PRELIMINARY RESEARCH STUDY FOR THE CONSTRUCTION OF A PILOT COGENERATION DESALINATION PLANT IN SOUTHERN CALIFORNIA

Prepared by
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Irvine, CA

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This preliminary research study, co-funded by Supersystems, Inc. and the Bureau of Reclamation, provides an evaluation for the construction of a pilot cogeneration/desalination plant at one of two sites in southern California. A conceptual plant design and a slightly consemative cost estimate were developed to evaluate the economic desirability and the overall system efficiency impact. The conceptual design includes a gas turbine-generator set with a heat recovery steam generator to produce electricity and steam. The steam is utilized in the desalination processes. For this study, two desalination technologies were considered: multi-effect distillation and multi-stage flash evaporation.

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As the Nation's principal conservation agency, the Department of the Interior has responsibility for most of our nationally-owned public lands and natural resources. This includes fostering sound use of our land and water resources; protecting our fish, wildlife, and biological diversity; preserving the environmental and cultural values of our national parks and historical places; and providing for the enjoyment of life through outdoor recreation. The Department assesses our energy and mined resources and works to ensure that their development is in the best interests of all people by encouraging stewardship and citizen participation in their care. The Department also has a major responsibility for American Indian reservation communities and for people who live in island territories under U.S. Administration.

Disclaimer

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TABLES

FIGURES

FIGURES • Continued

APPENDICES

ABBREVIATIONS

The "Abbreviations" used during the analysis of this report are as follows:

ac ft	Acre feet
AQMD	Air Quality Management District
Btu	British thermal unit
MMBtu	Million British thermal unit
$CaCO_3$	Calcium carbonate
CDA	Cellulose diacetate
CTA	Cellulose triacetate
DESAL	Desalination plant or system
DSL-1	Desal Program #1
ED	Electrodialysis
F	Degrees Fahrenheit
ft	Feet
gpdsf	Product water flux in the RO process, gallons per square foot day
g/kg	Grams per kilogram
gpd	Gallons per day
gpm	Gallons per minute
gpmsf	Gallons per minute per square foot
GT	Gas turbine unit
H	Enthalpy, Btu/lb
h - hr	hour
HgA	Pressure absolute, mercury
hp	Horsepower
HRSG	Heat Recovery Steam Generator
HTE	Horizontal Tube Evaporator
HTME	Horizontal Tube Multiple Effect
IRR	Internal Rate of Return
k	Thousand
kgal	Thousand gallons
kW	Kilowatt (1000 watts)
kWh	Kilowatt hours
lb	Pounds

ABBREVIATIONS - Continued

lb/hr, pph	Pounds per hour
MCL	Maximum contaminant level
MED	Multiple effect distillation
mil gal	Million gallons
MGD	Million gallons per day
mg/L	Milligrams per liter
$Mg(OH)_2$	Magnesium Hydroxide
MM	Million
MSF	Multistage Flash evaporator
MW	Megawatt (1000 kilowatts)
NC	Normally Closed
NO	Normally Open
R	Performance Ratio, pound of distillate per 1000 Btu heat input
PPM	Parts per million
psia	Pounds per square inch absolute pressure
psig	Pounds per square inch gauge pressure
RO	Reverse osmosis
SDWA	Safe Drinking Water Act
sq ft/cu ft	Square feet per cubic feet
TDS	Total dissolved solids
μg/L	Micrograms per liter
μmhos/cm	Micromhos per centimeter (conductivity)

METRIC SYSTEM

Kg/cm^2	Kilograms per square centimeter
Met Ton	Metric ton (2200 lb)
Kg	Kilograms (2.2 lb)
Mt	Meter (100 cm)
kPa	Kilopascal
L/S	Liters per second
Cu Mt	Cubic meter

SECTION 1
DESALTING: HISTORY & DEVELOPMENT

1.1 Desalting: Background

Desalting/Desalination/Desalinization: Means the same thing, and that is the removal of salts from seawater or brackish water. Over three quarters of the earth's surface is covered by salt water. This water is too salty to sustain human life, farming, or industry.

Basically, only water with total dissolved solids (TDS salts) of less than one thousand parts per million (PPM) is considered acceptable for community water supply. The World Health Organization in most of the cities in the United States have set the safe drinking water limits at 500 ppm, TDS.

The importance of salt removal from ocean water or other saline water resources reaches far beyond its mere technological aspects, because the availability of fresh water has a decisive effect on the-pattern of human development. The growth in world population and increased industrialization has intensified the quest for pure water. Recent fresh water shortages in California and in many parts of the world have cast a spotlight on the problem and led to greatly increased interest in it. Research and development funds and facilities have become available, and creative minds have been attracted to this subject.

1.2 Desalting History & US Contribution

During this century, one important step in desalting development came in the 1940's during World War II when various military establishments in arid areas needed water to supply their troops. The potential that desalting offered was recognized more widely, and work was continued after the war in various countries.

An abundance of literature on the subject of desalination can be found in the US today. This is due to the fact that the amount and intensity of the research and development effort, as judged by the published work in the literature, have been greater in this country than anywhere else. Encouragement and financial support by the United States Government, channeled mostly through the office of saline water, Department of the Interior, have played a decisive part in the rapid growth of this field. The US government actively funded research and development for over 30 years, spending about 300 million dollars in the process.

1.3 Seawater Desalination

Simply, the two main methods of removing salt from ocean water currently in use for large scale applications are: distillation and reverse osmosis. In distillation, sea water is heated until it is boiled. The salt remains in the water; the steam is captured and condensed into fresh water.

In reverse osmosis, hydrostatic pressure is applied to force sea water through a semi-permeable membrane, which will filter the salt from the water.

In both techniques, the leftover brine is piped back into the ocean. About 6-7 percent of that water is salt, compared with 3.5 percent for regular sea water.

1.4 California Drought

As a result of the recent five year drought, Californians have certainly learned that the solution to their water problems will have ‘to incorporate a combination of sources, including sea water desalination. The drought proved how unreliable the current water supplies are, with many State officials indicating that we are much better off relying on a reliable source of water, such as sea water desalination, instead of being dependent on rain.

On the average, two average size families in Southern California would consume one acre-foot, or 325,836 gallons (1.2 million liters) of water, during a year's time span.

Southern California normally gets one third of its water from the rain and snowfall on the western slope of the Sierra Nevada, which has been below average in the last five years. Southern California also gets about one-third of its supply from the Colorado River. But that source also is in peril. Because of a Supreme Court decision, an increasing amount of the river's flow will go to Arizona and Colorado.

The other one-third of the supply comes from local ground water - a source being increasingly tapped to meet our phenomenal growth; Southern California's population increased by 300,000 people per year throughout the 1980s, and is expected to grow by a similar amount in this decade.

The drought, the growth and the loss of Colorado River water means one thing, water experts say - Southern California no longer has an inexhaustible supply of water.

During 1987-1992, these five consecutive years of drought have greatly depleted the state's reservoirs, leading to widespread water restrictions. After months of asking to use less water because of the drought, Southern California's main supplier "MWD" recently approved a 24 percent increase in the wholesale price of water, to $244 an acre-foot, effective July 1, 1991 and another rate increase in 1993. These price increases are the biggest since 1983. The retail price of water typically is about twice the wholesale price.

1.5 Southern California Seawater Cooled Power Plant

In Southern California, 13 coastal power plants are in commercial operation and all use seawater for condenser cooling. The number of units and installed capacity are as follows:

Number of power units 52
Total Installed Capacity...1 1,734 MW

Assuming that all of these units are basically utilizing the conventional power plant boilers with the condensing type steam turbine and there is adequate land area to accommodate a desalination facility at each site, the integration of desalination plants with these power plants have the potential for desalinated water production of about 1600 MGD or 1,796,900 ac ft/yr. This production is adequate for the water consumption of 15 million persons by US standards.

1.6 Cogeneration in California

We have estimated that there are at least thirty-five cogeneration plants, directly located on the coast, or within a very short distance from the Pacific Ocean. These cogeneration facilities utilize seawater for cooling purposes. Some of these cogeneration facilities have additional space to accommodate seawater desalination plants.

Seawater desalination would have a positive impact on the qualification status of cogeneration systems, especially those who are operating with very small Federal Energy Regulatory Commission (FERC) efficiency margins. The addition of desalination plants to some of these cogeneration facilities would result in improving the qualification status of these facilities, and thus put them in compliance with the federal regulations for efficiency standards as required by the federal Public Utilities Regulatory Policy Act (PURPA) laws of 1976.

1.7 California Utilities & Desalination Potential

Desalination plant implementation for California electric utilities can be summarized in three distinct approaches:

1.7.1 Retrofit Approach:

- Existing plant: Integrate desalination plants.
  Minimum modifications and minimum power output reduction are the two major prime concerns.

1.7.2 Modify Approach:

- Repower, use existing site and integrate with desalination.
  Low cost water. Repowering efficiency improvement as a result.

1.7.3 New Power Facilities Approach:

- Cogeneration, dual purpose plant, etc.: Plan to integrate with desalination. Feasible, and most economical approach.

1.8 This Study

Super Systems, Inc. (SSI) was awarded a contract by the Bureau of Reclamation (BUREC) to perform a preliminary research study for the installation of a cogeneration/desalination facility. The plant will be located at one or two sites in Southern California.'

Both seawater desalination plants will be integrated with cogeneration systems for improved economics through the simultaneous production of electricity and desalinated water.

SECTION 2.0

EXECUTIVE SUMMARY & RECOMMENDATION

2.1 Background

This report presents a conceptual design and slightly conservative - order of magnitude - cost estimate to evaluate the economic desirability and impact of an addition of a desalination plant to the existing cogeneration plant in Santa Monica, CA and the construction of a new pilot cogeneration - desalination plant to be located in the area next to San Diego Gas and Electric's (SDG&E) Encena Power Plant in Carlsbad, CA.

In 1989, SSI finalized the design and supervised the construction of a 1.1 MW, gas turbine based cogen system with cooling and heating for the Santa Monica Bay "LOEWS" Hotel. The system went into commercial operation in early 1990.

The proposed desalination plant will utilize the excess steam which is not being utilized at the present time inside the Hotel. Also a good portion of the steam which drives the absorption chiller in summer can be utilized in winter for the desalination facility. The Hotel is located directly on the ocean and'seawater will be available to the plant from a seawater well.

We have also had numerous contacts with the Carlsbad Water District Manager and Engineers. During the month of September 1994, SSI made a 2 hour presentation before the City Water Commission. A unanimous vote to proceed with a seawater desalination plant was granted at the end of the meeting.

The Carlsbad pilot plant will include a small 4 MW size power generation facility with the electricity to be sold to the city and to SDG&E.

The combined power desalination system will probably represent the most cost effective option available today for the production of desalinated seawater. The combined desal and gas turbine will also form a qualified cogen facility "OF" and therefore will entitle the facility to all the advantages of QF cogeneration.

This Executive Summary presents the key findings of the technical and economic assessment of adding a desalination system to the existing cogeneration plant in Santa Monica and the construction of a new cogeneration/desalination plant in Carlsbad. Also, the rationale for the desalination assessment, the selected size, and the price to produce potable water is discussed. Conclusions and recommendations are also made at the end of the report.

The study program exceeded its scope of work by briefly investigating the technical and economic merits of a full scale, nominal 5 MGD, desalination facility to be installed in the Carlsbad area. Section 8.0 includes a cost comparison that shows the effect of desalination "Economy of Scale" for 0.35 and 5 MGD sizes.

2.2 Study Objectives & Approach

For this study, the following objectives and tasks were undertaken:

- Identify and describe the available desalination processes that could be utilized.
- Evaluate and screen the desalination processes based on the technical, environmental and economic factors.
- Identify the desalination processes most suitable for the existing Santa Monica cogeneration plant and the new proposed Carlsbad pilot plant.

- Identify those systems that are commercially available and can be installed at the site.
- Determine the technical feasibility, annual operating costs and the product water production.
- Provide capital and installed capital costs.
- Determine the area required and configuration.
- Determine the most economical desalination process(es).
- Determine any environmental concerns associated with construction of such a facility.
- Determine the impact of the addition of desalination to the existing Santa Monica cogeneration plant.
- Determined the expected desalinated water analysis.
- Determine the water cost per 1000 gallon and per cubic meter.
- Provide a milestone schedule that includes design, permits/licenses, procurement, construction, startup and testing.
- Prepare a 20 year cash flow analysis.

2.3 Selected Alternatives Highlights

The two commercially proven distillation processes available today are the multi-stage flash (MSF) and the multi effect distillation (MED). The MSF technology is currently more widely used and based on past use, as informed by a major MED equipment supplier, is more cost effective to install than the smaller size MED units. The MSF unit was selected for the

Santa Monica Bay location and with regard to Carlsbad, the MED unit was selected. As discussed in the report text, MED has many economical advantages over MSF, but a shorter track record and fewer years of operating data. Section 3.0 will illustrate that the MSF still represents over 85% of distillation processes in commercial operation in the world today.

Figure 2.1 is a simplified diagram for each recommended system considered in this study illustrating the basic components of each plant and the steam flow. For detailed descriptions of each system refer to section 4.0 for Santa Monica and section 5.0 for Carlsbad. Included in the system description sections are also detailed heat and mass balance diagrams for each proposed system.

2.4 Key Study Findings

Both projects are feasible. Both pilot plants either in Santa Monica or Carlsbad will produce distilled water from the facility. The permitting of the MSF pilot plant in Santa Monica will be much more difficult and time consuming because Santa Monica Bay is considered a major tourist attraction location.

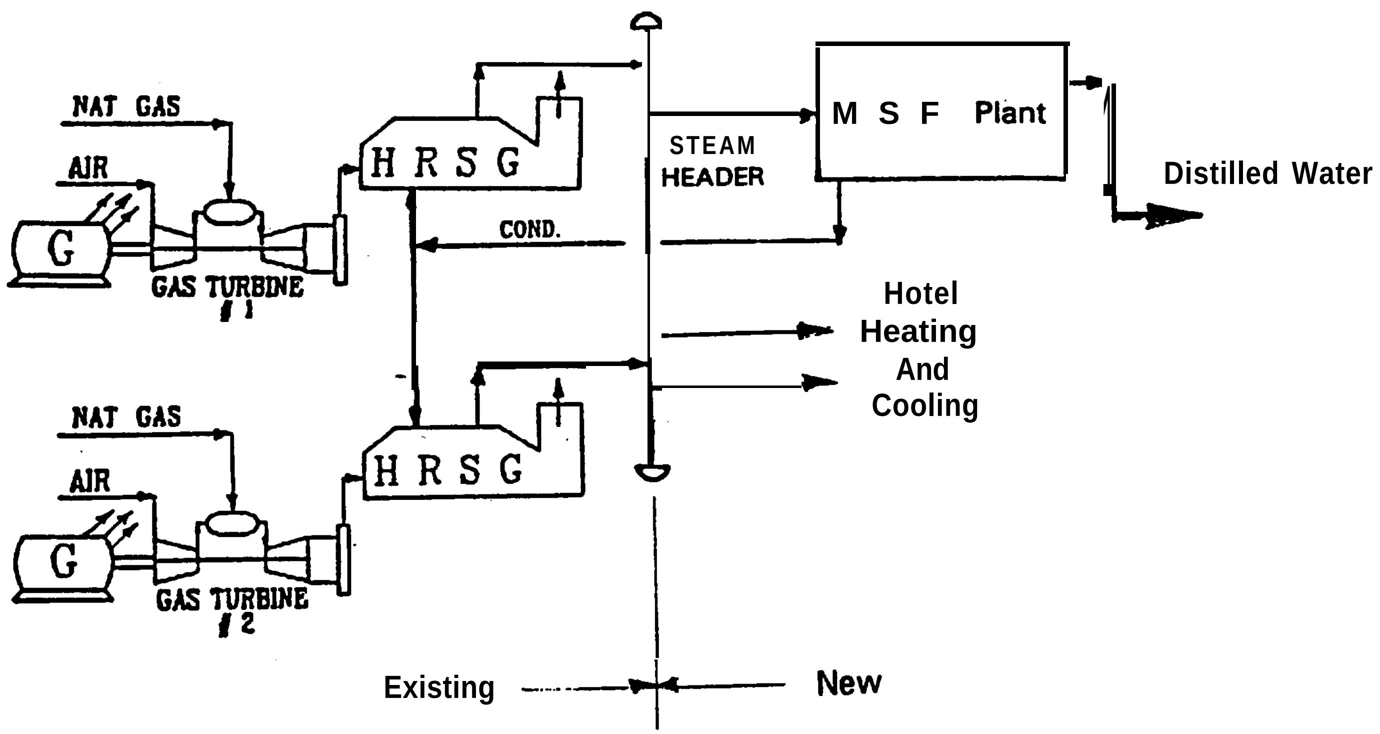
Table 2.1 summarizes the internal rate of return (IRR), required capital investment, BUREC required contribution, and other information for each system.

2.5 Recommendations & Pilot Plant Construction

We recommend constructing a facility for gas turbine cogeneration with seawater desalination (distillation) in the vicinity of Carlsbad.

SSI, BUREC and the Carlsbad Water District to co-finance the 350,000 gpd seawater desalination pilot facility to be located in Carlsbad. SSI's joint venture will provide funds for the power section of the facility. No BUREC contribution is required for the power generation portion.

SANTA MONICA BAY PLANT



CARLSBAD COGEN PILOT DESALINATION (ALL NEW)

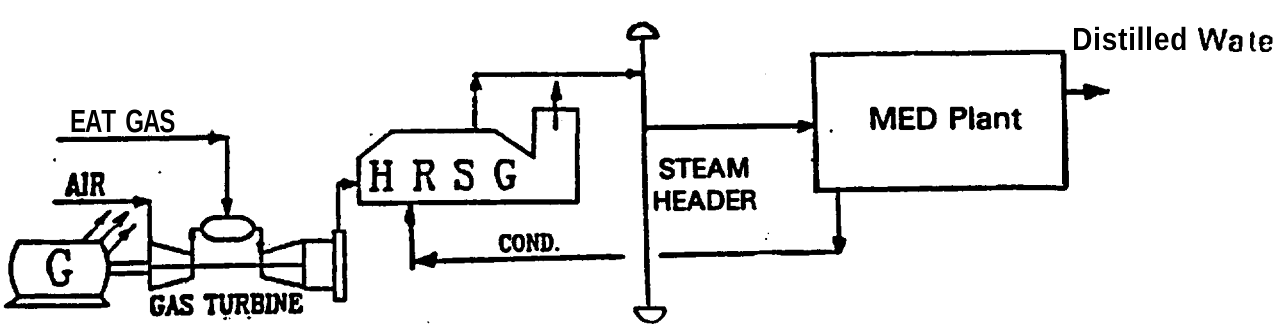


FIGURE 2.1

TABLE 2.1

OVERVIEW OF MAJOR PARAMETERS

	Santa Monica Plant Desalination		Carlsbad Pilot Plant Desalination	
Desalination Plant Sii MGD (lpm)	0.08	(210)	0.35	(920)
Required Steam lb/hr (Kg/hr)	6,000	(2722)	20,250	(9185)
Plant Installed Cost ($)	2,903,170		667,880	
BUREC Required Contribution ($)	270,000		270,000	
IRR with BUREC Contribution (%)	21.64		11.44	
Power Facilities	Existing 1 MW size cogen		New 4 MW size cogen	
Performance Ratio	4.6		6.3	
Required Area sq. ft. (sq. m)	313	(28)	11,761	(1059)

This pilot demonstration facility will provide an effective source of information during the commercial operation. If the recommended approach and technology is demonstrated to be a reliable system, the City may proceed with the construction of a full scale desalination plant.

2.6 Cost of Water:

The cost of product water from seawater desalination plants is very sensitive to plant capacity. The economy of scale is a major factor in determining the cost for water. Our analysis indicated that the cost of water for the Carlsbad pilot plant producing 0.35 MGD will be approximately $6/1000 gallons ($1.6/cubic meter).

A full scale facility is presented briefly in section 8. Preliminary cost analysis on the full scale plant indicated that the cost of water from a 5 MGD facility will be approximately $3.5/1000 gallon ($0.93/cubic meter) of distilled water produced.

2.7 Space Available

In Santa Monica, space is available for the 80,000 gal/day desalination system inside the hotel, on the southern corridor area, or across the street from the hotel, where the hotel owns a vacant piece of land.

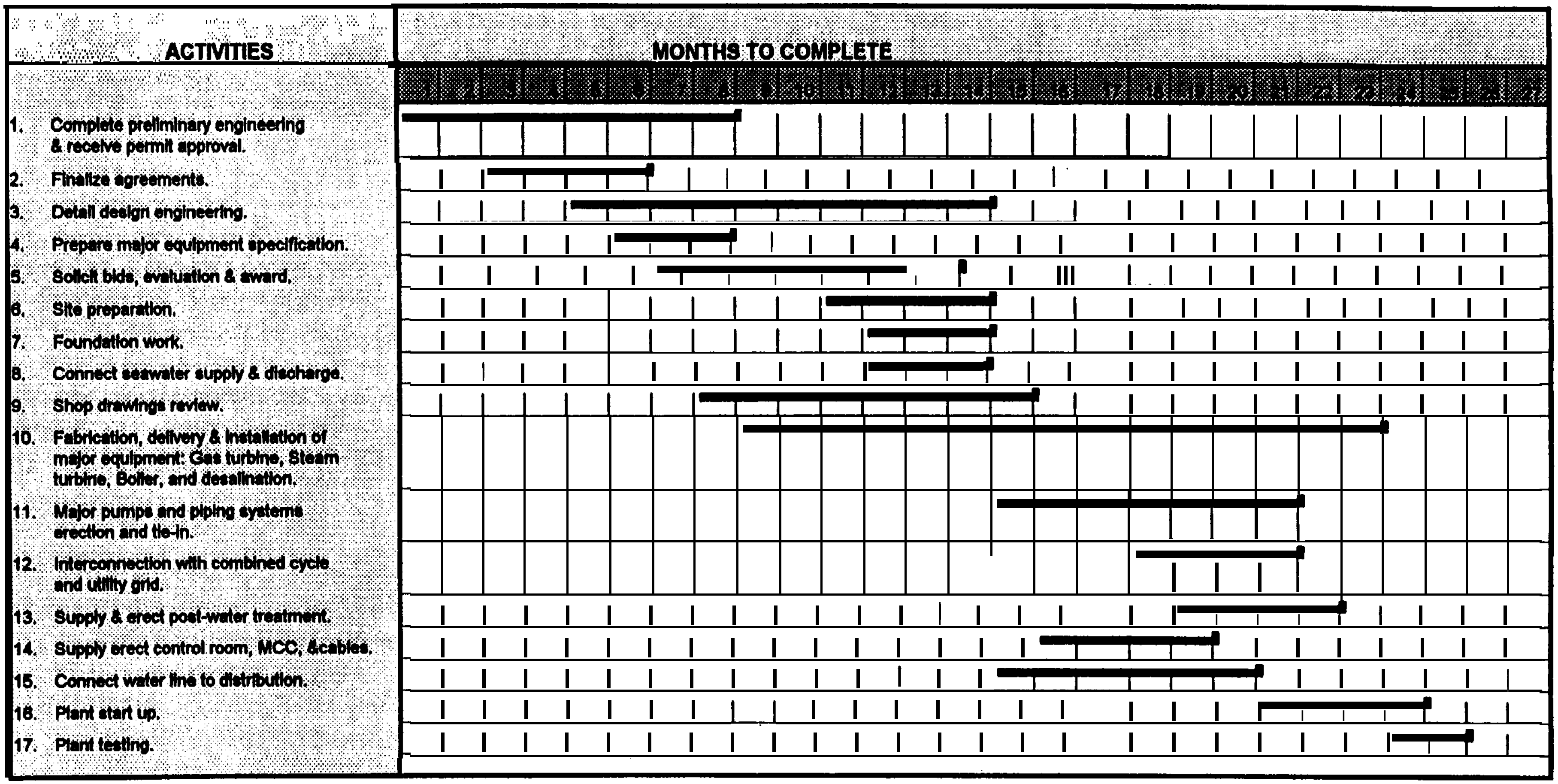
In Carlsbad, the facility can be located next to SDG&E's Encena power plant, and share the intake and outfall facilities. The plant can also be located inside the Encena waste water treatment facility which has an 800 ft long outfall already available.

2.8 Milestone Schedule

A milestone schedule has been developed for the Carlsbad pilot plant, fig. 2.2, which include both the cogeneration facility and the proposed desalination as well. Approximately 25 months are required for project

MILESTONE SCHEDULE

SAN DIEGO COUNTY **POWER/DESAL**



* THIS MILESTONE IS BASED ON EQUIPMENT SUPPLIERS AS WELL AS ACTUAL PLANT WHICH ARE ALREADY IN OPERATION OVERSEAS.

DRAWN: NNR	APPROVED:	DATE:	FIG: 2.2
SUPER SYSTEMS INC.	PLANT MILESTONE CARLSBAD PILOT PLANT		

completion. This period will cover the permitting phase, engineering, order of equipment, construction phase, start up, and testing.

The milestone schedule for the Santa Monica Bay Desalination plant is as shown in fig. 2.3, which includes only the proposed desalination plant. Approximately 14 months are required for project completion.

2.9 Environmental & Regulatory Issues

There is a trend at the present time in governmental and permitting agencies to encourage desalination plant construction as an additional source of water, in view of the years of drought that affected California recently.

The South Coast Air Quality Management District (SCAQMD) indicated that if desalination is part of a cogeneration system where the product water is sold to the public, they may consider an emission credit to the cogen system. Applying the same on the pilot plant at Carlsbad, SSI will negotiate an emission credit for the addition of the desalination system.

The integration of desalination with power generation in Carlsbad will allow the facility to take advantage of the applicable regulation of cogeneration systems.

