulsation dampeners and permeators were still unresolved. On November 6, 1984, ELECTRA further informed Polymetrics Inc. that urgent measures must be taken to solve the damaged permeator problem resulting from iron fouling due to corrosion of carbon steel dampeners.

In February 1985, Polymetrics replaced carbon steel dampeners with contract-specified stainless steel dampeners, but refused to replace damaged permeators, and instead put out a Warranty Status report on May 17, 1985 citing O&M deficiencies at the plant as the cause of irreversible damage to the permeators.

In his September 1985 report, "Operating Problems in Sal Island Desalination Plant Equipment Supplied by Polymetrics Inc.", ELECTRA Engineer Robalo made a recommendation, among others, that legal action be taken against Polymetrics Inc. for contract default relative to the damaged permeators. ELECTRA subsequently sent a letter to AID/Washington requesting assistance with the preparation of such legal action. However, shortly thereafter, Polymetrics declared bankruptcy and was bought out by a French firm. The question of legal action, therefore, became moot.

The question which remains now, is what happened to the Performance Bond. A copy of the Bond is in the USAID/Cape Verde file and the original is most likely in AID/W's files. Is the Performance Bond still valid? If so, AID/W should contact the American International Companies, the bonding representative of American Home Insurance, to determine how the $111,270 value of the Bond can be reassigned. A legal opinion from AFR/GC is also required as to the proper assignment of the $111,270, i.e. to AID or to the GOCV, given the fact that the AID Grant to the GOCV expires March 30, 1988.

Likely Claims

Permeators

On November 1986, ELECTRA received 26 Dupont Model B-10 640T permeators which were ordered from EMCO (US Supplier) along with other equipment and parts in order to put all three permeator trains into running order prior to complete turnover of the project to the GOCV by PACD of March 30, 1988. All equipment and parts were funded out of an additional allocation of $587,000 of AID funds obligated in FY 1987.

Three of these twenty-six permeators were installed in November 1987. Failure of these permeators occurred three months after installation or fifteen months after delivery. ELECTRA believes that failure was due to deficient conditioning of the membranes. Although ELECTRA'S specifications, which were accepted by the supplier, clearly state that a minimum of one year guarantee shall be given on permeators' performance after start-up, the procurement agent FETCO has informed USAID/Praia that the permeator warranty provided via the supplier, EMCO, was a standard 12 month manufacturer's warranty and that an option for additional cost was available for extended period warranties. No warranty was furnished to ELECTRA with the permeators, yet EMCO is claiming that in accepting them (EMCO) as a supplier, ELECTRA accepted EMCO's total package offer including the one-year manufacturer's warranty. There is a possibility that eleven new permeators from the same shipment will also prove to be deficient. Since total installed cost of each permeator, including shipping, procurement fee and transportation is around $10,000, this potential claim is not insignificant. AID legal counsel will be required and assistance to the GOCV will be appropriate should it become necessary. In any event, all legal claims will be reassigned to the GOCV effective PACD of March 30, 1988.

Crane Butterfly Valves

ELECTRA ordered from EMCO as much as 8 butterfly valves of various diameters to replace the existing ones -- Gar-Seal Garlock Series 500. EMCO proposed that CRANE valves be procured instead of GARLOCK as manufacturer specified that valves were adequate for seawater service. Three CRANE butterfly valves 6" were installed on the primary filters C and D on August 19, 1987. After three weeks of operation, on September 9, 1987, the valves were corroding and passing the iron on to the feedwater of the permeators.
Eng. Schroeder's report of October 1987 stated on page 26 "The New (Corroding) Replacement Butterfly Valves: The most serious problem in this area is that the replacement butterfly valves which were ordered are of an inferior design to the original equipment which they were to replace. In the original Garlock

valves, the entire wafer is a smooth plastic coated face. In the CRANE replacement valves, the smooth wafer is penetrated by an about half-inch diameter pin, which, of course, complicates the coating problem.

Inspection of the valve revealed corrosion in the area around the aforementioned pin, where the coating has apparently failed. This spurred inspection of the other new CRANE valves. Almost all of them appeared to have incipient failure of the coating in the same place."

Three CRANE butterfly valves 6", three 4" and one 8" were shipped in November 1987 to FETCO and on to EMCO. Only the three 6" butterfly valves were in operation, the others were brand new. All were shipped to FETCO for replacement by GARLOCK ones.

FETCO telex of March 23, 1988, transmitted the following reply from the authorized CRANE representative:
Inspection Report:
"Valves had broken gear wheels and handles.
Some valves were severely rusted due to exposure to environmental conditions. Adverse.
These valves are mechanically perfect except for conditions noted.
Valves are designed for sea water applications and have proven records in this service.
CRANE cannot be responsible for damage to valves due to poor handling and storage procedures.
EMCO will abide with CRANE findings and therefore cannot accept any returns."