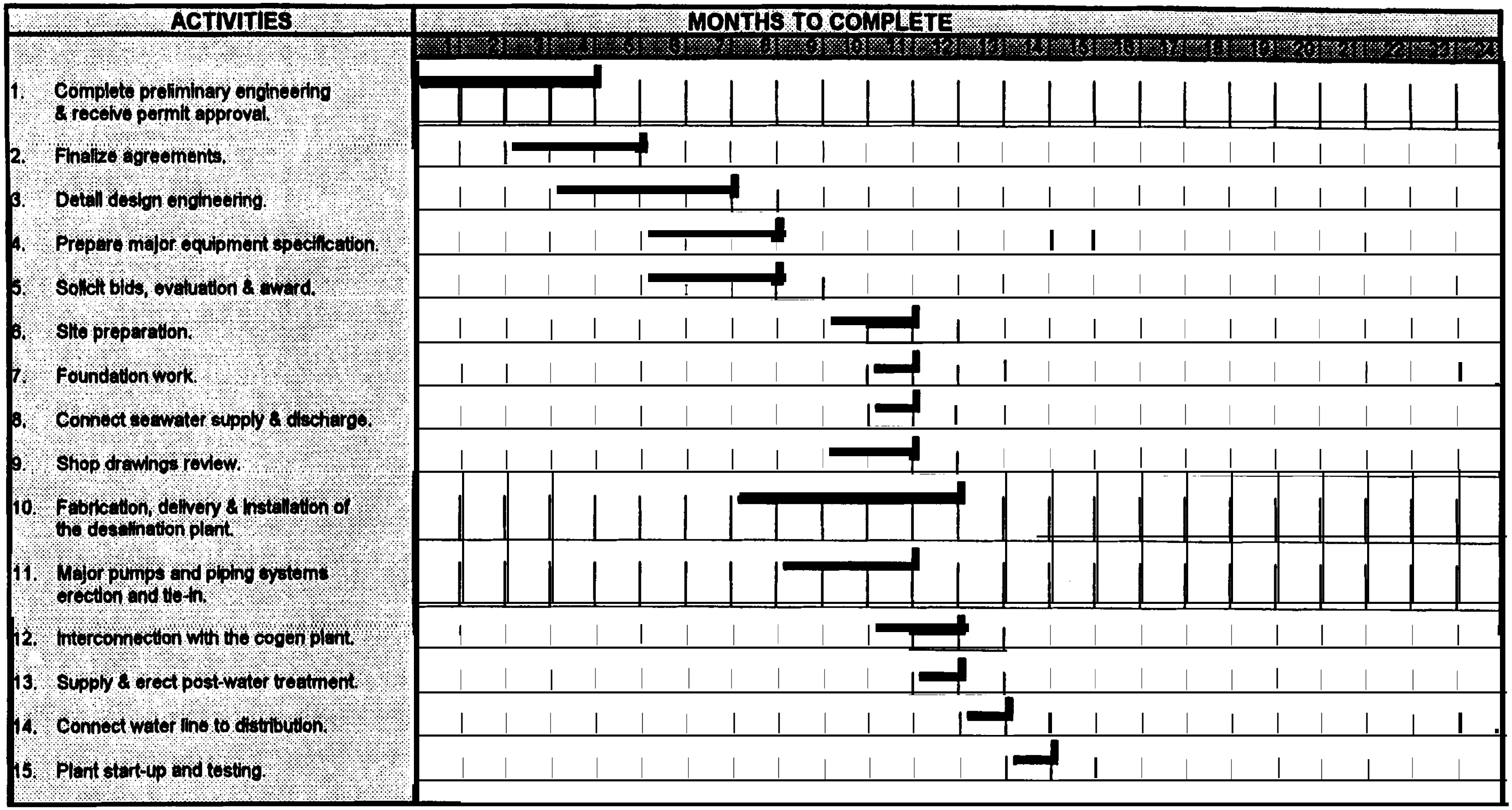
2.9.1 Other Environmental Issues

The key environmental issues for this project are summarized below:

- Brine blowdown disposal.
- Air Quality.
- Marine Biology.
- Noise.
- Construction impacts.

MILESTONE SCHEDULE .

SANTA MONICA BAY DESALINATION PLANT



• THIS MILESTONE IS BASED ON EQUIPMENT SUPPLIERS AS WELL AS ACTUAL PLANT WHICH ARE ALREADY IN OPERATION OVERSEAS.

DRAWN: NNR	APPROVED:	DATE:	FIG: 2.3
SUPER SYSTEMS INC.		PLANT MILESTONE SANTA MONICA BAY DESAL PLANT BUREAU OF RECLAMATION	

2.9.2 Brine Blowdown -Concentrate- Disposal

The major concerns related to concentrate disposal include;

- Blowdown (Discharge) Water Quality.
- Discharge Water Temperature.
- Heavy metals, such as copper, nickel, iron, . . . etc.
- Pretreatment chemicals.

Plant blowdown (concentrate) results from the extraction of product water from the seawater feed. At normal operating conditions, the concentration of salts in the discharge of the MED processes are as follows:

Process	Seawater Supply PPM	Discharge Flow PPM	Concent. Ratio (seawater = 1)	Total Flow GPM
MED: BD stream	34,800	69,600	2.00	227 Blow Down
MED: SW stream	34,800	34,800	1 .00	1030 SW

The two discharges will be mixed together, before entering the discharge outfall, which will reduce the discharge concentration and temperature.

2.9.3 Heavy Metal Discharges

Heavy metal discharges from a desalination plant are attributed to the corrosion of materials used in the construction of the desalination system. Normally, a deaerator vessel and injection of chemicals for oxygen (02) removal are an integral part to minimize corrosion in medium and large size desalination systems. Corrosion could be the result of poor selection of materials, effect of galvanic action, or poor operating practices. Higher operating temperatures will accelerate corrosion.

Discharge of. heavy metals from the MED process will not occur, because the ME process operates at low temperatures. The chosen materials of construction are normally highly resistant to corrosion; thus, heavy metal discharges are not expected.

2.10 Future Plan

1. Proceed with building 4 MW/350,000 gallon per day cogen/desal facility to be located in Carlsbad, CA.

2. SSI will be responsible for financing the cogeneration section. SSI has in place a joint venture who is interested in cofinancing the facility. The SSI joint venture is currently preparing final documents for a 6 - 8 MW cogeneration facility at Miramar, CA for the City of San Diego.

3. BUREC to contribute financially to the project in the range of 15%-30% of the total desalination facility installed costs..

4. Negotiate a long term contract with the City of Carlsbad to buy the product water from the facility. The City may offer other contributions to the project, which includes providing the site.

5. Negotiate with SDG&E (Encena power plant) to buy high purity distilled water for power plant make up at reduced prices (of approximately 50%) compared to current costs for producing such water.

6. Discuss locating the plant in a small portion of the vacant area next to the Encena plant. Only one third of one acre is required.

7. SSI is aware of the permitting requirement and has performed complete detailed engineering design for similar facilities in the past.

SECTION 3.0

DESALINATION TECHNOLOGY STATUS AND WORLDWIDE REVIEW & ASSESSMENT

3.1 Seawater Desalination Development

The application of desalting around the world to produce water on a relatively large scale: for villages, cities, and large industries started approximately 40 years ago. Seawater desalting application has now been developed, or grown, and is considered the main source for drinking water in many Middle East countries, North Africa, and islands in the Pacific Ocean, Caribbean, and other areas.

The technical process. for desalting seawater has been known for a long time. The problem was that the process was costly and inconvenient. A major path in development came in the 1940's during World War II when various military establishments in arid environments needed water to supply their troops. The potential that desalting offered was recognized by a wider audience, and work progressed after the war in various countries.

One of the most notable and consistent efforts came from the American government through its creation and funding of the Office of Saline Water (OSW) in the early 1950's, and later the Office of Water Research and Technology (OWRT). The American government funded research and development for over 30 years, totaling approximately 300 million dollars in the process. This money aided in providing the basic investigation and development for the different technologies for desalting sea and brackish waters. The congress of the United States, recognizing the importance of desalting, is currently discussing the allocation of a $90 million for desalination research and development.

Methods of removing salt from water can be divided into two classes:

1. Phase change methods such as freezing and distillation

2. Non phase change methods such as reverse osmosis, electrodialysis, ion exchange, and others.

In recent years, many desalination technologies emerged. The most known are:

• Multi Stage Flash	Large Size Application
• Multi Effect Distillation	Large Size Application
• Vertical Tube Evaporation	Small/Medium Size
• Vapor Compression	Small/Medium Size
• Reverse Osmosis	Large Size Application
• Electrodialysis	Small Size
• Ion Exchange	Small Size
• Freeze Separation	Small Size
• Critical Point Separation	Under research
• Membrane Distillation	Pilot scale/research
• Advance Membrane RO	Under research

Many of these technologies have been utilized for small size applications (less than 100,000 gal/day). The smaller size applications have been reported to operate with lower plant availability and higher costs of water.

- Small size: less than 100,000 gal/day
- Medium size: less than 500,000 gal/day
- Large size: 1 MGD to 240 MGD per project (one site), with a single unit size of 1 MGD to 10 MGD.

Application of the various desalting processes depends mainly on the total dissolved solids (TDS) concentration of the raw water. The selection of a desalting process for a particular application depends on several factors, including the following:

- Salt concentration in raw water
- Product water quality
- Availability and cost of energy and chemicals
- Land area available

3.2 Multi Stage Flash Distillation Technology & History

Distillation is the oldest of the desalination processes and the most widely used for seawater desalination applications. Simple stills were used on ships to make drinking water from seawater over 400 years ago. By 1900, relatively simple multiple effect distillers (MED) utilizing 2 to 4 effects were developed. During the mid 1950's, the multistage flash distillation process was originated from the energy conserving improvements to the multi effect distillation process.

As of 1990, the multistage flash accounts for 56% of the world's total desalination plants, about 60% of the world's total seawater desalination, and 89% (1366 MGD) of the world's seawater desalination for unit size of 2.4 and larger. A worldwide survey is shown in section 3.5 of this report.

3.2.1 Single Distiller

Figure 3.1 shows a single effect distillation where cold saline water is used for condensing the vapor which evolved from the hot seawater at the bottom of the vessel. Steam is used as the heating source.

3.2.2 Flash Distillation Principle

The flash distillation principle is simplified in figure 3.2. The saline water is heated at a temperature just under the boiling point at the pressure P in the brine heater. Inside the evaporator, P1 is lower than P due to the effect of cooler saline water inside the tube bundle. When hot saline water enters the evaporator, the reduced pressure causes an immediate

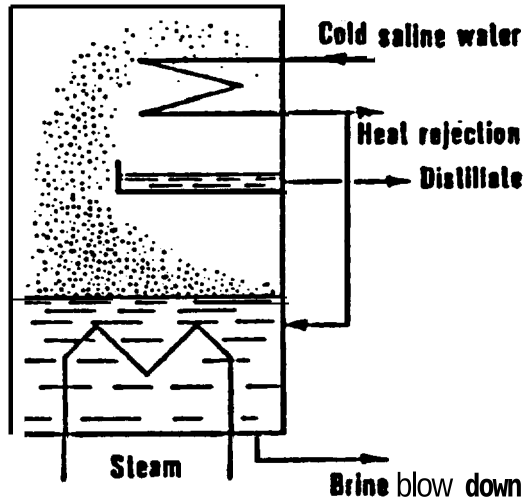


FIG. 3.1 : Single - effect distillation

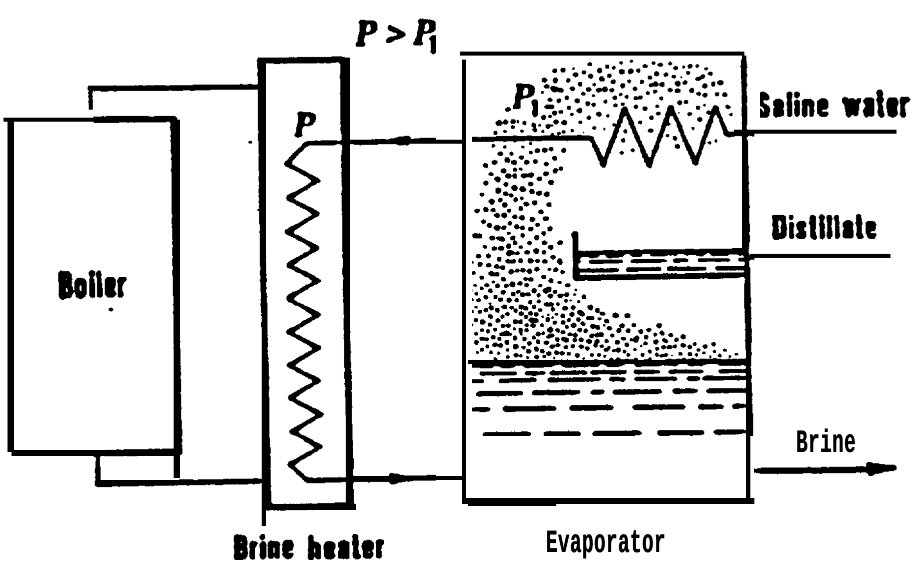


FIG. 3.2 : Flash distillation (principle)

transformation of pan of the liquid into steam; water flashes into steam. This steam condenses and gives up its latent heat to the incoming seawater.

3.2.3 MSF: Once Through vs. Recycled System

The MSF has two main configurations: the once through system which is used for small size plants and is characterized with high chemical and pumping costs and low capital costs. The second configuration is the brine recycle type. The recycle type is used for all the large sizes; up to 10 MGD per single unit. The recycle type is more economical to operate for sizes above 500,000 gal/day.

3.2.4 MSF: Once Through System

The MSF once through system is shown in figure 3.3. The principle of this system is described below.

When equilibrium is established in the evaporator, the saline solution can be introduced into a second evaporator the pressure of which (P2) is lower than P1. The same process takes place, and an additional part of the solution, proportional to P2 - P1, flashes into vapor. A number of flash chambers can be grouped in the same evaporator.

The raw water is heated progressively on circulation through the various stages from the last to the first. Additional heat is supplied to it in the brine heater. Then it flows from stage to stage giving up some vapor in each one. Its temperature decreases and the salt concentration increases from the first to the last stage.

3.2.5 Description of Flash Chamber

The arrangement of tube bundles in the evaporator shell is defined as the long tube design and the cross tube design, according to the two main configurations.

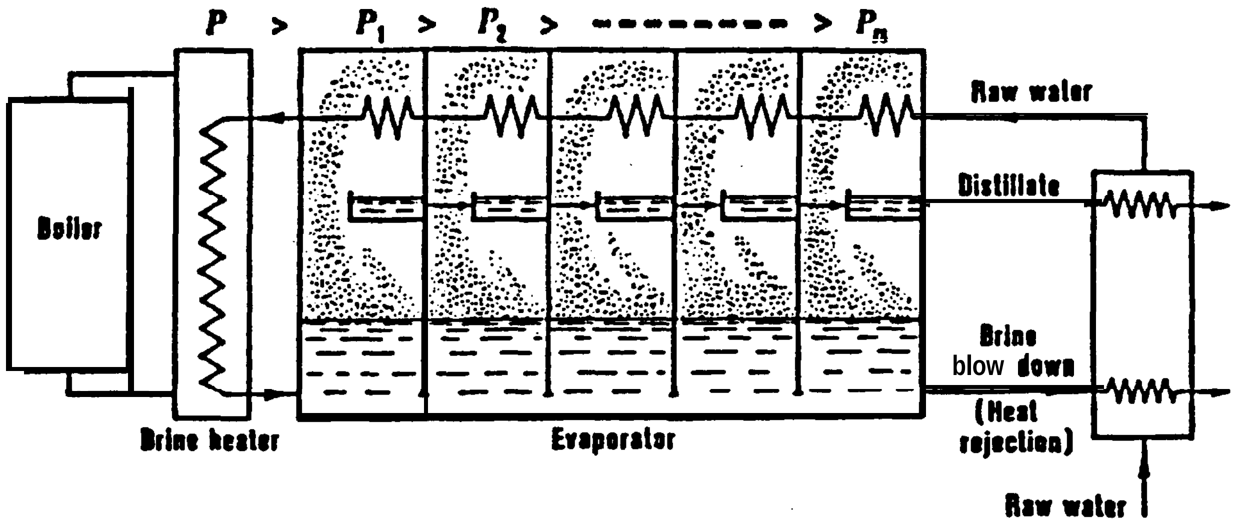


FIG.3.3 : Multi - stage flash distillation

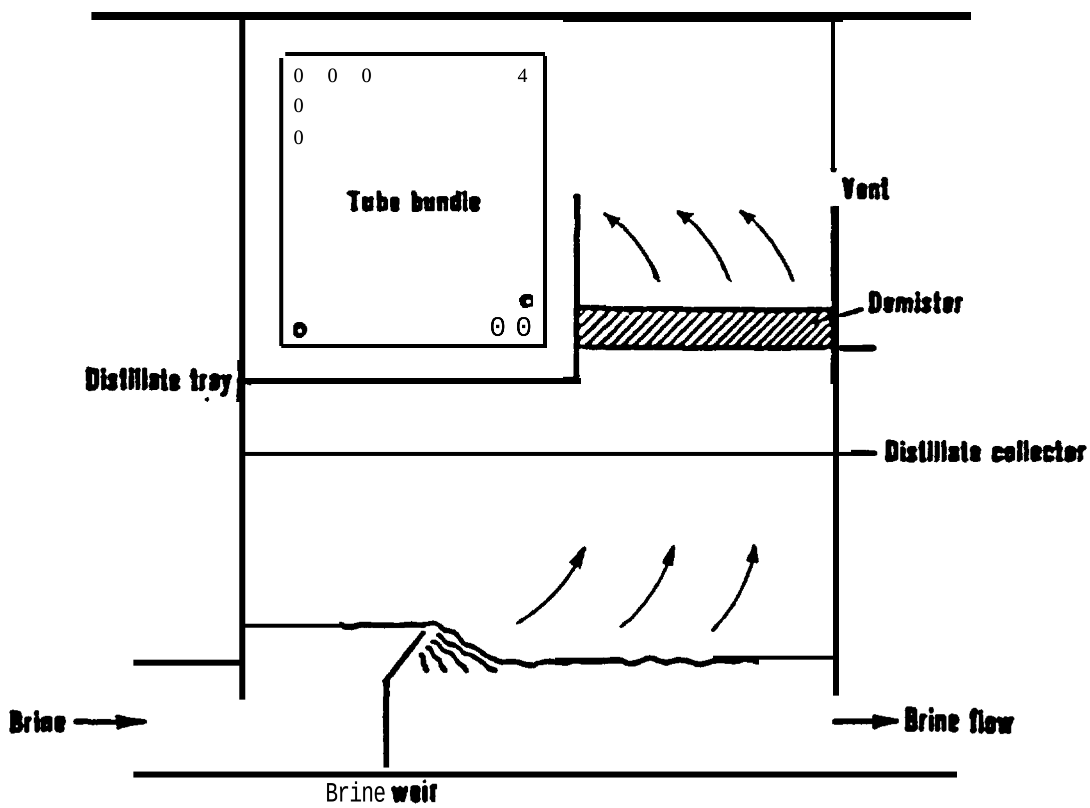


FIG. 3.4: Flash chamber (cross tube design)

In the long tube design, the tubes are parallel to the brine flow in the chambers. This lay-out permits the use of same tubes for several stages, and the use of tubes having the most economical length available on the market. It also permits a reduction in the number of tube-plates and water-boxes, allowing for lower pumping costs. The main disadvantage of this lay-out is that it imposes a certain geometry on the flash chambers, which may not be in keeping with optimum efficiency (chambers too long). This difficulty would be overcome if the heat transfer coefficient could be improved.

In the cross tube design, the tubes are perpendicular to the direction of brine flow in the stages. This lay-out makes water-boxes and tube-plates necessary for each chamber, thus leading to a considerable increase in pumping cost (about 25%). This disadvantage is counter-balanced by the possibility of designing chambers of a better efficiency.

The evaporator lay-out may be imposed by specific conditions, such as space for tube withdrawal. Both design arrangements have their supporters, but the choice between them must be based upon economic criteria.

Fig. 3.4 shows the schematic design of a flash chamber (cross design). Also, figures 3.5 and 3.6 illustrate the two arrangement configurations and differences. The brine flow rate is regulated by the pressure difference between two successive stages. The quantity of water flashing into vapor is proportional to the difference in temperature between the preceding stage and the one under consideration, to the specific heat of brine, to the flow rate of brine, and inversely proportional to the latent heat of vapor. In flashing, vapor carries over droplets of brine which have to be separated before condensing. The distillate would otherwise be contaminated. This is the role of the demister. Demisted vapor condenses on the tubes, and product water is collected in the distillate tray. Conversion plants are normally operated continuously as long as possible, and steady pressures have to be maintained in the chambers. Even a small increase in pressure makes the stage less efficient. Brine contains some gases, such as carbon dioxide, oxygen and air, which are released when

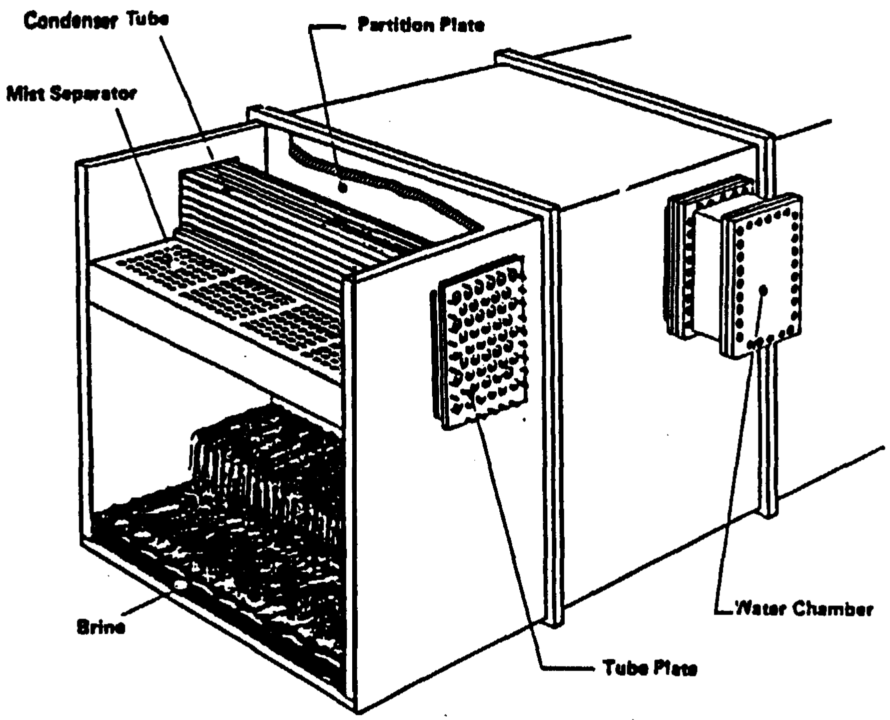


FIG. 3.5 Construction of Multi-Stage Flash Type Oesalination Plant (Cross-Tube Type)

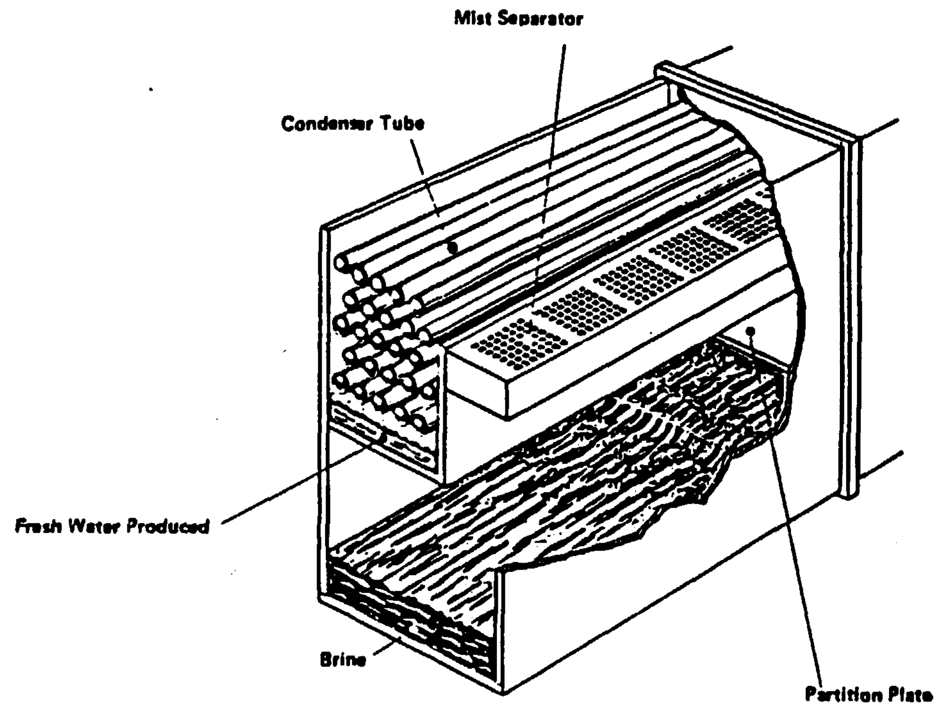


FIG. 3.6 Construction of Multi-Stage Flash Type Desalination Plant (Long-Tube Type)

flashing occurs. In order to avoid accumulation of non-condensable gases in the chambers, the stages are connected through a vent to a gas ejector. Since carbon dioxide is scale forming and oxygen corrosive, the bulk of these gases is usually removed from the feed water in desorption towers before entering the last stage of the evaporator.

The chamber geometry is a compromise between its various functions and annual cost. The brine must have and adequate residence time in the stages, so that the maximum quantities of vapor flash from the brine. A shallow and uniform depth of the brine stream is imposed by the hydrostatic and thermodynamic requirements. Therefore, the residence time necessitates that each stage should have a particular surface area. The chamber height is determined by the need for locating tube bundles possessing the appropriate heat transfer surface, and by the volume required for the vapor flow without excessive carry over. The chamber must be of maximum efficiency and require minimum investment.

3.2.6 Lay-out & Temperature Profile of MSF

Evaporators are, in fact, heat exchangers, and they therefore require a certain temperature difference between the two fluids to be able to work under economic conditions. These two remarks are important for understanding the various designs proposed for flash evaporation plants.

A feature of flash plants is that the rate of brine flow to be circulated through the whole system amounts to about 6 to 12 times the product flow rate. To obtain such a circulation rate, the once-through method requires that the plant be fed with the appropriate raw water flow rate. This also means that the amount of brine rejected is 5 to 11 times the quantity of water produced. This method implies high pre-treatment costs.

Figure 3.7 shows the once through system simultaneously with the temperature distribution along the evaporator and brine heater.

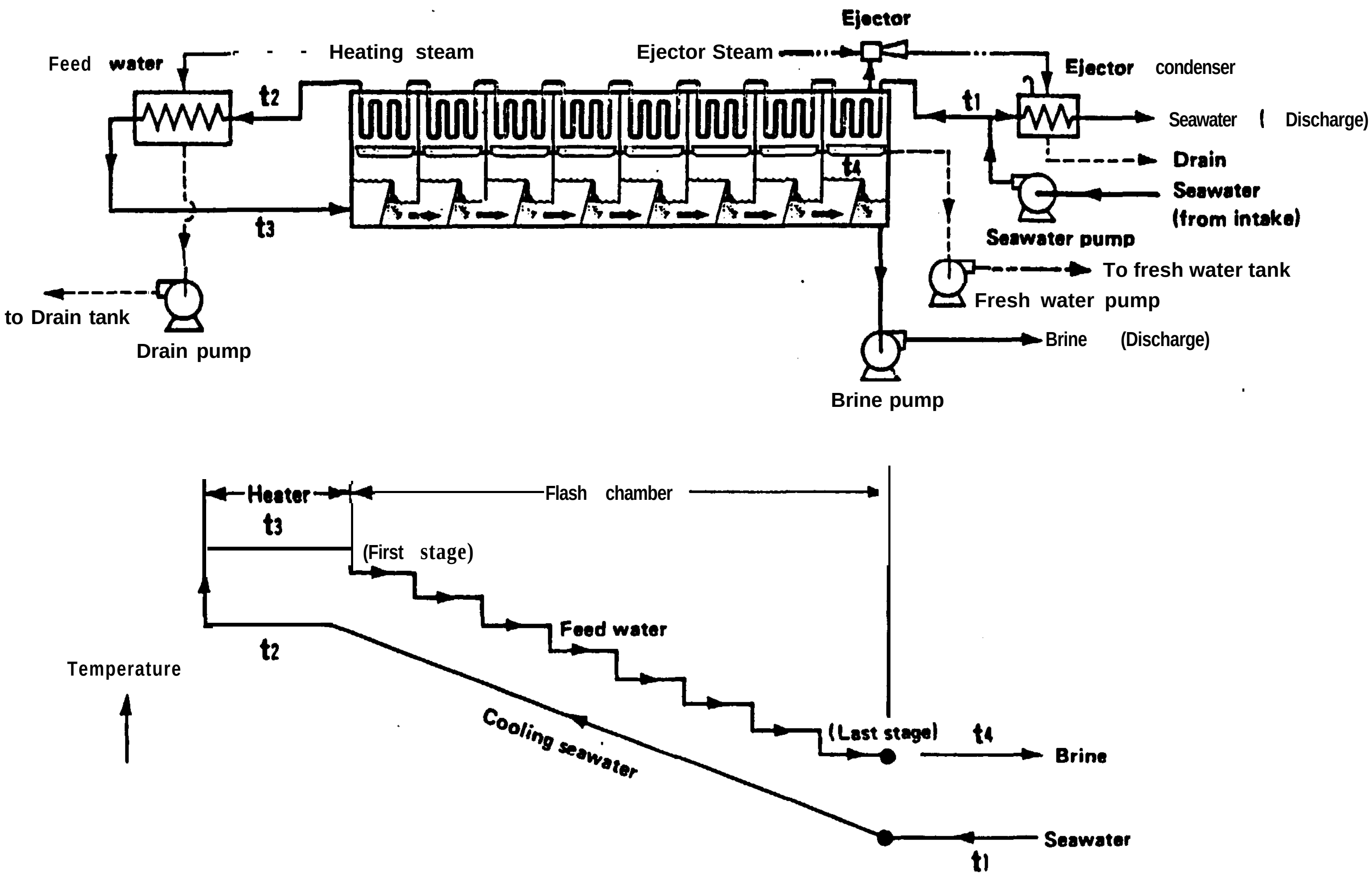


FIG. 3.7 Flow Diagram Once-Through System

3.2.7 MSF: Brine Recycle Type

Most of the plants presently under construction, or recently put into operation, are based on the flow-sheet reproduced in fig. 3.8. In such a design, the brine flow rate is obtained by brine recirculation. The plant consists of three sections: the brine heater or heat input section, the heat recovery stages in which the latent heat of condensation is entirely recovered for pre-heating the brine, and the heat rejection section. The last section is required for rejecting thermal energy supplied to the brine in the heat input section.

Figure 3.7 also indicates the need for a small portion of relatively high pressure steam (above 60 psig) to operate an ejector system for the removal of non-condensable gases.

3.2.8 MSF: Stage Length

In the design of a flash evaporator, it is important that the chamber be long enough so that the flowing brine stream residence time is sufficient to attain equilibrium. At the same time, the stage should not be so long that equilibrium is attained early since this results in an unnecessary increase in shell costs.

3.3 Multiple Effect Distillation (MED)

The multiple effect distillation (MED) process has been used for industrial distillation for a long time. One popular use for this process is the evaporation of juice from sugar cane in the production of sugar or the -production of salt with the evaporative process. Some of the early water distillation plants used the MED process, but this process was displaced by the MSF units because of cost factors and their apparent higher efficiency. However, in the past decade, interest in the MED process has renewed, and a number of new designs have been built. Most of these new MED units have been built around the concept of operating on lower temperatures and with reduced capital investment.

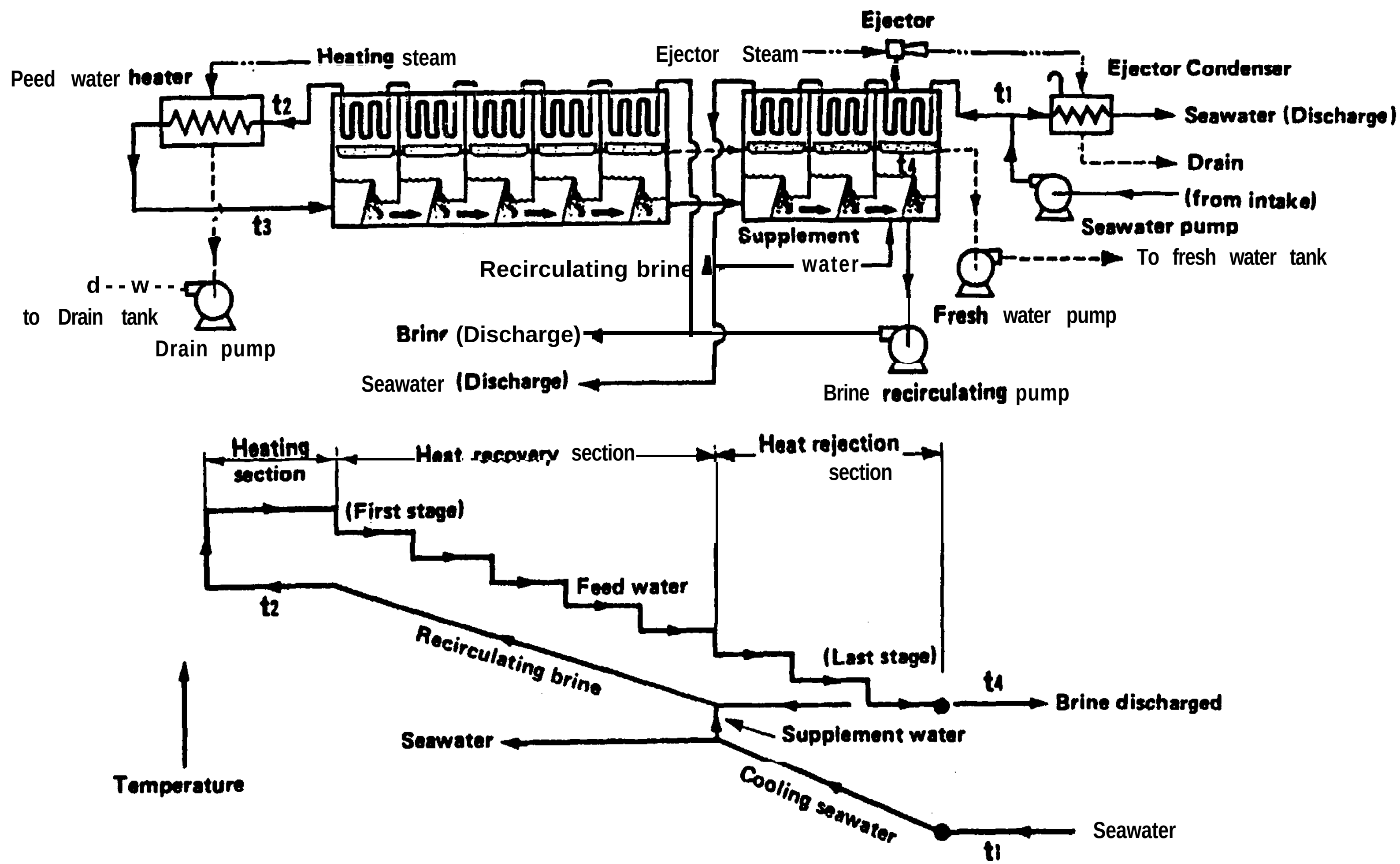


FIG. 3.8 Flow Diagram-Brine Recirculation System

MED, like the MSF process, takes place in a series of vessels (effects) and uses the principle of reducing the ambient pressure in the various effects, This permits the sea water feed to undergo multiple boiling without supplying additional heat after the first effect. In an MED plant, the sea water enters the first effect and is raised to the boiling point after being preheated in tubes. The sea water is either sprayed or otherwise distributed onto the surface of evaporator tubes in a thin film to promote rapid boiling and evaporation. The tubes are heated by steam from a boiler, or other source, which is condensed on the opposite side of the tubes. The condensate from the boiler steam is recycled to the boiler for reuse.

A Multiple effect distillation process is simplified in figure 3.9.

Only a portion of seawater applied to the tubes in the first effect is evaporated. The remaining feed water is fed to the second effect, where it is again applied to the tube bundle. These tubes are in turn being heated by the vapors created in the first effect. This vapor is condensed to fresh water product, while giving up heat to evaporate a portion of the remaining sea water feed in the next effect. This continues for several effects, with 8 or 16 effects being found in a typical large plant.

Usually, the remaining sea water in each effect must be pumped to the next effect so as to apply it to the next tube bundle. Additional condensation takes place in each effect on tubes that bring the feed water from its source through the plant to the first effect. This warms the feed water before it is evaporated in the first effect.

MED plants are typically built in units of 2000 to 10,000 Cu Mt (0.5 to 2.5 MGD). Some of the more recent plants have been built to operate with a top temperature (in the first effect) of about 70 C (158 F), which reduces the potential for scaling of sea water within the plant but in turn increases the need for additional heat transfer area in the form tubes. Most of the more recent applications for the MED plants have been in some of the Caribbean areas. Although the number of MED plants is still relatively small compared to MSF plants, their numbers have been increasing.

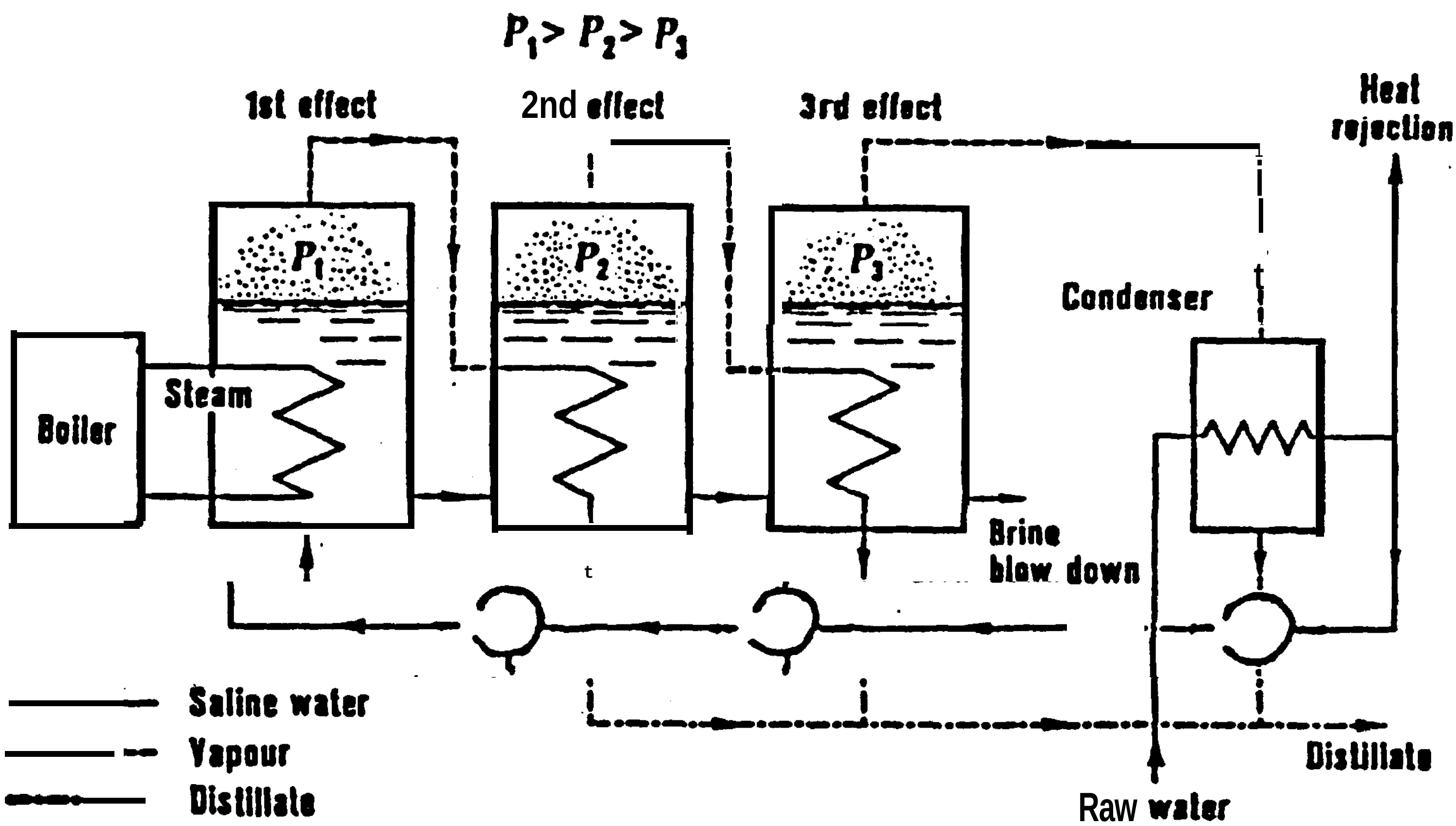


FIG.3.9 : Multi - effect distillation

It may be useful at this point to make the following remark. Stages in a multi-stage installation and effects in a multi-effect are quite different. The rate of distillate production of one effect is roughly equal to the quantity of vapor received. For any individual stage the production rate is a function of the saline flow rate, the stage area and the difference in pressure between the preceding stage and the one considered. So the production of one stage is not a function of the steam consumed in the brine heater, and the number of stages in a flash evaporator gives no information about the amount of distillate produced per pound of steam consumed (the performance ratio).

3.4 Distillation: Scale, Fouling & Pretreatment

3.4.1 Scale Protection

Scaling can be controlled with chemical additions, such as acid, polymer, or polyphosphates. Calcium sulfate scaling can be avoided if the top brine temperature and brine concentration are kept below certain levels during plant operation.

Generally, there are two types of scale: the non-alkaline hard scale ($CaSO_4$), and the alkaline soft scale which consists basically of calcium carbonate and magnesium hydroxide.

The feedwater in distillation processes is treated to prevent scale formation. For MSF plants, the top brine temperature leaving the brine heater is limited to 250 F for acid treatment to avoid calcium sulfate scale. For polymer treatment, the top brine temperature is limited to 235 F. The polyphosphates temperature limit is 195 F. These chemicals will eliminate, or reduce, the alkalinity in seawater to avoid CaC03 scaling.

Both the MSF and the MED is provided with a vacuum deaerator to remove 02, CO2 and other corrosive gases from the seawater feed to the plant.

Figure 3.10 shows the limits of $CaSO_4$ solubility at varying brine temperatures and concentrations. Plant design parameters should be selected in the area at the left of the Anhydrite line for scale protection. $CaSO_4$ scale, once formed, is almost impossible to remove and will require expensive plant retubing (the tube bundle cost in distillation plant is equal to about 35% of the total plant cost).

For the MED, scale is not as serious as in MSF due to the fact that MED plants normally operate at much lower top brine temperatures; between 160 F and 190 F.

Normally, the heat transfer surfaces are designed to allow some reduction in the overall heat transfer coefficient due to scale formation.

A mechanical tube cleaning system along with periodic acid cleaning of the tubes are normally recommended to recover any drop in water production due to scale formation of calcium carbonate and/or magnesium hydroxide.

3.4.2 Fouling

Since chemical water treatment and decarbonation/deaeration help to reduce scale build-up, a distinction is commonly made between the'heat recovery and the heat rejection stage fouling factor. This is because the heat rejection condenser cooling water is normally taken directly from the salt water inlet. Therefore, it has not been deaerated and is chemically untreated. This tends to increase fouling and scale in the heat rejection stages, resulting in a higher fouling factor.

Another important consideration associated with the fouling factor is the solubility of scale-producing calcium sulfate. In a low temperature plant (195 F or less), which is normally treated with a polyphosphate, there is a danger that above a specific temperature, the treatment will fail to prevent calcium sulfate production. As a result, heavy scale will form and the 'heat transfer process will be retarded. Under these conditions, it is not included to eliminate any traces of oxygen on the outlet side of the deaerator stream.

TABLE 3.2
TYPICAL SEAWATER ANALYSIS

Constituent	(concentration) Seawater (g/kg)	Constituent	(concentration) Seawater (g/kg)
Chlorine	19.190	Potassium	0.380
Sodium	10.664	Bicarbonate	0.145
Sulfate	2.650	Bromide	0.065
Magnesium	1.273	Strontium	0.013
Calcium	0.410		
		Total Dissolved Solids	34.790 ppm

3.4.4 Heat Transfer

In most of the distillation plants, the heat transfer process is essentially identical to that encountered in a counter flow heat exchanger. As such, it may be described by the following general relation of heat transfer in a heat exchanger:

$$Q = (U_{avg})\,(A)\,(LMTD)$$

where

Q = amount of heat transferred between the flashed vapor and the condenser cooling water

Uavg = average overall heat transfer coeffkient

A = heat transfer surface are (in this case, the surface area of the condenser tubes)

LMTD = the average log-mean temperature difference between the vapor and the cooling water

The amount of distillate produced is directly related to the amount of latent heat removed from the saturated vapor. For a desired production rate, one can use the above relationship to determine the required heat transfer surface area. This requires knowledge of the overall heat transfer coefficient and the log-mean temperature difference.

3.4.5 Overall Heat Transfer Coefficient

The overall heat transfer coefficient is a measure of the ease of heat transmission between two points at different temperatures. It is inversely proportional to the sum of the thermal resistances between the two points.

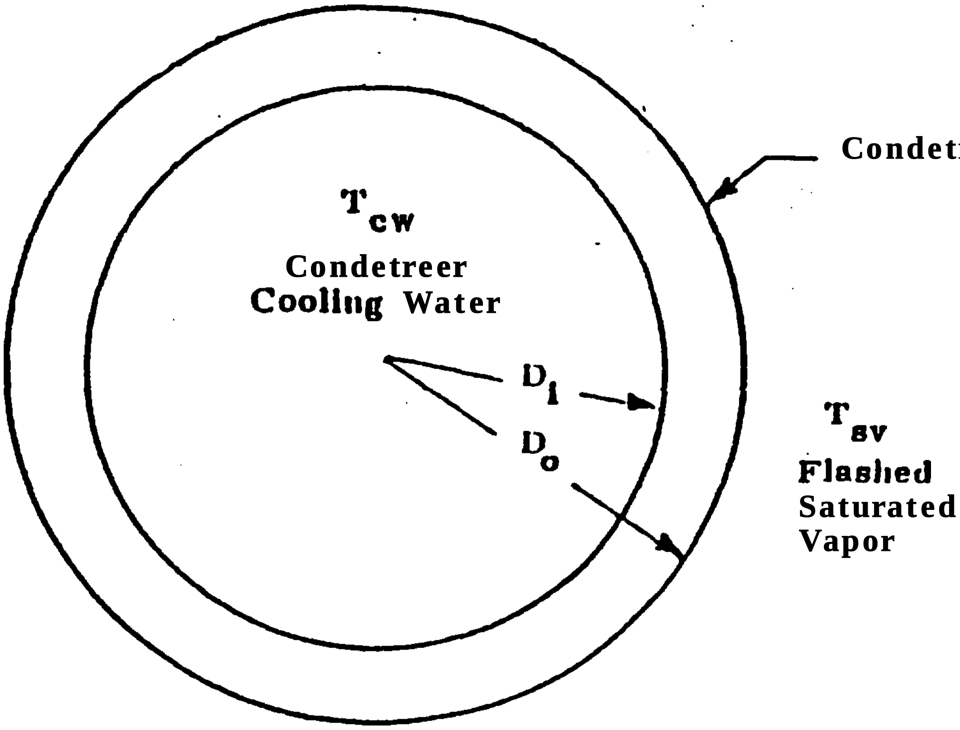
In a flash evaporator, transfer of heat occurs between the flashed saturated vapor and the condenser cooling water. Figure 3.11 illustrates the geometry of the transfer surfaces. The resistances to heat transfer between the saturated vapor at a temperature, T_{sv}, and the cooling water at a temperature of T_{cw} are in series, as shown in Figure 3.11. The resistances are defined as follows:

Rci	=	resistance to convection heat transfer between the following brine cooling water and the inner tube wall
Rfi	=	fouling or scale resistance on the brine side of the tube
Rw	=	resistance due to the tube wall
Rfo	=	fouling or scale resistance on the vapor side of the tube wall
Rnc	=	resistance due to the presence of noncondensable gases near the outside of the condenser tubes
Rco	=	resistance to convection heat transfer between the condensing steam and the outer tube wall

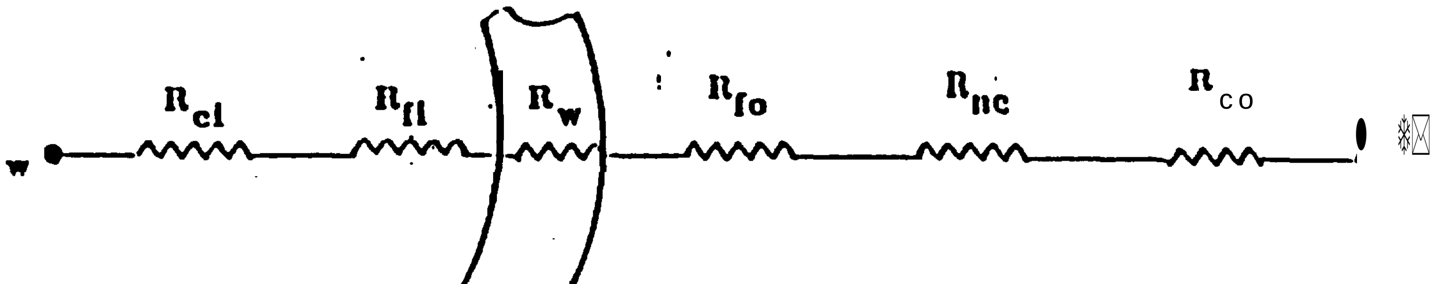
The overall heat transfer coefficient may be defined as:

$$U_{avg} = 1/R_T = (R_{ci} + R_{fi} + R_w + R_{fo} + R_{nc} + R_{co}) \cdot 1$$

For detailed multistage flash evaporator designs, the heat transfer coefficient is evaluated on a stage basis using the mean temperature of the



Condenser Tube Cross Section



$$R_T = R_{ci} + R_{fi} + R_w + R_{fo} + R_{nc} + R_{co}$$

FIG.3.11 Condensor Tube Heat Transfer

stage. From this, one can determine the distillate production in the stage and performs a summation over all stages.

3.4.6 Fouling Resistance

Generally, the inside and outside fouling resistances, and the resistance due to noncondensable gases, are lumped into an overall fouling factor.

$$Rf = Rfi + Rfo + Rnc$$

The values used for this overall resistance, Rf, are based primarily on experience and tend to reflect the conservatism or optimism of the designer.

3.4.7 Optimization of the Design

As for flash evaporators, multi-effect plants have to be optimized on the basis of data specific to each particular case. The effect of the variation of one item in the cost breakdown is similar for both processes. Based on present designs, and within the limits of approximation, the variation of the water cost with the plant capacity is similar to that for flash evaporators.

In conclusion, the following comment should be made regarding the present status of multi-effect distillation. As shown in the preceding pages, this process has many features which make it a serious competitor to flash evaporators.

3.4.8 Distillation Post Treatment

The MSF distillation plants normally produce distillate water with a TDS of less than 30 ppm, while the distillate from the MED plant is less than 20 ppm TDS. The distillate product is generally mineral free and has a corrosive nature due to its low pH, which normally ranges from 6.1 to 6.8. Post treatment is therefor necessary for safe drinking water. To meet the requirement of SDWA, lime and CO_2 are added to the distillate. Also, blending with a small amount of brackish or seawater is required. The calcium and alkalinity in the product water is normally adjusted between 40 and 60 mg/l as $CaCO_3$. The pH is normally maintained to about 7.2 to 7.6. Chlorine is also injected at the beginning of the product water pipe line.

A typical distillate water analysis is shown in Table 3.3:

TABLE 3.3
DISTILLATE PRODUCT TYPICAL ANALYSIS

	PPM
Chlorine	5.0
Alkalinity	1.0
Sulfate	1.0
Bicarbonate	0.5
Sodium	2.0
Calcium	0.1
Magnesium	0.2
Potassium	0.1
Stronium	0.2
Total Dissolved Solids	10

3.5 Desalination Processes Worldwide Review

Worldwide total installed desalination capacity, as of the end of 1990, is approximately 3,480 million gallons per day. Desalting equipment is now used in about 120 countries. Of this total, approximately 50 % of this desalting capacity is used to desalt seawater, mainly in the Middle East.

Table 3.4 is extracted from an inventory completed in 1990 for IDA by Klaus Wangnick, of Germany [Wangnick, 19901. This table shows 24 countries, ranked in order of capacity. Saudi Arabia is ranked number one with a total installed desalting capacity of 925 MGD, or 2840 ac ft. This capacity represents approximately 27 % of the total world capacity, mostly

TABLE 3-4

DESALINATION CAPACITY FOR 24 COUNTRIES
IN ORDER OF CAPACITIES**

S/NO	COUNTRY	CAPACITY CU M/DAY	CAPACITY MGD	CAPACITY AC FT/DAY
1	SAUDI ARAB.	3,503,082.0	925.5	2,840.4
2	KUWAIT	1,334,650.0	352.6	1,082.2
3	UAE	1,306,846.0	345.3	1,059.6
4	USA	1,272,625.0	336.2	1,031.9
5	LIBYA	576,119.0	152.2	467.1
6	IRAN	368,689.0	97.4	298.9
7	BAHRAIN	311,620.0	82.3	252.7
8	QATAR	308,138.0	81.4	249.8
9	ITALY	261,066.0	69.0	211.7
10	USSR	259,951.0	68.7	210.8
11	SPAIN	218,608.0	57.8	177.3
12	IRAQ	211,707.0	55.9	171.7
13	HONG KONG	183,582.0	48.5	148.9
14	ALGERIA	164,912.0	43.6	133.7
15	NETH.ANTILLE	156,170.0	41.3	126.6
16	JAPAN	148,251.0	39.2	120.2
17	OMAN	129,659.0	34.3	105.1
18	HOLLAND	95,888.0	25.3	77.7
19	VIRGIN IS.	90,666.0	24.0	73.5
20	GREAT BRITAIN	84,869.0	22.4	68.8
21	AUSTRALIA	79,487.0	21.0	64.5
22	MEXICO	77,707.0	20.5	63.0
23	GERMANYD	69,338.0	18.3	56.2
24	MALTA	66,245.0	17.5	53.7

** SOURCE : KLAUS WANGNICK, 1990 IDA PLANT INVENT

MSF plants. The U.S. is ranked number 4, after Kuwait and Emirates, with 336 MGD, or 1031 ac ft/day total installed capacity. Most of the capacity of the U.S. consists of plants in which the RO process is used to treat brackish ground water.

Wangnick's inventory indicates that the world's installed capacity consists mainly of the multi-stage flash distillation and RO processes. These two processes make up about 86 percent of the total capacity. The remaining 14 percent is made up of the multiple effect, electrodialysis, and vapor compression processes while the minor processes amounted to less than one percent.

Table 3.5 shows the worldwide desalting ranking by process:

TABLE 3.5
Summary of the 1990 IDA Inventory

Desalting Process	% of total World Capacity	Capacity million m^3/d	Capacity mgd
Multi-Stage Flash	56	7.4	1950
Reverse Osmosis	31	4.1	1080
Multiple Effect	5	0.7	180
Electrodialysis	5	0.6	160
Vapor Compression	3	0.4	110
TOTAL CAPACITY	100	13.2	3480

The MSF is ranked number one, followed by RO and MED. MED has a total world's capacity of 180 MGD. This capacity does not include plants under construction during 1989 and 1990 estimated at approximately 25 MGD.