USAID/Cape Verde sent a reply to FETCO telex which refutes this finding (PRAIA 0840, 3/28/88). ELECTRA may wish to pursue this matter with a legal claim.

CONCLUSIONS AND RECOMMENDATIONS

Conclusions

1. The performance of the desalination component of the project has been disappointing. The problems encountered and resulting low productivity and water quality can be attributed to a combination of design deficiencies, installation of inadequate materials, parts and fittings and inadequate plant maintenance due to inadequate funding by the GOCV.

2. Despite low production performance of the desalination plant, the project has improved considerably the availability of potable water and electric energy to Sal residents, and has in some measure improved the standard of living and public health. The project has so far been able to meet the growing demands for water and electric power in Sal and has stimulated appreciably the expansion of industry and commerce in Sal. It has also established a basis for continuing economic growth and with a relatively small additional capital investment, the GOCV will be able to expand the supply of potable water and electric power to meet the demands in Sal for many years to come.

3. The GOCV will have to provide adequate funds through its regular planning and budgeting exercise to assure timely ordering of equipment and parts so that routine maintenance of the desalination/power plant will become standard operating procedure. In this way, plant productivity and water quality can be improved and the need to undertake costly emergency rehabilitation of the plant avoided.

4. Polymetrics, the firm that purchased and installed the desalination equipment did not live up to the terms of its contract as a result of providing inadequate equipment, parts, valves, tubings and fittings, and by replacing some of these parts with other equally unsuitable parts. The equipment and parts supplier, EMCO, is also tending to be remiss in its responsibility to make good on proven defective butterfly valves and permeators. Should EMCO persist in its irresponsible attitude in the face of evidence of shipment of defective equipment, AID should assist the GOCV in filing a legal claim against EMCO. Furthermore, AID must seek ways to impress upon American suppliers and design firms the necessity of producing high quality work and standing behind their product in order to avoid further damaging the reputation (and export marketing ability) of the U.S. suppliers involved.

5. Based on recent statements made by various officials of the GOCV including ELECTRA personnel, good harmonious working relationships between AID and the GOCV remain intact despite the disappointing performance of the American firms such as Polymetrics, BRISC and EMCO. This is a tribute to the GOCV's appreciation of AID's good faith and effort to try to correct plant deficiencies and remedy problems before finally turning it over to the GOCV.

Recommendations

1. That ELECTRA, with the active participation of the plant operating staff, prepare an O&M plan for the plant and an equipment and parts replacement schedule to be used as a basis for annual budgeting and routine ordering of equipment and parts. AID's provision of training, preferably on-the-job, by technical experts could be requested if deemed necessary.

2. That the GOCV provide adequate funding to permit timely purchase of equipment, supplies and parts that would insure punctual maintenance of the plant, thereby guaranteeing a higher production level and water quality at a lower production cost.

3. ELECTRA should develop a training plan for plant personnel encompassing operation and maintenance procedures, equipment procurement inventory control and supply management. Again, AID's participation could be requested.

4. AID should assist the GOCV, in every way it can to file appropriate legal claims for default against suppliers, should they eventually refuse to replace butterfly valves and permeators which were probably defective upon receipt in Sal within the last year or two.

5. Price of the water for some or all consumers should be increased to reduce the plant's operational deficit for ELECTRA, thereby providing additional funding for adequate maintenance of the plant and a sinking fund (amortization) for replacement cost. The water tariff for industry, hotels and Airport could be significantly increased to a price close to the production cost. These steps should be considered in light of a national level review of water use and pricing policy which may soon be undertaken by the GOCV.

LESSONS LEARNED

1. For a relatively complex technical project like the Sal Desal/Power Project, AID needs to have a qualified field project engineer (DH or PSC) as a technical project manager to track the construction and installation progress, and evaluate to what extent the designated A/E responsible for supervision or control of the work is adequately representing AID's interest.

2. Procurement specifications, especially with respect to warranties, need to be clear and well-defined, e.g. there should be a detailed definition of a term such as "start-up" if the expiration date of the warranty is described as one year after start-up. There should also be a very thorough review of offers received from suppliers to assure consistency between specifications contained in the offer package and specifications contained in the request for proposal (RFP). A legal review of both the RFP and the offers received should be mandatory.

3. Performance warranties up to two years should be considered for plants involving sensitive equipment and relatively high technology in developing countries. Although this would tend to increase the price of the installation contract somewhat, it would provide greater assurance of efficient, cost effective plant performance for a high technology-sensitive project such as the desalination/power plant. There should be a period of follow up by a technical advisor for longer than seven months. Two years of periodic inspection and advice by an AID-hired consultant would tend to intercept problems before they reached crisis proportions and would serve as continued on-the-job training for plant operating staff, especially with respect to maintenance scheduling, and ordering of parts, inventory control, etc.

4. In attempting to reduce or contain project costs, A.I.D. should be very careful not to eliminate critical components of the project or to reduce below certain minimum standards, dimensions or sizes of operational parts intrinsic to successful project operation and maintenance.