SECTION 4.0

SANTA MONICA SYSTEM DESCRIPTION

4.1 The Overall System

The existing Santa Monica Bay “LOEWS” Hotel cogeneration facility located in Santa Monica, CA was designed by Supersystems, Inc. and has been in operation since 1990. The cogeneration facility is basically serving various cooling, heating and electrical operations. The cogeneration system is integrated with a 500 ton steam operated absorption chiller. Steam is also supplied to the jacuzzi, pool, laundry, space heating, domestic hot water and others. Refer to figure 4.1 for the process flow diagram of the existing system with the proposed desalination system incorporated.

The facility consists mainly of two Garrett model 831 dual-fired gas turbine generator sets with electric starter capability, two unfired waste heat boilers, and one 500 ton steam absorption chiller.

Each of the gas turbine units are driving a 515 KW electric generator. The generator is operating at 1800 rpm, 480 V, and 60 hertz.

At system full load conditions, approximately 27,200 lb/hr (12,364 Kg/hr) exhaust flue gas at 930^{o} F (499oC) from the gas turbine is ducted to two unfired type waste heat steam generators. The rated steam output from each of the two waste heat boilers is 4,600 lb/hr (2,091 Kg/hr) at 125 psig (8.8 Kg/cm^2), saturated. Total full load steam production is 9200 lb/hr (4182 Kg/hr). 6000 lb/hr (2727 Kg/hr) of steam will serve the new proposed desalination facility at 15 psig (1.06 Kg/cm^2).

FIGURE 4.1

SANTA MONICA BAY COGEN/DESAL PROCESS FLOW DIAGRAM

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CONFIDENTIAL & PROPRIETARY INFORMATION

Refer to figure 4.2 for a typical steam demand profile for the overall system. Upon inspection of the profile, we see that at approximately 1 to 2 p.m. steam production is at full load conditions which is 9200 lb/hr (4182 Kg/hr).

Electrically, the cogeneration system is serving the hotel in parallel with the SCE grid. During 1993 and 1994, the hotel became self-sufficient in electrical consumption and demand. No excess electricity is being supplied by the utility.

Refer to figure 4.3 for a typical electric demand profile for the overall system. As may be noticed at approximately 12 noon to 2 PM, the electric demand will typically be at its maximum amount.

We are including in the appendix "As Built Simplified" diagram for the Cogen plant in Santa Monica, originally designed by our firm.

4.2 Desalination Process Description

The desalination process consists of one Multi Stage Flash (MSF) unit which has a desalination capacity of 80,000 GPD (212 lpm) of product water in addition to the high purity distillate water for NOx steam injection and boiler make up. The MSF unit in this study is based on a unit supplied by Aqua-Chem, Inc.

There are over 200 MSF units of this size currently in commercial operation worldwide: Saudi Arabia, UA Emirates, Kuwait, Italy, Hong Kong, North Africa, and in some islands.

The various flow requirements, concentration ratios, heat transfer areas, number of stages/effects, the performance ratio, and other plant data are shown in Table 4.1.

Figure 4.2

Typical Steam Demand Profile for Santa Monica Bay Hotel

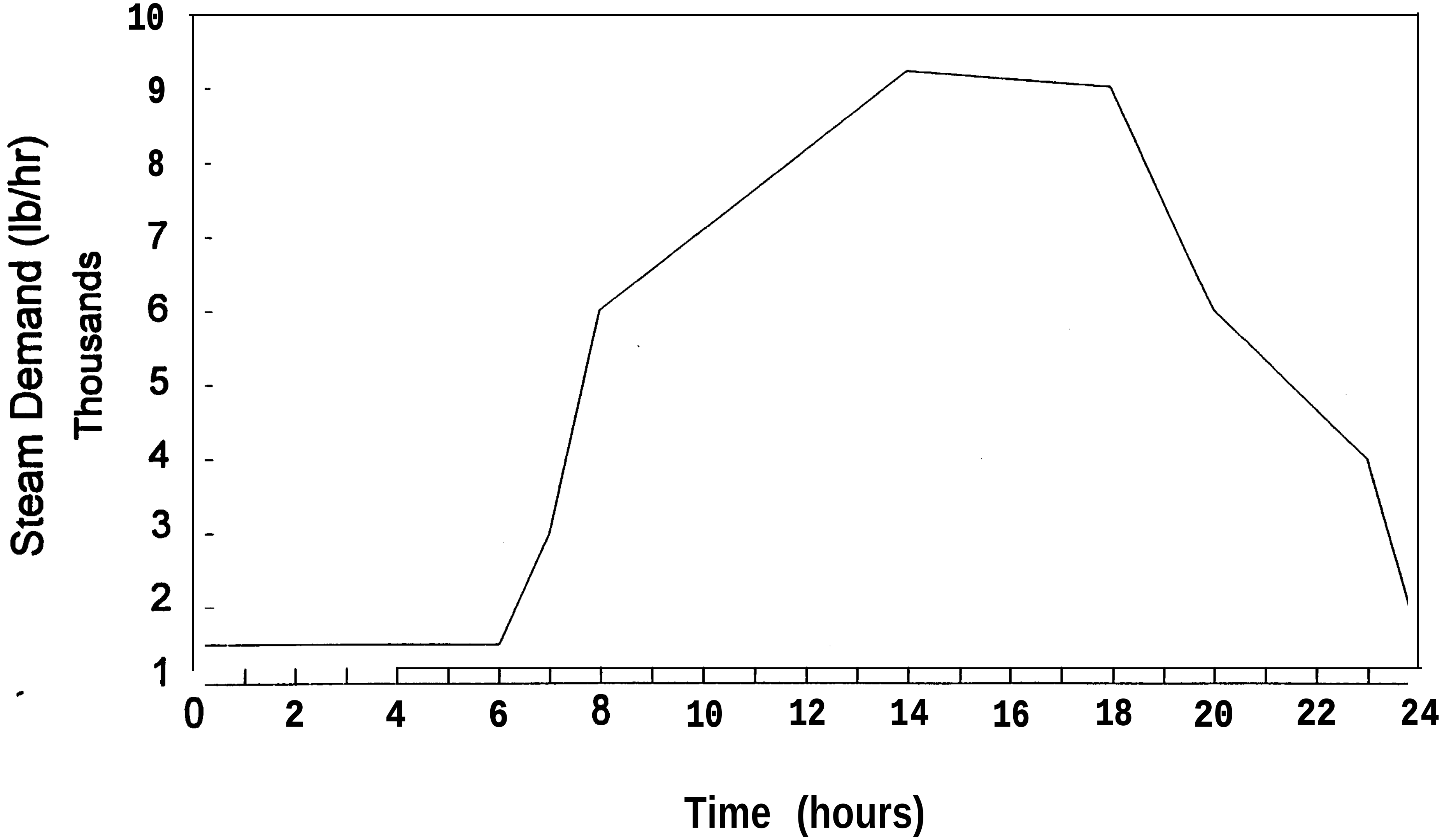


Figure 4.3

Typical Electric Demand Profile for Santa Monica Bay Hotel

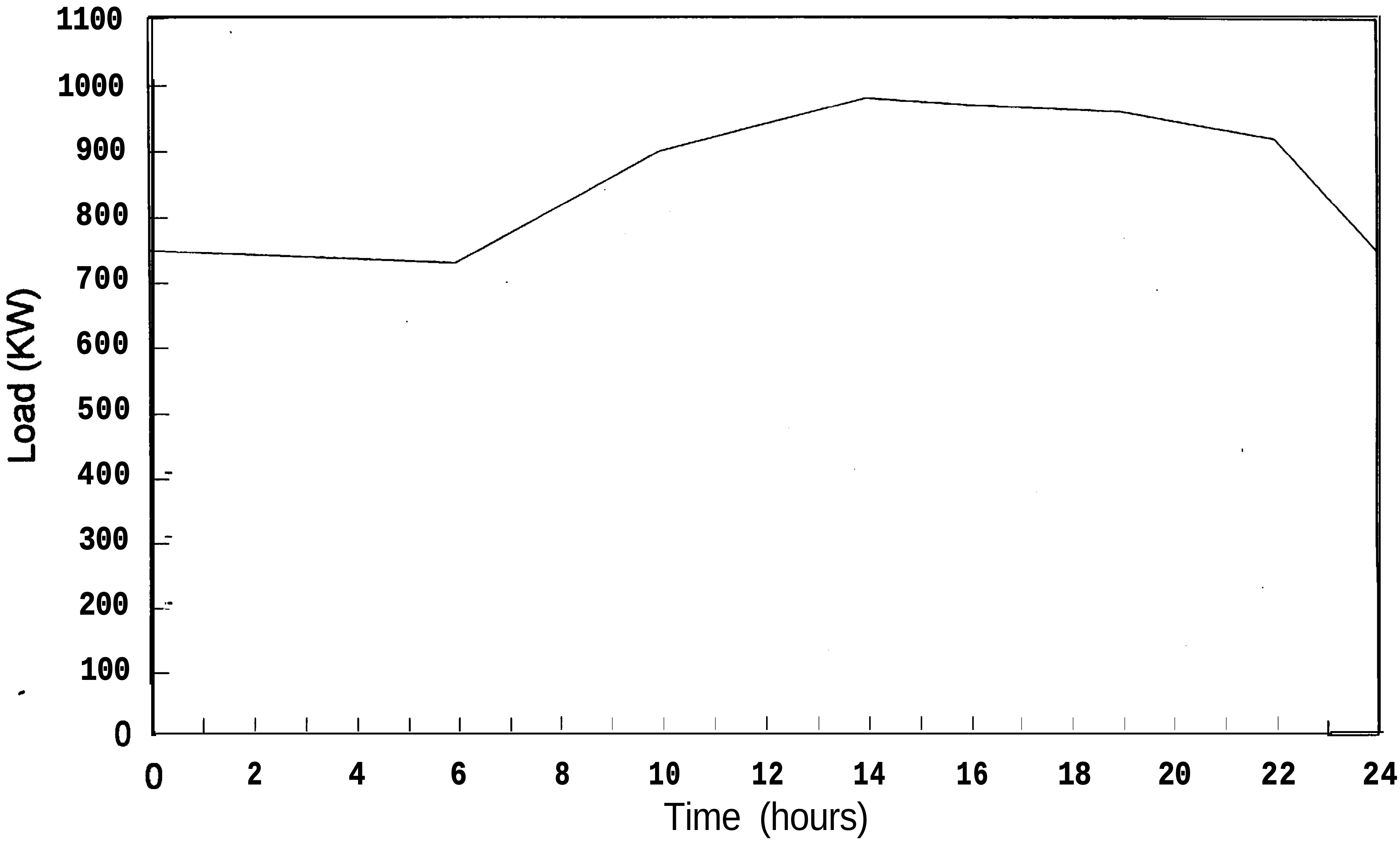


TABLE 4.1

TECHNICAL OUTLINES FOR
MULTI-STAGE FLASH
(ALL DATA FOR ONE 0.08 MGD UNIT)

GENERAL

TOP BRINE TEMP (F)	225	(107.2 C)
NUMBER OF STAGES	7	
PERFORMANCE RATIO LB DIST/1000 BTU	4.6	

PROCESS FLOW RATES

		CONC. RATIO
SEAWATER SUPPLY (GPM)	900 (3406 lpm)	1
PRODUCT WATER (GPM)	56 (212 lpm)	0
BLOWDOWNISEAWATER DISCHARGE (GPM)	840 (3180 lpm)	2
LP STEAM TO DESAL (LB/HR)	6000 (2727 Kg/hr)	NA
HP STEAM TO VENTING (LB/HR)	500 (227 Kg/hr)	NA

The steam consumed by the desalination system is approximately 65% of the total HRSG steam output. The hotel will utilize 35% of the steam, except during the summer months of June through September when more steam will be diverted to the absorption chiller and the desalination plant will be operating at partial load. Figure 4.4 is a cycle flow diagram for the MSF desalination process.

4.2.1 Total Steam to Desal

The operation of the desalination system will require approximately 6000 lb/hr (2727 Kg/hr) to the heating section. The ejector of the venting system will consume approximately 500 lb/hr (227 Kg/hr).

4.2.2 Condensate Return

The steam will condense in the heat input section of the desalination facility and condensate will be pumped back to the deaerator, then to the HRSG.

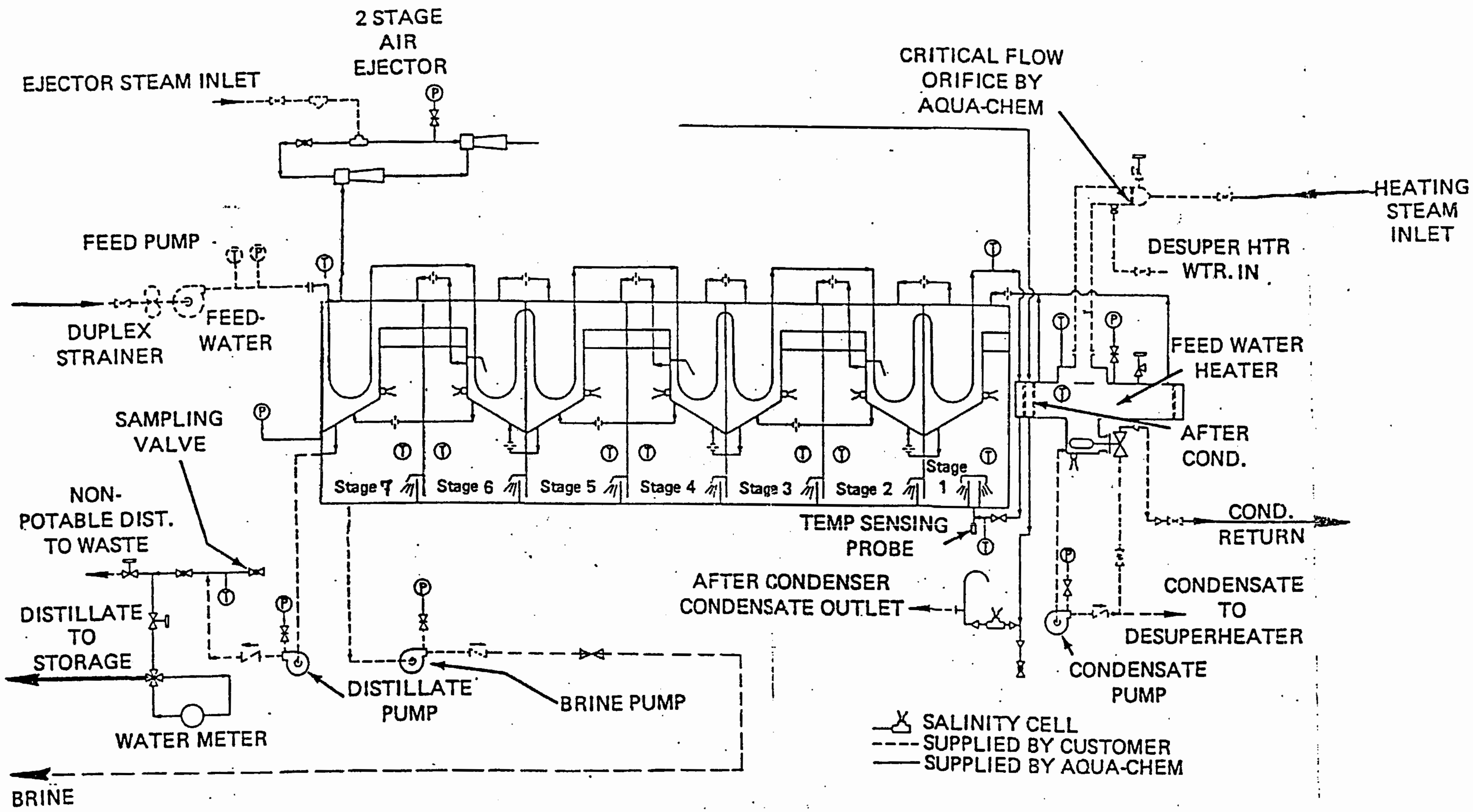
4.2.3 Evaporator Stages, Area, and Flow Rates:

Refer to table 4.1 for the technical outline of various flow rates for steam and water, the heat transfer area in different sections of the evaporator, and the top brine temperature leaving the heater section.

4.2.4 Performance Ratio (R)

The performance ratio (R) for this unit is 4.6 lb/kBtu. The performance ratio determines the amount of energy to operate the distillation system. The cost of the energy available to the MSF plant is a

MULTI-STAGE FLOW DIAGRAM



	CAPACITY GPD	FEEDWATER INLET	BRINE	DISTILLATE OUTLET	CONDENSATE HEATER	CONDENSATE AFTER COND.	HEATING STEAM	AIR EJECTOR STEAM
FLOW GPM	80,000	899	840	52.55	17.3	3.46	6,000	500
TEMP. F		65	90	75	215	220	241	350
PRESS. PSIG		35	10	20	45	0	10	125

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SUPERSYSTEMS Inc.

FLOW DIAGRAM
SANTA MONICA BAY DESALINATION

major factor when optimizing the desalination system as well as when optimizing the integration of power and desalination. A high energy cost will lead to a high performance ratio, and a low energy cost to a low performance ratio. An increase in daily capacity, based on the same energy cost, leads to a higher performance ratio. This is due to the size effect of scaling up the evaporator.

4.2.5 Evaporator: Capacity vs. Water Cost

The cost of product water from thermal desalination tends to significantly decrease as the size of the evaporator increases. This is of particular importance for an evaporator size between 4 MGD (10,600 lpm) and 7 MGD (18,550 lpm). Experience from operating plants overseas show that for a size between 7 and 10 MGD, the reduction in water cost is less than that for the smaller size. A water cost reduction of 20-25% is observed when the capacity increases from 4 to 7 MGD per unit.

4.2.6 Intake Seawater Supply & Discharge

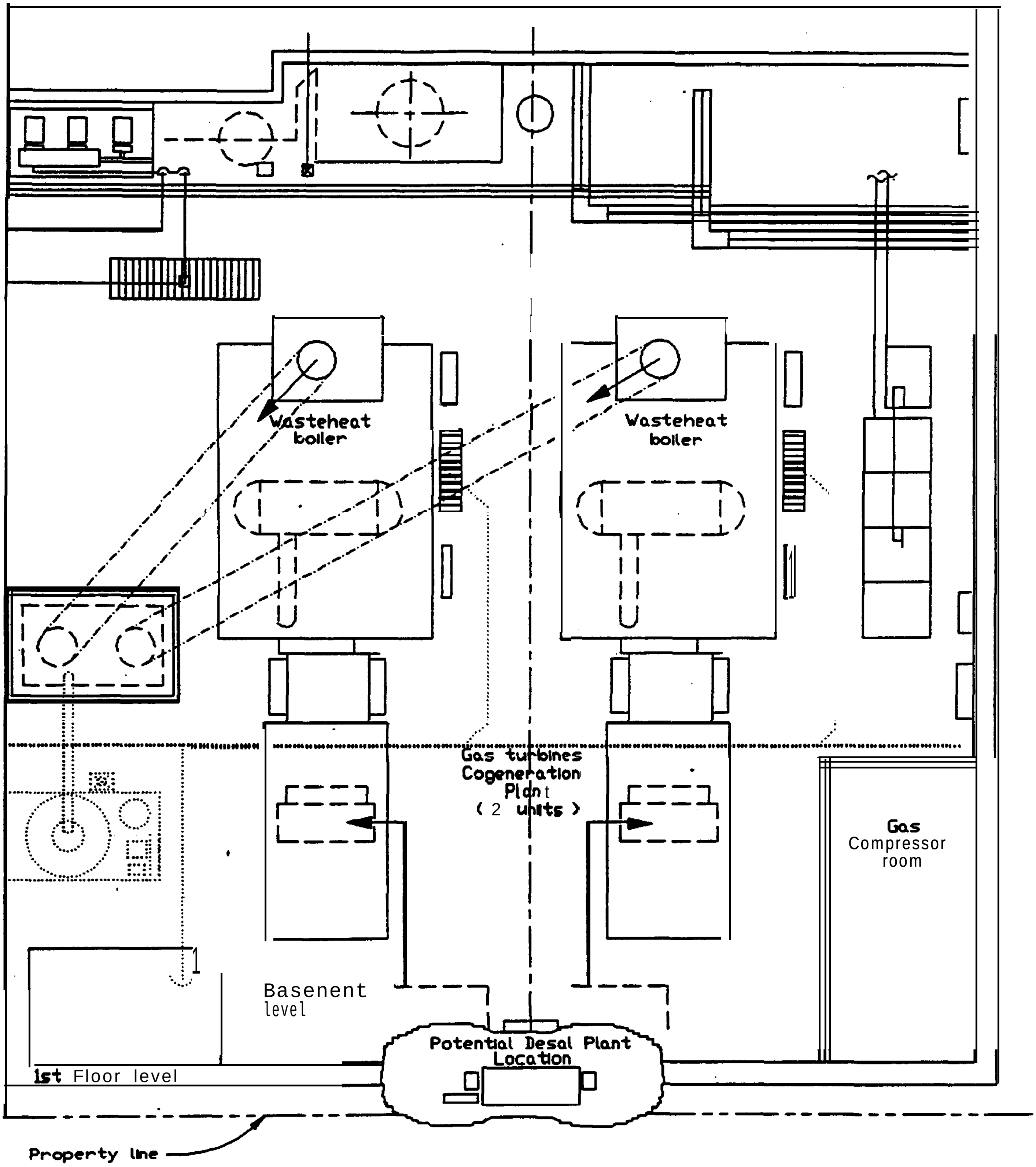
The 80,000 GPD unit requires 900 gpm (3406 lpm) of fresh seawater from the intake system. 840 gpm (3180 lpm) of seawater will be discharged.

4.2.7 Materials of Construction

The cost data is based on assuming copper nickel (90/10) tubes for the heat recovery and brine heater, copper nickel (70/30) for the heat rejection section. The vessel stages are carbon steel, with the first six stages cladded with stainless steel.

4.2.8 General Site Arrangement & Plant Dimensions

A site arrangement drawing shown in figure 4.5 illustrates the location and orientation of the proposed desalination facility. Also, a layout illustrating the required plant area is shown on figure 4.6. The area required will be approximately 313 sq. ft.

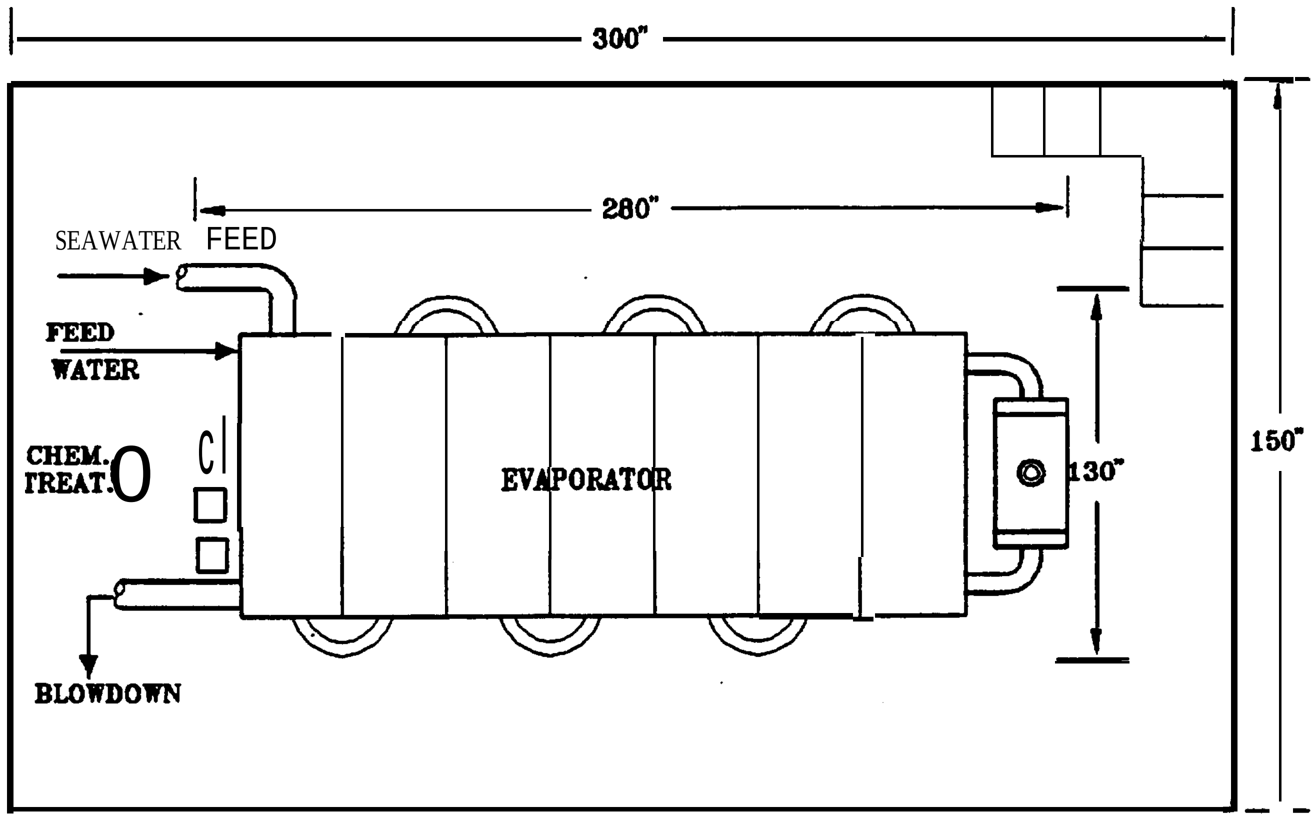


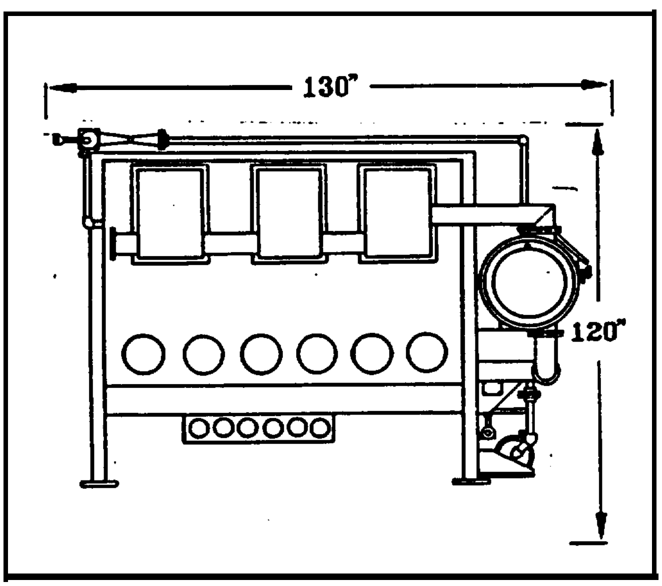
SCALE: N.T.S	DRAWN: NNR	APPROVED :	DATE:	FIG: 4.5

SUPERSYSTEMS Inc.

SANTA MONICA
DESAL'LOCATION

REQUIRED PLANT AREA





FRONT VIEW (ELEVATION)

SCALE: N.T.S.	DRAWN: NNR	APPROVED :	DATE:	FIG 4.6
SUPERSYSTEMS Inc.	PLANT LAYOUT SANTA MONICA BAY DESALINATION			

SECTION 5.0

CARLSBAD SYSTEM DESCRIPTION

5.1 The Overall System

The proposed power and desalination facility for Carlsbad, CA will consist mainly of one Centaur T-5700 solar turbine generator set, one - unfired - waste heat boiler and one MED desalination unit. Refer to figure 5.1 for a flow diagram of the proposed system.

The gas turbine unit will be driving a nominal 4040 KW electric generator set. The generator will be operating at 1800 rpm, 480 V, and 60 cycle/second. The pilot cogen desalination facility is expected to be located next to SDG & E Power Plant in Carlsbad. Refer to potential site pictures included in the appendix.

At system full load conditions, approximately 146,339 lb/hr (66,378 Kg/hr) exhaust flue gas at 948° F (509°C) from the gas turbine is ducted to an unfired type waste heat boiler (or otherwise called heat recovery steam generator, HRSG). The rated steam output from the waste heat boiler is 22,400 lb/hr (10,160 Kg/hr) at 15 psig (1.05 Kg/cm^2), saturated. The generated steam at 15 psig (1.05 Kg/cm^2) is supplied to the' desalination unit.

Electrically, the system will serve the in-house auxiliaries in parallel with the City of Carlsbad or SDG & E utility grid. Approximately 9.5% of the power will be supplied to in-house auxiliaries and the remainder will be sold to the particular utility. The potable water generated from the desalination unit process will be sold to the City of Carlsbad. A synchronization system with the electric utility will be provided to enable the intake and blowdown pumps to continue pumping and therefore to maintain a vacuum inside the effect chambers of the MED unit.

FIGURE 5.1

CARLSBAD COGEN/DESAL PROCESS FLOW DIAGRAM

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CONFIDENTIAL & PROPRIETARY INFORMATION

5.2 Desalination Process Description

The desalination process consists of one Multi Effect Distillation (MED) unit which has a desalination capacity of 0.35 MGD product water in addition to the high purity distillate water for NOx steam injection and boiler make up. The MED unit in this study is based on a unit supplied and manufactured by Ambient Technologies (Israeli Desalination). The predicted daily water production load profile is as shown in figure 5.2.

There are about 150 MED units of size equal to or larger than 0.35 MGD that are currently in commercial operation worldwide: Israel, Virgin Islands, USSR, and in many small islands. The largest size currently in operation is 4.5 MGD in Israel. In Western Cicily, city of Trapani, a french company has recently completed the construction of the world's largest MED which is totaled at 14.25 MGD. Plant start up occurred early in 1993.

The various flow requirements, concentration ratio, heat transfer area, number of stages/effects, the performance ratio, and other plant data are shown in Table 5.1.

The steam consumed by the desalination system is approximately 92% of the total HRSG steam output. The remaining steam is supplied to the venting system and plant deaerator. Figure 5.3 shows a cycle flow diagram for the MED desalination process.

5.2.1 Total Steam to Desal

The operation of the desalination system will require approximately 20,250 lb/hr (9185 Kg/hr) to the heating section. The ejector of the venting system will consume approximately 600 lb/hr (272 Kg/hr).

Figure 5.2

Carlsbad Pilot Plant Load Profile for Daily Water Production

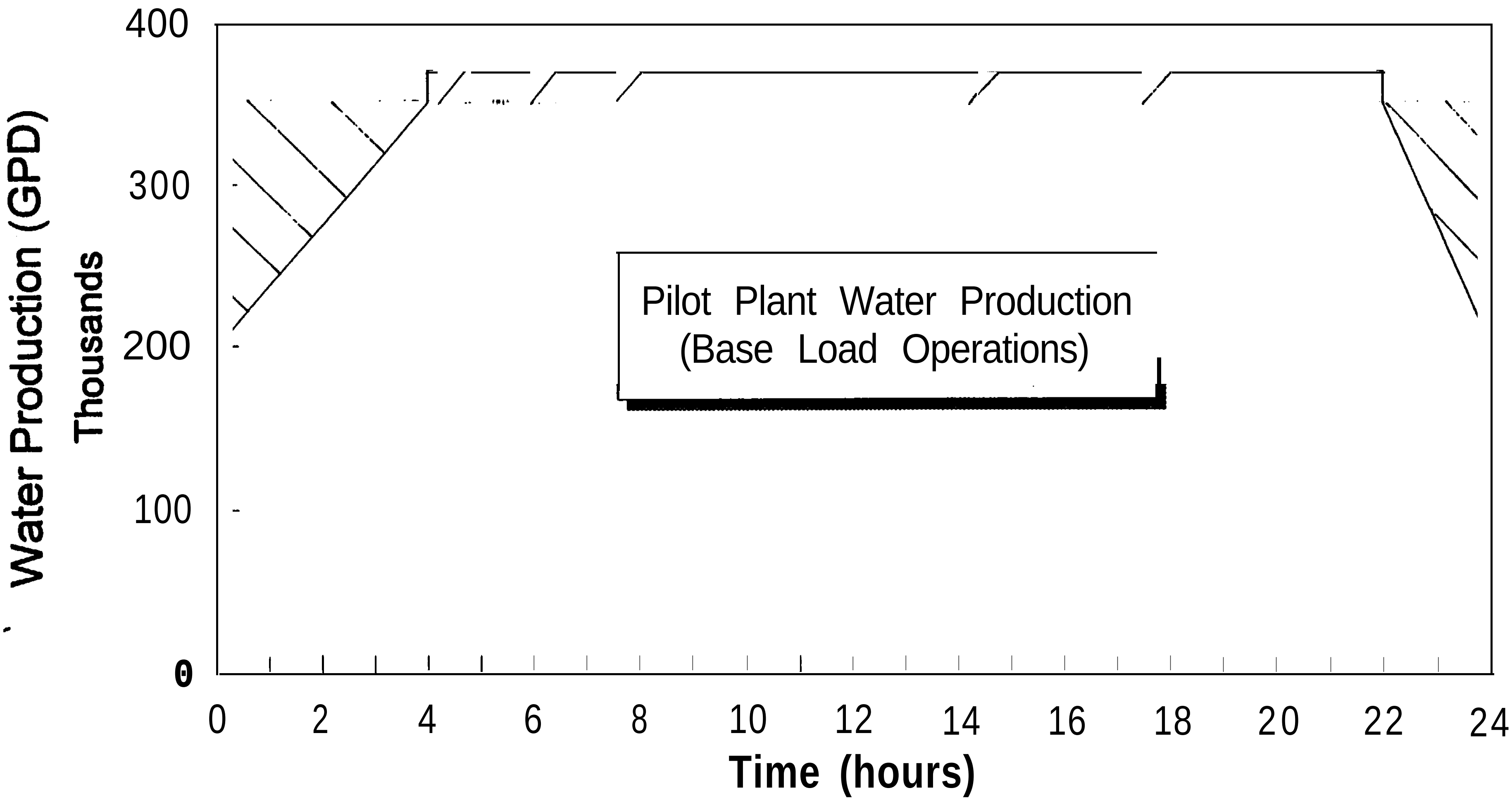


TABLE 5.1

TECHNICAL OUTLINES FOR MULTI-EFFECT DISTILLATION

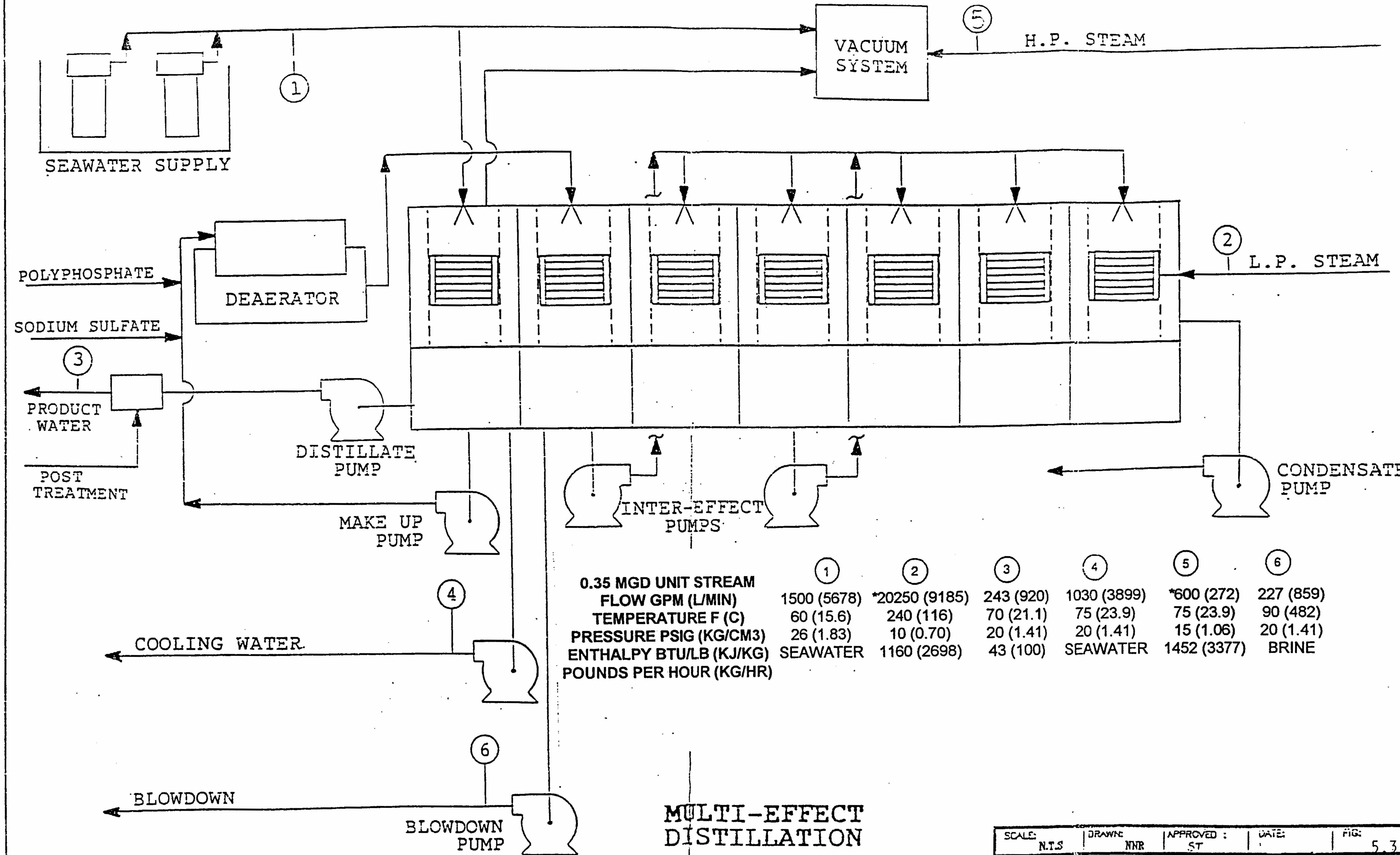
(ALL DATA FOR ONE 0.35 MGD UNIT)

GENERAL

TOP BRINE TEMP (F)	220	(104 C)
NUMBER OF EFFECTS	6	
PERFORMANCE RATIO LB DIST/1000 BTU	6.3	

PROCESS FLOW RATES

		CONC. RATIO
SEAWATER SUPPLY (GPM)	1500 (5678 lpm)	1
PRODUCT WATER (GPM)	243 (920 lpm)	0
BLOW DOWN (GPM)	227 (859 lpm)	2
SEAWATER TO DISCH (GPM)	1030 (3899 lpm)	1
LP STEAM TO DESAL (LB/HR)	20253 (9185 Kg/hr)	NA
HP STEAM TO VENTING (LB/HR)	600 (272 Kg/hr)	NA



0.35 MGD UNIT STREAM	1	2	3	4	5	6
FLOW GPM (L/MIN)	1500 (5678)	*20250 (9185)	243 (920)	1030 (3899)	*600 (272)	227 (859)
TEMPERATURE F (C)	60 (15.6)	240 (116)	70 (21.1)	75 (23.9)	75 (23.9)	90 (482)
PRESSURE PSIG (KG/CM3)	26 (1.83)	10 (0.70)	20 (1.41)	20 (1.41)	15 (1.06)	20 (1.41)
ENTHALPY BTU/LB (KJ/KG)	SEAWATER	1160 (2698)	43 (100)	SEAWATER	1452 (3377)	BRINE
POUNDS PER HOUR (KG/HR)						

MULTI-EFFECT DISTILLATION

SCALE: N.T.S	DRAWN: NNR	APPROVED: ST	DATE:	FIG: 5.3

SUPERSYSTEMS Inc.

SAN DIEGO COUNTY POWER/DESAL
MED PROCESS
BUREAU OF RECLAMATION

5.2.2 Condensate Return

The steam will condense in the heat input section of the desalination facility and condensate will be pumped back to the deaerator, then to the HRSG.

5.2.3 Evaporator Effects, Area, and Flow Rates:

Refer to table 5.1 for the technical outline of various flow rates for steam and water, the heat transfer area in different sections of the evaporator, and the top brine temperature leaving the heater section.

5.2.4 Materials of Construction

The materials of construction assumed in this case include aluminum tubing in both the evaporator and heat rejection sections of the plant and epoxy coated carbon steel for the evaporator bodies. Seawater evaporators using aluminum evaporator tubing have been in operation for about 20 years. Among the operating MED plants there are examples of successful operation with tube life projected at 20 years or more. However, there have also been examples where catastrophic corrosion of aluminum tubing have occurred.

The responses of MED plant suppliers reflects a difference in opinion as to the best tubing material choices. Ambient Technologies feels that aluminum tubing will achieve a 25 year life in both the evaporator and heat rejection sections, while Sidem recommends more conservative tubing materials including aluminum-brass and titanium based on their experiences with operating MED plants. Aluminum tubing with a projected life of 25 years was selected. A review of MED plants using aluminum tubing is in progress to further define tube replacement equal to approximately 5% of the tubes per year over the 25 year economic life of the unit.

52.5 Intake Seawater Supply & Discharge

A total seawater requirement of 1500 gpm (5678 lpm) is needed for the 0.35 MGD (920 Ipm) produced by the unit. 1030 gpm (3899 lpm) of seawater will be discharged. Our contact with the SDG&E Encena power plant indicated that the possible supply of a 6” seawater supply line can be taken from the power plant cooling water system. Therefore, we took into consideration the intake and outfall from the Encena power plant.

5.2.6 General Site Arrangement & Plant Dimensions

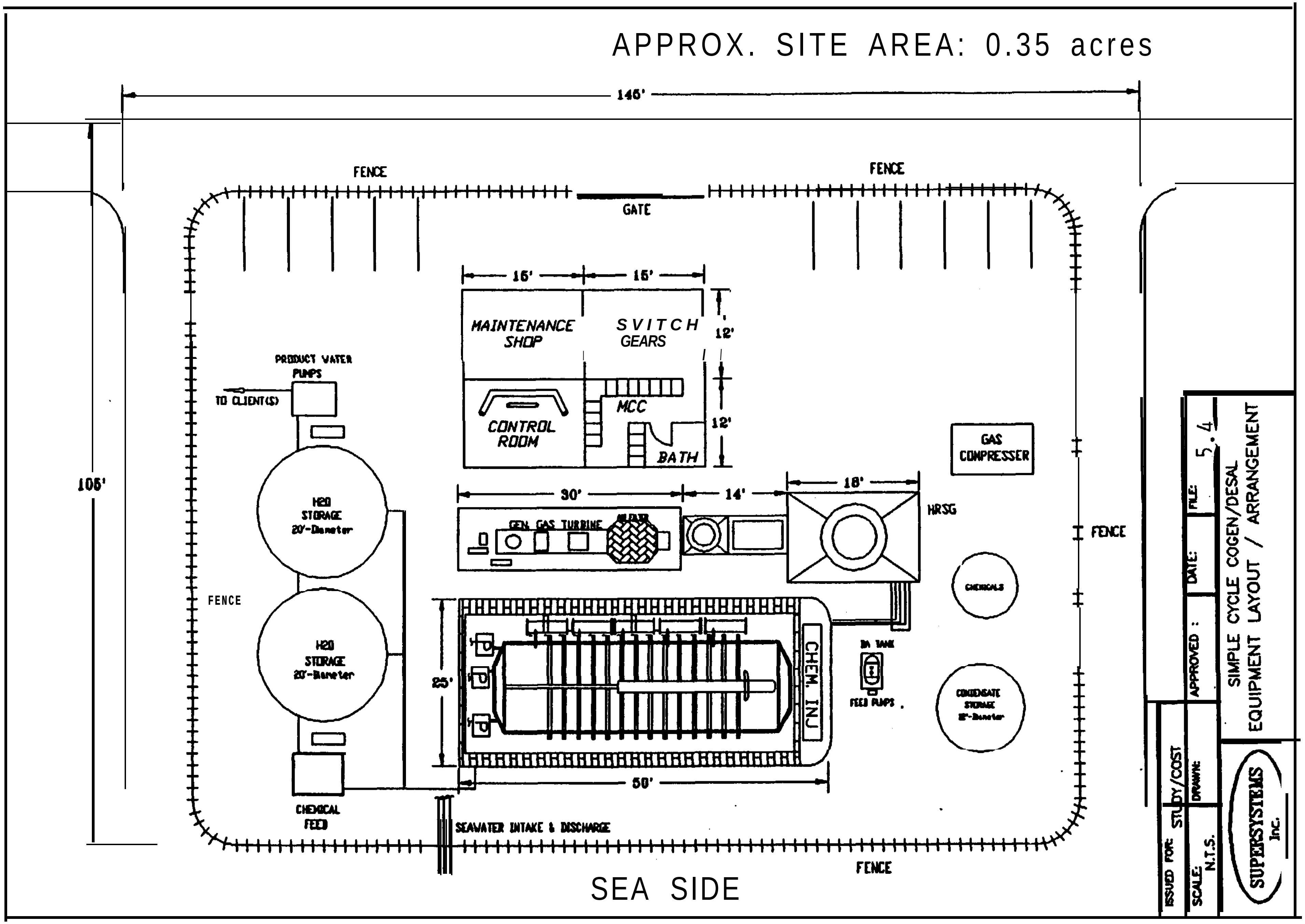
Two options for equipment arrangement are proposed. Option 1 (figure 5.4) will take up an area of 0.35 acres. Option 2 (figure 5.5) will take up an area of 0.27 acres. Option 2 is recommended due to its compactness and also considering the fact that land prices in the vicinity of Carlsbad, especially if it is close to the beaches as in our case, is relatively expensive.

5.2.7 Water Production

A daily water production for the Carlsbad pilot desalination facility is as shown in figure 5.2. The pilot plant will operate at its full load capacity the majority of the time. Around midnight, water will be directed to storage tanks and then pumped to the public during the day.

5.2.8 Encena Power Plant Make-up

The pilot plant will initially produce relatively high purity distilled water at less than 25 ppm. Part of the product water (approximately at 15%) could be produced at less than 5 ppm if the plant were located next to the SDG&E power plant; it will be feasible and cost effective for the Encina power plant to buy distilled water for boiler make up from the pilot plant. The cost of producing this distilled water is drastically less than producing water of this quality from a typical demineralization RO facility.


APPROX. SITE AREA: 0.35 acres
146'
105'
FENCE
FENCE
GATE
15'
15'
12'
12'
MAINTENANCE SHOP
SVITCH GEARS
CONTROL ROOM
MCC
BATH
PRODUCT WATER PUMPS
TO CLIENT(S)
H2O STORAGE 20'-Diameter
H2O STORAGE 20'-Diameter
FENCE
30'
14'
18'
GEN. GAS TURBINE
HRSG
GAS COMPRESSER
FENCE
CHEMICALS
25'
CHEM. INJ.
DA TANK
FEED PUMPS
CONDENSATE STORAGE 12'-Diameter
50'
CHEMICAL FEED
SEAWATER INTAKE & DISCHARGE
FENCE
SEA SIDE
SIMPLE CYCLE COGEN/DESAL
EQUIPMENT LAYOUT / ARRANGEMENT
FILE: 5.4
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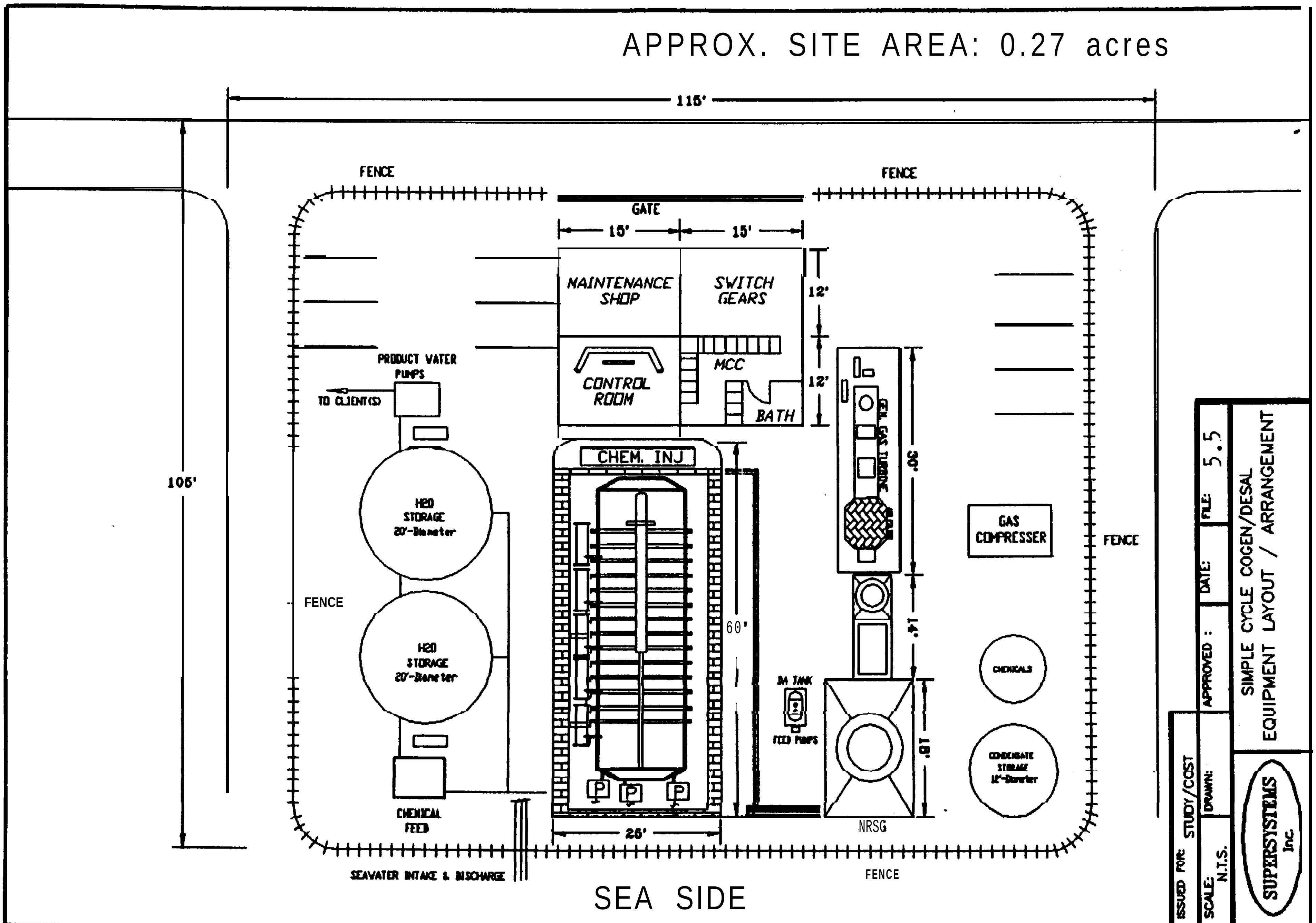
SUPERSYSTEMS Inc.


APPROX. SITE AREA: 0.27 acres
115'
105'
FENCE
FENCE
GATE
15'
15'
MAINTENANCE SHOP
SWITCH GEARS
12'
12'
CONTROL ROOM
MCC
BATH
PRODUCT WATER PUMPS
TO CLIENT(S)
H2O STORAGE 20'-Diameter
H2O STORAGE 20'-Diameter
FENCE
CHEM. INJ
60'
30'
14'
18'
GAS COMPRESSER
FENCE
DA TANK
FEED PUMPS
CHEMICALS
CONDENSATE STORAGE 12'-Diameter
NRSG
CHEMICAL FEED
26'
SEAWATER INTAKE & DISCHARGE
FENCE
SEA SIDE
SIMPLE CYCLE COGEN/DESAL
EQUIPMENT LAYOUT / ARRANGEMENT
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ISSUED FOR: STUDY/COST
SCALE: N.T.S.
SUPERSYSTEMS Inc.

SECTION 6.0

COST & ECONOMIC EVALUATION

6.1 Introduction

Cost is a primary factor in selecting a particular desalination technique for drinking water production. Desalination costs have decreased markedly in the last two decades. Recent cost analysis indicate that distillation processes have costs of approximately $3 to $6 per 1000 gallons under near optimum operating conditions for a medium size plant. If the desalination equipment is not operated efficiently, these latter costs can increase to as much as 88 to $10 per 1000 gallons, especially for smaller sizes. Some reduction in distillation costs may be realized from improvement in plant design, fabrication technique, heat exchange material, plant automation, and scale control technique. Energy costs for distillation plants (steam & electricity) represent about 60% of the cost of water. The minimum cost of water from seawater desalination occurs when power and desalination are combined in one "dual purpose facility" that simultaneously produces electricity and water.

This section presents appraisal level capital and operating costs for the Santa Monica desalination addition to the existing cogeneration plant as well as for the Carlsbad new cogeneration/desalination plant projects. The evaluation is based on costs for the current year 1995. The MSF desalination process is recommended to be used for Santa Monica and the MED process for Carlsbad. The economic evaluations are based on a first year cost comparison. Generally, all costs developed through the progress of this study are slightly on the conservative side.

In addition to the economic analysis of this section, Section 9.0 includes detailed life-span cash flow analysis for each proposed desalination facility.

All data input and assumptions used in the economic analysis are summarized in this section. A “Plant Factor” of 90% is included in the cost analysis for both projects. The “Plant Factor” represents a combination of plant availability and capacity.

6.2 Cost Basis

Costs developed for this study are based on experience of designing a number of large desalination projects overseas, current projects, six years operation and maintenance of 12 desalination and power plants in Saudi Arabia, vendor quotations, involvement in previous bid evaluation, price catalogs, other current in-house studies and projects, U.S. Office of Saline Water (OSW) reports and design information, and many other sources such as published papers and conference proceedings. Many desalination equipment manufacturers were contacted for current pricing information. All estimated costs are based on current 1995 prices.

6.3 Economic Parameters

Table 6.1 represents the major economic parameters that have been utilized through the progress of the evaluations. Annual escalation rates are indicated.

These economic parameters are also utilized for the cost of water analysis. The cost for steam is at approximately 81.50 per 1000 lb for Carlsbad and $0.25 per 1000 lb for Santa Monica. The rate is cheaper for Santa Monica because the waste heat generated for desalination is from the existing cogeneration plant. If the waste heat were not used for desalination, it would be vented to the atmosphere. The electricity rate for Carlsbad is approximately 5 cents per kWh and for Santa Monica it is 6 cents per kWh.

TABLE 6.1

ECONOMIC PARAMETERS

ECONOMIC **FACTORS**	(Carlsbad) MED		(Santa Monica) MSF	
Economic Life **(yrs)**	20.0		20.0	
Escalation Rates **(%)**				
Overall	5.0		5.0	
Steam	4.0		4.0	
Electricity	4.0		4.0	
Water	5.0		5.0	
Cost of Debt (%)	9.0		9.0	
STEAM				
$0000 LB	1.50		0.25	
LB/HR	20,250	(9185 **Kg/hr)**	6,000	(2722 **Kg/hr)**
ELECTRICITY				
C/KWH	5		6	
KWH/YR	832,200		306,600	
KW Load	95		35	
OPERATING LABOR				
$/HR	18		18	
CHEMICAL PRICES ($/TON)				
Polymer (HTA)	1720		1720	
Antifoam	2100		2100	
Sodium Bisulfite	2200		2200	
Caustic (50% Solution)	350		350	
Sodium Hexametaphosphate	1250		1250	
Limestone	65		65	
Chlorine	310		310	

6.4 Heat and Mass Balance Diagrams

To arrive at a relatively accurate and reliable capital and operating cost estimate, heat and mass balances of the systems were considered for each project. The generation of the heat and mass balance data resulted in obtaining fairly accurate numbers for the key parameters of each system, which are necessary for the economic evaluation and for estimating the cost of water in each case.

6.5 Systems Equipment Cost

Table 6.2 illustrates the basic equipment costs, other auxiliary equipment and the total equipment costs for the Santa Monica and Carlsbad projects, respectively. Estimates for the major capital equipment were derived from quotations provided by equipment suppliers. Cost estimates for conventional, non-process specific equipment were derived from experience on similar and/or completed projects and miscellaneous published data.

6.6 Total Project Installed Cost

The total direct capital costs, indirect capital costs, installed costs, annual operating costs, etc. have been estimated and are discussed below. The total project installed cost is assuming an installation in the current year 1995.

6.6.1 Direct Capital Costs

These costs include the items shown in table 6.3. These costs include the total equipment costs as supplied by manufacturers, transportation to the site (by suppliers), site development, and construction costs of basic system equipment. Additional costs included the interconnection piping work and piping racks for steam and condensate, the

TABLE 6.2

MAJOR EQUIPMENT LIST AND COST

GENERAL OUTLINES	(Carlsbad) YED		(Santa Monica) MSF	
Performance Ratio	6.3		4.6	
Desal Capacity (MGD)	0.35	(920 lpm)	0.08	(210 lpm)
Number of Units	1		1	

BASIC EQUIPMENT		
Evaporator includes:	6 effects	7 stages
Heat Recovery Section		
Heat Rejection Section		
Ejector System		
Pumps:		
Distillate		
Booster		
Blowdown		
Condensate		
Coolant		
Feed Treatment for Scale Protection		
PLANT BASIC EQUIPMENT COST ($)	**1,750,000**	**500,000**

ADDITIONAL EQUIPMENT		
Control, Instrumentation and Control Room Equipment	15,000	0
Building for Chemical Injection	9,000	0
Product Treatment Equipment	5,000	1,500
MCC and Switch Gears	40,000	6,500
Chemicals for Cleaning System	2,000	0
Interconnected Piping' and Valves	35,000	7,000
TOTAL EQUIPMENT COST ($)	**1,856,000**	515,000

TABLE 6.3

COST OF WATER FROM DESALINATION FACILITY

GENERAL OUTLINES	(Carlsbad) MED		(Santa Monica) MSF	
PERFORMANCE RATIO	6.3		4.6	
DESAL CAPACITY (MGD)	0.35	(920 lpm)	0.08	(210 lpm)
NUMBER OF UNITS	1		1	
PLANT AVL/CAP FACTOR	0.9		0.9	
)ESAL STEAM (LB/HR)	20,250	(9185 Kg/hr)	6,000	(2722 Kg/hr)
)ESAL ELECTRICITY (KW)	95		35	

'ROJECT INSTALLED COSTS ($)

)IRECT CAPITAL COSTS ($)		
Total Equipment	1,856,000	515,000
Transportation to Site	170,000	5,000
Construct, Site Devel., Build, etc.	470,000	60,000
Connect SW Supply/Disch	25,000	15,000
Connect Product Water to Storage	10,000	4,000
TOTAL DIRECT COSTS ($)	2,531,000	600,000
NDIRECT CAPITAL COSTS ($)		
Permitting	20,000	8,000
Engineering & Management	177,170	42,000
Land Acquisition	150,000	15,000
Contingency	25,000	20,000
TOTAL INDIRECT COSTS ($)	372,170	85,000
NSTALLED COSTS ($)	2,903,170	685,000
;APITAL AMORTIZATION ($/Yr)	319,349	75,350

TABLE 6.3 CONTINUED

UNIT COST	(Carlsbad) MED	(Santa Monica) MSF
Unit Cost of Steam ($/1000 lb)	1.50	0.25
Unit Cost of Elect ($/KWH)	0.05	0.08
Unit Cost ($/GPD)	8.29	8.56
FIRST YEAR (1885) OPERATING COSTS ($/Yr)		
Cost of Steam to Desal	239,477	11,826
Cost of Electricity to Desal	37,449	16,556
Cost of Chemicals to Desal	10,882	2,487
Labor & Maintenance	60,000	30,000
Insurance, Misc. & Overhead	2,500	2,000
ANNUAL COSTS ($/YR)	350,308	62,889
GROSS ANNUAL COSTS ($/Yr)	670,000	138,000
COST OF PRODUCT WATER (1885)		
$ PER 1000 GAL *	5.50	4.67
$ PER ACRE FOOT	1,792	1,521
$ PER CUBIC METER	1.45	1.23

* The cost of water from the smaller plant of Santa Monica is less than the cost of water for Carlsbad attributed to the steam cost in each as well as the transportation cost ($5000 from Milwaukee, US $170,000 from Israel)

seawater supply and discharge piping, and the connection of product water to the storage tanks.

6.6.2 Desalination Plant Total Equipment

- Evaporator including effects (or stages) and heating section
- Various pumps
- Ejector system
- Control room equipment
- Instrumentation & control
- Deaeration/decarbonator equipment
- Chemical injection sets: lime, scale protection chemical, antifoam, sodium sulfite, etc.
- Tube cleaning system
- Interconnecting piping and valves

6.6.3 indirect Capital Costs

The indirect capital costs include permitting by various agencies, such as the Coastal Commission, Land Commission, SCAQMD, State Water Resources Board, Los Angeles Regional Water Quality Control Board (LA-RWQCB), Department of Health Services (DHS), and others. A single package including all required data and details has to be submitted to the above agencies. Other indirect costs are as follows:

- Engineering & Management costs estimated at 7% of the total direct costs
- Land acquisition or leasing
- Working capital for two years span, during construction
- Contingency

Some of the indirect cost items are taken as a percentage of the total direct.

6.7 Project Operating Costs

The operating costs are based on actual plant consumption of chemicals, electricity and steam. The prices and consumption rates are indicated in table 6.1. Labor and maintenance are based on the number of operators required at $18/hr in addition to insurance and overhead expenses. .A total of two operators for repair and maintenance are assumed for the Carlsbad project; considering that the cogen's operators will be trained to operate both sections. One operator is assumed for Santa Monica because the operators of the existing cogeneration plant will supervise the desalination operation.

6.8 Cost Of Water For Each Process

The cost of product water from each process is the most important parameter in the evaluation. The cost of water for both projects were calculated based on a first year cost analysis (assuming the year to be 1995). Refer to table 6.3 for the results.

The cost of water for each project were as follows:

Santa Monica:	$5.50 per 1000 gal ($1.46 per cubic meter)
Carlsbad:	$4.67 per 1000 gal ($1.24 per cubic meter)

The City of Carlsbad has indicated that they are willing to buy the water for 20 years at an appropriate cost. Letters of correspondence with the city are included in the appendix.

6.9 Carlsbad Pilot Plant Construction

The costs for construction of the new cogeneration plant for this project will be approximately $4.5 million. These costs will be financed by a joint venture that will include Super Systems inc. The power portion of the plant will be based on a gas turbine concept and is not included in the scope of work for this study.

6.9.1 The Required Contribution from the Bureau of Reclamation

The Bureau of Reclamation's contribution for construction costs will be a maximum of $150,000 for the design, construction, and checkout testing in the first year, then $120,000 for the testing and evaluation in the second year. Table 6.4 compares the cost of water with BUREC contribution and without, for 1995.

TABLE 6.4

COMPARISON OF COST OF WATER WITH BUREC CONTRIBUTION

Plant	Cost of Water w/o BUREC contribution ($/1 000 gal)	($/cu.m)	Cost of Water w/ BUREC contribution ($11000 gal)	($/cu.m)
Santa Monica	4.67	1.23	3.65	0.96
Carlsbad	5.50	1.45	5.01	1.32

SECTION 7.0

ENVIRONMENTAL, PERMITTING AND REGULATORY ISSUES

7.1 Finished Water:

The finished water quality will have to meet State of California drinking water standards relative to organics, inorganics, and microbiologicat quality 8s well 8s the California Department of Health Service for potable water. The finished water TDS must be less than 500 mg/l. The product water from the desalination unit will have 8 TDS of approximately 340 mg/l. In addition, minimal post treatment of the water will be required.

7.2 Surface Water Treatment Rule (SWTR OF 1991)

The California Department of Health Services, and the Office of Drinking Water have indicated that seawater is considered to be 8 surface water source, and therefore is subject to the provisions of the SWTR, which are summarized below:

- A sanitary survey, 8s described in Section 64665 is required. A cursory survey may be acceptable during the drought emergency 8s long 8s it covers all significant sources of contamination.

- Coliform data shall be obtained from the source to determine the appropriate giardia and virus removal requirement.

- Desalination plant should not be located near any ocean outfall which discharges undisinfected wastewater.

- Desalination plants should provide a minimum of 0.5 log inactivation of giardia through disinfection.

- For Distillation Process: due to the lack of evidence demonstrating pathogen removal, and the possibility of particle carry over with the vapor, distillation shall not be granted any log removal credit for giardia or viruses unless such removals are demonstrated. Such demonstrations must meet the requirements for alternative technology specified in the Surface Water Treatment Rule and must also show that the process is reliable. Distillation facilities may require post-filtration processes to assure compliance with the SWTR.

- Any condition resulting in the breakthrough of microorganisms is reliably indicated by an increase in TDS. The unit should be continuously monitored for specific conductance. Any increase in specific conductance to a level exceeding a value to be identified in the operation plan should trigger an alarm and automatically shut down the unit.

- The treatment process should also include a provision for corrosion control because the product water from the desalination unit is low in pH, Ca, and Mg ions. The product water's specific conductance is primarily comprised of Mg and Cl ions.

- All desalination treatment plants shall be designed and operated to conform with California's SWTR. The surveyor shall submit for approval and follow an operations plan, Section 64661, SWTR.

- The treatment facilities should be operated by personnel who have been certified in accordance with the regulations relating to certification of water treatment facility operation, California Code of Regulations, Title 17.

SI METRIC CONVERSIONS

Multiply	By	To obtain
ft	0.3048	m
in	2.54	cm
ft^2	0.0929	m^2
gal	3.785	liters
gal	0.003785	m^3
lb	0.45359	Kg
psi	0.070307	Kg/cm^2
gpm	0.06309	L/s

7.3 AQMD & Permitting Issues

Because of the drought conditions between 1985 and 1992, there is a trend at the present time, in governmental and permitting agencies to encourage desalination plant construction as an additional source of water.

SCAQMD indicated that if desalination is part of a cogeneration system where the product water is sold to the public, they may consider an emission credit to the cogen system. Applying the same for the Carlsbad project, the City of Carlsbad may negotiate an emission credit for the addition of the desalination system with the local air quality district.

A stand alone. 0.35 MGD desalination system will emit approximately 240 lb/day of NOx with water injection for NOx control.

7.3.1 NOx Emission with Desalination

Information from the equipment supplier indicates that NOx emission will not exceed 240 lb/day. For the Carlsbad project, a request for an emission credit for the desalination system integration will be needed. The integration of desalination will make the facility also entitled to take advantage of the applicable regulation of cogeneration systems.

7.4' Key Environmental Issues

The key environmental issues for this project are summarized below:

- Brine blowdown disposal
- Heavy metal discharge
- Discharge temperature
- Pretreatment chemicals
- Air quality

Since it is important to minimize the adverse environmental impacts from any of the issues indicated above, the relevance of each issue to this project is discussed separately.

7.4.1 Brine Blowdown -Concentrate- Disposal

The major concerns related to concentrate disposal include:

- Blowdown (Discharge) Water Quality
- Discharge Water Temperature
- Heavy metals, such as copper, nickel, iron, etc.
- Pretreatment chemicals

All desalination processes produce a high-salinity waste concentrate that must be disposed of. The fraction of feedwater that becomes wastewater depends on the desalination process used, the plant design, the feedwater composition, and the type of concentrate treatment required prior to disposal. The amount of waste concentrate can be minimized by further desalinating the, waste concentrate(s) produced from. the desalination process. The moderately elevated temperature of waste concentrates may also cause potential ecological changes in the immediate vicinity of concentrate discharges in marine environments. The composition of the waste concentrates generally makes them unsuited for most subsequent industrial, municipal, or agricultural uses.

The waste concentrate from seawater distillation plants would probably be discharged into adjacent marine environments. All disposal options require site specific evaluations of costs and potential environmental impacts. To date, the problems associated with the disposal of waste concentrates have generally not been significant enough to override a decision to build a desalination plant. However, with increasingly stringent environmental and regulatory programs, the disposal of waste concentrates could become a primary consideration in siting future plants. Disposal costs could conceivably make some proposed desalination operations uneconomical. In California a number of seawater desalinators have been permitted without any major problems regarding water disposal.

Concentrate disposal is generally a less significant problem in coastal and marine environments due largely to the high levels of concentrate dilution that typically occur. However, with distillation, some organisms may be adversely impacted by the increased salinity of the wastewater and/or by higher concentrations of pretreatment chemicals or natural contaminants in the effluent. Moderately elevated temperatures of distillation effluents, which run about 10 to 15 degrees fahrenheit above feedwater temperatures, may not be a potential concern, depending on the organisms near the point of concentrate discharge. Laboratory bioassays using marine organisms from the proposed discharge area can be used to indicate the potential toxicity of desalination effluents.

At normal operating conditions, the concentration of salts in the discharge for each desalination process is as follows:

Process	Seawater Supply (PPM)	Discharge Flow (PPM)	Concentration Ratio (Seawater = 1)	Total Flow GPM (lpm)
MED:				
Blowdown	34,800	69,600	2.00	227 BD (859)
Seawater Discharge	34,800	34,800	1.00	1030 SW (5678)

7.4.2 Heavy Metal Discharges

Heavy metal discharges from a desalination plant are attributed to the corrosion of the materials of construction of the desalination system. Normally, a deaerator vessel and injection of chemicals for 0, removal are an integral part of the desalination system to minimize corrosion. Corrosion could be the result of poor selection of materials, an effect of galvanic action, or due to poor operating practices. Also, higher operating temperatures will accelerate corrosion.

Discharge of heavy metals from the desalination process will not occur because normal operating temperatures are low at approximately 2000F. The chosen materials of construction are normally highly resistant to corrosion; thus, heavy metal discharges are not expected due to material selection.

7.4.3 Temperature

The desalination process does raise the seawater discharge temperature. However, the temperature will increase by approximately 8 - 15 °F above fresh seawater levels. The net discharge seawater temperature from the desalination section is 69.8°F, when seawater temperature is 60°F.

7.4.4 Pretreatment Chemicals

All chemicals used in the pretreatment of water to be treated by desalination processes will have to be approved by the Food and Drug Administration (FDA) for potable water use. Therefore, no problems will result from the addition of these chemicals.

7.4.5 Air Quality

There are no emissions during normal/emergency operation of the desalination plant. The cogen plant emission may be credited due to desalination integration. Further discussions are required with the local air quality management district in the San Diego area.

7.5 Miscellaneous Environmental Issues

7.5.1 Noise

During normal and off-normal operating conditions, the desalination processes do not produce excessive noise levels. The primary source of noise will be from the gas turbine for the Carlsbad project (less than 82 dBA at 3 feet from the turbine).

7.5.2 Land Use

Permits for land use are not an issue for the Santa Monica project due to the fact that the chosen location already occupies an existing cogeneration plant. Land use permits will be needed for the Carlsbad project.

7.5.3 Marine Sealif e

In general, the net impact of the desalination plant is a slight increase in the discharge of seawater salinity and temperature of the seawater. The slight increases in discharge water salinity and seawater temperature are not expected to have any adverse impact on marine biology or sealife.

7.5.4 Cleaning Chemicals

Desalination plants require infrequent tube cleaning approximately every 4 - 6 months. The type of chemicals used are cleaning detergents and acids. The spent cleaning solution is normally diluted and neutralized in a special sump before discharge to the sewer system.

7.6 National Environmental Policy Act (NEPA)

The purpose of NEPA is to ensure that all major actions of the federal government are consistent with NEPA policy. Major federal actions range from new statutory and regulatory initiatives to the licensing of individual projects.

Environmental assessment reports for desalting plants may be required, as a minimum, and the report should consider the following:

- Air, water, chemical discharges from the plant
- Desalination type, capacity, operation, etc.
- Affected environment: air, land, noise, heat, and sea
- Environmental consequences

Land use plan, flood plan, and coastal zone management plan details are required.

The project can proceed if it is determined that it is environmentally sound. If no significant environmental impact is found, a "finding of no significant impact" is issued for public scrutiny. If there are no legitimate objections to the "negative declaration", then the project is approved and no further analysis will be required.

7.7 Coastal Management Act

The Coastal Zone Management Act basically deals with the nation's unique coastal area resources and the issues associated with their preservation. The Coastal Zone Management Act is working to ensure the safety of coastal ecosystems from any detrimental action. A complete report on the impact of the desalination system effluents has to be prepared and submitted for approval.

7.8 Plant Permitting Time Span

The permitting time for a desalination plant of the recommended size and type is expected to take between 6 - 8 months, as shown on the milestone schedule at the end of section 6. A well prepared environmental report that may include plant data, system description, water analysis, plant discharges, concentration levels, etc... significantly reduce the time required for plant permitting.

7.9 Federal Laws Indirectly Related to Desalination

During the 1960s there was growing concern that many aquatic environments were becoming polluted, believed to be a result of population increases, and industrial growth and development. As a result of this situation, the Congress passed numerous bills in the 1970s regulating the disposal of certain types of waste and protecting different disposal environments. The Safe Drinking Water and Clean Water Acts are most directly related to desalination.

Through the Safe Drinking Water ACT (SDWA) of 1974 the Environmental Protection Agency (EPA) and/or States have the authority to regulate the quality of public drinking water supplies, including those that rely on desalinating brackish groundwater. Private systems, many of which get their water from sources located underground, are not regulated under the SDWA.

Although the states retain the primary control over the use of groundwater, EPA grants are now available for partially funding State programs that protect sole source aquifers and wellhead areas supplying public water systems. EPA's enforcement powers to regulate underground injection wells have also been strengthened and streamlined.

In 1986 the SDWA was amended to increase the level to which EPA and states will be regulating public drinking water supplies. Current EPA guidelines recommend that drinking water supplies have less than: 500 ppm of total dissolved solids, 250 ppm for both chloride and sulfate ions, and 100 ppm calcium carbonate for hardness. Since these guidelines are not enforceable, these levels can legally be exceeded. However, at the present time and over the next few years EPA will be developing standards for over 80 other contaminants. For those water quality parameters that can not be easily measured by utilities, EPA can specify treatment techniques, rather than a numerical standard. Considering these increasingly stringent water quality standards, it is quite likely that the use of various desalination technologies for centralized water treatment and for point-of-use/point-of-entry treatment will probably increase in the approaching years.

Desalination demonstration projects could be considered for funding under the SDWA. Under Section 1444 EPA can make grants for State-approved projects that will: 1) Demonstrate a new or improved method, approach, or technology for providing a safe supply of drinking water to the public; or 2) investigate the health implications associated with the treatment and reuse of wastewater for potable purposes. Grants are limited to two-thirds of the cost of construction and three-fourths of any other costs. Priority is given to projects where there is a known or potential health hazard. This section also makes Federal loan guarantees available to private lenders for upgrading small public water systems.

Under the Clean Water Act desalination plants that discharge wastewater into the Nation's surface waters are required to have a National Pollutant Discharge Elimination System, or so called NPDES permit. Under NPDES, industrial and municipal dischargers are required to use the best available technology for cleaning up wastewater prior to its discharge into adjacent waterways.

SECTION 8.0

FULL SCALE PLANT OVERVIEW

8.1 Introduction

The purpose of this section is to provide an overview of a full scale power/seawater desalination facility to be constructed and installed at Carlsbad (or other location in San Diego County). The performance, plant economics, cost of water, commercial viability, and major problems encountered were analyzed based on SSI's experience in designing similar plants overseas.

8.2 Description of System

Refer to figure 8.1 and 8.2 for a general arrangement diagram for a typical nominal 5 MGD (full scale) power/desalination plant. The plant will consist mainly of its power section and desalination section. The main components of the power section will be a nominal 50 MW gas turbine/generator set and a heat recovery steam generator (HRSG). Typically, for generation of 4.8 MGD of potable water, an input of approximately 80,800 lb/hr (36,727 Kg/hr) of steam is required at the desalination unit. However, the steam required for desalination should be optimized. The HRSG will produce this much at 15 psig and 250 F. The plant will also produce a nominal 50 MW of electricity.

The main components of the desalination section will be the desalination unit itself (MED, MSF, etc.), the intake and discharge pump structure, and the post water treatment facility. For this study,. two 2.4 mgd product water desalination units were assumed. To produce 4.8 mgd of potable water, approximately 48,300 gpm (182,815 lpm) of seawater is needed at the intake structure. Approximately 41,356 gpm (156,532 lpm) of seawater is discharged back to the ocean (refer to figure 8.1 for. a balance of seawater flow). The product water will be at 70 F with less than 25 ppm of TDS.

8.3 Equipment Layout/Arrangement

A typical equipment arrangement of the plant is as shown on figure 8.2. The total layout will take up an area of approximately 4 acres. The layout illustrates two desalination units, each producing 2.4 mgd, side by side taking up a total area of approximately 0.5 acres.

8.4 Cost & Economic Evaluation

Based on the above data, the following is a comparison of the cost of water for the 0.35 mgd plant proposed for Carlsbad and a 4.8 mgd plant "economy of scale effect". It should be noted that this cost comparison, in both cases, is based on a "dual-purpose plant", that will simultaneously produce electricity and potable water. Refer to table 8.1 for the results of the comparison.

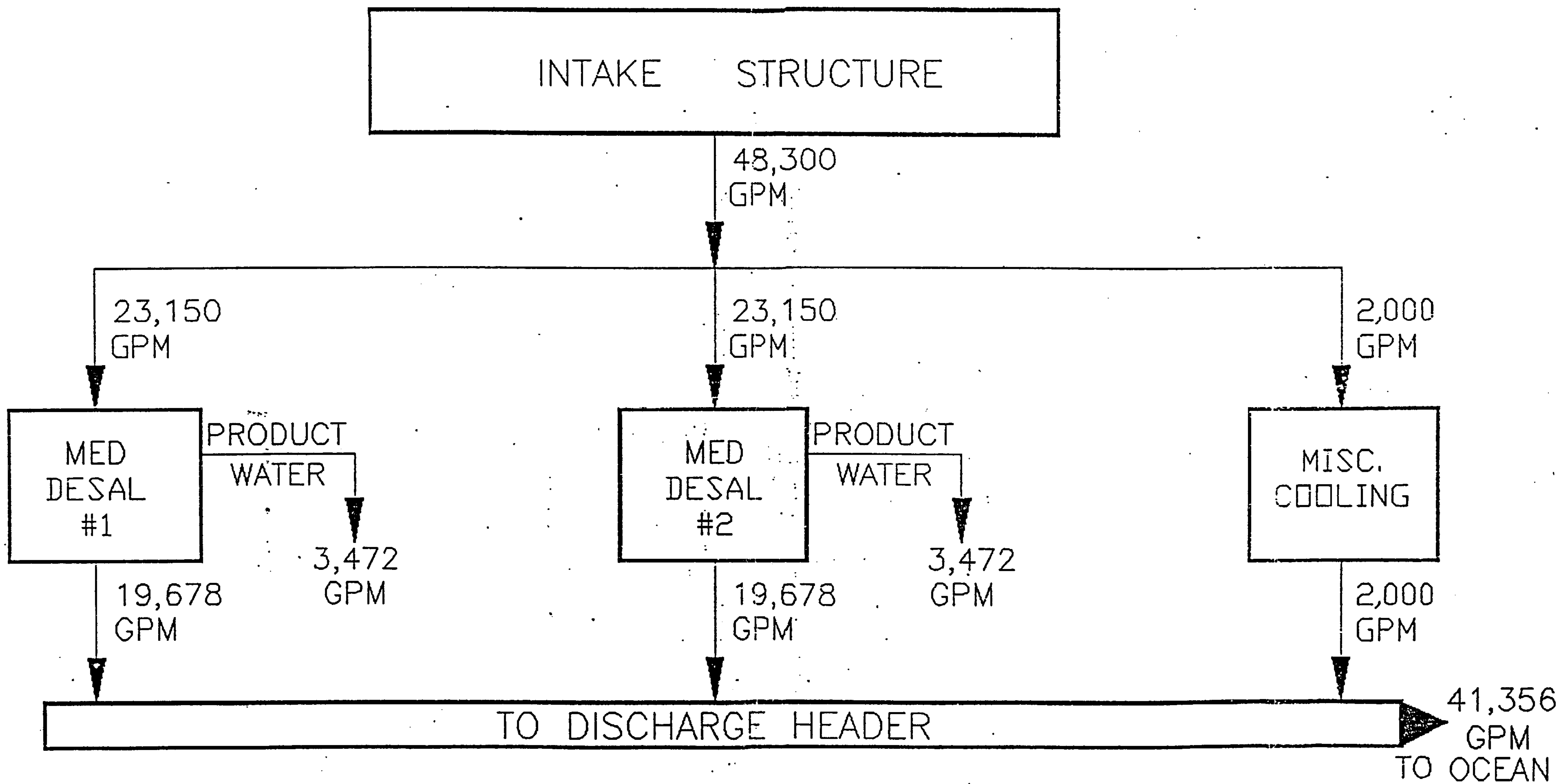
The cost of water is as follows:

0.35 mgd plant: $5.50/1 000 gallons

4.8 mgd plant: $3.08/1 000 gallons

The results indicate that there will be a reduction in the cost of water of approximately 44% when the size of the plant is enlarged from 0.35 mgd to 4.8 mgd. Both scenarios include the power plant with the desalination, but the cost does not include the power plant section.

SEAWATER FLOW BALANCE



SCALE: N.T.S	DRAWN:	APPROVED :	DATE:	FIG: 8.1
SUPERSYSTEMS Inc.	SEAWATER FLOW BALANCE BUREAU OF RECLAMATION			

FIGURE 8.2

EQUIPMENT LAYOUT/ARRANGEMENT

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TABLE 8.1

EFFECT OF ECONOMY OF SCALE
ON PRODUCT WATER COST

GENERAL OUTLINES	0.35 MGD		5.0 MGD	
DESAL CAPACITY (MGD)	0.35	(920 lpm)	5	(13,140 lpm)
NUMBER OF UNITS	1		1	
PLANT AVL/CAP FACTOR	0.9		0.9	
DESAL STEAM (LB/HR)	20,250	(9185 Kg/hr)	80,800	(36,727 Kg/hr)
DESAL ELECTRICITY (KW)	95		1394	

DESALINATION PLANT INSTALLED COSTS ($)		
DIRECT CAPITAL COSTS ($)		
Total Equipment	1,856,000	19,010,000
Transportation to Site	170,000	1,250,000
Construct, Site Devel., Build, etc.	470,000	3,003,000
Connect SW Supply/Disch	25,000	600,000
Connect Product Water to Storage	10,000	100,000
TOTAL DIRECT COSTS ($)	2,531,000	23,963,000
INDIRECT CAPITAL COSTS ($)		
Permitting	20,000	60,000
Engineering & Management	177,170	1,947,420
Land Acquisition	150,000	600,000
Contingency	25,000	432,760
TOTAL INDIRECT COSTS ($)	372,170	3,040,180
DESALINATION INSTALLED COSTS ($)	2,903,170	27,003,180
CAPITAL AMORTIZATION ($/Yr)	319,349	2,970,350

TABLE 8.1 CONTINUED

UNIT COST	0.35 MGD/ 4 MW	5.0 MGD/ 50 MW
Unit Cost of Steam ($/1000 lb)	1.50	1.25
Unit Cost of Elect ($/KWH)	0.05	0.05
Unit Cost ($/GPD)	8.29	5.40
FIRST YEAR OPERATING COSTS ($/Yr)		
Cost of Steam to Desal	239,477	796,284
Cost of Electricity to Desal	37,449	549,515
Cost of Chemicals to Desal	10,882	970,000
Labor & Maintenance	60,000	204,000
Insurance, Misc. & Overhead	2,500	126,100
ANNUAL COSTS ($/YR)	350,308	2,646,000
GROSS ANNUAL COSTS ($/Yr)	669,656	5,600,000
COST OF PRODUCT WATER		
$ PER 1000 GAL	5.50	3.08
$ PER ACRE FOOT	1,792	1,002
$ PER CUBIC METER	1.45	0.81

8.5 Commercial Viability

A survey of all desalination plants worldwide for plant size 2.4 mgd and larger is shown on table 8.2. This table displays the unit size, type of process, and the year of operation. Many of the larger desalination plants began operation in 1967 and 1968.

The larger size desalination facilities (worldwide) are shown in table 8.3 and figure 8.3. The total worldwide capacity of the most commonly used desalination processes (MSF, RO, and MED) are illustrated for plants that are larger than 2.4 mgd. This data are valid as of 1990.

8.6 Desalination Plants Major Problems

Most of the problems which have been observed or heard about in desalination plant operation in the past can ultimately be traced to corrosion of materials. Such corrosion problems are a direct result of the improper selection and application of the material, and the poor performance of the decarbonation and deaeration of the make up water stream to the evaporator by the designer and manufacturer of the plant. Poor operation techniques has also caused serious corrosion as well as scaling of portions of the evaporator heat transfer surfaces. In some plants, severe corrosion has been noticed in parts of the non-condensable gas venting system after 3 years of operation. Therefore, these problems were subject to extensive R & D programs in the past 10 years in many countries, and considerable progress has been realized in the areas of material selection, scale, and corrosion.

Conclusions from the R & D work are summarized below:

- A few areas of the plant are subject to major corrosion. These areas are: (a) waterboxes, (b) high temperature lines, (c) low pH make up lines, and (d) the heat exchangers of the venting system. Corrosion resistant material should be provided for these areas.

DESALINATION PLANTS WITH SIZE 9000 CU M OR LARGER PER DAY
(2.4 MGD) FOR SINGLE UNIT
SOURCE : EXTRACTED FROM 1990 IDA WORLDWIDE DESALTING PLANTS INVENTORY
BY KLAUS WANGNICK

COUNTRY	CAPACITY /UNIT MGD	TOTAL PLANT CAP MGD	TYPE OF PROCESS	FEED WATER	YEAR IN OPERATION
ARAB EMIRAT	2.4	7.2	MSF	SEA	1969
ARAB EMIRAT	7.2	7.2	MSF	SEA	1974
ARAB EMIRAT	3.96	15.85	MSF	SEA	1977
ARAB EMIRAT	3.57	7.13	MSF	SEA	1980
ARAB EMIRAT	2.38	2.38	RO	BRACK	1985
ARAB EMIRAT		0.06	RO	SEA	1988
ARAB EMIRAT	5.01	30	MSF	SEA	1981
ARAB EMIRAT	3.4	10.3	MSF	SEA	1979
ARAB EMIRAT	3.43	6.87	MSF	SEA	1980
ARAB EMIRAT	8.48	25.44	MSF	SEA	1983
ARAB EMIRAT	8.4	33.6	MSF	SEA	1988
ARAB EMIRAT	2.64	5.28	MSF	SEA	1983
ARAB EMIRAT	6.47	12.94	MSF	SEA	1981
ARAB EMIRAT	6.47	12.94	MSF	SEA	1985
ARAB EMIRAT	8.81	26.42	MSF	SEA	1988
ARAB EMIRAT	7.27	21.8	MSF	SEA	1979
ARAB EMIRAT	8.68	26	MSF	SEA	1987
ARAB EMIRAT	4.76	19.02	MSF	SEA	1980
ARAB EMIRAT	4.76	9.5	MSF	SEA	1980
ARAB EMIRAT	7.27	29.06	MSF	SEA	1986
BAHAMAS	2.4	2.4	MSF	SEA	1971
BAHRAIN	6.34	6.34	MSF	SEA	1985
BAHRAIN	8.45	25.36	MSF	SEA	1986
GERMANY	2.54	2.54	ME	WASTE	1977
GREECE	3.83	3.83	ED	BRACK	1978
HOLLAND	3.83	7.66	MSF	SEA	1969
HONG KONG	8	48.03	MSF	SEA	1975
IRAN	8.81	26.42	MSF	SEA	1989
IRAN	4.12	8.24	MSF	SEA	1991
IRAQ	3.17	6.34	RO	RIVER	1988
IRAQ	2.64	2.64	ED	BRACK	1978
ISRAEL	4.5	4.5	ME	SEA	1982
ITALY	2.53	2.53	MSF	SEA	1973
ITALY	3.8	3.8	MSF	SEA	1974
ITALY	3.96	7.92	MSF	SEA	1974
ITALY	3.8	3.8	MSF	SEA	1974
ITALY	3.8	3.8	MSF	SEA	1976
ITALY	4.44	4.44	MSF	SEA	1971
ITALY	9.5	9.5	MSF	SEA	1973
JAPAN	2.5	2.5	MSF	SEA	1975
KUWAIT	7.2	21.6	MSF	SEA	1978
KUWAIT	2.4	2.4	MSF	SEA	1968
KUWAIT	2.4	4.8	MSF	SEA	1968
KUWAIT	3.15	6.3	MSF	SEA	1971
KUWAIT	6.3	25.7	MSF	SEA	1971
KUWAIT	6	12	MSF	SEA	1975
KUWAIT	2.4	4.8	MSF	SEA	1968
KUWAIT	2.4	4.8	MSF	SEA	1970
KUWAIT	7.2	21.62	MSF	SEA	1982
KUWAIT	2.4	4.8	MSF	SEA	1968
LIBYA	2.64	7.92	MSF	SEA	1988
LIBYA	3.48	13.94	MSF	SEA	1980
LIBYA	2.77	8.32	MSF	SEA	1987
LIBYA	2.64	2.64	MSF	SEA	1986

LIBIA	2.64	[illegible]	[illegible]	SEA	
MEXICO	[illegible]	7.5	MSF	SEA	1969
NETH. ANTIL.	2.64	2.64	ME	SEA	1984
NETH. ANTIL.	2.64	2.64	ME	SEA	1987
NETH. ANTIL.	2.64	2.64	ME	SEA	1990
OMAN	6	6	MSF	SEA	1975
OMAN	7.22	7.22	MSF	SEA	1983
OMAN	7.23	14.26	MSF	SEA	1987
OMAN	7.2	14.4	MSF	SEA	1992
QATAR	2.92	5.83	MSF	SEA	1977
QATAR	2.92	5.83	MSF	SEA	1977
QATAR	6	24	MSF	SEA	1978
QATAR	6	24	MSF	SEA	1983
QATAR	3.01	6.02	MSF	SEA	1973
QATAR	3.01	6.02	MSF	SEA	1978
SAUDI ARABIA	6.08	36.46	MSF	SEA	1982
SAUDI ARABIA	5.07	10.15	MSF	SEA	1982
SAUDI ARABIA	6.24	62.4	MSF	SEA	1983
SAUDI ARABIA	6.25	62.45	MSF	SEA	1983
SAUDI ARABIA	6.26	62.62	MSF	SEA	1983
SAUDI ARABIA	6.2	62.09	MSF	SEA	1985
SAUDI ARABIA	2.97	5.94	MSF	SEA	1987
SAUDI ARABIA	2.5	7.3	MSF	SEA	1972
SAUDI ARABIA	7.05	70.54	MSF	SEA	1984
SAUDI ARABIA	7.2	28.8	MSF	SEA	1988
SAUDI ARABIA	2.5	5	MSF	SEA	1971
SAUDI ARABIA	2.5	11.62	MSF	SEA	1978
SAUDI ARABIA	6	24	MSF	SEA	1980
SAUDI ARABIA	6	60	MSF	SEA	1980
SAUDI ARABIA	5.89	28.92	MSF	SEA	1988
SAUDI ARABIA	2.54	10.14	RO	BRACK	1978
SAUDI ARABIA	2.63	7.9	RO	BRACK	1979
SAUDI ARABIA	2.63	7.9	RO	BRACK	1979
SAUDI ARABIA	3.17	15.85	RO	BRACK	1979
SAUDI ARABIA	2.41	14.46	MSF	SEA	1980
SAUDI ARABIA	5.81	29.06	MSF	SEA	1982
SAUDI ARABIA	2.54	5.07	MSF	SEA	1982
SAUDI ARABIA	2.4	7.2	MSF	SEA	1984
SPAIN	2.38	4.76	MSF	SEA	1978
USA	3	3	ME	SEA	1973
USA	3	3	HYBRI	SEA	1973
USA	2.5	2.5	RO	BRACK	1982
USA	2.63	2.63	MSF	SEA	1967
USA	2.5	2.5	RO	BRACK	1984
USA	2.4	12	RO	BRACK	1990
USA	2.88	2.88	RO	WASTE	1979
USSR	3.8	3.8	ME	SEA	1978
USSR	3.8	3.8	ME	SEA	1971
USSR	3.55	3.55	MSF	SEA	1972
USSR	3.8	3.8	ME	SEA	1973
USSR	3.8	3.8	ME	SEA	1975
USSR	3.8	7.6	ME	SEA	1980
USSR	3.3	3.3	ME	SEA	1992
USSR	4.44	4.44	ME	SEA	1993
USSR	5.52	11.03	ME	SEA	1980
USSR	3.8	7.6	MSF	WASTE	1979
VIRGIN ISLANDS	2.64	2.64	MSF	SEA	1967
IRAQ	3.17	6.34	RO	RIVER	1988
NETH. ANTIL.	2.64	2.64	ME	SEA	1990
OMAN	7	14.4	MSF	SEA	1992
USA	2.4	12	RO	BRACK	1990
USSR	3.3	3.3	ME	SEA	1992
USSR	4.44	4.44	ME	SEA	1993

FIGURE 8.3
WORLDWIDE CAPACITY BY PROCESS

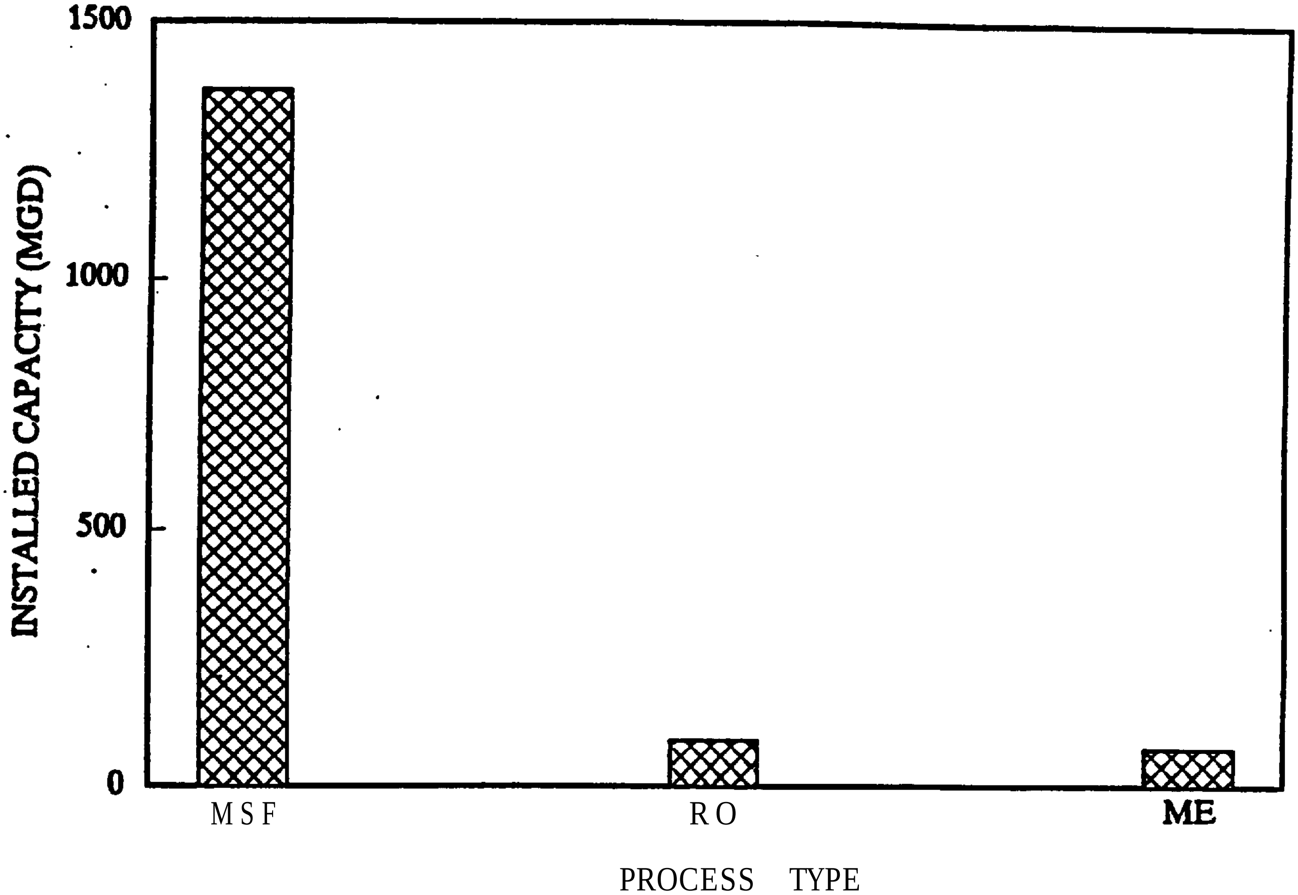

TABLE 8.3
WORLDWIDE SURVEY BY PROCESS
FOR PLANTS
LARGER THAN 2.4 MGD

PROCESS	INSTALLED CAPACITY* (MGD)	% OF TOTAL
MSF	1366.25	89.4
RO	88.79	5.8
MED	73.27	4.8

* *Capacities as of 1990.*

- Other areas of the plant that have comparatively mild corrosion can be protected from corrosion by merely providing an adequate corrosion allowance in the design.

- The areas where it is difficult to provide an allowance against corrosion, such as tubes and pumps, should be constructed of suitable corrosion resistant alloys.

SECTION 9.0

FINANCIAL - CASH FLOW - ANALYSIS

9.1 Introduction

Two cash flow analyses were developed for the recommended desalination system in each case, and are shown in this section. The financial analysis for the Carlsbad pilot plant is as shown on table 9.1 for case A and on table 9.2 for case B. The financial analysis for the Santa Monica plant is as shown on table 9.3 for case A and on table 9.4 for case B.

The economic factors used to generate the cash flow analyses are based from 1998 cash levels. Plant life is projected for 20 years beginning with the year 1998.

The two cases considered were as follows:

Case A: Assuming 100% finance with no contribution from BUREC

Case B: Assuming 100% finance with funds to be contributed by BUREC.

The basis of case B in each site financial analysis is to achieve a minimum internal rate of return "IRR" of 15 - 20%. Refer to table 9.5 for a summary of cash flow cases.

9.2 Off Peak Operation Cash Flow

The cash flow analysis was developed under the assumption that the desalination system is operating at 90% of the full capacity.

The cost of water in this case has a first year cost of $6.50 per 1000 gallons. Assuming that escalation rates for fuel, electricity, O&M, steam to desal, etc. increase, the cost of water will gradually increase over the life span as shown in the analysis. Escalation rates used in the analysis are as follows:

Steam	5 %
Water..	5 %
Labor..	4 %
General..	4 %

We have not included the economics of the power section for the Carlsbad pilot plant. The economics and financial analysis is based solely on the desalination facility. Our preliminary estimates on the power section indicated an acceptable economical parameter in relation to the IRR and payback from financial institutions.

9.3 Milestone Schedule

A milestone schedule was developed for each site and is shown in figure 9.1 for the Santa Monica Bay desalination and in figure 9.2 for the Carlsbad Pilot Plant.

We have estimated that a time period of 14 months will be required for the installation of the Santa Monica plant and 25 months for the installation of the Carlsbad pilot plant.

TABLE 9.1

CARLSBAD DESALINATION CASE A:
$ZERO BUREC CONTRIBUTION

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TABLE 9.1

CARLSBAD DESALINATION CASE A: $ZERO BUREC CONTRIBUTION (CONTINUED)

LEFT BLANK BECAUSE CONTAINS CONFIDENTIAL & PROPRIETARY INFORMATION

TABLE 9.2

CARLSBAD DESALINATION CASE B: $270,000 BUREC CONTRIBUTION

LEFT BLANK BECAUSE CONTAINS CONFIDENTIAL & PROPRIETARY INFORMATION

TABLE 9.2

CARLSBAD DESALINATION CASE B: $270,000 BUREC CONTRIBUTION (CONTINUED)

LEFT BLANK BECAUSE CONTAINS CONFIDENTIAL & PROPRIETARY INFORMATION

TABLE 9.3

SANTA MONICA DESALINATION CASE A:
$ZERO BUREC CONTRIBUTION

LEFT BLANK BECAUSE CONTAINS
CONFIDENTIAL & PROPRIETARY INFORMATION

TABLE 9.3

SANTA MONICA DESALINATION CASE A:
SZERO BUREC CONTRIBUTION
(CONTINUED)

LEFT BLANK BECAUSE CONTAINS
CONFIDENTIAL & PROPRIETARY INFORMATION

TABLE 9.4

SANTA MONICA DESALINATION CASE B:
$270,000 BUREC CONTRIBUTION

LEFT BLANK BECAUSE CONTAINS CONFIDENTIAL & PROPRIETARY INFORMATION

TABLE 9.4

SANTA MONICA DESALINATION CASE B:
$270,000 BUREC CONTRIBUTION
(CONTINUED)

LEFT BLANK BECAUSE CONTAINS CONFIDENTIAL & PROPRIETARY INFORMATION

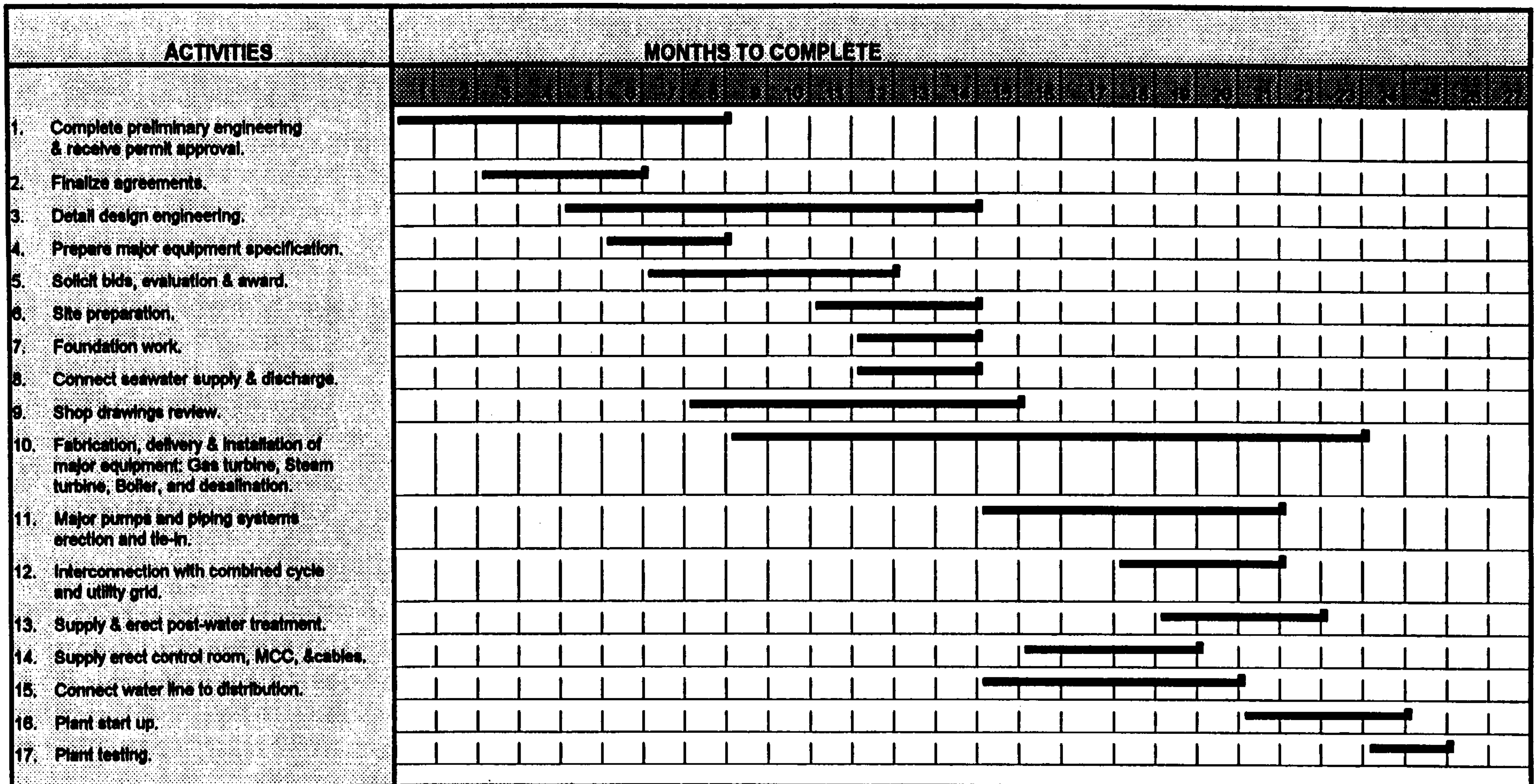
TABLE 9.5

SUMMARY OF CASH FLOW CASES

SANTA MONICA DESALINATION	IRR (%)
No BUREC Contribution	10.23
With $270,000 BUREC Contribution	21.54
CARLSBAD PILOT PLANT	
No BUREC Contribution	9.56
With $270,000 BUREC Contribution	11.44

MILESTONE SCHEDULE

SAN DIEGO COUNM POWER/DESAL

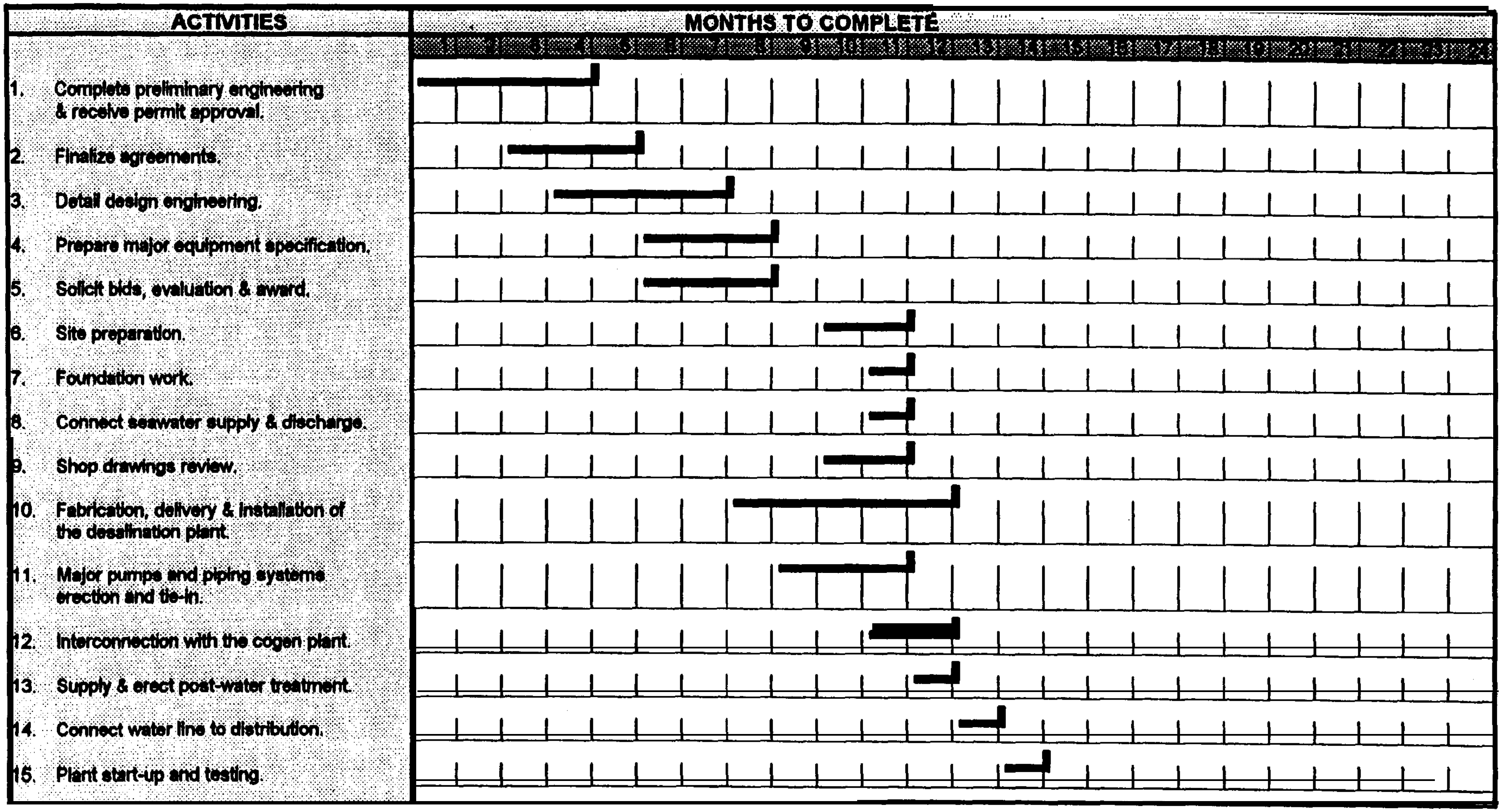


*THIS MILESTONE IS **BASED** ON EQUIPMENT SUPPLIERS AS WELL AS ACTUAL PLANT WHICH ARE ALREADY IN OPERATION **OVERSEAS.**

DRAWN: NNR	APPROVED:	DATE:	FIG: 9.1
SUPER SYSTEMS INC.		PLANT MILESTONE CARLSBAD PILOT PLANT	

MILESTONE SCHEDULE *

SANTA MONICA BAY DESALINATION PLANT



* THIS MILESTONE IS BASED ON EQUIPMENT SUPPLIERS AS WELL AS ACTUAL PLANT WHICH ARE ALREADY IN OPERATION OVERSEAS.

DRAWN: NNR	APPROVED:	DATE:	FIG: 9.2
SUPER SYSTEMS INC.		PLANT MILESTONE SANTA MONICA BAY DESAL PLANT BUREAU OF RECLAMATION	

APPENDIX A
SEAWATER DESALINATION GLOSSARY

Alkaline scale
Scale that will dissolve under acidic conditions: mainly calcium carbonate and magnesium hydroxide.

Anion
A negatively charged ion in solution.

Anti-sealant
A chemical that reduces scale formation.

Boiling point
The specific temperature and pressure at which the vapor pressure exerted by a liquid equals the ambient pressure.

Brackish water
A water source having a TDS between 1000 and 10,000 mg/L.

Brine
The concentrated salt water solution resulting from a desalination process.

Brine' Heater
The heat exchanger that serves as the heat input section of the multi-stage flash evaporation process.

Cation
A positively charged ion in solution.

Cellulose acetate
A polymer that is used to make semi-permeable membranes.

Colloid

A small discrete solid particle that will remain suspended in a solution.

Compaction

Compression of reverse osmosis membranes due to long-term exposure to pressure that results in a decreased water flux rate.

Combined cycle

A power plant where the electricity is produced from a combination of gas turbine and steam turbine units.

Concentration polarization

Localized high salt concentration at a membrane surface.

Condensate

The liquid that is produced by cooling a gas to below its dewpoint.

Conductivity

The ability of a solution to conduct electrical current.

Conversion

The amount of product water divided by the amount of feedwater; generally reported as a percent.

Deaerate

To remove dissolved gases from a liquid solution.

Demister

A device that removes entrained liquid droplets from a gas stream.

Diffusion

The movement of a molecule in solution due to a difference in a concentration of that solution.

Distillation

The conversion of a liquid to a gas to remove impurities.

Distillate

Product water from a multi-stage flash or multiple effect distillation unit.

Droplet separator

A device that removes entrained liquid droplets from a gas stream.

Dual purpose (DP)

An installation where both power and water are generated. Normally, both processes are interconnected.

Eductor - Ejector

A device that uses a high velocity liquid or gas stream flowing through a nozzle to produce a vacuum.

Effect

A stage in a water distillation or evaporation system where steam or water is condensed and its released energy is used to boil water.

Evaporation

A distillation process normally run at reduced pressures.

Falling film evaporation

A type of heat exchange system where a thin film of liquid flows by gravity over a heat exchange surface and is brought to boiling conditions.

Flash evaporation

The sudden boiling of a liquid due to a pressure reduction.

Flux

Flow of water through a semi-permeable membrane expressed as gallons of water per day per square foot of membrane area.

Fouling

A phenomenon in which organic or other materials are deposited on a surface and impair the transfer of mass or energy through that surface.

Hardness

The summation of calcium and magnesium ions in solution; generally reported as a calcium carbonate equivalent.

Hard scale

Calcium sulfate or other materials that cannot be dissolved by acid.

Heat exchanger

A device that allows thermal energy to be transferred from a high temperature medium to a low temperature medium.

Heat of vaporization

The amount of energy per unit mass required to boil a liquid.

Heat Input Section

The heat exchanger that serves as the heat input section of the evaporative process.

Heat rejection condenser

The final heat exchanger in a multiple-effect or multi-stage evaporator where seawater is used to condense the water vapor produced in the last effect.

Latent heat

The energy stored or released by a substance as it undergoes a physical change or state, e.g., ice melting to water or water boiling to steam.

Micron

Unit of measure equal to 10^{-6} meter.

Multiple-effect evaporation

An evaporative process consisting of several effects in series, where the heat produced in one effect serves as the heat source .in the next lower temperature effect.

Multi-stage flash evaporation

An evaporative system that uses several stages where all the heat produced in each stage is used to preheat the incoming seawater.

Non-alkaline scale

Calcium sulfate or other materials that cannot be dissolved by acid.

Osmosis

The transport of water through a membrane from a solution of low salt content to a solution of high salt content in an effort to equalize salt concentrations.

Permeator

A reverse osmosis production unit consisting of the RO membranes and pressure vessel.

pH

A logarithmic scale describing the concentration of hydrogen ions in a solution.

Plant factor

The amount of time a unit is in stream throughout the year at the percentage of design capacity.

Product

Product water from any desalination process.

Polyphosphates

A polymer containing phosphate compounds.

Recovery

The amount of product water divided by the amount of feedwater; generally reported as a percentage.

Reverse osmosis

The transport of water from a solution having a high salt concentration to a low salt concentration solution through a membrane by applying pressure to the solution having a high salt concentration.

Salt rejection

The selectivity to exclude dissolved ions from passing through the membrane.

Saturation

The maximum amount of material that can be dissolved in solution without forming a precipitate; the maximum amount of energy a compound can have without physically changing states.

Scale

Any material that forms a solid on surfaces; usually calcium sulfate, calcium carbonate, or magnesium hydroxide.

Simple cycle mode of operation

When the steam turbine generator set is down and the power plant is generating electricity from the gas turbine units and steam from the HRSG.

Single purpose plant (SP)

A facility wherein the only product manufactured is water or power.

Stage

A stage in a water distillation of evaporation system where steam or water vapor is condensed and its released energy is used to boil water.

Solubility

The amount of substance that can be dissolved in a given liquid under specified conditions.

Vapor compression evaporation

An evaporative system that uses mechanical or thermodynamic vapor compression to boost that vapor temperature so that compressed vapor can be used to drive the evaporative process.

APPENDIX B
BIBLIOGRAPHY .

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Communication from Ambient Technologies, Inc.

Communication from City of Carlsbad Water District

Communication from Aqua-Chem, Inc.

Carlsbad
Municipal Water District

5950 El Camino Real, Carlsbad, CA 92008
Engineering: (619) 438-3367
Administration: (619) 438-2722
Fax: (619) 431-1601

December 20, 1994

Sam Tadros
Supersystems, Inc.
17561 Teachers Avenue
Irvine, California 92714

Re: Seawater Desalination Study Phase I
CMWD Project No. 94-104

Dear Sam:

Reference is made to your letter dated December 13, 1994, regarding the-subject project and our discussion on the same date. After consideration of your proposal, we have the following response:

1. We understand the size 'of the' pilot plant to be investigated will be small. Your letter indicates a generator&e ranging between 500kW and 4mW, producing 100,000 to 500,000 gpd. (112 to 560 ac-ft/year).

2. We understand that the study will investigate two possible sites only including the Encina Power Plant and the Encina Water Pollution Control Facility. However, a letter of agreement with the S.D.G & E. Plant Manager will be necessary before including their property in the study.

3. The District can fund only $2,000.00 of the cost of the study plus contribute staff time to site descriptions and peripheral information on the seawater supply, brine disposal, blending facilities, environmental issues, etc.

4. At this time, we cannot commit to purchase of the water or power. Based on our review of the completed feasibility study, we hope to better understand the project scope and make a determination on whether to financially participate in the pilot plant. . Based on the information presented 'to date, it is our opinion that the District's share in cost of the pilot plant will be too high for the project water and power we would receive.

In conclusion, we are willing to participate in the Phase I Study but will not be committing to the construction of the pilot plant Based on the information developed on the Phase I Study, we hope to be able to make a decision on further participation in the pilot plant. If you have any comments or questions, you may reach me at ext. 126.

very truly yours,
CARLSBAD MUNICIPAL WATER DISTRICT

William E. Plummet, P.E.
District Engineer

WEP:sjs
CMWD 94-104

Carlsbad Municipal Water District

5950 El Camino Real, Carlsbad, CA 92008
Engineering: (619) 438-3367
Administration: (619) 438-2722
Fax: (619) 431-1601

October 7, 1994

Sam Tadros, P.E.
Supersystems, Inc.
17561 Teachers Avenue
Irvine, CA $2714

U.S. BUREC COGENERATION/DESALINATION PLANT FEASIBILITY STUDY

Thank you for your letter, dated September 19, 1994 which provides additional information regarding Cogen./Desalination.

Carlsbad Municipal Water Diict is interested in learning more about the feasibility of a pilot facility as well as the potential for a full scale facility. Therefore, I am requesting that you make a slide presentation, as referenced in your letter, to our Water Commission. The Water Commission is advisory to the Board of Directors (City Council). I would like to place you on our October 26th Commission meeting agenda scheduled for 200 p.m. in our board room. Please let me know if you would be available to make a presentation to the Commission to explain your potential arrangement with the Bureau of Reclamation and also the economics of desalting water and generating electricity.

Very truly yours,

Robert Greaney

ROBERT J. GREANEY
GENERAL MANAGER

cc: District Engineer . .

RJG:mg

SSI Comment
Slide presentation done in November 94 and the Water Commission has given unanimous vote to go ahead with the Cogeneration and Pilot plant.

City of Carlsbad
Planning Department

June 8, 1994

Sam Tadios
Supersystems, Inc.
17561 Teachers Avenue
Building A
Irvine, California 92714

Dear Mr. Tadios:

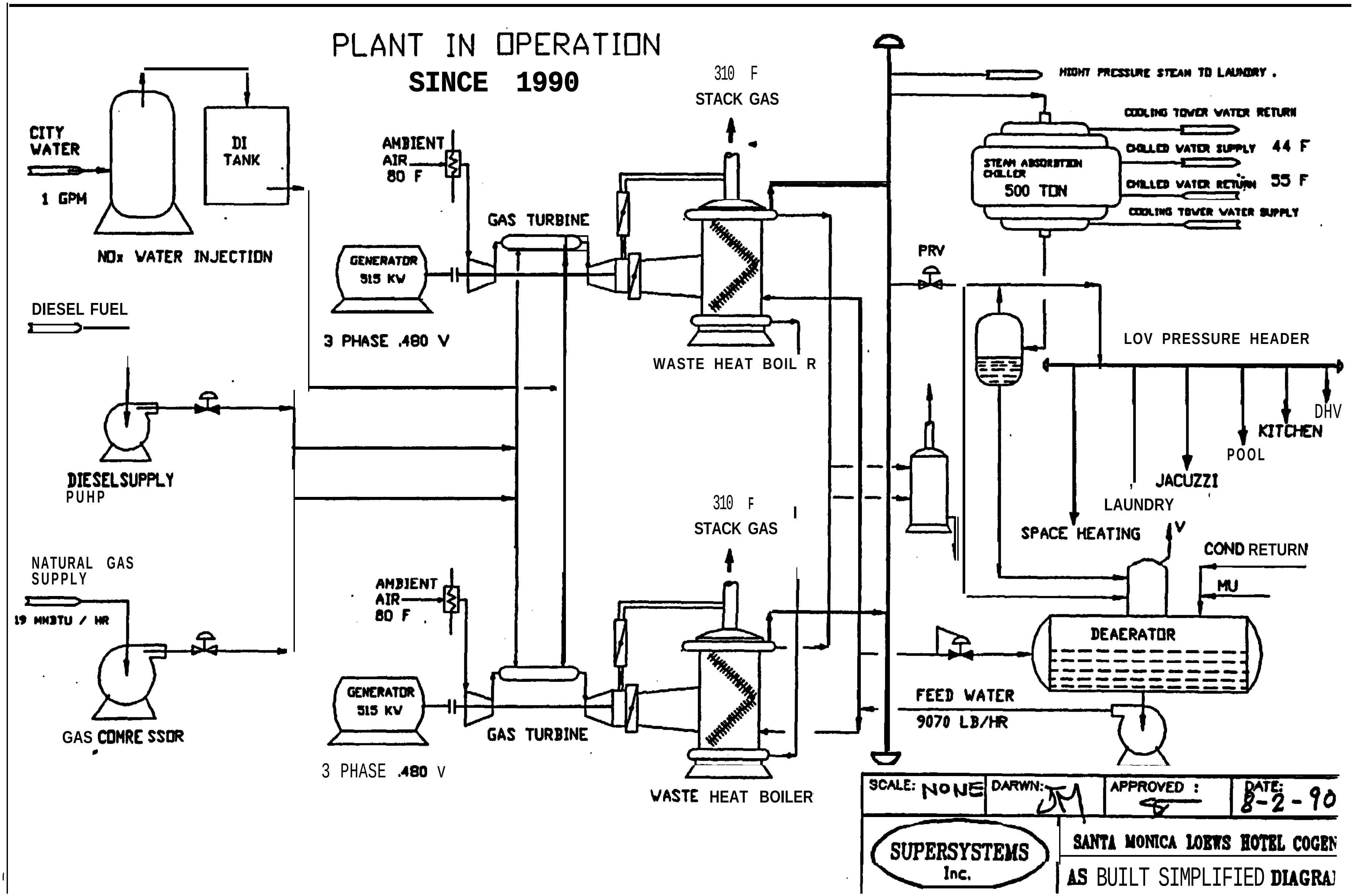
I have referred your recent letter regarding a desalination project to Bob Greaney, our Water District Manager. Your contacts should be with Bob because he is in charge of all water related issues in the City.

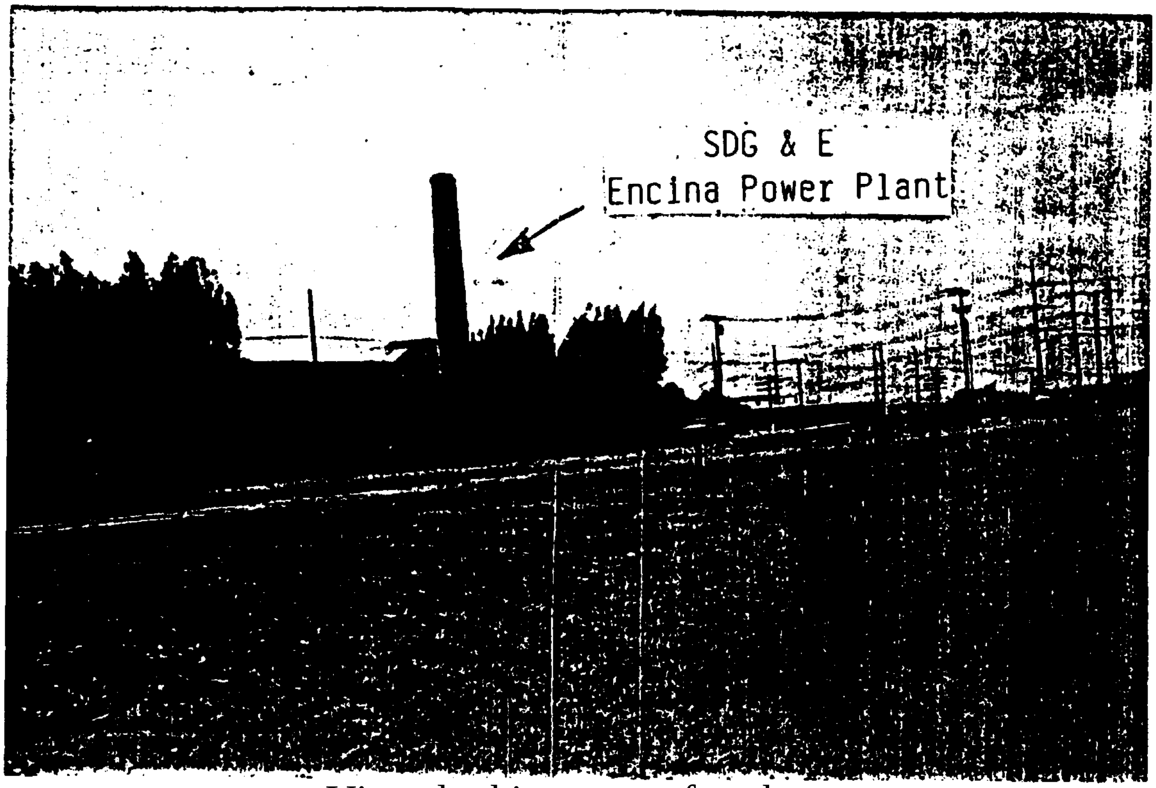
Sincerely,

CITY OF CARLSBAD

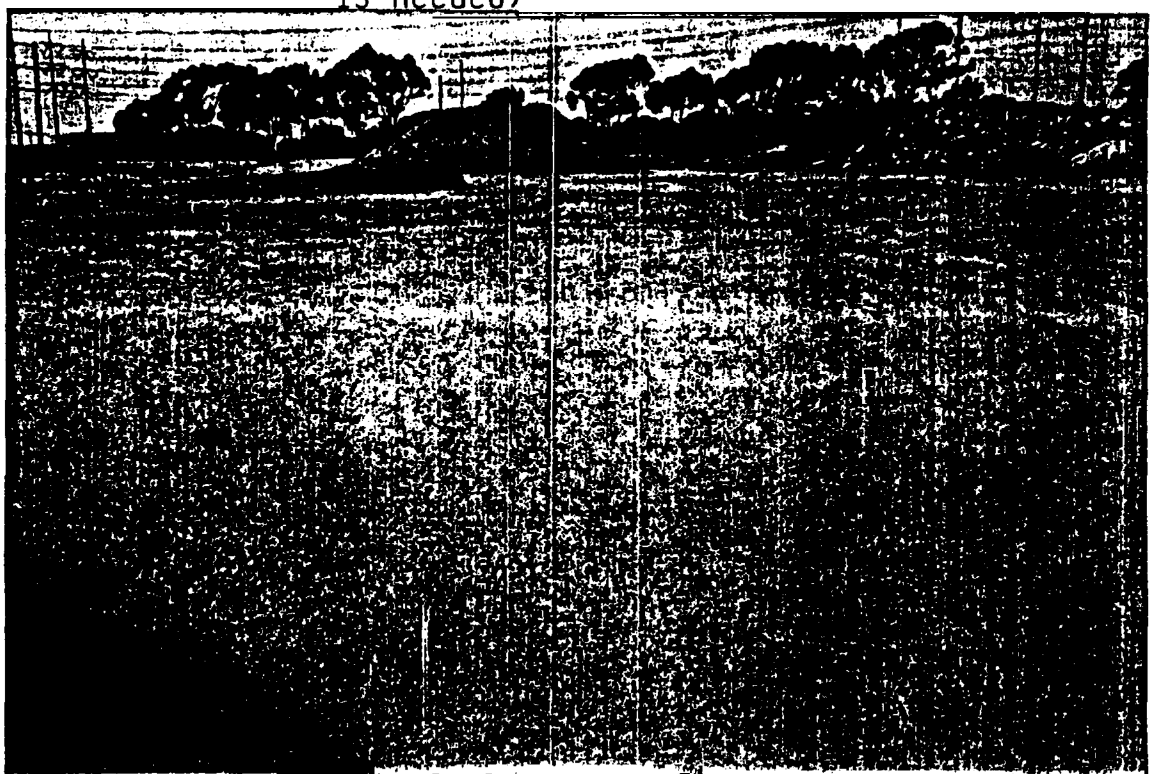
MICHAEL J. HOLZMILLER
Planning Director

arb


PLANT IN OPERATION
SINCE 1990
CITY WATER
1 GPM
DI TANK
NOx WATER INJECTION
DIESEL FUEL
DIESELSUPPLY PUHP
NATURAL GAS SUPPLY
19 MMBTU / HR
GAS COMRESSOR
AMBIENT AIR 80 F
GENERATOR 515 KW
3 PHASE .480 V
GAS TURBINE
AMBIENT AIR 80 F
GENERATOR 515 KV
GAS TURBINE
3 PHASE .480 V
310 F
STACK GAS
WASTE HEAT BOIL R
310 F
STACK GAS
WASTE HEAT BOILER
HIGHT PRESSURE STEAM TO LAUNDRY .
COOLING TOWER WATER RETURN
CHILLED WATER SUPPLY 44 F
CHILLED WATER RETURN 55 F
COOLING TOWER WATER SUPPLY
STEAM ABSORBTION CHILLER
500 TON
PRV
LOW PRESSURE HEADER
DHV
KITCHEN
POOL
JACUZZI
LAUNDRY
SPACE HEATING
COND RETURN
MU
DEAERATOR
FEED WATER
9070 LB/HR
SCALE: NONE
DARWN: JM
APPROVED :
DATE: 8-2-90
SUPERSYSTEMS Inc.
SANTA MONICA LOEWS HOTEL COGEN
AS BUILT SIMPLIFIED DIAGRA



View looking west for the area available for Pilot Plant Cogen/ Desalination (only portion of it is needed)



View lookina east

ambient technologies, inc.

24 January, 1994

Sam Tadros
Super Systems
17 56 1 Teacher Avenue
Irvine, CA 92714

Re: Small Scale MED

Dear Sam,

Attached is the smallest MED unit that we design. Such small MED units are usually not economical, and we recommend not to go lower than 300,000 G.P.D. unit.

Please do not hesitate to contact me for any additional information.

Yours truly,

Dan Mishkal

P.O. Box 11659, St. Thomas
U.S. Virgin Islands 00801
telephone: (809) 774-7800 . fax: (809) 776-9982

2999 Northeast 191st Street
Suite 407
No. Miami Beach, FL 33180
telephone: (305) 937-0610 · fax: (305) 937-2137

	350,000 G/D		500,000 G/D		1,000,000 G/D	
	R = 6	R = 9	R = 6	R = 9	R = 5	R = 9
1. Complete desal plant equipment FOB cost US$	1,750,000	2,300,000	2,700,000	3,200,000	4,400,000	5,000,000
2. Plant type (MSF MED)	MED	MED	MED	MED	MED	MED
3. Transport cost to Irvine, California US$	170,000	220,000	260,000	310,000	420,000	480,000
4. Daily chemical consumption for scale protection lb/day	32.1	32.4	46.4	46.4	92.8	92.8
5. Name of chemical and cost US$/1000lb	ID-204 1,720	ID-204 1,720	ID-204 1,720	ID-204 1,720	ID-204 1,720	ID-204 1,720
6. Rough and approx. cost for construction (assume Calif. area) US$	470,000	620,000	720,000	860,000	1,150,000	1,350,000
7. Expected electric consumption kW	95	95	125	125	220	220

[FXEH-AM]

aqua-chem, Inc.
Water Technologies Division

FAXES1 1

DATE: 4 February 1993

TO: SUPERSYSTEMS, INC
17561 Teachers Avenue
Irvine, CA 92714

ATTENTION: Mr Sam Tadros, PE, MSME
President

FAX NBR: 714 733 3430

FROM: Aqua-Chem, Inc.
P 0 Box 421
Milwaukee, Wisconsin 53201
Fax Number: (414) 577-2723

TOTAL NBR OF PAGES INCLUDING THIS COVER PAGE - 4

REFERENCE: Desalination Plant

Attached are drawings showing the general unit configuration and a diagram illustrating flows and temperatures. These drawings will be modified for your specific application when we agree on the scope of supply.

After review of these drawings, we can discuss in more detail your specific needs. A budgetary selling price for an **80,000** gpd unit at the efficiencies previously discussed would be $500,000. This price can vary significantly, depending on specific site requirements.

Please contact either myself or **Kris** Johanson, our Regional Sales Manager at 619 467 **6700** (telephone) to discuss this project further.

Regards,

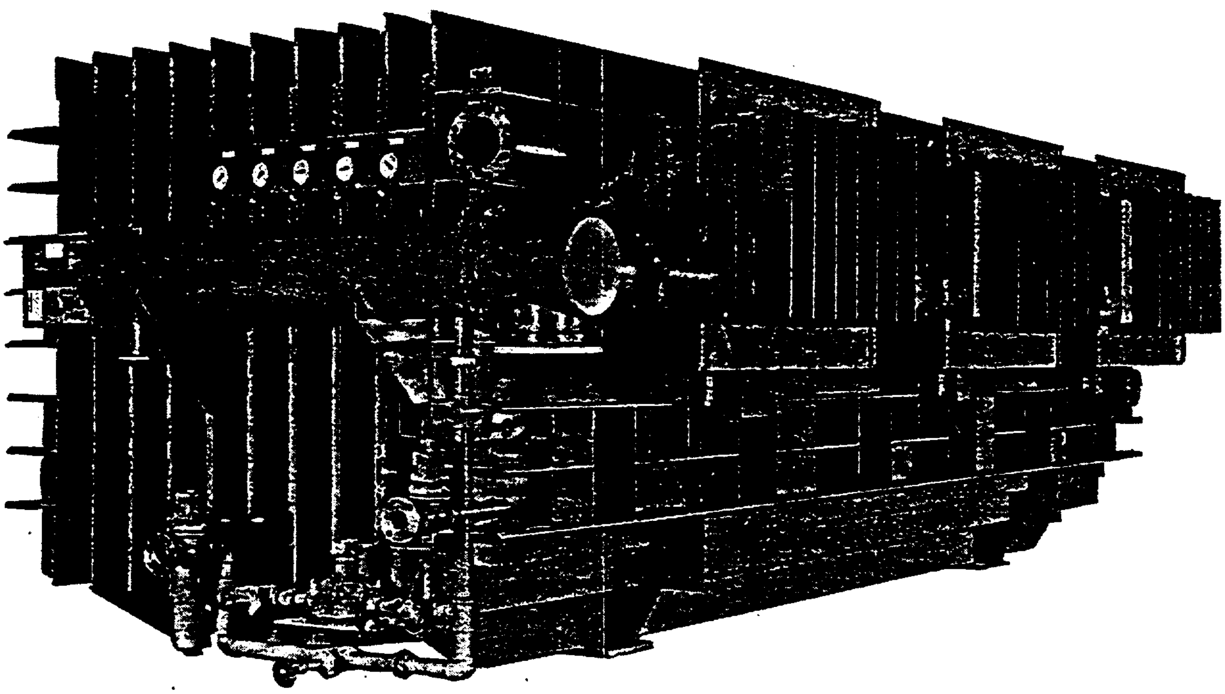
Mark J Gerschke

Mark J Gerschke
Market Sales Manager
Landbased Desalting

cc: **KJohanson**

AQUA-CHEM

. MULTI-STAGE FLASH
. DISTILLING PLANTS



Plants available in sizes from 2,000 gallons per day.
100,000 GPD six-stage flash shown.